PUBLICLY AVAILABLE SPECIFICATION

ISO/PAS 24565

First edition
2022-01

Petroleum and natural gas industries — Ceramic lined tubing

Industries du pétrole et du gaz naturel — Tubes de production avec revêtement céramique

Reference number
ISO/PAS 24565:2022(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

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

Users of this document should be aware that further or differing requirements can be needed for individual applications. This document is not intended to inhibit a manufacturer from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the manufacturer to identify and provide details of any variations from this document.

In this document, the following verbal forms are used:

— “shall” indicates a requirement;

— “should” indicates a recommendation;

— “can” indicates a possibility or a capability;

— “may” indicates a permission.

Petroleum and natural gas industries — Ceramic lined tubing

1 Scope

This document specifies requirements for ceramic lined tubing (CLT) used in the petroleum and natural gas industries, including configuration and materials, manufacturing, inspection and testing, marking, packaging, transportation, and storage.

This document is applicable to CLT manufactured by centrifugal self-propagating high-temperature synthesis.

The applicable outside diameter of CLT ranges from 42,16 mm (1,66 inch) to 114,3 mm (4-1/2 inch). The steel grades include H40, J55, and N80 type 1.

NOTE Applicability of this document to other sizes and higher steel grades can be by agreement between the manufacturer and the purchaser.

CLT is suitable for extracting multiphase fluid, hydrocarbon gas, hydrocarbon liquid, and water under corrosive, abrasive, wax deposition, scaling, and high temperature environments.

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.

ISO 2819, *Metallic coatings on metallic substrates — Electrodeposited and chemically deposited coatings — Review of methods available for testing adhesion*

ISO 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 10405, *Petroleum and natural gas industries — Care and use of casing and tubing*

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

ISO 14705, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for hardness of monolithic ceramics at room temperature*

ISO 15156-2, *Petroleum and natural gas industries — Materials for use in H2S-containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons*

ISO 21714, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining density of ceramic coatings*

ISO 23936-1, *Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production — Part 1: Thermoplastics*

API Spec 5B, *Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads*

ASTM A700, *Standard Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment*

ASTM D5420, *Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)*

ASTM G31, *Standard Guide for Laboratory Immersion Corrosion Testing of Metals*

3 Terms, definitions, symbols and abbreviated terms

3.1 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/

3.1.1
backing pipe
tubing before being lined with ceramic liner

3.1.2
bonding strength
shear strength required to shear the ceramic liner along the axial direction of the backing pipe

3.1.3
centrifugal self-propagating high-temperature synthesis
centrifugal SHS
self-propagating high-temperature synthesis under the centrifugal force generated by high-speed rotation, which is helpful to promote reaction and phase separation of molten products

Note 1 to entry: The centrifugal self-propagating high-temperature synthesis technology comprises the following steps. Fill Fe_2O_3 (or Fe_3O_4) powder and aluminium powder with a given proportion into a steel tubing. Fix the tubing with the powder on a centrifuge and rotate it with a high speed. Then, start the reaction when the rotating speed reaches a given value. The reaction can be maintained due to a large amount of reaction heat released by the exothermic reaction. Under the action of centrifugal force, molten products are separated into layers from each other due to the difference in their specific gravity, and after cooling, ceramic lined tubing is formed.

3.1.4
ceramic liner
ceramic layer formed on the inner wall of the backing pipe by centrifugal self-propagating high-temperature synthesis method

Note 1 to entry: It is attached to the inner wall of the backing pipe and has the functions of corrosion prevention, scale prevention, and wear resistance.

3.1.5
ceramic lined tubing
CLT
tubing with a ceramic liner stuck on to its inner wall made by centrifugal self-propagating high-temperature synthesis

3.1.6
corrosion barrier ring
CB ring
polymeric ring inserted between adjacent lengths of liner in a tubing string to provide continuity of corrosion protection

3.1.7
crushing strength
fracture strength of the ceramic liner when applying radial compression load on ceramic lined tubing

3.1.8
end cap
metal component used to seal the cut end of ceramic liner

3.1.9
flare of the end cap
edge formed by turning the outer edge of the end cap along the cross-section of the backing pipe

3.1.10
Label 1
dimensionless designation for the size or specified outside diameter that can be used when ordering the pipe

Note 1 to entry: See Table B.1.

3.1.11
Label 2
dimensionless designation for the mass per unit length that can be used when ordering the pipe

Note 1 to entry: See Table B.1.

