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	CLIENT: PETROBRAS E&P	SHEET:	1 of 17
	PROGRAM: E&P PRODUCTION		–
	AREA: SUBSEA INSTALLATIONS		NO SCALE / A4
	TITLE: WET THERMAL INSULATION FOR SUBSEA EQUIPMENT		EECE/EES
			INTERNA

INDEX OF REVISIONS

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0	ORIGINAL ISSUE – ET BASED IN I-ET-0000.00-0000-431-P9U-002

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1. INTRODUCTION

1.1. OBJECTIVE/SCOPE

1.1.1. The purpose of this Technical Specification is to define, complement and modify the requirements stated in ISO 12736 regarding the minimum requirements related to the application of wet thermal insulation on subsea equipment.

1.1.2. CONTRACTOR shall fulfill all the requirements presented within this Technical Specification.

1.1.3. This document shall be read in conjunction with the following standards and Technical Specifications:

- ISO 12736 – First Edition

  Title: Petroleum and natural gas industries – Wet thermal insulation coatings for pipelines, flow lines, equipment and subsea structures;

- I-ET-0000.00-0000-210-P9U-001

  Title: Pipeline Field Joint Coating and Field Repair of Linepipe Coating;

1.1.4. In case it is noted any sort of conflict between this Technical Specification and the aforementioned documents, the following precedence order shall be respected:

a) This Technical Specification;

b) ISO 12736;

c) I-ET-0000.00-0000-210-P9U-001.

2. WET THERMAL INSULATION REQUIREMENTS

2.1. CONTRACTOR shall fulfill the requirements of the following document for the insulation coating manufacturing:

- ISO 12736 – First Edition

  Title: Petroleum and natural gas industries – Wet thermal insulation coatings for pipelines, flow lines, equipment and subsea structures;

2.2. There are some additional and modified requirements which shall be fulfilled by CONTRACTOR. Additional and modified requirements to the aforementioned document are highlighted in this Technical Specification considering the following expressions:

- [ADDITION] – When CONTRACTOR shall consider additional requirements.
- [MODIFICATION] – When a partial or full modification in the referred item is required.
- [DELETED] – When the referred item shall be entirely disregarded by CONTRACTOR.

2.3. In case of custom insulation coatings are envisaged by CONTRACTOR and this type of insulation is not included within this document it can be pre-qualified following the same structure and requirements of this document before been proposed to PETROBRAS.

2.4. CONTRACTOR may propose custom insulation coatings not included within this Technical Specification since the insulation coating system is submitted to a pre-qualification program. The pre-qualification program shall be executed before its proposal to PETROBRAS and shall have the same structure and requirements described herein.

3. ADDITIONAL, MODIFIED AND DELETED REQUIREMENTS FOR WET THERMAL INSULATION APPLICATION RELATED TO ISO 12736.

3.1. The items mentioned below follow the sequence already defined within the ISO 12736. The standard section number is given in brackets.

3.2. **Introduction**

() Modification: “It is necessary that users of this ISO 12736 be aware that further or differing requirements can be required for individual applications.”

3.3. **Scope**

(1) (Modification): “This International Standard defines the minimum requirements for qualification, application, testing, handling, storage and transportation of new and existing wet thermal insulations systems for equipment and subsea structures in the petroleum and natural gas industries. The purpose of the system is to provide thermal insulation.

3.4. **Normative references**

(2) (Addition): “I-ET-0000.00-0000-210-P9U-001, Pipeline Field Joint Coating and Field Repair of Linepipe Coating.”

3.5. **Terms and definitions**

(3.22) (Modification): “Pi tape: precision vernier periphery tape that allows the direct measurement of the diameter of tubular objects without the need for calipers or micrometers.

3.6. **Acronyms**

(4) (Deleted): “4LPP four layer polypropylene.”

(4) Addition: “5LPP five layer polypropylene.”

(4) Addition: “HGM hollow glass microspheres.”

3.7. **Qualification Dossier**

(6.1) (Modification): “A qualification dossier of the proposed insulation system in accordance with this clause shall be presented by the system supplier for review. The requirements of this clause shall apply to all layers present in the insulations system. The content of such a dossier shall be in accordance with 6.2 and 6.3.”

