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**Oil and gas industries including  
lower carbon energy — Wet thermal  
insulation systems for pipelines and  
subsea equipment —**

Part 2:

**Qualification processes for production  
and application procedures**

*Industries du pétrole et du gaz, y compris les énergies à faible teneur  
en carbone — Systèmes d'isolation thermique en milieu humide pour  
conduites et équipements sous-marins —*

*Partie 2: Processus de qualification des modes opératoires de  
production et d'application*

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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 document 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](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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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](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 2, *Pipeline transportation systems*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 12736-2, together with ISO 12736-1 and ISO 12736-3, cancels and replaces ISO 12736:2014.

The main changes are as follows:

- clearer delineation between commercial projects and validation;
- introduction of material classes;
- elimination of system specific qualification testing tables;
- introduction of detailed thermal conductivity testing requirements;
- introduction of project specific functional tests;
- addition of [Annexes A](#) and [B](#) with guidelines for using this document and design of systems.

A list of all parts in the ISO 12736 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](http://www.iso.org/members.html).

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# Oil and gas industries including lower carbon energy — Wet thermal insulation systems for pipelines and subsea equipment —

## Part 2: Qualification processes for production and application procedures

### 1 Scope

This document specifies requirements for project specific product and process qualification of wet thermal insulation systems applied to pipelines in a factory setting and subsea equipment in the oil and gas industries.

This document is not applicable to:

- pre-fabricated insulation;
- thermal insulation in the annulus of a steel pipe-in-pipe system;
- maintenance works on existing installed wet thermal insulation systems;
- project qualification of anticorrosion coatings or the requirements for application thereof.

### 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 48-4, *Rubber, vulcanized or thermoplastic — Determination of hardness — Part 4: Indentation hardness by durometer method (Shore hardness)*

ISO 868, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 1133-1, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 1: Standard method*

ISO 1133-2, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 2: Method for materials sensitive to time-temperature history and/or moisture*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 1183-3, *Plastics — Methods for determining the density of non-cellular plastics — Part 3: Gas pycnometer method*

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 2884-2, *Paints and varnishes — Determination of viscosity using rotary viscometers — Part 2: Disc or ball viscometer operated at a specified speed*

## ISO 12736-2:2023(E)

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3219 (all parts), *Rheology*

ISO 3451-1:2019, *Plastics — Determination of ash — Part 1: General methods*

ISO 8301, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Heat flow meter apparatus*

ISO 8502-3, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

ISO 8502-4, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 4: Guidance on the estimation of the probability of condensation prior to paint application*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 12736-1, *Petroleum and natural gas industries — Wet thermal insulation systems for pipelines, flow lines, equipment and subsea structures — Part 1: Validation of materials and insulation systems*

ISO 80000-1, *Quantities and units — Part 1: General*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12736-1 and the following 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 agreed

specified in the purchase order

Note 1 to entry: To be discussed by the *system provider* (3.44) and *system purchaser* (3.45) with input from *end user* (3.11) as required.

#### 3.2 application procedure specification APS

quality specification document, or group of specifications, describing procedures, method, equipment, tools, etc. used for *system* (3.44) application

#### 3.3 batch

quantity of *material* (3.25) produced in a continuous manufacturing operation using raw materials of the same source or grade

#### 3.4 bend

permanently curved or angled section of tubular pipe

#### 3.5 blown foam

insulation *material* (3.25) formed by incorporating a gas phase into a polymer matrix

**3.6****certificate of analysis**

document provided by the manufacturer that indicates results of specific tests or analysis, including test methodology, performed on a specified lot of the manufacturer's product and corresponding conformity ranges

**3.7****chamfer**

exposed pre-shaped termination of a *system* (3.43) to be interfaced with

Note 1 to entry: Chamfer geometry (e.g. angle, shape) and tolerances are project specific.

**3.8****construction joint**

*interface* (3.19) where both *systems* (3.43) are identical

**3.9****cool down time**

time taken for a fluid contained within a *pipeline* (3.27) or *subsea equipment* (3.41) to reach a pre-determined temperature from specific start temperatures (internal and external) when flow is stopped

**3.10****cutback**

length of item left uncoated at each end for joining purposes

Note 1 to entry: Welding is an example of joining purposes.

**3.11****end user**

company that owns and/or operates the *pipeline* (3.27) or *subsea equipment* (3.41)

**3.12****factory applied**

applied in a permanent facility

**3.13****field joint**

uncoated area that results when two pipe sections, or a pipe section and a *fitting* (3.14), with *cutbacks* (3.10) are assembled by welding or other methods

**3.14****fitting**

receptacle on a piece of *subsea equipment* (3.41), which interfaces to a *pipeline* (3.27)

**3.15****high molecular weight precursor thermoset**

*material* (3.25), which is a polymeric compound that remains malleable until application of sufficient heat to cause network formation and then does not flow upon reheating

EXAMPLE Butyl rubber.

**3.16****inorganic syntactic foam**

insulation *material* (3.25) formed by dispersing inorganic hollow particles within a polymer matrix

**3.17****inspection and test plan****ITP**

document providing an overview of the sequence of inspections and tests, including appropriate resources and procedures

### 3.18

#### **inspection document**

document issued by the *system provider* (3.44) and attesting that the supplied *system* (3.43) is in conformity with the requirement given in the purchase order

Note 1 to entry: See also ISO 10474.

### 3.19

#### **interface**

location where two *systems* (3.43) meet and affect each other

Note 1 to entry: A *field joint* (3.13) *system* (3.43) has two interfaces.

Note 2 to entry: In the case of multilayer *systems* (3.43), interfaces can be made up of multiple sub-interfaces.

### 3.20

#### **J-lay**

method of *pipeline* (3.27) installation in which pipelines are assembled by welding together pre-insulated pipes with subsequent application of a *field joint* (3.13) *system* (3.43) in a vertical position, onboard an installation vessel with a tower

Note 1 to entry: The pipeline is lowered into the water vertically and creates a characteristic J-shape when touching the seabed.

Note 2 to entry: This method is used mainly for deep water.

### 3.21

#### **jumper**

short section of *pipeline* (3.27) that transfers fluid between two pieces of *subsea equipment* (3.41)

### 3.22

#### **liquid precursor elastomeric thermoset**

*material* (3.25), which is a polymeric compound with its glass transition below ambient temperature, that is produced via combination of one or more components that can be pumped and flow as liquids and which react to create a crosslinked polymer that does not flow upon reheating

EXAMPLE Liquid precursor silicone rubber.

### 3.23

#### **liquid precursor non-elastomeric thermoset**

*material* (3.25), which is a polymeric compound with its glass transition above ambient temperature, that is produced via combination of one or more components that can be pumped and flow as liquids and which react to create a crosslinked polymer that does not flow upon reheating

EXAMPLE Liquid epoxy.

### 3.24

#### **mainline**

portion of a *pipeline* (3.27) that is not a *field joint* (3.13)

### 3.25

#### **material**

polymeric compound applied to the *substrate* (3.42) to be protected/insulated in units of discrete thickness (layers) to build up a *system* (3.43)

### 3.26

#### **material manufacturer**

entity responsible for the manufacture of one or more *materials* (3.25) utilized in a *system* (3.43)

**3.27****pipeline**

flowline

tubular piping used to convey fluids

Note 1 to entry: Pipeline includes *jumpers* (3.21), *risers* (3.34) and *field joints* (3.13).

**3.28****pi tape**

precision Vernier periphery tape that allows the direct and accurate measurement of the diameter of tubular objects without the need for callipers or micrometres

**3.29****pre-fabricated insulation**

section of stand-alone insulation, which is factory manufactured into its final form and then installed in the field by mechanically fastening or bonding to a corrosion protected structure

**3.30****pre-production trial****PPT**

series of tests performed immediately before the start of production, designed to demonstrate that the requirements of the *validated* (3.49) *system* (3.43), the *procedure qualification trial* (3.31) or both are achieved

Note 1 to entry: Requirements for PPT are as outlined in this document and as *agreed* (3.1).

**3.31****procedure qualification trial****PQT**

series of tests designed to demonstrate that the *materials* (3.25), *system provider* (3.44), equipment and procedures can produce the *system* (3.43) in accordance with the *validation dossier* (3.50) and meet specific *project* (3.32) requirements

Note 1 to entry: Requirements for PQT are as outlined in this document and as *agreed* (3.1).

**3.32****project**

scope of work agreed upon contractually between *system purchaser* (3.45) and *system provider* (3.44)

**3.33****R-lay**

reel-lay

method of *pipeline* (3.27) installation in which long *stalks* (3.40) of pre-insulated pipes are pre-assembled by welding and application of *field joint* (3.13) *system* (3.43) onshore before being spooled onto large reels onboard the installation vessel, which then lays the pipes by unspooling the reel offshore

**3.34****riser**

vertical portion of a *pipeline* (3.27), including the bottom bend, arriving on or departing from an offshore surface installation

**3.35****safety data sheet****SDS**

DEPRECATED: material safety data sheet

document intended to provide workers and emergency personnel with procedures for handling and working with a *material* (3.25) utilized in the manufacture of the *system* (3.43) in a safe manner including physical data, first aid, etc.

Note 1 to entry: Physical data can include flash point and toxicity.

**3.36**

**service life**

specified period of use for a *system* (3.43) in service

**3.37**

**rough coat**

modification of the outermost layer of the *system* (3.43) for increased roughness

**3.38**

**S-lay**

method of *pipeline* (3.27) installation in which pipelines are assembled by welding together pre-insulated pipes, with subsequent application of a *field joint* (3.13) *system* (3.43), onboard an installation vessel in a horizontal orientation

Note 1 to entry: The pipeline curvature created from the vessel down to the seabed is a characteristic S-shape.

Note 2 to entry: This method is used mainly for low to medium water depths.

**3.39**

**solid/solid filled**

insulation *material* (3.25) which systematically does not contain voids or hollow particles

**3.40**

**stalk**

continuous string of welded and *field joint* (3.13) coated pipe, which is prepared in readiness for pipe spooling onto a *R-lay* (3.33) barge

Note 1 to entry: A number of stalks will normally be required to make up a *pipeline* (3.27).

**3.41**

**subsea equipment**

components from a subsea production system, including subsea processing items and structures, meant to control hydrocarbons, not including *pipelines* (3.27)

EXAMPLE Valve, connector, manifold, christmas tree, flowline end termination.