3.1.12
self-propagating high-temperature synthesis
SHS
technique for synthesizing materials by using the heat released by the exothermic reaction to make the reaction proceed spontaneously

3.1.13
thermite
mixture of aluminium powder, metal oxides (such as Fe_2O_3 or Fe_3O_4) and related additives that generate a large amount of heat when ignited

3.2 Symbols and abbreviated terms

3.2.1 Symbols

d	inside diameter of ceramic lined tubing
t	wall thickness of backing pipe

3.2.2 Abbreviated terms

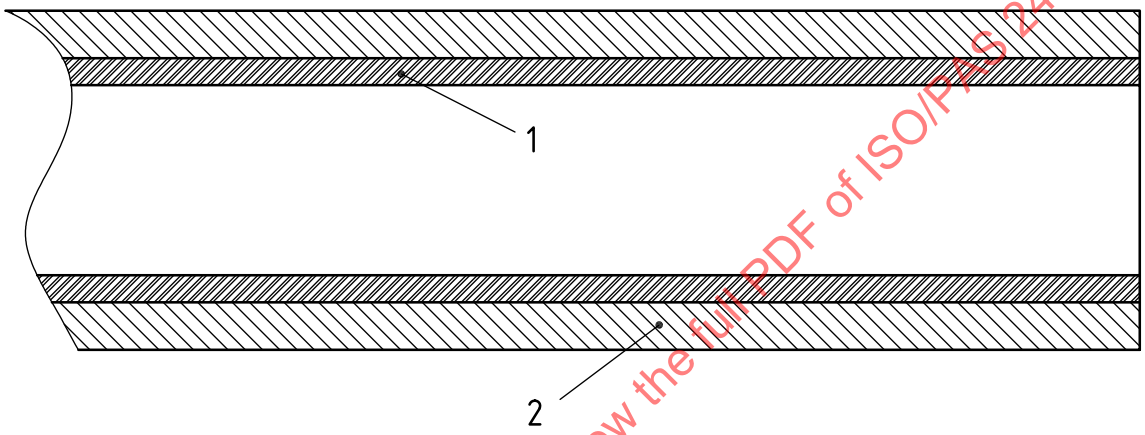
AQL	acceptance quality limit
CAL	connection assessment level
CB	corrosion barrier
CLT	ceramic lined tubing
EU	API Spec 5B external upset tubing connection
HIC	hydrogen induced cracking
NU	API Spec 5B non-upset tubing connection

OD	outside diameter of CLT
PTFE	polytetrafluoroethylene
SCC	stress corrosion cracking
SSC	sulfide stress cracking

4 CLT configuration and materials

4.1 Configuration

CLT consists of backing pipe and ceramic liner. The typical configuration of CLT is shown in Figure 1 and Figure 2.

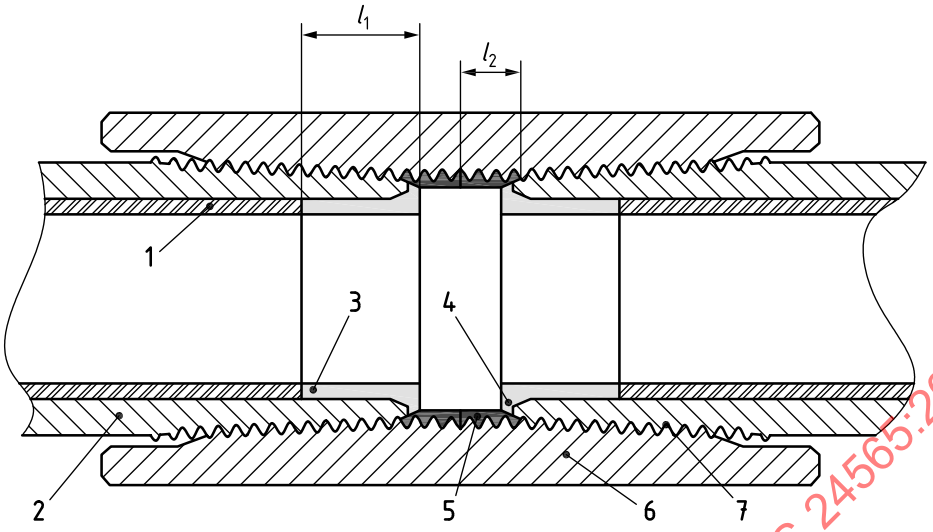


Key

1 ceramic liner

2 backing pipe

Figure 1 — Configuration of CLT body



Key

1 ceramic liner
2 backing pipe
3 end cap
4 flare of the end cap
5 CB ring
6 coupling
7 threads
l_1 end cap length
l_2 CB ring length

Figure 2 — Example of configuration of CLT coupling based on API Spec 5B (round) thread

4.2 Pipe ends

Unless otherwise specified by the purchaser, CLT shall be supplied with API Spec 5B threads at both ends and with corresponding couplings. If agreed by the manufacturer and the purchaser, CLT may be supplied without couplings, and/or with plain ends, and/or with connections specified by the purchaser.

