

EXTERNAL FIELD JOINT AND REHABILITATION COATING SYSTEMS FOR LINE PIPE

DEP 31.40.30.37-Gen.

January 2008

DESIGN AND ENGINEERING PRACTICE



This document is restricted. Neither the whole nor any part of this document may be disclosed to any third party without the prior written consent of Shell Global Solutions International B.V., The Netherlands. The copyright of this document is vested in this company. All rights reserved. Neither the whole nor any part of this document may be reproduced, stored in any retrieval system or transmitted in any form or by any means (electronic, mechanical, reprographic, recording or otherwise) without the prior written consent of the copyright owner.

PREFACE

DEPs (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell Global Solutions International B.V. (Shell GSI)

and/or

Shell International Exploration and Production B.V. (SIEP)

and/or

other Shell Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Shell Operating Units. Where appropriate they are based on, or reference is made to, international, regional, national and industry standards.

The objective is to set the recommended standard for good design and engineering practice applied by Shell companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use DEPs is granted by Shell GSI, in most cases under Service Agreements primarily with Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Service Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or other Shell Service Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Service Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Service Company, or companies affiliated to these companies, that may issue DEPs or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell GSI. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE.....	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	5
1.4	ABBREVIATIONS	6
1.5	CROSS-REFERENCES	6
1.6	COMMENTS ON THIS DEP	6
2	GENERAL INFORMATION	7
2.1	GENERAL	7
2.2	CLASSIFICATION OF THE COATING SYSTEMS	7
2.3	INFORMATION TO BE SUBMITTED BY THE PRINCIPAL	9
2.4	INFORMATION TO BE SUBMITTED BY THE CONTRACTOR	10
3.	COATING SYSTEM REQUIREMENTS	11
3.1	GENERAL	11
3.2	FINISHED COATING SYSTEM REQUIREMENTS.....	13
4.	FIELD JOINT COATING SYSTEM APPLICATION AND QUALITY CONTROL	29
4.1	PIPE SURFACE AND PIPE LINE COATING PREPARATION	29
4.2	FIELD JOINT COATING INSTALLATION	30
4.3	QUALITY CONTROL DURING FIELD APPLICATION	30
5.	FIELD JOINT COATING SYSTEM QUALIFICATION	34
5.1	GENERAL	34
5.2	SYSTEM IDENTIFICATION.....	34
5.3	MANUFACTURER'S DATA	34
5.4	COATING SYSTEM QUALIFICATION	37
6.	APPLICATOR QUALIFICATION	38
6.1	GENERAL	38
6.2	FIELD JOINT COATING APPLICATION PROCEDURE.....	38
6.3	APPLICATOR QUALIFICATION.....	38
7.	INSPECTION AND TEST PROCEDURES	40
7.1	SURFACE FINISH AFTER BLAST CLEANING	40
7.2	COATING THICKNESS	40
7.3	HOLIDAY TEST	40
7.4	COATING ADHESION.....	40
7.5	IMPACT RESISTANCE	43
7.6	INDENTATION.....	44
7.7	FLEXIBILITY	45
7.8	HOT WATER SOAK	45
7.9	CATHODIC DISBONDING RESISTANCE	46
7.10	THERMAL AGEING.....	47
7.11	LAP SHEAR.....	48
7.12	DEGREE OF CURE OF FBE.....	48
7.13	MICROSCOPIC EXAMINATION	49
7.14	SELF-HEALING	49
7.15	DRIP RESISTANCE	49
7.16	PEEL TEST FOR OUTER WRAP.....	50
7.17	CONDUCTIVITY MONITORING OF BLASTING MATERIAL EXTRACTS	51
8.	COATING REPAIR	52
9.	DOCUMENTATION	53
9.1	QUALIFICATION RECORDS	53
9.2	FIELD RECORDS	53
10.	REFERENCES	54

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for field-applied coating systems used for external coating of field joints during the construction of buried or submerged pipelines. It specifies the requirements for coating materials, coating application, inspection and testing and gives procedures for the qualification of coating materials and coating applicators.

The DEP is applicable to the following generic types of field joint coating systems:

- Liquid epoxy
- Liquid polyurethane
- Heat shrink sleeves
- Polyethylene
- Polypropylene
- Fusion bonded epoxy
- Visco-elastic self-healing wrappings

Cold-applied tapes may be used if they fulfill the requirements specified for heat shrink sleeves (3.2.2).

Coal tar enamel and pre-preg fibre reinforced polymers (e.g. UV cured) field joint coating systems shall not be used.

Injection-moulded polyurethane field joint coatings are excluded from the scope of this DEP; it is allowed to use this type of coating, especially in combination with thermal insulation line pipe coating systems, if approved by the Principal and if a qualification program has been performed.

Field joint coatings for elastomeric riser coatings are covered by the riser coating DEP 31.40.30.36-Gen. Field joint coatings of Thermally Sprayed Aluminium (TSA) are covered by DEP 30.48.40.31-Gen.

This DEP is also applicable to coating systems applied in the field as repair (rehabilitation) coating systems to damaged and deteriorated coatings for buried or submerged pipelines.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This DEP is intended to be used by all involved in the design, procurement, manufacturing, and application of field joint coating systems for pipe for oil and gas production, oil refineries, chemical plants, gas plants and distribution depots and installations.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

adhesive	an intermediate coating layer to improve adhesion between the primer and the coating (three layer system) or between the steel and the coating (two layer system).
applicator	the party that applies the coating to the field joint in the field.
batch	the amount of materials produced within one uninterrupted production run of maximum 8 h under constant production conditions.
chemical pre-treatment	treatment of the blast cleaned pipe surface with a chemical solution before application of the primer or adhesive to improve adhesion of the first coating layer (phosphate, chromate).
field joint	part of the pipeline where pipes have been welded together and where, as a consequence, there is a discontinuity in the pipe coating
general qualification	qualification of a product as a generic field joint coating system
holiday	a defect penetrating through the coating to the steel pipe surface, of such dimensions that it is detectable by means of the specified procedures.
inspector	the party appointed by the Principal to witness the Applicator's quality control of coating materials and the coating process.
maximum design temperature	temperature which is specified by the Principal as the maximum design temperature of the the pipeline.
primer	a coating layer, applied directly onto the bare or pre-treated steel surface to improve the adhesion of the final coating to the pipe surface.
shift	a production run of which the beginning and end coincide with a change in personnel. In the context of the quality control procedures of this DEP, the maximum duration of a shift is 10 h.
specific project qualification	qualification of a product for application for the specified project
three layer system	a coating system consisting of three layers: primer, adhesive and outer layer.

1.4 ABBREVIATIONS

DN	-	Diameter Nominal (mm)
FBE	-	Fusion Bonded Epoxy
ITP	-	Inspection Test Plan
PE	-	Polyethylene
PP	-	Polypropylene
UV	-	Ultraviolet light

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (10).

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com. Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards folder.

2 GENERAL INFORMATION

2.1 GENERAL

This DEP shall be used for general qualification of external field joint systems and products, and to define the requirements for qualification, application and testing of external field joint systems for specific projects including rehabilitation or repairs of existing pipelines/equipment coating systems.

General field joint coating qualification is performed for the purpose of an overall qualification of field joint coating system and Applicator, but is not necessarily related to a specific project. With this process, a list of qualified coating systems and Applicators is developed, from which the Principal may select a field joint coating system and Applicator for a specific project.

The general qualification may be given independent of line pipe diameter and wall thickness. When qualification is required for a specific project, additional testing should be performed on the specific line pipe diameters and wall thicknesses during the applicator qualification, see section (6).

The field joint coating system shall be suitable for the temperature range, based on the maximum design temperature of the pipeline. This DEP does not identify maximum temperature limits for generic coating systems because there are a large variety of available grades of systems and components. The maximum allowable temperature for a coating system is defined by the choice of the individual components.

For general coating qualification, the coating Manufacturer/Applicator shall specify the temperature range.