**3.42**

**substrate**

surface to which a *material* (3.25) is applied or will be applied

**3.43**

**system**

all of the various *materials* (3.25) and the combination thereof, which can include layers of anti-corrosion, insulation, adhesive, and protective materials, as defined by cross-section to the underlying *substrate* (3.42) at a single point, which function together to act as a *wet thermal insulation* (3.51)

**3.44**

**system provider**

entity that is selling the applied *system* (3.43)

**3.45**

**system purchaser**

entity that is purchasing the applied *system* (3.43)

**3.46**

**thermal conductivity**

**k-value**

heat flow through a unit length of *material* (3.25) under the influence of a thermal gradient

Note 1 to entry: Thermal conductivity is expressed in  $W \cdot m^{-1} \cdot K^{-1}$ .

**3.47****thermoplastic**

*material* (3.25), which is a polymeric compound that solidifies upon cooling and can flow and be reformed upon reheating

EXAMPLE Polypropylene.

**3.48****U-value**

overall heat transfer coefficient

rate of heat transfer from a reference surface under the influence of a thermal gradient

Note 1 to entry: U-value is expressed in  $W \cdot m^{-2} \cdot K^{-1}$ .

**3.49****validation**

demonstration of *material* (3.25) and *system* (3.43) performance during storage, handling and operation, within a specified envelope of use, as determined by the *system provider* (3.44)

**3.50****validation dossier**

collection of documentation and test reports, prepared in accordance with specific requirements, which provides detailed information on the proposed *system* (3.43), method of application, the *materials* (3.25) which form said *system* (3.43), and demonstration of *system* (3.43) performance

Note 1 to entry: Specific requirements are found in ISO 12736-1:2023, 7.6

**3.51****wet thermal insulation**

*system* (3.43) that provides external corrosion protection and thermal insulation, and that is in direct contact with surrounding seawater

**4 Symbols and abbreviated terms****4.1 Symbols**

$C_p$	specific heat capacity, expressed in joules per kilograms kelvin
$k$	thermal conductivity, expressed in watts per meter kelvin
$M$	mass, expressed in grams
$M_{ash}$	mass of inorganic microspheres in the inorganic syntactic foam material sample, expressed in grams
$M_{total}$	mass of the inorganic syntactic foam material sample, expressed in grams
$Q_{ave}$	average value of heat flux transducers signals, expressed in microvolts
$Q_{Lower}$	lower plate heat flux transducer signal, expressed in microvolts
$Q_{Lower,Average}$	average lower plate heat flux transducer signal, expressed in microvolts
$Q_{Ref Mat ave}$	average value of heat flux transducers signals for reference material sample, expressed in watts per microvolts
$Q_{Ref Mat ave,i}$	average value of heat flux transducers signals for reference material sample $i$ , where $i = 1$ or $2$ , and $1$ is typically the thinner sample, expressed in watts per microvolts

$Q_{\text{Upper}}$	upper plate heat flux transducer signal, expressed in microvolts
$Q_{\text{Upper,Average}}$	average upper plate heat flux transducer signal, expressed in microvolts
$S_{\text{Cal1}}$	single-thickness calibration factor, proportional factor between the electrical signal and heat flow, expressed in watts per microvolts
$S_{\text{Cal2}}$	two-thickness calibration factor, proportional factor between the electrical signal and heat flow, expressed in watts per microvolts
$S_{\text{Cal,Lower}}$	lower plate calibration factor, expressed in watts per microvolts
$S_{\text{Cal,Upper}}$	upper plate calibration factor, expressed in watts per microvolts
$R_{\text{Cal}}$	calibration contact resistance, expressed in metre square degrees kelvin per watt
$2R_{\text{Cal,Lower}}$	lower plate calibration contact resistance, expressed in metre square degrees kelvin per watt
$2R_{\text{Cal,Upper}}$	upper plate calibration contact resistance, expressed in metre square degrees kelvin per watt
$\Delta T$	average temperature difference across the sample(s), expressed in degrees Celsius
$T_{\text{g}}$	glass transition temperature, expressed in degrees Celsius
$T_{\text{Lower}}$	lower plate temperature, expressed in degrees Celsius
$T_{\text{Upper}}$	upper plate temperature, expressed in degrees Celsius
$V_{\text{ash}}$	volume of inorganic microspheres in the inorganic syntactic foam material sample, expressed in cubic centimetres
$V_{\text{polymer}}$	volume of polymer in the inorganic syntactic foam material sample, expressed in cubic centimetres
$V_{\text{total}}$	volume of the inorganic syntactic foam material sample, based on the measured $M_{\text{total}}$ and $\rho_{\text{total}}$ , expressed in cubic centimetres
$V_{\text{void}}$	volume of entrapped air in the inorganic syntactic foam material sample, expressed in cubic centimetres
$W_{\text{ash}}$	mass ratio of inorganic microspheres in the inorganic syntactic foam material sample as per <a href="#">Formula (E.1)</a> , dimensionless
$W_{\text{polymer}}$	mass ratio of polymer in the inorganic syntactic foam material sample, calculated as per <a href="#">Formula (E.4)</a> , dimensionless
$x_{\text{ave}}$	average measured thickness of the sample, expressed in metres
$x_{\text{Ref Mat ave}}$	average thickness of the reference material sample, expressed in metres
$x_{\text{Ref Mat ave},i}$	average thickness of reference material sample $i$ , where $i = 1$ or $2$ , and $1$ is typically the thinner sample, expressed in metres
$\lambda_{\text{Ref Mat}}$	thermal conductivity of the calibration reference material, expressed in watts per metre kelvin
$\lambda_{\text{sampleB1}}$	single thickness sample thermal conductivity, Test Type B1, expressed in watts per metre kelvin

$\lambda_{\text{sampleB2}}$	single thickness sample thermal conductivity, Test Type B2, expressed in watts per metre kelvin
$\rho$	material density, expressed in kilograms per cubic metre
$\rho_{\text{ash}}$	density of the inorganic microspheres, measured in grams per cubic centimetre
$\rho_{\text{polymer}}$	density of the polymer in the inorganic syntactic foam material sample, expressed in grams per cubic centimetre
$\rho_{\text{theoretical}}$	theoretical density of the inorganic syntactic foam material sample assuming no voids, expressed in grams per cubic centimetres, as per <a href="#">Formula (E.3)</a>
$\rho_{\text{total}}$	density of the inorganic syntactic foam material sample, expressed in grams per cubic centimetres
$\varphi_{\text{void}}$	air entrapment volume ratio, dimensionless
$\psi$	thermal diffusivity of the material, expressed in metres squared per second

## 4.2 Abbreviated terms

ACC	anti-corrosion coating
DMA	dynamic mechanical analysis
EHTC	external heat transfer coefficient
HSE	health, safety and the environment
MFR	melt flow rate
OD	outer diameter
OHTC	overall heat transfer coefficient
QC	quality control
UV	ultraviolet

## 5 Conformance

### 5.1 Rounding

Unless otherwise stated in this document, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with ISO 80000-1.

NOTE For the purpose of this provision, the rounding method of ASTM E29 is equivalent to ISO 80000-1:2022, Annex B, Rule A.

### 5.2 Conformity to requirement

Systems for quality and environmental management, and the competence of testing and calibration laboratories, should be used.

NOTE The following documents can be used:

- ISO 29001 gives sector-specific requirements with guidance for the use of quality management systems;

- ISO 14001 gives requirements with guidance for the use of environmental management systems;
- ISO/IEC 17025 gives general requirements for the competence of testing and calibration laboratories.

The system provider shall be responsible for conforming with all the applicable requirements for the application of this document. The system purchaser shall be allowed to make any investigation necessary to ensure conformity by the system provider and to reject any material and/or system that does not conform with this document.

## 6 Material classes

The wet thermal insulation systems covered by this document are based on materials classified in [Table 1](#). Each material used to make up the system shall have been classified into the appropriate class by the system provider as part of the validation dossier in accordance with ISO 12736-1.

**Table 1 — Material classes**

	Solid/solid filled	Blown foam	Inorganic syntactic foam
Thermoplastics	1A	1B	1C
Liquid precursor non-elastomeric thermosets	2A	2B	2C
Liquid precursor elastomeric thermosets	3A	3B	3C
High molecular weight precursor thermosets	4A	4B	4C

NOTE Reproduced from ISO 12736-1:2023, Table 1.

## 7 Project specific qualification processes for production and application procedures

### 7.1 General requirements

The following requirements apply for project specific qualification and QC activities:

- a) All materials and systems shall be previously validated in conformity with the requirements of ISO 12736-1 by the system provider.
- b) The validation dossier of the materials and system shall be given by the system provider to the system purchaser for approval.
- c) If the ACC selected by the system purchaser is different from the one used by the system provider for validation, both parties shall agree upon a test program to ensure that ACC and insulation materials are compatible for the project requirements.
- d) The preparation of a project specific APS and related ITP is required and shall be approved by the system purchaser.
- e) If requested by the system purchaser, a PQT can be performed for qualification of the approved APS (or part of it) and performed according to an approved ITP.
- f) Before production starts, a PPT shall be performed according to a dedicated ITP. By agreement, the PPT and the PQT can be executed at the same time, i.e. the PQT and the PPT can be merged.
- g) Those parts of the project specific qualification process that are waived by the system purchaser, shall be clearly stated and identified in the contract.
- h) During the production, an inspection system shall be implemented by the system provider to monitor and execute all the inspection activities reported in the approved ITP for production.

- i) Inspection and testing shall be carried out during production in accordance with the approved ITP.
- j) Test procedures references, testing frequencies, acceptance criteria shall be specified in the ITP.
- k) If other materials than those classified in [Table 1](#) are used, the system provider shall have identified the class that most closely represents the material and shall provide a gap analysis to the requirements for that class to be included in the validation dossier.
- l) Damaged areas created by testing shall be removed and repaired in accordance with [Clause 9](#).
- m) The system provider shall prepare a set of samples or pipe sections according to the dimensions and characteristics approved by the system purchaser, in order to perform any required destructive tests on the applied insulation system.
- n) All data collected during inspections and tests shall be recorded in a proper form and shall be delivered to the system purchaser as required in the ITP.

## 7.2 Purchase order requirements

### 7.2.1 General information

The purchase order, and optionally the request for quotation if known, shall include the following information:

- a) reference to this document (i.e. ISO 12736-2:2023);
- b) wet thermal insulation system to be utilized;
- c) project conditions (e.g. water depth, operating temperature and design temperature, installation method);
- d) thermal performance requirements;
- e) identification and description of item to be insulated (e.g. item quantity, outside diameter, external geometry, wall thickness, nominal length, grade of steel);
- f) identification of the ACC selected by system purchaser or already applied to the items to be insulated;
- g) cutback configuration, ends finish, at least cutback length and chamfer angle, length of visible ACC, temporary protection;
- h) presence and requirements for rough coat;
- i) requirement for execution of any PQT;
- j) type of inspection document, in accordance with ISO 10474, and frequency in which signed copies shall be transmitted to the system purchaser;
- k) number of pipes or items required for PPT and optional PQT.