4.3 Connection type

Lengths of CLT are connected with each other with coupling, as shown in Figure 2. In this example involving the API 5B connections, the continuity between ceramic liners is ensured by using an end cap or flare as well as a polymeric CB ring. This assembly aims at protecting the coupling or pin extremities from any contact with the production fluid that could induce corrosion. Other forms of coupling protection devices are acceptable. Polymeric CB rings are usually provided on the inner wall of coupling to ensure the integrity of anti-corrosion between adjacent tubing lengths. The amount of compression applied to the CB ring is controlled by the distance between the pin ends during make-up.

The pipe ends can be protected from corrosion by an end cap or flare, which will extend over the whole pipe end (i.e. over the whole pipe wall thickness) so to allow matching the selected connection. The flare of the end cap is tightly attached to the CB ring on the coupling, thus ensuring the integrity of the whole connecting structure.

Other types of connection, such as premium connection, may also be used. In such a case, the coupling protection shall be adjusted to the proprietary design.

4.4 Material requirements

4.4.1 Backing pipe

When using new tubing as the backing pipe, its dimensions and properties shall conform to the requirements of ISO 11960. When used in a sour environment, the backing pipe shall conform to the requirements of resistance to sulfide stress cracking as specified in ISO 15156-2.

Previously-used tubing may also be used as the backing pipe. Typical well or conditions where these products can be used are general water injection, layered water injection and oil extraction. The minimum wall thickness of the used tubing shall be greater than 2,8 mm, unless otherwise agreed. The technical requirements for material, performance, and testing of the used tubing should be determined based on experiences of the purchaser and manufacturer and the requirements of working conditions. At least, mechanical properties during tension and impact and the hardness of the used tubing shall conform to the requirements of ISO 11960. Tubing previously used in a sour environment is not recommended for use as a backing pipe.

4.4.2 Thermite

Inert gas atomized aluminium powder with an active aluminium content of not less than 98 wt.% should be used as the thermite. The particle size of aluminium powder should be not less than 200 mesh (75 µm).

Industrial grade Fe_2O_3 (or Fe_3O_4) powder should be used with the particle size of not less than 200 mesh (75 µm).

4.4.3 End cap and CB ring

The end cap shall be compatible with the fluid to be transported. It is usually made of stainless steel and is bonded to the ceramic liner with a suitable adhesive. Other types of end cap materials shall meet the requirements of relevant standards.

CB rings are typically made from polymer materials that meet the requirements of corrosion, temperature, and wear resistance for the bore fluids, usually, elastomers or fiber-filled PTFE.

The length of the end cap l_1 shall conform to the requirements in Table 1. The length of the CB ring l_2 shall be designed according to connection type.

Table 1 — Length range of end cap

Label 1	End cap length, l_1 mm
≤2-7/8	20 to 25
>2-7/8	25 to 30

5 Manufacturing

5.1 Treatment of backing pipe

5.1.1 Distinguishing of the used tubing

Manufacturers and/or used tubing suppliers should establish procedures or basis for identifying and distinguishing the steel grade of used tubing. Element analysis, metallographic structure analysis and mechanical properties test are available procedures and/or references. The standard colour code for the steel grade should be then painted onto the used tubing.

5.1.2 Blast-cleaning

The organic residue on the inner wall of the new tubing shall be removed. Physical, chemical, or mechanical methods should be used to remove oil, wax, sand, scale, rust, and other organic residues and impurities in the used tubing before blast-cleaning.

All the backing pipes shall be blast-cleaned before making the ceramic liner. The blast-cleaning grade for the treated inner surface of the steel tubing shall be Sa 2-1/2 – 3 as specified in ISO 8501-1, and the total roughness shall be 25 µm to 76 µm. The inner surface shall be free of visible pipe defects such as cracks, pits, and burrs. The blast-cleaning grade for treated outer surface shall be Sa 1–2 as specified in ISO 8501-1. The outer surface shall be free from pollutants such as visible oil, grease, mill scale, paint coatings, etc.

5.1.3 Straightening of the used tubing

If the straightness of the used tubing does not conform to ISO 11960, it shall be straightened as specified in 6.4.3. The straightness of the used tubing after straightening shall be as per ISO 11960.

5.2 Manufacture of CLT

5.2.1 Thermite mixing

The thermite shall not agglomerate and the mixing time of thermite shall not be less than 1 h.

5.2.2 Filling

Fill the thermite into the backing pipe and keep the thermite evenly distributed in the backing pipe. The backing pipe filled with thermite shall be kept horizontal and the maximum inclination of the pipe shall not exceed 5°.

5.2.3 Lining

Adjust the centre of the backing pipe before the centrifuge starts. Ignite the thermite after the centrifuge reaches the rotating rate specified by the manufacturer and rotates smoothly. After completing the reaction, decelerate the centrifuge smoothly until it stops. The CLT can be taken out after cooling.

5.2.4 Heat treatment

No heat treatment is required for H40, J55, and N80 type 1 non-upset and upset tubing after lining ceramic.

