INTERNATIONAL STANDARD

ISO 21329

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Petroleum and natural gas industries — Pipeline transportation systems — Test procedures for mechanical connectors

Industries du pétrole et du gaz naturel — Systèmes de transport par conduites — Modes opératoires d'essai des connecteurs mécaniques

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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 21329 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

Introduction

In some circumstances mechanical connectors provide a lower cost and/or enabling advantage to welded connectors usually used for pipelines. However, use of mechanical connectors has raised concerns about pipeline integrity due to the potential for leak paths and absence of a direct method of inspection. In the past, reassurance of the integrity of mechanical pipeline connectors has relied upon design information provided by the manufacturer, the results of finite element analysis and past experience.

This International Standard is primarily applicable to connectors to be used in a large number, and hence there is a significant burden in the number of connectors that need to be tested. However, it is recognized that the test burden can be reduced in project-specific cases, for example if there is no concern about fatigue, if the connector will not be subjected to fully restrained forces and/or if the connector design is less sensitive to accuracy of tolerance matching of components at assembly.

The tests specified in this International Standard provide a physical demonstration of the integrity of the pipeline connector. This International Standard has been developed from three main sources.

The first is the *Low cost pipeline connector systems joint industry project (JIP),* (1995-1997)[14], which defined the load envelopes for pipelines, identified the practical issues of installation, and conducted demonstration physical tests on three types of mechanical connectors.

The second source is ISO 13679, which has a parallel function for downhole connections.

The third is the *Connection testing specification JIP*, (1999-2000)[15]. The JIP was sponsored by oil companies, connector suppliers, pipeline construction contractors and design consultants.

Petroleum and natural gas industries — Pipeline transportation systems — Test procedures for mechanical connectors

1 Scope

This International Standard specifies requirements and provides guidance for the testing of mechanical connectors for use in pipeline transportation systems for the petroleum and natural gas industries as defined in ISO 13623.

The tests specified in this International Standard are intended to form part of the design verification process for connectors. They provide objective evidence that connectors conform to a defined performance envelope.

This International Standard does not cover the use of design procedures as part of the qualification process for mechanical connectors, nor does it address fabrication and quality control. However, it can be used as input to a qualification procedure.

Although its principles can be applied, this International Standard does not address

a) connectors that are designed to rotate in use,

b) manifolds,

c) topsides pipework or piping,

d) flanges,

e) connectors used in pipelines installed by reeling or J-tube pulls,

f) factory acceptance testing,

g) statistical bases for risk analysis.

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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 783:1999, *Metallic materials — Tensile testing at elevated temperature*

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 requirement 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 6892:1998, *Metallic materials — Tensile testing at ambient temperature*

ISO 9327, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 13679:2002, *Petroleum and natural gas industries — Procedures for testing casing and tubing connections*

EN 10213, *Technical delivery conditions for steel castings for pressure purposes*

EN 10222-1, *Steel forgings for pressure purposes – Part 1: General requirements for open die forgings*

ASTM A 370[1)], *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A 487/A 487M, *Standard Specification for Steel Castings Suitable for Pressure Service*

ASTM A 694/A 694M, *Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
actual yield strength
yield strength of material determined from specimens directly related to components used in construction of the test samples

3.2
application level
service loading envelope encompassing a group of pipeline and riser applications

3.3
batch
group of items manufactured or machined under controlled conditions to ensure consistent chemical composition, processing and heat treatment such that the group can be considered as a single population

3.4
by agreement
unless otherwise indicated, agreement between the manufacturer and purchaser at the time of enquiry and order

NOTE Adapted from ISO 3183-2:1996.

3.5
connector
mechanical device used to connect adjacent components in the pipeline

1) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA

3.6
galling
localized damage to material surfaces resulting from contact conditions

NOTE Galling can be caused by cold welding of contacting material surfaces followed by tearing of the weld during further sliding or rotation.

3.7
heat, noun
batch of steel prepared in one steel-making operation

[ISO 15590-1:2001]

3.8
liner
internal layer of a material different to that of the pipe body

NOTE The liner material may be, for example, plastic or non-ferrous.

3.9
load envelope
limit of loads (axial, pressure, torsion, bending, fatigue and temperature) within which a connector operates during service or is tested

3.10
manufacturer
organization responsible for the design and manufacture of the equipment

NOTE 1 The manufacturer is not necessarily the vendor.

NOTE 2 Adapted from ISO 13707:2000.

3.11
operational restrained test
simulation of the loads due to operational cycling on a section of pipeline that is fully axially constrained

3.12
operational unrestrained test
simulation of the loads due to operational cycling on a section of pipeline or riser that is not axially constrained and may have axial tension due to self-weight or externally applied tension

3.13
pipeline
those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances up to and including the isolating valves

[ISO 13623:2000]

3.14
purchaser
individual or organization that issues the order and specification to the vendor

NOTE The purchaser may be the owner or the owner's agent.

[ISO 13707:2000]

3.15
reverse torque
Z
torque applied during tests to simulate loads that might cause the connector to rotate or unscrew, if applicable

3.16
riser
that part of an offshore pipeline, including subsea spool pieces, which extends from the seabed to the pipeline termination on an offshore installation

[ISO 13623:2000]

3.17
seal
barrier that resists the passage of fluids

[ISO 13678:2000]

3.18
multiple seals
sealing system that consists of more than one independent barrier and of which each barrier forms a seal itself

3.19
specified minimum yield strength
minimum yield strength required by the specification or standard under which the material is purchased

[ISO 13623:2000]

3.20
test sample
assembly of a connector and two pieces of pipe specifically for testing

4 Symbols and abbreviated terms

4.1 Symbols

$A_{F,un}$ operational unrestrained axial factor

A_s specified cross-sectional area of pipe

$B_{F,hy}$ bending factor for hydrostatic pressure test

$B_{F,in}$ bending factor for installation

$B_{F,un}$ bending factor for unrestrained operation tests

D_i specified pipe inside diameter

D_o specified pipe outside diameter

E_p Young's modulus of pipe

F_{re} axial force for restrained operation

F_{un} axial force for unrestrained operation

f_{vM} von Mises' factor

H_r depth rating

K load multiplication factor

K_F torque factor

K_{cc} ratio of actual to specified minimum yield stress of the critical connector component material

K_p ratio of actual to specified minimum yield stress of the pipe body material

K_{SCF} stress concentration factor

L length of test sample between inner supports

L_g grip length of pipe

L_p unsupported pipe length for test sample

L_s length between scribe mark and coupling on test sample

M_{in} bending moment for installation

M_{hy} bending moment for hydrostatic pressure test

M_{un} bending moment for unrestrained operation

N_c total number of cycles

p_d design pressure

p_{ex} external hydrostatic pressure

p_H internal pressure value to be used for testing

p_{op} operating pressure based on MAOP at the connector

p_r manufacturer's rated pressure

p_t hydrostatic test pressure

S_L lowest fatigue stress range

S_M middle fatigue stress range

S_H highest fatigue stress range

S-N stress versus number of cycles in fatigue curve

$\sigma_{ax,re}$ restrained axial stress

σ_{ayc} actual yield stress of the connector critical component

σ_{ayp} actual yield stress of the pipe body material

σ_{syc} specified minimum yield stress of the connector critical component

σ_{syp} specified minimum yield stress of the pipe body material

$T_{d.max}$ maximum design temperature

$T_{d.min}$ minimum design temperature

T_{HT} maximum test temperature

T_{LT} minimum test temperature

T_{max} maximum rated temperature

T_{min} minimum rated temperature

$T_{op,max}$ maximum operating temperature

$T_{op,min}$ minimum operating temperature

t specified wall thickness

t_{min} minimum wall thickness accounting for manufacturing tolerances

υ Poisson ratio of the pipe body

Z reverse torque

Z_{mu} make-up torque

4.2 Abbreviated terms

CRA corrosion-resistant alloy

FEA finite element analysis

ID inside diameter

MAOP maximum allowable operating pressure

OD outside diameter

5 Test categories

5.1 General

Connectors shall be tested according to the

— pressure, temperature and depth ratings, as defined in 5.2,

— intended application level, as defined in 5.3,

— confidence level as defined in 5.4.

The application level sets the loading and the confidence level the number of test samples. The general intention of the test is to demonstrate that the connector is stronger than the associated pipe under all applicable conditions of static and fatigue loadings, and remains leak-tight.

It is recommended that the connectors be tested to the highest application and confidence levels for which they are suitable. If the loading exceeds that defined in application level 4, the loading to be applied in the test shall be increased accordingly and recorded in the test report.

5.2 Pressure, temperature and depth ratings

5.2.1 Pressure rating

Connectors shall be tested according to the pressure defined in 11.3. The rated pressure shall take into account any reduction in material strength at the rated temperature. For a specific pipeline or riser duty, connectors may be de-rated to the pipeline/riser design pressure, p_{d}, or MAOP, p_{op}, at the connector location by agreement.

5.2.2 Temperature rating

Connectors shall be tested to the minimum and maximum temperatures as defined in 11.3. For a specific pipeline or riser duty, connectors may be de-rated to the pipeline/riser design or operating temperature at the connector location by agreement.

5.2.3 Depth rating

Connectors intended for use underwater shall be tested according to their rated depth, H_{r}. Connectors may be de-rated to the pipeline/riser operating depth for a specific pipeline or riser duty at the connector location and by agreement.

5.3 Application levels

A total of four application levels are defined, with increasing severity from application level 1 upwards. The loading factors for each application level are detailed in Table 1. Testing to a given application level validates connectors for lower application levels.

Annex A specifies application levels.

5.4 Confidence levels

The purchaser shall specify the required confidence level. Two confidence levels are defined in Table 2, with increasing consequence of failure.

— Normal: for temporary conditions where failure implies risk of human injury, significant environmental pollution or very high economic or political consequences. For this confidence level, no frequent human activity is anticipated along the pipeline route.

— High: for operating conditions where failure implies high risk of human injury, significant environmental pollution or very high economic or political consequences. This is the confidence level required for areas with frequent human activity, e.g. those parts of the pipeline or riser near the platform or in areas populated with more than 50 persons/km^2.

Table 1 — Test load factors

Test	Subclause	Load factor for application level			
		1	2	3	4
Make, break and torque tests Torque factor – K_F	10.5, C.1	0	0	0,05	0,05
Installation tests[a] Bending factor – $B_{F,in}$	11.4	0,3	0,85	0,95	0,95
Hydrostatic pressure tests Bending factor – $B_{F,hy}$	11.5	0	1,0	1,0	1,0
Operational cycles unrestrained tests Bending factor – $B_{F,un}$ Axial factor – $A_{F,un}$	11.6	0,3 0 [b]	0,3 0 [b]	0,9 0 [b]	0,9 0,2
Other von Mises' factor – f_{vM}	C.2.2	NA	0,96	0,96	0,96

[a] In all cases, if the water depth H_r > 500 m the effect of external hydrostatic pressure shall be considered.

[b] In the case of a suspended riser, the connector may have $A_{F,un}$ > 0. Allowance should be made for this when defining an application level within the range 1 to 3.

Table 2 — Test requirements, test sample numbers and confidence levels

Requirements		Subclause reference	Confidence level normal	Confidence level high
Connector geometry and performance data		7.3	In all cases	
Number of test samples to prepare		6.5	8 numbered 1 to 4 and 9 to 12	12 numbered 1 to 12
			Test sample number(s)	
Make, break and torque tests	Repeated make-up and breakout	10.3	1 to 4	1 to 8
	Final make-up	10.4	All	All
	Reverse torque	10.5	1 to 4	1 to 8
Service load tests	Installation tests	11.4	1 to 4	1 to 8
	Hydrostatic pressure tests	11.5	1 to 4	1 to 8
	Operational unrestrained tests Total number of cycles, N_c	11.6	1, 3 20	1, 3, 5, 7 100
	Operational restrained tests Total number of cycles, N_c	11.7	2, 4 20	2, 4, 6, 8 100
Limit load tests	Pressure-to-failure test	12.4	1	1
	Compression-to-failure test	12.3	NA	5
	Bending-to-failure test	12.5	4	4
	Tension-to-failure test	12.2	NA	7
Fatigue tests	Bending fatigue-to-failure test	13		
	S_L, see 13.2.4		2, 9	2, 6, 9
	S_M, see 13.2.4		10, 11	10, 11 (see NOTE)
	S_H, see 13.2.4		3, 12	3, 8, 12

'All' signifies all test samples shall undergo the specific test.

NOTE In many applications some modes of testing may not be necessary, e.g. where fully restrained conditions cannot occur, and where it may not be necessary to conduct limit compression tests to failure. This would make the third connector available for fatigue testing.

6 Test requirements

6.1 General

Connectors intended for a specific application level shall be tested according to the sequence shown in Table 2.

6.2 Purpose of tests

6.2.1 Introduction

The purpose of the tests is to simulate conditions that can occur during installation, commissioning and operation. The test requirements comprise four sets of procedures as outlined below. The tests shall be witnessed either by an inspector appointed by the purchaser or an independent third party. The fatigue-loading test is optional, and for a specific project it is the responsibility of the purchaser to define the fatigue loading.

6.2.2 Make, break and torque tests

The make-and-break procedures determine the ability of the connectors to resist wear and galling during repeated make-up, if applicable. The torque procedures assess the ability of the connector to resist torque, which could cause the connector to become undone or else cause loss of sealing integrity.

6.2.3 Service-load tests

The service-load tests simulate the installation loads, the hydrostatic pressure test loads, and the operational loads on a connector. For example, operational unrestrained tests simulate the loads due to operational cycling on a portion of pipeline or riser that is not axially constrained and may have axial tension due to self-weight or externally applied tension. Operational restrained tests simulate the loads due to operational cycling on a portion of pipeline that is fully axially constrained.

6.2.4 Limit-load tests

Limit-load tests are conducted to establish the structural and sealing limits of the connector. These limits are important for establishing the reliability limits of connectors under field conditions, and are also useful for correlating with strain gauge and finite element analysis results. Procedures are given for the following:

— tension-to-failure test, which applies to pipelines where there is a risk of inducing a high tensile load during operation;

— compression-to-failure test, which applies to pipelines where there is a credible risk of high compressive loads during operation, particularly if used with axial strains beyond yield, or where there is a risk of local buckling of the pipe;

— pressure-to-failure test, which applies to pipelines where there is a credible risk of high internal or external pressure loads during operation. These tests give a measure of the margin of safety against internal and external overpressurization, the latter only being required for deep-water pipelines and risers.

6.2.5 Bending-fatigue tests

The fatigue test is a full-scale design verification test requiring the connector to achieve without failure the minimum number of stress cycles predicted by the manufacturer.

The purposes of the fatigue test are to

a) verify the manufacturer's prediction of the fatigue performance,

b) allow the purchaser to select a connector with sufficient fatigue strength for the required duty.

6.3 Basis for mechanical loads

The performance of the connector as determined in this International Standard shall be related to actual yield values, σ_{ayc} rather than to specified minimum yield values, σ_{syc}.

In addition, the mechanical loads applied to the connector according to the requirements of this International Standard are based on the specified minimum yield stress, σ_{syp} and physical dimensions of the pipe body.

Consequently, the test loads are adjusted up to take into account the actual material strength being greater than the minimum. This is done by applying a load factor to the calculated loads based on the ratio between actual and specified yield stress.

The tests carried out in accordance with this International Standard shall determine the

— actual yield strength of the critical connector component material, σ_{ayc} in accordance with 7.6.3,

— actual yield stress σ_{ayp}, of the pipe body used in the test sample(s) in accordance with 7.6.3.

Factors shall be determined in accordance with Equations (1) and (2).

$$K_{cc} = \frac{\sigma_{ayc}}{\sigma_{syc}} \quad (1)$$

where

K_{cc} is the ratio of actual to specified minimum yield stress of the critical connector component;

σ_{ayc} is the actual yield stress of the critical connector component;

σ_{syc} is the specified minimum yield stress of the critical connector component.

$$K_{p} = \frac{\sigma_{ayp}}{\sigma_{syp}} \quad (2)$$

where

K_p is the ratio of actual to specified minimum yield stress of the pipe body material;

σ_{ayp} is the actual yield stress of the pipe body material;

σ_{syp} is the specified minimum yield stress of the pipe body material.

The mechanical loads applied in the test shall be multiplied by the factor K, which is the lesser of K_p or K_{cc} for the relevant materials.

The factor K is applied in the calculation of loads given in Annex C.

6.4 Test-house selection

The testing facilities shall satisfy the requirements in Clause 8. The testing shall be carried out either by a test house independent of the manufacturer, or by the manufacturer with independent verification.

6.5 Selection of tests and number of test samples

The test samples shall be numbered as shown in Table 2 and shall retain their designated number throughout the tests.

Table 1 defines the load factors to be applied during the tests for a given application level. The test shall take into account external hydrostatic pressure if the specified depth exceeds 500 m. Tests to take into account external pressure at shallower depths may also be carried out if specified.

Tests shall be carried out in the lifetime sequence of loading of the connector, as shown in Figure 1, for each test sample, i.e. running from top to bottom of Table 2.

Tests on different samples may be run in parallel. If the same service-load test is required on multiple test samples, a single assembly of those test samples may be used.

The number of tests and test samples may be reduced for a particular application level if it can be shown that there is no need to carry out the tests.

EXAMPLE Tests to simulate high installation and operational restrained-loading conditions may not be applicable for a connector intended for use on a spool piece. Similarly there is no need to test for bending fatigue if it can be shown that fatigue loading, for example due to vortex-induced vibration, will not occur.

