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Qualification of casing connections for thermal wells

Qualification des raccordements de boîtiers pour les puits thermométriques

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This first edition of ISO/TS 12835 cancels and replaces ISO/PAS 12835:2013, which has been technically revised.

The main changes are as follows:

— all optional tasks moved to Annex D;

— added option to perform thermal cycle test with cooling to intermediate temperatures;

— changed specification for to-failure portions of bend test and limit-strain test, allowing them to be performed with water only.

A list of all parts in the ISO 12835 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document, also known to industry users as Thermal Well Casing Connection Evaluation Protocol (TWCCEP), is intended to facilitate assessment and qualification of threaded casing connections for service in intermediate or production casing strings in thermal recovery wells and in other wells experiencing significant temperature excursions such as in geothermal applications.

The extensive effort involved in replicating thermal well field conditions in a laboratory environment limits the extent of physical testing that can reasonably be undertaken in an evaluation program. The evaluation procedure adopted in this document balances technical rigor and practicality to provide a baseline level of confidence in the candidate connection's performance. Connection users should consider the scope of this evaluation and appropriate additions to address operation-specific conditions. Successful field use of a connection meeting the requirements of this protocol does not preclude an operator's need to employ appropriate product quality assurance measures and field operating practices.

Only outcomes of the performed full-scale tests are compared with assessment criteria to determine suitability of the candidate connection for the intended field service. While this document aims to enable a statistically significant full-scale test, it does not demand a rigorous check of a true statistical placement of the tested sample responses relative to field connection performance, and thus inherently assumes that the test specimens are representative of subsequent field connections. For this reason, only connections with the same design parameters as the candidate connection should be considered representative of the connection assessed under this protocol.

This document is the culmination of a thorough review of factors contributing to performance of casing connections in thermal well applications. The evaluation procedure adopted in this document has been developed using input from operators' descriptions of field practices, manufacturers' feedback on connection design and production, available literature, knowledge of past connection qualification programs, and additional analytical and experimental work performed in support of the protocol development.

Qualification of casing connections for thermal wells

1 Scope

This document provides procedures for assessment of casing connections for those field applications in which the operating temperatures cyclically vary between minimum values appreciably below 180 °C and maximum values that range from 180 °C to 350 °C or above, and in which the primary axial loading on the casing-connection system is strain-based and driven by constrained thermal expansion and leads to a stress state that exceeds the casing-connection system's yield envelope.

NOTE This document can be considered complementary to ISO 13679 (and its core content per API Specification 5C5), which applies to classic elastic-design applications.

This document contains an evaluation procedure for a candidate connection comprising of uniquely defined pin, box and interfacial components. The evaluation procedure includes:

— Material property tests to assess relevant properties of the candidate connection pin and box components;

— Analytical tasks to determine configuration of connection samples for physical tests, which are chosen based on worst-case combinations of the connection geometry and material properties;

— Full-scale testing tasks to measure the candidate connection galling resistance, structural integrity and sealability under loading representative of connection assembly and thermal well service.

This document does not address impacts of external pressure, incomplete lateral pipe support, rotational fatigue, formation-induced shear, or environmentally-induced corrosion or cracking.

Clause 6 describes fundamental assumptions adopted in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

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

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E21, *Standard Test Methods for Elevated-Temperature Tension Tests of Metallic Materials*

ASTM E831-06, *Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis*

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

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
ambient temperature
ambient temperature in the facility where a physical testing task is executed

3.2
application severity level
connection loading specifications assumed to be representative for a range of operational conditions, which determine the scope of analysis and testing required by the *evaluation procedure* (3.13) for those operational conditions

3.3
assigner
party that commissions an *evaluation program* (3.14), controls its execution, and owns the rights to that evaluation program's data and results

3.4
average string strain
average axial strain along the *controlled elongation interval* (3.11) of a *specimen string* (3.36)

3.5
bend test specimens
subset of *candidate connection specimens* (3.8) subjected to the optional *bending evaluation* (3.6) per the *evaluation procedure* (3.13)

3.6
bending evaluation
analysis and physical testing conducted to determine sensitivity of a *candidate connection* (3.7) to casing curvature

3.7
candidate connection
casing connection product that is being evaluated, and is uniquely defined by its design features and production specifications with respect to size, weight, and component materials including pin, box, and interfacial components

3.8
candidate connection specimens
set of connection specimens that is representative of design and features of the *candidate connection* (3.7), and is provided for an *evaluation program* (3.14) of that candidate connection

3.9
casing pup
short piece of casing pipe cut from a mother joint

3.10
connection
single design-specific assembly of pin and box and interfacial component(s)

3.11
controlled elongation interval
portion of a *specimen string* (3.36), along which the elongation is measured and controlled