(6.1) (Addition): “Historical data shall have been approved by a Third Party Inspection Company or PETROBRAS representative.”

(6.3) (Deleted): “The wet insulation system supplier can select any anti-corrosion coating believed to be suitable for the maximum rated temperature of its insulation system and with which the system will pass the qualification requirements of this International Standard.”

(6.3) (Addition): “The anticorrosion coating system shall be indicated by PETROBRAS through a Coating Assessment Technical Specification.”

3.8. **Layer test requirements**

(7.1) (Modification): “Table 2 specifies properties to be tested. Tests are mandatory.”

(Table 1) (Modification): “Test procedure for Hydrostatic compressive behavior shall be ‘Tri-axial compression and creep test’.”

(Table 1) (Addition): “The test period of ‘tri-axial compression and creep test’ shall be at least 28 days and test period shall be enough in order to allow the extrapolation of data for 30 years.”

(Table 1) (Addition): “Water absorption: it shall be considered a test period necessary for the sample to saturate in water at 23°C ± 1°C. Method 1 of ISO 62 shall be adopted. The test period shall be enough in order to allow the extrapolation of data for 30 years.”

(7.2) (Addition): “These tests are mandatory and their performance shall be witnessed by a Third Party Inspection Company or an end user representative.”

(7.2.4) (Deleted).

(7.2.5) (Addition): “In order to demonstrate the suitability of the material to UV exposure, the insulation material shall be tested in accordance with ISO 21809-1 Annex G. It shall be considered a test period of 3000 hours. In case insulation is not based on PE or PP material CONTRACTOR shall propose UV resistance tests.”

3.9. Insulation system test requirements

(8.1) (Modification): In case tests parameters defined by insulation system supplier is out of range of specific project design conditions the tests shall be performed again within the correct range.”

(8.1) (Deleted): “If applicable, testing shall include a field joint applied in accordance with the requirements of Clause 10.”

(Table 3) Deleted: “Field joints (8.2.8).”

(8.2.2) (Modification): “Baseline tests (mandatory).”

(Modification): “The following tests shall be carried out on the complete insulation system prior to any simulated installation or…”

(Modification): “- CD test shall be performed at 23°C for 28 days in accordance with project Coating Assessment Technical Specification.”

(8.2.3) Deleted.

(8.2.4) Deleted.

(8.2.5) Deleted.

(8.2.7) Deleted.

(8.2.8) Deleted.

(8.2.9) Modification: “Simulated service test (subsea equipment) (mandatory).”

(8.2.9) Modification: “- confirm that the cool down time and define the U-value of the insulation system when subjected to…”

(8.2.9) Modification: “adhesion test or peel test (8.2.2) shall be carried out for comparison with baseline tests.”

(8.2.9) Modification: “samples of the insulation material shall be taken from the test piece after completion of the simulated service testing and subjected to the material property testing described in 7.1. To be performed only the following tests: density, tensile properties, and hardness. Acceptance criteria in the range as obtained in 7.1.”

3.10. **Application process and quality control**

(9.1) Modification: “If other system types are used, this clause shall be used as…….”

(9.3) Addition: “In order to speed up the approval process of APS and ITP, documents may be issued as independent documents.”

(9.4) Modification: “The APS shall be qualified by a PQT. Test methods, acceptance criteria and frequencies for PQT shall be specified in the ITP.”

(9.4) Addition: “If the proposed coating system has been already qualified by PETROBRAS, the specific conditions demanding the execution of a new PQT are as follows:

Key Variable	Specific conditions requiring a new full PQT
Insulation material	Change of any coating material composing the insulation system
Equipment	Change of methodology for the coating application
Volume of material produced	Range of volume of material produced are to be qualified during PQT
Insulation thickness OD	Range of variation in thickness of coating are to be defined during PQT
Key process parameters	Out of the tolerance previously qualified (e.g. temperatures, pressure of extrusion/pumping, rotation of the screw/pump flow, etc.)
Qualification dossier	As per item 6 and 3.7

(9.4) Addition: “In case of projects with Clad/Lined pipes, the PQT may be carried out using carbon steel pipes. Nevertheless a further demonstration shall be done in a later stage considering all the necessary actions to be taken along the coating process in order to avoid the contamination of CRA material.”