The suitability of a coating system for a particular temperature class shall be demonstrated by performing the qualification tests at the relevant test temperature given in this DEP. For a specific project, additional testing should be performed at temperatures specified by the Principal.

Unless otherwise agreed, the selection of the field joint coating system for a given project shall be made by the Principal.

2.2 CLASSIFICATION OF THE COATING SYSTEMS

The field joint coating system shall be suitable to provide corrosion protection to the field joints of a pipeline to the same standard or better than the pipe coating system used on the main body of the pipeline.

The field joint coating system described in this DEP shall be manufactured to obtain the required coating properties under the prevailing design, installation and operating conditions.

2.2.1 Coating types

2.2.1.1 Liquid epoxy

Liquid epoxy and epoxy-modified coatings are two-pack coating systems composed of a base (epoxy resin) and a curing agent. The coating system can be modified with other components.

Reinforcement of the coating systems can be achieved by using glass fibres or glass flakes.

2.2.1.2 Liquid polyurethane

Liquid polyurethane and polyurethane-modified coatings are two-pack coating systems composed of polyol (pack A) and isocyanate (pack B). The coating system can be modified with other components.

2.2.1.3 Heat shrink sleeve

A heat shrink sleeve is a type of field joint coating, applied to a pre-heated pipeline in the form of a sleeve or wrap, which shrinks in the circumferential direction under the influence of heat or by other means, forming an adherent field joint coating.

The shrink sleeve consists of a polyolefin (PE or PP) based backing with an adhesive layer (mastic or hot melt) on one side. The shrink sleeve may be applied with or without a primer.

2.2.1.4 Polyethylene

Polyethylene heat shrink sleeve

This type of polyethylene coating is described in (2.2.1.3).

Flame sprayed polyethylene

This coating shall be applied over an epoxy primer coating (either a powder applied by dusting or electrostatic spray or a spray-applied liquid coating). The primer shall be overcoated with modified polyethylene powder applied by spray or by flame spray and the required thickness shall be achieved by further flame spray application of the modified polyethylene powder.

Polyethylene tape / sheet

This coating shall be applied over an epoxy primer coating (either a powder applied by dusting or electrostatic spray or a spray applied liquid coating). The primer shall be overcoated with modified polyethylene powder applied by spray and the required thickness shall be achieved by wrapping the joint with polyethylene tape/sheet; either in a spiral or a single piece large enough to cover the required area.

2.2.1.5 Polypropylene

Polypropylene heat shrink sleeve

This type of coating is described in (2.2.1.3). For this coating type a polypropylene copolymer adhesive layer and epoxy primer layer shall be used.

Flame sprayed polypropylene

This coating shall be applied over an epoxy primer coating (either a powder applied by dusting or electrostatic spray or a spray applied liquid coating). The primer shall be overcoated with modified polypropylene powder applied by spray or by flame spray and the required thickness shall be achieved by further flame spray application of the modified polypropylene powder.

Polypropylene tape / sheet

This coating shall be applied over an epoxy primer coating (either a powder applied by dusting or electrostatic spray or a spray applied liquid coating). The primer shall be overcoated with modified polypropylene powder applied by spray and the required thickness shall be achieved by wrapping the joint with polypropylene tape/sheet; either in a spiral or a single piece large enough to cover the required area.

Injected moulded polypropylene

This coating shall be applied over an epoxy primer coating (either a powder applied by dusting or electrostatic spray or a spray applied liquid coating). The primer shall be overcoated with modified polypropylene powder applied by spray and the required thickness achieved by injecting polypropylene into a suitable mould around the joint.

2.2.1.6 Fusion bonded epoxy

This coating shall consist of a fusion bonded epoxy layer applied by spraying epoxy powder on an electrostatically heated pipe surface.

2.2.1.7 Visco-elastic self-healing wrapping system

This coating system shall consist of two layers. The first layer is a visco-elastic polymeric tape with self-healing properties to provide corrosion protection to the underlying substrate. The second layer is an outerwrap applied to provide mechanical protection.

2.2.2 Temperature

The suitability of a field joint coating for a particular temperature shall be demonstrated by performing the qualification tests at the relevant test temperature given in this DEP.

2.2.3 Pipe coating compatibility

The field joint coating shall possess the required adhesive properties when applied on the base pipe and the various line pipe coating materials. The preheat and application temperatures required for the application of the field joint coating shall not cause loss of functional properties of the line pipe coating.

The generic types of line pipe coatings are:

- Polyethylene
- Polypropylene
- Fusion Bonded Epoxy
- Hot applied bitumen, asphalt or coal tar enamels

The suitability of the field joint coating for use with a particular line pipe coating system shall be demonstrated by carrying out a full application procedure followed by adhesion testing using the generic types of pipe coating as a substrate where required by this specification. Additionally, any deterioration or loss of functional properties of the line pipe coating due to the application of the field joint coating using recommended procedures shall render the field joint coating unsuitable for use in conjunction with that type of line pipe coating.

2.2.4 Pipeline diameter

The field joint coating shall be suitable for application in the field on the pipeline diameters used in a specific project, in accordance with the manufacturer's application instructions.

Variation in pipeline diameter is not part of the common qualification procedure, except when different diameters require different application procedures (e.g. flame heating rather than induction heating, or one-person rather than two-person application). The Contractor shall demonstrate that a field joint coating, applied on the pipeline of specified diameter in the field, complies with this DEP.

Procedures for the testing of applied field joint coating in the field are specified in (4). Qualification of the Applicator is specified in (6).

2.3 INFORMATION TO BE SUBMITTED BY THE PRINCIPAL

For a project qualification, the Principal shall supply technical information to the Contractor regarding the project, in particular the installation and operating conditions. This information shall include at least:

- project name;
- number of field joints to be coated;
- the type and thickness of the field joint coating required;
- line pipe coating cut back length;
- end preparation and bevel angle of line pipe coating;
- the type and thickness of the line pipe coating;
- the minimum and maximum operating temperature of the pipeline;
- description of steel pipe;
- the applicable coating specification;
- the geographical area (land/subsea);

- expected ambient temperature range during installation;
- installation method;
- soil and backfill conditions for land pipelines;
- seabed trenching, laying and burial conditions for subsea pipelines;
- subsequent coatings to be applied (e.g. weight coating, insulation);
- requirements for anti-slip treatment;
- type of cathodic protection system.

2.4 INFORMATION TO BE SUBMITTED BY THE CONTRACTOR

The Contractor shall submit information to the Principal on the field joint coating system to be used. This information shall include at least:

- coating system identification (5.2);
- Manufacturer's data (5.3);
- coating system qualification information (5.4);
- coating installation procedures;
- proposed coating Applicator(s);
- Applicator's qualification information (6);

The Contractor shall confirm that the field joint coating system is suitable for use under the specified conditions (2.3).

3. COATING SYSTEM REQUIREMENTS

3.1 GENERAL

The field joint coating system shall be suitable for the pipeline installation and operating conditions specified by the Principal (2.3).

Before commencing installation, the Contractor shall demonstrate that the coating system will fulfil the qualification requirements in accordance with (5.4). Any modification of a qualified field joint coating system shall require re-qualification of the modified system.

The Contractor shall demonstrate by effective quality control procedures in accordance with (4.3) that the coating, as applied in the field, fulfils the requirements of this DEP.

3.1.1 Immersed service

3.1.1.1 General

The Principal shall specify if the field joint coating will be used in continuously immersed service (examples of which are subsea pipelines, pipelines in swamps, river crossings, etc). If it is not certain, but possible, that this type of service applies (e.g. with varying ground water levels), immersed service should be specified for the selection of field joint coatings.

For immersed service, the field joint coating shall retain all functional properties after exposure to the specified immersed conditions.

3.1.1.2 Test procedure

At least three coated test samples shall be immersed in tap water at the test temperature specified in Table 1. The test sample shall consist of the field joint coating applied on steel with weld bead and shall overlap the existing line pipe coating. The bare edges of the sample shall be coated to prevent ingress of moisture beneath the coating.