For higher grade materials, heat treatment of the full CLT should be required and negotiated between the manufacture and the purchaser.

5.2.5 Installation of the end cap

The end cap is an interference fit with the inner surface of the CLT end. First, machine the inner surface of the CLT end based on the length and wall thickness of the end cap, and ensure that the cross section of the ceramic liner is smooth. Apply the adhesive evenly on the outer surface of the end cap, then insert the end cap into the CLT. After curing, the adhesive shall seal the interface between the end cap and the backing pipe and the gap between cross sections of the ceramic liner and the end cap to avoid galvanic corrosion and crevice corrosion. The flare of the end cap can be welded to the backing pipe to increase the reliability of the connection.

5.2.6 Threading

Machining the threads on pipe ends to the dimensions and tolerances specified in API Spec 5B or specified in the selected connection specifications.

5.3 Manufacture of CB Ring

The molding conditions for the elastomer or PTFE billets used for CB ring manufacture shall be documented. The CB rings shall be molded and/or machined to the exact dimensions required for the specific type of steel connection used.

5.4 Installation of CB Rings

There are two CB rings in the example of CLT coupling as shown in Figure 2. The outer surface of every CB ring has the same thread with the coupling. Apply the adhesive evenly on the thread and cross-section of the CB ring, then screw the CB ring into the coupling. Then, install another CB ring as described above. The gap between cross-sections of the CB rings will be fully filled with the cured adhesive. After that, machine the other cross-section of the CB ring to the exact dimensions to match the end cap.

5.5 Traceability

The manufacturer shall establish and follow procedures for maintaining and/or identifying the lot number of the backing pipe upon applying the ceramic liner. The lot number shall be marked on products as specified in 8.1.

The manufacturer shall also establish and follow procedures for identifying the lot number of CLT and mark the products as required.

5.6 Purchaser inspection

When an inspector representing the purchaser desires to inspect pipe or witness quality control tests, the inspector shall be given reasonable notice of the start of the production as well as the time at which the product will be available for witness or inspection. The inspector shall have ready access to all parts relevant to the manufacturing of the CLT of the manufacturer's facility during the fabrication cycle. The manufacturer shall afford all reasonable and safe facilities to meet the inspector's requirement of the product manufactured in accordance with this document. All inspections shall be made at the place of manufacture before shipment unless otherwise specified on the purchase agreement and shall be conducted so as not to interfere unnecessarily with the operation of the facility. The purchase agreement should require written acceptance from the purchaser's inspectors for each lot before shipment.

6 Inspection and testing

6.1 General

This clause specifies inspection and testing for backing pipe, ceramic liner and CLT based on their configuration and property requirements.

Inspection and testing in 6.3, 6.4.1, 6.4.3 and 6.4.7 are related to technological qualification, while others are dedicated to product qualification.

6.2 Inspection of backing pipe

The specific inspection items and methods for new tubing and used tubing should be determined through the agreement between the purchaser and the manufacturer.

Inspecting for the backing pipe should be performed in accordance with ISO 15463.

The wall thickness of the used tubing should be inspected by ultrasonic inspection in accordance with ISO 10893-12.

6.3 Inspection of ceramic liner

6.3.1 Surface

The ceramic liner shall be flat and smooth, free of lumps, flaking, cracks, accidental inclusions, pin-holes, and other visible defects that expose tubing metal. The surface quality inspection of the ceramic liner is given in Annex A.

6.3.2 Thickness

The thickness of the ceramic liner for sizes up to and including 114,3 mm (4-1/2 inch) shall conform to Table B.1, with the tolerances specified in Table 2. The thickness testing of the ceramic liner is given in Annex C.

Table 2 — Thickness tolerances of ceramic liner

Wall thickness of backing pipe, t mm	Thickness tolerances of ceramic liner mm
$t \leq 5{,}51$	±0,5
$5{,}51 < t \leq 10{,}54$	±0,7
$10{,}54 < t \leq 13{,}46$	±1,0
$13{,}46 < t$	±1,5

6.3.3 Hardness and density

Hardness and density of ceramic liner shall conform to Table 3. The sampling position shall be more than 100 mm away from the pin end of the CLT. The inner surface of the ceramic liner shall be polished to remove 0,2 mm when testing its hardness and density in accordance with ISO 14705 and ISO 21714, respectively.

Table 3 — Requirements for ceramic liner hardness and density

Hardness of ceramic liner $HV_{0,5}$	Density of ceramic liner g/cm^3
≥1 100	≥3,4

6.4 Inspection of CLT

6.4.1 Dimensions test

Dimensions and mass of CLT for sizes up to and including 114,3 mm (4-1/2 inch) are specified in Table B.1. The dimensions of other CLT can be agreed between the purchaser and the manufacturer. Diameter measurement, wall thickness measurement, and mass (weight) determination shall be implemented in accordance with ISO 11960.