If tests are project-specific, pipe of the same dimensions, tolerances and material properties as the project pipe shall be used for the tests.

NOTE Annex F provides guidance on the choice of sizes to be tested if multiple sizes of connectors are used in a project. Annex F also indicates how the results of testing can be extended to other sizes and grades of connector.

6.6 Additional tests

The purchaser should consider the additional tests described in Annex G for connectors subject to special applications. These applications can include, but are not limited to, the following:

a) connectors with elastomeric seals;

b) misalignment at make-up;

c) rapid cool-down conditions;

d) severe sour service;

e) fire exposure;

f) compression beyond yield;

g) crevice corrosion;

h) impact;

i) J-lay.

6.7 Prior test results

Prior connector test results meeting the requirements of this International Standard may be substituted for repeat tests.

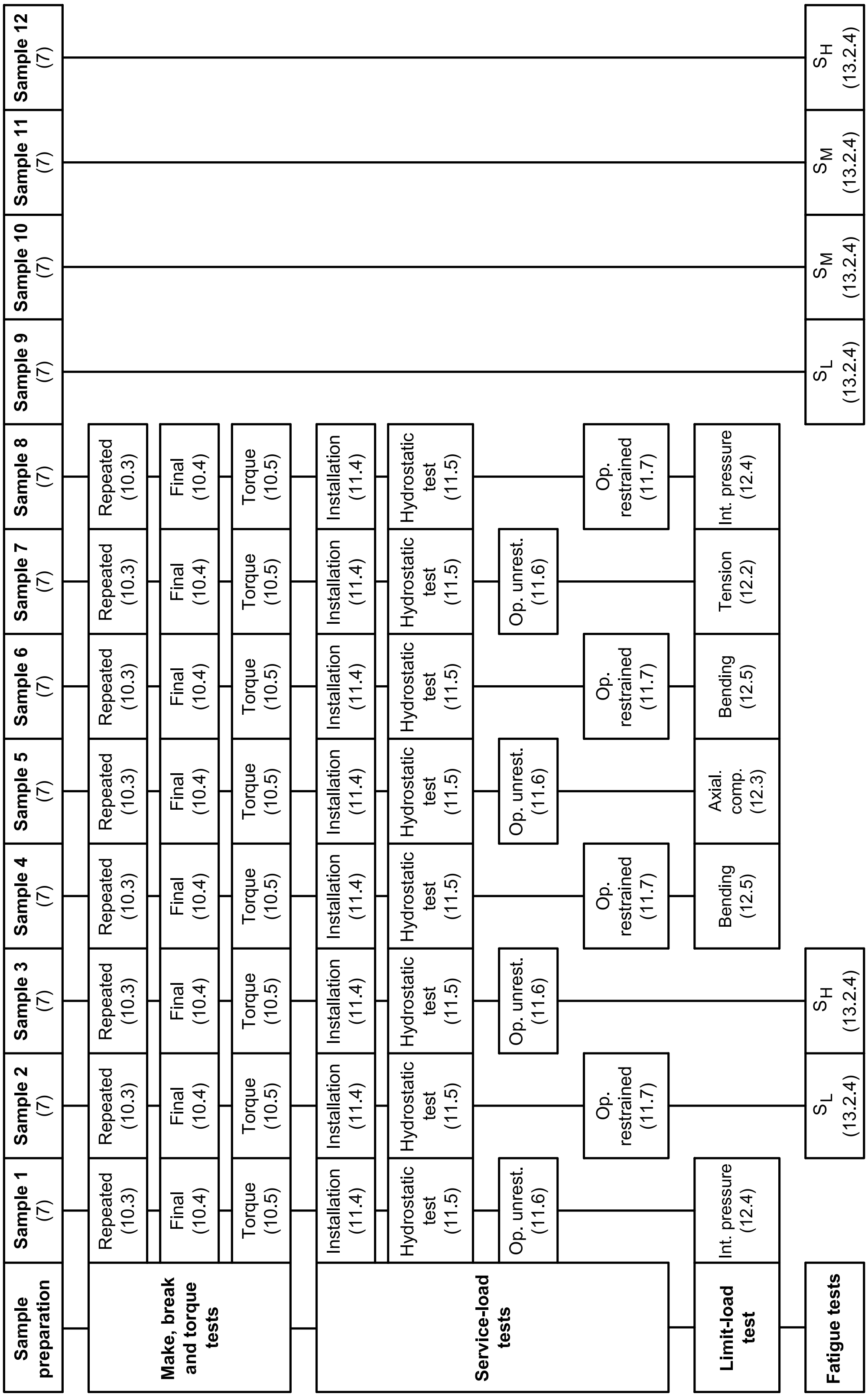


Figure 1 — Flow diagram showing test sequence, with relevant subclause number

7 Connector manufacturer requirements

7.1 General

The manufacturer shall issue a declaration of conformity stating that the connectors manufactured for the purpose of these tests are of the same design, temperature and pressure ratings and extremes of tolerances (see 7.5) as those to be supplied for pipeline service.

NOTE ISO/IEC Guide 22 contains information on declaration of conformity.

7.2 Quality control

Quality control procedures for the manufacturing of test samples shall be documented and shall be consistent with procedures used for connectors manufactured for pipeline service.

The manufacturer shall provide a quality plan. This shall include procedure or drawing numbers as well as associated revision levels for all applicable sub-tier documents (e.g. manufacturing, gauge calibration, gauging procedure, surface treatment, etc.).

7.3 Connector geometry and performance data

The manufacturer shall provide connector geometry and performance data (see Annex B) describing the connector's geometry and performance properties in terms of tension, compression, internal pressure, external pressure, bending and torque. The data shall also specify the minimum failure loads for the connector and identify the component that is the cause of failure.

The data shall specify the make-up torque or force and speed of make-up if appropriate. If the application of pipeline torque can cause damage to the connector, e.g. screwed connector, the manufacturer shall specify the torque rating of the connector.

The manufacturer shall identify the critical dimensions and tolerances in the data provided. In addition to the data required herein, the manufacturer should document other data, e.g. seal material limitations, considered pertinent to these tests.

The manufacturer shall develop a minimum failure load or load surface for load combinations. The actual failure load can then be used to determine the safety factor.

7.4 Selection of diameter

The test connectors should be of the same size as intended for the pipeline service.

NOTE Guidance on test sizes and extrapolation of test data to other sizes is given in Annex F.

7.5 Setting tolerances

7.5.1 Worst-case performance objectives

For design verification, connectors shall be tested at the worst-case configuration and condition determined from drawings, quality plan, running/doping procedures, make-up torques/forces, etc.

The manufacturer shall use analytical, computational [such as finite element analysis (FEA)], and/or experimental techniques such as strain-gauge testing to provide objective evidence that the extreme dimensional configurations of the product resulting in worst-case performance are tested.

To select worst-case performance objectives, the manufacturer shall take into account the minimum and maximum extremes of local seal contact pressure, total seal load, and total active seal contact length as influenced by machining parameters. For threaded and coupled connections, side A and side B shall be machined to identical dimensional objectives.

NOTE The specific machining dimensions depend on the type of connector.

Machining tolerances shall be set by the manufacturer to produce the worst-case performance of the connector, including, but not limited to, considerations of the tolerances on

- seal interferences,
- pin nose thickness,
- surface roughness,
- thread tapers,
- thread interferences.

7.5.2 Example of machining tolerances

As an example, for metal-to-metal sealing, tapered thread, connections with pin nose torque shoulders, Table 3 shows combinations of seal and thread diameters, thread tapers and final make-up torques which have been found to provide the worst-case performance extremes corresponding to the test objectives in Table 2. For this type of connection, the manufacturer should machine the specimens to the extremes in Table 4 unless the techniques described in 7.5.1 indicate other tolerances should be tested.

Table 3 — Example of test sample tolerances

Test sample No.	Body	Seal	Torque	Lubricant	Pin body taper	Box body taper	Misalignment
1[a]	High	Low	High	Low	Slow[c]	Fast[c]	None
2[b]	Low	High	High	Low	Fast	Slow	None
3	Low	Low	Low	Low	Slow	Fast	Maximum
4	High	High	High	High	Nominal	Nominal	None
5	High	Low	High	High	Slow	Fast	None
6	Low	High	Low	Low	Fast	Slow	None
7	Low	Low	High	Low	Slow	Fast	None
8	High	High	Low	High	Nominal	Nominal	None
9-12	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	None

[a] Tolerances test for body galling.

[b] Tolerances test for seal galling.

[c] “Fast” refers to a steep taper that enables rapid make-up; “slow” has a shallow taper and takes longer to make up.

Table 4 — Tolerance limits on machining objectives

Item	Positive tolerance	Negative tolerance
Maximum body tolerance	No limit	0,025 mm (0,001 in)
Maximum seal tolerance	No limit	0,025 mm (0,001 in)
Minimum body tolerance	0,025 mm (0,001 in)	No limit
Minimum seal tolerance	0,025 mm (0,001 in)	No limit
Maximum pin/body taper (fast)	No limit	0,001 mm/mm (0,001 in/in)
Minimum pin/body taper (slow)	0,001 mm/mm (0,001 in/in)	No limit
Taper increments shall apply to every incremental measurement of taper along the body		

7.6 Connector material requirements

7.6.1 General

As a minimum:

— connector material shall be from one batch;

— the manufacturer shall provide material mill certificates for the materials used in the connector;

— material shall be in compliance with material specification.

For integral connectors, material for both pin and box shall come from the same heat.

7.6.2 Material properties

If the critical connector component is made from forged material the manufacturer shall provide test coupons in accordance with EN 10222-1 and ISO 9327.

NOTE 1 For the purposes of this provision, ASTM A 694/A 694M is equivalent to EN 10222-1 and ISO 9327.

If the critical connector component is made from cast material, the manufacturer shall provide test coupons in accordance with EN 10213 or ASTM A 487/A 487M respectively. Either a strip coupon (recommended) or the largest practical round coupon, conforming to ISO 148-1 or ISO 6892, shall be used.

NOTE 2 For the purposes of this provision, ASTM A 370 is equivalent to ISO 148-1 or ISO 6892.

If the critical connector component is machined on steel line pipe, mechanical test coupons shall be provided in accordance with ISO 3183-1, ISO 3183-2 or ISO 3183-3. The coupon shall be taken from the middle of the pipe joint.

If the connector is manufactured from a material other than carbon steel, those references that are specific to steel shall be replaced by the most relevant standard for the connector material.

For each set of test samples the connector material properties shall be determined in accordance with 7.6.3.

The ratios of yield stress K_{cc}, shall be determined in accordance with Equation (1), see 6.3.

7.6.3 Procedures for material testing

The following procedures shall apply.

a) A tensile test shall be performed at room temperature in accordance with ISO 148-1 or ISO 6892.

NOTE For the purposes of this provision, ASTM A 370 is equivalent to ISO 148-1 or ISO 6892.

b) A further tensile test shall be performed at T_{max}. The actual coupon temperature shall be monitored and reported in accordance with ISO 783.

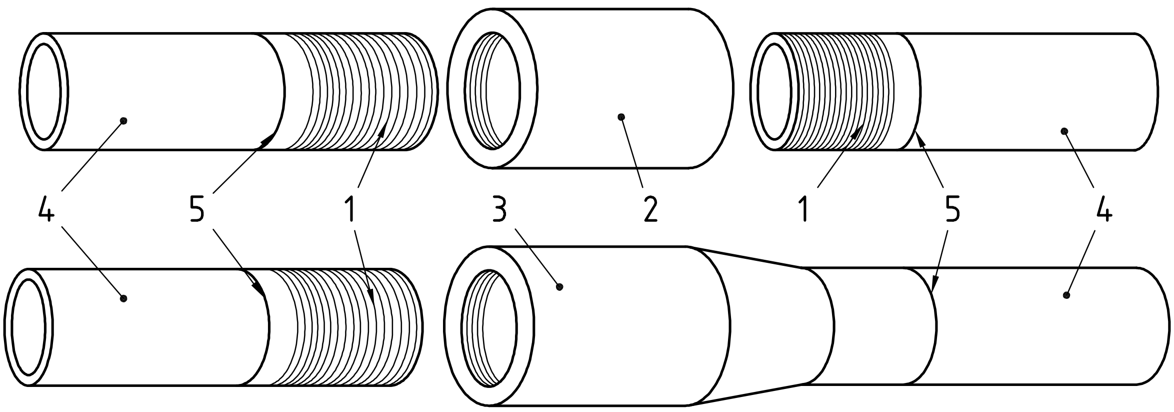
c) The material property test data for the room- and elevated-temperature tests shall be reported on separate material property data records, see Table D.1. The stress-strain curves shall be attached to the data record.

Consideration needs to be given to the limits of qualification of a connector if, within a specific strength grade, high-strength pipe is tested. Consideration needs to be given to the possible effects of anisotropy on 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.

7.7 Preparation of test samples

7.7.1 Test sample layout

The layout of components making up the test sample is shown in Figure 2.



Key

1 pin or hub

2 coupling or clamp

3 integral coupling

4 pipe piece to which pin or integral coupling is joined

5 weld of connector pin or hub to pipe piece

NOTE 1 The connector comprises items 1, 2 and 3. The test samples comprise items 1 to 5.

NOTE 2 A test sample connects at least two pieces of pipe pups (i.e. one coupling or clamp and two pins or hubs for coupled connectors, or one box and one pin for integral connectors).

Figure 2 — Test sample layout

7.7.2 Length of test samples

For each individual test sample, each pipe piece shall have as a minimum:

a) an unsupported pipe length L_p (see Figure 3) calculated from the following formula:

$$L_p \geqslant D_o + 6\sqrt{D_o t} \quad (3)$$

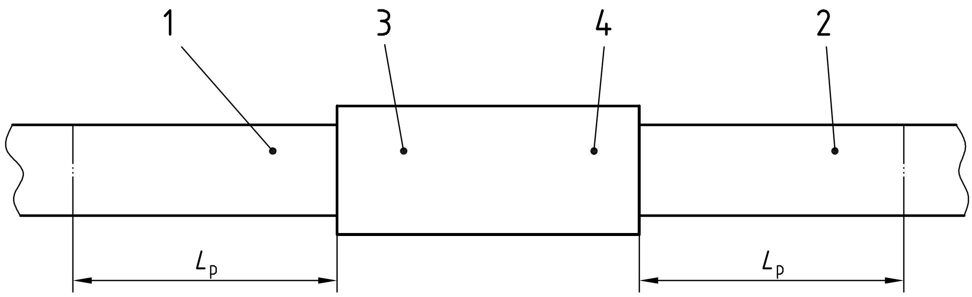
where

D_o is the specified pipe outside diameter;

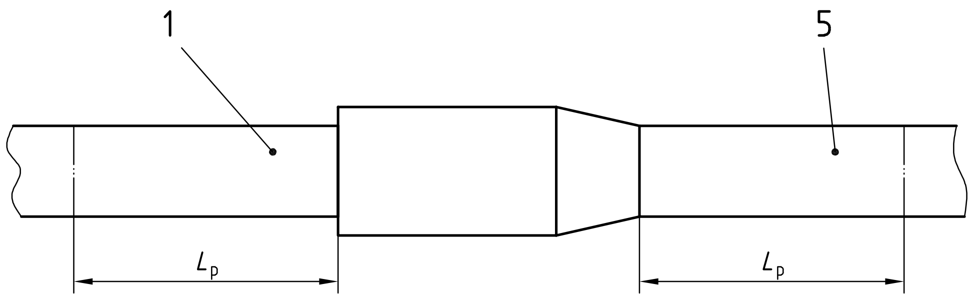
t is the specified wall thickness.

b) additional length for gripping.

The test house may also require a certain minimum length of test piece to fit its equipment.



a) Coupled connector test sample



b) Integral connector test sample

Key

1 pin — A side

2 pin — B side

3 coupling — A side

4 coupling — B side

5 integral coupling — B side

The connector number shall be clearly identified on each component.

Figure 3 — Test sample nomenclature

7.7.3 Connectors made from machined pipe

If connectors are made from machined pipe, the connector test samples should be manufactured in a manner consistent with standard mill and thread practices as follows:

a) machine connectors for upset pipe on upset pipe;

b) machine connectors for swaged pipe on swaged pipe;

c) machine flush connectors for as-rolled pipe on as-rolled pipe.

Connector test samples may be manufactured from material stock by machining external upsets to replicate the product configuration. If the upsets are machined, the length and depth of the configuration that is not normally machined shall be to the minimum dimensions allowed by the manufacturer.

7.7.4 Additional pipe pup piece

It may be necessary to weld the connectors to a pipe pup piece to provide the required length of test sample as defined in 7.7.2.

If applicable, the connectors shall be welded to pipe pups having the same size and the same specification as that used in service. The pipe pup piece shall be manufactured consistent with standard mill practices.

NOTE The assumption is made that the pipe has been designed to withstand the service loads, e.g. external collapse if applicable, that are applied in Clause 11.

The welding of the connector pin or hub to the pup pieces shall be in accordance with procedures specified by the connector manufacturer as agreed with the user.

With regard to the additional pipe pup pieces, for each set of test samples the following apply:

a) all pipe pup material shall come from one batch;

b) material mill certificates shall be obtained from the suppliers of the pipe pup pieces;

c) all pipe pup material shall be in compliance with a specified material specification;

d) the actual minimum pipe pup body wall thickness shall be within the tolerance allowed by ISO 3183-1, ISO 3183-2 or ISO 3183-3;

e) the pipe pup material properties shall be determined in accordance with 7.6.3.

