

Petroleum and natural gas industries — Procedures for testing casing and tubing connections

The European Standard EN ISO 13679:2006 has the status of a British Standard.

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National foreword

This British Standard was published by BSI. It is the UK implementation of EN ISO 13679:2006. It is identical with ISO 13679:2002.

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A list of organizations represented on PSE/17/-/5 can be obtained on request to its secretary.

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des connexions pour tubes de cuvelage et de production
(ISO 13679:2002)

Erdöl- und Erdgasgewinnung - Prüfverfahren an
Verbindungen für Futter- und Steigrohre

This European Standard was approved by CEN on 6 October 2006.

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Foreword

The text of ISO 13679:2002 has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum and natural gas industries" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 13679:2006 by Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2007, and conflicting national standards shall be withdrawn at the latest by April 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 13679:2002 has been approved by CEN as EN ISO 13679:2006 without any modifications.

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Petroleum and natural gas industries — Procedures for testing casing and tubing connections

*Industries du pétrole et du gaz naturel — Procédures de test des
connexions pour tubes de cuvelage et de production*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13679 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 5, *Casing, tubing and drill pipe*.

Introduction

This International Standard is part of a process to provide reliable tubing and casing connections for the oil and natural gas industry which are fit for purpose. It has been developed based on improvements to API Recommended Practice 5C5 and proprietary test procedures, with input from leading users, manufacturers and testing consultants from around the world. This International Standard represents the knowledge of many years of testing and qualification experiences.

The validation of 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 which 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. Although pipe body test and limit loads are well understood in general, the same cannot be stated for the connection. These failure modes and loads are generally different and often less than that of the pipe. Consequently experimental validation is required. Well design matches the test and limit loads of both the connection and pipe to the well conditions to provide load capacities with suitable reliability.

The validation of test and limit loads requires testing at the extremes of performance parameters to these defined loads. Testing at the extremes of the performance parameters assures that the production population, which falls within these limits, will meet or exceed the performance of the test population. Thread connection performance parameters include dimensional tolerances, mechanical properties, surface treatment, make-up torque and the type and amount of thread compound. For typical proprietary connections, worst-case tolerances are known and defined in this International Standard. For other connections design analysis is required to define worst-case tolerance combinations.

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

This International Standard consists of the following major parts. Based on manufacturer's-supplied data specified in Annex A and/or calculations in Annex B, tests are conducted in accordance with Clauses 4 to 8 and reported on the data forms given in Annex C. Annex D lists all the information that is to be provided in the full report whereas Annex E lists the information that is to be provided in a summary test report. This summary test report lists the minimum information necessary to fully specify the connection tested and its preparation is intended for broader distribution. Annex F gives an example of a load frame calibration. Annex G gives considerations for possible connection product line qualification. Annex H provides guidelines for supplemental tests, which may be required for special applications. Annex I gives the design rationale for this International Standard. Annex J gives requirements for connections that contain both a metal-to-metal seal and a resilient seal which are tested separately.

Supplementary tests may be appropriate for specific applications that are not evaluated by the tests herein. The user and manufacturer should discuss well applications and limitations of the connection being considered.

Representatives of users and/or other third party personnel are encouraged to monitor the tests. ISO 13679 covers the testing of connections for the most commonly encountered well conditions. Not all possible service scenarios are included. For example, the presence of a corrosive fluid, which may influence the service performance of a connection, is not considered.

This International Standard includes provisions of various nature. These are identified by the use of certain verbal forms:

— SHALL is used to indicate that a provision is a REQUIREMENT, i.e. MANDATORY;

- SHOULD is used to indicate that a provision is a RECOMMENDATION to be used as good practice, but is not mandatory;
- MAY is used to indicate that a provision is OPTIONAL, i.e. indicates a course of action permissible within the limits of the document;
- CAN is used to indicate statements of POSSIBILITY and CAPABILITY.

Petroleum and natural gas industries — Procedures for testing casing and tubing connections

1 Scope

This International Standard establishes minimum design verification testing procedures and acceptance criteria for casing and tubing connections for the oil and natural gas industries. These physical tests are part of a design verification process and provide objective evidence that the connection conforms to the manufacturer's claimed test load envelope and limit loads.

It categorizes test severity into four test classes.

It describes a system of identification codes for connections.

This International Standard does not provide the statistical basis for risk analysis.

This International Standard addresses only three of the five distinct types of primary loads to which casing and tubing strings are subjected in wells: fluid pressure (internal and/or external), axial force (tension or compression), bending (buckling and/or wellbore deviation), as well as make-up torsion. It does not address rotation torsion and non-axisymmetric (area, line or point contact) loads.

This International Standard specifies tests to be performed to determine the galling tendency, sealing performance and structural integrity of casing and tubing connections. The words casing and tubing apply to the service application and not to the diameter of the pipe.

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.

ISO 3183-1, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 1: Pipes of requirement class A*

ISO 3183-2, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 2: Pipes of requirements class B*

ISO 3183-3, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 3: Pipes of requirement class C*

ISO 10400:1993, *Petroleum and natural gas industries — Formulae and calculation for casing, tubing, drill pipe, and line pipe properties*

ISO 10422, *Petroleum and natural gas industries — Threading, gauging and thread inspection of casing, tubing and line pipe threads*

ISO 11960, *Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells*

ISO 13680, *Petroleum and natural gas industries — Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock — Technical delivery conditions*

API Bul 5C3, *Bulletin on formulas and calculations for casing, tubing, drill pipe and line pipe properties*

API Spec 5B, *Specification for threading, gauging, and thread inspection of casing, tubing, and line threads (U.S. Customary Units)*

API Spec 5L, *Specification for line pipe*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the following terms, definitions, symbols and abbreviated terms apply.

3.1 Terms and definitions

3.1.1

ambient temperature

actual room temperature in the test lab with no residual heat remaining in test specimens from previous thermal tests

3.1.2

axial-pressure load diagram

plot of pressure versus axial load showing pipe and/or connection test load envelope or limit load extremes

3.1.3

connection

assembly consisting of either two pins and a coupling or one pin and an integral box

3.1.4

failure load

load at which the pipe body or connection will fail catastrophically as in an axial separation, a rupture, large permanent deformation (e.g. buckling or collapse) or massive loss of sealing integrity

3.1.5

galling

cold welding of contacting material surfaces followed by tearing of the metal during further sliding/rotation

NOTE 1 Galling results from the sliding of metallic surfaces that are under high bearing forces. Galling can generally be attributed to insufficient lubrication between the mating surfaces. The purpose of the lubricating medium is to minimize metal-to-metal contact and allow efficient sliding of the surfaces. Other ways to prevent galling are to reduce the bearing forces or reduce the sliding distance.

NOTE 2 There are several degrees of galling used for repair and reporting purposes as defined in 3.1.5.1 to 3.1.5.3.

3.1.5.1

light galling

galling that can be repaired by the use of abrasive paper

3.1.5.2

moderate galling

galling that can be repaired by the use of fine files and abrasive paper

3.1.5.3

severe galling

galling that cannot be repaired by the use of fine files and abrasive paper

3.1.6

leak

any positive displacement of fluid in the measuring system during hold periods

3.1.7**limit load**

load combination extreme (axial load and/or pressure) which defines the failure conditions for the connection or maximum load resulting in large permanent deformation (such as buckling) prior to catastrophic failure

3.1.8**lot**

lengths of pipe with the same specified dimensions and grade from the same heat of steel which are heat-treated as part of a continuous operation (or batch)

3.1.9**metal-to-metal seal**

seal or sealing system that relies on intimate and usually high contact stress of mating metal surfaces to achieve a seal

NOTE The thread compound can affect, both beneficially and detrimentally, the performance of a metal seal.

3.1.10**mother joint**

length of pipe or coupling stock from which short lengths are cut for machining connection test specimens

3.1.11**multiple seals**

sealing system, which consists of more than one independent barrier, and of which each barrier forms a seal itself

3.1.12**pipe string**

pipe body and the connection

3.1.13**pup joint**

short pipe length usually with threaded ends

3.1.14**resilient seal**

seal or sealing system, which relies on entrapment of a seal ring within a section of the connection (e.g. in the thread-form, on a seal area, etc.) to achieve a seal

3.1.15**seal**

barrier to prevent the passage of fluids

3.1.16**seal ovality**

maximum seal diameter minus the minimum seal diameter divided by the average seal diameter multiplied by 100

NOTE Seal ovality is expressed as a percentage.

3.1.17**single seal**

one barrier or multiple barriers that cannot be physically differentiated in their function

3.1.18**specimen**

connection between two pieces of pipe

NOTE The specimen can be composed of one coupling and two pins for coupled connections, or one pin and one box for integral connections.

3.1.19

test load envelope

extremes of loads (axial load, pressure, bending) and temperature within which the connection will perform cyclically

NOTE The manufacturer has the primary responsibility for defining the test load envelope for their connection products (see 4.1).

3.1.20

thread lot

all products manufactured on a given machine during a continuous production cycle that is not interrupted by a catastrophic tool failure or injurious machine malfunction (excluding worn tools or minor tool breakage), tool holder change (except rough boring bar) or any other malfunction of either threading equipment or inspection gauges

3.1.21

thread seal

seal or sealing system, which relies on intimate fitting of the thread-form and usually entrapment of the thread compound within the thread-form to achieve a seal

3.2 Symbols and abbreviated terms

3.2.1 Symbols

A_i	Area calculated based on the pipe inside diameter
A_o	Area calculated based on the pipe outside diameter
A_p	Cross-section area of pipe body
C	Compressive axial force
D	Specified pipe outside diameter
D_i	Inside diameter
D_o	Outside diameter
D_{leg}	Effective dogleg severity expressed in degrees per thirty metres
E_r	Error in load frame calibration
E_{rp}	Error in load frame calibration expressed in percent
F	Failure
F_a	Axial force, tension or compression
F_b	Bending equivalent axial force
F_c	Published joint strength of the connection when the joint strength is the compressive rated load of the connection
F_f	Actual load frame axial force, tension or compression
F_i	Indicated load frame axial force, tension or compression

F_t	Published joint strength of the connection when the joint strength is the tensile parting or failure load of the connection
F_y	Published joint strength of the connection when the joint strength is the tensile yield load of the connection
I	Moment of inertia
K_c	Compression efficiency factor of the connection
K_{pi}	Internal pressure efficiency factor of the connection
K_{pe}	External pressure efficiency factor of the connection
K_t	Tension efficiency factor of the connection
k_i, k_o	Geometric variable
L_A	Length of pin A end from coupling face (or connection) to end cap or grip length
L_B	Length of pin B end from coupling face (or connection) to end cap or grip length
L_c	Length of coupling or connection if integral
L_{pj}	Minimum unsupported pup joint length
M	Bending moment
M_o	Super bending moment
p_c	ISO 10400 collapse rating for specified wall thickness and actual specimen yield strength
p_i	Internal pressure
p_{ib}	Internal pressure with bending
p_{ih}	High internal pressure
p_{in}	Normalized internal test pressure
p_{il}	Low internal pressure
p_{iyp}	ISO 10400:1993, Section 3, internal yield pressure for the pipe body
p_o	External pressure
p_{ob}	External pressure with bending
p_{on}	Normalized external test pressure
p_{tc}	Thermal cycle pressure at elevated temperature
p_y	Maximum pressure for an internal fibre stress S_{yt}

q_{ac}	Actual leak rate to be reported
q_o	Observed leak rate
R	Radius of curvature of the pipe body at the axis of the pipe
S_t	100 % of minimum of the specimen mother joint tensile strength (measured at room temperature or at elevated temperature as given in Table 1) for a pipe member or coupling in a T&C specimen (pin or box member for an integral connection)
S_y	100 % of minimum of the specimen mother joint yield strength (measured at room temperature or at elevated temperature as given in Table 1) for a pipe member or coupling in a T&C specimen (pin or box member for an integral connection)
S_{yt}	95 % S_y for Series A and B tests, and 80 %, 90 % and 95 % for Series C tests (see 5.12.4)
t	Specified pipe wall thickness
t_{ac}	Actual minimum wall thickness
T	Tension axial force
η_{lds}	Leak detection system efficiency
σ	Stress
σ_a	Axial stress without bending
σ_{ab}	Axial stress with bending
σ_{ao}	Axial stress with super critical bending
σ_b	Axial stress due to bending
σ_{bo}	Axial stress due to super critical bending
σ_c	Axial compressive yield strength if available or otherwise axial tensile yield strength
σ_h	Hoop (tangential) stress
σ_{ho}	Hoop (tangential) stress at outside diameter
σ_r	Radial (normal) stress
σ_{ro}	Radial (normal) stress at outside diameter
σ_t	Transverse tensile yield strength if available or otherwise axial tensile yield strength
σ_{tc}	Defined transverse compressive yield strength if available or otherwise axial tensile yield strength
σ_v	Von Mises equivalent stress
σ_y	Axial tensile yield strength, normally the ISO/API axial tensile yield strength