(9.4) Modification: “The PQT shall be carried out in presence of the PETROBRAS and designated CONTRACTOR’s representative, if applicable.”

(9.5) Modification: “A PPT is not required in case the PQT is developed in the same yard of the final insulation application.”

(9.6.2) Deleted.

3.11. Polyurethane applied in liquid form

(9.6.3.1) Modification: “Polyurethane is applied in liquid form using suitable dispensing equipment. It may be either in solid or syntactic form.”

(9.6.3.1) Modification: “The suitable anticorrosion coating shall be in accordance with the project specific Coating Assessment Technical Specification.”

(Table 6) Modification: “Table 6 – Minimum inspection and testing requirements for PU.

Property	Units	Test method	Requirements	Frequency		
				PQT	PPT	Production
Raw material testing (Manufacturer’s data)						
Density (polyol)	Relative to water at 1.0	Manufacturer’s method	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Viscosity (polyol)	cPs	ISO 3104 or ISO 3219	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Gel time of mixed system (polyol + iso)	s	Manufacturer’s method	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Hardness of cured system	Shore A or Shore D	ISO 868	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Isocyanate content	%	ISO 14896	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Density (glass microspheres)	g/cm^3	Manufacturer’s method	$0.35 \leq \rho \leq 0.41$	Each batch	Each batch	Each batch
Crush strength (glass microspheres)	%	Manufacturer’s method	≥ 80% minimum fraction survival at 5500 psi ≥ 90% target fraction survival at 5500 psi	Each batch	Each batch	Each batch
Substrate preparation						
Environmental conditions and substrate temperature	°C	ISO 8502-4	Minimum 3°C above dew point	Each item	Each item	Start of each shift
Anticorrosion coating surface preparation	-	Visual	If applicable, abrasion with sand paper grit 50 minimum and dust vacuum cleaning	Each item	Each item	Each item
Adhesion promoter application (if required)						
Material Certificate	-	-	Conformity certificate issued by manufacturer.	Each batch	Each batch	Each batch
Pot life	min	Stop watch	Cure time check in accordance with manufacturer’s recommendation	Each batch	Each batch	Each batch
Mix ratio	Ratio by weight	Weight measurement	Ratio and tolerance according to manufacturer’s recommendation	Start of PQT	Start of PPT	Each shift
Visual appearance	-	Visual	Within manufacturer’s recommendation. Comparative visual test panels from PQT.	Each item	Each item	Each item
PU application						
Mix ratio	Ratio by	Weight	As per manufacturer’s	Start of PQT	Start of PPT	Once per

	weight	measurement	recommendation with a maximum variation of ± 2 %			shift or at start of each pouring
Verification of raw material properties by a "cup shot"	Visual	Cured 500cm^3 (approximately) fixed mass sample at 23°C	Good mixing. No air, no discoloration from unmixed components, etc.	Start of PQT	Start of PPT	Start of each shift
Gel time check (machine dispensed)	s	Stop watch	To be used as reference for maximum pour time limitations	Once	Once	Once per shift
Visual inspection of the mould prior to moulding	-	Visual	Clean, no adhering PU. Releasing agent applied on entire inner surface of the mould.	Each item	Each item	Each pipe
Raw material processing temperature	°C	Thermocouple	As per manufacturer's recommendation	Once	Once	Once per shift
Mould temperature	°C	Thermocouple	Acceptable range to be established during PQT	Each item	Each item	Monitor continuously and record once per hour
Anticorrosion coating surface temperature	°C	Contact thermometer	Acceptable range to be established during PQT	Each item	Each item	Monitor continuously and record once per hour
Minimum demoulding time	s	Stop watch	Acceptable range to be established during PQT	Each item	Each item	Monitor continuously and record once per hour
Hardness immediately after demoulding	Shore A	ISO 868 or ASTM D2240	≥ 50	Each item	Each item	Each item
Laboratory testing						
Density	kg/m^3	ISO 1183 or ASTM D792	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	Once per shift
Tensile strength at yield	MPa	ISO 527 or ASTM D638	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	Once per shift
Elongation at break	MPa	ISO 527 or ASTM D638	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	Once per shift
Modulus of elasticity	MPa	ASTM D638	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	Once per shift
Secant modulus	MPa	ASTM D638	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	Once per shift
Compressive strength	MPa	ISO 844	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once for PQT	Once for PPT	N/A
Thermal conductivity	W/(m.K)	ISO 8301	In accordance with thermal insulation design (test at 23°C ±	5 tests on 2 pipes (total	3 tests	N/A