The ratios of yield stress K_p shall be determined in accordance with Equation (2), see 6.3.

7.7.5 Grooved torque shoulder

For connectors with a torque shoulder on the front of the pin, the A ends (B ends for integral connections) of test samples 1, 3, 5 and 6 shall have torque shoulders grooved as shown in Figure 12 of ISO 13679:2002 in order to simulate possible handling damage. Grooves shall be applied before first make-up. Other test samples may have the torque shoulder grooved by agreement.

Other types of connector may also have the torque shoulder crippled by agreement.

7.7.6 Multiple seals

If multiple metal or resilient seals are arranged in series, the additional seals (extraneous seals) not providing the primary sealing function shall be bypassed. This shall include torque shoulders that cannot be disabled with porting. Disabling of the seals shall consist of a positive-pressure bypass with a minimum structural disturbance of the connector. All bypassing grooves shall be deburred. If an extraneous seal does not prevent pressure from reaching the primary seal, it shall not be disabled.

7.7.7 Test sample labelling

The test samples shall be clearly identified before delivery to the test house, taking into account the requirements of 6.5 and Table 2.

Figure 3 presents information for a set of test samples and the nomenclature to be used. The nomenclature is designed to identify each set of test samples, each test sample in the set, each pin and box, and each make-up configuration.

7.8 Ports

For connectors with multiple seals that have not been disabled or bypassed, a port for pressure monitoring should be inserted between each adjacent seal and the pressure recorded whenever internal or external pressure is applied to the connector.

If appropriate, the port shall be plugged during make-up of the connector. The plug shall be flush with the inside surface of the connector.

NOTE Testing seals individually enables an understanding of connection seal redundancy, evaluation of seal independence and the effect of the resilient seal on the metal-to-metal seal.

7.9 Replacement test samples

If a test sample is damaged before testing is completed, a replacement test sample is required. This test sample shall be machined and assembled to the same tolerances as the damaged test sample, and all testing required for the original test sample shall be repeated. Replacement and/or re-machined components of test samples shall be identified by “R1” after the “A” or “B” identification, see Figure 3, the first time they are reworked, “R2” the second time they are reworked, etc.

7.10 Test record retention

The manufacturer is required to maintain a file on each test, including any retest that may have been required to qualify a particular connector. As a minimum, this file shall contain sufficient documentation to satisfy the reporting documentation requirements as described in Annex E and shall be maintained until 10 years after cessation of manufacture.

The test results shall be assembled into a test report. All photographs specified in this International Standard shall include identification of significant items shown in the photographs and shall be included in the test report.

8 Test-house preparations

8.1 General

The test house conducting the tests shall either be accredited by a recognized national or international accreditation organization or comply in full with 8.2.

NOTE Typical test-house standards are ISO/IEC 17025, EN 45001, EN 45002 and EN 45003.

The test house shall provide the following:

- set-up details for each test;
- step-by-step procedures for each test;
- calculated loadings for each test;
- any planned deviations from this International Standard.

The test house shall keep a log of the testing undertaken on each connector, detailing the dates and times of each step in the procedure and any anomalies that occur during testing.

8.2 Calibration requirements

8.2.1 Equipment calibration

Before testing begins, load frames to be used for the tests shall be in calibration. In addition, based on manufacturer or test-house experience, measuring and recording instruments, such as pressure gauges and thermocouples, shall be calibrated periodically. Copies of valid calibration test reports for the load frame, temperature-, pressure- and torque-measuring devices shall be retained in the connector summary test report, in accordance with Annex E.

8.2.2 Annual calibration of load frame

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 devices such as load cells, traceable to appropriate national standards.

The calibration shall 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 minimum calibration load is defined as the lowest load, usually 10 % of the maximum load, that the frame will repeatedly calibrate within ± 1 % error. The minimum frame calibration load shall not be greater than 50 % of the tension or compression rating of the connector being evaluated. The maximum frame calibration load shall be greater than the maximum anticipated failure load of the test sample.

The percent error, E_{rp}, for calibration of the loading frame is calculated as follows:

$$E_{rp} = \frac{F_i - F_a}{F_a}$$

where

F_i is the indicated load;

F_a is the actual load.

The percentage error for all loads within the loading range of the frame shall not exceed ± 1 %.

8.2.3 Load frame verification

If the load frame is subjected to unusual loads, such as applying a load beyond the calibration range or a failure occurs at an unexpected load that could indicate a calibration problem, the calibration bar shall be used to verify the load frame calibration. This calibration bar shall be traceable to appropriate national standards and certified annually in accordance with the requirements in 8.2.2. Alternatively, a full annual calibration can be performed.

8.2.4 Pressure transducer calibrations

Each pressure transducer shall be calibrated annually, and should be recalibrated prior to each test. The percent error for pressure within the loading range shall not exceed ± 1 %.

8.2.5 Make-up/breakout tool calibrations

The make-up tool shall be calibrated annually. The percent error for torque within the loading range shall not exceed ± 1 %.

8.3 Pressurization media

All service-load pressure tests as shown in Table 2 shall be conducted using nitrogen gas as the pressurization medium, except in the case of hydrostatic tests. Filler bars shall be used to reduce the volume of gas and reduce the risk to the safety of test personnel where appropriate.

All load-limit tests, hydrostatic tests and external pressure tests shall be conducted using fresh water, oil or other solids-free liquid.

9 Leak detection

9.1 Leak-detection methods

Leak detection involves both gas-detection and water-detection methods.

For some connectors it is possible to detect leakage by measuring pressure build-up in a closed volume between a primary and a secondary seal. If this is not possible, alternative means of detecting leakage shall be provided.

EXAMPLE 1 An illustration of a method of gas-bubble detection is shown in Figure 4.

EXAMPLE 2 Alternatively, a tracer gas such as helium can be used, with a sniffer based on gas chromatography or spectrometry systems.

Visual means of leak detection may be used for the hydrostatic pressure and limit-load tests because of their short duration. For the fatigue tests, an automated means of leak detection should be provided since continuous visual observation is not possible.

The test house shall propose means of leak testing in accordance with the requirements of 9.2.

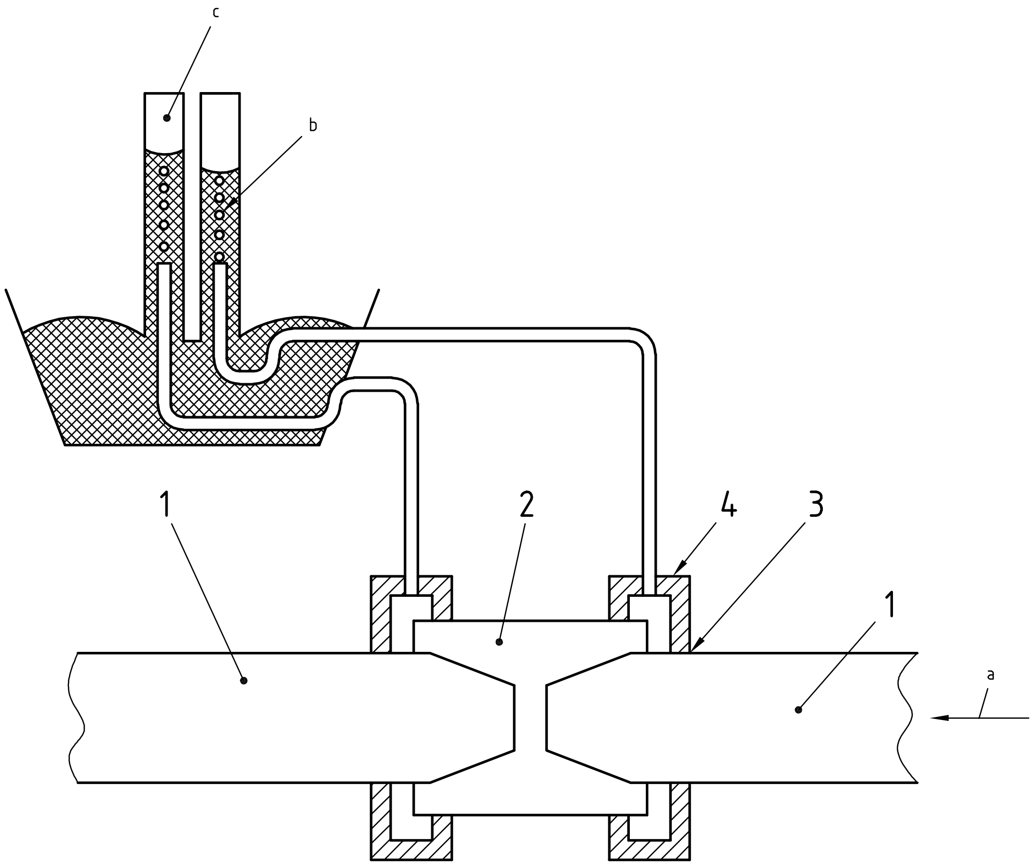
9.2 Leak-detection sensitivity

When undertaking a liquid test, the leak-measuring system shall be capable of measuring a leak as small as 0,9 cm^3 within a 15-min time interval. When undertaking a gas test, the leak-measuring system shall be capable of measuring a total leak as small as 1×10^{-4} cm^3/s at standard conditions.The source of leaks shall be identified. If leakage is generated from a source outside the connector, leak paths shall be blocked off and testing continued.

NOTE A sensor, calibrated to detect the tracer gas, can be used to verify that the bubbles detected are coming from the pressure medium and not from the lubricant de-gassing or thermal expansion of the connector or the test equipment.

9.3 External pressure leak detection

External pressure leak detection is recognised as more difficult and less accurate than internal pressure leak detection. All external pressure tests shall be conducted with fresh water. A suitable method of testing is described in ISO 13679.



Key

1 pin

2 coupling or clamp

3 high-temperature-resistant silicone rubber sealant

4 connector leakage captured by metal leak detection chambers

[a] Sample pressurized with helium-nitrogen mixture.

[b] Leaks appear as bubbles in inverted cylinders filled with water.

[c] Collected gas later analysed for helium. The presence of helium confirms connector leakage.

Figure 4 — Leak detection method

10 Make-and-break testing

10.1 General requirements

10.1.1 Approach

Test samples shall be made up or broken out in accordance with the field make-up procedures, using the same types of tooling or equipment, specified by the manufacturer.

10.1.2 Data recording

The make-up and breakout procedures and results shall be recorded in accordance with Table D.4 and Annex E. Graphs shall be plotted such that they are legible and at a scale covering the range of the test.

10.1.3 Orientation

Test samples shall be made up horizontally or vertically to match their intended use.

10.1.4 Lubricants

If a lubricant is needed for the make-up of the connector, the manufacturer shall specify the type and the amount to be used, with tolerances. The lubricant shall be the same as that used in field applications and shall be used for all test samples. The manufacturer shall also specify the areas to which the lubricant shall be applied.

NOTE The term “lubricants” also includes sealants and environmentally friendly “green” lubricants.

10.1.5 Non-breakout requirements

If a connector is non-reversible by design, or if reversibility is a capability but not a requirement, the breakout tests shall not apply. The connector shall then be made up only once, as described in 10.4. An additional non-reversible connector may be made up in accordance with the manufacturer’s procedure and then sectioned after make-up to ensure that no galling or gross distortion has occurred.

10.1.6 Breakout

Test samples shall be broken out according to the manufacturer’s procedure. During breakout of the test sample, the coupling shall be gripped to ensure breakout of the intended side of the connector.

10.1.7 Inspection

The test samples shall be inspected following each breakout. Connector non-conformance or damage shall be recorded and correlated with the torque versus make-up position plots to enable evaluation of the cause. Galling to the connector or pipe shall be photographed prior to refurbishment, and the photographs shall be included in the detailed test report in accordance with Annex E.

10.1.8 Refurbishment

Following each breakout, critical connector components may be refurbished. Only techniques stipulated by the manufacturer for field use shall be used for refurbishment.

10.1.9 Torque shoulder and seal crippling

If applicable, torque shoulder and seal crippling according to 7.7.5 should be performed just prior to the last make-up in order to minimise influence on make-up or breakout performance.

10.2 Make-up method

10.2.1 General

10.2.2 and 10.2.3 refer to the make-up of connectors that require a load to be applied in either the rotational or axial direction relative to the connector body. If a connector system uses an alternative make-up method, the criteria required for these tests shall be adapted to suit the actual make-up method.

10.2.2 Rotationally made-up connectors

10.2.2.1 Make-up torque

The test samples shall be made up according to the manufacturer’s procedure. The make-up torque values specified in the test procedures shall be the maximum and minimum recommended by the manufacturer.

The value of maximum torque specified in the test procedures shall not be less than 95 % of the maximum value recommended by the manufacturer.

The value of minimum torque specified in the test procedures shall not be more than 105 % of the minimum value recommended by the manufacturer.

If the actual make-up torque lies outside these values, the connector shall be broken out and re-made.

10.2.2.2 Make-up speed

The manufacturer shall specify the make-up speed range. Connectors shall be made up within that range.

10.2.2.3 Plots

The make-up torque shall be monitored and recorded on torque-turn plots with a resolution of at least 1 % of the maximum torque and 1 % of a turn. All plots shall be retained and included in the detailed test report, in accordance with Annex E.

Each plot shall be annotated to identify the test sample label (see 7.7.7), make-up number, date, time and observations at the time of make-up.

10.2.3 Axially made-up connectors

10.2.3.1 Make-up force

The test samples shall be made-up according to the manufacturer's procedure. The make-up and breakout forces specified in the test procedures shall be the maximum and minimum values recommended by the manufacturer.

The value of maximum force specified in the test procedures shall not be less than 95 % of the maximum value recommended by the manufacturer.

The value of minimum force specified in the test procedures shall not be more than 105 % of the minimum value recommended by the manufacturer.

If the actual make-up force lies outside the acceptable value, the connector shall be broken out and re-made.

10.2.3.2 Make-up velocity

The manufacturer shall specify the velocity range for make-up. All connectors shall be made up within ± 10 % of the maximum recommended velocity.

10.2.3.3 Plots

Make-up and breakout forces shall be monitored and recorded on force plots with a resolution of at least 1 % of the force. All plots of force versus make-up and breakout position shall be retained and shall be included in the detailed test report, in accordance with Annex E.

Each plot shall be annotated to indicate the test sample, pin-end and box-end, make-up number, date, time and observations at the time of make-up.

10.3 Repeated make-up and breakout

This test is for wear and galling resistance. Non-reversible connectors are exempt, see 10.1.5. The following steps shall be carried out.

a) Make up the test samples according to the requirements of 10.2.

b) Use the maximum make-up torque Z_{mu} for each rotational connector to provide input to Equation (C.1), where applicable.

c) Break out the connectors and record the breakout torque, where applicable, on the "Test sample make-up/breakout data", Table D.4.

d) After each breakout, clean the pin and coupling and inspect for galling. Galling shall be photographed.

e) Refurbish light galling as allowed in the manufacturer’s procedure.

NOTE Light galling is galling that can be repaired by the use of fine files and/or abrasive paper.

f) Repeat the above sequence, a) to e), to give a total of five make-ups; the connector shall be left broken out.

10.4 Final make-up

In the final make-up, the connector is assembled ready for testing. In the case of coupled connectors, assemble the A and B ends identically. The following steps shall be carried out.

a) Make up the test samples according to 10.2 with tolerances as specified in Table 3.

b) Record the results in the "Test sample make-up/breakout data", Table D.4.

10.5 Reverse-torque tests of non-rotational make-up connectors

These tests determine the resistance of the connector to reverse-torque loading, which could cause the connector to either undo or otherwise disturb the sealing faces during installation and operation.

If make-up requires rotation of the connector body, the reverse-torque capability shall be determined by comparing the breakout torque with the make-up torque using the criteria given in 10.6.2.

If make-up does not require rotation of the connector body, the torque resistance of the connector may be determined by applying a torque with a magnitude derived from Equation (C.2) and holding for 1 h. The connector may be broken out to enable inspection of the sealing surfaces and then made up again, according to the requirements of 10.4.

10.6 Acceptance criteria

10.6.1 Make-up and breakout tests

The connector passes the make-up and breakout tests if it exhibits no damage or only light galling. Any heavier galling is not acceptable (see 10.3).

The reason for galling shall be evaluated. If the cause of the galling can be proved to be other than design, a minimum of two replacement test samples shall be re-tested through the make-up and breakout sequence, to confirm acceptance. If the galling problem cannot be resolved, the connector shall have failed the test.

10.6.2 Reverse-torque tests

For rotational make-up of connector body, the minimum breakout torque of each connector as determined in 10.3 shall be higher than the larger result of Equations (C.1) and (C.2).

For connectors that do not require rotational make-up of connector body, no rotation of the connector, damage to sealing components or gross distortion shall be permitted.

11 Service-load test

11.1 Set-up

11.1.1 Bending-moment calculation and control

The test shall use a bending device that gives a constant bending moment across the connector and beyond, for the distance L shown in Figure 5. L_p is defined in 7.7.2 and L_g is the grip length. This shall be used for single- or multiple-sample testing. A four-point bending rig is acceptable; a three-point bending rig is not acceptable. The pipe shall be of constant cross-section between the outer load points. Strain-gauge rosettes shall be attached to the test sample(s) at each of the locations shown in Figure 5. A minimum of four strain gauges shall be arranged at 90° intervals in the 12, 3, 6, and 9 o'clock positions, to pick up the neutral axis and peak bending strains. Additional strain gauges may also be attached to monitor stresses at design hot spots. 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. A calculation of moment distribution shall be generated for the actual load-frame configuration and test sample. The moment distribution shall be verified by taking strain-gauge readings and reported in accordance with Annex E.

