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

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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.

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

Annex B specifies the minimum recommendations 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.

This RP is not a prescriptive document. If agreed between Company and Supplier, prescriptive requirements for wet insulation systems presented in ISO 12736 could be utilized.

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.

ASTM C165, *Standard Test Method for Measuring Compressive Properties of Thermal Insulations*

ASTM C167, *Standard Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations*

ASTM C303 , *Standard Test Method for Dimensions and Density of Preformed Block and Board–Type Thermal Insulation*

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 C1763, *Standard Test Method for Water Absorption*

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 D5034, *Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)*

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

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*

ISO 12736[4], *Petroleum and natural gas industries — Wet thermal insulation systems for pipelines and subsea equipment Part 1: Validation of materials and insulation systems*

ISO 12736, *Petroleum and natural gas industries — Wet thermal insulation systems for pipelines and subsea equipment Part 2: Qualification processes for production and application procedures*

ISO 12736, *Petroleum and natural gas industries — Wet thermal insulation systems for pipelines and subsea equipment Part 3: Interfaces between systems, field joint system, field repairs and prefabricated insulation*

[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.
[4] The International Organization for Standardizations, Chemin de Blandonnet 8 CP 401 1214 Vernier, Geneva Switzerland

3 Terms, Definitions, and Abbreviations

3.1 General

For the purposes of this document, the following apply.

3.1.1
aerogel
A nanoporous high performance dry insulation material made from amorphous silica

3.1.2
applicator
Person or team in charge of applying or installing the insulation material.

3.1.3
Batch/lot
Quantity of insulation material produced in a single manufacturing run with identical processing parameters.

3.1.4
company
Organization that possesses ownership of supplied equipment to be insulated.

3.1.5
component
Any self-contained part of a larger entity.

3.1.6
contractor
Organization responsible of purchasing the insulation application.

3.1.7
cooldown time
Time taken for a fluid contained within the equipment to reach a predetermined temperature from a specified start temperature when fluid flow is stopped.

3.1.8
cutback
Length of pipe left uncoated at each end for joining purposes (e.g., welding).

3.1.9
dry insulation system
Insulation system not in direct contact with seawater or other liquid ambient environments.

3.1.10
Equipment
Refers to subsea trees, manifolds, pipelines, pipeline end terminations (PLETs), flowline jumpers, mid-line structures, etc. as it pertains to the placement of structure, sacrificial anodes, handling appurtenances, etc. to ensure the integrity of the insulation's construction.

3.1.11
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

3.1.12
Hold point
H
point in the manufacturing process 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 point may include a 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 sign-off has taken place.

3.1.13
holiday
Discontinuity in a protective anticorrosion coating that exposes unprotected metal surface to the environment.

3.1.14
inspector
Authorized agent of Company or Contractor.

3.1.15
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.

3.1.16
item
Any part, component, device, assembly, subsystem, functional unit, equipment, or system that can be individually considered.

3.1.17
monitor
M
Allowance of Company or third-party inspection to observe the manufacturing process at no prescribed step, with no interruption of manufacturing schedule or procedures, and without approval of manufacturing steps observed.

3.1.18
precast and half shell insulation
A form of insulation that is preformed and subsequently affixed to the equipment.

3.1.19
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.

3.1.20
raw material supplier
Organization that provides base material used to manufacture the insulation system.

3.1.21
service life
Specified maximum period of time the insulation system is in service.

3.1.22
shelf life
Specified maximum period of time the insulation can be stored prior to installation under prescribed storage requirements.

3.1.23
supplier
Organization that provides the insulation material.

3.1.24
U-value
U value, also known as thermal transmittance, is the rate of transfer of heat through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. The units of measurement are W/m^2K.

NOTE U value is also called the overall heat transfer coefficient. (OHTC)

3.1.25
validation
Confirmation that the 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.

3.1.26
verification
Confirmation that specified design requirements have been fulfilled, through the provision of objective evidence. For example, verification can be performed by inspection, demonstration, test, validation.

NOTE Partial verification could be achieved by validation/calculations(for wet and dry systems), design reviews(for wet and dry systems), and hydrostatic testing (only for wet insulation systems).

3.1.27
wet insulation systems
Insulation systems in direct contact with seawater and/or other liquids in the marine environment.

3.1.28
witness
W
Allowance of a third-party inspector to observe a particular or a prescribed set of manufacturing steps planned to occur on a certain date.