### 7.2.2 Additional information

The purchase order, and the request for quotation if known, should specify which of the following provisions apply for the specific item ordered:

- a) special requirements relative to supply of materials (e.g. manufacturer-specific products and certification);
- b) tracking and traceability of items to be insulated to material batches;
- c) inspection of incoming items;

- d) holiday inspection of ACC before application of insulation, including responsibility for repair of ACC;
- e) inspection and testing plan and/or daily log;
- f) required modifications to PQT, if applicable, PPT or production ITP requirements with respect to the requirements of this document;
- g) additional PQT test requirement (e.g. functional testing);
- h) marking of insulated item and any colour coding requirement at external surface;
- i) permissible number of repairs on applied insulation, maximum area of repair and acceptable locations of repairs;
- j) entity responsible for performing insulation repairs;
- k) handling and storage procedures;
- l) protection against adverse ambient conditions during storage;
- m) documentation and schedule for supply of documentation.

### 7.3 Production qualification process

#### 7.3.1 Process description

The production qualification process consists of:

- PQT, if requested by the system purchaser, which shall be performed in conformance with an approved APS and its related ITP (see [7.3.3](#), [7.4.1](#) and [7.4.2](#), respectively);
- PPT, which shall be performed in conformance with an approved APS and its related ITP (see [7.3.4](#), [7.4.1](#) and [7.4.2](#));
- inspection during production (see [7.3.5](#)), which shall be performed in conformance with an approved ITP (see [7.4.2](#)).

If requested and agreed per [7.2.2](#), item f), the PQT and the PPT may be performed at the same time, just before production start. In this case, the PQT and PPT tests can be merged.

It is allowed to issue only one APS and one ITP grouping the PPT and production activity.

#### 7.3.2 Project specific qualification considerations

Functional tests may be requested by the system purchaser per [7.2.2](#), item g) if the specific project conditions are outside the test parameter ranges, reported in the validation dossier, or to provide additional information to support the specific project requirements (e.g. cyclic loading for steel catenary risers).

Examples of system tests which can be customized as project specific functional tests can be found in ISO 12736-1:2023, Table 3, such as:

- installation tests:
  - simulated bending test (see ISO 12736-1:2023, Annex D).
- in-service tests:
  - impact (see ISO 12736-1:2023, Annex F);
  - simulated service test (see ISO 12736-1:2023, Annex G);

- hydrostatic collapse (see ISO 12736-1:2023, Annex C).

Typically, functional tests are performed during the PQT to allow for availability of results and identification of risks in advance of production.

The system purchaser may request additional pipe to be coated during the PQT to facilitate specialist installation tests by a third party or the installation contractor (e.g. tensioner, clamp and roller box tests).

Careful consideration should be given to include a field joint system in the test arrangement where it is known that differences in system properties or integrity of interface adhesion between the mainline and field joint systems (see ISO 12736-3) can affect the outcome of the test.

### 7.3.3 Procedure qualification trial

If required by the system purchaser per [7.2.1](#), item i), the APS shall be validated by a PQT. Test methods, acceptance criteria and frequencies for the PQT shall be in accordance with [Tables 2 to 9](#) and shall be specified in the ITP.

The main purpose of the PQT is to demonstrate that the APS, ITP, equipment and personnel (e.g. skills relevant to their tasks) are able to apply the selected insulation system to achieve the stated performance of the system in accordance with the validation dossier. It is not intended to validate the selection of the system for a project. However, the APS and ITP used in the PQT can be compared with the APS and ITP used for the system application during system validation and, if applicable, a gap analysis can be carried out.

For projects with specific requirements outside the envelope of testing and historical data contained within the validation dossier, the PQT may also be utilized to test and demonstrate project specific performance at the system purchaser's request.

Repair procedures shall be established for each system in accordance with [Clause 9](#). Repair procedures shall include repair down to steel in accordance with an appropriate ACC standard. Repair procedures and performance shall be tested at the PQT stage.

Evaluation of the removal of deteriorated/damaged system and repair of it shall be part of the PQT. The selected methods shall be risk assessed to ensure there is no damage to the metallic substrate. HSE risks associated with removal of the insulation shall be assessed before the PQT.

The PQT should be carried out in the presence of the system purchaser (or their representative), unless otherwise agreed in the purchase order.

The system provider may request the material manufacturer to assist during the PQT to ensure the correct processing and application of the material(s) and to train the system provider's personnel.

Qualification tests shall be carried out on representative pipes or subsea components. The shape of the workpiece shall simulate stress raisers present on the actual piece(s) to be coated. The length and volume of insulation on the workpiece shall be representative. A feature representing a weld cap in the steel structure shall be included in the test piece.

The application process parameters during the PQT shall reflect the anticipated application parameters during the actual project. If heating of the area to be coated is specified in the APS, parameters shall be optimized to minimize detrimental effects to any existing system.

All tools and equipment (e.g. for induction heating, abrasive blasting, materials application and inspection) to be used for PQT shall be of the same model as those to be used for the actual production.

The system provider shall submit a complete report of the qualification test results to the system purchaser for approval.

Relevant parameters for the application process recorded during PQT shall be implemented during PPT and production. The allowable ranges for these parameters should be agreed between the system

provider, system purchaser and/or end user, and included in the APS and ITP. If these parameters fall outside the required ranges, additional testing shall be performed to demonstrate equal or better performance when compared to PQT and PPT.

#### 7.3.4 Pre-production trial

A PPT shall be performed at start of production to verify the PQT or any previous qualification or historical data.

If agreed by the purchase order and if a PQT is performed just before production start, the PPT can be considered as included in the PQT itself with no need for a repetition.

Test methods, acceptance criteria and frequencies for the PPT shall be specified for the system in a dedicated ITP.

The PPT shall be carried out in the presence of the system purchaser (or their representative) at the start of operations when equipment and personnel are mobilized on site or the laying vessel. The PPT shall be performed on the first length of pipe or component to be coated or, if agreed, on a dummy pipe or structure which is representative of the project requirements in length, volume and shape.

The system provider shall submit a complete report of the tests containing the values and other results obtained in the PPT.

#### 7.3.5 Production testing

The system provider shall perform inspection and testing during production in accordance with the ITP to verify the substrate preparation, raw materials and system application.

The ITP shall be prepared by the system provider and shall be approved by the system purchaser prior to the start of production. The ITP shall identify all inspection activities and tests, their frequency and the relevant inspection authorities.

### 7.4 Application procedures

#### 7.4.1 Application procedure specification

The APS shall be prepared by the system provider based upon their experience and the validation dossier, SDS and application instructions. Before use and before the start of the PQT/PPT, the APS shall be approved by the system purchaser. Once approved, the APS shall not be changed without prior written authorization from the system purchaser.

The responsibilities and interactions between each party involved in the process shall be clearly described.

The APS shall be specific to the system being applied.

The APS shall cover all items associated with quality control as defined in this document and any agreed options for the specific system.

All application work, testing and inspection shall be carried out according to the APS.

The APS shall address the following as a minimum, where applicable to the system:

- a) material(s) identification;
- b) tools, consumables, and equipment required to apply the system;
- c) equipment set up and calibration;
- d) approved solvents or other cleaning agents to be used to clean substrates;

- e) inspection of existing ACC (e.g. cutback, bevel, holiday detection, repairs and precautionary measures, when necessary);
- f) preparation of substrates and substrate's contamination mitigation;
- g) preheating methods, for existing system and repair material;
- h) substrate temperature range for surface preparation;
- i) ambient conditions considering dew point temperature at the substrate to be coated;
- j) material preparation requirements (e.g. drying, mixing, pot life and thinning procedures, vacuum, extrusion parameters, pre-heats);
- k) system thickness range;
- l) system application method and critical equipment range settings;
- m) material/system curing or cooling schedule and conditions, including limitations such as minimum time before mould removal and minimum time before movement of item;
- n) overcoat time, if applicable;
- o) repair methods, considering the range of possible repair scenarios from substrate damage to damage down to steel, and repairs performed in the fabrication location and remote locations;
- p) remedial actions;
- q) removal procedure;
- r) time to inspection;
- s) handling and storage requirements for raw materials, insulated pipes and equipment, protection of cutbacks, including the following, as applicable:
  - 1) temperature limitations (e.g. freezing, excessive heat);
  - 2) humidity;
  - 3) protection from the elements (e.g. snow, rain, sunlight);
  - 4) protection from contaminants (e.g. dust, water, chemicals);
  - 5) expiration date;
  - 6) protection from physical damage.

#### 7.4.2 Inspection and test plan

A dedicated ITP shall be prepared by the system provider for each of the process steps (PQT, PPT, production). The contents of the ITP shall reflect all the process items, the items to be inspected and tested including the frequency thereof, and the acceptance criteria.

The following shall be listed at the minimum:

- a) selected system;
- b) identification of the item to be coated and substrate;
- c) description of the activities;
- d) inspection points for each of the activities;
- e) applicable reference documents including procedures and methods;

- f) applicable instruments and tools;
- g) acceptance criteria;
- h) frequency of the checks;
- i) type of report;
- j) persons/parties required to be present at the inspections/intervention points.

All reporting and logs (e.g. traveller sheets, job cards) shall at least include all the requirements of the ITP.

### 7.4.3 Qualification of operators

#### 7.4.3.1 General

The operators shall be qualified to undertake the system application procedure and repair work. The qualification via a specific training scheme may be verified by demonstration at PQT (if any), during PPT, or during supervised participation in production. The specific training scheme is established by the system provider, subject to approval by the system purchaser and/or end user.

The system provider may request the material manufacturer(s) and equipment suppliers to provide technical assistance to the operators, if necessary.

Proof of successful qualification shall be documented.

Inspectors carrying out the QC activities and inspections shall be trained and qualified.

The inspector competency may be demonstrated by attested experience, specific training by the system provider and/or by the certification body in conformance with the certification schemes approved by the system purchaser.

#### 7.4.3.2 Requirements

The system provider shall be responsible for ensuring that the operators are trained and qualified for their specific activity prior to the start of work by:

- a) preparing test samples in accordance with the approved APS;
- b) evaluating test samples against acceptance criteria;
- c) evaluating general competency under criteria described in this subclause.

Test samples shall be made of pipe or components that approximate, as closely as practicable, to the situations and conditions that will be found during construction or repair.