11.1.2 External pressure test

If a pressure chamber is placed around the connector, the end seals of the chamber shall be sufficiently flexible to allow deflection of the pipe at the bending load.

11.1.3 Pressure monitoring

A pressure transducer shall be connected to, and measure the pressure in, the internal and external cavities of the test sample. The pressure transducer shall be located at the test sample and not at the source of the pressure.

11.1.4 Load application

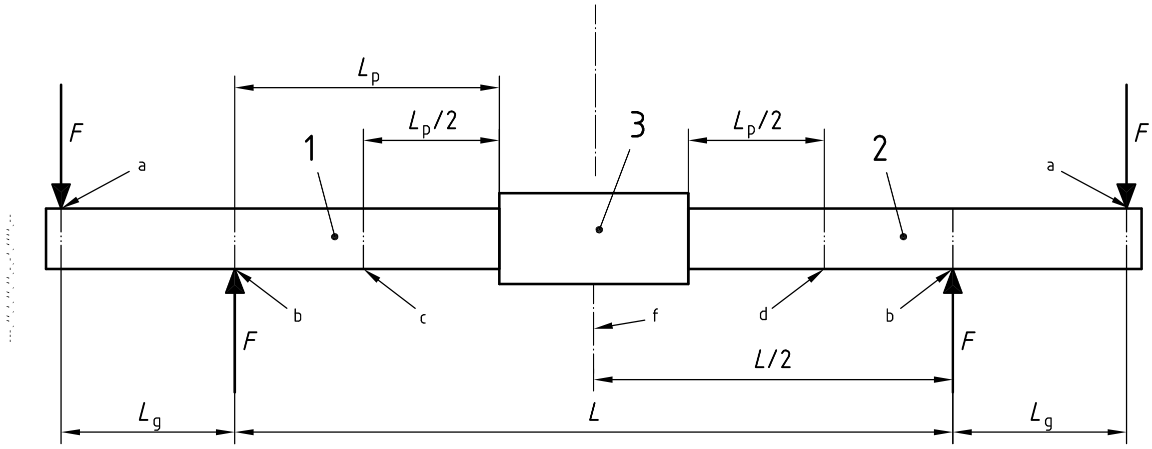
For bending, compression and tension tests, load each sample at maximum bending and axial stress rates of 100 MPa/min (15 000 psi/min).

Pressurize each test sample at a maximum hoop stress rate of 100 MPa/min (15 000 psi/min).

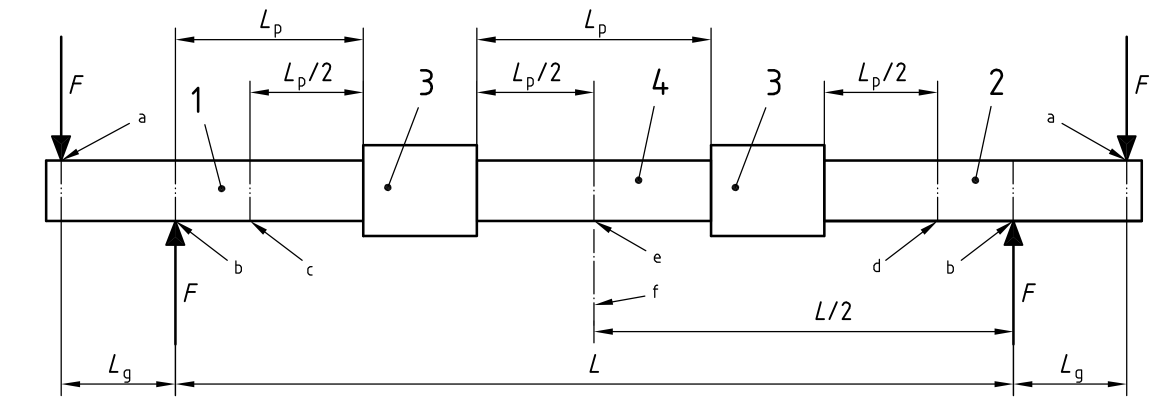
NOTE These rates are specified to ensure that accurate sealing and structural performance data are recorded in the tests.

Loading and pressurizing the test sample may be performed continuously or intermittently. In the case of intermittent loading and pressurizing, the rates between load and pressure increments shall not exceed the stipulated rates.

In combined-load testing, the total axial load is the sum of the load-frame axial load plus the pressure-induced axial load.



a) Single sample



b) Multiple sample

Key

1 pin A

2 pin B

3 coupling

4 pipe pup connecting pin A and pin B

F reaction force.

a Outer load point.

b Inner load point.

c Position of strain gauge plane for pin A.

d Position of strain gauge plane for pin B.

e Position of strain gauge plane for item 4.

f Position of centreline.

Figure 5 — Four-point bending arrangement

11.1.5 Data recording

Record the pressures, axial load, deflection and temperature continuously versus time. The test record should allow space for annotations. Retain these data in the report in accordance with Annex E.

Plot graphs such that they are legible and at a scale covering the range of the test.

11.2 Confirmation of seal integrity

For some connectors it is normal practice to confirm seal integrity before carrying out the hydrostatic pressure test in the field. If applicable to enable an evaluation of the integrity of the primary seal, pressurize the volume between two adjacent seals prior to carrying out the service-load tests. If applicable, at the appropriate stage in the testing sequence, i.e. before installation or before hydrostatic pressure testing, the test house shall carry out the following procedure.

Pressurize the volume between the seals using fresh water. The rate of pressure increase and magnitude of final pressure shall be in accordance with the manufacturer's documentation and Annex B. Maintain this pressure for sufficient time (minimum of 5 min) to demonstrate that there is no leak.

NOTE The application of pressure can load the seal in the “wrong” direction, which could affect the subsequent performance of the seal.

11.3 Selection of test pressures and temperatures

11.3.1 Tests at rated depth, pressure and temperature

If testing is carried out at the manufacturer's maximum and minimum rated pressures and temperatures, the following shall apply:

$$T_{HT} = T_{max} \quad (4)$$

$$T_{LT} = T_{min} \quad (5)$$

$$p_H = p_r \quad (6)$$

$$H_T = H_r \quad (7)$$

where

T_{HT} is the maximum test temperature;

T_{LT} is the minimum test temperature;

p_H is the nominal upper pressure for service-load tests;

H_T is the depth upon which the external pressure is based.

11.3.2 Tests at design or operating conditions

If the purchaser requires tests to be carried out at pressures and temperatures related to either the design or operating conditions, then the following shall apply:

$$T_{HT} = T_{d,max} \quad (8)$$

or

$$T_{HT} = T_{op,max} \quad (9)$$

where

$T_{d,max}$ is the maximum design temperature;

$T_{op,max}$ is the maximum operating temperature;

$$T_{LT} = T_{d,min} \quad (10)$$

or

$$T_{LT} = T_{op,min} \quad (11)$$

where

$T_{d,min}$ is the minimum design temperature;

$T_{op,min}$ is the minimum operating temperature.

Similarly

$$p_H = p_d \quad (12)$$

or

$$p_H = p_{op} \quad (13)$$

where

p_d is the design pressure;

p_{op} is the operating pressure.

and

$$H_T = H_d \quad (14)$$

where H_d is the design depth.

11.3.3 Other factors

The following selection of test temperatures shall be acceptable, by agreement with the purchaser, if

— T_{min} is greater than the ambient laboratory temperature,

— $T_{d,min}$ or $T_{op,min}$ is less than ambient, requiring the test rig to be cooled.

$$T_{LT} = T_{amb} \quad (15)$$

$$T_{HT} = T_{amb} + (T_{d,max} - T_{d,min}) \quad (16)$$

or

$$T_{HT} = T_{amb} + (T_{op,max} - T_{op,min}) \quad (17)$$

where

T_{amb} is the ambient temperature;

$T_{d,min}$ is the minimum design temperature;

$T_{op,min}$ is the minimum operating temperature.

11.4 Installation tests

11.4.1 General

These tests simulate bending and pressure loads during installation. If the depth rating, H_r, is in excess of 500 m, see Table 1, then the test shall also include external hydrostatic pressure loads.

NOTE The following tests assume that external collapse of the pipe under bending will not occur, and that the magnitude of bending loads to be applied can be based on a von Mises' criterion.

11.4.2 Procedure for test without external pressure

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Set up the test in accordance with 11.1.

c) Ensure the internal cavity of the test sample is clean and dry.

d) Carry out the seal-integrity pressure test in accordance with 11.2.

e) Perform tests and record data in accordance with 11.1.4 and 11.1.5.

f) Determine the bending moment for installation, M_{in}, as per Equation (C.6).

g) Apply bending moment to the connector in a cyclic manner as shown in Figure 6; the holds shall be sufficiently long to allow stabilization but not less than 15 min.

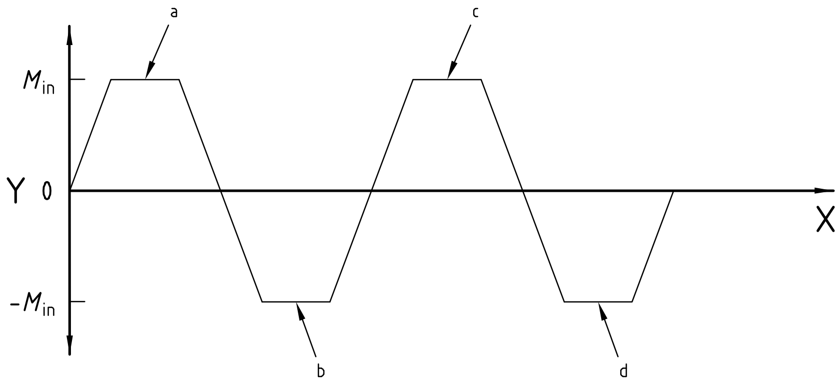
h) Record the following data:

- central displacement and applied bending moment versus time throughout the test;
- strain-gauge measurements at peak- and zero-load points;
- temperature of test sample;
- any residual bending of the test sample when the loads are removed.

i) Release all loads.

Consider the test acceptable if

- there are no gross deformations, such as plastic hinge, in the pipe, or dislocation of the connector,
- there is no residual bending of the test sample greater than 5 mm over the length of the test sample.



Key

X time

Y bending moment

[a] Hold period 1.

[b] Hold period 2.

[c] Hold period 3.

[d] Hold period 4.

Figure 6 — Installation full bending cycle

11.4.3 Procedure for test with external pressure

If applicable, carry out this procedure after 11.4.2 using the same test samples, via the following steps.

a) Use test sample numbers in accordance with Table 2.

b) Set up the test in accordance with 11.1.

c) Ensure that the internal cavity of the test sample is clean and dry.

d) Carry out the seal-integrity pressure test in accordance with 11.2.

e) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4 and 11.1.5.

f) Apply an external hydrostatic test in accordance with 11.5. The external pressure p_{ex} shall be as per Equation (C.5).

g) Determine the bending moment for installation, M_{in}, as per Equation (C.6).

h) Apply bending moment to the connector. The loading rate shall be in accordance with 11.1.4.

i) Apply bending moment to the connector in a cyclic manner as shown in Figure 6; the holds shall be sufficiently long to allow stabilization and not less than 15 min.

j) The following data shall be recorded:

— central displacement and applied bending moment versus time, throughout the test;

— pressure versus time, for the external hydrostatic pressure test;

— visible signs of leakage;

— strain-gauge measurements at peak- and zero-load points;

— temperature of test sample;

— any residual bending of the test sample when the loads are removed;

— any rotation of the connector relative to the pipe.

k) Release all loads.

Consider the test acceptable if

— there are no gross deformations, such as plastic hinge, in the pipe, or dislocation of the connector,

— there are no visible signs of leakage or decrease in hydrostatic pressure due to inward leakage, see 9.3,

— there is no residual bending of the test sample greater than 5 mm over the length of the test sample.

NOTE It is only possible to test the collapse conditions for external pressure using a yield criterion because collapse criterion based on the ultimate strength of the pipe will depend on the ovality of the pipe, which is project-specific.

11.5 Hydrostatic pressure tests

This test simulates the loads on the connector due to hydrostatic pressure testing.

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Set up the test in accordance with 11.1.

c) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

d) Carry out a seal-integrity pressure test in accordance with 11.2, if applicable.

e) Fill the test sample(s) with fresh water and raise the pressure to the hydrostatic test pressure, p_{t}, as per Equation (C.13) or (C.14), as applicable.

f) Hold the pressure for a minimum of 1 h and check the sample for leaks.

g) Determine the bending moment, M_{hy}, for the hydrostatic test as per Equation (C.15).

h) Apply bending moment to the test sample(s).

i) Hold all loads for 24 h.

j) Release all loads on completion of i).

k) Measure any residual bending of the test sample; if necessary bend the test sample straight again, if feasible.

l) Record the following data:

— pressure versus time;

— bending moment applied versus central displacement;

— temperature of test sample;

— strain-gauge measurements;

— visible signs of leakage;

— residual bending of the test sample prior to restraightening.

Consider the test acceptable if

- there is no pressure drop due to leakage from the connector, and all pressure changes that are observed during the hold period can be accounted for,
- there are no gross deformations, such as plastic hinge, in the pipe, or dislocation of the connector.

11.6 Operational unrestrained tests

11.6.1 Set-up

In addition to pressure and bending loads, this test includes thermal cycling. Samples may be tested in series with at least one unsupported pipe length, L_p, between connectors.

The test apparatus shall apply uniform heating to the test assembly.

NOTE This can be achieved, e.g., by heating the internal fluid and wrapping the connector in insulation material.

Thermal cycling temperatures shall be monitored during testing with at least one thermocouple. Steps shall be taken to 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 connector's temperature.

The temperature cycle shall run from T_{LT} to T_{HT}, see 11.3.

11.6.2 Test procedure

The following steps shall be carried out.

a) Use the test sample numbers in accordance with Table 2.

b) Set the test up in accordance with 11.1 and 11.6.1.

c) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

d) Apply the internal pressure, p_H, see 11.3, and maintain constant throughout the high-pressure test sequence.

NOTE 1 This is the first of the high-pressure cycles shown in Figure 7 a).

e) Heat the test sample to the upper test temperature, T_{HT}.

f) Determine the axial tensile load, F_{un}, in addition to the pressure end cap force, as per Equation (C.24).

g) Apply the axial tensile load to the test sample.

h) Determine the bending moment, M_{un}, as per Equation (C.19).

i) Apply the bending moment to the test sample.

j) Hold the loads constant for at least 5 min, t_h (see Figure 7) after pressure stabilization.

k) Remove the bending and axial loads.

l) Reduce the temperature to T_{LT}.

NOTE 2 Steps e) to l) comprise the first of the intermediate load cycles shown in Figure 7 b).

m) Cycle the bending, axial and temperature loads in accordance with e) to l) at high pressure for one-fifth of the total number of cycles, N_c as given in Table 2 and shown in Figure 7 b).

n) Bleed off the internal pressure.

o) Apply the low pressure of 0,5 MPa (5 bar) and seal off the pressure source.

NOTE 3 This is the first of the low-pressure cycles shown in Figure 7 a).

p) Cycle the bending, axial and temperature loads in accordance with e) to l) at low pressure for one-fifth of the total number of cycles, N_c, as shown in Figure 7 b).

q) Bleed off the internal pressure.

r) Repeat the high-pressure cycle in accordance with d) to l) above.

s) Repeat the low-pressure cycle in accordance with p) to q) above.

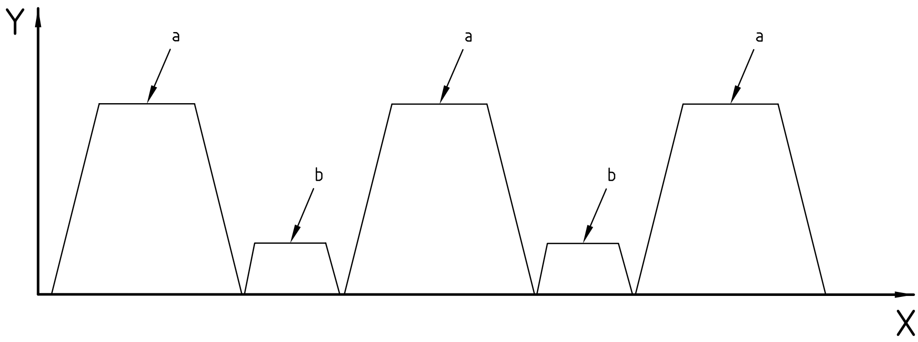
t) Repeat the high-pressure cycle in accordance with d) to l) above.

u) Record the following:

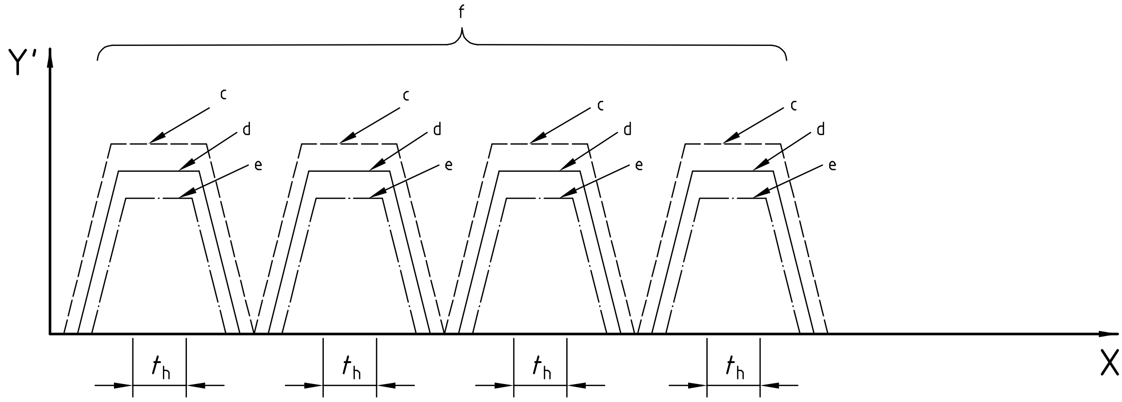
- pressure and temperature versus time;
- axial force and bending moment versus time.