3.2.2 Abbreviations

CAL	Connection application level for which the successfully tested pipe [size, mass (label: weight), grade] and connections are intended to be used
CCS	Critical cross-section
CCW	Counter-clockwise direction
CW	Clockwise direction
CEPL	Capped end pressure load (tension)
CEYP	Capped end yield pressure
CRA	Corrosion-resistant alloy
EUE	External upset end
FMU	Final make-up specimen condition
kips	1 000 lbf (pound-force)
ksi	1 000 lbf (pound-force) per square inch
lb	Pound mass
LL	Limit load
LP	Load point
LP1	Limit load test path 1
LP2	Limit load test path 2
LP3	Limit load test path 3
LP4	Limit load test path 4
LP5	Limit load test path 5
LP6	Limit load test path 6
LP7	Limit load test path 7
LP8	Limit load test path 8
M/B	Make-up/break-out
MBG	Make/break galling test specimen condition
MC	Mechanical cycle
MT	Material test coupon
MTC	Metal seal threaded and coupled connection
MTM	Metal-to-metal seal

MU	Make-up
OCTG	Oil country tubular goods
PTFE	Polytetrafluoroethylene
r/min	Revolutions per minute
RRG	Round-robin galling test specimen condition
RS	Resilient seal
SRG	Seal ring groove
Std	Standard
TC	Thermal cycle
TLE	Test load envelope
TSC	Thread sealing connection
T&C	Threaded and coupled
VME	Von Mises equivalent stress

4 General requirements

4.1 Connection geometry, test load envelope and performance data sheet

The manufacturer shall provide connection geometry and a performance data sheet for the product stating its connection application level and its geometry and performance properties in terms of tension, compression, internal pressure, external pressure, bending, and torque compared to the pipe body. See Table A.1 for the connection geometry and performance data sheet. The manufacturer shall provide a drawing, which is representative of the cross-sectional area of the connection. The manufacturer shall also provide a test load envelope in graphical form (VME plot) and should quantify limit loads. The manufacturer's own method of calculation should be used to derive the connection test load envelope and to calculate the test loads. Performance data or the method described in Annex B may be used.

Annex B has been provided as a means by which a manufacturer or user may estimate the test load envelope using a connection performance model based on capacities of specific critical cross-sections in the connection.

The manufacturer should define as completely as possible the limit loads for each connection. A user may also make an independent estimate of the limit loads. Limit loads shall be greater than the test load envelope.

It is critical that the combined load capacity described by the test load envelope be defined near and throughout the conditions where the dominant load sensitivity of the connection may change from pressure to axial force and/or bending or vice versa. Connection equations, whether analytically or experimentally based, shall define the test load envelope for all combinations of pressure and axial force and for bending (as applicable). These equations shall also be suitable to calculate the test loads based on actual yield strength and geometry of the specimen and include any other structural or sealing performance requirements. The form of the equation shall facilitate the calculation of the pressure value given the axial load, with or without bending.

Since casing and tubing connection designs and the resultant performance can vary widely, no overall requirement for the minimum number of values in a tabular data format can be mandated. However, it is

expected that approximately 10 combined load values of pressure and axial force per quadrant should be sufficient to define the test and limit loads. If a connection design exhibits changes in load sensitivities, the loads at which the changes in load sensitivity occur shall be provided.

In the calculation of both pipe body and connection load capacities, it is the intent of this International Standard to test the specimens to as high a load or combination of loads as safely practical.

In the event that unanticipated events result in deviations to the detailed requirements and or procedures, such deviations shall be clearly identified in the documentation.

4.2 Quality control

All quality control procedures for the manufacturing of test specimens shall be documented and shall be consistent with procedures used for connections manufactured for well service. The connection manufacturer shall ensure that the connections manufactured for the purpose of these design verification tests are of the same design and manufactured to the same dimensions and extremes of tolerances (see Clause 6) as those supplied for well service. The connection manufacturer shall issue a declaration of conformity (see for example, ISO/IEC Guide 22). The manufacturer shall provide the process control plan. This process control plan shall include procedure number or drawing number as well as associated revision levels for all applicable sub-tier documents (manufacturing, gauge calibration, gauging procedure, surface treatment, etc.). These procedures and any others determined necessary to provide a consistent product for well service shall be used during manufacturing of all test specimens (see A.4).

5 General test requirements

5.1 Test classes

5.1.1 Principle

Connection performance data are generated by testing. Passing the tests demonstrates conformance of the connection to the specified connection application level. Failure of some or all tests may result in a revision of the connection design or a revision of the test or limit loads. In the first case, the testing shall be repeated. In the second case, the tests that failed shall be repeated unless they conform to the revised load envelope.

Four test classes, known as connection application levels, are defined. These relate to increasingly arduous mechanical service conditions in the application of casing and tubing connections. The test classes increase in severity by increasing the number of test parameters and test specimens.

The classes of tests do not include all possible service scenarios. For example, the presence of a corrosive fluid, which may influence the service performance of a connection is not considered and is beyond the scope of this International Standard.

The user of this International Standard shall specify the connection application level required based upon the needs for the particular service intended. Users of the connection should be familiar with the defined connection application levels, the test load envelope and the limit loads. The connection application levels (abbreviated CAL) are defined as follows.

a) Connection application level IV (8 specimens): most severe application

CAL IV is intended for production and injection tubing and casing for gas service. CAL IV test procedures expose the connection to cyclical test loads including internal pressure, external pressure, tension, compression and bending. CAL IV test procedures expose the connection to extensive thermal and thermal/pressure-tension cycling incurring a cumulative exposure of about 50 h to gas at an elevated temperature of 180 °C (356 °F) and pressure. Limit load tests to failure are conducted in all four quadrants of the axial-pressure load diagram.

b) Connection application level III (6 specimens): severe application

CAL III is intended for production and injection tubing and casing for gas and liquid service. CAL III test procedures expose the connection to cyclical test loads including internal pressure, external pressure, tension and compression. Bending is an optional load for CAL III testing. The CAL III test procedures for thermal and thermal/pressure-tension cycling are less severe than CAL IV and incurring a cumulative exposure of 5 h to gas at an elevated temperature of 135 °C (275 °F) and pressure. Limit load tests to failure are conducted in all four quadrants of the axial-pressure load diagram.

c) Connection application level II (4 specimens): less severe application

CAL II is intended for production and injection tubing and casing, protective casing and for gas and liquid service with limited exposure to significant external pressure. CAL II test procedures expose the connection to cyclical test loads including internal pressure, tension and compression. Bending is an optional load for CAL II testing and external pressure is not included. The CAL II test procedures for thermal and thermal/pressure-tension cycling are the same as CAL III. Limit load tests for CAL II to failure are conducted with internal pressure and axial load.

d) Connection application level I (3 specimens): least severe application

CAL I is intended for liquid service. CAL I test procedures expose the connection to cyclical test loads, including internal pressure, tension and compression, using a liquid test fluid. Bending is optional for CAL I testing and external pressure is not included. CAL I testing is conducted at ambient temperatures. Limit load tests are conducted in two quadrants of the axial-pressure load diagram.

5.1.2 Previous tests

Connection test data obtained from tests performed prior to the establishment of this International Standard may also be used as part of a design verification process or application test sequence, provided that parties to agreements based on this International Standard can agree such tests were substantially conducted to the technical and documentation requirements of this International Standard and that they give comparable results.

5.1.3 Abbreviated tests and deviations

Some of the tests herein, rather than the complete test programme, may be adequate to verify suitability for specific applications when experience and related test data, for example on other sizes, are available. Deviation to the tests specified herein are acceptable, provided:

- a) the planned deviations are clearly documented in advance,
- b) there is clear agreement between the parties involved, and
- c) the deviations are clearly identified in both the summary report and the full report of the tests.

A discussion of product line qualification and use of interpolation and extrapolation considerations is provided in Annex G. More stringent acceptance requirements, sensitivity requirements and/or more extended informative data may be agreed by the user and manufacturer.

5.2 Test matrix

Table 1 shows a matrix relating the connection application level to the relevant total number of test specimens, their identification numbers and the relevant tests. Figure 1 is a summary of the test programme. Specimens may be tested in series with multiple specimens in a single assembly. However, test loads shall be imposed to the highest levels as required by the highest strength specimen.

Table 1 — Test matrix — Test series and specimen identification numbers

Connection application level	Series A (see 7.3.3) 4 quadrants with mechanical cycles	Series B (see 7.3.4) 2 quadrants with mechanical cycles	Series C thermal cycling (see 7.3.5) Thermal/pressure and tension cycling	Bake and thermal cycle temperature	Internal test pressure medium (external is liquid)
IV Total number of specimens = 8	At ambient temperature Specimens 2,4,5,7	Bending required at ambient temperature Specimens 1,3,6,8	5 mechanical at ambient temperature 50 thermal with pressure/tension ^a 5 mechanical at elevated temperature 50 thermal with pressure/tension ^a 5 mechanical at ambient temperature Specimens 1,2,3,4	180 °C (356 °F)	Gas
III Total number of specimens = 6	At ambient temperature Specimens 2,4,5	Bending optional at ambient temperature Specimens 1,3,6	5 mechanical at ambient temperature 5 thermal with pressure/tension 5 mechanical at elevated temperature 5 thermal with pressure/tension 5 mechanical at ambient temperature Specimens 1,2,3,4	135 °C (275 °F)	Gas
II Total number of specimens = 4	CAL II does not require external pressure test	Bending optional at ambient temperature Specimens 1,2,3,4	5 mechanical at ambient temperature 5 thermal with pressure/tension 5 mechanical at elevated temperature 5 thermal with pressure/tension 5 mechanical at ambient temperature Specimens 1,2,3,4	135 °C (275 °F)	Gas
I Total number of specimens = 3	CAL I does not require external pressure test	Bending optional at ambient temperature Specimens 1,2,3	CAL I does not require thermal cycling test	CAL I does not require bake	Liquid

^a Only five thermal cycles are required for CAL IV casing. Five thermal cycles also apply to CAL IV tubing with redundant seals tested to Annex J.