			2°C)	10 samples)		
Hydrostatic strength – Tri-axial compression and creep test	%	Annex A	≤ 5% (extrapolated to 20 years). Test to be performed at a pressure ≥ 1.1*(Maximum water depth) during 28 days.	3 tests	N/A	N/A
Mass ratio of glass microspheres (GSPU)	%	Annex J	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Glass microspheres density after processing (GSPU)	%	Annex J	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Entrapped air ratio (GSPU)	%	Annex J	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Adhesion pull off	MPa	ISO 4624	≥ 5MPa	Each item	Each item	Once per shift
Hardness	Shore A or Shore D	ISO 868 or ASTM D2240	Within manufacturer's certificate of conformity range	Each item	Each item	Each item
Insulation thickness	mm	PI tape or electronic equipment	In accordance with thermal insulation design	Each item	Each item	Each item
Concentricity (for pipes only)	mm	Straight edge ruler or electronic equipment at cutback area	± 10% of nominal thickness, but not greater than 4mm	Each item, 8 measure-ments	Each item, 8 measure-ments	Once per shift
Ovality (for pipes only)	%	Caliper and PI tape	$(OD_{max} - OD_{min})/OD_{PI\ tape} < 2$	Each item	Each item	1st pipe then every 20th pipe
Cutback	mm	Measurement	By agreement	Each item	Each item	Each item
Removal of release agent	-	Visual	-	Each item	Each item	Each item
Visual inspection	-	Visual	Mouldings are free from large air traps, porosity, debris, knit lines, cavities, cracks and disbondments at joints and substrate interfaces. Cosmetic surface faults may be accepted.	Each item	Each item	Each item

3.12. **PU foam application using spray or injection method with extruded polyolefin outer jacket**

(9.6.3.2) Deleted.

3.13. Silicone insulation systems

(9.6.3.4) Modification: “The application of pre-cast forms is not acceptable for linepipes and subsea equipment.”

(Table 8) Modification: “Table 8 – Minimum inspection and testing requirements for silicone

Property	Units	Test method	Requirements	Frequency		
				PQT	PPT	Production
Raw material testing (Manufacturer’s data)						
Viscosity	cPs	ISO 2884	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Gel time	min	Manufacturer	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Hardness of cures system	Shore A	ISO 868 or ASTM D2240	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Density	kg/m^3	ISO 1183-1	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Tensile properties (modulus, elongation at break, tensile strength at break)	MPa %	ISO 37	Within the manufacturer’s certificate of conformity range	Each batch	Each batch	Each batch
Density (glass microspheres) if applicable	g/cm^3	Manufacturer	$0.35 \leq \rho \leq 0.41$	Each batch	Each batch	Each batch
Crush strength (glass microspheres) if applicable	MPa	Manufacturer	≥ 80% minimum fraction survival at 5500 psi ≥ 90% target fraction survival at 5500 psi	Each batch	Each batch	Each batch
Substrate preparation						
Environmental conditions and substrate temperature	°C	ISO 8502-4	Minimum 3°C above dew point	Each item	Each item	Start of each shift
Anti-corrosion coating surface preparation	-	Visual	If applicable, abrasion with sand paper grit 50 minimum and dust vacuum cleaning	Each item	Each item	Each item
Adhesion promoter application						
Over coating time	s	-	Time check in accordance with manufacturer’s recommendation	Each item	Each item	Each item
Visual appearance	-	Visual	Within manufacturer’s recommendation. Comparative visual test panels from PQT	Each item	Each item	Each item
Silicon application						
Mix ratio	Ratio by weight	Weight measurements	± 5% from manufacturer’s data sheet	One item	One item	Once per shift
Verification of raw material properties by a	Visual	Cured $500cm^3$ (approximately) fixed mass	Good mixing. No air, no discoloration from unmixed components, etc.	Start of PQT	Start of PPT	Start of each shift