6.4.2 Length measurement

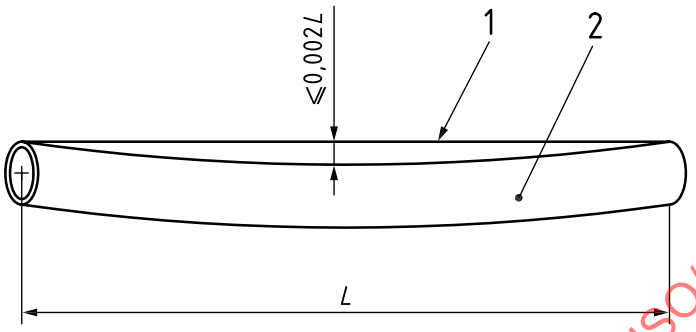
CLT shall be supplied in length conforming to the length requirements specified in ISO 11960. The length of accessories such as coupling stock and pup joints shall be as specified on the agreement. The length of each finished product shall be determined in accordance with ISO 11960. Length shall be measured in metres and accurate to centimetres.

6.4.3 Straightness evaluation

All CLT shall be visually examined. The straightness of questionably bent lengths or crooked extremities shall be evaluated in accordance with ISO 11960. Deviation from straight, or chord height, shall not exceed the following:

— 0,2 % of the total length of the CLT measured from one end to the other, for CLT Label 1: 4-1/2 and larger, as shown in Figure 3;

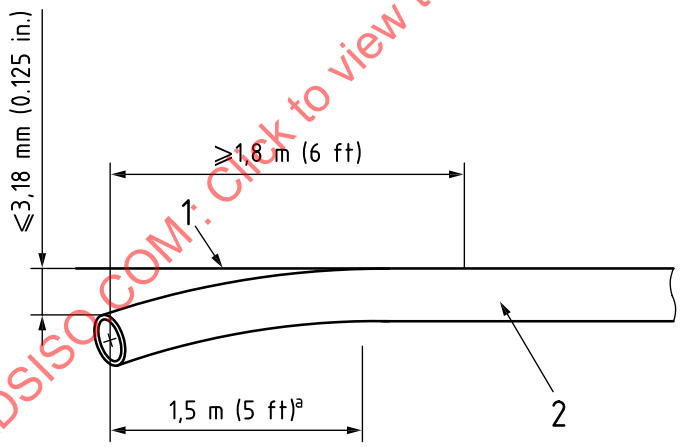
— 3,18 mm (1/8 in) maximum drop in the 1,5 m (5,0 ft) length at each end, as shown in Figure 4.



Key

1 taut string or wire
2 tubing

Figure 3 — Full-length straightness measurement



Key

1 straight line
2 tubing
a Hooked end.

Figure 4 — End straightness measurement

6.4.4 Thread and end cap inspection

The thread of CLT with API threads shall be inspected in accordance with API Spec 5B. Premium connections shall be inspected according to the purchase agreement.

The supplier shall ensure that there is no direct contact between the end cap and the liner. As required by 5.2.5, the gap between cross sections of the ceramic liner and the end cap will be fully filled with the cured adhesive. This area should be inspected by penetrant testing as specified in ISO 3452-1.

6.4.5 Drift test

Each length of CLT shall be drift-tested throughout its entire length. Drift dimensions (length and diameter) shall conform with Table 4 or be determined by agreement between the purchaser and the manufacturer.

Table 4 — Standard drift mandrel size

Label 1	Standard drift mandrel size min. mm	
	Length	Diameter
≤2-7/8	1 067	*d*-2,38
>2-7/8	1 067	*d*-3,18

6.4.6 Hydrostatic test

The pressure tolerance of CLT with the used tubing shall not be lower than that of the original new tubing. The test pressure of CLT shall be the hydrostatic test pressure of the original new tubing calculated in accordance with ISO 11960 and held for not less than 5 s. The hydrostatic test shall be carried out in accordance with ISO 11960 without leakage. The ceramic liner shall be free from cracks and flaking after the hydrostatic test.

Hydrostatic test for CLT with the new tubing as the backing pipe should be determined by agreement between the purchaser and the manufacturer.

6.4.7 Corrosion test

The corrosion resistance of CLT shall meet the requirements in Table 5. Corrosion resistance of CLT shall be tested and calculated by the static immersion method in accordance with ASTM G31. A specimen with a length of 130 mm ± 2 mm shall be taken at least 100 mm away from the pin end of CLT. Press a non-metallic end cap with an O-ring onto one end of the exposure specimen to form a cup assembly. Then, transfer the chemical solution in Table 5 into the exposure specimen to start the immersion test at ambient temperature for 30 days.