3.12
effective string length
portion of the total length of a *specimen string* (3.36) that is assumed to deform appreciably under mechanical forces in the *thermal cycle test* (3.42)

3.13
evaluation procedure
set of analytical and testing tasks performed to assess performance of the *candidate connection specimens* (3.8)

3.14
evaluation program
evaluation of a *candidate connection* (3.7) by means of the *evaluation procedure* (3.13)

3.15
evaluation report
collectively, all documents prepared by an *evaluator* (3.16), according to applicable reporting requirements, that describe execution history and results of an *evaluation program* (3.14)

3.16
evaluator
party that performs analytical and testing tasks required by an *evaluation procedure* (3.13)

3.17
excluded connection
connection (3.10) that has been evaluated in a full-scale test but whose performance has been excluded from comparison with *threshold performance requirements* (3.44)

3.18
galling
cold welding of contacting material surfaces followed by tearing of metal during subsequent sliding

3.19
high cycle temperature
highest temperature targeted in the *thermal cycle test* (3.42)

3.20
inspection report
collectively, all documents prepared by an *inspector* (3.21) that describe conformance of the executed *evaluation program* (3.14) with applicable specifications

3.21
inspector
party that verifies conformance of the executed *evaluation program* (3.14) with applicable specifications

3.22
integral specimen
single connection consisting of one *casing pup* (3.9) with a box end and one casing pup with a pin end

3.23
interfacial component
design-specific component of a *connection* (3.10) applied to the pin and box either during their manufacturing (e.g. coating) or during the connection assembly (e.g. thread compound)

3.24
limit-strain specimens
subset of *candidate connection specimens* (3.8) subjected to the *limit-strain test* (3.25) per the *evaluation procedure* (3.13)

3.25
limit-strain test
tension test, to structural failure, of the *limit-strain specimens* (3.24)

3.26
low cycle temperature
lowest temperature targeted in the *thermal cycle test* (3.42)

3.27
lower-bound temperature
lowest temperature expected in thermal cycles in field applications

3.28
make-break specimens
subset of *candidate connection specimens* (3.8) subjected to multiple make-ups and break-outs per the *evaluation procedure* (3.13)

3.29
make-up support pin
pin component of *candidate connection* (3.7) with seal removed, used to support a coupling's open end during make-up and break-out of that coupling's opposite end

3.30
material coupon
cylindrical section of pipe from which *material strip specimens* (3.31) are cut

3.31
material strip specimen
longitudinal steel strip cut from a *material coupon* (3.30) and machined for use in mechanical property characterization tests

3.32
prior evaluation data
set of data acquired in a connection performance assessment carried out by analysis and/or physical tests prior to issuance of this protocol and/or according to a procedure/protocol different than the *evaluation procedure* (3.13)

3.33
program roles
collective reference to the roles of *assigner* (3.3), *supplier* (3.38), *evaluator* (3.16) and *inspector* (3.21)

3.34
repairable galling
galling (3.18) that can be repaired according to a *supplier's* (3.38) field-repair procedure for a *candidate connection* (3.7)

3.35
severe galling
galling (3.18) that cannot be repaired according to a *supplier's* (3.38) field-repair procedure for a *candidate connection* (3.7)

3.36
specimen string
collective reference to a single connection specimen and/or an in-series assembly of two or more connection specimens in a *thermal cycle test* (3.42)

3.37
substantially qualified party
person/company possessing technical skills and experience necessary to perform a task, as designated by the *assigner* (3.3) and the *supplier* (3.38)

3.38
supplier
party that manufactures *candidate connection* (3.7)

3.39
tensile strain threshold
tensile strain value that a connection specimen is expected to survive during a *limit-strain test* (3.25)

3.40
test specimen
connection specimen that is provided for a full-scale test

3.41
thermal cycle specimens
subset of *candidate connection specimens* (3.8) subjected to the *thermal cycle test* (3.42) per the *evaluation procedure* (3.13)

3.42
thermal cycle test
thermo-mechanical test of connection specimens, in which several thermal cycles are applied between the *low cycle temperature* (3.26) and the *high cycle temperature* (3.19)

3.43
threaded-and-coupled specimen
two connections consisting of a single coupling and two *casing pups* (3.9) with pin ends joined by that coupling

3.44
threshold performance requirements
set of connection performance criteria for a *candidate connection* (3.7) considered as having met applicable minimum performance requirements

3.45
upper-bound temperature
highest temperature expected in thermal cycles in field applications