"cup shot"		sample at 23°C				
Visual inspection of the mould	-	Visual	Clean, without any contamination	Each pipe	Each pipe	Each pipe
Laboratory testing						
Density	kg/m^3	ISO 1183	In accordance with thermal insulation design (test at 23°C ± 2°C)	Once	Once	Once per shift
Tensile strength and elongation at break	MPa %	ISO 37	Within the manufacturer's certificate of conformity range	One test	One test	N/A
Compressive strength	MPa	ISO 844	Within the manufacturer's certificate of conformity range	Each pipe	N/A	N/A
Adhesion (pull off)	MPa	ISO 4624	≥ 5MPa	Each pipe	Each pipe	Once per shift
Thermal conductivity	W/m.K)	ISO 8301	In accordance with thermal insulation design (test at 23°C ± 2°C)	3 samples	3 samples	N/A
Final inspection						
Hardness	Shore A	ISO 868	Within the manufacturer's certificate of conformity range	Each item	Each item	Each item
Insulation thickness	mm	PI tape or electronic equipment or vent port	In accordance with thermal insulation design	Each item	Each item	Each item
Concentricity (for pipes only)	mm	Straight edge ruler or electronic equipment at cutback area	± 10% of nominal thickness, but not greater than 4mm.	Each pipe, 8 measure-ments	Each pipe, 8 measure-ments	Once per shift
Ovality (for pipes only)	%	Caliper and PI tape	$(OD_{max} - OD_{min})/OD_{PItape} < 2$	Each pipe	Each pipe	1st pipe then every 20th pipe
Cutback	mm	Tape measurement	In accordance with thermal insulation design	Each item	Each item	Each item
Visual inspection	-	Visual and optical microscope	Free of voids, blisters, cracks and separation from anticorrosion coating.	Each item	Each item	Each item

3.14. **Rubber coating on steel**

(9.6.5.2) Deleted.

3.15. Rubber coating on other materials

(Table 10) Modification: "Table 10 – Minimum inspection and testing requirements for rubber on to other materials

Property	Units	Test method	Requirements	Frequency		
				PQT	PPT	Production
Raw material testing (Manufacturer's data)						
Vulcanization characteristics	Nm	ISO 6502	Within the manufacturer's certificate of conformity range. Vulcanization curve and parameters values to be supplied.	Each batch	Each batch	Each batch
Hardness	Shore A	ISO 7619-1	Within the manufacturer's certificate of conformity range	Each batch	Each batch	Each batch
Density	kg/m^3	ISO 2781	Within the manufacturer's certificate of conformity range	Each batch	Each batch	Each batch
Substrate preparation						
Environmental conditions and substrate temperature	°C	ISO 8502-4	Minimum 3°C above dew point	Each item	Each item	Start of each shift
Surface conditions prior to preparation	-	Visual Inspection	No oil, grease or similar contaminations	Each item	Each item	Each item
Substrate surface preparation	-	Visual	If applicable, abrasion with sand paper grit 50 minimum and dust vacuum cleaning	Each item	Each item	Each item
Rubber primer application						
Environmental conditions and substrate temperature	°C	ISO 8502-4	Minimum 3°C above dew point	Each item	Each item	Each item
Over coating time	min	-	Time check in accordance with manufacturer's recommendation	Each item	Each item	Each item
Visual appearance	-	Visual	Within manufacturer's recommendation. Comparative test panels from PQT	Each item	Each item	Each item
Rubber application						
Vulcanization temperature	°C	Contact thermometer couple	Acceptable range to be established during PQT	Each item monitored	Each item monitored	Each item monitored
Vulcanization time	min	Stop watch	Acceptable range to be established during PQT	Each item	Each item	Each item
Vulcanization pressure	MPa	Manufacturer specification	Acceptable range to be established during PQT	Each item	Each item	Each item
Laboratory testing						
Thermal conductivity	W/(m.K)	ISO 8301	In accordance with thermal insulation design (test to be performed at 23°C ± 2°C)	Once [a]	Once [a]	N/A
Specific heat	J/(kg.K)	ISO 11357	In accordance with thermal insulation design (test to be	Once [a]	Once [a]	N/A