Consider the test acceptable if

- loads remain stable during hold times,
- a leak rate of 0,9 cm^3 over a 15-min period is not exceeded and does not have a tendency to increase,
- there is no fatigue cracking in the connector or in the pipe,
- there are no gross deformations, such as plastic hinge, in the pipe, or dislocation of the connector.



a) Sequence of high and low pressure cycles



b) Number of loading cycles within each pressure cycle

Key

X time

Y pressure

Y′ load

[a] High pressure cycles (total of 3).

[b] Low pressure cycles (total of 2).

[c] Temperature.

[d] Axial load.

[e] Bending.

[f] Number of intermediate cycles = $N_c/5$.

t_h is the hold time.

Figure 7 — Unrestrained load cycling

11.7 Operational restrained tests

The following steps shall be carried out.

a) Use the test sample numbers in accordance with Table 2.

b) Set up the test in accordance with 11.6.1.

c) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

d) Apply the high internal pressure, p_H, see 11.3 and maintain constant throughout the high-pressure test sequence.

NOTE 1 This is the first of the high-pressure cycles shown in Figure 7 a).

e) Heat the test sample to the upper test temperature, T_{HT}.

f) Determine the axial compressive load, F_{re}, in addition to the pressure end cap force, as per Equation (C.26).

g) Apply the axial compressive load to the test sample.

h) Hold the loads constant for at least 5 min, T_h, after pressure stabilization.

i) Remove the axial compressive load.

j) Reduce the temperature to T_{LT}.

NOTE 2 Steps e) to j) comprise the first of the intermediate load cycles shown in Figure 8.

k) Cycle the axial compressive and temperature loads at high pressure, in accordance with e) to j), for one-fifth of the total number of cycles, N_c as given in Table 2 and shown in Figure 8.

l) Bleed off the internal pressure.

m) Apply a low pressure of 0,5 MPa (5 bar) and seal off the pressure source.

NOTE 3 This is the first of the low-pressure cycles shown in Figure 7 a).

n) cycle the axial compressive and temperature loads at low pressure, in accordance with e) to j), for one-fifth of the total number of cycles, N_c, as shown in Figure 8.

o) Bleed off the internal pressure.

p) Repeat the high-pressure cycle in accordance with d) to j) above.

q) Repeat the low-pressure cycle in accordance with n) to o) above.

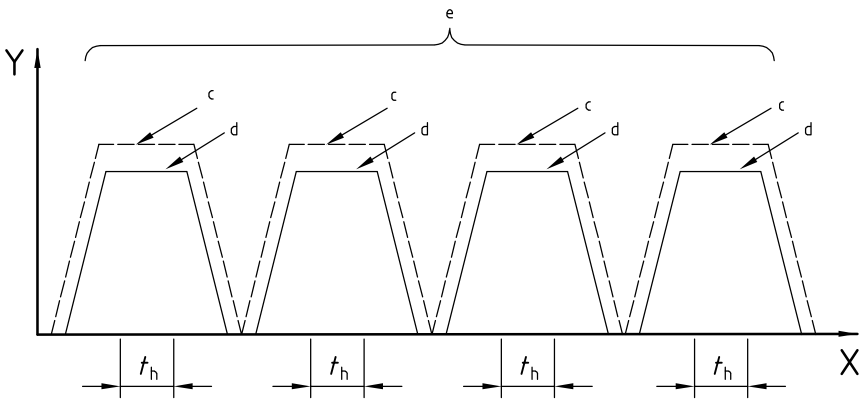
r) Repeat the high-pressure cycle in accordance with d) to j) above.

s) Record the following:

- pressure and temperature continuously versus time;
- axial force versus time.

Consider the test acceptable if

- loads remain stable during hold periods,
- a leak rate of 0,9 cm^3 over a 15-min period is not exceeded and does not have a tendency to increase,
- there is no fatigue cracking in the connector, or in the pipe,
- there are no gross deformations, such as plastic hinge, in the pipe, or dislocation of the connector.



Key

X time

Y load

c Temperature.

d Compressive axial load.

e Number of intermediate cycles = $N_c/5$.

t_h is the hold period.

Figure 8 — Number of loading cycles within each restrained load pressure cycle

12 Limit-load tests

12.1 General

12.1.1 Test loads

An estimate of failure load shall be available in the manufacturer's connector geometry and performance data, see 7.3.

12.1.2 Test conduct

During limit load tests, reductions in the load and pressure should be avoided. In combined loading failure tests, the pressure shall be maintained within ± 2 % of the target pressure up to the point of failure.

Test samples shall be scribed to allow measuring of pipe length, L_S (see Table D.6) before and after tests.

Strain-gauge data from the pipe-body gauges shall be recorded during limit-load tests.

For threaded connectors, additional strain gauges shall be placed on the outside of the connector above the location of the most highly loaded thread. The location of this thread shall be supplied by the manufacturer.

If the connector has been broken out after service-load tests and prior to limit-load tests, then after make-up it shall be heated for 24 h at T_{HT}, see 11.3, and then cooled to room temperature.

12.1.3 Test results

If the connector does not reach its predicted minimum failure load (see 7.3), the test sample shall be returned to the manufacturer who shall advise a new minimum failure load.

If structural or leakage failure at the end fixtures gripping the test sample occurs and invalidates the test, the test shall be repeated unless the test sample is at imminent failure as indicated, for example, by gross deformation.

12.1.4 Failure mode

Preferably the testing should demonstrate that the connector is stronger than the pipe to which it is attached. For example, in combined bending and internal pressure tests the plastic hinge should be formed in the pipe before connector failure.

12.2 Tension-to-failure test

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

c) The axial tension load to be initially applied to the test sample shall be 80 % of the connector tensile rating provided by the manufacturer in accordance with Annex B.

d) Apply this tensile load to the test sample.

e) Apply the internal pressure, p_H, (see 11.3) and, after stabilization, hold for 15 min.

f) Release the tensile load.

g) Hold the internal pressure, p_H, for 15 min.

NOTE Holding the pressure at this point facilitates detection of leaks which occur after the tension load is released.

h) Release the pressure.

i) Increase tension load from d) by 10 %, and apply to the test sample.

j) Repeat steps e) to i) until failure.

Connector failure shall be considered to be one of the following:

— continuous seal leak;

— fracture;

— gross deformation of the connector or pipe, leading to a reduction in load.

k) Remove all loads.

l) Report the results of each test on a separate “Limit-load test data” record, Table D.6.

The test report (see E.3) shall contain representative photographs of the failure test sample, showing the location and mode of failure, and the following data:

— manufacturer’s rated failure load;

— actual failure load;

— actual internal pressure at failure;

— actual failure mode;

— strain-gauge readings;

— lengths and diameters before and after the test as per the limit-load test data, Table D.6.

12.3 Compression-to-failure test

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Support the pipe laterally to prevent strut buckling.

c) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

d) Determine the axial compressive load, F_{re}, in addition to the pressure end cap force, as per Equation (C.26).

e) Apply the axial compressive load to the test sample.

f) Release the compressive load.

g) Apply the internal pressure, p_H, (see 11.3) and, after stabilization, hold for 15 min.

h) Release the pressure.

NOTE Leakage is most likely to occur when the compressive load is released.

i) Increase F_{re} from e) by 10 %, and apply to the test sample.

j) Repeat steps f) to i) until failure.

Failure of the connector shall be considered to be one of the following:

— continuous seal leak;

— local buckle in pipe and/or connector;

— gross deformation of the connector or pipe, leading to a reduction in load.

k) Remove load and pressure.

l) Report the results of the test on a separate “Limit-load test data” record, Table D.6.

The test report (see E.3) shall contain representative photographs of the failure test sample, and the following data:

— manufacturer’s rated failure load;

— actual failure load;

— actual pressure at failure;

— actual failure mode;

— strain-gauge readings;

— lengths and diameters before and after the test as per limit-load test data, Table D.6.

12.4 Pressure-to-failure test

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

c) Increase the internal pressure to test sample failure. The rate of pressure loading shall be in accordance with 11.1.4.

Failure of the connector shall be considered to be one of the following:

— continuous seal leak;

— gross deformation of the connector or pipe leading to a reduction in pressure.

— A failure in the end fitting or grip attachment shall necessitate a repair and retest.

d) Depressurize the test sample.

e) The results of each test shall be reported on a separate “Limit-load test data” record, Table D.6.

The test report, in accordance with E.3, shall contain representative photographs of the failure test sample, and the following data:

— manufacturer’s rated failure pressure;

— actual failure pressure;

— strain-gauge readings;

— lengths and diameters before and after the test as per limit-load test data, Table D.6.

12.5 Bending-to-failure test

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

c) Apply the internal pressure, p_H, (see 11.3) and, after stabilization, hold for 15 min.

d) Increase bending load to test sample failure. The rate of bending loading shall be in accordance with 11.1.4.

Failure of the connector shall be considered to be one of the following:

— continuous seal leak;

— local buckle in pipe and/or connector;

— gross deformation of the connector or pipe, leading to a reduction in load.

e) Remove load and pressure.

f) Report the results of each test on a separate “Limit-load test data” record, Table D.6.

The test report, in accordance with E.3, shall contain representative photographs of the failure test sample, and the following data:

- manufacturer's rated failure bending moment;
- actual failure bending moment;
- internal pressure;
- central displacement, diameters and strains versus time;
- final strains and central displacement with loads removed.

13 Bending-fatigue test procedures

13.1 General

The fatigue curve used to calculate the minimum number of cycles to failure shall be the appropriate curve for the connector material and the service environment. For connectors where seawater may come into contact with the fatigue initiation site, the effect of the seawater in reducing the fatigue life shall be evaluated.

The connector full-scale tests may be conducted in air and the results scaled to account for the appropriate curves of the connector material in the service environment.

It is permissible to extrapolate the fatigue results of connectors made from carbon steel to other materials and environments.

13.2 Setting stress ranges for the test

13.2.1 Guidance

Annex H contains further guidance on the connector fatigue evaluation set out below. Guidance is given on the effect of mean static loads, axial loads and scope to reduce the number of tests in some circumstances.

13.2.2 Stress concentration factor

The stress concentration factor K_{SCF} is defined as:

$$K_{\mathrm{SCF}} = \frac{\Delta S_{\mathrm{ps}}}{\Delta S_{\mathrm{as}}} \tag{18}$$

where

ΔS_{ps} is the largest change in principal stress in connector;

ΔS_{as} is the largest change in principal stress in the pipe at a distance remote from the connector.

The manufacturer shall determine the largest stress concentration factor K_{SCF}, within the connector for the range of axial loads it can experience in service. The K_{SCF} shall be defined for each cyclic stress range, see 13.2.4. If the preload/external mean load affects the K_{SCF}, relevant K_{SCF}s should be applied in the fatigue assessment.

NOTE The use of finite element analysis has been found to be a suitable technique.

13.2.3 Axial load

The manufacturer shall define the axial load that gives the highest K_{SCF}, hence the maximum rate of cyclic bending-fatigue damage.

NOTE Discrepancies can occur when comparing the results of tests performed at a mean stress of zero with those using other mean stresses (because welding residual stresses may be compressive at a weld root), which would lead to artificially long lives. Tests under tensile mean stress provide results more appropriate to real applications.

13.2.4 Stress ranges

The manufacturer shall select three stress ranges, S_L, S_M and S_H, for cyclic bending tests. These shall be sufficiently spread out so that it is possible from the results to determine the slope of the S-N curve. They shall encompass the maximum and minimum values of bending that the fatigue analysis will use, so that extrapolation of results is not required.

13.2.5 Number of cycles

For each stress range, the manufacturer shall predict the number of cycles to failure based on an S-N curve appropriate for the parent material, factored by the K_{SCF}.

13.3 Bending-fatigue test set-up

The bending-fatigue test set-up shall meet the following requirements.

a) A fatigue test rig should be designed such that the connector is cycled in bending at all points around its circumference; a one-plane cyclic bending test rig may be used with a defined correction factor for one-plane cyclic bending versus circumferential bending.

b) The frequency shall not exceed 50 Hz, and shall not cause the connector to heat up beyond the maximum design temperature.

c) The tests shall be carried out in air at room temperature.

d) The test arrangement shall apply a uniform bending moment, within a tolerance of ± 5 %, across the connector and for a length L_p either side.

e) The leak detection method shall be in accordance with 9.1.

f) Internal pressure may, by agreement, be used to develop the axial load defined in 13.2.3.

g) Multiple samples may be tested together.

NOTE 1 Practicalities can limit the testing of large connectors to one-plane four-point bending.

NOTE 2 Internal pressure can have an effect on connector fatigue performance.

13.4 Bending-fatigue test procedure

The following steps shall be carried out.

a) Use test sample numbers in accordance with Table 2.

b) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4, and 11.1.5.

c) Apply the axial load defined in 13.2.3.

d) Apply the cyclic bending-stress ranges defined in 13.2.4 to the relevant connector samples defined in Table 2.

e) Repeat this cycle to connector failure.

Failure of the connector shall be considered to be one of the following:

— continuous seal leak, as determined in accordance with Clause 9 and implied by all pressure changes that are observed that cannot be accounted for;

— any other structural damage which can occur, such as cracking in the connector or the pipe adjacent to the connector or the welds between the connector and the pipe.

Failure in the pipe away from the connector shall necessitate a repair and continuation of testing.

f) Remove all loads and depressurize the test sample, if applicable.

g) Break out and inspect the connector. Non-reversible connectors shall be sectioned and inspected.

Failure of one sample in a test with multiple samples shall necessitate a repair or replacement, and a continuation of the test until all the samples have failed at least once.

h) Report the results of each test on a separate "Fatigue test data" record, Table D.7.

The test report in accordance with E.3 shall contain representative photographs of the failure test sample, and the following data:

— stress range;

— actual number of cycles to failure;

— internal pressure;

— strains;

— comment on type of failure and inspection results.

13.5 Interpretation of fatigue results

The manufacturer shall find the best fit to the S-N curve for the data, and shall derive a design curve two standard deviations below this curve. Annex H gives guidance.

NOTE The design curve may alternatively be expressed in terms of a standard S-N curve (including two standard deviations below the mean) for the parent material plus a K_{SCF} for the connector.

The manufacturer shall explain in the test report any discrepancy between his design predictions and the test results, including

— the location of fatigue damage within the connector;

— the type of damage, such as cracks or wear;

— the fatigue life achieved.

Annex A
(normative)

Application levels

A.1 General

This annex provides guidance on the selection of the appropriate application level for the connector tests. The examples given are for typical service conditions or duties. In specific cases, the design of the pipeline or riser and connector can require a higher or lower application level to be used.

The loading associated with a particular application level (see Table 1) shall exceed the expected loads of the intended application.

The loadings for each application level are characterized in Table A.1.

Table A.1 — Service-load characteristics for various applications

Service	**Installation**				**Hydro-test**			**Operation unrestrained**					**Operation restrained**				
Load type and level applied	Bending	Torque	External pressure	Internal pressure	Internal pressure	Bending	Torque	Temperature	Pressure and surge	Bending	Axial	Torque	Temperature	Pressure and surge	Bending	Axial compression	Torque
Application level 1	S	S	S	S	B	S	S	B	B	S	S	S	not applicable				
Application level 2	**B**	S	S	S	B	S	S	B	B	S	S	S	**B**	**B**	S	**B**	S
Application level 3	B	S	S	S	B	**B**	S	B	B	**B**	S	S	B	B	**B**	B	S
Application level 4	B	S	S	S	B	B	S	B	B	B	**B**	S	B	B	B	B	S

S denotes small load, from 0 % σ_{syp} to 30 % σ_{syp}.

B denotes high load, from 30 % σ_{syp} to 100 % σ_{syp}.

NOTE 1 Where loadings have increased from one application level to the next, these are shown in bold.

NOTE 2 External pressure is mandatory only for water depths greater than 500 m.

Generally the fatigue loadings for each application level are as shown in Table A.2. However, it is possible to have other fatigue characteristics within each application level, and the fatigue requirements shall be assessed accordingly depending on the application.

Table A.2 — Fatigue-load characteristics for various applications

Service	Fatigue		
Load type and level applied	Bending	Axial	Hoop
Application level 1	S	S	S
Application level 2	S	S	S
Application level 3	**B**	S	S
Application level 4	B	**B**	S
S denotes small load from 0 % σ_{syp} to 10 % σ_{syp}			
B denotes high load, from > 10% σ_{syp}			
NOTE Where loadings have increased from one application level to the next, these are shown in bold.			

A.2 Application level 1

The main loads are internal pressure, external pressure (except onshore), temperature and axial tension. Level 1 applications include low bending and no compression, and generally low fatigue.

NOTE 1 There are unlikely to be any Level 1 applications onshore, where most lines are subject to installation bending and restrained operation.

EXAMPLE Typical examples include

— offshore tensioned-riser midspan,

— offshore catenary-riser midspan.