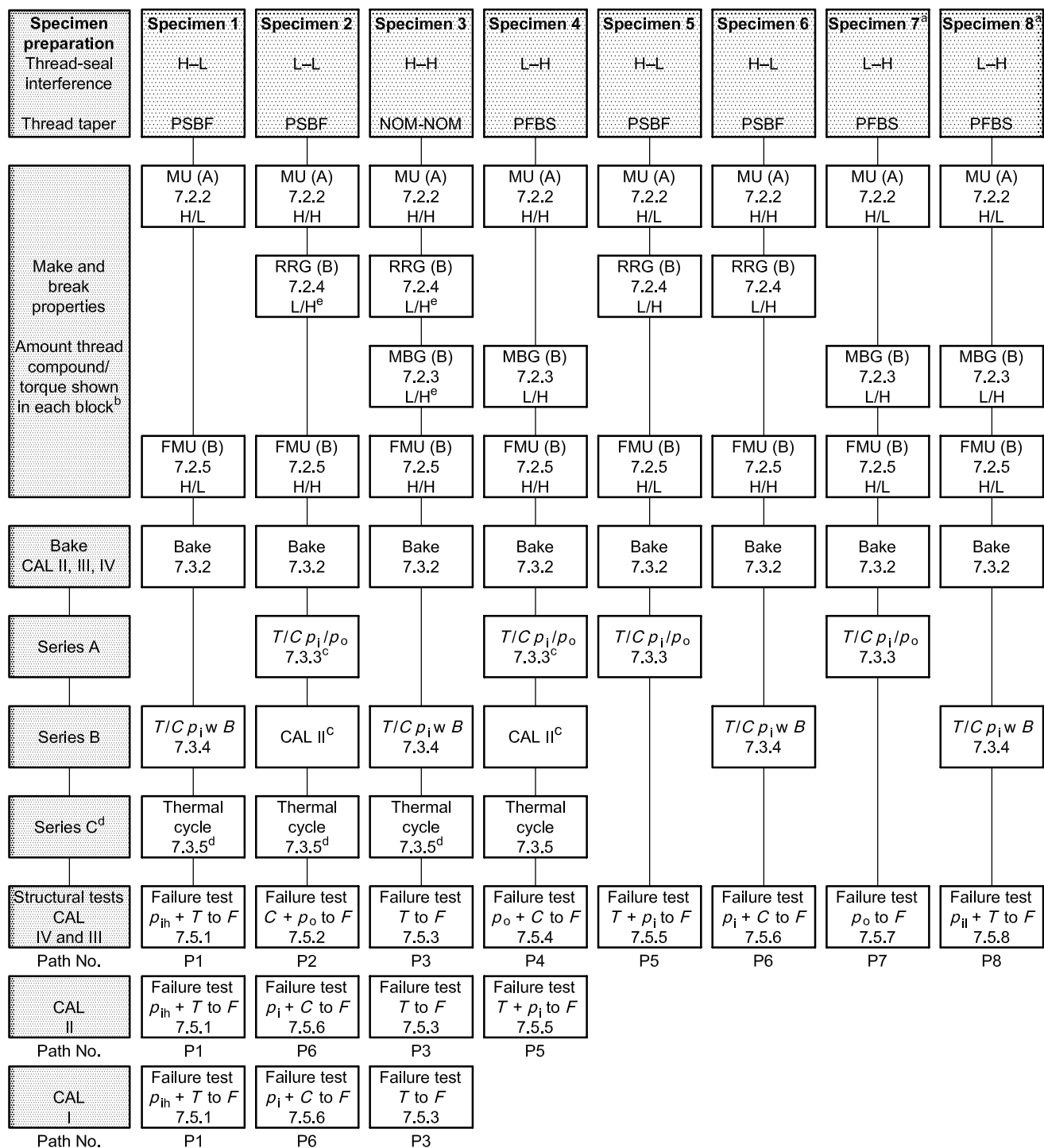


Figure 1 — Connection application level test programme

The abbreviations shown refer to the following test method titles:

(A):	Connection A end
(B):	Connection B end
MU:	7.2.2 Make-up
MBG:	7.2.3 Make-up/break-out test for galling resistance
RRG:	7.2.4 Round-robin make-up/break-out for galling resistance
FMU:	7.2.5 Final make-up
Bake:	7.3.2
$T/C\ p_i/p_o$:	Tension, compression internal pressure and external pressure
$T/C\ p_i/wB$:	Tension, compression internal pressure and bending
$p_{ih} + T$ to F :	7.5.1 High internal pressure with tension increasing to failure
$C + p_o$ to F :	7.5.2 Compression with external pressure increasing to failure
T to F :	7.5.3 Tension increasing to failure.
$p_o + C$ to F :	7.5.4 External pressure with compression increasing to failure
$T + p_i$ to F :	7.5.5 Tension with internal pressure increasing to failure
$p_i + C$ to F :	7.5.6 Internal pressure with compression increasing to failure
p_o to F :	7.5.7 External pressure increasing to failure
$p_{il} + T$ to F :	7.5.8 Low internal pressure with tension increasing to failure

Thread-seal interference abbreviations:

H-L:	Thread high – seal low
L-L:	Thread low – seal low
H-H:	Thread high – seal high
L-H:	Thread low – seal high

Thread taper abbreviations:

PSBF:	Pin slow taper box fast taper
PFBS:	Pin fast taper box slow taper
NOM-NOM:	Pin nominal taper box nominal taper

Thread compound/torque abbreviations:

H/L:	High amount of compound/low torque
H/H:	High amount of compound/high torque
L/H:	Low amount of compound/low torque

- ^a For CAL III, do not use Specimens 7 and 8.
- ^b Applicable for CAL II, CAL III and CAL IV, only. For CAL I make/break conditions refer to Tables 5 and 6.
- ^c CAL II specimens receive only Series B and Series C testing (See Table 1).
- ^d CAL I does not require Series C testing (see Table 1).
- ^e For CAL I, RRG on specimens 2 and 3 is not required. Specimen 2 receives MU only. Specimen 3 receives MBG.

Figure 1 (continued)

5.3 Test programme

5.3.1 Physical testing

Conduct a physical test programme of make-up/break-out tests, test load envelope tests and limit load tests in accordance with the procedures stated in this International Standard.

Instructions in this International Standard shall be followed. If adverse conditions not specifically addressed in this International Standard are encountered, all deviations from this International Standard shall be documented in the test reports. In addition, a statement(s) should be provided to justify why the tests should be considered adequate.

5.3.2 Assessment of test results

5.3.2.1 General

Assess the results of the physical test programme, in accordance with Clause 8, following the procedure given in 5.3.2.2 to 5.3.2.4.

5.3.2.2 Test results that conform to the stated connection application level

By successfully conforming to the requirements for all the make/break tests, the test load envelope tests and the limit load tests, the connection in the size, mass (label: weight) and grade of material (i.e. same yield strength and chemistry) tested has demonstrated conformance to the connection rating at the stated connection application level.

Limit load tests have minimum acceptance criteria, which define passing the tests. The TLE may be adjusted, as described below, after the tests in order to achieve passing.

5.3.2.3 Test results that do not conform to the stated connection application level

When the test results do not conform to the requirements of the test load envelope tests, the results may be evaluated for:

- a) a connection design revision followed by a full re-test; or
- b) a revision of the test load envelope followed by re-test of all test specimen(s) which did not meet the requirements of the revised test load envelope for that specimen.

For a premature limit load test failure

- a design revision and full retest of all specimens shall be performed, or
- a revision of the TLE shall be made.

If the test results comply with the revised TLE and limit loads, no further testing or action is required. All limit loads shall exceed the test load envelope.

In case of the malfunctioning of testing facilities or test execution, which is not related to product design, neither a connection design revision, test load envelope revision nor limit load revision is required, but the specimen(s) or replacement specimen(s) shall be re-tested in full. Any event not conforming to acceptance criteria shall be reported. The number of retests and the need for the retests shall be included on the summary and detailed test reports.

5.3.2.4 Reporting of test results

Report the assessment of test results in the first section of full and summary test reports. All connection leaks, regardless of volume or rate, shall be reported on the data sheets and identified on the pressure plots. All equipment leaks, regardless of volume or rate, shall also be identified on the pressure plots.

5.4 Calibration and accreditation requirements

5.4.1 Accreditation

The laboratory conducting these tests shall be either

- a) accredited by a recognized national or international accreditation body, or
- b) at a minimum, comply in full with 5.4.2 to 5.4.5.

5.4.2 Equipment calibration

Before testing begins, ensure that all load frames to be used for the tests have a valid calibration. In addition, based on the connection manufacturer's or test laboratory's experience, measuring and recording instruments, such as pressure gauges and thermocouples, shall be calibrated periodically. The test laboratory standards for calibration and all of the calibrations shall be documented. Copies of current calibration test reports for the load frame, temperature, pressure and torque measuring devices shall be included in the detailed test report.

Equipment calibration during a test programme may be appropriate based on the required test loads and past equipment usage.

5.4.3 Annual load frame calibration

Each load frame used in an axial load or combined load test shall be calibrated in both tension and compression modes at least annually with device(s) (i.e. load cells) traceable to national standards bodies.

The calibration should consist of two passes of a minimum of 10 equal increments ranging from the minimum calibration load to the maximum calibration load (defined as the "loading range"). The calibration range of the load frame shall cover the range of loads that will be applied in the test programme. The maximum frame calibration load shall be greater than the maximum anticipated failure load of the connection/pipe being evaluated.

The error, E_r , and the percent error, E_{rp} are calculated as follows:

$$E_r = F_i - F_f \quad (1)$$

$$E_{rp} = 100 \frac{E_r}{F_f} \quad (2)$$

where

F_i is the indicated load;

F_f is the actual load.

The percent error for all loads within the loading range of the frame shall not exceed $\pm 1,0$ % (see Annex F for an example).

5.4.4 Load frame verification

In the event that the load frame is subjected to unusual loads, such as applying a load beyond the calibration range or if a failure occurs at an unexpected load that could indicate a calibration problem, a calibration bar shall be used to verify the load frame calibration. This calibration bar shall be traceable to national standards bodies and certified annually. In lieu of using the calibration bar, a full annual calibration may be performed.

5.4.5 Pressure transducer calibrations

Each pressure transducer shall be calibrated at least annually. The percent error for pressures within the loading range shall not exceed $\pm 1,0\%$.

5.5 Rehearsal tests

Rehearsal tests are recommended. The purpose of a rehearsal test is to give the opportunity to, in an abbreviated format, softly validate the connection design and testing procedures prior to beginning the official testing. Test specimens for the official test should be threaded after the rehearsal tests are complete and especially if material availability is a concern. For rehearsal testing, the specimen(s) with low metal seal interference shall be tested for pressure sealing. Specimens with high metal seal interference shall be used to validate the galling sensitivity of the connection.

5.6 Material property tests

Test the pipe material mechanically to determine the yield strength for calculation of the connection testing loads and acceptance criteria.

The mechanical properties of the material shall be characterized by a documented procedure consistent with the specification for the material. Typically this is ISO 11960 for low alloy steel or ISO 13680 for corrosion-resistant alloys. For connections machined on line pipe the procedure shall be in accordance with ISO 3183-1, ISO 3183-2, or ISO 3183-3 or API Spec 5L.

NOTE 1 For the purposes of this provision, ISO 11960 is equivalent to API Spec 5CT.

Tensile test specimens shall be cut from both ends of all lengths of pipe and coupling stock. In addition, tensile test specimens shall be cut from the middle of all lengths of pipe and from the middle of lengths of coupling stock longer than 3 m (9.8 ft). Tensile test specimens and the results of the tests shall be traceable to the mother tubes and the location within the tube.

An alternative layout for pipe pups and tensile test specimens is given in Figure C.1. This layout provides the material strength directly adjacent to the threaded connection. If specimens are cut as specified in Figure C.1, the manufacturer shall modify the material property data sheet, as shown in Form C.1, to show the correct coupon location and shall include a sketch similar to Figure C.1 showing the actual location of the specimen pups and material coupons. If this alternate method is used, an elevated tensile test coupon should be taken at each location where mechanical properties are measured. The measured yield strengths adjacent to the thread to be used during the connection evaluation on each pup shall be the values used to calculate the test loads.

Either a strip specimen (preferred) or the largest practical ASTM round specimen (see ASTM A370) shall be used. The yield strength determined shall be the yield strength used for calculations. Additionally, the 0,2 % offset proof stress shall be reported for information. A sketch of the test coupon shall be shown in the material property data sheet, Form C.1. For one coupling and one pipe, plot the stress-strain or load-strain behaviour from zero strain to 2 % strain minimum or to coupon failure (whichever occurs first) for one Series A or Series B specimen and at elevated temperature for one Series C specimen.

Perform one ambient temperature tensile test on each material coupon.

Perform one elevated temperature tensile test at 135 °C (275 °F) for CAL II and CAL III and at 180 °C (356 °F) for CAL IV on each middle coupon or on one of the end coupons of coupling stock shorter than 3 m (9.8 ft).

For each elevated temperature test, report the actual coupon temperature by monitoring with a thermocouple attached to the coupon.

Perform a chemical analysis on each middle material coupon or one of the end coupons of coupling stock less than or equal to 3 m long (9.8 ft).

Report the material property data required on the material property data sheet, Form C.1.

NOTE 2 Consideration needs to be given to the limits of qualification of a connection if, within a specific strength grade, high strength pipe is tested. Consideration needs to be given to the possible effects of anisotropy of mechanical properties and of residual stress in cold worked CRA pipe (see ISO 13680 for information). Axial tensile testing may not be sufficient to adequately characterize the pipe.