Table 1 Water test temperature for immersed service

Maximum design temperature, °C	Test temperature, °C
< 20	20 ± 2
20 to 60	60 ± 2
60 to 80	80 ± 2
> 80	Maximum design temperature ± 2

For immersed service the immersion time shall be 100 days, after which the coated sample shall be removed from the water bath and allowed to cool to ambient temperature. The coating shall then be examined visually and tested as specified in Table 2. The coating properties shall be tested on the steel, on the weld and on the overlap with the existing line pipe coating.

The coating requirements after immersion are similar as for the requirements specified for the 28 days Hot Water Soak test (7.8).

Table 2 specifies the coating properties to be tested at ambient temperature after immersion and the acceptance criteria for each coating type.

The visco-elastic self-healing wrapping system shall also be tested for its self-healing properties in accordance with (7.14) after immersion.

Table 2 Acceptance criteria for testing after immersion

Field joint coating type	Property		
	Adhesion	Flexibility	Destructive
Liquid epoxy/ polyurethane	No blistering (less than 10 % of the test area) ≤ rating 2 > 7 N/mm ²	> 2 % strain	7.12
Heat Shrink Sleeve	PE backed > 2.5 N/mm	PP backed > 4.0 N/mm	7.12
Polyethylene/ polypropylene	PE > 4 N/mm	PP > 15 N/mm	7.12
FBE	No blistering (less than 10 % of the test area) ≤ rating 2 > 7 N/mm ²	> 2 % strain	
Visco-elastic self-healing wrapping	Substrate coverage > 95 % Remaining thickness > 0.6 mm > 0.2 N/mm Self-healing requirement		7.12

3.2 FINISHED COATING SYSTEM REQUIREMENTS

3.2.1 Liquid epoxy and liquid polyurethane

3.2.1.1 Acceptance criteria

The acceptance criteria shall be in accordance with Table 3.

Table 3 Acceptance criteria for liquid coatings

Property	Requirement	Section
Visual appearance	Free from blisters, scratches, etc.	3.2.1.2
Total thickness	By agreement or specified	3.2.1.3
Holiday test	No holidays	3.2.1.4
Hardness Shore D	In accordance with manufacturer's specification	3.2.1.5
Adhesion	rating 1 > 10 N/mm ²	3.2.1.6
Impact	5 J/mm (at 23 °C) 3 J/mm (at 0 °C)	3.2.1.7
Indentation	< 0.2 mm (at 23 °C) < 0.4 mm (at T _{max})	3.2.1.8
Flexibility	No holidays	3.2.1.9
Hot water soak 28 days	No blistering (less than 10 % of the test area) ≤ rating 2 > 7 N/mm ² > 2 % strain	3.2.1.10
Cathodic disbonding	see Table 4	3.2.1.11
Thermal ageing 100 days	No blistering ≤ rating 2 > 7 N/mm ² > 2 % strain	3.2.1.12

3.2.1.2 Visual appearance

The coating shall be free from blisters, visual holidays, scratches or any other irregularities and shall have a uniform colour and gloss.

3.2.1.3 Coating thickness

The minimum thickness of the coatings shall be as specified or agreed between the Principal and the Contractor and shall not be less than the manufacturer's recommendation.

The coating thickness shall be measured in accordance with (7.2).

3.2.1.4 Holidays

The coating system shall be free from holidays when tested in accordance with (7.3).

The test voltage shall be 5 kV/mm, with a maximum of 25 kV.

3.2.1.5 Shore D hardness

The requirement shall be in accordance with the manufacturer' specification.

The test shall be carried out in accordance with the method defined in ISO 868.

3.2.1.6 Adhesion

The adhesion of the coating system on the pipe surface and the plant coating shall be tested. The adhesion of the coating system shall be such that any attempt to remove the coating shall result in a cohesive break in the coating material and not in an adhesive failure of the coating/substrate interface (maximum rating 1) when tested in accordance with (7.4.2).

The adhesion of the coating system shall also be tested by the dolly pull-off method in accordance with (7.4.3). The pull-off adhesion strength shall be more than 10 N/mm² and the failure mode shall be cohesive for more than 75 % of surface area.

For information, test results may be given when tested at the maximum design temperature.

3.2.1.7 Impact resistance

The impact resistance of the coating system at ambient temperature shall be more than 5 J/mm at 23 °C and 3 J/mm at 0 °C when tested in accordance with (7.5)

3.2.1.8 Indentation resistance

The indentation shall be not more than 0.2 mm at 23 °C and not more than 0.4 mm at the maximum design temperature when tested in accordance with (7.6).

3.2.1.9 Flexibility

The flexibility of the coating shall be such that holidays do not appear when tested in accordance with (7.7).

At 0 °C a 2 % strain, and at 23 °C a 3 % strain, shall be induced in the coating of the sample.

3.2.1.10 Hot water soak

Hot water resistance shall be tested in accordance with (7.8) at a test temperature related to the maximum design temperature as specified in Table 15. The test duration shall be 28 days. After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding and shall show an adhesion rating of maximum 2 when tested in accordance with (7.4.2).

The adhesion of the coating system on the pipe surface and the plant coating shall also be tested by the dolly pull-off method (7.4.3). The pull off adhesion strength shall be more than 7 N/mm² and the major failure mode (> 75 % of surface area) shall be cohesive.

The flexibility of the coating after exposure shall be such that holidays do not appear when it is tested in accordance with the procedure in (7.7) with 2 % strain induced in the coating of the sample at 23 °C.

3.2.1.11 Cathodic disbonding resistance

Cathodic disbonding shall be tested in accordance with (7.9) at a test temperature related to the maximum design temperature as specified in Table 4. The duration of the test for coating qualification shall be 28 days. After the test, the maximum radius of disbonding shall be less than the value given in Table 4.

Table 4 Cathodic disbonding resistance for liquid coatings

Maximum design temperature, °C	Test temperature, °C	Maximum disbonding radius, mm
< 20	20 ± 2	5
20 to 60	60 ± 2	10
60 to 80	80 ± 2	10
> 80	Maximum design temperature ± 2 (but no higher than 95 ± 2)	10

3.2.1.12 Thermal ageing

Thermal ageing shall be tested in accordance with (7.10) at a test temperature related to the maximum design temperature as specified in Table 16. The duration of the test shall be 100 days. After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding and shall show an adhesion rating of maximum 2 when tested in accordance with (7.4.2).

The adhesion of the coating system on the pipe surface and the plant coating shall also be tested by the dolly pull-off method (7.4.3). The pull off adhesion strength shall be more than 7 N/mm² and the major failure mode (> 75 % of surface area) shall be cohesive.

The flexibility of the coating after exposure shall be such that holidays do not appear when it is tested in accordance with the procedure in (7.7) with 2 % strain induced in the coating of the sample at 23 °C.

3.2.2 Heat shrink sleeve

3.2.2.1 Acceptance criteria

The acceptance criteria shall be in accordance with Table 5.

Table 5 Acceptance criteria for heat shrink sleeves

Property	Requirement		Section
Visual appearance	Free from blisters, scratches, etc.		3.2.2.2
Total thickness	By agreement or specified		3.2.2.3
Holiday test	No holidays		3.2.2.4
Adhesion (peel strength), 20 °C 25 to 60 °C > 60 °C	PE backed > 2,5 N/mm > 0.5 N/mm > 0.3 N/mm	PP backed > 4.0 N/mm > 2.0 N/mm > 2.0 N/mm	3.2.2.5
Lap shear strength, 20 °C 25 to 60 °C > 60 °C	PE backed 0.5 N/mm ² 0.3 N/mm ² 0.1 N/mm ²	PP backed 2.0 N/mm ² 0.5 N/mm ² 0.5 N/mm ²	3.2.2.6
Impact	> 15 J		3.2.2.7
Indentation (remaining thickness)	> 0.6 mm		3.2.2.8
Hot water soak 28 days	PE backed > 2.5 N/mm	PP backed > 4.0 N/mm	3.2.2.9
Cathodic disbonding	see Table 6		3.2.2.10
Thermal ageing 100 days	PE backed > 1.8 N/mm	PP backed > 3.0 N/mm	3.2.2.11
Destructive testing	Regular distribution of adhesive.No bare steel visible, etc		3.2.2.12

3.2.2.2 Visual appearance

The applied heat shrink sleeve shall be free from blisters formed by entrapped air, pinholes, scratches, burn marks or any other irregularities and shall have a uniform colour and gloss.