The tests should show no porosity in the coating and no formation during the manufacturing process. After the tests, it shall be confirmed that the liner material is not incompatible with the production fluid regarding the different corrosion mechanisms (for instance, HIC, SSC, SCC, intergranular corrosion, localized corrosion). This latter should be documented by agreement between the manufacturer and the purchaser. Typically, this could be done through a combination of static pressure tests at elevated temperature in fluids representative of corrosive downhole environments as well as hydrogen permeability measurements.

Table 5 — Corrosion resistance of CLT

Chemical solutions	Mass loss $g/m^2 \cdot h$
10 % HCl	≤0,1
10 % H_2SO_4	≤0,15

6.4.8 Tensile and impact test

Product-body tensile and impact test specimens shall be full-section specimens taken from CLT. Ceramic liner will fall off from the backing pipe when taking the specimens. The tensile and impact properties of specimens without ceramic liner shall be tested in accordance with ISO 11960.

6.4.9 Connection test

6.4.9.1 Connection qualification

The CLT connection qualification should be carried out in accordance with ISO 13679, whereby the connection manufacturer should advice on the connection properties as well as the CAL, including the loading envelop. The level of performance that would be achieved might not be limited by the connection itself but from failure of the ceramic liner or its protection mode (end caps or flare).

6.4.9.2 Evaluation of corrosion integrity

The manufacturer shall be responsible for the end cap and CB integrity of the coupling/connection, and shall be able to demonstrate this integrity for their particular designs of liner and connection geometry. The manufacturer shall demonstrate absence of corrosion due to galvanic coupling between dissimilar materials or crevice corrosion in confined areas. Typically, this should be through a combination of static pressure tests at elevated temperature and/or flow loop tests of lined and coupled samples in fluids representative of corrosive downhole environments.

6.5 Additional tests

6.5.1 General

The manufacturer shall ensure that the CLT has suitable integrity under the mechanical and thermal loads to be encountered during installation and use in any given service.

6.5.2 Impact test

The impact resistance of CLT shall be measured by a falling weight. The test procedure shall be in accordance with ASTM D5420. A specimen with a length of 200 mm ± 2 mm shall be taken at least 100 mm away from the pin end of CLT. A striker with ahead radius of 5 mm and a total mass of 10 kg is used. When visible cracks, fracture, and flaking of the ceramic liner under the natural light after impacting are observed, the impact energy shall be calculated.

6.5.3 Crushing strength test

The external pressure resistance of CLT shall be obtained through the crushing strength test. The crushing strength test should be carried out in accordance with ISO 2739. Three specimens with a length of 50 mm ± 1 mm shall be taken at least 100 mm away from the pin end of CLT. When hearing the breaking sound of the ceramic liner, stop the test and record the load to calculate the radial crushing strength in accordance with ISO 2739.

6.5.4 Bonding strength test

Three specimens with a length of 20 mm ± 1 mm shall be taken at least 100 mm away from the pin end of CLT.

The specimen shall be placed horizontally on the test platform as shown in Figure 5. The contact between the indenter and the ceramic liner shall be at least 1/2 of the thickness of the ceramic liner, but the indenter shall not contact the interface between the backing pipe and the ceramic liner. The load shall be applied gradually to the indenter at 10 mm/min. The maximum load when the ceramic liner

is separated from the backing pipe shall be measured to calculate the bonding strength according to Formula (1). Take the average value of the three specimens.

$$F = \frac{W}{3{,}14 \times D \times L} \tag{1}$$

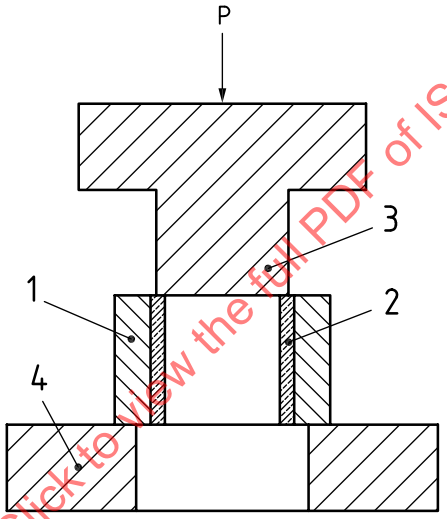
Where,

F is the bonding strength, in megapascals (MPa);

W is the maximum load when the ceramic liner is separated from the backing pipe, in newtons (N);

D is the average inside diameter of the backing pipe, in millimetres (mm);

L is the length of the specimen, in millimetres (mm).