5.7 Make-up and break-out procedures

5.7.1 Principle

Make-up and break-out procedures and the thread compound used during testing should be consistent with normal industry practice used in the field.

5.7.2 Make-up thread compound

The connection manufacturer shall specify the type and amount, with tolerances, of thread compound that shall be applied to the connection, as well as the areas to which the thread compound shall be applied. These thread compound criteria shall be the same as those used for field applications. The same thread compound shall be used for all test specimens. Preferably, the maximum and minimum quantities should be specified as mass. In addition, the manufacturer shall provide photographs and descriptions of how the thread compound is to be applied. This includes photographs of connections with minimum and maximum thread compound.

5.7.3 Make-up torques

The make-up torques specified in Clause 7 are either the maximum or minimum torque recommended by the manufacturer. For a high specified torque, 95 % of the maximum or a greater torque is acceptable. For a low specified torque, 105 % of the minimum or a lower torque is acceptable. If the actual make-up torque lies outside the required values, the connection shall be broken out and re-torqued. The manufacturer shall specify the rotational frequency (r/min) range for make-up. All connections should be made up at no less than 90 % of the maximum recommended rotational frequency (r/min).

5.7.4 Make-up procedure

Make up each connection in the following manner. Record the results in the specimen make-up/break-out data sheet, Form C.2.

For each make-up, clean and dry the connection completely, then weigh and record the amount of lubricant applied to each connection member (pin and coupling or box). Monitor and record make-up and break-out torques on torque-versus-turn plots. The turn resolution shall be at least 1/1 000 th of a turn. Torque-versus-turn plots for all make-ups of Clause 7 and any additional make-ups considered relevant shall be included in the full test report (see Clause 8 and Annex D). At the time of make-up, annotate each plot to indicate the test specimen, pin-end and box-end, make-up number, date, time and any unusual observations.

Connections should be made up using tongs and tong dies typical of those used in the field. Vertical make-up should be used. For coupled connections, floating of the coupling is prohibited (i.e. each side shall be made up separately). Photograph all make-up equipment and at least one connection being made up. When gripping couplings (or boxes), clamping forces should be controlled to prevent adverse distortion of the internally threaded member.

When performing the make and break procedure, it is acceptable to have a “dummy pin” in the end that is not being made up to help avoid damage.

5.7.5 Break-out procedure

Break-out the connection test specimen with the same tongs and instrumentation as in 5.7.4 in accordance with the manufacturer's procedure. Record the results in the specimen make-up/break-out data sheet, Form C.2.

5.7.6 Break-out refurbishment

Following each break-out, pins and boxes may be refurbished using only techniques stipulated by the connection manufacturer for field use. All such repairs shall be fully documented including repair time. Any galling or other nonconformity shall be reported. A galling evaluation, including a clear description of the size and nature of the damage, shall be part of the final report. Photographs shall be made of the galled surface, repaired surface, repaired surface after the next break-out and the repaired surface after the final break-out and shall be included in the final report.

5.7.7 Connection test specimen inspection

Inspect the connection test specimens carefully following each break-out. Evaluate and document on the torque-versus-turn plots any correlation with observed connection galling. On the torque-versus-turn plots, document any observations or variances that contributed to other make-up concerns (coupling or pin spinning in tong dies, computer glitch/electrical spike which results in no torque-versus-plot printout, etc.). Record dimensional inspection results on the specimen geometry data sheet, Form C.3.

5.8 Internal pressure leak detection

5.8.1 Principle

Leak detection requirements are critical for those connections that need to be gas or liquid tight. Alternate methods of leak detection are shown below for use on different types of connections. The casing and tubing connections shall be subjected to internal pressure and monitored with a system capable of trapping and measuring all connection leakage.

5.8.2 Pressurization media

For CAL II, III, and IV, all tests with internal pressure to verify the test load envelope shall be conducted with dry nitrogen. At the option of any of the parties to the test, a 5 % helium tracer gas may be added. For CAL I, all tests with internal pressure to verify the test load envelope shall be conducted with solids-free liquid or dry nitrogen as agreed in the test plans. All limit load tests (i.e. planned failure tests) shall be conducted with liquid as the pressuring medium unless otherwise specified and agreed in the test plans.

5.8.3 Test safety

For safety considerations, specimens subjected to gas pressure testing should include an inserted filler bar. The filler bar material should either not be porous or should bleed off the test medium quickly to avoid problems with interpreting the test results. The bar should be dimensioned to reduce the internal specimen volume substantially but shall not result in any mechanical interference with the specimen when the specimen deforms during test execution (see Figure 8 in 5.10.2). Filler bars should be centralized to ensure no contact with the test specimen D_i within one pipe diameter of the connection.

5.9 Internal pressure leak trap device

5.9.1 Alternatives

The connection test specimen shall contain one, or more, of the following internal pressure leak trap devices. When the tests will be at elevated temperature, the materials shall be rated for temperature above the test temperature.

5.9.2 Collared leak trap device

A collared leak trap device consisting of an O-ring held against the face or OD of the box by a ported collar containing a flange with at least four bolt-holes. Four longitudinal bolts maintain the collar tight against the face for sealing. A second O-ring is used to seal the collar against the pipe body using a separate bolted ring as shown in Figure 2.

5.9.3 Flexible boot leak trap device

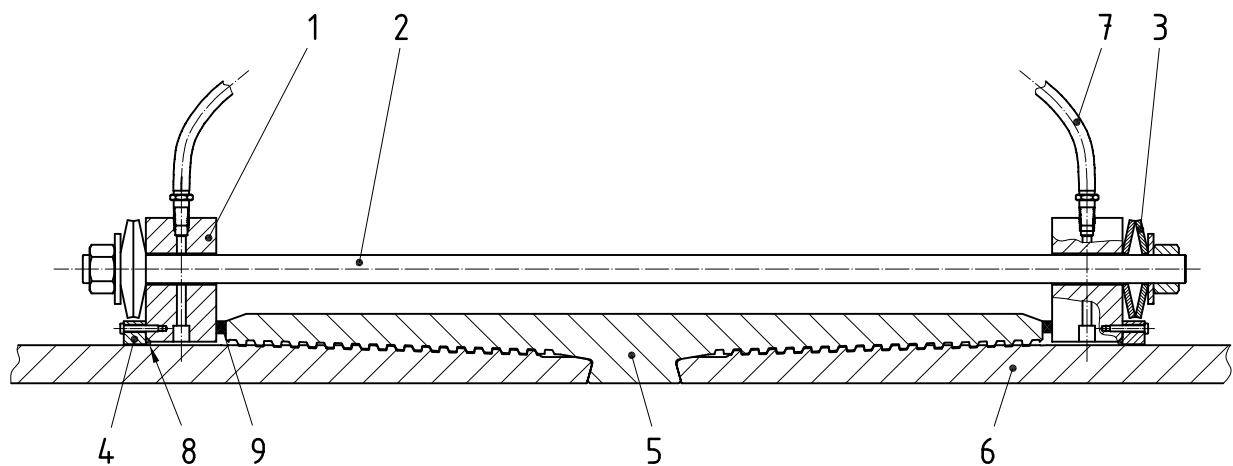
A flexible boot trap device consisting of a flexible material, such as silicone, that encapsulates the end of the box. A sealant is used between the pipe OD, box OD and the boot. Hose clamps are used to secure the boot to the pipe and the box OD. A tube is placed between the boot and pipe OD, using the sealant to ensure that escaping gas exits by the boot as shown in Figure 3.

5.9.4 Ported box leak trap device

A vent hole is drilled through the box over the pin run-out threads near the end of the box face to allow escaping gas to exit the connection. The hole is tapped and fitted with a threaded adapter to which a flexible hose is attached. The face of the box shall be sealed to prevent any gas from escaping out of the end of the box as shown in Figure 4.

Assemble the ported box (Figure 4) in the following manner:

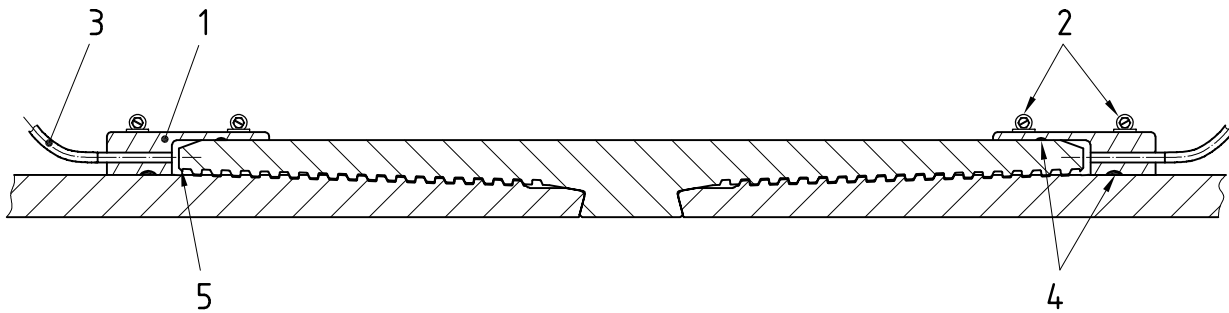
- a) drill, tap and de-burr holes before make-up;
- b) assemble connection;
- c) install threaded fittings into holes using thread sealer, such as PTFE;
- d) clean and seal the ends of the coupling with silicone sealant or equivalent;
- e) allow sealant to cure.



Key

- | | |
|-------------------|--------------------|
| 1 metallic flange | 6 pipe |
| 2 threaded rod | 7 flexible hose |
| 3 springs | 8 o-ring |
| 4 threaded nut | 9 flat face gasket |
| 5 coupling | |

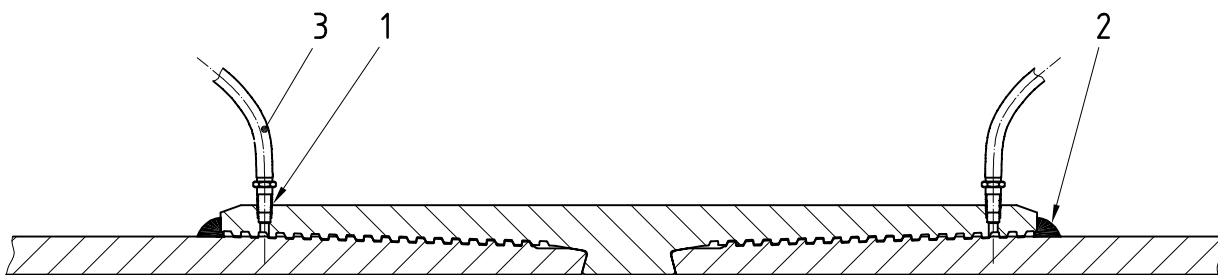
Figure 2 — Collared leak trap device for internal pressure leak detection



Key

- 1 flexible boot
- 2 hose clamps
- 3 metal tube or flexible hose (heat resistant for Test Series C)
- 4 sealant
- 5 small gap for good leak detection sensitivity

Figure 3 — Flexible boot leak trap device for internal pressure leak detection



Key

- 1 tapped hole in run out threads with threaded fitting
- 2 sealant
- 3 flexible hose

Figure 4 — Ported box leak trap device for internal pressure leak detection

5.9.5 Pressure test of leak trapping devices

Each trapping device shall be tested as follows:

- a) check sealant and fitting for leaks by attaching a hose to a pressure supply; apply a gas pressure of 0,007 mPa to 0,014 mPa (1 psi to 2 psi) air or nitrogen; close off from supply and observe pressure gauge for a decrease in pressure;
- b) tighten or repair trapping device as necessary;
- c) periodically remove fitting, clean hole as necessary and re-pressure test system as above;
- d) ports may be close to metal-to-metal seal by agreement.

5.9.6 Internal pressure leak detection sensitivity

The monitoring and measuring system for internal pressure leak detection shall meet a minimum leak indication sensitivity of $0,9 \text{ cm}^3/15 \text{ min}$ time period using a graduated cylinder of $0,1 \text{ cm}^3$ graduations or a sensitivity of $1 \times 10^{-4} \text{ cm}^3/\text{s}$ under standard conditions for gas chromatograph or spectrometer system. If helium tracer gas is used, the graduated cylinder based system shall have the capability of capturing the accumulated gas for the analysis of helium content to verify or discount leak events.