capacity			performed at 23°C ± 2°C)			
Tensile strength and elongation at break	MPa %	ISO 37	Within manufacturer's certificate of conformity range	Once [b]	Once [b]	N/A
Tear strength	N/mm	ISO 34	Within manufacturer's certificate of conformity range	Once [b]	Once [b]	N/A
Density	g/cm^3	ISO 2781	In accordance with thermal insulation design (test to be performed at 23°C ± 2°C)	Once	Once	N/A
Adhesion test / peel test (on pipe or test plate)	N/mm	ISO 21809-1 ISO 813	Acceptable range do be defined during PQT, but must be greater than 2.5N/mm	Once per pipe	Once per pipe	Each vulcaniza-tion batch
Final inspection						
Hardness	Shore A	ISO 7619-1	Within manufacturer's certificate of conformity range	Each item	Each item	Each item
Total insulation thickness	mm	PI tape or electronic equipment	In accordance with thermal insulation design	Each item	Each item	Each item
Concentricity (for pipes only)	mm	Straight edge ruler or electronic equipment at cutback area	± 10% of nominal thickness, but not greater than 4mm	Each pipe, 8 measure-ments	Each pipe, 8 measure-ments	Once per shift
Ovality (for pipes only)	%	Caliper and PI tape	$(OD_{max} - OD_{min})/OD_{PItape} < 2$	Each pipe	Each pipe	1st pipe then every 20th pipe
Cutback	mm	Tape measurement	In accordance with thermal insulation design. No disbondment between layers or defects/voids	Each item	Each item	Each item
Visual inspection	-	Visual	Free from defects	Each item	Each item	Each item

a Middle layer only, due to the difficulty of machining proper samples from thin inner and outer layer.

b Middle and outer layer only, due to the difficulty of machining proper samples from thin inner layer.

3.16. Epoxy insulation systems

(Table 11) Modification: "Table 11 – Minimum inspection and testing requirements for epoxy systems

Property	Units	Test method	Requirements	Frequency		
				PQT	PPT	Production
Raw material testing (Manufacturer's data)						
Wet density	kg/m^3	ISO 2811-1	Within the manufacturer's certificate of conformity range	Each batch	N/A	Each batch
Gel time of system	h	0.5 mass at 23ºC	Within the manufacturer's certificate of conformity range	Each batch	N/A	Each batch
Hardness of cured system	Shore A/D	ISO 868	Within the manufacturer's certificate of conformity range	Each batch	Each batch	Each batch
Density (glass micro-spheres)	kg/m^3	Manufacturer	$0.35 \leq \rho \leq 0.41$	Each batch	Each batch	Each batch
Crush strength (glass micro-spheres)	psi	????	≥ 80% minimum fraction survival at 5500 psi ≥ 90% target fraction survival at 5500 psi	Each batch	Each batch	Each batch
Hydrostatic Compression	MPa	Annex A	Within the manufacturer's certificate of conformity range	Once for PQT	N/A	N/A
Substrate preparation						
Environmental conditions and substrate temperature	°C	ISO 8502-4	Minimum 3°C above dew point	Each item	Each item	Start of each shift
Surface conditions prior to preparation		Visual Inspection	No oil, grease or similar contaminations	Each item	Each item	Each iItem
Anticorrosion coating surface preparation	-	Visual	If applicable, abrasion with sand paper grit 50 minimum and dust vacuum cleaning	Each item	Each item	Each item
Epoxy application						
Mix ratio	ratio by weight	Weight measurement	As per manufacturer's recommendation with a maximum of ± 5 %.	Once	Once	At each application
Verification of raw material properties by a "cup shot"	Visual	Cured 0.5l fixed mass sample at 23ºC	Good mixing. No air, no discolouration from unmixed components, etc	Start of PQT	Start of PPT	Start of each application
Visual inspection of mould prior to filling	Visual	-	Clean, with no debris	Each item	Each item	Each item
Mould temperature	°C	Thermocouple	Acceptable range to be established during PQT	Each item	Each item	Each item
Exotherm temperature during moulding	°C	Thermocouple	Acceptable range to be established during PQT. The exotherm should be checked at the centre of the maximum thickness during cure	One item	One item	N/A

