# Recommended Practice for Wet and Dry Thermal Insulation of Subsea Flowlines and Equipment

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## Contents

# Recommended Practice for Wet and Dry Thermal Insulation of Subsea Flowlines and Equipment

## 1 General

### 1.1 Scope

This recommended practice (RP) provides guidance for the performance, qualification, application, quality control, handling, and storage requirements of wet and dry thermal insulation for subsea applications in the petroleum and gas industries. This guideline also covers the inspection of the insulation, and the repair of insulation defects. For flowlines, the installation method is not defined and may be either S-lay, J-lay, or reel-lay. This guideline is intended to cover all three installation methods. This guideline also takes into consideration the design and structural handling of subsea trees, manifolds, pipeline end terminations (PLETs), flowline jumpers, etc. as it pertains to the placement of structure, sacrificial anodes, handling appurtenances, etc. to ensure the integrity of the insulation's construction.

Annex A specifies the minimum requirements for the performance qualification testing and inspection testing requirements for wet insulation systems (insulations in direct contact with seawater).

Annex B specifies the minimum requirements for the performance qualification testing and inspection testing requirements for dry insulation systems (insulations not in direct contact with seawater).

This document is not intended to address either installation procedures or proprietary fabrication of any particular insulation type.

### 1.2 Applicability

This RP is applicable to the following systems and components:

— flowlines and risers;

— christmas tree, valve block, and piping;

— manifold valves and pipework;

— PLET piping;

— jumpers (i.e. piping and bends);

— connectors and fittings;

— valves and chokes.

## 2 Normative References

The following reference documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 5L1, *Recommended Practice for Railroad Transportation of Line Pipe*

API Recommended Practice 5LW, *Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*

ASTM C518 [1], *Standard Test Method for Steady State Thermal Transmission Properties by Means of Heat Flow Meter Apparatus*

ASTM C1511, *Standard Test Method for Determining the Water Retention (Repellency) Characteristics of Glass Fiber Insulation*

ASTM D412*, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension*

ASTM D575, *Standard Test Methods for Rubber Properties in Compression*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D695, *Standard Test Method for Compressive Properties of Rigid Plastics*

ASTM D696*, Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C With a Vitreous Silica Dilatometer*

ASTM D792, *Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement*

ASTM D1621, *Standard Test Method for Compressive Properties of Rigid Cellular Plastics*

ASTM D2240, *Standard Test Method for Rubber Property—Durometer Hardness*

ASTM D2842, *Standard Test Method for Water Absorption of Rigid Cellular Plastics*

ASTM D4060, *Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*

ASTM E228, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

ASTM E831, *Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis*

ASTM E1269, *Determining Specific Heat Capacity by Differential Scanning Calorimetry*

SSPC-SP-5 [2]/NACE No. 1 [3], *Joint Surface Preparation Standard: White Metal Blast Cleaning*

# 3 Terms, Definitions, and Abbreviations

## 3.1 General

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

**3.1.1**
**aerogel**
Silica aerogel material used for pipe-in-pipe (PiP) insulation.

**3.1.2**
**applicator**
Person or team in charge of applying insulation material in equipment.

[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
[2] The Society for Protective Coatings, 40 24th Street, Sixth Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.
[3] NACE International, 1440 South Creek Drive, Houston, Texas 77084, www.nace.org.

**3.1.3**
**batch**
Quantity of insulation material produced in a single manufacturing run with identical processing parameters.

**3.1.4**
**certificate of conformance**
**COC**
Certificate of conformity issued by the manufacturer.

**3.1.5**
**coating**
Layer or layers of material(s) applied on the surface of pipeline and other subsea pressure-containing equipment for mechanical and corrosion protection, thermal insulation, weight control, or other purpose.

**3.1.6**
**company**
Organization that possesses ownership of supplied equipment.

**3.1.7**
**component**
Any self-contained part of a larger entity.

**3.1.8**
**contractor**
Organization responsible to purchaser for the insulation application.

**3.1.9**
**cooldown time**
Time taken for a fluid contained within a pipeline to reach a predetermined temperature from a specified start temperature when fluid flow is stopped.

**3.1.10**
**cutback**
Length of pipe left uncoated at each end for joining purposes (e.g. welding).

**3.1.11**
**design temperature**
Maximum and/or minimum temperature specified for the purpose of design.

**3.1.12**
**dimensions**
Overall physical component or assembly envelope dimensions (length × width × height).

**3.1.13**
**dry insulation system**
Insulation system not in direct contact with seawater.

**3.1.14**
**end-of-life**
Reference to a parameter of interest at the end of the specified field lifetime based on conditions given in tender documents.