When using a graduated cylinder, take care to compensate for changes in barometric pressure because these changes may affect the leak detection sensitivity. It is recommended that prior to beginning any tests, a separate “dummy” graduated cylinder (see Figure 5) replicating the leak detection device be set-up. This separate “dummy” graduated cylinder would be used during analysis to determine if a connection is leaking or if the change is due to a change in barometric pressure. The separate “dummy” graduated cylinder should contain a gas bubble consistent with the size of the bubble in the inverted graduated cylinders of the connections being monitored.

Leak indicators may be evaluated regarding their source if there is reason to believe the leakage is not from the connection. A sensor calibrated to detect helium may be used to verify that any bubbles detected are coming from the pressure medium and not from the thread compound de-gassing or from thermal expansion of the connection or test equipment. Evaluation of the leakage source shall be based on conclusive analysis of the leakage gas. If leakage is generated from a source other than the connection (e.g. the end caps), the leakage source shall be repaired and testing continued. Report all leaks and their source (pressure fitting, valve, connection, etc.). All leak indicators shall be reported and the basis for discounting leakage clearly explained in the test report.

5.9.7 Internal pressure leak detection by bubble method

5.9.7.1 Principle

A leak detection system based on the bubble method is shown in Figure 5. The system is based on capturing any and all gas that passes through a connection and collecting the gas in a container for measuring the volume. The main components of the system are:

- a) a means of trapping the gas, such as the leak trap devices described above;
- b) a tube or flexible hose that connects the leak trap device to a bubble collection tube;
- c) a bubble collection tube that consists of a clear graduated cylinder with $0,1 \text{ cm}^3$ or smaller scale divisions. The cylinder is filled with water and a flexible hose is placed inside the open end of the cylinder. The cylinder and the end of the hose are submerged in a container of water and then inverted (see Figure 5). A leak is visually detected if bubbles rise in the cylinder. The gas from the bubbles is measured using the scale on the cylinder.

5.9.7.2 System verification for bubble method

Verify all internal pressure leak detection systems prior to a test programme by testing for leaks and assessing sensitivity.

- a) Test the system for leaks by applying $0,007 \text{ mPa}$ to $0,014 \text{ mPa}$ (1 psi to 2 psi) air or nitrogen gas pressure. When the pressure stabilizes, close off the gas supply. Observe the pressure gauge for 2 min for stability. Any drop in pressure indicates a system leak. Locate and repair any system leaks. Repeat this procedure until the gas pressure remains stable for a minimum 2-min hold period.
- b) Determine the sensitivity efficiency of the bubble leak detection system by introducing air and measuring the output air in each bubble tube. Inject the air in 1 cm^3 increments up to at least 10 cm^3 . Determine the average relationship of output volume to input volume by plotting the data as shown in Figure 6. The initial amount of input air required to start output air in the bubble tube (pre-charge) shall be recorded, but will not affect the calculated leak rate and is therefore not considered in this sensitivity efficiency. The sensitivity efficiency shall be at least 70 %. If it is less than 70 %, reconfigure the system to increase

sensitivity. This sensitivity efficiency shall be used to correct all observed leak rates and volumes during test execution according to Equation (3).

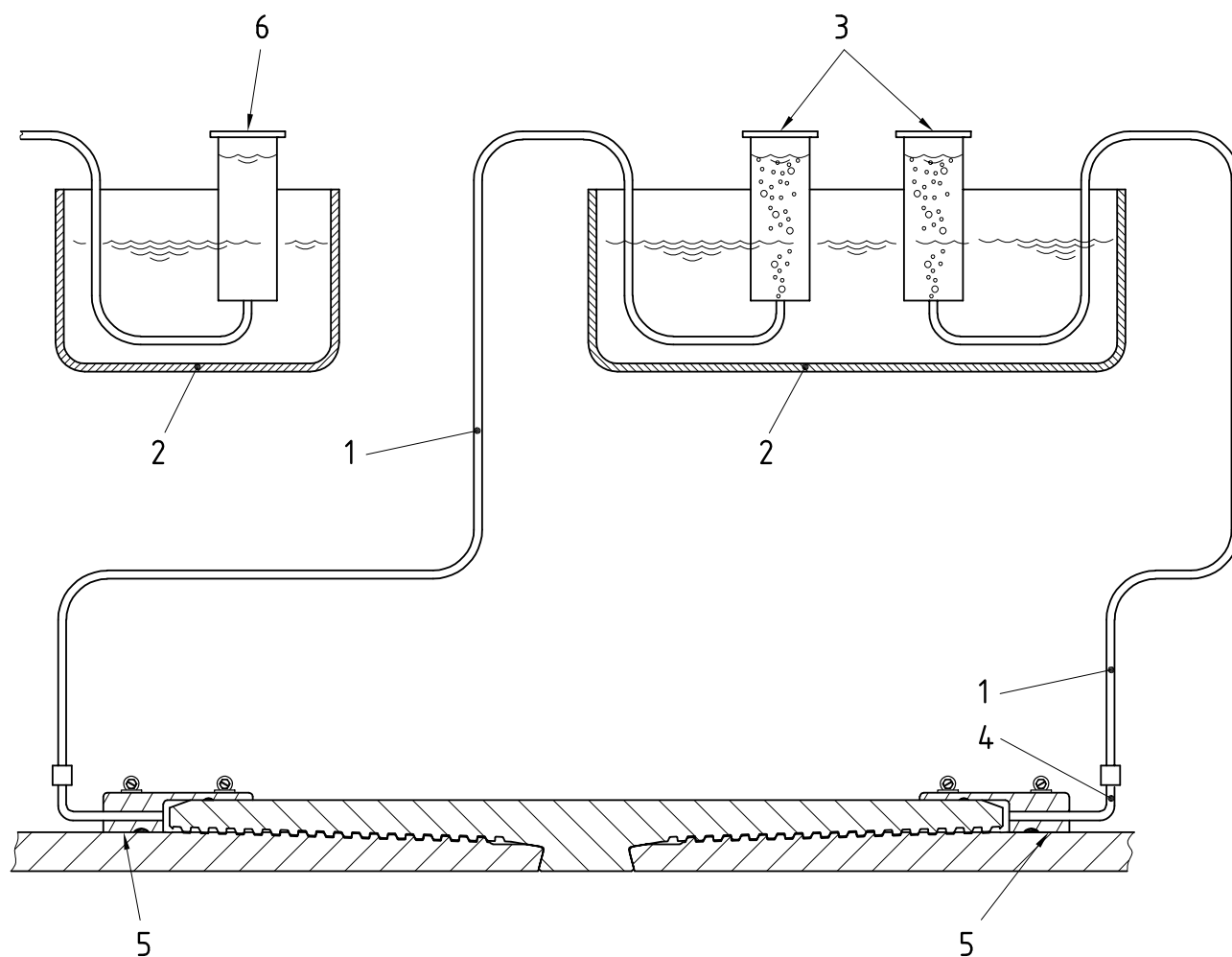
$$q_{ac} = \frac{q_o}{\eta_{lds}} \quad (3)$$

where

q_{ac} is the actual leak rate to be reported;

q_o is the observed leak rate;

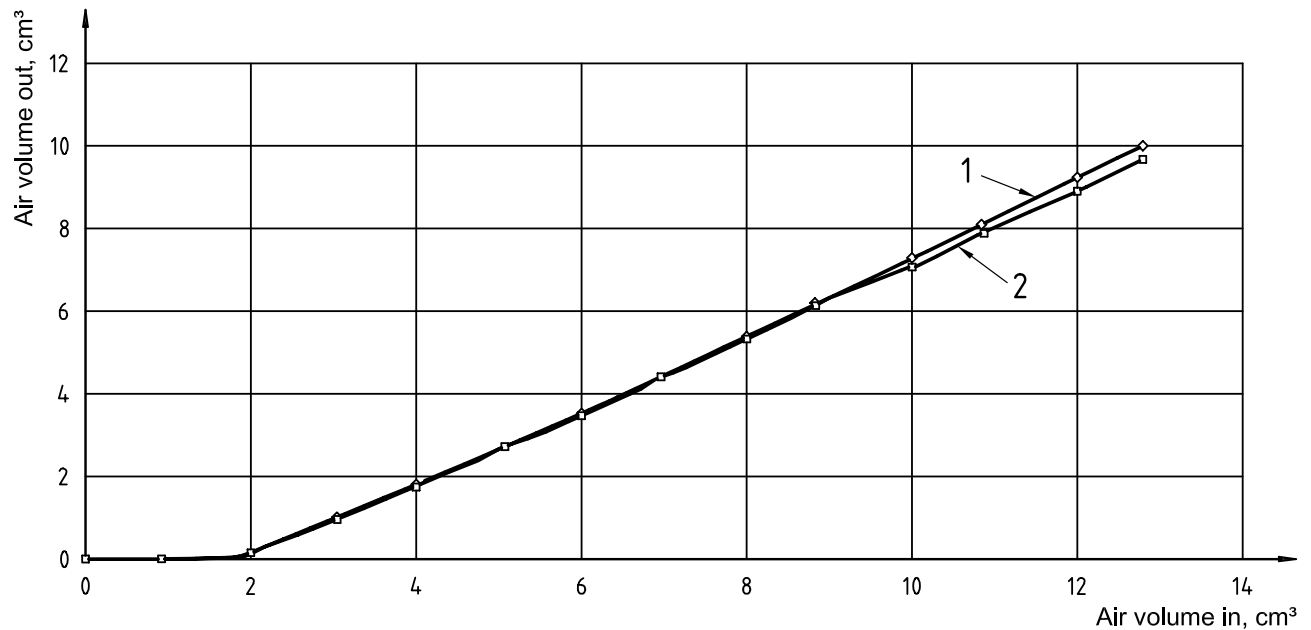
η_{lds} is the leak detection system efficiency.



Key

- 1 flexible hose
- 2 water tank
- 3 graduated cylinders
- 4 heat resistant tube
- 5 leak trap devices
- 6 dummy graduated cylinder (same size and height above top of water as cylinders, see 3)

Figure 5 — Internal pressure leak detection by bubble method



Key

- 1 specimen end A
- 2 specimen end B

Figure 6 — Example of a plot for determining leak detection sensitivity

5.9.7.3 Start of test

Before starting a test load envelope test, pre-charge each leak detection system by injecting air into the system near the box until a small amount of air collects in the bubble tube. Record this volume as the initial amount of gas to be subtracted from any additional gas collected in the tube. This pre-charge volume shall be sufficient to lower the water level to the scales on the graduated cylinder prior to the initiation of the test sequences.