The adhesive shall be regularly distributed under the full area of the sleeve and shall be visible at both ends of the sleeves around the full circumference of the pipe.

3.2.2.3 Total thickness

For the shrink sleeves the thickness in the as-delivered state shall be as specified by the manufacturer of the shrink sleeve. The applied shrink sleeve shall be of even thickness over the total sleeve surface allowing for some variation on weld seams.

The minimum value measured on top of the weld shall not be less than 75 % of the nominal sleeve thickness.

The thickness shall be measured in accordance with the method described in (7.2).

3.2.2.4 Holidays

The applied shrink sleeve shall be free from holidays and/or pinholes that are indicated when tested in accordance with (7.3).

The test voltage shall be 5 kV/mm + 5 kV, with a maximum of 25 kV.

3.2.2.5 Adhesion

The adhesion of the shrink sleeve to the pipe steel, the weld and the pipe coating shall be determined as peel strength, measured at room temperature and at a test temperature related to the maximum design temperature using the test procedure in (7.4.4). The minimum peel strength values at the given test temperature shall be as specified in Table 5.

After each peel strength test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the shrink sleeve adhesive component and the (primed) pipe or weld surface.

There shall be no adhesive failure between the shrink sleeve adhesive component and the pipe coating or shrink sleeve backing over more than 10% of the test surface.

3.2.2.6 Lap shear strength

The lap shear strength of the shrink sleeve adhesive to steel shall be determined at room temperature and at a test temperature related to the maximum design temperature in accordance with the test method described in (7.11). The minimum lap shear strength values at the given test temperature shall be as specified in Table 5.

The mode of failure shall be cohesive within the adhesive layer.

3.2.2.7 Impact resistance

The impact resistance of the shrink sleeve system shall be tested at $(23 \pm 3) ^\circ\text{C}$ in accordance with the test method described in (7.5)

The minimum impact resistance shall be 15 J for all pipe diameters.

3.2.2.8 Indentation resistance

The indentation resistance of the shrink sleeve shall be tested at room temperature and at maximum design temperature in accordance with the test method described in (7.6).

The minimum remaining thickness after indentation shall be more than 0.6 mm.

3.2.2.9 Hot water soak

Hot water resistance shall be tested in accordance with (7.8) at a test temperature related to the maximum design temperature as specified in Table 15. The duration of the test shall be 28 days.

After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding.

The adhesion of the shrink sleeve to the pipe steel, the weld and the pipe coating shall be more than 2.5 N/mm for PE backed sleeves and more than 4.0 N/mm for PP backed sleeves when tested in accordance with (7.4.4) at 23 °C.

3.2.2.10 Cathodic disbonding resistance

Cathodic disbonding shall be tested in accordance with (7.9) at a test temperature related to the maximum design temperature as specified in Table 6. The duration of the test shall be 28 days. After the test, the maximum radius of disbonding shall be less than the value given in Table 6.

Table 6 Cathodic disbonding resistance for heat shrink sleeves

Maximum design temperature, °C	Test temperature, °C	Maximum disbonding radius, mm	
		PE backed	PP backed
< 20	20 ± 2	5	3
20 to 60	60 ± 2	10	5
60 to 80	80 ± 2	15	10
> 80	Maximum design temperature ± 2 (but no higher than 95 ± 2)	15	15

3.2.2.11 Thermal ageing

Thermal ageing resistance shall be tested in accordance with (7.10) at a test temperature related to the maximum design temperature as specified in Table 16. The duration of the test for coating qualification shall be 100 days.

After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding.

The adhesion of the shrink sleeve to the pipe steel, the weld and the pipe coating shall be more than 1.8 N/mm for PE backed sleeves and more than 3.0 N/mm for PP backed sleeves when tested in accordance with (7.4.4) at 23 °C.

3.2.2.12 Destructive testing

The regular distribution of the adhesive and the adhesion of the adhesive to the steel surface shall be demonstrated by complete removal of a sleeve by cutting the sleeve into smaller sections and pulling it from the pipe

After removal of the sleeve the pipe surface shall be visually examined.

The sleeve fails the test if:

- more than 5 % of the steel surface shows bare steel or primer, or
- more than 5 % of the circumference on the weld shows bare steel or primer or
- at 20 mm at either side of the weld shows bare steel (wagon tracking) or primer, or
- more than 5 % of the pipe coating is bare or
- more than 5 % of the surface area shows voids (signs of air inclusions)

3.2.3 Polypropylene and polyethylene

3.2.3.1 Acceptance criteria

The requirements for polyethylene and polypropylene heat shrink sleeves are given in (3.2.2). For the other types of polyethylene and polypropylene coating systems the acceptance criteria shall be in accordance with Table 7.

Table 7 Acceptance criteria for polyethylene and polypropylene coatings

Property	Requirement		Section
Visual appearance	No blisters, etc.		3.2.3.2
Total thickness	By agreement or specified		3.2.3.3
Holiday test	No holidays		3.2.3.4
Adhesion (peel strength), at 23 °C at T _{max}	PE > 4 N/mm > 1.5 N/mm	PP > 15 N/mm > 2.0 N/mm	3.2.3.5
Impact	> 15 J		3.2.3.6
Indentation at 23 °C at T _{max}	PE < 0.1 mm < 0.6 mm	PP < 0.1 mm < 1.0 mm	3.2.3.7
Hot water soak 28 days	> 4 N/mm	> 15 N/mm	3.2.3.8
Cathodic disbonding	See Table 8		3.2.3.9
Thermal ageing 100 days	> 3 N/mm	> 10 N/mm	3.2.3.10
Destructive testing	No bare steel Regular distribution of primer and adhesive		3.2.3.11
Degree of cure of FBE primer	ΔTg value shall be between –2 °C and +3 °C.		3.2.3.12
Microscopic examination of FBE primer	No voids Maximum of 2 for foaming		3.2.3.13
Oxygen Induced Time, (only for flame sprayed systems)	> 20 minutes		3.2.3.14

3.2.3.2 Visual appearance

The coating shall be free from blisters, pinholes, scratches or any other irregularities and shall have a uniform colour and gloss.

3.2.3.3 Total coating thickness

The minimum thickness of the coating shall be agreed between the Principal and the Contractor and shall not be less than the manufacturer's recommendation.

The coating thickness shall be measured in accordance with (7.2).

3.2.3.4 Holidays

The coating system shall be free from holidays when tested in accordance with (7.3).

The test voltage shall be 10 kV/mm, with a maximum of 25 kV.

3.2.3.5 Adhesion

The adhesion of the coating system to the pipe steel, the weld and the pipe coating shall be determined as peel strength, measured at room temperature and at a test temperature related to the maximum design temperature using the test procedure in (7.4.4). The minimum peel strength values at the given test temperature shall be as specified in Table 7.

If the coating cannot be peeled from the line pipe, the minimum peel resistance value shall be recorded as larger than the measured tensile force at yield.

After each peel strength test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the PP/PE adhesive and the primed pipe or weld surface.

3.2.3.6 Impact resistance

The impact resistance of the PE coating system shall be tested only at 23 °C; the impact resistance of PP shall be tested at 0 °C and 23 °C.

The testing shall be carried out in accordance with the procedure in (7.5).

The minimum impact resistance shall be 15 Joules for all pipe diameters.

3.2.3.7 Indentation resistance

The indentation resistance of the coating system shall be tested at room temperature and at a temperature related to the maximum design temperature in accordance with the test procedure given in (7.6).

The minimum indentation values at the given test temperature shall be as specified in Table 7.

3.2.3.8 Hot water soak

Hot water resistance shall be tested in accordance with (7.8) at a test temperature related to the maximum design temperature as specified in Table 15. The duration of the test shall be 28 days.