NOTE 2 Such connectors may still need a high fatigue capability.

A.3 Application level 2

Loads in addition to those of application level 1 are axial compression and installation bending. Operational bending is still low in this application.

EXAMPLE Typical examples include

— buried landline,

— buried subsea pipeline.

A.4 Application level 3

Loads in addition to those of application level 2 are bending during operation, and bending fatigue.

EXAMPLE Typical examples include

- unburied subsea pipeline,
- wellhead jumper,
- landline, above ground,
- spoolpiece,
- flowline in bundle,
- fixed riser,
- suspended riser near seabed.

A.5 Application level 4

Loads in addition to those of application level 3 are axial tension, axial fatigue and greater bending fatigue.

EXAMPLE 1 A typical example is a suspended riser in the wave zone. Top-tension risers are similar, however may have a low installation bending load.

EXAMPLE 2 J-lay installation.

For J-lay, the tensile stresses at the top of the lay curve may exceed 20 % σ_{syp}. In these circumstances an additional test may be required in accordance with G.13.

Annex B
(normative)

Connector geometry and performance data

The manufacturer shall provide the following information relating to connector geometry and performance data:

a) size, mass, wall thickness, grade and the product name of the connector;

— if different from the pipe body, the coupling or upset grade;

— connector axial and bending load transmission system and locking system.

NOTE Examples of locking systems include threads, friction, grip, forged, balls/forged, flanged or machined.

b) a description listing the design features and benefits of the threads, seals, shoulders and body configuration;

c) the following design capabilities of the connector:

— design pressure rating;

— maximum and minimum design temperature ratings;

— maximum tensile rating;

— maximum compressive rating;

— maximum bending rating;

— maximum torque rating;

— maximum water-depth rating (or external pressure rating).

d) minimum failure loads and cause of failure for items listed in c);

e) the maximum reverse-torque rating, if applicable;

f) a representative cross-sectional diagram of the connector identifying the critical planes for tension, compression, internal pressure, external pressure and bending;

g) a description of the connector manufacturing specifications;

h) identification of critical dimensions and tolerances;

i) if applicable, a list of the maximum and minimum machined tolerances as specified in 7.5;

j) the type of surface treatment(s) for pin and box sealing surfaces or threads and seals;

k) where applicable, make-up parameters listing:

— lubricant, type, coverage, and application method;

— make-up speed;

— required shoulder torque values;

— minimum and maximum final make-up torque/force values;

— the maximum allowable misalignment and associated bending moment for connector make-up.

l) if applicable, a description of connector refurbishment and methodology for refurbishment.

Table B.1 gives an example table layout for a threaded connector.

Table B.1 — Connector geometry and performance property data for a threaded connector

(A) Identification

Product description:

Material__________ __________ __________ __________ ____________________

Size / Wall thick. / Mat. grade / Product name

Coupling or upset grade: ____________________ (if different from pipe body)

Pipe body configuration: ____________________

Pressure-containment system, internal: ____________________

External: ____________________

(B) Description: ____________________

____

____

____

(C) Pressure, temperature and depth ratings

(D) Diagram: (Attach separate page with schematic diagram)

(E) Connector manufacturing specifications

Complete documentation detailing all of the applicable specifications and procedures, with the associated control numbers and revision levels necessary for all manufacture, inspection and installation of the product, should be listed. Where not applicable, please put “N/A”.

Process control plan No.__________ Revision No./Date __________

Pin drawing No. __________ Revision No./Date __________

Box drawing No. __________ Revision No./Date __________

Pin thread drawing No. __________ Revision No./Date __________

Box thread drawing No. __________ Revision No./Date __________

Seal ring drawing No. __________ Revision No./Date __________

Surface treatment(s) specification No. __________ Revision No./Date __________

Gauging and inspection procedures No.__________ Revision No./Date __________

Seal ring inspection procedures No.__________ Revision No./Date __________

Swage/stress-relief procedures No. __________ Revision No./Date __________

Field running procedures No. __________ Revision No./Date __________

First article/last article procedures No. __________ Revision No./Date __________

Field connector refurbishment procedure No.__________ Revision No./Date __________

Other relevant data: __________ Revision No./Date __________

(F) Surface treatment

Type of pin surface treatment:

Type of box surface treatment:

Annex C
(normative)

Calculation of connector service loads

C.1 Reverse torque, Z

The reverse torque Z shall be the lesser of Equations (C.1) and (C.2). Equation (C.1) shall only apply for connectors that are made up by applying a torque relative to the pipe direction, e.g. screwed connectors.

$$Z = 0{,}60 \cdot Z_{mu} \tag{C.1}$$

$$Z = K_F \cdot K \cdot \sigma_{syp} \cdot \frac{2 \cdot J}{D_o} \tag{C.2}$$

where

D_o is the specified pipe outside diameter;

K is the lesser of the result of Equation (1) or Equation (2), see 6.3;

σ_{syp} is the specified minimum yield stress of the pipe body material;

Z_{mu} is the make-up torque for the connector as determined in 10.3;

K_F is the torque factor given in Table 1;

$$J = \pi \cdot \frac{(D_o^4 - D_i^4)}{32} \tag{C.3}$$

$$D_i = D_o - (2 \cdot t) \tag{C.4}$$

t is the specified pipe body wall thickness

C.2 Installation

C.2.1 External hydrostatic pressure, p_{ex}

$$p_{ex} = \rho_{sw} \cdot H_T \cdot g \tag{C.5}$$

where

ρ_{sw} is the density of seawater;

g is the acceleration due to gravity;

H_T is the depth upon which the pressure is based as defined in 11.3.

NOTE Default value ρ_{sw} = 1 025 kg/m^3.

C.2.2 Bending moment, M_{in}

The bending moment M_{in} under installation conditions is

$$M_{in} = K \cdot \sigma_b \cdot \frac{2 \cdot I}{D_o} \quad \text{(C.6)}$$

NOTE Both the connector and pipe are subjected to the same bending moment under four-point bending.

where σ_b is the lesser of the following:

$$\sigma_b = \left| \frac{\sigma_h + \sqrt{\left\{ \sigma_h^2 - 4\left[\sigma_h^2 + 3 \cdot \tau^2 - \left(f_{vM} \cdot \sigma_{syp} \right)^2 \right] \right\}}}{2} \right| \quad \text{(C.7)}$$

$$\sigma_b = \left| \frac{\sigma_h - \sqrt{\left\{ \sigma_h^2 - 4\left[\sigma_h^2 + 3 \cdot \tau^2 - \left(f_{vM} \cdot \sigma_{syp} \right)^2 \right] \right\}}}{2} \right| \quad \text{(C.8)}$$

$$\sigma_b = B_{F,in} \cdot \sigma_{syp} \quad \text{(C.9)}$$

and

$B_{F,in}$ is the installation-bending factor from Table 1;

f_{vM} is the von Mises' factor from Table 1;

σ_h is the pipe body hoop stress $= -\dfrac{p_{ex} \cdot (D_o - t_{min})}{2 \cdot t_{min}}$ (C.10)

τ is the pipe body torsional stress = 0; (C.11)

t_{min} is the minimum wall thickness accounting for manufacturing tolerances

$$I = \pi \cdot \frac{(D_o^4 - D_i^4)}{64} \quad \text{(C.12)}$$

C.3 Hydrostatic test pressure

C.3.1 Internal pressure, p_t

The hydrostatic test pressure p_t shall be the lesser of:

$$p_t = 1{,}5 \cdot p_H \quad \text{(C.13)}$$

$$p_t = \frac{0{,}9 \cdot K \cdot \sigma_{syp} \cdot 2 \cdot t_{min}}{(D_o - t_{min})} \quad \text{(C.14)}$$

where

t_{min} is the minimum wall thickness accounting for manufacturing tolerances;

p_H is the hydrostatic pressure based on manufacturer's rating, design or operating pressure as defined in 11.3.

C.3.2 Bending moment, M_{hy}

The bending moment due to the hydrostatic pressure test is given by Equation (C.15).

$$M_{hy} = K \cdot \sigma_b \cdot \frac{2 \cdot I}{D_o} \quad \text{(C.15)}$$

where σ_b is the lesser of the following:

$$\sigma_b = \left| \sqrt{\left(V_F \cdot \sigma_{syp}\right)^2 - 0{,}75 \cdot \sigma_h^2} \right| \quad \text{(C.16)}$$

$$\sigma_b = B_{F,hy} \cdot K \cdot \sigma_{syp} \quad \text{(C.17)}$$

and

$B_{F,hy}$ is the hydrotest bending factor from Table 1;

pipe body hoop stress $$\sigma_h = \frac{p_t \cdot (D_o - t_{min})}{2 \cdot t_{min}} \quad \text{(C.18)}$$

C.4 Operation unrestrained

C.4.1 Bending moment, M_{un}

The bending moment M_{un} under operation unrestrained conditions is

$$M_{un} = K \cdot \sigma_b \cdot \frac{2 \cdot I}{D_o} \quad \text{(C.19)}$$

where σ_b is the lesser of the following:

$$\sigma_b = \left| -A_{F,un} \cdot \sigma_{syp} + \sqrt{\left(f_{vM} \cdot \sigma_{syp}\right)^2 - 0{,}75 \cdot \sigma_h^2 - 3 \cdot \tau^2} \right| \quad \text{(C.20)}$$

$$\sigma_b = \left| -A_{F,un} \cdot \sigma_{syp} - \sqrt{\left(f_{vM} \cdot \sigma_{syp}\right)^2 - 0{,}75 \cdot \sigma_h^2 - 3 \cdot \tau^2} \right| \quad \text{(C.21)}$$

$$\sigma_b = B_{F,un} \cdot \sigma_{syp} \quad \text{(C.22)}$$

and

$B_{F,un}$ is the unrestrained bending factor from Table 1;

$A_{F,un}$ is the unrestrained axial load factor from Table 1;

pipe body torsional stress $\tau = 0$. (C.23)

C.4.2 Axial force, F_{un}

The axial force, F_{un}, under operation unrestrained conditions is:

$$F_{un} = A_{F,un} \cdot K \cdot \sigma_{syp} \cdot A_s \quad \text{(C.24)}$$

where A_s is the specified cross-sectional area of pipe

$$A_s = \frac{\pi}{4} \cdot \left(D_o^2 - D_i^2 \right) \quad \text{(C.25)}$$

C.5 Operation restrained axial force, F_{re}

The operation restrained axial force, F_{re}, is given by:

$$F_{re} = (E_p \cdot \alpha \cdot \theta + \sigma_{ax,re} - \upsilon \cdot \sigma_h) \cdot A_s \quad \text{(C.26)}$$

where

θ is the temperature differential;

α is the thermal expansion coefficient of the pipe body;

E_p is the Young's modulus of the pipe body;

υ is the Poisson ratio of the pipe body.

The restrained axial stress, $\sigma_{ax,re}$, is:

$$\sigma_{ax,re} = \frac{p_H \cdot D_i^2}{\left(D_o^2 - D_i^2 \right)} \quad \text{(C.27)}$$

Annex D
(normative)

Test data tables

This annex contains the following data tables:

a) Table D.1: Connector material property data;

b) Table D.2: Pipe body material property data;

c) Table D.3: Test sample preparation data;

d) Table D.4: Test sample make-up/breakout data;

e) Table D.5: Service load test log;

f) Table D.6: Limit load test data;

g) Table D.7: Fatigue test data.

The manufacturer may adapt these tables to suit particular connector requirements and assembly methods.

Table D.1 — Connector material property data

Test sample No._________ Coupling No.____________ to____________ Pin A No. __________________ to ______________ Pin B No. ________________ to _____________

Connector manufacturer _____________________________ Connector type _________________________ Steel manufacturer____

Tensile test performer ______________________________ Date(s) _________________________ Location ____

Materials specification ____

Strain measurement method _____________ Specified OD______________ Nominal wall thickness ______________________ Grade____

Chemical constituent, %	C	Si	Mn	Cr	Mo	Nb	Ti	Al	P	S	B	Ni
Specified chemistry												
Coupling chemistry												
Pin A chemistry												
Pin B chemistry												

Location		Heat number	Joint number	Coupon	Yield strength MPa	0,2% offset proof stress MPa	Ultimate stress MPa	Elongation %	E MPa	Test temp. °C
Room temperature	Pin A			End 1						
				End 2						
				Middle						
				Average						
	Pin B			End 1						
				End 2						
				Middle						
				Average						
	Coupling			End 1						
				End 2						
				Middle						
				Average						
T_{max}	Pin A			Middle						
	Pin B			Middle						
	Coupling			Middle						
Material stress-strain curves at room and elevated temperatures shall be attached to this data record.										

Test coupon sketch: with nominal dimensions

Table D.2 — Pipe body material property data

Test sample No.____________

Tensile test performer________________________ Date(s)________________________ Location________________________

Materials specification____

Strain measurement method________________ Specified OD________________ Nominal wall thickness__________ Grade __________

Chemical constituent, %	C	Si	Mn	Cr	Mo	Nb	Ti	Al	P	S	B	Ni
Specified chemistry												
Coupling chemistry												
Pin A chemistry												
Pin B chemistry												

Location		Heat number	Joint number	Coupon	Yield strength MPa	0,2% offset proof stress MPa	Ultimate stress MPa	Elongation %	E MPa	Test temp. °C
Room temperature	Pin A end			End 1						
				End 2						
				Middle						
				Average						
	Pin B end			End 1						
				End 2						
				Middle						
				Average						
T_{max}	Pin A			Middle						
	Pin B			Middle						
Material stress-strain curves at room and elevated temperatures shall be attached to this data record.										

Test coupon sketch: with nominal dimensions

Table D.3 —Test sample preparation data

Test sample No.____________ Coupling No._____________________ Pin or Box ______________________________

Connector manufacturer____________________________________ Connector type______________________________

Steel manufacturer ____

Tensile test performer____Date(s _______________________________

Location ____

Materials specification____

Strain measurement method___________________________ Specified OD ____________________________________

Nominal wall thickness ____ Grade _______________________

Location	Design value	Actual measured value	Maximum tolerance	Minimum tolerance	Actual tolerance
Connector					
Seal tolerance					
Pin nose thickness					
Surface roughness					
Thread taper					
Thread interference					
Centre-to-contact surface					
Centre-to-end					
Facing					
Coupling					
Pup pipe body					
Wall thickness					
Outside diameter					

Table D.4 — Test sample make-up/breakout data

Connector manufacturer__________ Connector type__________ Drawing No.__________ Rev. No.__________ Rev. date __________

Specified OD__________ Wall thickness__________ Grade __________

Make-up site__________ Date(s)__________ Make-up machine __________

Anti-galling treatment box__________ Anti-galling treatment pin __________

Thread lubricant manufacturer__________ Type__________ Product No. __________

Seal ring material __________

Reference torque for torque versus make-up position plot __________

Test sample No.	Make-up No.	Pin No.	Box No.	Mass of lubricant g	Planned make-up torque	Shoulder torque	Turns to shoulder	Total torque	Total turns	Make-up speed r/min	Breakout torque	Refurbishing and galling observations	Photo ref.	Torque turns plot ref.

Data recorded by__________ Date__________

Data witnessed by__________ Date__________

Table D.5 — Service-load test log

Specified OD__________ Wall thickness__________ Grade __________

Connector manufacturer__________ Connector type__________ Drawing No.__________ Rev. No.__________ Rev. date __________

Test No.__________ Date__________ Test sample No. __________

Box No.	Pin No.	Load point No.	Time into hold	Pressure at leak	Machine load at leak	Total axial load at leak	Leak duration	Total hold time h	Notes	Hold period					
										Maximum temp. °C	Minimum temp. °C	Maximum pressure	Minimum pressure	Maximum machine load	Minimum machine load

Data recorded by__________ Date__________

Data witnessed by__________ Date__________

Table D.6 — Limit-load test data

Specified test sample No. ______

Test description ______ Test No ______

Specified OD ______ Wall thickness ______ Grade ______

Connector manufacturer ______ Connector type ______

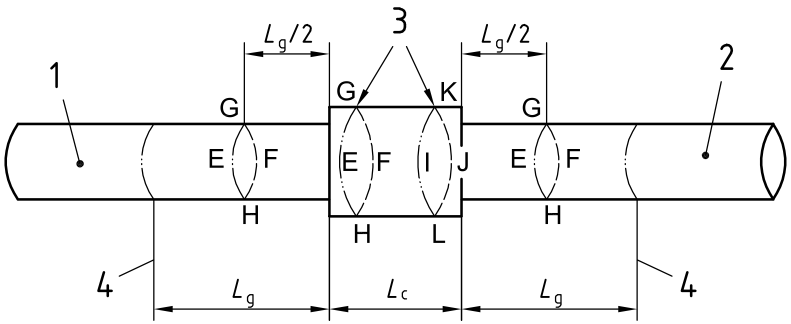
Pressure medium ______

Pressurizing rate (min.) ______ Axial loading rate (min.) ______

Pin A	Diameter	Length	Before	After
	E-F			
	G-H			
		L_S		

L_S is the distance between scribe mark on pin and the coupling.

L_C is the coupling length.



Key

1 pin A

2 pin B

3 coupling

4 grip

NOTE 1 Measurement points across diameter:

E – F

G – H

I – J

K – L

NOTE 2 On coupling, measurements should be over seal groove if applicable.