The system purchaser may witness and/or audit any or all aspects of the operator training and qualification testing process or may specify a third party to follow the training process.

The training shall cover the appropriate APS for the applicable systems and shall include at least:

- a) check of environmental conditions;
- b) substrate cleanliness and profile;
- c) preheating methods, if required;
- d) substrate preparation (including ACC) and application procedures;
- e) correct use of tools and operation of equipment;
- f) inspection methods;

g) system removal and repair methods.

Involvement of the material manufacturer in system application training is recommended.

Upon successful completion of the operator qualification testing, the system provider or a third-party training body shall provide a certificate of operator qualification that states the following:

- a) name of system provider's operatives;
- b) system or systems for which the operator is qualified;
- c) equipment which the operator is qualified to operate;
- d) APS used to qualify the operator;
- e) date of qualification testing.

For traceability, the documentary evidence shall provide a unique identifier for each qualified operator.

#### 7.4.3.3 Competency determination

Competency shall be determined by:

- a) reviewing the system provider's certificates of operator qualification for appropriateness for the system and the version of the APS to be applied, in which the operator shall have:
  - 1) applied the selected system using the approved APS, including substrate preparation;
  - 2) applied the selected system within the previous year;
- b) witnessing the coating operator in order to verify:
  - 1) applying the selected system to the piece in accordance with the APS, including substrate preparation;
  - 2) meeting the acceptance criteria for the selected sample(s).

The system purchaser may waive the requirements of item b), if the system provider demonstrates that the certificate of qualification, training and experience are sufficient to ensure competency.

## 8 Production testing and inspection

### 8.1 General

The system, in addition to the materials that make up said system, shall have been validated in conformance with the requirements of ISO 12736-1. The resulting validation dossier and PQT/PPT reports shall provide the baseline data required for quality control during production.

### 8.2 Material tests and inspection

Subsea wet thermal insulation systems are typically built-up as a single or multiple layers applied over a substrate, which may already be coated with an appropriate ACC.

Application and testing of ACCs shall be performed in accordance with the relevant standard as agreed.

Raw materials and material application shall meet the requirements of [Table 2](#) to [Table 6](#), dependent on classification of the material in question.

### 8.3 System tests and inspection

The applied system shall meet the requirements of [Table 7](#) to [Table 9](#), dependent on classification of the materials which make up the system, as per [Table 1](#).

### 8.4 Inspection documents and traceability

The inspection documents are released by the system provider and shall be in accordance with ISO 10474.

The system purchaser shall specify in the purchase order the required ISO 10474 designation of the inspection document and any specific requirements for the format and content of the document.

Records shall be maintained on a shift and daily basis and shall be available for inspection by the system purchaser (or their representative).

The inspection documents signed by the system provider shall be transmitted to the system purchaser at a frequency specified in the purchase order.

### 8.5 Guidance in generating an ITP

The inspection and test plan for the system shall be based upon [Table 2](#) to [Table 9](#). In each table, the property to be tested, the test method, the requirement for acceptance and the frequency of testing are identified. The properties indicated with a check mark in the appropriate column are required for each material class as per [Table 1](#).

A system can be made up of either a single material layer or multiple material layers of the same or different classes. For each applied layer, the appropriate properties for the class of material shall be tested.

The following requirements shall be included in the ITP, where appropriate:

- a) Raw material testing in [Table 2](#) shall be applicable for each material used in the system.
- b) Substrate preparation and inspection in [Table 3](#) shall be applicable for a layer applied directly to a steel substrate. In case a reference standard is not available, ISO 21809-3 can be adopted as reference for substrate preparation requirements.
- c) Polymeric substrate preparation and inspection in [Table 4](#) shall be applicable for any layer which is to be applied on top of a polymeric substrate (not onto steel). This polymeric substrate may be an anti-corrosion layer or previously applied insulation layer.
- d) If a liquid adhesion promoter is required between the insulation layer to be applied and the substrate, the inspection of [Table 5](#) shall be applicable.
- e) Inspection parameters in [Table 6](#) shall be applicable for the application of each insulation layer.
- f) Laboratory testing in [Table 7](#) shall be applicable for each of the as-applied insulation layers.
- g) For each layer that is not the final outer layer of the system, intermediate inspection in [Table 8](#) shall be applicable. If multiple layers are being applied concurrently in the same pass, intermediate inspection in [Table 8](#) shall be relevant only for the outermost layer.
- h) For the final layer applied, which is the outermost layer of the system, final inspection in [Table 9](#) shall be applicable.

Table 2 — Raw material testing<sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes												Frequency					
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production			
				A	B	C	A	B	C	A	B	C	A	B	C						
Density /specific gravity of each material component	kg/m <sup>3</sup>	ISO 1183-1 or ISO 2781 or material manufacturer's method	Within material manufacturer's certificate of analysis conformity range	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Each raw material batch	Each raw material batch	Each raw material batch	
Viscosity (of each component)	Pa.s	ISO 3104 or the ISO 3219 series or ISO 2884-2 or material manufacturer's method	Within material manufacturer's certificate of analysis conformity range		√	√	√	√	√	√	√	√	√	√	√	√	√	Each raw material batch	Each raw material batch	Each raw material batch	
MFR	g/ min	ISO 1133-1 and ISO 1133-2 or material manufacturer's method	Within material manufacturer's certificate of analysis conformity range	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Each raw material batch	Each raw material batch	Each raw material batch	
Density of inorganic microspheres	g/cm <sup>3</sup>	Material manufacturer's method	Within material manufacturer's certificate of analysis conformity range													√		Each raw material batch	Each raw material batch	Each raw material batch	
Crush strength of inorganic microspheres	MPa	Material manufacturer's method	Within material manufacturer's certificate of analysis conformity range														√	√	Each raw material batch	Each raw material batch	Each raw material batch
Functionality content <sup>b</sup> (e.g. isocyanate)	%	Specific to functionality (e.g. ISO 14896)	Within material manufacturer's certificate of analysis conformity range		√	√	√	√	√	√	√	√	√	√	√	√	√	Each raw material batch	Each raw material batch	Each raw material batch	
Gel time / reactivity of cured system	s	Material manufacturer's method	Within material manufacturer's certificate of analysis conformity range												√	√	√	Each raw material batch	Each raw material batch	Each raw material batch	

<sup>a</sup> Raw material testing to be found on material manufacturer's certificate of analysis or tested by system provider, if otherwise unavailable.

<sup>b</sup> If applicable per APS.

Table 2 (continued)

Property	Units	Test method	Requirements	Applicable classes												Frequency			
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production	
				A	B	C	A	B	C	A	B	C	A	B	C				
Cure characteristics	Nm	ISO 6502 (rheometer) or material manufacturer's method	Within material manufacturer's certificate of analysis conformity range					√	√	√				√	√	√	Each raw material batch	Each raw material batch	Each raw material batch
Density (of cured system)	kg/m <sup>3</sup>	ISO 1183-1	Within material manufacturer's certificate of analysis conformity range											√	√	√	Each raw material batch	Each raw material batch	Each raw material batch
Hardness of cured system	Shore A or Shore D	ISO 868 or ISO 48-4	Within material manufacturer's certificate of analysis conformity range											√	√	√	Each raw material batch	Each raw material batch	Each raw material batch
Appearance	--	Visual	Within material manufacturer's certificate of analysis conformity range	√	√	√	√	√	√	√	√	√	√	√	√	√	Each raw material batch	Each raw material batch	Each raw material batch

<sup>a</sup> Raw material testing to be found on material manufacturer's certificate of analysis or tested by system provider, if otherwise unavailable.

<sup>b</sup> If applicable per APS.



Table 3 — Steel substrate preparation <sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes												Frequency				
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production		
				A	B	C	A	B	C	A	B	C	A	B	C					
Steel substrate preparation	-	As per applicable ACC standard, such as ISO 21809-3	As per applicable ACC standard, such as ISO 21809-3	√	√	√	√	√	√	√	√	√	√	√	√	√	√	As per applicable ACC standard	As per applicable ACC standard	As per applicable ACC standard

<sup>a</sup> Applicable if insulation material is being applied directly to steel substrate.

Table 4 — Polymeric substrate preparation <sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes												Frequency			
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production	
				A	B	C	A	B	C	A	B	C	A	B	C				
Holiday inspection <sup>b</sup>	-	Applicable ACC standard	If applicable, no holidays, free of damage	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Cleaning of substrate	-	As per APS	Substrate to be cleaned	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Visual inspection of previously coated substrate for cleanliness	-	Visual inspection	The substrate shall be free from moisture, contamination, oil and grease	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Environmental conditions Dew point and relative humidity to be recorded	°C	ISO 8502-3	Acceptable range to be established during PQT or PPT. Minimum 3 °C above dew point	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Start of each shift
Substrate abrasion <sup>b</sup>	-	Visual inspection	If applicable, abrasion with sand paper grit 40 minimum and dust vacuum cleaning (alternative methods of mechanical surface preparation may be agreed); wipe substrate with lint free cloth	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Dust test <sup>c</sup>	-	ISO 8502-3	Dust quantity and size ≤ class 2, rating 2	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item

<sup>a</sup> Applicable if insulation material is being applied to a previously applied polymeric substrate.

<sup>b</sup> If applicable per APS.

<sup>c</sup> Only applicable if substrate is abraded.



Table 5 — Liquid adhesion promoter/primer application <sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes									Frequency						
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production	
				A	B	C	A	B	C	A	B	C	A	B	C				
Environmental conditions	°C	ISO 8502-4	Minimum 3 °C above dew point	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Start of each shift
Pot life	min	Stop watch	Cure time check in accordance with material manufacturer's recommendation	√	√	√	√	√	√	√	√	√	√	√	√	√	Start of PQT or each mix batch	Start of PPT or each mix batch	Start of each shift or each mix batch
Mix ratio <sup>a</sup>	ratio by weight	Weight measurement	Ratio and tolerance to material manufacturer's recommendation	√	√	√	√	√	√	√	√	√	√	√	√	√	Start of PQT or each mix batch	Start of PPT or each mix batch	Start of each shift or each mix batch
Over coating time	min	Stop watch	Time check in accordance with material manufacturer's recommendation	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Visual appearance	-	Visual	Within material manufacturer's recommendation Comparative visual test panels from PQT or PPT to be used for production	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item

<sup>a</sup> If applicable per APS.