4 Abbreviated terms and symbols

4.1 Abbreviated terms

ASL	application severity level
BF	fast box taper
BS	slow box taper
CSS	cyclic steam stimulation
CTE	coefficient of thermal expansion
FEA	finite element analysis
IC	integral connection
max.	maximum
min.	minimum
PF	fast pin taper
PS	slow pin taper
SAGD	steam assisted gravity drainage
TC	threaded-and-coupled connection
TWCCEP	thermal well casing connection evaluation protocol
TF(WGS)	final make-up torque for specimen with WGS configuration
TF(WGT)	final make-up torque for specimen with WGT configuration

TF(WSC-M)	final make-up torque for specimen with WSC configuration and multiple make-ups
TF(WSC-S)	final make-up torque for specimen with WSC configuration and single make-up
TF(WST-M)	final make-up torque for specimen with WST configuration and multiple make-ups
TF(WST-S)	final make-up torque for specimen with WST configuration and single make- up
WGS	worst-case tolerance combination for galling in seal
WGT	worst-case tolerance combination for galling in threads
WSC	worst-case tolerance combination for sealability in compression at high temperature
WST	worst-case tolerance combination for sealability in tension at low temperature

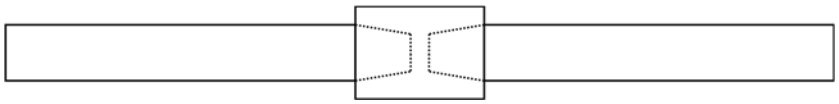
4.2 Symbols

D	casing outside diameter
L_{CEI}	length of controlled elongation interval
L_{eff}	effective string length
L_p	unsupported pup length (pup length excluding make-up loss, i.e. pin-box overlaps at each end)
L_{TTS}	lower-bound temperature strain increment
$p_{SS}(T)$	saturated steam pressure at temperature T
S_{LCF}	strain-length compensating factor
S_{RI}	temperature range strain increment
t	casing wall thickness
T	temperature
T_{amb}	ambient temperature
T_{hc}	high cycle temperature
T_{lb}	lower-bound temperature for a given application severity level
T_{lc}	low cycle temperature
T_{ub}	upper-bound temperature for a given application severity level
α_a	average coefficient of thermal expansion
$\Delta\varepsilon_{LL}$	strain increment for application in the limit-strain test
$\Delta\rho$	curvature increment
ε_{TEa}	average residual post-cycle strain
ρ_{MAX}	maximum test curvature

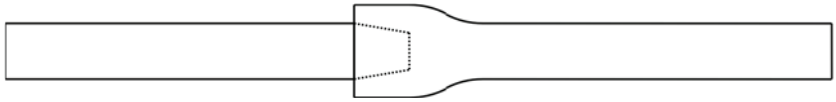
5 Program overview

5.1 Illustrations of selected definitions

Figure 1 illustrates two types of connection specimens that may be submitted for an evaluation program. Figure 1a shows a threaded-and-coupled (TC) specimen and Figure 1b shows an integral connection (IC) specimen. A TC specimen contains two connections (two "sides" of the coupling) creating two possible leak paths. An IC specimen contains one connection, resulting in a single possible leak path.



a) Threaded-and-coupled specimen

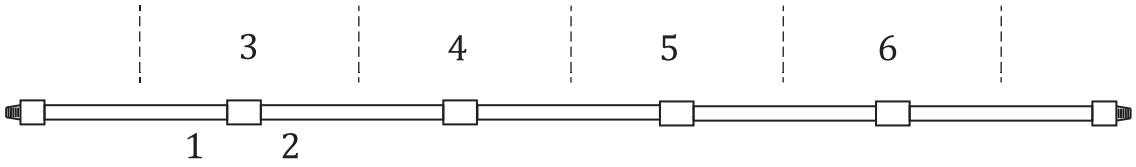


b) Integral connection specimen

Figure 1 — Illustration of connection specimens

When full-scale testing is conducted on strings containing multiple connection specimens assembled in series, some casing pups are shared by two adjacent specimens (which can be either TC or IC). Each such shared casing pup is considered to consist of two halves, with each half belonging to the specimen that includes the corresponding pin end or integral box end.

Figure 2 illustrates an example of a string assembly with four connection specimens. For consistency with requirements for the thermal cycle test, in which a four-specimen string assembly may be used, the example in Figure 2 shows Specimens 3, 4, 5, and 6 (refer to 10.1 for specimen numbers). For TC specimens, the two specimen leak paths can be distinguished by the specimen number and letters "A" and "B" referring to each coupling side.



Key

1 side A leak path 3A
2 side B leak path 3B
3 Specimen 3
4 Specimen 4
5 Specimen 5
6 Specimen 6

Figure 2 — Illustration of connection string assembly

5.2 Program flowchart

Figure 3 illustrates five main components (blocks) of an evaluation program. A detailed description of the program blocks and tasks is provided in Clause 10.