NOTE Sign-off by the inspection party for the witness point takes place after manufacturing steps are observed; if inspector 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 Company specify the performance requirements to the Supplier as applicable for the insulation system and minimally include the following.

4.1.2 General System Requirements

General systems requirements for the equipment 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 and handling 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 and application,

j) insulation application method,

k) Pipeline installation methods.

4.1.3 Specific Requirements for Wet Insulation Systems

a) Pipeline or equipment (e.g., subsea connectors, flanges, valves, etc.) to be insulated

b) corrosion protection coating details,

c) anticorrosion coating field joint cutback length

d) line pipe insulation cutback length and geometry specified by design

e) compatible field joint insulation type and geometry

f) Storage and handling requirements

g) maximum wet service temperature,

h) U-value or cooldown time requirements.

4.1.4 Specific Requirements for Dry Insulation Systems

a) Pipe-in-pipe materials and dimensions, including centralizers (if applicable)

b) Pipe-in Pipe type of coatings or insulations, insulation thicknesses, insulation lengths

c) K value at reference temperature,

d) Storage and handling requirements,

e) Maximum operating temperature

4.1.5 Flowline, Riser, and Pipeline Information

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) Design temperatures (minimum, maximum and normal operating temperatures)

4.1.6 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 Company, 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 applicator 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 applicator may suffice for this purpose.

4.2 Design Life Requirements

4.2.1 General

The insulation to be used should be suitable for the specified application and for the design and life of the system, and it should minimally:

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

b) be suitable to withstand thermo-mechanical forces associated with operating conditions,

c) be designed to allow thermal expansion/contraction of the pipeline/flowline/riser/equipment (for wet insulation only unless dry insulation system is provided in the form of pre-cast elements);

d) 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

4.2.2 Design Life Requirements for Wet Insulation Systems

For wet insulation systems, the following design requirements should minimally:

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

b) 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);

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

d) be suitable for use with cathodic protection;

e) be suitable for design and ambient temperatures;

f) be installable by proposed installation method;

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

h) 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 Marking

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

a) name of supplier;

b) material identification;

c) batch number/ lot number (if applicable);

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) 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 applied material batch/lot 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 limitations (including limitations in temperature cycling from maximum to minimum temperature);

d) compression strength;

e) specific heat;

f) aging performance with service life estimation;

g) hydrophobicity

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

In addition, the following material characteristics apply to wet insulation only (see Appendix A):

h) tensile strength and elongation at break;

i) hardness;

j) abrasion (including compliance test method);

k) fluid permeability (seawater absorption);

l) thermal diffusivity;

m) ultraviolet (UV) resistance, max exposure to direct sunlight (k and m);

n) hydrostatic crush strength;

o) maximum uncovered exposure to direct sunlight;

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

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 raw material supplier's recommended shelf life;

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

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, Company, and Applicator of the insulation system prior to commencement of work.

For field joints apply to wet insulation systems, if agreed between Company and Supplier, prescriptive recommendation provided in ISO 12736 part 3 should also be followed, including but not limited to product qualification testing, production testing and inspection and requirements for repair. Specific requirements for wet field joint materials are presented in Appendix A.

For field joints apply dry insulation systems, field joint application and installation procedure should be per supplier recommendations and approved by company-prior to commencement of work.
Specific requirements for dry field joint materials are presented in Appendix B.

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

For wet insulation systems see section A.4.1.
For dry insulation systems see section B.4.1.

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.

For PQT additional requirements for wet insulation system refer to A.5.1.

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.

For tests and qualification for the PQT refer also to sections A.4.3 for wet insulation systems and B.4.2 for dry insulation systems.

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

Refer to A.5.1 for the MPS documentation for wet insulation systems and B.5.1 for the MPS documentation for wet insulation systems.

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 Manufacturing data Qualification and testing data			X

Project deliverables Daily logs and reports 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,d]	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.

[d] If agreed between parties, prescriptive test specified in section 9.6 of ISO 12736 could be used.

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 Company 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. These recommendations are intended, as applicable, for PQT, PPT and production. 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[c]

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 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 applied material batch	Company to advise
Measure concentricity at the pipe ends	Each pipe/component [b]	Company to advise

[a] Requirement based on type of insulation.

[b] When insulation is directly applied to it, a component is defined as an unattached individual component, an unattached sub assembly or a sub assembly that is part of a larger fabrication. It can be but is not necessarily an individual casting or molding.