After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding.

The peel strength adhesion of the polymeric coating to the pipe steel, the weld and the pipe coating shall be more than 4 N/mm for PE and more than 15 N/mm for PP when tested in accordance with (7.4.4) at 23 °C.

3.2.3.9 Cathodic disbonding resistance

Cathodic disbonding shall be tested in accordance with (7.9) at a test temperature related to the maximum design temperature as specified in Table 8. The duration of the test shall be 28 days. After the test, the maximum radius of disbonding shall be as given in Table 8.

Table 8 Cathodic disbonding resistance for PE and PP coatings

Maximum design temperature, °C	Test temperature, °C	Maximum radius of disbonding, mm	
		PE	PP
< 20	20 ± 2	5	3
20 to 60	60 ± 2	10	5
60 to 80	80 ± 2	15	7
> 80	Maximum design temperature ± 2 (but no higher than 95 ± 2)	15	7

3.2.3.10 Thermal ageing

Thermal ageing resistance shall be tested in accordance with (7.10) at a test temperature related to the maximum design temperature as specified in Table 16. The duration of the test shall be 100 days.

After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding.

The peel strength adhesion of the polymeric coating to the pipe steel, the weld and the pipe coating shall be more than 3 N/mm for PE and more than 10 N/mm for PP when tested in accordance with (7.4.4) at 23 °C.

3.2.3.11 Destructive testing

The regular distribution of the adhesive and the adhesion of the adhesive to the steel and pipe coating surface shall be demonstrated by complete removal of a field joint coating by cutting the coating system into smaller sections and pulling it from the pipe

After removal of the coating the pipe surface shall be visually examined.

The coating fails the test if:

- more than 5 % of the steel surface shows bare steel or
- more than 5 % of the circumference on the weld shows bare steel or
- at 20 mm at either side of the weld shows bare steel (wagon tracking) or
- more than 5 % of the pipe coating is bare or
- more than 5 % of the surface area shows voids (signs of air inclusions).

3.2.3.12 Degree of cure of FBE primer

The degree of cure of the FBE primer shall be determined by differential scanning calorimetry (DSC) in accordance with (7.12). The ΔT_g value shall be between -2 °C and +3 °C.

3.2.3.13 Microscopic examination

A sample of the FBE primer layer shall be examined for the presence of foaming, voids and contamination in accordance with the procedure in (7.13). The maximum degree of foaming, both through-film and across-film, shall be 2 on the scale given in Figure 4. The coating interface shall be free of contamination by foreign matter.

3.2.3.14 Oxygen Induced Time (OIT)

The Oxygen Induced Time (OIT) for flame sprayed PE/PP coating systems shall be tested in accordance with ISO 11357-6 at a temperature of 200 °C for PE and at 220 °C for PP. The OIT shall be more than 20 minutes.

3.2.4 Fusion bonded epoxy

3.2.4.1 Acceptance criteria

The acceptance criteria shall be in accordance with Table 9.

Table 9 Minimum coating properties for FBE coating systems

Property	Requirement	Section
Visual appearance	No blisters, etc	3.2.4.2
Total thickness, μm	475 ± 75	3.2.4.3
Holiday test	No holidays	3.2.4.4
Adhesion	$> 10 \text{ N/mm}^2$ rating 1	3.2.4.5
Impact	$> 5 \text{ J/mm}$	3.2.4.6
Indentation	$< 0.2\text{mm}$ (at 23°C) $< 0.4\text{mm}$ (at T_{max})	3.2.4.7
Flexibility	No holidays	3.2.4.8
Hot water soak 28 days	No blistering $\leq$ rating 2 $> 7 \text{ N/mm}^2$ $> 2\%$ strain	3.2.4.9
Cathodic disbonding	See Table 10	3.2.4.10
Thermal ageing 100 days	No blistering $\leq$ rating 2 $> 7 \text{ N/mm}^2$ $> 2\%$ strain	3.2.4.11
Degree of cure	ΔT_g value shall be between -2°C and $+3^\circ\text{C}$.	3.2.4.12
Microscopic examination	No voids Maximum rate 2 for foaming.	3.2.4.13

3.2.4.2 Visual appearance

The coating shall be free from blisters, visual holidays, scratches or any other irregularities and shall have a uniform colour and gloss.

3.2.4.3 Coating thickness

The thickness of the cured FBE coating shall be $475 \mu\text{m} \pm 75 \mu\text{m}$.

For offshore pipes where the weld area is later to be coated with an field joint infill such as PU foam, bitumen mastic or other infill material, the thickness of the cured FBE coating shall be $725 \mu\text{m} \pm 75 \mu\text{m}$.

The coating thickness shall be measured in accordance with (7.2).

3.2.4.4 Holidays

The coating system shall be free from holidays that are indicated when tested in accordance with (7.3).

The test voltage shall be 5 kV/mm, with a maximum of 25 kV.

3.2.4.5 Adhesion

The adhesion of the coating system on the pipe surface and the plant coating shall be tested. The adhesion of the coating system shall be such that any attempt to remove the coating shall result in a cohesive break in the coating material and not in an adhesive failure of the coating/substrate interface (maximum rating 1) when tested in accordance with (7.4.2).

The adhesion of the coating system shall also be tested by the dolly pull-off method in accordance with (7.4.3). The pull-off adhesion strength shall be more than 10 N/mm² and the failure mode shall be cohesive for more than 75 % of surface area.

For information, test results may be given when tested at the maximum design temperature.

3.2.4.6 Impact resistance

The impact resistance of the coating system at ambient temperature shall be more than 5 J/mm when tested in accordance with the procedure in (7.5).

3.2.4.7 Indentation resistance

The indentation shall be not more than 0.2 mm at 23 °C and 0.4 mm at the maximum design temperature when tested in accordance with (7.6).

3.2.4.8 Flexibility

The flexibility of the coating shall be such that holidays do not appear when tested in accordance with (7.7).

At 0 °C a 2 % strain and at 23 °C a 3 % strain shall be induced in the coating of the sample.

3.2.4.9 Hot water soak

Hot water resistance shall be tested in accordance with (7.8) at a test temperature related to the maximum design temperature as specified in Table 15. The duration of the test shall be 28 days. After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding and shall show an adhesion rating of maximum 2 when tested in accordance with (7.4.2).

The adhesion of the coating system on the pipe surface and the plant coating shall also be tested by the dolly pull-off method (7.4.3). The pull off adhesion strength shall be more than 7 N/mm² and the major failure mode (> 75 % of surface area) shall be cohesive.

The flexibility of the coating after exposure shall be such that holidays do not appear when it is tested in accordance with the procedure in (7.7) when 2 % strain at 23 °C shall be induced in the coating of the sample.

3.2.4.10 Cathodic disbonding resistance

Cathodic disbonding shall be tested in accordance with (7.9) at a test temperature related to the operating temperature as specified in Table 10. The duration of the test shall be 28 days. After the test, the maximum radius of disbonding shall be less than the value given Table 10.

Table 10 Cathodic disbonding resistance for FBE coatings

Maximum design temperature, °C	Test temperature, °C	Maximum disbonding radius, mm
< 20	20 ± 2	5
20 to 60	60 ± 2	10
60 to 80	80 ± 2	10
> 80	Maximum design temperature ± 2 (but no higher than 95 ± 2)	10

3.2.4.11 Thermal ageing

Thermal ageing resistance shall be tested in accordance with (7.10) at a test temperature related to the maximum design temperature as specified in Table 16. The duration of the test shall be 100 days. After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding and shall show an adhesion rating of maximum 2 when tested in accordance with (7.4.2).

The adhesion of the coating system on the pipe surface and the plant coating shall also be tested by the dolly pull-off method (7.4.3). The pull off adhesion strength shall be more than 7 N/mm² and the major failure mode (> 75 % of surface area) shall be cohesive.