Pin B	Diameter	Length	Before	After
	E-F			
	G-H			
		L_S		

Box	Diameter	Length	Before	After	Diameter	Before	After
	E - F				I - J		
	G - H				K - L		
		L_C					

At leakage: pressure ______ Machine load ______ Total load ______ Pin No. ______

At failure: pressure ______ Machine load ______ Total load ______

Maximum test parameters ______ Machine load ______ Total load ______

Description of location/mode of failure: leakage rate (cm^3/h) and other comments ______ Test machine ______

Data recorded by ______ Date ______

Data witnessed by ______ Date ______

Table D.7 — Fatigue test data

Specified OD__________ Wall thickness__________ Grade __________

Connector manufacturer__________ Connector type__________ Drawing No.__________ Rev. No.__________ Rev. Date__________

Test No.__________ Date__________ Test sample number__________ T_{amb}__________

K_{SCF}__________ Axial load to provide highest K_{SCF} __________ Bending stress range S__________ Prediction of No. cycles to failure at S__________

Coupling No.	Pin No.	Load point No.	Cycle rate	Internal pressure	Additional axial load	Cycles to failure	Description of failure	Results of inspection	Notes	Hold Period					

Data recorded by__________ Date__________

Data witnessed by__________ Date__________

Annex E
(normative)

Connector test reports — Content

E.1 General

The following requirements cover the manufacturer's detailed report and the summary report on the connector tests. The manufacturer and test house shall provide the information required to fully specify the tested connector, make it up correctly, have confidence that it will perform as desired, and make the purchaser aware of any potential difficulties.

Both reports shall identify deviations from the specified procedures of manufacturing and testing (if any), but should not duplicate information on the test sample preparation and test procedures that are already found in this International Standard. Also, additional tests that were performed, but are not required for an application level, shall be included in the test report and shall be clearly identified as additional to the requirements of this International Standard.

E.2 Manufacturer's detailed report

E.2.1 General information

The manufacturer's detailed report shall be kept by the manufacturer for a sufficient period to ensure traceability whilst the connector is in service. This shall be no less than 25 years.

After the tests have been performed, the test report shall be included in the manufacturer's detailed report as an appendix.

The report shall contain at least the information as listed in E.2.2 to E.2.4, and any further information considered relevant to the testing of the connector.

E.2.2 Materials

The manufacturer's report shall contain the following information:

a) mill certificates for items supplied to test house, including connectors, pup joints, seal rings, etc.;

b) material test reports for tests carried out, including failed tests at ambient and elevated temperatures.

E.2.3 Quality control

The manufacturer's report shall contain the following information:

a) manufacturing process control plan;

b) all QC procedures used in the production of the test samples, including manufacturing, gauge calibration, gauging procedure, surface treatment, etc.

E.2.4 Machining

The manufacturer's report shall contain the following information:

a) copies of machining drawings for the test samples, showing the worst-case machining tolerance and the actual production tolerances for the connectors;

b) copies of machining drawings for seal rings;

c) copies of machining drawings for pup joints;

d) details of seal port machining.

E.3 Test report

E.3.1 General information

The test report shall be issued to the purchaser and the manufacturer. After the test has been performed, the test report shall be included in the manufacturer's detailed report as an appendix.

The test report shall contain at least the information as listed in E.3.2 to E.3.7, and any further information considered relevant to the testing of the connector.

The test report shall also contain any additional test requirements, see 6.6, and results.

E.3.2 Summary

The test report shall contain the following information:

a) connector geometry and performance data in accordance with Annex B;

b) application level and fatigue limit tested;

c) material description and grade;

d) main test results, e.g. pass or fail.

E.3.3 Introduction

The test report introduction shall contain the following information:

a) statement of what was tested and what is believed to be acceptable. Indicate any limitations;

b) statement of personnel who executed specific test;

c) statement of which tests, if any, were omitted, why they were omitted, and why the connector should be considered adequately evaluated without the tests being completed. Deviations shall be included with the applicable procedures or tests that were followed. No comments are required if the tests were fully performed as specified. Manufacturer de-rating for axial loads and internal or external pressure shall be reported;

d) when (months and year) and where the tests were performed; personnel coordinating the tests; details of witnesses of the tests.

E.3.4 Test sample preparation

The test report shall contain the following information:

a) the source of the test sample materials and summary of related mechanical properties;

b) the ratio of material yield strength at elevated temperature to material yield strength at ambient temperature;

c) the ratio of material ultimate strength at elevated temperature to material ultimate strength at ambient temperature;

d) the value of elevated temperature used.

E.3.5 Make-up/breakout tests

The test report shall contain the following information:

a) occurrence and photographs of galling damage, reason for occurrence of galling, and refurbishment carried out;

b) make-up velocity;

c) reference torque and force, shoulder torque, total torque and force, turns past shoulder, and turns to full make-up;

d) breakout torque and force ranges prior to pressure and temperature testing;

e) breakout torque and force ranges subsequent to pressure and temperature testing ;

f) statement of whether any connectors were over-torqued, and whether any problems resulted;

g) photographs of pertinent areas on test samples before and after doping. Also, photographs of the make-up machinery, process, and connectors where non-conformances are suspected. Photographs of any damage before and after cleaning and after field dressing.

E.3.6 Service load tests

For each applicable test, the following information shall be included:

a) test pressure, axial load, bending moments and temperature;

b) maximum pressure at room temperature and at elevated temperature;

c) the test fluid used (i.e. nitrogen, oil, fresh water, other);

d) how leakage was monitored;

e) whether leakage was observed, and if so, at what pressure this occurred, at what frequency, and the leak rate;

f) methods of heat application and monitoring;

g) problems encountered.

E.3.7 Load-limit tests

The test report shall contain the following information:

a) failure location and failure mode;

b) failure loads (pressure and axial);

c) any leaks before failure (pressure and frequency);

d) photographs of any damage to the pipe or connector after failure.

Annex F
(informative)

Test sizes and data extrapolation considerations

F.1 Purpose of testing

Qualification of a product line allows both manufacturers and purchasers to benefit from evaluation of salient performance parameters over a range of diameters, D/t ratios, grades, etc. Due to limitations regarding interrelationships of leak resistance and lubricant data, relying entirely on analysis (such as the finite-element method) is not sufficient for qualification. Conversely, full-scale physical testing on every diameter, mass and grade is neither necessary nor practical. Consequently the recommended methodology requires testing, to provide the necessary empirical data, and analysis, which ensures consistent control of the performance parameters. The test population includes worst-case combinations of the production population in terms of dimensions while verifying material specification.

If a product line is qualified by this method, the actual test sizes should be clearly identified.

F.2 Product line

A product line is a set of products that are designed with common criteria (i.e. uniform seal geometry, consistent geometric changes, and similar and consistent seal interferences) across the sizes and grades specified. Product line qualification may cover the entire product range or may be limited to pipe sizes.

Standard product line qualification would be performed on a high strength material and on a low strength material.

Within each product line are product sectors that group connectors into specific diameter and pressure ranges. The size of each product sector should be limited and should closely match the example given in Table F.1 to provide consistency of information for users.

Table F.1 — Example of product sectors in product line

Diameter mm (in)	Pressure range MPa (psi)				
	2,07 to 4,14 (300 to 600)	4,14 to 6,21 (600 to 900)	6,21 to 8,62 (900 to 1 250)	8,62 to 17,24 (1 250 to 2 500)	17,24 to 34,48 (2 500 to 5 000)
60,3 to 168,3 (2,375 to 6,625)					
168,3 to 273,1 (6,625 to 10,75)					
273,1 to 406,4 (10,75 to 16)					
406,4 to 508 (16 to 20)					
508 to 609,6 (20 to 24)					
609,6 to 711,2 (24 to 28)					
711,2 to 812,8 (28 to 32)					
812,8 to 914,4 (32 to 36)					

F.3 Tests

The test sizes are intended to experimentally define the performance of connectors at extremes and intermediate points of the product line. Such sizes may have to be identified based on the most common nominal pipe sizes, and may be adjusted by the manufacturer for specific products. Typically the size to be tested falls midway within each product sector as defined in F.2.

The sizes chosen can also be influenced by the perception of risk by the purchaser, i.e. more tests would be done if the consequences of a failure were worse, and vice versa.

Test results should meet acceptance criteria in every size and grade tested, in order to meet requirements for product line qualification.

F.4 Analysis

The analysis portion of the product line qualification is intended to complement the test portion, and provide confidence in the application of sizes not tested. Basic leak performance data, such as contact pressure to preclude leak, will not be defined in the analysis. Rather, calculations will be compared to analysis results of those tested. Critical parameters such as stress and contact parameters of the untested configurations should fall within the ranges of those tested. The portion of a product line which includes stresses beyond, or contact pressure outside the tested empirical basis should not be qualified without additional physical testing. Since testing is being used to bound extremes, the role of analysis is reduced to evaluating continuity in design between tested sizes.

The process of a full product-line qualification as described above, even if greatly reducing the required number of tests, still bears a significant cost, either from tests or from analyses. However, as the process of the full qualification proceeds, a partial qualification can be achieved provided tests and analyses already performed "cover" the range under partial qualification, in a way similar to the full qualification described above.

Annex G
(informative)

Additional testing for special applications

G.1 Introduction

This International Standard covers the testing of connectors for the most commonly encountered pipeline conditions. There are, however, many special and extreme conditions not covered in Clauses 10, 11 and 12 in which connectors could be used which are outside the scope of this International Standard. This annex provides guidance on potential supplementary testing which may be required for such conditions. In cases when the service application extends beyond the scope of this International Standard, the purchaser should consult and agree with the manufacturer (or the connector test house) on the test procedures required to confirm the structural/sealing integrity of the connector under the anticipated loading regimes. It is the responsibility of the purchaser to assess the application of the connector and specify further tests as required.

Listed below are examples of specialized service conditions:

— tests of multiple-seal connectors, such as separate external seals;

— tests of elastomeric seals;

— removal of corrosion allowance;

— lubricant pressure entrapment;

— tension-leg platforms, floating facilities and compliant towers;

— make-and-break trials to simulate extreme field assembly/stabbing conditions;

— rapid cooling (quenching) of a connector seal;

— probabilistic connector performance;

— high-alloy corrosion-resistant materials with anisotropic material properties;

— plastic-lined pipe;

— extreme sour service pipelines;

— J-lay in deep water depths.

The following subclauses present some of the test aspects that should be considered for various special applications. Suggested test procedures are given for the three most common additional tests: compression beyond yield, crevice corrosion and impact tests.

Separate test samples should be supplied for these tests, in addition to those samples specified in Table 2.

G.2 Tests of elastomeric seals

If a connector contains elastomeric seals, which under certain conditions seal against the internal conditions of the pipeline, tests should be conducted to prove the seal capabilities and should cover as a minimum:

- explosive decompression;
- loss of sealing capacity through ageing.

G.3 Corrosion allowance

If there is a possibility of a global loss of corrosion allowance over the life of the connector, then a full set of the service-limit and load-limit tests should be undertaken with the corrosion allowance removed. This is in addition to the tests listed within this International Standard.

G.4 Make-and-break tests to simulate field conditions

G.4.1 General

The assembly tests described in the main body of this International Standard are conducted with pup joints assembled under controlled test laboratory conditions. Actual field running can involve more severe conditions due to

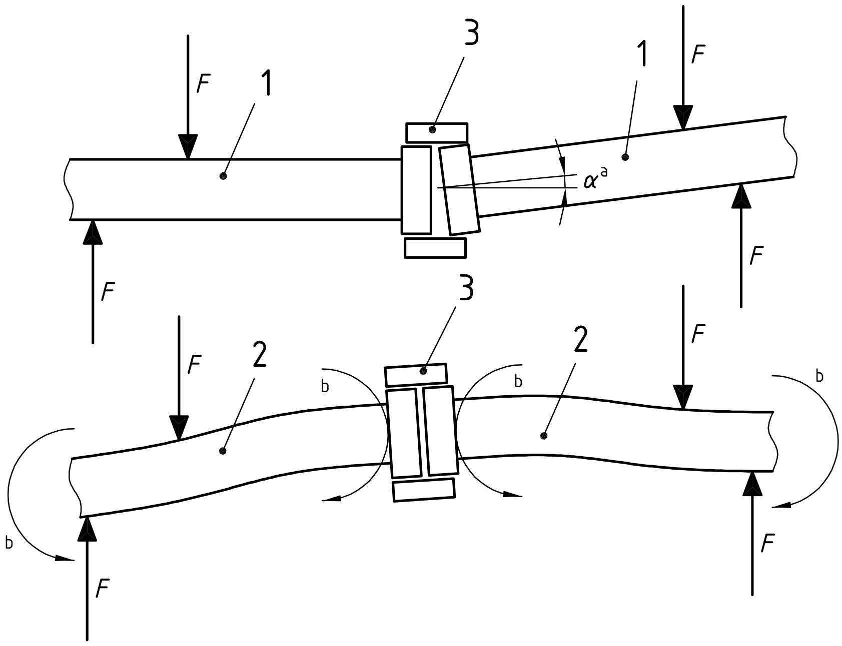
- the requirement for full-length pipe joints,
- effects of misalignments, which can be either intentional or otherwise,
- floating vessel movement,
- human factors involving doping, stabbing, make-up, etc.

Because of these issues, justification may exist to simulate field running and stabbing for particular projects. For example, in the case of a vertical make-up, a full-size joint, or pup joint with a weight representing a full-size joint, can be stabbed into a coupling and assembled. This procedure can be repeated with the joint at various angles to simulate incorrect stabbing.

G.4.2 Demonstration of misalignment capability

If a misalignment capability is specified in the connector performance data (see 7.3) or specified by the purchaser, this should be demonstrated during final make-up (see 10.4) and during the make-up and breakout tests (10.3), if applicable. This should be carried out using a minimum of one test sample in a manner such that the initial misalignment angle and the resultant bending moment do not exceed the specified limits provided by the manufacturer in 7.5.1.

A suitable test rig is required that can provide both the misalignment angle at make-up and the bending moment restraint, as shown in Figure G.1.



Key

1 one-half of connector pin or hub and pup piece assembly at start of make-up with specified misalignment angle

2 one-half of connector pin or hub and pup piece assembly at completion of make-up

3 coupling or clamp

F Reaction force.

[a] Initial misalignment angle.

[b] Direction of resultant bending moment after make-up is completed.

Figure G.1 — Make-up with initial misalignment

G.5 Lubricant-pressure entrapment in threaded connectors

Lubricant-pressure build-up within a connector can significantly impact the performance of the connector by causing severe plastic deformation of the seal region. If this occurs, the make-up torque can be absorbed in overcoming the pressure build-up, which results in a reduction of pre-load within the connector.

If it is desired to understand the effects of lubricant quantities on the performance of a connector, the following recommended test procedure should be considered.

a) Drill a porthole into the pin or box member downstream of the primary internal pressure seal to allow the thread pressure in the region to be monitored during make-up. The hole should be tapped to allow a pressure transducer to be connected directly.

b) Prior to assembly, conduct detailed gauging measurements of the seal diameter and of the bore adjacent to the seal.

c) Apply the lubricant, using the manufacturer's recommended procedure and quantity.

d) Assemble the connector using the manufacturer's minimum recommended make-up torque.

e) Measure and record the lubricant pressure. (An analog system should be used with the pressure transducer.)

f) Break out the connector, clean threads and seal, re-gauge connector.

g) Repeat steps c) to f) using the manufacturer’s normal make-up torque in place of minimum make-up torque.

h) Repeat steps c) to f) using the manufacturer’s maximum make-up torque in place of minimum make-up torque.

i) Repeat steps c) to h) using double the quantity of manufacturer’s recommended lubricant.

j) Repeat steps c) to h) using triple the quantity of manufacturer’s recommended lubricant.

If excessive plastic deformation is recorded for the conditions using the manufacturer's recommended quantity of lubricant, caution in the use of the connector is advised.

If excessive plastic deformation is recorded for double or triple the quantity of lubricant, then personnel responsible for running the connector should be made aware of the consequences of over-doping, and specialized doping procedures should be considered.

G.6 Rapid cool-down conditions

Some pipeline operating conditions, such as blowdown, can cause a rapid cool-down. This cooling can cause the connector pin seal to thermally contract faster than the box, and the primary metal-to-metal seal can sometimes open, thereby causing a connector leak.

NOTE Metal-to-metal sealing systems rely on an intimate and usually high contact stress of mating metal surfaces to achieve a seal.

Test procedures for evaluating rapid cool-down or quenching should be considered for pipelines that have unusually high operating temperatures and could experience rapid cool-down.

G.7 Plastic-lined pipe

In plastic-lined pipe, collapse of the liner during pipeline decompression could occur if the seal between the liner and connector fails. Therefore this should be included as one of the additional tests during the qualification testing.

G.8 Severe sour service pipelines

Additional testing may be required for severe sour service pipelines if embrittlement of the connector is considered an issue.

G.9 Fire test

Connectors that are used in locations where there is the potential for fire hazards should undergo a fire test. The type of test should be appropriate to the location where the connector is to be used, e.g. jet fire for risers and pool fire for onshore/topsides.

The fire test should be in accordance with API Spec 6FB.