**3.1.15**
**equipment data**
Technical, operational, and environmental parameters characterizing the design and use of equipment.

**3.1.16**
**failure**
Termination of the ability of an item to perform a required function.

**3.1.17**
**field joint**
Uncoated area that results when two pipe sections or a pipe section and a fitting with coating cutbacks are assembled, by welding or other means, in the field.

**3.1.18**
**hold**
**H**
Allowance of a purchaser or third-party inspection to observe a particular or a prescribed set of manufacturing steps planned to occur on a certain date; constituting a firm stoppage of the manufacturing schedule and procedures around the announced “hold start date.”

NOTE A hold may include sign-off and approval by the inspection party for the witness point that has taken place and manufacturing steps that have been observed; manufacturing cannot continue until inspection arrival and sign-off has taken place.

**3.1.19**
**holiday**
Discontinuity in a protective anticorrosion coating that exposes unprotected metal surface to the environment.

**3.1.20**
**inspection and test plan**
Minimum requirement of the activities for quality control and inspection agreed prior to commencement of work.

**3.1.21**
**inspector**
Authorized agent of purchaser.

**3.1.22**
**insulation system**
Any combinations of pretreatment, anticorrosion coating, insulation, and/or protective outer sheath as applicable to achieve the corrosion protection and insulation properties as described in this RP.

**3.1.23**
**item**
Any part, component, device, assembly, subsystem, functional unit, equipment, or system that can be individually considered.

**3.1.24**
**k-value**
Thermal conductivity coefficient of heat transmission that measures the heating or loss rate of insulation per surface area.

**3.1.25**
**layer**
Formulation of materials used by the applicator to build up the insulation system.

**3.1.26**
**lot**
Specific number of units of insulation elements (such as packages or sheets) used on insulation systems.

**3.1.27**
**manufacturer**
Organization responsible for the manufacture of insulation material(s).

**3.1.28**
**material data sheet**
Document containing data regarding the physical and mechanical properties of a particular material used in the insulation process and guidelines and recommendations for its processing and use.

**3.1.29**
**material safety data sheet**
**MSDS**
Document containing data intended to provide workers and emergency personnel with procedures for handling and working with the material in a safe manner and physical data such as flash point, toxicity, and first aid.

NOTE The MSDSs are usually issued in accordance with the applicable regulatory body.

**3.1.30**
**monitor**
**M**
Allowance of purchaser or third-party inspection to observe the manufacturing process at no particular prescribed step, with no interruption of manufacturing schedule or procedures, and without approval of manufacturing steps observed.

**3.1.31**
**operating temperature**
Maximum and/or minimum temperature experienced during installation and operation of the equipment.

**3.1.32**
**operator**
Company, corporation, enterprise, or part thereof that possesses ownership of supplied equipment.

**3.1.33**
**performance requirements**
Requirements from the end user dealing with overall operating conditions of the insulation system.

**3.1.34**
**precast and half shell insulation**
Insulation that is preformed and subsequently affixed to the equipment.

**3.1.35**
**preproduction test**
**PPT**
Testing conducted at the beginning of production to verify that the manufacturing procedure specification can be successfully followed onsite.

**3.1.36**
**procedure qualification test**
**PQT**
Qualification intended to demonstrate the suitability of the insulation system and method of application.

**3.1.37**
**purchaser**
Owner organiztion or the authorized agency that purchases the insulation system.

**3.1.38**
**qualification**
Process of confirming by examination, testing, or some other defining evidence that the insulation system meets specified requirements for the intended use as mutually agreed between the parties.

**3.1.39**
**raw material supplier**
Organization that provides based material used on insulation system.

**3.1.40**
**service life**
Specified maximum period of time the insulation system is in service.

**3.1.41**
**shelf life**
Specified maximum period of time the insulation is to be stored prior to installation under prescribed storage requirements.

**3.1.42**
**specification**
Document in which the functional, performance, operating characteristics, and limits of an item required by customer are stated.

**3.1.43**
**supplier**
Organization that provides and is responsible for insulation material.

**3.1.44**
**U-value**
Local quantity of heat that passes in unit time through unit area of a plate with a unit temperature variation along the path of heat flux.

NOTE This is also called the overall heat transfer coefficient.

**3.1.45**
**validation**
Confirmation that the operational requirements for a specific use or application have been fulfilled, through the provision of objective evidence.

NOTE Validation could be achieved by qualification testing and/or system integration testing.

**3.1.46**
**verification**
Confirmation that specified design requirements have been fulfilled, through the provision of objective evidence.

NOTE Verification could be achieved by calculations, design reviews, and hydrostatic testing.