Laboratory testing						
Cured density	kg/m^3	ISO 1183 Method A	In accordance with thermal insulation design (test to be performed at 23°C ± 2°C)	Once for PQT	Every batch of raw material	Once per shift
Glass transition temperature	ºC	ISO 11357-2	In accordance with thermal insulation design	Once for PQT	Every batch of raw material	Once per shift
Mass ratio of glass microspheres	%	As per Annex I	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Glass microspheres density after processing	%	As per Annex I	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Entrapped air ratio	%	As per Annex I	Acceptable range to be established during PQT	Each item	2 items	Once per shift
Tensile strength and elongation at break	MPa	ISO 527	Within manufacturer's certificate of conformity range	One test	N/A	N/A
Adhesion	MPa	ISO 4624	Pull off test > 5 MPa or acceptable range to be established during PQT	Each item	Each item	Once per shift
Thermal conductivity	W/(m.K)	ISO 8301	In accordance with thermal insulation design (test to be performed at 23°C ± 2°C)	Once for PQT	Every batch of raw material	N/A
Hydrostatic Compression	MPa	As per Annex A	In accordance with thermal insulation design (test to be performed at 23°C ± 2°C)	Once for PQT	Every batch of raw material	N/A
Final inspection						
Hardness	Shore D	ISO 868	Within manufacturer's certificate of conformity range	Each item	Each item	Each item
Insulation thickness	mm	PI tape or electronic equipment	In accordance with thermal insulation design	Each item	Each item	Each item
Concentricity (for pipes)	mm	Straight edge ruler or electronic equipment at cutback area	± 10% of nominal thickness, but not greater than 4mm	Each pipe, 8 measure-ments	Each pipe, 8 measure-ments	Once per shift
Ovality (for pipes)	%	Caliper and PI tape	$(OD_{max} - OD_{min})/OD_{PItape} < 2$	Each item	Each item	1st pipe then every 20th pipe
Cutback	mm	Tape measurement	In accordance with thermal insulation design. No disbondment between layers or defects/voids	Each item	Each item	Each item
Visual inspection	-	Visual	Mouldings are free from air traps, porosity, debris, knit lines, cavities and disbondments at joints and substrate interfaces. Cosmetic surface faults may be accepted	Each item	Each item	Each item

3.17. **Phenolic insulation systems**

(9.6.7) Deleted.

3.18. **Requirements for field joints**

(10) Deleted.

3.19. **Handling, storage and transportation requirements**

(11) Addition: “A specific procedure encompassing the operations of handling, storage at coating yard and also the transportation shall be supplied to PETROBRAS’ for approval.”

(11) Addition: “The partial thermal insulation coating shall be protected from UV degradation ‘between passes’ (if applicable).”

(11) Addition: “Regarding the storage of insulated equipment, the equipment shall be covered all the time.

3.20. **Hydrostatic compressive behavior/Tri-axial test procedures**

(A.1) Modification: “Hydrostatic test is not acceptable for evaluation of thermal insulation coating systems mentioned within this Technical Specification. The tri-axial compression and creep test procedure shall be used.”

(A.3) Modification: “The duration of the test is 28 days.”

3.21. **Simulated bend test**

(Annex B) Deleted.

3.22. **Cyclic (fatigue) bend test**

(Annex C) Deleted.

3.23. **Simulated tensioner test**

(Annex D) Deleted.

3.24. **Simulated service test (factory applied coating)**

(Annex F) Deleted.

3.25. **Simulated service test (field joint)**

(Annex G) Deleted.

3.26. **Simulated service test (subsea equipment)**

(Annex H) Addition: “On completion of the test and/or at one or more agreed points during test, a cooldown simulation using an active cooldown cycle approach is required.”

3.27. **Ring shear test procedure**

(Annex I) Deleted.