The flexibility of the coating after exposure shall be such that holidays do not appear when it is tested in accordance with the procedure in (7.7) when 2 % strain at 23 °C shall be induced in the coating of the sample.

3.2.4.12 Degree of cure

The degree of cure shall be determined by differential scanning calorimetry in accordance with (7.12). The ΔT_g value shall be between -2 °C and +3 °C.

3.2.4.13 Microscopic examination

A sample of the applied coating shall be examined for the presence of foaming, voids and contamination in accordance with the procedure in (7.13). The maximum degree of foaming shall be 2 on the scale given in Figure 4, both through-film and across-film. The coating interface shall be free of contamination by foreign matter.

3.2.5 Visco-elastic self-healing coating system

3.2.5.1 Acceptance criteria

The acceptance criteria shall be in accordance with Table 11.

Table 11 Minimum coating properties for visco-elastic self-healing coating systems

Property	Requirement	Section
Visual appearance	No blisters, etc	3.2.5.2
Total thickness	By agreement or specified	3.2.5.3
Holiday test	No holidays	3.2.5.4
Adhesion at 23 °C at T _{max}	Substrate coverage > 95 % Remaining thickness > 0.6 mm > 0.2 N/mm > 0.02 N/mm	3.2.5.5
Lap shear at 23 °C at T _{max}	Substrate coverage > 95 % Remaining thickness > 0.6 mm > 0.02 N/mm ² > 0.003 N/mm ²	3.2.5.6
Impact	> 15 J	3.2.5.7
Indentation	No holidays remaining thickness > 0.6 mm	3.2.5.8
Self-healing	No holidays Remaining thickness > 0.6 mm	3.2.5.9
Drip resistance	No dripping of compound	3.2.5.10
Hot water soak 28 days	Substrate coverage > 95 % Remaining thickness > 0.6 mm > 0.2 N/mm Self-healing requirement	3.2.5.11
Cathodic disbonding	< 1 mm	3.2.5.12
Thermal ageing 100 days	Substrate coverage > 95 % Remaining thickness > 0.6 mm > 0.2 N/mm Self-healing requirement	3.2.5.13
Destructive testing	No bare steel visible. Regular distribution of primer and adhesive	3.2.5.14
Peel of outer wrap outer/outer (at 23 °C) outer/outer (at T _{max}) inner/outer (at 23 °C) inner/outer (at T _{max})	> 0.4 N/mm > 0.05 N/mm > 0.4 N/mm > 0.05 N/mm	3.2.5.15

3.2.5.2 Visual appearance

The applied coating shall be free from blisters formed by entrapped air, pinholes, scratches, or any other irregularities and shall have a uniform colour and gloss.

The first layer shall be uniformly distributed under the full area of the field joint and shall be visible at both ends of the outer wrap around the full circumference of the pipe.

3.2.5.3 Total thickness

The thickness in the as-delivered state shall be as specified by the manufacturer of the coating. The applied visco-elastic self-healing wrapping system shall be of even thickness over the total field joint surface allowing for some variation on weld seams.

The minimum value measured on top of the weld shall not be less than 75 % of the nominal thickness.

The thickness shall be measured in accordance with the method described in (7.2).

3.2.5.4 Holidays

The applied shrink sleeve shall be free from holidays and/or pinholes that are indicated when tested in accordance with (7.3).

The test voltage shall be 5 kV/mm + 5 kV, with a maximum of 25 kV.

3.2.5.5 Adhesion

The adhesion of the coating system to the pipe steel, the weld and the pipe coating shall be determined as peel strength, measured at room temperature and at a test temperature related to the maximum design temperature using the test procedure in (7.4.4). The minimum peel strength values at the given test temperature shall be as specified in Table 11.

After each peel strength test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the visco elastic material and the substrate (pipe, weld surface or pipe coating). There shall be a cohesive failure, leaving the compound covering the substrate for more than 95 %. The remaining thickness on the substrate shall be more than 0.6 mm.

3.2.5.6 Lap shear strength

The lap shear strength of the visco-elastic self-healing material to steel shall be determined at room temperature and at a test temperature related to the maximum design temperature in accordance with the test method described in (7.11). The minimum lap shear strength values at the given test temperature shall be as specified in Table 11.

After each lap shear test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the visco elastic material and the steel substrate. There shall be a cohesive failure, leaving the compound covering the substrate for more than 95 %. The remaining thickness on the substrate shall be more than 0.6 mm.

3.2.5.7 Impact resistance

The impact resistance of the shrink sleeve system shall be tested at room temperature and at a test temperature related to the maximum operating temperature in accordance with the test method described in (7.5).

The minimum impact resistance shall be 15 Joules for all pipe diameters and no holidays shall be observed after 1 h of applying the impact energy.

3.2.5.8 Indentation resistance

The indentation resistance of the coating system shall be tested at room temperature and at maximum design temperature in accordance with the test method described in (7.6).

There shall be no holidays and the minimum remaining thickness after indentation shall be more than 0.6 mm when measured 1 h after removing the indentator from the coating.

3.2.5.9 Self-healing

The self-healing behaviour of the coating system shall be tested at room temperature and at maximum design temperature in accordance with the test method described in (7.14).

There shall be no holidays and the minimum coating thickness recovered in the defect shall be more than 0.6 mm when measured 24 h after preparing the artificial defect in the coating.

3.2.5.10 Drip resistance

The drip resistance of the visco-elastic self-healing coating material shall be tested at room temperature and at maximum design temperature in accordance with the test method described in (7.15).

There shall be no dripping of any compound.

3.2.5.11 Hot water soak

Hot water resistance shall be tested in accordance with (7.8) at a test temperature related to the maximum design temperature as specified in Table 15. The duration of the test shall be 28 days.

After the exposure, the coating shall show no significant evidence (less than 10 % of the test area) of blistering or disbonding.

The adhesion of the coating system to the pipe steel, the weld and the pipe coating shall be determined as peel strength, measured at room temperature using the test procedure in (7.4.4). The minimum peel strength value tested at ambient temperature shall be more than 0.2 N/mm

After each peel strength test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the visco elastic material and the substrate (pipe, weld surface or pipe coating). There shall be a cohesive failure, leaving the compound covering the substrate for more than 95 %. The remaining thickness on the substrate shall be more than 0.6 mm.

The self-healing behaviour of the coating system shall be tested at room temperature in accordance with the test method described in (7.14).

There shall be no holidays and the minimum thickness recovered in the defect shall be more than 0.6 mm when measured 24 h after preparing the artificial defect in the coating.

3.2.5.12 Cathodic disbonding resistance

Cathodic disbonding shall be tested in accordance with (7.9) at room temperature and at a test temperature related to the maximum design temperature as specified in Table 12. The duration of the test shall be 28 days. After the test, the maximum radius of disbonding shall be less than 1 mm.

Table 12 Cathodic disbonding resistance test temperatures

Maximum design temperature, °C	Test temperature, °C
< 20	20 ± 2
20 to 60	60 ± 2
60 to 80	80 ± 2
> 80	Maximum design temperature ± 2 (but no higher than 95 ± 2)

3.2.5.13 Thermal ageing

Thermal ageing resistance shall be tested in accordance with (7.10) at a test temperature related to the maximum design temperature as specified in Table 16. The duration of the test shall be 100 days.

After the exposure, the coating shall show no significant evidence of blistering or disbonding.

The adhesion of the coating system to the pipe steel, the weld and the pipe coating shall be determined as peel strength, measured at room temperature using the test procedure in (7.4.4). The minimum peel strength value tested at ambient temperature shall be more than 0.2 N/mm.

After each peel strength test the test surface shall be examined for the mode of failure. There shall be no adhesive failure between the visco elastic material and the substrate (pipe, weld surface or pipe coating). There shall be a cohesive failure, leaving the compound covering the substrate for more than 95 %. The remaining thickness on the substrate shall be more than 0.6 mm.

The self-healing behaviour of the coating system shall be tested at room temperature in accordance with the test method described in (7.14).

There shall be no holidays and the minimum thickness recovered in the defect shall be more than 0.6 mm when measured 24 h after preparing the artificial defect in the coating.