**3.1.47**
**weight**
Item’s gross weight in air.

**3.1.48**
**wet insulation systems**
Insulation systems in direct contact with seawater.

**3.1.49**
**witness**
**W**
Allowance of a purchaser or third-party inspector to observe a particular or a prescribed set of manufacturing steps planned to occur on a certain date, constituting a 24-hour interruption of the manufacturing schedule and procedures around the announced “witness start date.”

NOTE Sign-off by the inspection party for the witness point takes place and manufacturing steps observed are approved; in the event that inspection does not arrive for witness within the announced time (or 24 hours thereafter), manufacturing is allowed to proceed.

## 3.2 Abbreviations

For the purposes of this RP, the following abbreviations apply.

| | |
|---|---|
| COC | certificate of conformance |
| H | hold |
| ID | inner diameter |
| ITP | inspection and test plan |
| M | monitor |
| MPS | manufacturing procedure specification |
| OD | outer diameter |
| PiP | pipe-in-pipe |
| PLET | pipeline end termination |
| PPT | preproduction test |
| PQT | procedure qualification test |
| UV | ultraviolet |
| W | witness |

# 4 General Requirements

## 4.1 Performance Requirements

### 4.1.1 Performance Specification

It is recommended that the purchaser specify the performance requirements to the supplier as applicable for the insulation system and minimally include the following.

### 4.1.2 General Requirements

General requirements for insulation should include but not be limited to:

a) U-value and specific reference [i.e. indicate whether the U-value is based upon inner diameter (ID) or outer diameter (OD) basis];

b) required cooldown time;

c) storage requirements;

d) design and operating temperatures (maximum and minimum);

e) design water depth;

f) production fluid properties (e.g. density, thermal conductivity, heat capacity, flowrates);

g) seawater temperature (at surface and bottom);

h) service life;

i) environmental conditions during storage and handling;

j) corrosion protection coating details;

k) maximum dry service temperature;

l) maximum wet service temperature;

m) insulation application method.

#### 4.1.3 Flowline, Riser, and Pipeline Requirements

Information about the flowline, riser, and pipeline to be insulated should include but not be limited to:

a) length,

b) wall thickness,

c) ID,

d) pipe material,

e) installation method,

f) dynamic/static application,

g) anticorrosion coating field joint cutback length,

h) line pipe insulation cutback length and geometry specified by design,

i) compatible field joint insulation type and geometry.

#### 4.1.4 Insulation Requirements

Insulation requirements should include but not be limited to dimensional drawings, the details of the components to be insulated, and the insulation to be applied.

Unless otherwise specified by the purchaser, items such as subsea lifting points; pad-eyes; closure (flange) bolting; structural bolting; electronic sensors and instrumentation; all ROV access, override, and hydraulic-stab locations; and all other specialty hardware items should NOT be insulated, and access to these areas and features should be maintained.

If insulation is to be applied in close proximity to the above items, the installer should work with the equipment vendors and/or purchaser to determine the minimum setback distances and clearances to be maintained for the above items.

NOTE Simple sketches and/or guidance instructions to the installer may suffice for this purpose.

## 4.2 Design Life Requirements

The insulation coating to be used should be suitable for the specified application and for the design and life of the system. Design life requirements should minimally:

a) be suitable for long term use (design life);

b) be capable of maintaining acceptable insulation properties at the specified maximum water depth;

c) be capable of withstanding external water pressure equivalent to the specified maximum water depth (specified maximum water depth = actual water depth × company required safety factor);

d) be produced in such a manner that the integrity of the anticorrosion layer is maintained;

e) be suitable for use with cathodic protection;

f) be suitable for design and ambient temperatures;

g) be designed to allow thermal expansion/contraction of the pipeline/flowline/riser/equipment;

h) be installable by proposed installation method;

i) be manufactured of materials that should minimize contribution to biological oxygen demand either by direct degradation or via leachant release;

j) be designed to achieve the specified cooldown period in a shut-in condition, starting at the specified initial shut-in temperature, and finishing at the specified final shut-in temperature. It should be assumed in all cases that the internal bores/voids of components are gas filled;

k) be suitable for application on all relevant surfaces and shapes.

Insulation coating qualification matrices and inspection test frequencies for wet and dry insulations are detailed in Annex A and Annex B, respectively.

## 4.3 Material Requirements

### 4.3.1 General

As agreed between the parties, materials used for insulation should be clearly marked with the following details:

a) name of supplier;

b) material identification;

c) batch number;

d) date of manufacture;

e) quantity;

f) manufacturing compliance (requirements to be agreed between company and manufacturing, e.g. serial number, etc.);

g) shelf life and storage requirements;

h) safety data;

i) lot number (if applicable);

j) waste disposal plan.