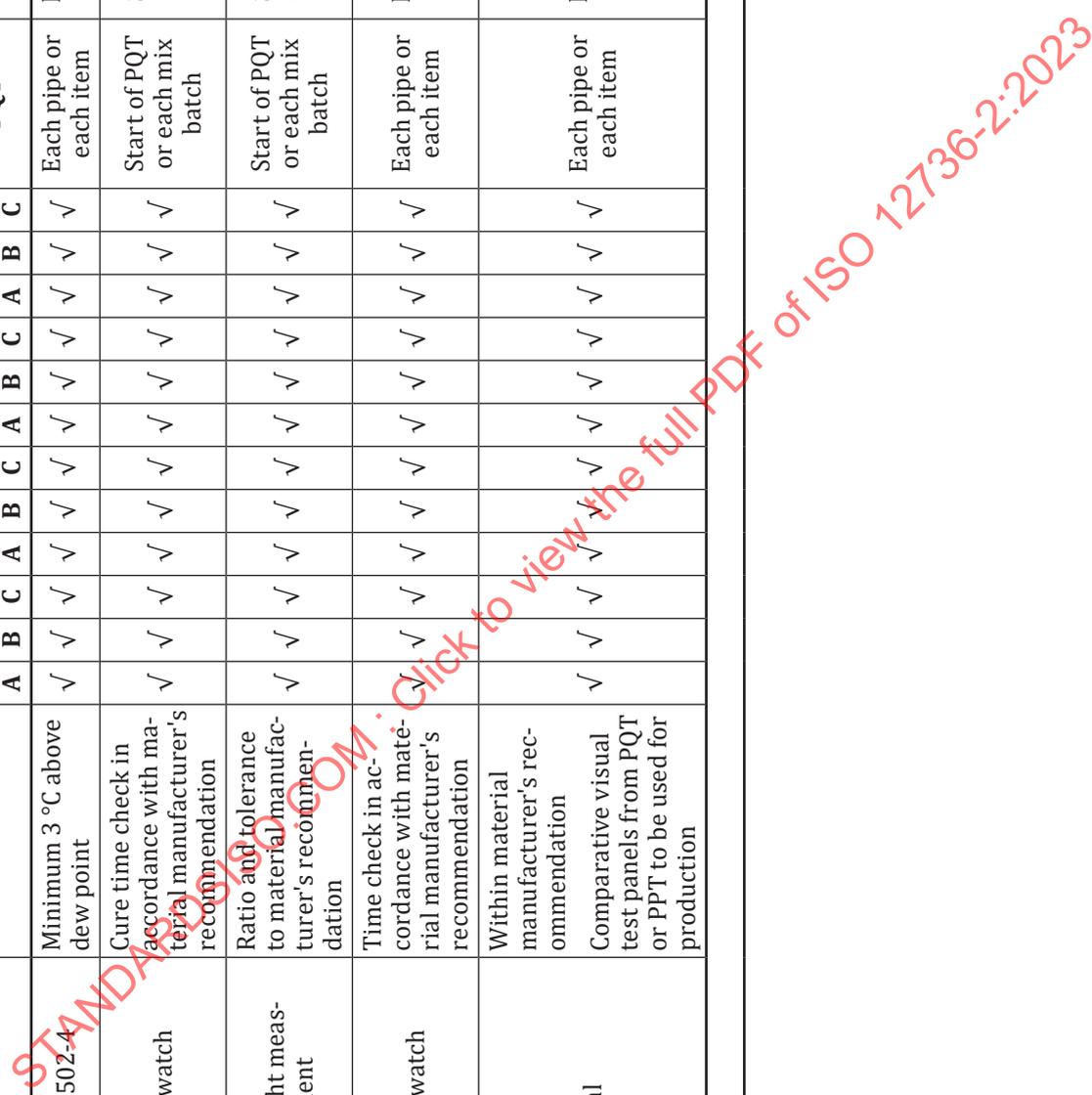


Table 6 — Materials application

Property	Units	Test method	Requirements	Applicable classes									Frequency					
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production
				A	B	C	A	B	C	A	B	C	A	B	C			
Extrusion temperature	°C	Infrared pyrometer or equivalent on extrudate as it is existing in the die	Acceptable range to be established during PQT or PPT	√	√											Each pipe or each item	Each pipe or each item	All pipes/items checked with infrared pyrometer; recorded once per hour for pipe or recorded for each item
Mix ratio	ratio by weight	Weight measurement	Ratio and tolerance to material manufacturer's recommendation	√	√		√	√		√	√					Start of PQT	Start of PPT	Start of each shift
Cupshot test	-	Visual	Good mixing, no air, no discolouration from unmixed components etc.	√	√		√	√		√	√					Start of PQT	Start of PPT	Start of each shift
Gel time check (machine dispensed) <sup>a</sup>	s	Stop watch	To be used as reference for maximum pour time limitations	√			√	√		√	√					Once	Once	Once per shift or start of each pouring
Visual inspection of the mould prior to moulding	-	Visual	Clean, correctly aligned and supported, adequate seal	√			√	√		√	√					Each pipe or each item	Each pipe or each item	Each pipe or each cast
Raw material processing temperature	°C	Thermocouple	Within material manufacturer's recommendation	√			√	√		√	√					Once	Once	Once per shift
Mould temperature <sup>a</sup>	°C	Thermocouple and non-contact thermometer	Acceptable range to be established during PQT or PPT	√			√	√		√	√					Each pipe or each item	Each pipe or each item	Continuous monitor and record once per hour

<sup>a</sup> If applicable per APS.

Table 6 (continued)

Property	Units	Test method	Requirements	Applicable classes												Frequency		
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production
				A	B	C	A	B	C	A	B	C	A	B	C			
Substrate temperature after primer application <sup>a</sup>	°C	Thermocouple, contact thermometer, or non-contact thermometer	If applicable, acceptable range to be established during PQT or PPT	✓	✓	✓	✓	✓	✓	✓	✓				Each pipe or each item	Each pipe or each item	All pipes/items checked with infrared pyrometer; recorded once per hour for pipe or recorded for each item	
Exotherm temperature during moulding <sup>a</sup>	°C	Thermocouple, contact thermometer, or non-contact thermometer	Acceptable range to be established during PQT or PPT The exotherm should be checked at the centre of the maximum thickness during cure	✓	✓	✓	✓	✓	✓	✓	✓				One item	One item	As agreed	
Minimum de-moulding time	s (or h as applicable for materials)	Timing device	Acceptable range to be established during PQT or PPT	✓	✓	✓	✓	✓	✓	✓	✓				Each pipe or each item	Each pipe or each item	Each pipe or each item	
Material density	kg/m <sup>3</sup>	Sampled from the mould venting; test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier	✓	✓	✓	✓	✓	✓	✓	✓				Each pipe or each item	Each pipe or each item	Each pipe or each item	
Cross-section porosity check	-	Sampled from the mould venting; naked eye (no magnification)	In accordance with the criteria reported in the validation dossier	✓	✓	✓	✓	✓	✓	✓	✓				Each pipe or each item	Each pipe or each item	Each pipe or each item	

<sup>a</sup> If applicable per APS.

Table 6 (continued)

Property	Units	Test method	Requirements	Applicable classes												Frequency			
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production	
				A	B	C	A	B	C	A	B	C	A	B	C				
Vulcanisation temperature	°C	Contact thermometer	Acceptable range to be established during PQT or PPT, or according to material manufacturer procedure.											√	√	√	Each pipe or each item monitored	Each pipe or each item monitored	Each pipe or each item monitored
Vulcanisation time	min	Stop watch	Acceptable range to be established during PQT or PPT											√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Vulcanisation pressure	MPa	System provider specific	Acceptable range to be established during PQT or PPT											√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item

<sup>a</sup> If applicable per APS.

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Table 7 — System offline testing – Laboratory testing

Property	Units	Test method	Requirements	Applicable classes												Frequency				
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production <sup>d</sup>		
				A	B	C	A	B	C	A	B	C	A	B	C					
Density	kg/m <sup>3</sup>	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or item	Each pipe or item	Once per shift
Density	kg/m <sup>3</sup>	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C	√									√					Once for PQT	Once for PPT	N/A
Interlayer adhesion test between insulation layers and between insulation and substrate	MPa	Test method as supplied in validation dossier or as agreed	Acceptable range to be established during PQT or PPT	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or item	Once or as agreed	Once per shift or as agreed
System shear resistance of materials <sup>a</sup>	MPa	ISO 12736-1:2023, Annex E	As agreed	√														Once for PQT	N/A	N/A
System shear resistance of inter-layer bond	MPa	ISO 12736-1:2023, Annex E	As agreed if applicable	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Once for PQT	N/A	N/A
Thermal conductivity <sup>a</sup>	W.m <sup>-1</sup> .K <sup>-1</sup>	Annex D	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C	√	√	√	√	√	√	√	√	√	√	√	√	√	√	Once for PQT	Once or as agreed	As agreed

<sup>a</sup> Not applicable for layers of a single material built up to <10 mm in thickness, which may be done in multiple applications.  
<sup>b</sup> Applicable only for inorganic syntactic foams where the hollow particle is a glass microsphere or other inorganic microsphere.  
<sup>c</sup> Not applicable for materials whose residual ash consists of more than the incorporated hollow particles (e.g. silicones).  
<sup>d</sup> May be tested on separate representative test coupon, if there is no convenient location for sampling on the item to be coated.  
<sup>e</sup> Applicable only for projects to be installed by R-lay.



Table 7 (continued)

Property	Units	Test method	Requirements	Applicable classes												Frequency				
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production <sup>d</sup>		
				A	B	C	A	B	C	A	B	C	A	B	C					
Closed cell content	%	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C		√						√							Once per pipe or item	Once or as agreed	Once per shift or as agreed
Tear strength	N/mm	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C				√			√	√	√	√					Once for PQT	N/A	N/A
Notched Charpy impact strength <sup>e</sup>	kJ/m <sup>2</sup>	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C	√	√		√	√	√	√	√	√	√					Once for PQT	N/A	N/A
Glass transition temperature	°C	Test method as supplied in validation dossier/ ITP	In accordance with the value and range reported in the validation dossier		√		√	√	√	√	√	√	√					Once for PQT	N/A	N/A
Hydrostatic collapse <sup>a</sup>	MPa	ISO 12736-1:2023, Annex C	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C						√									Once for PQT	N/A	N/A
Triaxial compression and creep <sup>a</sup>		ISO 12736-1:2023, Annex C	In accordance with the predicted value and range utilized in the system design		√				√									Once for PQT	N/A	N/A

<sup>a</sup> Not applicable for layers of a single material built up to <10 mm in thickness, which may be done in multiple applications.  
<sup>b</sup> Applicable only for inorganic syntactic foams where the hollow particle is a glass microsphere or other inorganic microsphere.  
<sup>c</sup> Not applicable for materials whose residual ash consists of more than the incorporated hollow particles (e.g. silicones).  
<sup>d</sup> May be tested on separate representative test coupon, if there is no convenient location for sampling on the item to be coated.  
<sup>e</sup> Applicable only for projects to be installed by R-lay.