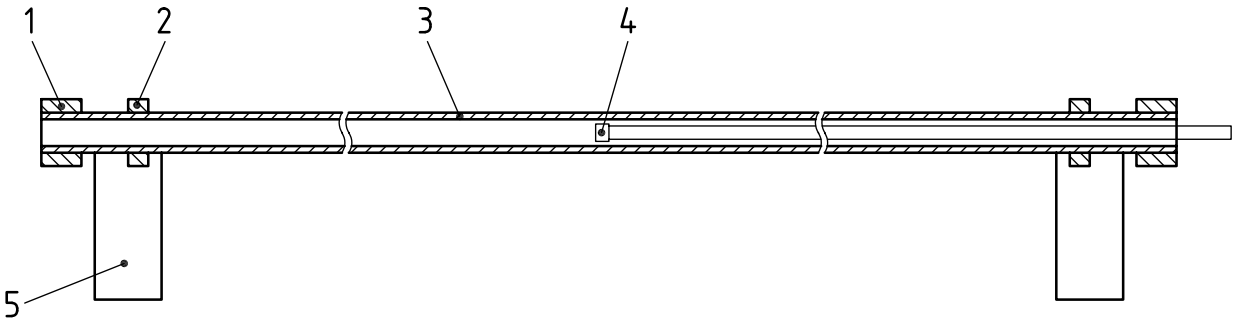
Key

1 backing pipe
2 ceramic liner
3 indenter
4 platform
P loading direction

Figure 5 — Bonding strength test

6.5.5 Bending test

The bending test of CLT should be set up as illustrated in Figure 6. Both ends of the full-length CLT specified in Table 4 are inserted into the sleeves that are installed on the fixed pier. The endoscope probe shall be placed into the middle point inside the pipe, where the surface of the ceramic liner can be transmitted timely to the computer to monitor if cracks are generated. Then, apply a tensile load at the middle point of the CLT by using a manual chain pulley. Increase the displacement gradually while observing the surface morphology of ceramic liner on the computer. Terminate the test when cracks are observed in the ceramic liner in the computer imaging system, and the cumulative displacement of the middle point of the pipe at this time is the maximum deflection of this CLT sample.



Key

1 coupling
2 sleeve
3 CLT
4 endoscope probe
5 fixed pier

Figure 6 — Bending test

6.5.6 Thermal shock test

Thermal shock test shall be performed in accordance with ISO 2819. Take a specimen with a length of 200 mm ± 2 mm at the position greater than 100 mm away from the pin end of CLT. The specimen shall be quenched in water at room temperature after heating in an oven at 300 °C for 2 h. The ceramic liner shall be free from cracks and flaking after thermal shock test. The ceramic liner shall not reveal disbonding on a pipe coupon, or after ring split-up if carried out on a pipe ring.

6.6 CB ring test

All polymeric materials can be subject to physical and chemical degradation when immersed in water, hydrocarbons, and other fluids. Consequently, chemical compatibility with produced and injected fluids and production chemicals, shall be characterized in accordance with ISO 23936-1.

6.7 End cap test

When the end cap comes into contact with the sour environment, the test shall be conducted to meet the required sulfide stress cracking resistance specified in ISO 15156-2.

6.8 Inspection frequency and acceptance criteria

6.8.1 Lot

CLT lengths with the same size manufactured by using the same process with the same batch of materials and formula are defined as an inspection lot. The number of CLT of each lot shall not exceed 1 000, or shall be the output of 30 consecutive days of the production line if the 30 days output is not more than 1 000 pieces.

6.8.2 Inspection frequency

6.8.2.1 The inspection frequency of backing pipe shall conform to ISO 11960, or be agreed between the purchaser and the manufacturer.

6.8.2.2 The following items shall be tested individually:

1) wall thickness of used tubing to be used as the backing pipe;

2) surface quality of ceramic liner;

3) thread, drift, length, straightness, and hydrostatic test of CLT.

6.8.2.3 Thickness, hardness, and density of ceramic liner, as well as size, corrosion resistance of 6.4.7, tensile and impact property of CLT shall be tested by sampling inspection. The sampling plan shall conform to Table 6. This sampling plan for inspection shall be in accordance with ISO 2859-1. Inspection level I with AQL of 6.5 shall be selected.

Table 6 — Single sampling plan for inspection

Lot size N	Sample size n	Acceptance number A_c	Rejection number R_e
≤150	8	1	2
151 to 280	13	2	3
281 to 500	20	3	4
501 to 1 000	32	5	6

6.8.2.4 Connection properties of 6.4.9 should be verified when design, size, weight or steel grade is changed as per ISO 13679 as required by the customer.

6.8.2.5 The additional inspection of the CLT, the inspection frequency, and the acceptance criteria of CB ring and end cap shall be agreed on by the purchaser and the manufacturer.

6.8.3 Acceptance criteria

6.8.3.1 Any individual length shall be rejected and not counted in the lot if it does not meet the requirement specified in 6.8.2.1 and 6.8.2.2.