### 4.3.2 Technical Data

The contractor should obtain from the supplier copies of their most recent technical data sheets describing the product, its general performance, safety and environmental considerations, and application requirements. Supplier certification for each batch of product used is also recommended to be provided to contractor. The material characteristics and performance information may include:

a) density;

b) thermal conductivity;

c) temperature limitation (including limitations in temperature cycling from maximum to minimum temperature);

d) tensile strength and elongation at break;

e) compression strength;

f) hardness;

g) abrasion (including compliance test method);

h) fluid permeability (seawater absorption);

i) aging test with service life estimation;

NOTE Depending on the type of insulation material, clear determination and acceptance criteria are provided by the manufacturing and approved by the company.

j) thermal diffusivity;

k) ultraviolet (UV) resistance;

l) hydrostatic crush strength;

m) maximum uncovered exposure to direct sunlight;

n) fracture toughness (based on type of insulation);

o) specific heat.

### 4.3.3 Raw Material Requirements

The insulation raw materials acceptable for use should be:

a) in the supplier’s original, unopened, and undamaged containers;

b) stored in a dry, clean location, at a temperature in accordance with the supplier’s recommended temperature range;

c) acceptable with respect to product quality control test results;

d) applied within the supplier’s recommended shelf life;

e) recertified only by the raw material supplier, if possible, and only if agreed by the parties.

### 4.4 Field Joints Requirements

Field joints are a particular area of concern and often a source of problems for wet and dry insulation as possible areas for heat loss and cathodic shielding. A field joint application and installation procedure should be agreed among the supplier, operator, and applicator of insulation system prior to commencement of work.

## 5 Application Process and Quality Control

### 5.1 General

It is recommended that the contractor demonstrates that the insulation system and method of application will fulfill the specific project requirements

### 5.2 Quality Control of Raw Materials

The contractor should obtain from the insulation supplier a certification for each batch or lot of raw material. The certification should as a minimum include the following:

a) product name, designation, batch number, and/or lot number;

b) product quality control test results for each batch and lot number. A certificate of conformance (COC) may be substituted for test results.

Additionally, it is recommended that at least one (1) test per batch of material be conducted after shipping to manufacturing facility or contractor work site (where product is mixed, molded, or fabricated to the geometric shapes needed for the application) to ensure it meets the specified properties, unless otherwise approved by company. The intent of this test is to ensure that the raw materials meet insulation-specified properties prior to application.

Finally, field joints, precast components, and half shells are of particular concern, and care should be taken during the coating process.

### 5.3 Procedure Qualification Test

#### 5.3.1 General

A procedure qualification test (PQT) is intended to demonstrate the suitability of the insulation system and methods of application.

Test methods, acceptance criteria, and testing frequencies for the PQT should be specified in the inspection and test plan (ITP).

The PQT should be carried out on geometries components or applications similar to those of the project. Previously documented PQT reports may be used for design validation, as mutually agreed between parties.

The PQT should include tests to prove the integrity of the techniques proposed for repairs. The tests should include, as a minimum, the following tests: adhesion, density, and hardness. All repair materials should be suitable for service and should be demonstrated to be fully compatible with the parent insulation material.

The PQT should be performed on field joints reporting the same data as PQTs and preproduction tests (PPTs) without field joints.

### 5.3.2 PQT Qualification

The contractor should provide qualification documentation as part of the PQT as follows:

a) description of the insulation system, including its overall thickness required to fulfill the thermal performance requirements stated by the company, with the corresponding design data;

b) test data for the insulation material qualification;

c) test data for the insulation system qualification;

d) qualification data for the application process.

Tests and qualification for the PQT data should not only prescribe to, but also verify the following:

a) water absorption;

b) creep or compression set;

c) heat transfer coefficient;

d) thermal insulation performance test—a full size test should be performed to verify thermal performance of the finish applied product and allow comparison with theoretical cooldown analysis;

e) differential temperature effects (i.e. external seawater temperature versus internal fluid temperatures);

f) thermal expansion effects;

g) compressibility;

h) adhesion between insulation coating systems, bonding systems, and anti-corrosion coating systems;

i) accelerated ageing tests of all materials and combinations of materials;

j) mechanical strength (tensile, compression, bending, etc.);

k) material and cathodic protection system compatibility (for systems without an anticorrosion coating under the insulation).

## 5.4 Manufacturing Procedure Specification

### 5.4.1 General

A manufacturing procedure specification (MPS) should be qualified by a PQT. The manufacturing operation should be performed by the applicator in accordance with the MPS.