Table 8 — Intermediate layer inspection <sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes									Frequency					
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production
				A	B	C	A	B	C	A	B	C	A	B	C			
Substrate temperature control after cooling	°C	Thermocouple	<80 °C	√	√	√									Each pipe or each item	Each pipe or each item	Three times per shift	
Thickness control	mm	PI tape / electronic equipment or as specified at PQT	As specified	√	√	√	√	√	√	√	√	√	√	√	Each pipe at 5 longitudinal locations; number of locations for items as agreed	Each pipe at 5 longitudinal locations; each item as agreed at PQT	Each pipe at each end plus an additional 3 longitudinal locations for the first 5 pipes of each shift; each item as agreed at PQT	
Hardness	Shore A or Shore D	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C		√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item	
Removal of release agent <sup>b</sup>	-	As qualified during PQT	-		√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item	
Visual	-	Naked eye (no magnification)	Free from visible large air traps, porosity, debris, knit lines, cavities, unwetted fillers and disbondment at interfaces and/or substrates Cosmetic surface faults may be accepted	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item	

<sup>a</sup> Intermediate layer inspection, if additional layers are still to be applied.

<sup>b</sup> If applicable per APS.

Table 9 — Final inspection <sup>a</sup>

Property	Units	Test method	Requirements	Applicable classes									Frequency						
				Class 1			Class 2			Class 3			Class 4			PQT	PPT	Production	
				A	B	C	A	B	C	A	B	C	A	B	C				
Total system thickness	mm	PI tape / electronic equipment or as specified at PQT	As specified	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe at 5 longitudinal locations; each item as agreed at PQT	Each pipe at 5 longitudinal locations for the first 5 pipes of each shift; each item as agreed at PQT	Each pipe at each end plus an additional 3 longitudinal locations for the first 5 pipes of each shift; each item as agreed at PQT
Ovality <sup>c</sup>	%	Caliper and PI tape	$(\varnothing_{outer,max} - \varnothing_{outer,min}) / \varnothing_{outer,pi} < 2\%$	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe; as agreed at PQT for items	1 <sup>st</sup> pipe then every 20 <sup>th</sup> pipe; as agreed at PQT for items	1 <sup>st</sup> pipe then every 20 <sup>th</sup> pipe at 8 circumferential locations; as agreed at PQT for items
Concentricity <sup>c</sup>	-	Straight edge ruler or electronic equipment at cutback area	±10 % of nominal thickness	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe at 8 circumferential locations; as agreed	Each pipe at 8 circumferential locations; as agreed at PQT for items	Each pipe or each item
Hardness	Shore A or Shore D	Test method as supplied in validation dossier	In accordance with the value and range reported in the validation dossier at 23 °C ± 2 °C		√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item
Cutback <sup>b</sup>	mm	Straight edge ruler, tape measure or electronic equipment at cutback area	As specified, if applicable	√	√	√	√	√	√	√	√	√	√	√	√	√	Each pipe or each item	Each pipe or each item	Each pipe or each item

<sup>a</sup> Final inspection after application of final layer.

<sup>b</sup> If applicable per APS.

<sup>c</sup> Applicable for pipe only, including bends.



## 9 Factory repair

### 9.1 General

Defects or damage in the applied system and applied systems that have been subjected to destructive testing shall be repaired.

NOTE Defects or damage can be caused by the application process, transportation, handling and storage at the system provider's yard or in the related storage area.

The party responsible for carrying out the repairs to the factory applied or fabrication yard applied system shall be clearly identified.

A detailed repair procedure, equipment and materials for repair shall be established and qualified prior to the commencement of the application of the system at the PQT stage in accordance with [7.3.3](#).

Repair materials shall have been previously validated in accordance with ISO 12736-1:2023, 7.4.

Defects or damage on the system shall be repaired and inspected using materials and procedures in accordance with the approved APS and ITP. The APS and ITP shall include at least:

- a) repair type and classification;
- b) damage sizing;
- c) requirements for removal, if required;
- d) repair materials;
- e) application procedures;
- f) inspections.

### 9.2 Damage/defect characterization

The repair procedure shall detail minimum / maximum areas for which each type of repair is acceptable.

Repair procedures for damage to the system can be categorized as:

- minor damage to insulation materials not penetrating to the ACC;
- minor damage penetrating to the steel;
- major damage greater than a specified surface area.

The requirements for each type of repair shall be documented in the APS.

### 9.3 Testing

The system that has been repaired in accordance with the agreed repair procedure shall be tested in accordance with the requirements as agreed to demonstrate that the repair does not have a detrimental effect on pipeline or subsea equipment performance.

Test requirements and acceptance criteria shall be agreed prior to the commencement of the PQT and documented in the ITP.

## 10 Final documentation

The system provider shall provide the final project documentation that at least contains:

- a) technical validation dossier in accordance with ISO 12736-1;

- b) APS including repairs and system removal procedures;
- c) ITP;
- d) PPT and/or PQT test report and records in accordance with [8.3](#);
- e) manufacturing inspection report, process parameter records and records in accordance with this document;
- f) raw material data sheet and SDS;
- g) raw material certificates of analysis;
- h) tally records and/or finished goods reports.

## 11 Handling, storage and transportation

### 11.1 Handling, storage and transportation at coating yard

If any of the raw materials are subject to specific transport and storage conditions, the party responsible for the delivery shall provide a full log of measurements verifying that these conditions have been met. This log shall cover the entire duration between departure from the premises of the delivering party and arrival at the system provider's work site.

In order to preserve the integrity of the system after its application, specifically during transport and installation, the system purchaser requires the system provider's expertise on the as-applied materials. The system provider shall provide an assessment of the vulnerabilities of the applied system against exposures to UV, high and low temperatures, humidity, atmospheric precipitation, condensation, particulate contamination, movement of the steelwork during transportation, expansion/contraction of the underlying steelwork due to temperature fluctuations, and procedures for protection against said vulnerabilities as necessary.

If the items to be insulated are pipes, the system provider shall provide the system purchaser with a recommendation for the stacking of coated pipes. This recommendation shall be supported by documented calculations demonstrating that the system will not be damaged due to the stacking loads.

The above is applicable for the system between passes (where applicable) as well as for the completed system.

### 11.2 Handling, storage and transportation at site

In order to preserve the integrity of the insulation system after its application, specifically during transport and installation, the system purchaser requires the system provider's expertise on the as-applied materials.

The system provider shall review the system purchaser's transport and installation procedures and shall advise the system purchaser of the acceptability of the anticipated loads for the integrity of the insulation system and its adhesion to the structure, item or component. This review shall include an assessment of the scheduled time between application of the insulation system and movement, transportation or installation of the structure, item or component.

In the event that the system provider cannot evaluate the acceptability of the transport and installation procedures, the system provider shall advise the system purchaser of the maximum loads, local and global, as well as maximum torsional and bending moment that the insulation system is able to withstand without incurring bulk damage or disbondment.

## **Annex A** (informative)

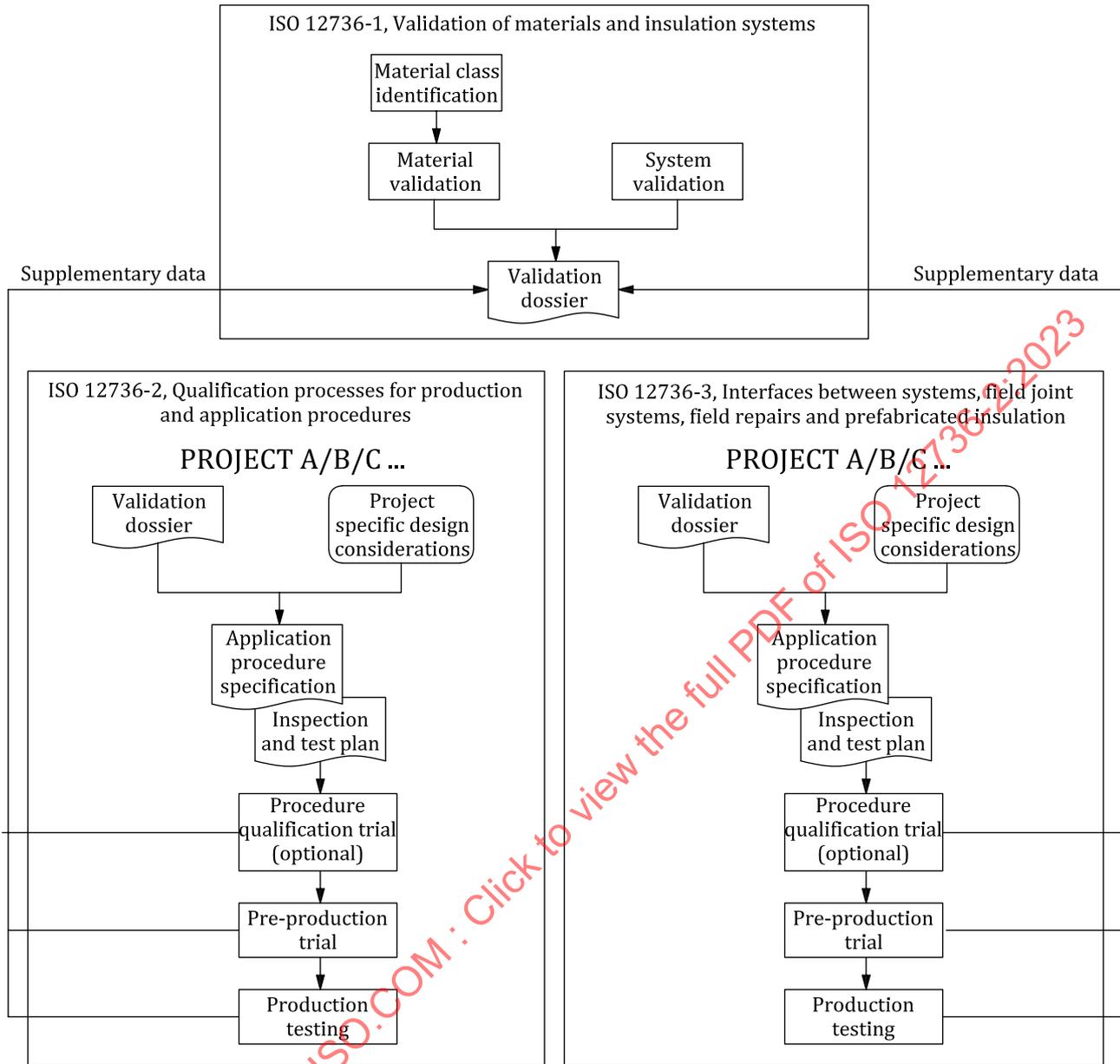
### **Guidelines for using this document**

#### **A.1 General**

The intention of this annex is to provide guidelines for using this document.