5.9.8 Internal pressure leak detection by helium mass spectrometer method

5.9.8.1 Principle

A leak detection system using a helium mass spectrometer (see Figure 7) includes the following:

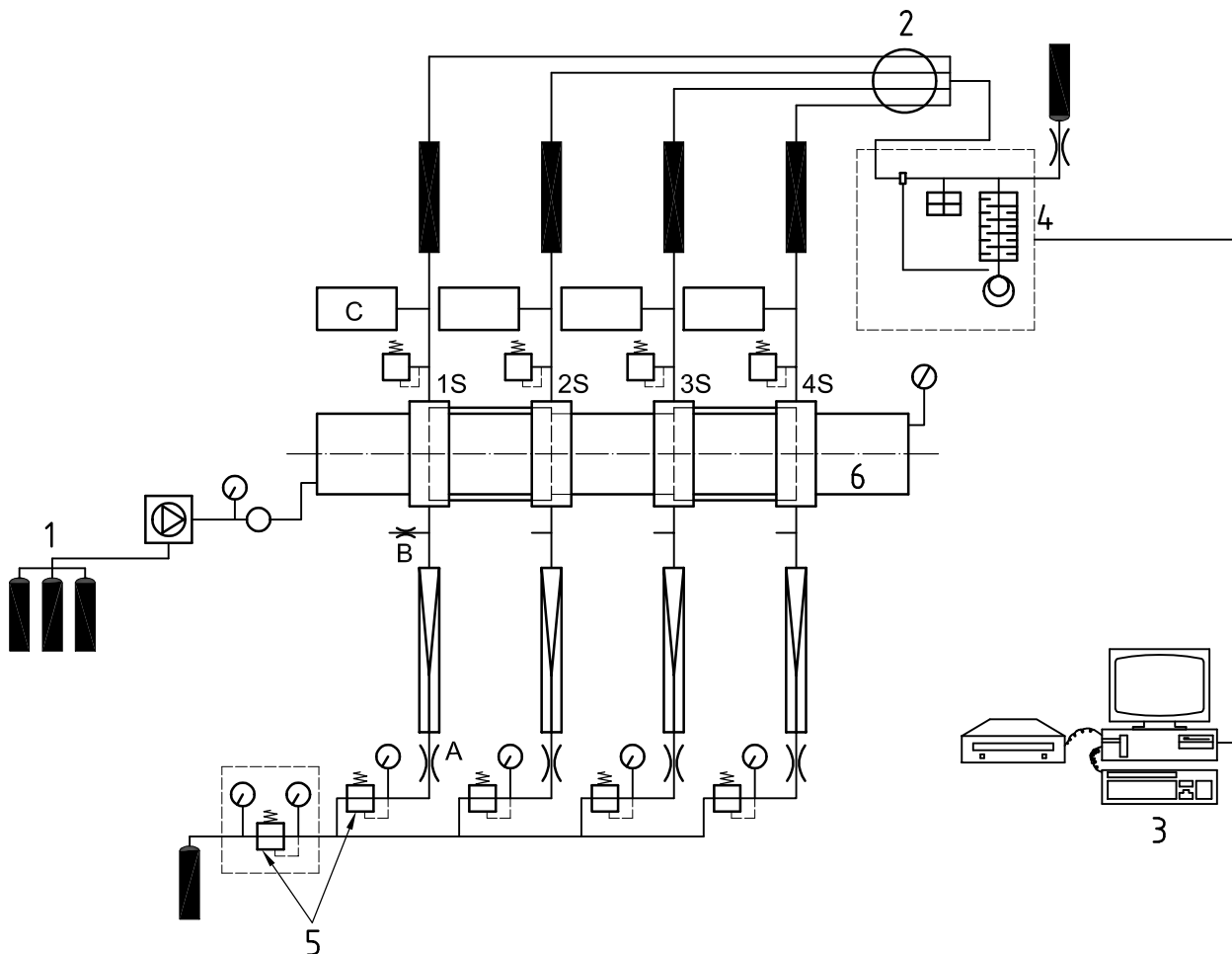
- a) a means of trapping the gas;
- b) a tube or flexible hose connecting the leak trap device to a carrier gas line;
- c) a pure nitrogen carrier gas line that connects to a mass spectrometer;
- d) a helium mass spectrometer (generally, the mass spectrometer uses a sniffing method of leak measurement, and consequently, much care shall be taken to ensure the sniffer is working properly at atmospheric pressure).

5.9.8.2 System accuracy

The helium leak measuring system shall be capable of measuring a total leak of $1 \times 10^{-4} \text{ cm}^3/\text{s}$ under standard conditions or lower leakage rate.

5.9.8.3 Calibration

The complete system shall be calibrated to the equipment supplier's recommendation and at least once annually using a certified calibrated leak source. The calibrated leak source shall be used in place of a test specimen with all other components of the leak detection system in place.



Key

- 1 internal pressure source
- 2 sampling valve
- 3 data logger
- 4 mass spectrometer detector
- 5 carrier gas regulators
- 6 test specimen (shown with two couplings and four connections: 1S, 2S, 3S and 4S)

Figure 7 — Leak detection by helium mass spectrometer method

5.9.8.4 Multiple specimen leak measurement

A manifold scanner can be used to test multiple connections or specimens. Minimum required sniffing time varies with equipment and shall be determined and demonstrated before starting the test. Each line shall be sniffed no less than once per minute.

5.9.8.5 System verification

Before each test, flush the system with nitrogen or nitrogen with helium and then test by sniffing the gas through the complete line and leak trap device. Check for proper helium content of the gas, demonstrating that the lines are not plugged.

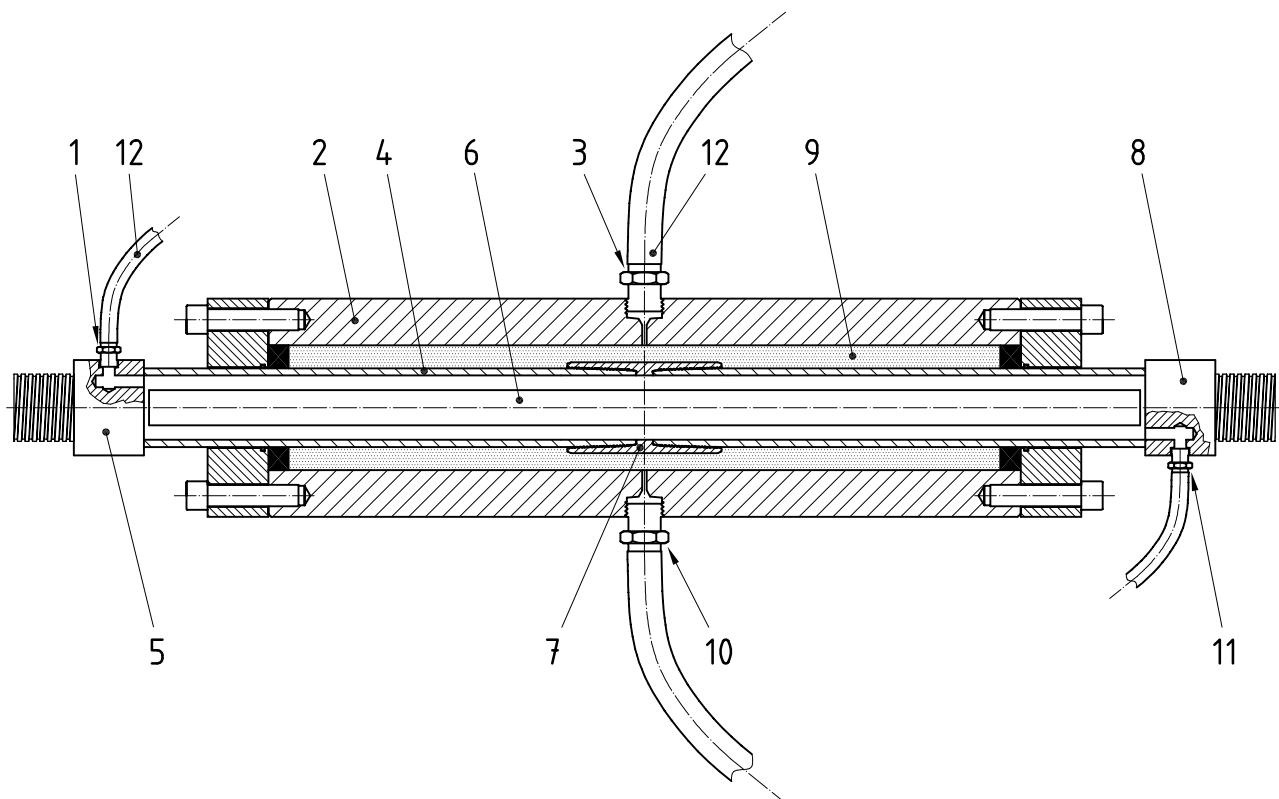
5.10 External pressure leak detection

5.10.1 Principle

The casing and tubing connections shall be subjected to external pressure within a system capable of detecting the external pressure leakage. External pressure leak detection is recognized as more difficult and less accurate than internal pressure leak detection. All external pressure tests shall be conducted with fresh water. All displacements shall be reported.

5.10.2 Test safety

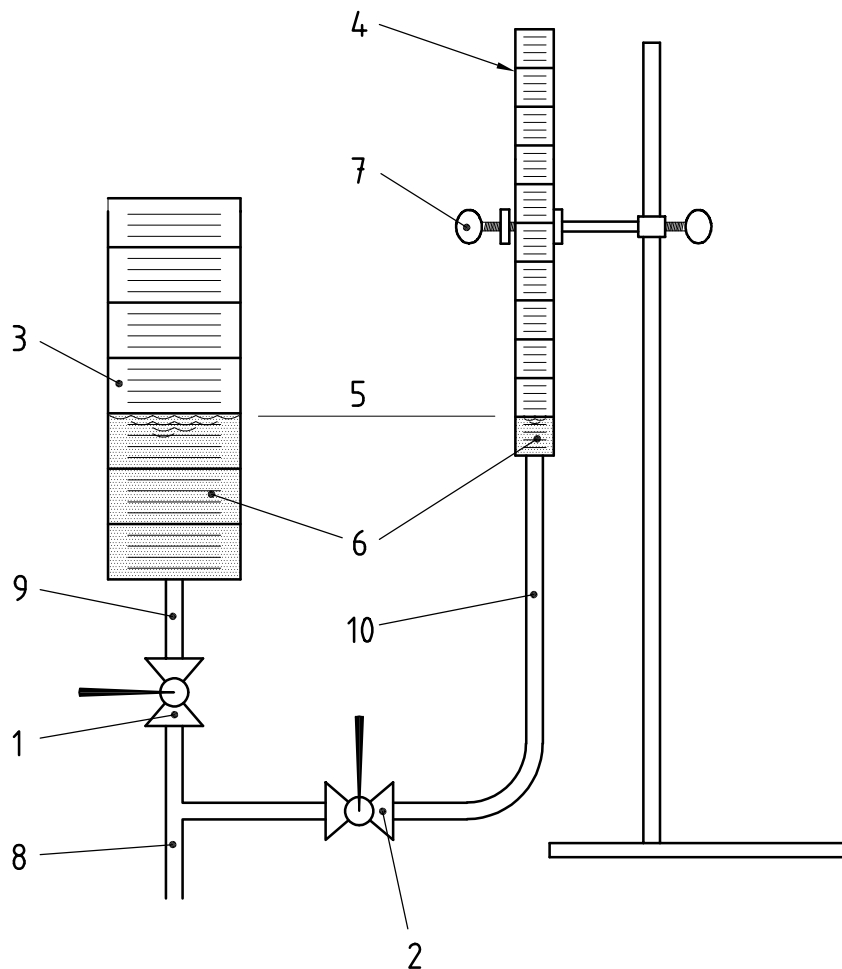
If external pressure testing is performed in conjunction with internal pressure testing, the specimens should have an internal filler bar as specified in 5.8.3 (see Figure 8).



Key

- | | |
|---|---|
| 1 port for pressure transducer for internal gas test, leak detection for external pressure test, shop air inlet to drain water after external pressure test | 6 internal filler bar, for safety |
| 2 external pressure chamber | 7 test connection |
| 3 hole, equipped with flexible hose to leak detection for internal pressure test or pressure transducer for external pressure test | 8 end cap containing bottom internal port, see 11 |
| 4 test pipe | 9 chamber, fully filled with water |
| 5 end cap, containing top internal port, see 1 | 10 hole, for water pressure inlet to chamber |
| | 11 port for gas pressure inlet, water fill for external pressure test, water drain after external pressure test |
| | 12 flexible hose that attaches to leak detection system (see 8 in Figure 9) |

Figure 8 — Example set-up for Test Series A



Key

- 1 valve to large graduated cylinder
- 2 valve to small graduated cylinder
- 3 large graduated cylinder with open top (approximately 100 cm³ to 200 cm³)
- 4 small graduated cylinder with 0,1 cm³ graduates with open top (approximately 25 cm³)
- 5 water level
- 6 coloured water
- 7 adjustable cylinder support to allow bottom of cylinder to be located at 100 cm³ to 200 cm³ water level at start of each hold period
- 8 flexible hose attached to top of chamber for internal gas tests and top port at one of end caps for external tests
- 9 flexible hose to large cylinder
- 10 flexible hose to small cylinder

Figure 9 — Example of leak detection system for Test Series A

5.10.3 Ported end caps

Connection test specimen end caps shall have holes that allow the inside of the specimen to be filled with water. These holes shall have high-pressure fittings able to contain internal pressure during internal pressure tests. Normally two holes are required, i.e. one for water inlet and one for air exit (air bleed). The air bleed hole shall be at the opposite end of the specimen from the water inlet hole. The bleed hole shall be located in the end cap so as to allow all of the air to be removed from the inside of the specimen. The ports shall also be

located in such a manner as to allow all the water to be removed from the specimen for subsequent internal gas tests.