6.8.3.2 The lot size shall be reconfirmed according to the results of 6.8.3.1. Then, the final sample size shall be determined according to Table 6 to carry out the sampling inspection specified in 6.8.2.3. If any of the inspection and testing results representing a lot in 6.8.2.3 does not meet the specified requirements, another two more pieces of individual CLT from the same lot shall be re-tested. If both lengths re-tested conform to the requirements, the lot shall be accepted except for the initial failed one. If one or both of the re-tested product analyses fail, the manufacturer shall choose one of the following options: the entire lot shall be rejected or each of the remaining products shall be tested individually.

7 Documentation

7.1 Documents provided by the purchaser

The purchaser shall provide the design, operating conditions, and order requirements of CLT, which include, but are not limited to:

— Pressure requirements (and pressure range in the case of cyclic pressure)

— Maximum and minimum temperature

— Internal fluids

— Expected lifetime

— Quantity and specification

— Threaded or plain-end

— Type of connection

— With or without coupling

— Pipe ends

— Length range

— Drifting requirements

— Delivery date and shipping instructions

— Inspection by purchaser

7.2 Documents provided by the manufacturer

The manufacturer shall provide the purchaser with a written description containing at least the following information:

— Dimensions, including the nominal inside diameter, wall thickness and weight of the liner

— Description of the materials used

— Information of manufacturing process

— Test report

A full qualification test report shall be made available to the purchaser on request. The purchaser shall define the data that shall be provided in the Qualification Test Report.

8 Marking, packaging, transportation, and storage

8.1 Marking

CLT shall be marked by the manufacturer with the information included but are not limited to the following:

— Name of manufacturer

— Date of manufacture

— Backing pipe identification

— Lot identification number

— Mass of CLT per metre

Additional marking as specified by the manufacturer or purchaser is allowed, e.g. marking “CLT” on the pipe.

The marking of the backing pipe shall conform to the requirements of ISO 11960. A colour code identification system shall be used to denote the conditions of CLT manufactured with the used tubing in accordance with ISO 10405.

Markings shall be applied within three feet of the connection. Markings shall be readily visible and applied by water-resistant paint or ink stencil. Markings shall not overlap and shall be applied in a manner not to damage the pipe or couplings.

8.2 Packaging

The packaging and quality certificate of CLT shall conform with the requirements of ASTM A700.

Thread surface of CLT shall be coated with thread compound and covered with thread protector before packaging. Thread compound and the thread protector shall be specified by the connection manufacturer and/or the customer.

All couplings shall be screwed onto the pipe power-tight, except those to be screwed on handling-tight as specified on the purchase agreement.

8.3 Transportation

The CLT shall be prevented from a strong collision, violent landing, or strike in the process of manufacturing, constructing, and other transport processes. It is not allowed to directly knock the ceramic liner and the end cap of the pipe with any metal instruments.

During the handling process, the threads at both ends of the CLT shall be protected carefully from any damage. No iron bars shall be inserted into the pipe for lifting or carrying. A spreader bar shall be used to keep CLT straight during the lifting operations.

Flat trailer shall be used in transportation. CLT shall be placed on the wooden stringers and tied up with the binding tape. Bending or damage caused by suspending of CLT shall be avoided.

8.4 Storage

Unless otherwise specified on the purchase agreement, the pipe and couplings shall be coated to prevent rusting during storage and transportation. The coating shall be smooth, compact, and not peel off. The coating shall be capable of protecting the pipe for at least 3 months.

The first layer of CLT lengths shall be no less than 500 mm (20 in) above the ground to keep moisture and dirt away from the pipe. There shall be no sewage, harmful chemicals, or other corrosive material in the stacking area.

The CLT lengths should be placed on properly spaced supports to prevent the CLT lengths from being bent, or the threads from being damaged. The wooden strips as separators are provided between layers of the pipe so that no load applied to the coupling. At least three wooden strips are required between any two layers. All strips shall be placed perpendicular to the pipe and aligned vertically in individual rows. In each layer, when the pipe is staggered, adjacent pipes stagger about the length of the coupling.

For safety, ease of inspection and handling, CLT shall not be stacked higher than 3 m (10 ft), and not be higher than five layers at the rig. Pipe in storage should be inspected periodically and the protective coatings should be applied whenever necessary to avoid corrosion.

Annex A
(informative)

Testing method for surface quality of ceramic liner

A.1 Principle

Surface morphology of ceramic liner is 30 times magnified and captured by the camera in a testing device, then displayed onto the screen of the monitor.

A.2 Instruments

Required instruments include:

— Colour monitor

— Camera equipped with high-brightness LED light

A.3 Test procedures

Fix the camera and high lighting device on the testing support and adjust the clarity of the camera to fix its focus.

The testing support is rotated continuously to make a spiral circular movement while the linear inspection is conducted to determine the quality of the inner surface of the ceramic liner.

The surface quality of ceramic liner can be evaluated from images displayed on the monitor.

Annex B
(normative)

List of CLT products