ContraTherm® C25-770-01

High Temperature and Pressure

Silicone Subsea Insulation Material.

Pre-Qualification Dossier

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1. Introduction

The purpose of this document is to collate all the test data and evidence available for the ContraTherm® C25-770-01 Subsea product and to compare it against industry requirements generally as stipulated in the InSpec JIP Documents:

Document 1-1-4-140/SP01 'Specification for Insulation and Buoyancy Materials'

Document 1-1-4-140/RP01 'Recommended Practice for Insulation and Buoyancy Materials'

Insulation materials are required and selected by the industry as suitable for installation on subsea production systems such as Xmas trees, manifolds, jumper spools and associated equipment. This document summarises the test data available to support industry qualification and acceptance of the material as suitable for use in varying field conditions on differing project requirements.

2. Applicable Insulation Systems

The InSpec specification covers the whole range of offshore insulation applications. AIS is only minded with one sector, *'Integral External Insulation'*, and even then only with *'subsea components such as wellheads, Xmas trees, manifolds and jumpers'* as defined at Specification Section 1.3.1b. This limitation will render some of the specification as inappropriate as it is directly related to specific test requirements for other applications.

3. Typical Design Requirements

Each individual project will have specific design requirements for the subsea production system and which must be attained by the selected insulation material. This document is designed as a general material qualification dossier applicable to numerous fields and as such a generic design requirement must be assumed. Where individual field requirements exceed the generic design stipulated below, further qualification test data must be obtained to prove the appropriateness of the product for the specific field.

3.1 Generic Qualification Design Requirement

The field design data assumed in the document is given in the table below.

Design Variable	Design Value
Maximum Operating Water Depth	2500m
Peak Production Fluid Temperature	150°C
Minimum Temperature	-20°C
External Seawater Temperature	4°C

3.2 Functional Insulation Requirements

The general industry requirements for an insulation material/system for use on subsea production systems are:

- Shall have a low thermal conductivity to ensure an optimised coating thickness as thin as possible.

- Shall retain its insulating properties under the applicable hydrostatic compression loads and production temperatures whilst exposed to seawater for the project design life.
- Shall be compatible with all surrounding fluids.
- Shall be able to withstand the extreme project conditions (i.e. peak fluid temperature, operating deformations) whilst still meeting the performance requirements.
- Shall be suitable for application on all relevant surfaces and shapes.
- Shall meet the specified project design life considering the parent insulation material and its bond to the substrate.
- Shall be repairable following damage or field jointing equipment inshore and offshore.
- Shall allow application in a manner that makes removal for repair/disassembly of subsea structure components practical.
- Shall have good adhesion to the proposed corrosion protection system used on the components to be insulated.
- Shall have a method of application that ensures an optimised adherence and/or sealing to avoid any ingress and flowing of water within the insulation system.

This qualification document addresses all of the listed points following the completion of qualification programmes.

3.3 Specific Insulation Qualification Requirements

Insulation materials for subsea use are subjected to qualification programmes that cover not only the insulation material but also the application and installation aspects. As a minimum, pre-qualification testing is required to address the following aspects.

- Water absorption (at end of life)
- Thermal Conductivity (start and end of life)
- Specific Heat Capacity
- Differential temperature effects (seawater temperature vs production fluid temperature)
- Thermal expansion effects
- Compressibility
- Adhesion between insulation coating systems, bonding systems and corrosion coating systems.
- Accelerated ageing tests of insulation material.
- Mechanical strength (tensile, compressions, toughness).

- Material and cathodic protection system compatibility
- Flexibility (for maximum jumper/spool deformation)
- Storage life and requirements before installation (i.e. ozone and UV degradation) and evidence insulation can withstand transport, storage, installation and operational stresses.

3.4 Qualification Evidence

Qualification must be demonstrated either through a programme of qualification testing or through relevant field experience.

4.0 The ContraTherm® C25-770-01 System

The ContraTherm® C25-770-01 Subsea System has been developed specifically for use on deep water thermal insulation applications on subsea production equipment including but not limited to Xmas trees, manifolds, jumpers/spool pieces flow line end terminations and associated equipment.

The C25-770-01 insulation foam consists of hollow glass microspheres dispersed within a Silicone resin matrix which provides the necessary degree of integrity and flexibility to be used in dynamic as well as static structures. The low coefficient of thermal conductivity and the robust mechanical structure of the material are well suited for thermal insulation applications. The thickness of the applied insulation material is determined by the insulation performance requirement of each specific project.