[c] If agreed between parties, alternative Inspection Frequency and Acceptance Criteria specified in section 8.5 of ISO 12736-2 could be used.

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.4 Application Process and Quality Control

A.4.1 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 if agreed with operator.

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 -specified properties prior to application.

Particular care is recommended during the insulation process of field joints, precast components, and half shells, as these components are of particular concern.

A.4.2 Procedure Qualification Test

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.

A.4.3 Procedure Qualification Test/ SST

Tests and qualification for the PQT data should not only prescribe, 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).

A.5 Manufacturing Procedure Specification

A.5.1 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.

A.6 Preproduction Test

A PPT should be performed at the beginning of production at the production site to validate 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. The 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.

A.6.1 Final Product Handling and Storage

Insulated parts should be handled in accordance with 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.

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.	Mean Temp.	Aged Values [a]
Thermal conductivity	ASTM C518 [b]			x	x
Specific heat capacity	ASTM E1269 [c,h]	Taken across a temperature range			
Density	ASTM C167,C303 and D792 [d]	x			
thickness (measured flat)	See B.2.5	x			
Hydrophobicity/Water retention	ASTM C1511 and C1763 [g]	x			
Tensile properties (optional)	ASTM D638 and/or D412 and D5034	x			x
Compressive strength(optional)	ASTM C165 and RT and D695	x			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.

[g] See B.2.6

[h] When heat transfer is considered so low that testing is not practical, a calculated heat Capacity could be used.

B.2.2 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.2.3 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 (Thermal conductivity value of an insulation material at a certain reference temperature) of the insulation should be measured per single batch/lot (if applicable). Typically, two measurements should be made per lot of manufactured insulation materials. Measurements should be performed and recorded for all manufactured lots.

B.2.4 Thickness, length, Width Measurements

Insulation thickness, width, and length measurements are made with the material is a flat position, repeated over a regular basis .

B.2.5 Hydrophobicity/Water Retention Testing

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

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.

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

Property	Inspection Frequency	Acceptance Criteria
Thickness on assembled package	Per regular interval	Supplier to advise
Thermal conductivity	Per lot	Supplier to advise
Hydrophobicity [a]	Per lot	Water must bead
Density	Per lot	Supplier to advise
Width and length [a]	Per regular interval	Supplier to advise

[a] If applicable.

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.

B.3.3 Ply Widths and Lengths

If the insulation system is made of insulation prepackages or from an assembly of plies of insulation material, in some cases 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. The acceptance criteria for the individual ply dimensions and tolerances shall be aligned with those stipulated by the supplier at contract award

B.3.4 Assembled Insulation Thickness

The insulation package system, including required thickness of the assembled thermal insulation 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 verified and recorded on an agreed frequency with the Company Customer 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.
The acceptance criteria for the assembled package thickness and tolerances shall be aligned with those stipulated by the supplier at contract award.

B.4 Application Process and Quality Control

B.4.1 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.4.2 Procedure Qualification Test/ SST

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

a) water absorption;

b) 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;

c) thermal expansion effects; (only applicable for pre-cast or less flexible dry insulation options)

d) mechanical strength (tensile, compression, bending, etc.); (only applicable for pre-cast or less flexible dry insulation options)

B.5 Manufacturing Procedure Specification

B.5.1 MPS Documentation

The MPS should document the following:

- scope,
- detailed description of the process (i.e. step by step),
- verification of acceptance criteria,

All surfaces should be prepared in accordance with the insulation manufacturers' recommendations. Prior to insulation installation. Auxiliary equipment, such as centralizers, shall be ready for installation.

Bibliography

[1] API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

[2] API Specification 5L, *Specification for Line Pipe, 46h Edition*

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

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

[5] API Specification 17D, *Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment*

[6] API Recommended Practice 17Q, *Subsea Equipment Qualification—Standardized Process for Documentation*

[7] ASTM C356, *Standard Test Method for Linear Shrinkage of Preformed High-Temperature Thermal Insulation Subjected to Soaking Heat*

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

[9] ASTM D4541*, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers*

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

[11] ISO 9000 [5], *Quality Management and Quality Assurance Standards*

[12] NACE SP0274 [6], *High Voltage Electrical Inspection of Pipeline Coatings Prior to Installatio*n

[13] NACE RP0287, *Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape*

[14] NACE RP0394, *Application, Performance, and Quality Control of Plant-Applied, Fusion Bonded Epoxy External Pipe Coating*

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

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

[17] 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.