The relation between this document and ISO 12736-1 and ISO 12736-3 is represented in [Figure A.1](#).

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ISO 12736-1 focuses on requirements for validation of the material(s) and the wet thermal insulation system. The deliverable from ISO 12736-1 is a validation dossier for the wet thermal insulation system.

ISO 12736-2 focuses on the requirements for the project specific qualification, production, and repair of wet thermal insulation systems applied to pipelines in a factory and subsea equipment. The input for ISO 12736-2 is the validation dossier from ISO 12736-1. The results of the PQT, PPT and production testing are fed back into the validation dossier.

ISO 12736-3 focuses on the requirements for the project specific qualification and production of the interfaces between wet thermal insulation systems and field repairs. The input for ISO 12736-3 is the validation dossier from ISO 12736-1. The results of the PQT, PPT and production testing are fed back into the validation dossier.

**Figure A.1 — Relation between this document, ISO 12736-1 and ISO 12736-3**

## A.2 Material classes

Wet thermal insulation is provided by materials that are applied to the steel surface of pipes or subsea equipment. These materials may be applied in discrete layers which make up a system. In [Table 1](#), the

known classes of materials are identified. All materials presently used for wet thermal insulation are defined by this class system.

The performance of new innovative materials and technologies, when developed at an industrial level, should be compared to the current technologies and defined in accordance with the classes presented in [Table 1](#).

For systems with known track record, any deviations from required testing per ISO 12736-1 should be identified via a gap analysis and should be agreed between the system provider and the system purchaser. These deviations should be noted in the PO.

A material in a system is validated to the material maximum rated temperature and maximum rated pressure as specified by the system provider and as detailed in ISO 12736-1.

The system purchaser, on the basis of the validation dossier, can determine their own temperature and pressure limits for usage, which do not necessarily match to those given in the validation dossier either for materials and/or system.

### A.3 Design considerations

Design considerations for wet thermal insulation systems on pipes and subsea equipment as well as their interfaces are addressed in [Annex B](#).

Design considerations can be seen as advice for design of the steel structures to be insulated in order to avoid premature degradation of the insulation system or the structure itself by corrosion, and thermal and mechanical design considerations for the thermal insulation system.

### A.4 Qualification for production and application procedures

This document is dedicated to the qualification and quality control of the actual production of wet thermal insulation systems for a project.

For project specific qualification, a final APS and ITP are in place. The APS and ITP used for application of the wet thermal insulation system during the system validation are the basis of the final project specific APS and ITP. An explanation of any changes made from the validation phase should be presented to the system purchaser.

The minimum inspection and testing requirements to be included in the ITP for each class of material used in the system are described in [Clause 8](#).

In order to qualify a system for a project, a PPT and optionally a PQT are required, which are conducted in accordance with the approved APS and ITP. If agreed with the system purchaser, the PQT can be performed immediately prior to production, in which case the PPT is included in the PQT.

The requirements for PQT, PPT and production are described in [7.3.3](#), [7.3.4](#), [7.3.5](#), and [Clause 8](#). For a project with specific requirements outside the envelope of data contained within the validation dossier, the PQT can also be utilized to test and demonstrate project specific performance at the system purchaser's request as per [7.3.2](#). Examples of such project specific functional tests are simulated bending tests, impact tests, simulated service, cyclic loading or hydrostatic collapse.

For pipelines, a simulated tensioner or friction clamp tests are considered appropriate for installation by R-lay, S-lay or J-lay methods. However, the parameters and thus results for these tests are specific to the installation vessel to be used. This testing is typically performed by the operator of the installation vessel. The system supplier can be requested to produce and provide additional specimens during PQT to facilitate such testing or other specialist installation tests.

The multiple data points outputted from the clamp and tensioner tests are unique to the equipment type and are used to determine the equipment settings for a specific set of commercial project conditions (top tension and temperature). It is therefore considered that standardizing a test in the context of

system validation will not yield meaningful results that can be used to characterize the system for installation using any design of tensioner and clamp equipment. Performance can only be confirmed at the project stage.

The pipe axial load (top tension) is transferred to the equipment through the insulation system. A compressive squeeze load is applied through pads to the outside of the insulation to resist slippage between the pad and the insulation, with the insulation supporting the shear load.

In order for a system to be considered suitable for handling using the tensioner and clamp, small scale test results available as part of the validation dossier can help with the engineering assessment prior to commercial projects. The mechanical properties of the materials making up the system as well as the system shear capacity can be used to compare with an existing wet thermal insulation system with known performance. The following small scale tests listed in ISO 12736-1:2023, Table 2 in addition to the system shear adhesion strength testing as per ISO 12736-1:2023, 7.3.3.2 are useful:

- hardness;
- compressive strength;
- tensile strength;
- tear strength;
- DMA.

For project specific functional tests for pipelines, preferably a field joint and a field joint system in accordance with ISO 12736-3, should be included in the test piece to evaluate not only the system, but also the interface with the field joint system.

Typical project specific functional tests can be found in ISO 12736-1:2023, Table 3, such as:

- installation tests:
  - simulated bending test (see ISO 12736-1:2023, Annex D);
- in-service tests:
  - impact (see ISO 12736-1:2023, Annex F);
  - simulated service test (see ISO 12736-1:2023, Annex G);
  - hydrostatic collapse (see ISO 12736-1:2023, Annex C).

The testing program to be performed by the system provider in order to qualify the wet thermal insulation system for a project is usually specified by:

- the type of component to be insulated (e.g. pipes, jumpers, risers, subsea equipment);
- the project specific operating envelope (e.g. external pressure, operating temperature range, cooldown requirements);
- the project specific conditions (e.g. water depth, conditions at sea bottom, impact risk, service life);
- the project specific potential installation methods (J-lay, S-lay, R-lay, lay barge technical features).

In case the EHTC has a significant impact on the U-value, to be quantified by the system purchaser, the water management system should include agitation/circulation device to ensure a consistent EHTC throughout the test period. For such configuration, additional redundant sensors to measure the bulk ambient temperature (i.e. not located on the external surface of the system) should be considered.

The system provider is responsible for identifying the applicable tests as listed in [Table 2](#) to [Table 9](#). Additional testing can be requested by the system purchaser or specimens for testing by the operator of the installation vessel.

For systems applied to field joints and other interfaces, the test program for qualification is specified in ISO 12736-3.

In addition to qualification of the application process of the system, the application operatives should also be qualified. The requirements for qualification of the operatives are presented in [7.4.3](#).

## A.5 Factory repair

In the event of damage to the thermal insulation system, repair procedures are required, which are compatible with each material in the system or for the complete system.

The definition and characterization of repair type, damage sizing, requirements for system removal (if required), repair materials and application procedures are presented in:

- [Clause 9](#) for factory applied/fabrication site applied thermal insulation systems;
- ISO 12736-3:2023, Clause 9 for thermal insulation repaired in field and for field joint systems;
- ISO 12736-1:2023, 7.4 for validation of repair materials.

## A.6 Interfaces

It is possible that systems must interface. Interfaces between systems utilizing dissimilar materials can create challenges, for example with substrate preparation requirements, application temperatures and adhesion. An insulation system map can be used to identify interfaces between different material types at an early phase in order that suitable application procedures and acceptance criteria can be specified, tested and mutually agreed with all parties (i.e. material manufacturer, applicator, purchaser and end user) in accordance with ISO 12736-3.

A field joint system is defined as the coating applied after two pipe sections with coating cutbacks have been assembled, by welding, in the field or on a fabrication site.

The requirements for field joint system and field joint system qualification are described in ISO 12736-3:2023, Clause 7. Field joint system production testing requirements are described in ISO 12736-3:2023, Clause 8.

## A.7 Final documentation

The requirements for final documentation for factory applied/fabrication site applied system and field joint system are presented in [Clause 10](#) and ISO 12736-3:2023, Clause 10, respectively.

## A.8 Handling, storage and transportation

Additional handling, storage and transportation requirements can be applicable for thermal insulation systems, for example if an insulated structure is to be transported before the system has properly cured. The requirements of the system should also be identified by the system provider to the system purchaser at an early stage so that these can be incorporated in the handling, storage and transportation schedules.

## Annex B (informative)

### Guidelines on the design of wet thermal insulation systems on a project basis

#### B.1 General

Design of a wet thermal insulation system on a project basis should take into account both thermal and mechanical requirements during application, storage, installation and operation. Expected effects over the operational lifetime of the system which can affect thermal performance should also be taken into account in the initial start-of-life design, so that performance over the entire lifetime will meet the requirements.

#### B.2 Designing for thermal performance

##### B.2.1 General

Design of system for thermal performance is driven either by the OHTC or U-Value (steady-state operation) or the specified cool down time (transient operation) requirements. In cases where both have been specified, the design is driven by whichever requirement results in the higher system thickness.

With respect to material properties, U-value is driven by thermal conductivity only, while cool down time is driven by thermal conductivity (k-value), density and specific heat capacity ( $C_p$ ). All of these material properties are themselves dependent on temperature, time, pressure and the potential for water ingress.

During initial service, the material properties will vary through the insulation depth due to a temperature gradient caused by the inner heat from the pipe/structure contents and the outer cold sea water. As time progresses, the change and rate of change in these properties due to temperature, pressure and water absorption will also vary through the insulation depth due to both the temperature gradient and water absorption beginning from the outer layers and moving inwards. Therefore, it is of interest to break down the insulation system in elementary layers, each one having its own set of properties at a given time of operation, which will be called for design calculations.

Change in properties and geometry over time can occur due to thermal effects (e.g. material crystallization or additional cross-linking), water absorption or densification of the material (i.e. reduction in void space), which should be taken into account in the initial design. The following information should be considered:

- information on thermal effects can be obtained from the 12-month exposure testing in accordance with ISO 12736-1:2023, 7.2.2.3 and 7.2.2.4;
- information on the potential for water absorption can be obtained from the 12-month exposure testing in accordance with ISO 12736-1:2023, 7.2.2.2;
- information on material densification can be obtained from tri-axial creep testing in accordance with ISO 12736-1:2023, Annex C or appropriately instrumented simulated service testing.