### 5.4.2 MPS Documentation

The MPS should document the following:

a) scope,

b) detailed description of the manufacturing process (i.e. step by step),

c) PPT inspection and ITP,

d) critical process parameters that affect material properties,

e) ITP incorporating acceptance criteria,

f) handling and storage procedures.

All critical parameters recorded during the PQT should be implemented during production. All applicable storage procedures, mixing procedures, application procedures, and potting and curing times should be strictly adhered to when applying the insulation systems. All surfaces to be permanently coated should be prepared in accordance with the insulation manufacturers' recommendations in order to ensure good adhesion. Areas of components that are not to be insulated because it would be detrimental to their function should be suitably masked and protected during application of the insulation system. Areas such as threads, nuts, flange interfaces, etc. that may require to be disassembled for repair should be coated in a suitable release compound, if practical, prior to applying the insulation coating system to allow for subsequent ease of removal.

Additionally, care should be taken in applying the insulation system that produce heat (exothermic reaction) during the mixing process to avoid cracking of the coating as a result of differential cooling (i.e. applying a thick coating to a cold surface). The thickness of the insulating coating should be measured at regular interval using a suitable method (i.e. magnetic induction, eddy current, or ultrasonic) on all coated components.

## 5.5 Inspection and Test Plan

The ITP should be prepared by contractor and approved by company. It is recommended that the ITP is presented as a flowchart illustrating the inspection points, and its relative location in the process, where conformance of characteristics is recommended. The ITP should identify all inspection activities and tests (including frequency and acceptance criteria). The contractor should include additional inspection points for the contractor's own verification of quality, which will be subject to approval.

A column for the company to identify the following inspection points is recommended to be included on the ITP:

a) inspection points;

b) M (monitor), W (witness), and H (hold) and what they mean in terms of notification requirements;

c) notification of W or H points at domestic locations should be given no less than 10 calendar days in advance;

d) notification of W or H points at foreign locations should be given no less than 15 calendar days in advance.

## 5.6 Operators Certification

The contractor should ensure that the personnel involved in the insulation operation are trained and qualified. The qualification training program and training records should be available for company review.

## 5.7 Preproduction Test

A PPT should be performed at the beginning of production at the production site to verify the PQT. The "PPT start" point is a M, W, or H point for the purchaser or third-party inspector. The PPT should be carried out in the presence of a purchaser representative and should follow the ITP. PPT may include series of nondestructive or destructive quality control tests. If destructive tests are required, it is recommended that the purchaser increases the total quantity of insulation to be acquired.

### 5.8 Production Tests

The contractor should conduct inspection and testing during production in accordance with an ITP to verify the surface preparation and insulation application. A COC may be substituted for test results.

### 5.9 Test Failure

In the event that a parameter measured fails to meet the acceptance criteria for a specified test, the parameter may be reevaluated and/or rechecked.

### 5.10 Process Certification

The contractor should ensure that process equipment/methods are consistent with PQT. All equipment should be operable with maintenance records.

## 6 Handling and Storage Requirements

### 6.1 General

Handling, storage, and transportation procedures should be according to supplier's recommendation. This information should be included in supplier's fabrication package specification.

The supplier should provide effective packaging for fabricated insulation in order to prevent damage during normal storage and shipment via road trailer or sea container.

### 6.2 Purchaser Free Issued Materials

For piping, the pipe identification (mill and heat number) should be entered into the contractor's pipe tracking system while unloading. The tracking system should allow for a complete audit trail of the pipe from receipt to shipping through the insulation process.

During the storage and insulation application, the pipe should be handled in a way to prevent damage to the pipe body and ends.

### 6.3 Insulation Materials Handling

Insulation materials should be handled and stored in accordance with applicable safety regulations and insulation supplier recommendations. Insulation materials should not be used after the expiration date unless recertified by the manufacturer and approved by the purchaser. All material with damaged packaging, with an expired shelf life, without full traceability, or with suspected contamination/deterioration should be rejected.

### 6.4 Final Product Handling and Storage

Insulated parts should be handled in accordance to supplier's recommendations. Insulated parts should be handled using wide soft slings, padded end hooks, or padded lift forks. Handling devices should not contain any sharp pointed parts such as bolts or rivets. Exposure to sunlight and other environmental elements may affect the material performance and should be considered when storing insulated parts.

Insulated parts temporarily stored and handled should be protected from damage. Pipe should be loaded in accordance with API 5L1 or API 5LW if applicable. Loading and shipping by any other mode of transport should conform to the applicable standards and comply with government regulations.