5.10.4 Set-up for Test Series A

An example set-up for Test Series A is shown in Figure 8. During Test Series A, pressure loading changes from internal pressure to external pressure and back several times. To minimize test time, the tests may be conducted with an external pressure chamber in place for the entire series A. The external chamber may be used as part of the internal pressure leak detection system subject to the following requirements.

- a) Seek a leak detection sensitivity of $1 \times 10^{-3} \text{ cm}^3/\text{s}$; however absolute demonstration may not be possible.
- b) Fill the external chamber and flexible hose with water.
- c) To validate suspected leaks, perform additional tests to confirm the rate and source.

5.10.5 Leak detection and measurement by water level

For internal gas tests, fill the flexible hose at the top of the chamber (see 12 in Figure 8) with water and connect it to the leak detection system shown as 8 in Figure 9.

For external pressure tests, fill the inside of the specimen with water. Fill the flexible hose from the top of one of the end caps (see 1 in Figure 8) with water and connect it to the leak detection system shown as 8 in Figure 9.

During external pressure testing, a chamber encloses the test connection and some portion of the pipe on both sides of the connection. During the external pressure testing, it has been observed that immediately after reaching full pressure and axial load, there may be significant (greater than $0,9 \text{ cm}^3/15 \text{ min}$) water displacement. This displacement usually exhibits a decreasing trend and is a “stabilization period” that shall be performed before starting the required ISO hold period. In view of this test behaviour, the following criteria should be used for external pressure tests.

- a) Apply the full required external test pressure and close the pressure line valves from the pressurizing pump.
- b) Small pressure increases may be necessary immediately after closing the valves in order to maintain the required pressure.
- c) Begin recording the frame loads, pressures and bubble tube readings shortly after closing the valves (within approximately 2 min).
- d) Record the frame loads, pressures and bubble tube readings in 5-min increments.
- e) Note the trend of the bubble tube displacements. A decreasing trend in displacement is normal and indicates no connection leakage. A steady trend greater than $0,9 \text{ cm}^3/15 \text{ min}$ or an increasing trend indicates a possible connection leak.
- f) A hold period is considered to be leak free when the following are satisfied:
 - 1) for a 15-min hold:
 - i) four consecutive 5-min holds have been made;
 - ii) the sum of the first three 5-min holds and the sum of the last three 5-min holds (i.e. two consecutive rolling 15-min holds) do not exceed $0,9 \text{ cm}^3$ positive displacement;
 - iii) the 5-min hold period displacements do not show an increasing trend in displacement;

- 2) for a 60-min hold:
 - i) thirteen consecutive 5-min holds have been made;
 - ii) the sum of the first twelve 5-min holds and the sum of the last twelve 5-min holds (i.e. two consecutive rolling 60-min holds) do not exceed $0,9 \text{ cm}^3/15\text{-min}$ positive displacement;
 - iii) the 5-min hold period displacements do not show an increasing trend in displacement.

For both internal and external tests, at the start of the test, the large graduated cylinder shown in Figure 9 is approximately half filled with water. Before test loads are applied and adjusted, the large valve (see 1 in Figure 9) is opened and the small valve (see 2 in Figure 9) is closed. The water level inside the large cylinder will rise or fall with the applied test loads. At the start of a hold period, the small valve (see 2 in Figure 9) is opened and the position of the small graduated cylinder is adjusted up or down so that the water level in the small cylinder is near the bottom of the cylinder. The large valve (see 1 in Figure 9) is then closed. If a specimen leak occurs, the water level in the small cylinder will rise and can be observed and measured in time to give a leak rate. A colouring agent should be added to the water inside the cylinders for ease of viewing the water level.

The water level in the small cylinder shall be recorded at the start and end of each hold period and at the intervals stated in 7.3.2 when a leak occurs to determine the leak characteristic.

5.11 Data acquisition and test methods

5.11.1 General

The correct and adequate recording of data is fundamental to the qualification programme. Without adequate records, it will not be possible to provide the objective evidence of the qualification of a connection.

5.11.2 Principle

For Test Series A, the primary loading is pressure and axial force at ambient temperature. Bending loads are recognized as a secondary load accompanying axial load and shall be minimized as much as possible by careful alignment of end caps and load frame. For Series B CAL IV tests, test bending loads are deliberately added to the axial loads. For Series B CAL III, II and I tests, added bending loads are optional. Specimens tested in Series B with applied bending shall be instrumented to determine the bending load.

5.11.3 Procedure

5.11.3.1 General

Monitor and record the internal or external pressure, frame load, bending load and temperature that are applied to the specimen. For all tests record the pressures, axial load and temperature continuously versus time. Data may either be recorded continuously or digitally. For digital data acquisition systems, the data acquisition rate should be appropriate for the expected load and pressure changes but shall not be less than 1 scan of all channels every 15 s.

Draw a graph of the pressure in the sealing proof tests using a pressure scale from zero to a full scale greater than the maximum anticipated test load pressure. Draw a graph of the pressure applied in failure tests using a full-scale pressure range greater than two times the maximum anticipated test load pressure. Draw a graph of the machine tension load in sealing proof tests using a full-scale load range from zero to full scale greater than the maximum anticipated test load tension. Draw a graph of the machine load in failure tests using a full-scale load range of greater than 1,5 times the maximum anticipated test load tension. Temperature versus time shall also be plotted using an appropriate resolution scale. Annotate the graphs for ease of later interpretation.

5.11.3.2 Pressure and/or tension loads

Connect a pressure transducer to the internal or external pressure cavity of the specimen. Locate the pressure transducer at the air bleed hole and not at the pressure inlet hole.

Load each specimen at an axial stress rate of 105 MPa/min (15 000 psi/min) or less. Load each specimen with pressure at a rate of 105 MPa/min (15 000 psi/min) or less. Loading the specimens may be performed continuously or intermittently. However, in the case of intermittent loading the rates for axial load and pressure increments shall not exceed the maximum rates. There is no maximum or minimum rate for removing pressure or axial loads.

NOTE These rates are specified to ensure that accurate sealing and structural performance data are recorded in the tests.

5.11.3.3 Bending loads

When measuring bending using strain gauges, place the four biaxial strain gauge rosettes on at least one of the pipe bodies (and preferably on both pipe bodies) at a single cross-section plane and at a distance of at least $3\sqrt{Dt}$ from the connection and any end cap or gripping fixture. Equally space the strain gauges around the circumference at 90° spacing. The position/orientation of each gauge shall be documented. Other instrumentation may be used to monitor bending if its accuracy can be shown to be equivalent to four biaxial strain gauge rosettes.

Apply and control bending at the connection to at least the minimum bending moment for deliberate bending tests as determined by measured strains from the pipe body strain gauges and according to the moment distribution calculation below for three-point bending. Monitor the pipe body strain gauges, calculate the bending stress, moment and dogleg and continuously record the dogleg.

Three load methods for deliberate bending are recognized:

a) Four-point bending:

For a four-point bending fixture, locate both bending load cylinders at equal distances from the end reaction points and ensure they impose equal load.

b) Three-point bending:

For three-point bending (centre load applied on the coupling), apply a correction to the strain data bending results in proportion to the ratio of the distance from the outer load point to the centre of the coupling divided by the distance from the outer point to the centre of the strain gauges. This correction gives the bending values at the coupling.

c) Uniform bending from rotating end fixtures:

For rotating end fixtures, the applied bending moment shall be the same on both ends.

5.11.3.4 Tests to failure

Monitor and record the internal or external pressure and axial load that is applied to the specimen.

For each failure test, photograph the specimen after failure and show the location and mode of failure. Record major loads and dimensions on the limit load test data sheet Form C.4. Report and retain test data in the test reports (see Clause 9 and Annex D).

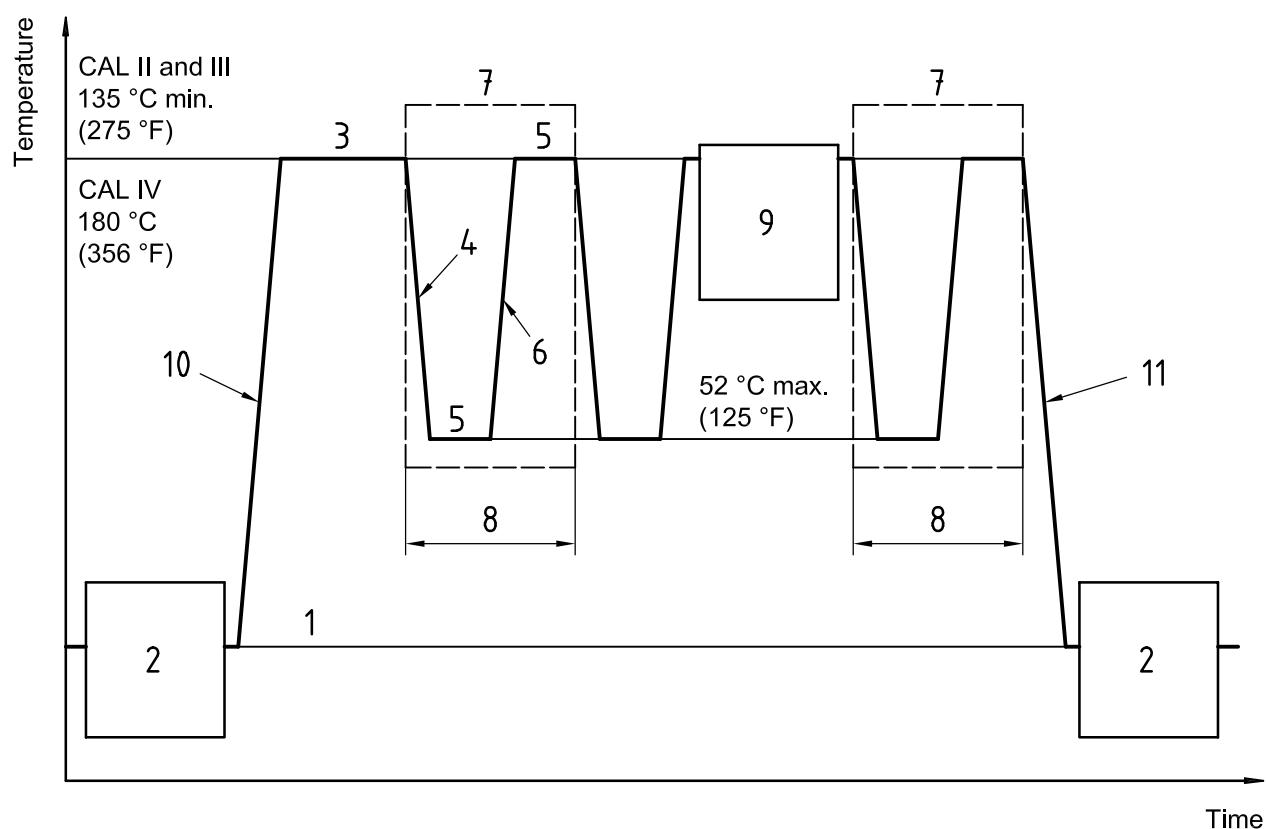
5.12 Thermal cycling tests

5.12.1 General

The purpose of thermal cycling is to approximate service conditions and accelerate potential leakage by applying thermal cycling while the connection is subject to axial tension and internal pressure loads.

5.12.2 Principle

A thermal cycle is a change from “maximum” temperature to “minimum” temperature and back to “maximum” temperature and is illustrated in Figure 10.



Key

- 1 ambient temperature
- 2 five pressure/tension cycles at ambient temperature
- 3 minimum 60-min hold at elevated temperature
- 4 cooldown
- 5 minimum 5-min hold
- 6 heat up
- 7 perform five thermal cycles for CAL II and III tubing and casing as well as CAL IV casing, and 50 thermal cycles for CAL IV tubing. Perform five thermal cycles for CAL IV tubing with redundant seal tested to Annex J.
- 8 typical thermal cycle (shall be at least 30 minutes)
- 9 five pressure/tension cycles at 135 °C (275 °F) for CAL II and III and at 180 °C (356 °F) for CAL IV
- 10 initial heatup
- 11 final cooldown

Figure 10 — Test Series C thermal/mechanical cycles for CAL II, III, and IV

5.12.3 Apparatus

The temperature changes for the thermal cycling tests may be produced by any means capable of producing sufficiently large temperature variations throughout the connections of the test specimens. The apparatus should avoid subjecting the test specimens to a substantially higher temperature than required by the test procedure.