3.2.5.14 Destructive testing

The regular distribution of the visco-elastic material and the adhesion of the visco-elastic coating to the steel and pipe coating surface shall be demonstrated by complete removal of a field joint coating by cutting the field joint coating into smaller sections and pulling it from the pipe

After removal of the field joint coating the substrate surface shall be visually examined.

The coating system fails the test if:

- more than 5 % of the steel surface shows bare steel or
- more than 5 % of the circumference on the weld shows bare steel or
- and 20 mm at either side of the weld shows bare steel (wagon tracking) or
- more than 5 % of the pipe coating is bare or
- more than 5 % of the surface area shows voids (signs of air inclusions).

3.2.5.15 Peel strength of outer wrap

The peel strength of the outer wrap to a) the outer wrap itself and b) to the inner visco-elastic self-healing material shall be tested at room temperature and at maximum design temperature in accordance with the test method described in (7.16).

The minimum peel strength values at the given test temperature shall be as specified in Table 11.

4. FIELD JOINT COATING SYSTEM APPLICATION AND QUALITY CONTROL

The Coating Manufacturer shall submit full application procedures, which shall at least consist of:

1. Surface preparation of the steel surface (method, cleanliness, profile).
2. Preparation of the line pipe coating at the overlap (method, roughness, chamfer)
3. Application of primer (method, thickness), if applicable
4. Pre-heating requirements (method, temperature, testing)
5. Method of application
6. Quality control procedures

The application procedures shall be qualified by the Contractor or Applicator, for both the product and the individual application personnel, under the supervision of the Coating Manufacturer. If required, multiple application procedure qualifications shall be undertaken to cover the full range of pipeline diameters, wall thicknesses and corrosion coating types as applicable.

The Contractor shall be responsible for all aspects of safety and personal protection related to the field coating application to be done. Environmental regulations and rules shall be met.

All personnel shall be provided with approved personnel protection e.g. protective clothing, safety glasses, safety shoes, hard hats, goggles, earplugs and any other necessary safety equipment. All safety equipment shall be maintained to a good working condition.

Adequate warning signs shall be prominently displaced on each access way to all areas where abrasive blasting and field joint coating application is in progress.

Handling and disposal of hazardous waste resulting from the Contractor's field joint coating activities shall be in accordance with applicable regulations and any additional requirements specified by the Principal.

4.1 PIPE SURFACE AND PIPE LINE COATING PREPARATION

The surface to be coated shall be dry and free of all surface contamination. Oil, grease, and other contaminants shall be removed, before blast cleaning, by a suitable solvent or detergent. Salt contamination, chemical cleaning agents and remaining detergents shall be washed off using potable water.

The pipe surface shall be cleaned of mill scale, rust and other foreign matter by a blast cleaning or another abrasive cleaning method to achieve a minimum surface cleanliness of Sa 2½. For stainless steel pipes, stainless steel abrasives or non-ferrous abrasives shall be used for blast cleaning. The surface shall have a sharp, angular profile and shall be in accordance with the field joint coating Manufacturers specification. During cleaning the pipe joint surface temperature shall be more than 3 °C above the ambient dew point. The ambient relative humidity shall not exceed 85 %.

Compressed air for blast cleaning shall be free from oil, condensed moisture and any other contaminants and shall conform to the requirements of ASTM D 4285. Blasting equipment that includes devices to recycle abrasives shall have equipment that ensures removal of dust, fines, corrosion material and any other contaminants.

The maximum residual chloride level on the blast-cleaned surface shall be 20 mg/m², in accordance with ISO 8502-6 (7.1) or using Elcometer 130, SCM 400 Salt Contamination Meter, or any other method approved by the Principal.

The dust level on the blast-cleaned surface at the time of coating shall not exceed quantity rating 2 in accordance with ISO 8502-3.

Immediately after blast cleaning, all remaining weld spatter and irregularities shall be removed from the pipe surface by chiselling and/or grinding. Any treated surface with an

area larger than 25 cm² shall be re-blasted to the cleanliness and roughness as specified above.

No repairs to the pipe joint may be made without a written procedure agreed by the Principal.

The factory applied coating adjacent to the joint area shall be prepared to provide a suitable surface for the field joint coating to adhere. The preparation methods shall be submitted by the Applicator.

4.2 FIELD JOINT COATING INSTALLATION

The maximum time between surface preparation and start of the field joint coating application shall be no longer than 4 h. Pipe joints whose coating is delayed beyond this period, or pipes showing any visible rust stains, shall be blast cleaned again.

Before application, the temperature of the joint substrate shall be at least 3 °C above the dew point and the joint shall be dry.

The application of the coating shall be strictly in accordance with the coating Manufacturer's application procedures and applied by qualified personnel, see (6).

For all field coating applications, the surface temperature of the joint shall comply with the requirements specified in the application procedures. Heating equipment shall be controlled to maintain uniform temperatures throughout the coating process. The temperature of the joint shall be monitored using suitable means in order to fulfil the application requirements. Induction heating should be used for pipeline nominal diameters above 600 mm. The method of heating used during qualification shall also be used on site during application.

For multi-layer systems, the temperature and time between subsequent layers shall be controlled to obtain sufficient interlayer adhesion. The required layer thickness of the primer (if required) and the total coating layer shall be specified in the application procedures.

Batches of coating components shall be used in the same sequential order in which they were manufactured.

4.3 QUALITY CONTROL DURING FIELD APPLICATION

4.3.1 General

All personnel and techniques and equipment shall be qualified. Certification and records of qualification shall be maintained on site and shall be traceable to individual applicators and equipment. During field application of the coating, the Applicator (or Contractor as directed by the Principal) shall carry out all quality control activities needed to ensure that the coating is being applied in accordance with the approved coating application procedures and that the final product complies with the requirements of this DEP.

The inspection and testing procedures shall be carried out as agreed between Principal and Contractor in the Quality Plan (or Inspection and Test Plan).

The minimum quality control tests to be performed shall be as indicated in Table 13.

Records of all coating application and quality control test results shall be kept in accordance with (9).

4.3.2 Ambient conditions

The Applicator shall measure the ambient conditions at regular intervals during blasting and coating using certified and calibrated instrumentation and keep records of prevailing temperature, humidity and dew point. If the environmental conditions lead to parameters that are outside the limits specified in the qualified procedures or this DEP, the application shall be suspended until the requirements are met.

4.3.3 Inspection of uncoated joints before blasting

Before surface preparation starts, each joint shall be visually examined for dents, laps, weld spatter or any other defects to avoid coating unusable joints.

The pipe surface and adjacent factory coating shall be visually checked for contamination, e.g. dirt, oil or grease. Contaminated pipes shall be cleaned. Pipes with non-adherent and/degraded pipe coating shall be rejected.

4.3.4 Inspection after blasting

Every joint shall be inspected for surface cleanliness. Joints that do not comply with the requirements of (4.1) shall be rejected and cleaned again.

The surface profile shall be measured at regular intervals (one out of every 10 joints and a minimum of twice per shift). If the surface profile is outside the specified limits, the blasting material shall be checked and replaced as necessary. The affected joints shall be re-blasted.

One out of every 100 joints, with a minimum of once per 24 h, shall be checked for dust and chloride contamination on the blasted surface (7.1). If contamination of the surface occurs, the quality of the blast cleaning material and process shall be examined according (7.17). If the conductivity of the blasting material is greater than 50 $\mu\text{S}/\text{cm}$, the blasting material shall be replaced.

4.3.5 Application temperatures

The temperature of the pipe surface during application shall be checked by means of suitable instruments, e.g., infrared sensors, contact thermometers or thermocouples and shall be in accordance with the application guidelines. Tempil sticks shall not be used,

The monitoring instruments shall be independent of the temperature control equipment. The instruments shall be calibrated once per 24 h.

Field joint coatings applied outside the qualified temperature range, the joint shall be identified by marking and subjected to additional quality control tests (4.3.6) at the discretion of the Inspector. Joints that do not comply with the quality control requirements shall be rejected, cleaned and recoated.