# 7 Documentation

## 7.1 Documentation Prior to Commencement of Work

Documentation prior to commencement of work should include the following:

a) quality plan and ITP,

b) project-specific MPS (including handling and storage procedures),

NOTE Other project specific MPS documentation may include environmental controls, insulation procedure qualification, and personnel qualification.

c) insulation material and system qualification reports,

d) PQT,

e) material certificates,

f) piping/equipment tracking systems,

g) PPT results.

## 7.2 Documentation at Delivery of Work

Documentation at the time of delivery should include the following:

a) approved copies of documents identified in 7.1,

b) unique identification number of each coated equipment/pipe,

c) production testing results in addition to individual test results.

## 7.3 Documentation Submittal Schedule

A documentation submittal schedule, as presented in Table 1, is recommended.

**Table 1—Documentation Submittal Schedule**

| Document Description | With Quote | After Purchase Order | After Final Delivery |
|---|---|---|---|
| Fabrication and delivery schedule | X | | |
| Manufacturing procedure specification | X | | |
| Inspection and test plans | | X | |
| Insulation data sheets | X | | |
| As-built manufacturing data book<br>Manufacturing data<br>Qualification and testing data | | | X |
| Project deliverables<br>Daily logs and reports<br>Quality control documents | | | X |

## 7.4 Marking

General marking requirements are to be provided by the supplier and agreed upon by the company. The supplier should maintain documentation for each raw material production run including, but not limited to, the following:

a) numbers for each batch of raw material,

b) production run dates.

The following information should be labelled onto each insulation package using a labeling method that should contrast sharply with the insulation material background color:

a) supplier part number,

b) supplier name,

c) orientation of the insulation material (if applicable) for installation (i.e. “This Side Up”).

# Annex A
(normative)

# Recommended Performance Qualification Testing and Inspection Testing Requirements for Wet Insulation Systems

## A.1 Qualification Testing

This annex includes recommendations for performance qualification testing and inspection testing requirements for wet insulation systems.

## A.2 Performance Qualification Testing for Wet Insulation Systems

### A.2.1 General

This section identifies the minimum recommendations for performance qualification testing to be used for wet insulation systems. Table A.1 identifies the recommended performance qualification matrix for wet insulation systems.

**Table A.1—Performance Qualification Matrix for Wet Insulation Systems**

| Material Property | Test Specification [c] | Room Temp. | Max Temp. | Min Temp. | Aged Values [a] |
|---|---|---|---|---|---|
| Thermal conductivity | ASTM C518 | x | x | | x |
| Specific heat capacity | ASTM E1269 [b] | x | x | | x |
| Water absorption | ASTM D575 and/or D2842 | x | x | | x |
| Density | ASTM D792 | x | | | x |
| Tensile properties | ASTM D638 and/or D412 | x | x | x | x |
| Hardness | ASTM D2240 | x | | | x |
| Compressive strength | ASTM D695 or D575 or D1621 | x | x | x | x |
| Hydrostatic compression | Manufacturer specification | x | x | | |
| Test adhesion | See A.2.6 | x | | | |
| Coefficient of thermal expansion | ASTM E228, E831, and/or D696 | | x | x | |
| Abrasion | ASTM D4060 | x | | | |
| Weathering and UV resistance | See A.2.3 | x | | | |
| Bend test | See A.2.4 | x | | | |
| Fatigue testing | See A.2.5 | x | | | |

[a] See A.2.2.

[b] If agreed between parties a test procedure based on ASTM C351 (withdrawn) could be used.

[c] Alternative test specifications may be proposed by the supplier for approval.

### A.2.2 Aging

The purpose of the aging test is to determine and help predict the properties of the insulation materials over its lifetime in the field and to provide evidence that the insulation material satisfies the thermal insulation performance as expected/advertised. It is the responsibility of the contractor to provide suitable material and system aging test procedures that qualitatively represent the design life of the insulation systems in subsea environments.

### A.2.3 Weathering and UV Resistance

Real-time weathering and UV resistance data can be accepted. The procedure should be mutually agreed between the parties.

### A.2.4 Bend Test (Flowlines and Risers)

A bend test should be conducted on a full size, production quality sample (including a field joint) to verify adequate bonding and integrity between the field joint, the parent material, and the anticorrosion coating.

The qualification should include bending and straightening trials to validate the use of the system for S-lay, reel-lay, and J-lay installation. The full-scale bending test arrangement should be such that it simulates the cycles of reeling and straightening to which a pipeline would be subjected during the installation phase. The radius of curvature of the guiding shoe should be equal to or less than the radius of the installation vessel reel hub and it should be determined upon selection of the installation contractor.

The test pipe sample should be cooled to approximately 4 °C (40 °F) prior to start of bending and the test sample should be left on the reel in the bent position overnight.