The maximum temperature observed on the test specimen should be recorded at each load condition when the temperature observed is more than 16 °C (30 °F) higher than the intended test temperature.

5.12.4 Procedure

Refer to 7.3.5 and Figure 10 for thermal cycle load steps. A minimum time of 5 min shall elapse at or above the maximum temperature and 5 min at or below the minimum temperature. The maximum temperature shall be greater than or equal to 135 °C (275 °F) for CAL II and CAL III and greater than or equal to 180 °C (356 °F) for CAL IV. The minimum temperature for all application levels shall be less than or equal to 52 °C (125 °F). Minimum time per cycle is 30 min. Cycles may be continuous or interrupted as required for overnight shutdown or equipment repair. The five pressure/tension cycles performed at the beginning and end of Test Series C shall be performed at ambient temperature.

At ambient temperature the maximum mechanical loads are as specified in a) and b).

- a) Tension is the lesser of 80 % pipe body yield (or coupling yield) or 80 % connection test load envelope based on material yield at ambient temperature.
- b) Internal pressure is the lesser of 95 % VME pipe body yield (or coupling yield) or 95 % VME connection test load envelope, with both loads based on the above 80 % tension and material yield at ambient temperature.

At elevated temperature the maximum mechanical loads are as specified in c) and d).

- c) Internal pressure is the same as the ambient pressure above.
- d) Tension is the lesser of 90 % VME pipe body yield (or coupling yield) or 90 % VME connection test load envelope based on material yield at the specified elevated temperature.

Other methods to establish the pressure and tension for ambient and elevated temperature tests may be used provided the intent is consistent with having a high internal test pressure for both the ambient and elevated temperature tests and as high an axial load as practical. The basis for using the alternate method shall be documented in the test report.

Monitor the temperature during testing with thermocouples. Ensure that the temperature measured is not affected by local temperature variations in the vicinity of the thermocouple and that the temperature measured is representative of the connection's temperature. If heating or cooling is only being applied on one side of the connection, temperature measurements should be taken on the opposite side from where the temperature variations are being applied.

If the testing apparatus has been shown to apply uniform heating and cooling to the specimens, a single thermocouple may be used to monitor the thermal-cycling tests. If significant temperature variations are possible in the specimen, multiple thermocouples shall be used and an average temperature from all thermocouples shall be used to monitor the tests.

During the thermal cycling test, there may be small changes in the water level in the graduated cylinders. Variations of $\pm 0,1 \text{ cm}^3$ to $\pm 0,4 \text{ cm}^3$ and more occur randomly and may not be related to a connection leak. The rapid thermal changes and barometric pressure changes cause these water level variations. The 5-min hot and cold holds only have a $0,3 \text{ cm}^3$ allowable displacement ($0,9 \text{ cm}^3/15 \text{ min} = 0,3 \text{ cm}^3/5 \text{ min}$). Therefore, the leak evaluation criteria for this test are as follows.

- If during any of the 5-min hold periods, more than 0,3 cm³ is collected from a specimen, then the hold shall be extended another 10 min, for a total of 15 min.
- If the displacement is more than 0,9 cm³ for the 15 min-hold, then a 1-h hold shall be performed to characterize the leak, recording the displacement in 5-min intervals (as required in 7.3.2).

6 Connection test specimen preparation

6.1 General connection test objectives

Control and definition of test specimens is critical since this testing method is based on extreme-tolerance/worst-case connection configuration evaluation and not random sampling of a population. Extreme-tolerance evaluation addresses performance parameters of dimensions, mechanical properties, make-up torque and the type and amount of thread compound. Product tolerances are based on performance, manufacturing capabilities and cost of manufacture. It is significant to recognize that this test procedure does not provide the statistical basis for risk analysis.

Manufacture and test the connection specimens at the worst-case performance extremes that can be produced according to the drawings, quality plan, running (including doping) procedures and make-up torques described in the connection geometry and performance data test sheets and quality control procedures. Table 2 gives general connection test specimen objectives for each specimen. Table 3 gives guidance for selecting specimens for testing a metal-to-metal sealing, tapered thread connection with a torque shoulder. The test specimen extremes shall conform to these test objectives. For connections with attributes different than Table 3, worst-case extremes shall be determined and documented and used in the tests.

Table 2 — Connection test specimen objectives for all CAL

Specimen number	Make-up objective	Test load objective	Limit load testing			
			Testing objective	Text reference	Test path number ^a	
					CAL I and II	CAL III and IV
1	Thread galling	Minimum leak integrity ^b	High internal pressure with tension increasing to failure	7.5.1	LP1	LP1
2	Pin maximum axial stress	Leak resistance at maximum make-up tightness ^b	Compression with external pressure increasing to failure	7.5.2	LP6 (see 7.5.6)	LP2
3	Maximum box hoop stress	Leak resistance at maximum make-up tightness ^b	Tension to failure	7.5.3	LP3	LP3
4	Worst-seal galling tendency ^b	Minimum leak integrity	External pressure with compression increasing to failure	7.5.4	LP5 (see 7.5.5) (CAL II only)	LP4
5	Thread galling	Minimum leak integrity ^b	Tension with internal pressure increasing to failure	7.5.5		LP5
6	Worst-thread galling tendency ^b	Minimum leak integrity	Internal pressure with compression increasing to failure	7.5.6		LP6
7	Worst-seal galling tendency ^b	Maximum leak integrity	External pressure to failure	7.5.7		LP7 (CAL IV only)
8	Worst-seal galling tendency ^b	Maximum leak integrity	Low internal pressure with tension increasing to failure	7.5.8		LP8 (CAL IV only)

^a Test path numbers refer to failure tests shown in Figure 18 or Figure 19.

^b Primary test objective.

Table 3 — Guidelines for selecting connection test specimens for testing a metal-to-metal sealing, tapered thread connection with a torque shoulder

Specimen number	Summary of objectives	Made-up condition	Thread interference	Seal interference	Pin thread taper	Box thread taper	Final torque
1	Sealing	Minimum seal interference	High	Low	Slow	Fast	Minimum
2	Sealing	Maximum torque into shoulder	Low	Low	Slow	Fast	Maximum
3	Sealing	Maximum overall tightness	High	High	Nominal	Nominal	Maximum
4	Seal galling and sealing	Maximum seal interference	Low	High	Fast	Slow	Maximum
5	Sealing	Minimum seal interference	High	Low	Slow	Fast	Minimum
6	Thread galling and sealing	Minimum seal interference	High	Low	Slow	Fast	Maximum
7	Seal galling and sealing	Maximum seal interference	Low	High	Fast	Slow	Minimum
8	Seal galling and sealing	Maximum seal interference	Low	High	Fast	Slow	Minimum

6.2 Connection test specimen identification and marking

Identify each connection test specimen by marking with the following information (see Figure 11).

- The connection test specimen number (i.e. 1, 2, 3, 4, 5, 6, 7 or 8) shall be placed on both pups and the couplings (as applicable).
- The pup joint designation (A or B) shall be placed after the specimen number.
- The coupling side designation (A or B) shall be placed at the appropriate end of the coupling.
- Identify replacement and/or re-machined connections with an “R1” after the “A” or “B” identification the first time they are reworked, “R2” the second time they are reworked, etc.

6.3 Connection test specimen preparation

6.3.1 Additional and unsupported pipe lengths

Prepare connection test specimens such that for each specimen, each pipe length has:

- minimum unsupported pup joint length L_{pj} (see Figure 11) that is calculated from Equation (4):

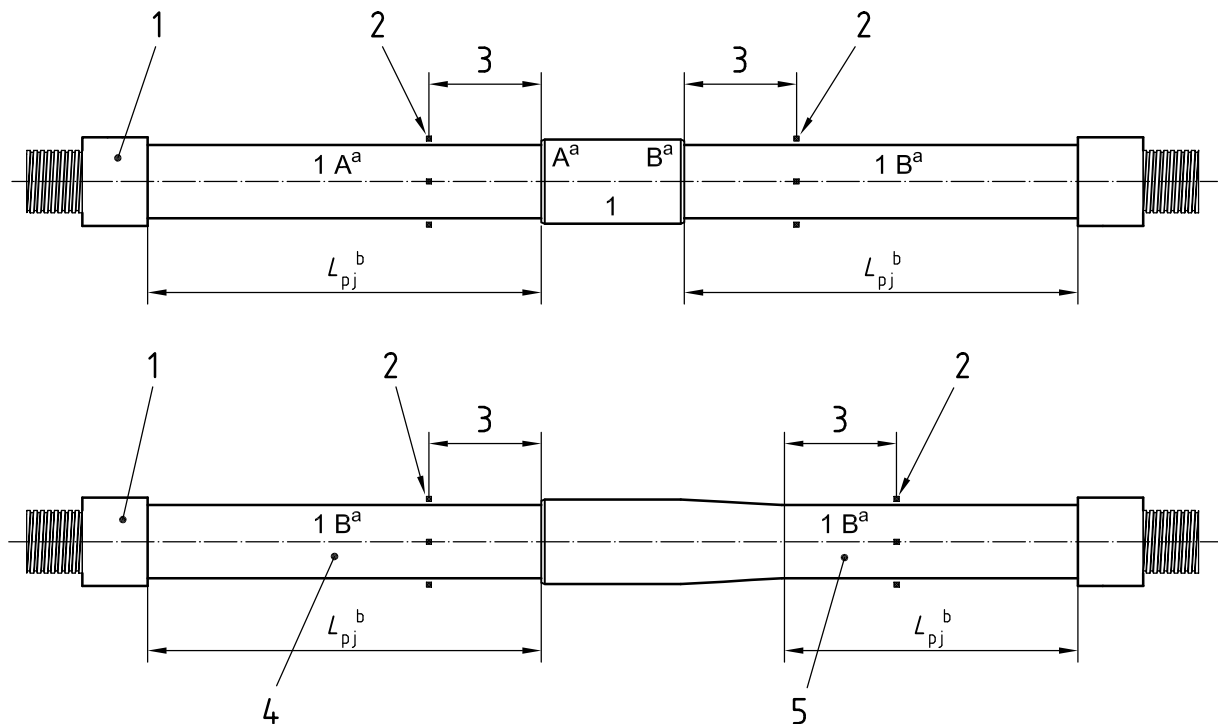
$$L_{pj} \geq D + 6\sqrt{Dt} \quad (4)$$

where

D is the specified pipe outside diameter;

t is the specified wall thickness;

- additional length for gripping and/or plugs shall be provided.
- scribe specimens to allow measurement of lengths L_A , L_B and L_C and record them on Form C.3.



Key

- 1 end fixture
- 2 strain gauge rosettes for measuring bending
- 3 minimum distance of $3\sqrt{Dt}$ between strain gauge rosettes and connection (leaving minimum distance of $D + 3\sqrt{Dt}$ between strain gauge rosettes and end fixture)
- 4 pin
- 5 box
- a Connection specimen number is designated by 1,2,3, etc. and A and B are pup joint and coupling side designations.
- b L_{pj} is the minimum unsupported pup joint length ($D + 6\sqrt{Dt}$), see 6.3.1.

Figure 11 — Connection test specimen nomenclature and unsupported length

6.3.2 Pipe and coupling stock

Connection test specimens should be machined on pipe and coupling stock that is manufactured consistent with standard mill/thread practices as follows:

- a) machine connections for upset pipe on upset pipe;
- b) machine connections for swaged pipe on swaged pipe;
- c) machine flush connections for plain-end pipe on plain-end pipe.

It is acceptable, but less desirable, to manufacture connection specimens from material stock by machining external upsets to replicate the product configuration. If the upsets are machined, the configuration that is not normally machined, and the length shall be to the minimum allowed by the manufacturer. The test reports shall indicate that the test specimens were machined from thick wall cylinders, when applicable.