5.0 ContraTherm® Pre-Qualification Data

The following section provides test data relevant to the qualification requirements detailed at 3.0 above.

5.1 Generic Qualification Design Requirement

5.1.1 Maximum Operating Conditions

Advanced Insulation Systems has completed a number of full scale simulated service testing at pressures up to 250 bar generally equivalent to 2500 msw at an operating fluid temperature of up to 150°C.

<u>BP Angola</u>
This test was conducted in accordance with Cameron Doc Ref. – X-109993-01 for the purpose of qualification for the BP Angola Block 31 project. The detail of these tests are reported in Appendix 1 “SUBSEA THERMAL INSULATION COATING MATERIALS C25-770 Silicone Coating Material Pressurised Simulated Service Test - 150°C /2000m” dated July 2010.

<u>Exxon Mobil</u>
This test was conducted in accordance with Exxon Mobil Global Practice GP65-08-01at operating conditions of 2500 msw pressure and 150°C maximum fluid temperature.
Results are reported in Doc: SWRI Project No. 18-15604 included in Appendix 2.

<u>BP Gulf of Mexico</u>
This test was carried out in accordance with Cameron Doc Ref. SD-044609-01 and was sponsored jointly by AIS, BP and Cameron. We expect to receive the full report from the sponsors and this may be able to be included as a separate appendix once permission has been granted.

5.2 Specific Insulation Qualification Requirements

5.2.1 Water Absorption

AIS has undertaken water absorption tests on ContraTherm® C25-770-01 insulation foam as part of accelerated ageing tests completed in pressure vessel at varying temperatures and pressures. These tests are detailed in Report TRL10024 "Aged properties of C25-770-01". See appendix 6. Water absorption on the bare foam is measured at <5%.

5.2.2 Thermal Conductivity

Thermal conductivity has been measured in accordance with ISO 8301 (ASTM C-518) using the Fox 200 thermal conductivity analyser from LaserComp. Measurements were made at a mean temperature of 20°C and a temperature differential of 20°C between the hot and cold plate.

The new condition dry thermal conductivity of ContraTherm® C25-770-01 foam is 0.155 W/mK.

AIS has completed accelerated ageing tests under HP/HT conditions in order to determine aged thermal and mechanical properties. These tests are summarised in section 5.2.9 and are detailed in Report TRL10024 "Aged properties of C25-770-01". See appendix 6.

The measured aged thermal conductivity is 0.18 W/mK.

5.2.3 Specific Heat Capacity

The specific heat capacity testing of Contratherm® C25-770-01 has been conducted in accordance with DSC method ASTM E-1269 at a test temperature of 40 – 80°C.

The new condition dry Specific Heat Capacity of ContraTherm® C25-770-01 foam is 1270 J/KgK.

AIS has completed accelerated ageing tests under HP/HT conditions in order to determine aged thermal and mechanical properties. These tests are summarised in section 5.2.6 and are detailed in Report TRL10024 "Aged properties of C25-770-01". See appendix 6.

The measured aged specific heat capacity is 1700 J/KgK.

5.2.4 Compressibility

The compressive strength of the C25-770-01 insulation foam has been tested to ASTM D-695 giving an average result of 1.5 MPa at 10% strain.
Hydrostatic compressive strength has been demonstrated at >25 MPa through extensive testing in an AIS pressure vessel.

5.2.5 Adhesion between insulation coating and corrosion coating system

ContraTherm® C25-770-01 is suitable for application over traditional high temperature corrosion coating systems and will adhere well to systems such as Sigma Phenguard. Extended exposure to simulated service conditions has been shown not to cause significant loss of adhesion.

Typical pull-off values before exposure are in the region of 2.4 MPa and this reduces to 2.11 MPa after 90 days see report AIS TRL10022 at appendix 4.

5.2.6 Mechanical Strength

The mechanical properties of ContraTherm® have been determined and are presented in section 6 table 1.

5.2.7 Accelerated ageing tests of insulation material.

Accelerated ageing tests have been completed in the AIS in-house pressure vessel facility at a maximum temperature of 100°C and at a hydrostatic pressure of 250 bar. Results are summarised in section 6 table 2.

Full results are detailed in Report TRL10030 "Aged properties of C25-770-01". See appendix 6.

Biological effects such as fungal and marine growth have not been tested in accordance with INSPEC however it is not perceived there will be an issue with this area especially considering the water depths at which the material will operate and the inherent resistance of silicone based insulation materials to fouling.

5.2.8 Material and Cathodic Protection System Compatibility

Cathodic disbondment testing is used to test electrolytic disbondment of primers on steel substrates and the testing with insulation materials is to determine any detrimental effect of adding the insulation.