The field joint should be oriented such that the interface between the field joint and the parent material is located at the point of maximum strain. To simulate the strain experienced as the pipe passes through the straightener, the test string should be reverse strained to a curvature that is estimated to leave the pipe straight when not under load. This bend-straighten cycle should be performed four times.

After the bending is complete, the coating and field joints should be visually checked. No visible cracks should be allowed, and there should be no disbondment between the anticorrosion coating and the insulation material or between the field joint and parent insulation material. Field joint sections should be cut and sectioned to determine if internal cracks have occurred.

### A.2.5 Fatigue Testing (Optional for Risers)

A dynamic fatigue testing should be performed to determine the dynamic integrity of the insulation system. The sample should be a minimum of 6 m (20 ft) long and should incorporate the proposed field joint. The test should be performed incorporating the following parameters:

a) 0.2 % strain;

b) 1,000,000 cycles at frequency no greater than 10 Hz;

c) ambient temperature and atmospheric pressure.

The acceptance criteria should be that there is no cracking or disbondment of the insulation upon visual inspection.

### A.2.6 Adhesion Test

Adhesion between all interfaces of the insulation system, including field joint and precast and half shell insulation, should be verified. Testing should be performed as agreed between the parties.

The test procedure should be submitted to purchaser for approval.

## A.3 Inspection Recommendations for Wet Insulation Systems

### A.3.1 General

This section identifies the minimum recommendations for inspection of wet insulation systems. Table A.2 identifies the recommended inspection frequency and acceptance criteria for wet insulation systems.

**Table A.2—Inspection Frequency and Acceptance Criteria for Wet Insulation Systems**

| Property | Inspection Frequency | Acceptance Criteria |
|---|---|---|
| Environmental conditions | Once per hour | >3 °C (5 °F) above dew point |
| Surface condition before preparation | Each pipe/component | Free of holidays, damage oil, and grease deposits |
| Surface condition after abrasion [a] | Each pipe/component | Uniform abrasion |
| Primer ratio [a] | Each mix | ±2 % of coating supplied stated ratio |
| Primer application | Each pipe/component | Supplier to advise recommendation |
| Preheat temperature | Each pipe/component | Supplier to advise recommendation |
| Sample for gel time and mixture quality [a] | Each shift | Supplier to advise |
| Cutback length | Each pipe/component | Company to advise |
| Mold temperature | Each pipe/component | Supplier to advise |
| Mold removing time [a] | Each pipe/component | Supplier to advise |
| Visual examination | Each pipe/component | Per A.3.3 |
| Thickness examination | Each pipe/component | As per ITP agreed with purchaser/company (e.g. target thickness ±5 % nominal: >1 % target thickness) |
| Hardness examination | Each pipe/component | Supplier to advise |
| Sounding [a] | Each pipe/component | No audible change in tone |
| Adhesion | Once per shift | Supplier to advise |
| Density | Once per shift | Supplier to advise |
| Cross section examination | Twice per shift | As per agreements with client on ITP (e.g. free of delamination, disbondment, porosity, voids, or blisters), samples to come from first and last specimens |
| Thermal conductivity [a] | 1 in 400 pipes and/or material batch | Company to advise |
| Measure concentricity at the pipe ends | Each pipe/component | Company to advise |

[a] Requirement based on type of insulation.

### A.3.2 Visual Examination

Total (100 %) visual examination should be performed on each insulated component. The coating should be free from blisters, frosting, holidays, scratches, voids, porosity, or any other irregularities that are a detriment to the insulation purpose and the coating should have a uniform color.

There should be no visual evidence of disbondment between the anticorrosion coating and the steel and between the anticorrosion coating and the insulation layer.

### A.3.3 Inspection and Test Plan

See 5.5.

# Annex B
(normative)

# Recommended Performance Qualification Testing and Inspection Testing Requirements for Dry Insulation Systems

## B.1 Qualification Testing

This annex includes recommendations for performance qualification testing and inspection testing requirements for dry insulation systems.

## B.2 Performance Qualification Testing for Dry Insulation Systems

### B.2.1 General

This section identifies the minimum recommendations for performance qualification testing to be used for dry insulation systems. Table B.1 identifies the recommended performance qualification matrix for dry insulation systems.