Thermal effects, water absorption or densification of the material can result in increased material k-value and will reduce the insulative performance of the system over the product lifetime. The consequence of any thermal effects requires direct measurement of k-value. Direct measurement of k-value after long-term exposure testing can be problematic due to potential surface roughening and

distortion of samples, which requires removal of the outer material most affected by the exposure before testing. In addition, k-value testing above ambient temperature will be inaccurate due to the loss of any absorbed water during sample conditioning and establishment of steady-state conditions. The effect of water absorption and material densification on material k-values can be calculated utilizing Maxwell's or Bruggemann's theories<sup>[6]</sup>.

The consequence of any thermal effects on  $C_p$  or density requires direct measurement.  $C_p$  testing of water saturated samples exposed to long-term hot wet exposures will be inaccurate due to the loss of any absorbed water during sample heating.  $C_p$  is normalized by weight and is thus unaffected by material densification. The effect of water absorption on  $C_p$  can be estimated utilizing a simple linear mass fraction combination. The effect of water absorption and densification on material density can be estimated by using predicted mass change and volume change over the life span to calculate a new density value.

In interpreting the results from this testing, the effects during operation should be considered from a system perspective rather than a material perspective to avoid over-conservatism in the design. For example, while a small specimen of a single material can demonstrate high levels of water absorption in a short time-span in water absorption testing in service, water absorption over the system's lifetime will be rate limited due to outer solid barrier layers or colder surrounding material. The system designer should adequately justify and demonstrate consideration of these expected changes during service in their initial design.

### B.2.2 Steady-state operation

In designing for U-value, the relevant material property is thermal conductivity (k-value).

The U-value can be specified in reference to either the internal surface or external surface of the piece to be insulated.

Theoretical equations for heat transfer and numerical tools (e.g. FEA software) allow for the evaluation of U-value, considering temperature and time dependencies as well as complex geometries, in the case of structures. An iterative design process is performed until all criteria are met.

### B.2.3 Transient operation

In designing for heat-up or cool down time of the system, the relevant material properties are thermal conductivity (k-value), specific heat capacity ( $C_p$ ) and material density ( $\rho$ ). These properties together can be expressed as the thermal diffusivity of the material ( $\Psi$ ), which is the ratio of heat transfer to heat storage as showed in [Formula \(B.1\)](#):

$$\Psi = \frac{k}{C_p \cdot \rho} \quad (\text{B.1})$$

Thermal diffusivity of the material can be thought of as a measure of the thermal inertia of a material.

For this type of design, the properties of the pipe/structure contents should also be clearly specified by the system purchaser as their properties can also have a very significant effect on cool down time, and thus the required system thickness.

As with other material properties discussed in [B.2.1](#), the thermal diffusivity of the material is dependent on both temperature and possible effects during operation. The design should take these dependencies into consideration.

As per steady-state operation, theoretical equations and numerical tools (e.g. FEA software) allow for the evaluation of the cool down time, taking into consideration temperature and time dependencies, as well as complex geometries, in an iterative design process.

## B.3 Designing for mechanical performance

### B.3.1 General

Design of the system for mechanical performance is mainly driven by requirements for installation, but considerations for storage, transport and operation are also of importance. The size and weight of the piece to be coated has a significant effect on the magnitude of mechanical forces that the system will observe.

### B.3.2 Storage and transport

Loads due to handling and stacking should be appropriately accounted for in the design, or limitations clearly noted in product documentation. Loads can cause local deformation or collapse of the wet thermal insulation system. Handling can also result in bending of the system, which can cause cracking.

Thermal stresses due to temperature fluctuations and mismatch of thermal expansion coefficients between system and steel can also result in disbondment and/or crack formation. Temperature limitations in storage should be clearly identified.

The mechanical strength and toughness of the applied system, including interlayer bonds, should be sufficient to withstand these forces at the temperatures, which can be observed during storage and transportation. In addition, geometrical design of the applied system should be done to provide sufficient thermal performance in operation and to avoid areas which can act as stress concentrators (i.e. sharp angles) or areas which are easily damaged (i.e. thin protrusions).

The system should be appropriately designed for outdoor exposure (i.e. protection from water ingress and weathering), which can affect mechanical performance. This can be circumvented through properly specified storage procedures.

System ends and any uninsulated cut backs as necessary should be properly protected, for example by applying a temporary protection. System ends should also be designed to facilitate the field joint system application on site.

For materials that are sensitive to tear, additional precautions should be taken to protect the outer surface during storage and installation as well as during operation.

### B.3.3 Pipeline/Structure installation

#### B.3.3.1 General

Significant loads can be incurred on the insulation system during installation due to handling, especially for installations occurring in deep waters in which the components are heavier due to the thicker steel required to resist hydrostatic forces and, in the case of pipelines, the very long length that the installation vessel is required to support from the surface to the seabed.

#### B.3.3.2 Pipelines

In the case of pipelines, installation can happen via tow-in, J-lay, S-lay or R-lay. System selection, both factory applied and field joint systems, should be done with the installation method in mind as each installation method has varying levels of requirements. The system's mechanical properties should be sufficient to withstand gripping forces due to tensioner clamps, bending due to reeling, and potential impacts due to unexpected occurrences, such as dropped pipe or planned impacts due to burial, as specified by the project.

A non-exhaustive list of loads encountered for the three main installation methods is given below:

a) R-lay:

- bending loads created when the pipeline is reeled onto the vessel drum;

- local loads/strains at the area between joints generated by stiffness mismatches between mainline and field joint system;
  - tensioner squeeze and shear loads (back tension).
- b) S-lay:
- roller loads (fire line and roller boxes on stinger), especially for field joint systems;
  - tensioner squeeze and shear loads;
  - bending loads (in extreme cases).
- c) J-lay:
- clamp squeeze and shear loads;
  - accidental clash with bottom/guarding rollers.

Maximum OD, pipe weight and gripping with tensioners/friction clamps should be considered for systems applied to pipeline.

The friction of the system surface with any tensioner pads is also important to allow the pipe to be gripped securely. In some cases, application of a suitable outer “rough coat” with higher surface roughness/coefficient of friction might be necessary.

Axial shear stress resistance between and within system layers should be sufficient to allow for resistance to the pipe slipping in relation to the outer layer during vertical handling of single, double, and/or quad-joints as necessary.

Geometrically, the system should be designed with a continuous surface with no sudden large changes in OD resulting in edges that can cause disruption to pipe handling systems (e.g. tensioners and/or friction clamps during feeding of the pipe string). This is especially applicable at the location of the field joint system.

Significant mismatches in system stiffness along the length of the pipe for thick systems can result in kinking of the pipe string during bending operations, which should be considered.

The full-scale tests described in ISO 12736-1:2023, Annexes D, E, and F can be used to evaluate bending capacity, shear resistance and impact resistance of the systems.

### **B.3.3.3 Jumpers/Subsea equipment**

Lifting of subsea equipment during transport and installation can result in significant compressive forces on the applied insulation if lifting points and jigs have not been appropriately designed.

In addition, dependent on the geometry of the piece, the structure or portions of the structures can have a mechanical response during transportation (i.e. bending movements) and installation, especially when hydrostatic forces are applied. A structural analysis of the system should be performed taking into account the movements of the steel during transportation, the installation of the structure onto the seabed and the associated load cases.

## **B.3.4 Operation**

### **B.3.4.1 Pipelines**

In operation, mechanical requirements are generally low. Pipelines installed with burial or rock-dumping are well-protected from impacts. Pipelines installed exposed on the seabed can be exposed to trawls in areas with high fishing traffic. Impact resistance of the system over the lifespan of the pipeline should be considered. Fatigue resistance of the system can be a concern if significant wave action on the seabed is expected or in cases of pipeline spans. Fatigue is also a concern for risers,

although typically, fatigue of the steel pipe is the limitation, not the wet thermal insulation system. The full-scale test described in [Annex C](#) can be used to evaluate for fatigue resistance.

Axial shear stresses can occur due to thermal expansion of the pipe and vertical sections, such as risers. While these forces can be quite high, the stresses are generally low due to the large surface area of the pipe string. Axial shear testing of the system, as per ISO 12736-1:2023, Annex E, at elevated temperatures expected during service is necessary to gauge this risk.

### B.3.4.2 Jumpers/Subsea equipment/Subsea structures

In the case of structures, the insulation should be able to withstand the operational loads, such as abrasion (if in contact with the seabed) or induced vibrations (e.g. by slugging). Typically, in service, subsea equipment and their insulation are isolated from impacts by protective subsea structures.

During operation, due to temperature and/or water ingress, the system can experience volume changes, which can result in rupture due to potentially complex geometries. These aspects should also be considered in design.

## B.4 Field joint system design

Field joint systems should be designed to maintain the properties as close as possible to the system coating the pipe/subsea equipment, but are often limited by the field conditions and installation requirements. Fast application cycle times are required to ensure acceptable project economics, which limits the complexity of the field joint system design and the application process.

Compatibility of the field joint system and application process to the system coating the pipe/subsea equipment is necessary. The field joint system should also meet the pipeline mechanical performance requirements as described in [Clause B.3](#) or appropriate mitigations put in place. It is desired to achieve strong adhesion between the field joint and pipe/subsea equipment systems to minimize water ingress. In cases where this is not possible, the effect of potential water ingress on both the insulation and ACC should be considered.

In the case of pipelines/flowlines/risers, field joint coatings can have differing thermal properties and thus different thermal performance from the main pipe section insulation because of the need to maintain a similar thickness (see [B.3.3.2](#)). For steady-state operation, this results in slightly increasing or decreasing (typically increasing) the overall thickness to maintain the U-value of the full pipe string to the required value. For transient operation, the potential for a field joint area to reach the cool-down limit temperature first should be considered.

## B.5 Designing for anticorrosion compatibility

Compatibility and adhesion of the insulation to the ACC should be considered. The insulation materials and application method for the insulation materials should not interfere with the proper functioning of the ACC. At minimum, sufficient bonding or interaction to withstand the required mechanical loads is necessary as described in [Clause B.3](#).

## B.6 Designing for system application

The overall geometrical design should be planned to facilitate the application of the system without lack of continuity. Application of insulation sections should be designed in order to facilitate the application of any adjoining sections. Care should be taken for the sealing of any exposed faces.

In general, designs should be simple and excessive complexity should be avoided where possible (e.g. interfaces between dissimilar materials). If dissimilar materials coupling is not avoidable by design, the requirement for adhesion between the material should be considered during the design phase and the potential effect (or not) on cool down time or water ingress.