Cathodic disbondment has been tested in line with the INSPEC requirements following the procedure ASTM G-42, the test temperature was 65°C. The test was conducted on a 4"square carbon steel plate shot blasted to SA2.5 and coated in a phenolic epoxy paint system. The test demonstrated that the addition of ContraTherm® C25-770-01 had caused no detrimental effect in the ability of the primer to resist cathodic disbondment. The reported disbondment was 0 mmr.

See Exova report Ref. N952742 dated 26/04/2010 attached at appendix 5.

5.2.9 Flexibility

Silicone resin based insulation systems are inherently flexible materials and for this reason it is not deemed necessary to conduct full scale bend tests although these can be carried out at the request of the client where required.

5.2.10 Ozone/UV Resistance

Cured silicone resins have fully saturated backbones and are resistant to UV degradation. Environmental exposure testing has been conducted in accordance with two standards as follows:

BS EN ISO 4892-2 - Xenon Arc Exposure; Method A, Cycle 1 - 1860 hours total exposure time.

ASTM G153:2004 - Carbon Arc Exposure; Cycle 6 – 672 hours total exposure time.

Following exposure, an assessment was made on colour change and measurements were made of the Shore A hardness and tensile properties. There was a degree of colour fade in both tests and there was a slight increase in hardness and tensile strength over un-exposed material. Full results are reported in appendices 7 and 8.

5.2.11 Abrasion Resistance

Resistance to abrasion has been measured according to ASTM D4060-07 - Taber Abrasion Resistance.
The load used was 250g and the test duration was 1000 cycles.

Initially, the test was carried out using a "Medium Coarse" wheel type CS-17 which gave a very low wear index and an unstable reading. Wear Index was estimated at around 58.

Additional testing was subsequently carried out using the "Heavy Coarse" wheel H22 and this gave more stable values resulting in a wear index of 195.

6.0 Summary of Material Properties – Qualification Level

Table 1 – Properties of C25-770-01

Property	Test Method	Units SI / English	Result
Maximum Service Depth	SST	m ft	2500 8200
Maximum Operating Temperature	SST	°C °F	150 300
Density	ASTM D-792	Kg/m^3 lb/ft^3	770 48
Thermal Conductivity (dry)	ASTM C-518	W/m.K BTU/ft.hr.°F	0.155 0.09
Thermal Conductivity (wet)	ASTM C-518	W/m.K BTU/ft.hr.°F	0.18 0.106
Specific Heat Capacity (new)	ASTM E-1269	J/kgK Btu/lb.°F	1270 0.305
Specific Heat Capacity (aged) 8 weeks 96°C (204°F) and 250 bar (3625 psi)	ASTM E-1269	J/kg.K Btu/lb.°F	1700 0.408
Tensile Strength	ASTM D-638	MPa PSI	2.5 360
Tensile Strain to Failure	ASTM D-638	%	90
Compressive Strength @10% strain	ASTM D-695	MPa PSI	1.5 217
Poisson's Ratio	-	-	0.445
Hardness	ASTM D-2240	Shore A	75
Water Absorption 8 weeks 96°C (204°F) and 250 bar (3625 psi)		%	<5

Table 2 - Accelerated ageing Performance

Property	Units SI	Control	1000h 250 bar 100 deg C	2000h 250 bar 100 deg C	3000h 250 bar 100 deg C
Density	Kg/m3	785	797	802	816
Thermal Conductivity	W/mK	0.165	0.1619	0.1595	0.1591
Specific Heat Capacity	J/kgK	1.57	1.37	1.45	1.53
Tensile Strength	MPa	2.481	2.358	2.218	2.213
Tensile Strain to Failure	%	76.3	63.5	82.5	71.4
Tensile Modulus	MPa	8.7	7.5	7.5	8.7
Compressive Strength @10% strain	MPa	1.356	1.346	1.097	1.288
Hardness	Shore A	82	77	73	71
Water Absorption 100°C and 250 bar	%	N/A	1.56	3.1	3.55

7.0 Conclusions

The data provided within this pre-qualification dossier proves that the ContraTherm® C25-770-01 Subsea Insulation System meets the requirements of the assumed generic qualification requirements stipulated at 3.1 and meet the INSPEC Specification and Recommended Practice Requirements, where applicable, as detailed at 1.0 above.

The ContraTherm® C25-770-01 Subsea Insulation System meets the functional insulation requirements listed at 3.2 as demonstrated within this document and from an operational perspective as detailed in AIS application procedures and manuals.