**Table B.1—Performance Qualification Matrix for Dry Insulation Systems**

| Material Property | Test Specification [e] | Room Temp. | Max Temp. | Min Temp. | Aged Values [a] |
|---|---|---|---|---|---|
| Thermal conductivity | ASTM C518 [b] | x | x | | x |
| Specific heat capacity | ASTM E1269 [c] | x | x | | x |
| Density | ASTM D792 [d] | x | | | x |
| Installed thickness tolerance | See B.2.5 | x | | | |
| Hydrophobicity [e] | See B.2.6 | x | | | |
| Water retention | ASTM C1511 | x | | | |
| Tensile properties | ASTM D638 and/or D412 | x | x | x | x |
| Compressive strength | ASTM D695 | x | x | x | x |
| Bend test | See B.2.7 | x | | | |

[a] See B.2.2.

[b] See B.2.4.

[c] If agreed between parties, a test procedure based on ASTM C351 (withdrawn) could be used.

[d] See B.2.3.

[e] Alternative suitable methods may be proposed by supplier.

### B.2.2 Aging

See A.2.2.

### B.2.3 Density

Dry insulation density testing is conducted depending on the dry insulation type. The supplier should advise on the type of insulation density testing to be used.

### B.2.4 Thermal Conductivity Testing

Thermal conductivity testing should be performed in accordance with ASTM C518 or an equivalent test to be proposed by the supplier and approved by the company.

The k-value of the insulation should be measured per single ply (if applicable). Two measurements should be made per lot of manufactured insulation materials. Measurements should be performed and recorded for all manufactured lots.

### B.2.5 Installed Thickness Tolerance

Dry insulation diameter measurements should be based on diameter of reference pipe (OD of internal pipe for PiP systems). The thickness is to be within ±5 % of nominal.

### B.2.6 Hydrophobicity Testing

If applicable, a hydrophobicity testing procedure should be advised by the supplier.

Two measurements should be made per lot of manufactured insulation materials. Measurements should be performed and recorded for all manufactured lots. The test should include spraying the surface of the insulation with a small stream of water and examining the bead geometry of the surface. Beading of the water constitutes a pass.

### B.2.7 Bend Test (Flowlines and Risers)

See A.2.4.

## B.3 Inspection Recommendations for Dry Insulation Systems

### B.3.1 General

This section identifies the minimum recommendations for inspection of dry insulation systems. Table B.2 identifies the recommended Inspection frequency and acceptance criteria for dry insulation systems.

### B.3.2 Visual Examination

Total (100 %) visual examination is required. Gaps in the insulation, spacer requirements, and other items that constitute the dry insulation system should be visually inspected. The supplier should provide recommendations on the minimum visual examination requirements.

### B.3.3 Inspection Test Plan

See 5.5.

**Table B.2—Inspection Frequency and Acceptance Criteria for Dry Insulation Systems**

| Property | Inspection Frequency | Acceptance Criteria |
|---|---|---|
| Thickness on assembled package | Per lot | Supplier to advise |
| Thermal conductivity | Per lot | Supplier to advise |
| Hydrophobicity [a] [b] | Per lot | Water must bead |
| Density | Per lot | Supplier to advise |
| Width and length [a] | Twice per shift (beginning and end) | Supplier to advise |
| Overall dimension before installation [a] | Per shift | See B.3.4 |
| Overall dimension after installation [a] | Per shift | See B.3.5 |

[a] If applicable.

[b] AEROGEL only.

### B.3.4 Ply Widths and Lengths

If the insulation system is made of insulation prepackages or from an assembly of plies of insulation material, it is recommended that plies are cut to size to ensure that the final assembly, when wrapped around the flowline, completely covers the pipe. As a result each ply in the stack-up must be cut to a precise size. The ply cutting is automated and requires validation of cutting accuracy at the beginning and the end of each shift. For one assembled insulation package, at the beginning and end of each shift, the dimensions (length and width) of individual plies should be measured and recorded. All plies, however, should be checked visually using the assembly tooling.

The supplier should advise the individual ply dimensions and tolerances.

### B.3.5 Assembled Insulation Thickness

If the insulation system is made of insulation prepackages, the total thickness of the assembled thermal insulation package should be checked using a simple reference probe. Measurements should be made when the assembled thermal insulation package is laid flat on a table. Insulation thickness should be measured at least once on each assembled panel. At a minimum, it is recommended that the first panel and the last panel of each manufacturing shift should be recorded.

The supplier should provide recommendations for the assembled package thickness and tolerances.

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[2] API Specification 5L, *Specification for Line Pipe*, 44th Edition

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[5] ASTM D3418 [4], *Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry*

[6] ASTM E228, *Standard Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer*

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[11] SSPC-SP-1 [7], *Solvent Cleaning*

[12] SSPC-SP-10/NACE No. 2, *Near-White Blast Cleaning*


[4] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

[5] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

[6] NACE International, 1440 South Creek Drive, Houston, Texas 77084, www.nace.org.

[7] The Society for Protective Coatings, 40 24th Street, Sixth Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

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