G.10 Compression beyond yield

Pipelines that are allowed to strain in axial compression on the first cycle should be similarly strained during the operational restrained test, detailed in 11.7. This additional test simulates these conditions, as follows.

a) Apply torque, pressure and temperature in accordance with 11.7. When applying the compressive axial force to represent axial constraint, control the displacement (rather than the force) such that the axial strain measured on the pipe increases in compression by an amount ε where:

$$\varepsilon = \alpha \cdot \theta + \frac{\left(\sigma_{\text{ax}} - \upsilon \cdot \sigma_{\text{h}}\right)}{E_p}$$

where

α is the coefficient of thermal expansion

θ is the temperature differential

σ_{ax} is the axial stress

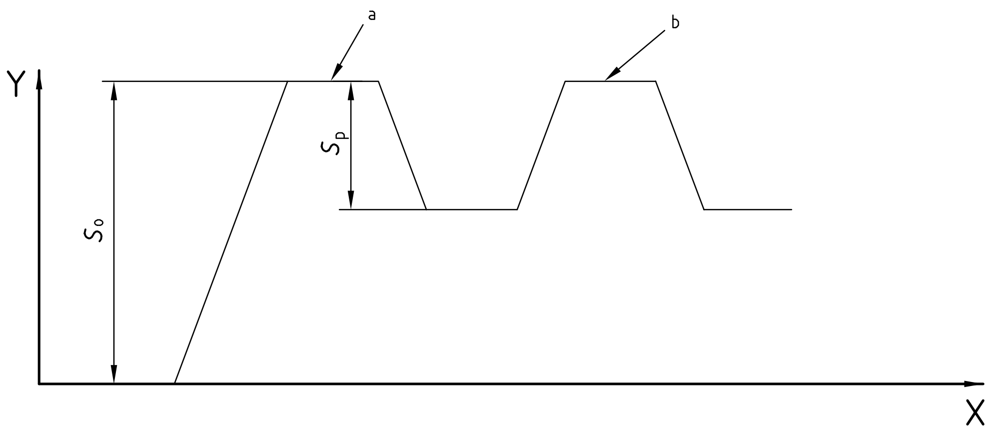
σ_{h} is the hoop stress

υ is the Poisson ratio

E_{p} is the Young's modulus of the pipe

This is shown graphically in Figure G.2.

b) On removing the compression, note the change in axial strain ε_1 (less than ε because the pipe has yielded), and then remove the other loads. On subsequent cycles, apply the compressive force as shown in C.4.2.



Key

X Time.

Y Compression.

S_{o} maximum static amplitude

S_{p} amplitude of the fluctuation

[a] Duration of the first cycle.

[b] Duration of subsequent cycles.

Figure G.2 — Initial compression beyond yield

G.11 Crevice corrosion

This is an accelerated corrosion test to determine whether the pipeline fluids will cause crevice corrosion on the connector. The corrosive elements of the pipeline contents should be used for the corrosion test.

The following procedure is recommended.

a) For carbon steel, use crevice-corrosion material test coupons inside an inert container. For other materials use a full-scale connector (materials such as 13Cr depend on crack geometry, stress state and, possibly, the presence of elements in the dope).

b) Place a sample of the corrosive elements which the pipeline may contain inside the test sample/container, to the maximum concentrations at which these elements are found in the pipeline.

c) Hold internal pressure at p_{op} at the maximum rated temperature for the pipe.

d) Replenish the corrosive elements as necessary.

e) Maintain the test conditions for four weeks.

f) Dismantle and inspect the coupons.

g) Extrapolate results for field design life (care is needed, as crevice corrosion can be self-limiting).

h) The verification report should contain representative photographs of the test sample and the following data:

— amount and type of corrosive elements;

— test sample temperature for the duration of the test;

— internal pressure for the duration of the test;

— maximum depth of corrosion.

The test material is acceptable if the extrapolated results for field-life corrosion do not exceed the design corrosion allowance for that material.

G.12 Impact

G.12.1 General

This test impacts the connector with the maximum trawl-board impulse for unburied offshore lines, or the maximum anticipated third-party impact impulse for landlines.

Impact tests should be conducted both on the body of the connector and on the pipe adjacent to the connector.

The impact energies should be equivalent to those considered likely for the pipeline application and location, i.e. a maximum credible trawl-board load on a subsea pipeline.

G.12.2 Impact test set-up

The hammer should be fabricated to give a total mass equivalent to that of the likely impacting object. The impacting face should be fabricated from solid steel, fully fixed and supported by the hammer, with a similar configuration to that of the likely impacting object.

If no values for impact energies are given, then a value of 35 kJ should be used in all tests.

Assess the maximum number of times an individual connector on the line would be hit during the pipeline design life. Apply the above number of impacts to the connector complete with any coating or field joint.

The test piece should have a length of 12 m, with the connector located in the centre of the test piece, and should be fully supported along its length by compacted sandbags. Each end should be securely pinned to the laboratory reaction floor.

The test sample should include a gas/water accumulator to prevent hydraulic lock (water hammer) effects when the hammer impacts. The accumulator port on the pipeline test piece should have a minimum diameter of 50 mm (2 in).

G.12.3 Impact tests

The following procedure is recommended.

a) Set up test in accordance with G.12.2 such that the impact is on the main connector body.

b) Pressurize test piece internally to 2 MPa [20 bar(g)].

c) Perform leak detection, tests and recording of data in accordance with 9, 11.1.4 and 11.1.5.

d) Impact the hammer on connector (box) the required number of times.

e) After denting, the coatings should be removed. The pipe surface over and around the dents should be polished and sprayed with a photoelastic film.

f) The pipe should then be pressurized with fresh water at room temperature to 0 %, 50 %, 100 % and 150 % of MAOP, stabilizing for an hour at each stage, and then holding long enough to take readings.

   NOTE At 150 % of MAOP, hoop stress in the pipeline will remain below $^2/_3$ of the material specified yield stress σ_{syp}.

g) The verification report should contain representative photographs of the failure test sample, and the following data:

   1) a record of the hammer mass and height;

   2) measurements of the amount of hammer “bounce” for each impact;

   3) a photograph of damage after each impact;

   4) profiles of steel in axial and hoop directions, showing dent depth, width and length;

   5) diameter measurements of the pipeline at the dent and at 90° to the dent, before and after the impact;

   6) manufacturer’s rated failure-impact energy;

   7) anticipated failure-impact energy, using actual mechanical properties and dimensions;

   8) actual failure-impact energy;

   9) the ratio of actual failure-impact energy to anticipated failure-impact energy;

   10) internal pressure versus time (to show amount of water hammer);

   11) strain measurements;

Repeat a) to g) on the pin end of the pipe immediately adjacent to the main body of the connector.

The connector is considered to have passed the test if

— the connector maintains pressure integrity at 150 % MAOP for 1 h (strength test),

— the combined dent depth and ovality does not exceed 10 % of diameter (piggability test),

— the stress concentration factors (K_{SCF}) around dents are not sufficient to reduce the fatigue life to below the design life (in order to assess fatigue life, the expected pressure variations in the pipeline during its operational life will be needed).

G.13 J-lay in deep water

The tensile stresses at the surface portion of the pipeline during J-lay installation may exceed 20 % of pipeline yield stress, depending on water depth. If the pipeline tensile stress exceeds 20 % of yield, the following additional test should be carried out on each connector just before step f) in 11.4.2.

Apply a tensile load equivalent to the maximum expected tensile stress for not less than 15 min, and record the magnitude of load applied.

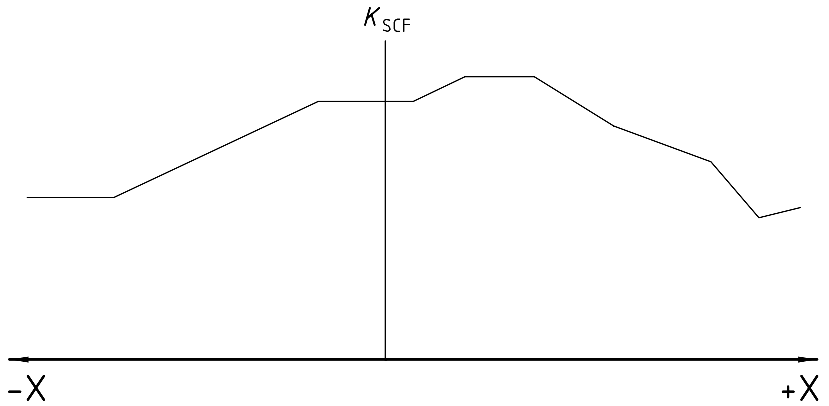
Annex H
(informative)

Additional information on fatigue

H.1 Finite-element analysis

H.1.1 Background

In order to determine the fatigue life of a connector, it is necessary to locate and quantify the biggest change in principal stresses (i.e. the stress range) due to a bending cycle. With a linear elastic structure, this could be done by applying a unit bending moment and looking for the largest principal stress. However, connectors often exhibit a more complicated behaviour, where the load is redistributed as contacting surfaces in the seals and the threads load and unload within the connector. As a result, the stress range at any given point may vary non-linearly with applied axial force (including bending moments). This behaviour is illustrated in Figure H.1 below.



Key

+X axial tension

–X axial compression

Figure H.1 — Schematic of variation of K_{SCF} with axial load

H.1.2 Approach

In order to conduct a fatigue test, it is necessary to find the worst combination of mean axial load and cyclic bending moment. To do so, the manufacturer may use finite-element modelling to determine the stress state at various axial loads and bending moments. The following approach may be used.

— An axisymmetric approach to the finite-element modelling should be used. However, bending loads should be applied using an equivalent axial force, even though this is not physically representative. The equivalent axial force gives an axial stress equal to the peak bending stress. Further points on the modelling are given in H.1.3.

— The connector should be modelled for a number (e.g. 10) of load cases where a constant axial load is applied. The axial load cases should be set in a range from the most compressive mean axial load plus most compressive bending load, through to the most tensile mean axial load plus most tensile bending load.

— For each of the axial load cases, the finite-element analysis outputs the stress state in each element.

— By comparing sets of results for adjacent load cases, the change in principal stress for each element should be found, and hence the location and magnitude of the stress range. (One approach is to compare the largest principal stresses in each element, however, this may miss the true peak range if those stresses have changed in direction. A more precise alternative is to compare the direct stress in a complete range of directions within each element.)

— From the change in principal stress, the stress concentration factor, K_{SCF}, should be found from Equation (18).

— Plotting K_{SCF} versus axial load gives a graph as shown in Figure H.1. This curve shows the peak K_{SCF} values for a given axial load, and may combine results from a number of different elements within the connector.

H.1.3 Finite-element modelling

Particular points on the finite-element modelling are as follows.

— The finite-element model should be dimensioned to take into account the most onerous set (with regard to fatigue performance) of manufacturing tolerances.

— The finite element mesh should be refined at the fatigue-sensitive locations until the stress results are insensitive to further refinements.

— The loading sequence should simulate the make-up of the connector as well as the application of axial, bending and pressure loads.

— Because fatigue is a function of change in stress, linear elastic properties may be used in order to determine stress ranges, accepting that local areas may exceed yield. Alternatively, if elasto-plastic properties are used, the model should be cycled until it reaches a stable condition in which no further plastic yielding is taking place, prior to finding fatigue stress ranges.

H.2 Selection of fatigue test loads

This subclause addresses how to determine the mean axial load and the cyclic bending stress from the plot of peak K_{SCF} versus axial load as detailed in H.1 above. The stress ranges are found as follows.

— Find the peak K_{SCF} for the connector, and the corresponding axial load.

— Select an S-N curve for the parent plate, forming the mean less two standard deviation prediction of the number of cycles to failure N for a given stress range S. The recommended curve is DNV RP-C202 curve B1[8]. The curve is factored depending on whether the fatigue location within the connector could be in air, subject to seawater with cathodic protection, or subject to water/sour conditions without cathodic protection.

— Predict the S-N curve for the connector as the parent material curve with the stress range factored by the K_{SCF}:

$$N = \overline{a} \cdot \left(S \cdot K_{SCF} \right)^{m} \quad \text{(H.1)}$$

where

$\overline{a}$, m are parameters defining the parent plate S-N curve;

S is the stress range.

— Find the stress ranges to give predicted fatigue lives of 1×10^5 cycles, 2×10^5 cycles, and 4×10^5 cycles. Alternative values may be selected so long as there is a similar spread of stress range so that the gradient of the S-N curve can be found.

— For normal confidence level, run two samples at each stress level. For high confidence, run three samples at each stress level. Riser connectors should be run at a high confidence level.

— Ensure that the stress ranges cover those seen in practice, since the results may not be extrapolated. For practical reasons, the stress range should not be so small that the connector test runs for more than 10^7 cycles. This may be assessed using the parent mean S-N curve plus two standard deviations, factored by the K_{SCF}.

NOTE Equation (H.1) is dependent on the units for S.

H.3 Alternative fatigue load selection approach

H.3.1 General

The following two methods are also employed in the connector evaluation when it is to be used for a specific duty, such that the fatigue loading is known.

H.3.2 Fatigue loads for a specific duty using three ranges

For a project-specific duty where the fatigue-loading regime for an application is known, the long-term fluctuating distribution stress range for the connector may be simulated by three overlapping test stress ranges, as shown in Figure H.2. The stress ranges should cover the minimum, midpoint and maximum values of the long-term range. These test stress ranges should overlap sufficiently to encompass any non-linear effects of the connector. The test stress ranges should be suitably broad to give a practical number of cycles to failure.

H.3.3 Fatigue loads for a specific duty using block testing

As an alternative to H.3.2 above, block testing may be carried out using three stress ranges, high, medium and low, all of which are cycled around the mean stress as supplied by the manufacturer. The stress ranges and number of cycles for each stress range should reflect the envisaged in-service fatigue-loading regime, e.g. 1 000, 500 and 20 cycles for the low, medium and high stress ranges, respectively. The connector should then be cycled through all three stress ranges until failure.

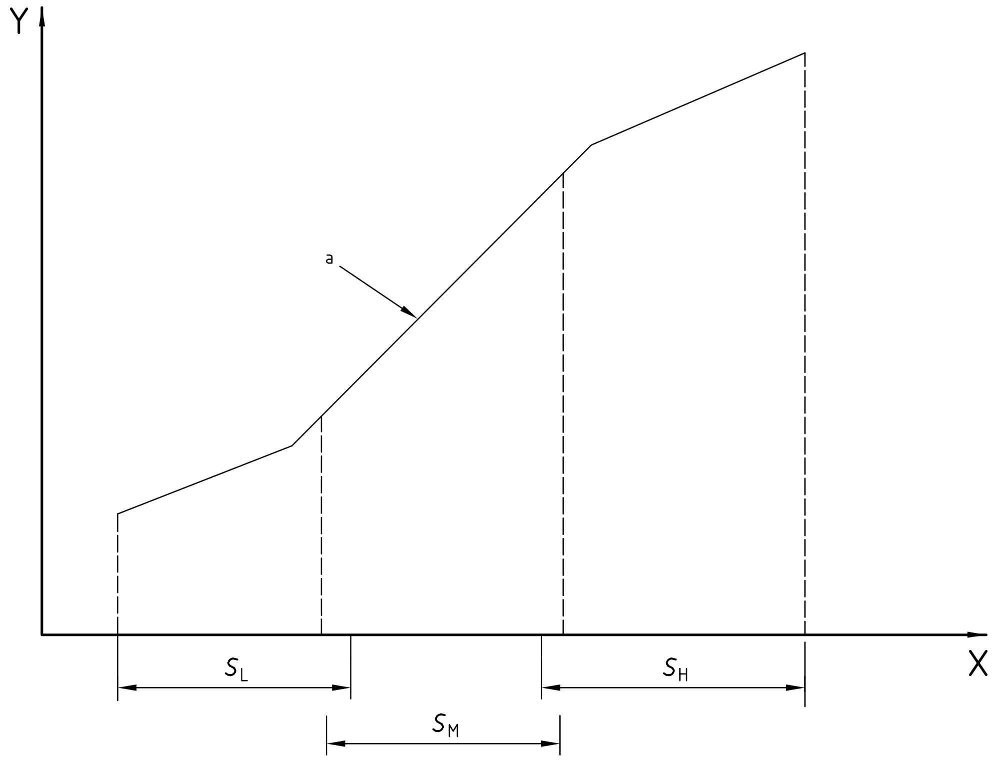
Miner's rule should be applied to the number of cycles of each test stress range to find the accumulated number of cycles for the connector.

H.4 Reduced-fatigue testing

If testing is required to confirm that the maximum stress in the connectors is below the fatigue limit of the material, three test specimens should be tested at the designated stress amplitude.

H.5 Axial loads

Axial fatigue tests should be undertaken on connectors that are subject to axial fatigue loads.



Key

S_L is the low end of the stress range

S_M is the middle of the stress range

S_H is the top end of the stress range

[a] Due to movement and changing surface contact within the connector, there may be a non-linear relationship between stress and bending load.

Figure H.2 — Test stress ranges

Connectors may be tested under cyclic bending with a defined correction factor for cyclic bending versus cyclic tension.

NOTE Top-tensioned risers can suffer from tension fatigue.

H.6 Effect of mean loads

Some applications, such as suspended risers, are subject to mean static loading (tension, bending, torsion, pressure, and their combinations). The mean static loading can affect the fatigue performance. FEA can be used to extrapolate from the fatigue test results to predict fatigue life with mean static loading.

H.7 Statistical interpretation of fatigue test results

This subclause explains how to assess the fatigue test results to give a design S-N curve for the connector. The method comprises

- plotting the failure points on a graph of applied stress range S versus $\log_{10}N$,
- using linear regression, finding a straight-line least-squares fit to the data and the standard deviation,
- finding the straight line representing the mean less two standard deviations. This is the design curve for the connector;
- comparing it with predictions.

NOTE This may alternatively be expressed in terms of the B1 curve[8] and a K_{SCF}. This is done by finding the best-fit line with the same gradient as the B1 curve, dropping two standard deviations from there, and finding the K_{SCF} which would marry the two curves if applied to the B1 curve.

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