4.3.6 Appearance, thickness and holidays

Immediately following coating application, each coated joint shall be visually checked for imperfections and irregularities of the coating and for the absence of holidays (7.3). Joints that do not comply with the requirements shall be rejected, cleaned and recoated.

No holidays are allowed in the final coating. If holidays are detected, the coating shall be repaired with an appropriate repair coating system. The number of allowable repairs shall be agreed between the Coating Applicator and Principal and specified in the ITP.

The total thickness of the applied coating system shall be measured in accordance with (7.2) at regular intervals (one out of every 10 joints, with a minimum of twice per shift). The minimum thickness shall be as agreed between the Coating Manufacturer/ Applicator and Principal. When the measured layer thickness is out of the required range, additional measurements should be taken and corrective actions should provide that the coating shall be applied within the agreed layer thickness range.

4.3.7 Destructive testing

One out of every 100 applied field joint coatings (with a minimum of one per 24 h) shall be selected for adhesion testing of the coating. Testing of the adhesion of the field joint coating system to the steel surface, weld and to the overlap at the existing line pipe coating shall be performed.

The tests shall commence as soon as possible after coating to allow readjustment of the coating process if required.

If agreed between the Coating Applicator and Principal, additional destructive testing shall be performed depending on the type of field joint coating applied.

4.3.8 Acceptance of failed joints

In the event of joints failing to meet the requirements as specified in this section, preceding joints coated after the last acceptable joints and the joints coated following the failed joint shall be considered suspect and shall be marked for further testing.

The Applicator shall propose and agree with the Principal to a test programme to trace any of the suspect joints affected by the same failure. Further testing shall involve inspection and examination similar to that carried out on the original rejected joints. Based on the test results, the final acceptance or rejection of the suspect joints shall be made by the Principal.

In addition, the Applicator may be required to stop application and carry out a full investigation into the source of the problem; he shall submit the results to the Principal before receiving permission from the Principal to recommence production.

Table 13 Minimum quality control requirements for field joint coatings

Property	Section	Test method	Test frequency
Ambient conditions	4.3.2		all
Surface condition before blasting	4.3.3	visual	each pipe
Cleanliness of blast cleaned surface	4.3.4	7.1	each pipe
Surface profile	4.3.4	7.1	one out of every 10 joints (minimum 2 per shift)
Surface cleanliness Chlorides Dust	4.3.4	7.1	one out of every 100 joints (minimum 1 per 24 h)
Blast cleaning materials and process	4.3.4	7.17	once per shift or related to (4.3.3)
Pipe surface temperature during coating application	4.3.5	-	each pipe
Appearance	4.3.6	visual	each pipe
Coating thickness	4.3.6	7.2	one out of every 10 joints (minimum 2 per shift)
Holiday detection	4.3.6	7.3	each pipe
Adhesion	4.3.7	7.4	one out of every 100 joints (minimum 1 per 24 h)

5. FIELD JOINT COATING SYSTEM QUALIFICATION

5.1 GENERAL

Before a field joint coating system may be applied in the field, the Contractor shall submit all the data specified in (5.2) and (5.3) and shall ensure that both the coating system, application procedure and the Applicator have been qualified in accordance with the procedures in (5.4) and (6).

5.2 SYSTEM IDENTIFICATION

The Contractor shall submit information to the Principal to enable identification of the specific field joint coating system. This information shall include as a minimum:

- system designation or trade name;
- name of coating Manufacturer(s);
- generic type of system;
- coating application process;
- system structure (e.g. 2-layer or 3-layer);
- structure components (primer, adhesive, outer layer) ;
- service temperature range;
- total nominal coating thickness;
- compatibility to line pipe coating system;
- suitability for immersed services
- relevant international/national coating standard approvals.

5.3 MANUFACTURER'S DATA

5.3.1 Liquid epoxy and polyurethane

The following data shall be submitted on the liquid epoxy or polyurethane components

- Trade name
- Type of base (epoxy resin) and extender modification and type of curing agent (for liquid epoxy)
- Type of polyol and isocyanate (for polyurethane)
- Colour
- Solids by weight and volume
- Theoretical coverage per m² for nominal thickness
- Storage conditions and shelf life
- Application procedures, pot life, overcoating time

5.3.2 Heat shrink sleeve

The Shrink Sleeve Manufacturer/Supplier shall submit technical data on the system and system components for information of the Principal.

5.3.2.1 Primer

The following data shall be submitted on the primer (if applicable).

- The generic type of primer
- For liquid primers the solids content, the type of solvent and the density
- The method of application (brush, roller, spray, etc.)
- Required storage conditions, shelf life
- The nominal dry-film-thickness or spreading rate

- Application procedures, temperature, pot life, overcoating times, if applicable, for various ambient temperatures (10 °C to 50 °C).
- Health and safety data sheets

5.3.2.2 Adhesive

The following data shall be submitted on the shrink sleeve adhesive

- Generic type of adhesive
- Nominal thickness of the adhesive
- Softening point of the adhesive

5.3.2.3 Shrink sleeve material

The following data shall be submitted on the outer sheath material:

- Generic type of sheath material
- Nominal thickness of the sheath
- Mechanical properties of the sheath film (tensile strength, elongation)
- Storage conditions, shelf life
- Shape of delivered product (tubular, wrap or tape)
- For wrappings, the type of closure
- Colour

5.3.3 Polyethylene and polypropylene

The Coating Manufacturer/Supplier shall submit technical data on the system and system components for information of the Principal.

5.3.3.1 Primer

The following data shall be submitted on the primer (if applicable):

- the generic type of primer;
- for liquid primers the solids content, the type of solvent and the density;
- for powder epoxy primers the density, curing and gel time, particle size, moisture content, thermal analysis, recommended film thickness, colour;
- typical film properties (flexibility, cathodic disbonding resistance, etc.);
- the method of application (brush, roller, spray, electrostatic spray, etc.);
- storage conditions and shelf life;
- the nominal dry film thickness or spreading rate;
- application procedures, temperature, pot life, overcoating times;
- HSE datasheets.

5.3.3.2 Adhesive

The following data shall be submitted on the adhesive (if applicable):

- the generic type of adhesive;
- the method of application (powder spray, etc.);
- the nominal thickness;
- storage conditions and shelf life.

5.3.3.3 Coating material

The following data shall be submitted on the polyethylene or polypropylene outer layer material:

- generic type of material (e.g. high/medium/low density PE/PP);
- delivered product (sheet, powder, granules, liquid etc.);
- storage conditions, shelf life;
- colour;
- nominal thickness of the outer layer;
- mechanical properties of the outer layer film (tensile strength, elongation);
- data on resistance to bio-degradation.

5.3.4 Fusion bonded epoxy

The following basic properties of the epoxy powder resin are requested:

Infrared scan

An infrared spectrogram, carried out by means of a standard KBr disc, shall be submitted for comparison with all subsequent batches produced.

Particle size analysis

The particle size distribution analysis shall be carried out in accordance with ISO 8130-1. The Coating Contractor shall confirm that the particle size is suitable for the electrostatic spraying equipment used by the proposed Applicator.

Density

The density of the powder shall be measured in accordance with ISO 8130-2 or ISO 8130-3.

Curing schedule and gel time

A curing schedule shall show the gel time and minimum curing time required for full curing of the coating at various recommended application temperatures. The gel time shall be determined in accordance with ISO 8130-6.

Moisture content

The moisture content of the powder shall be determined by means of ISO 8130-7 and shall not exceed 0.5 % by mass.

Storage stability

The storage stability of the epoxy powder shall be determined in accordance with ISO 8130-8.

Thermal analysis

A thermal analysis shall be made by means of differential scanning calorimetry in accordance with (7.12) to determine the glass transition temperatures and the enthalpy of curing of the powder.

5.3.5 Visco-elastic self-healing coating system

The following technical data on the system and system components shall be submitted for information of the Principal.

5.3.5.1 Visco-elastic self-healing wrapping

- colour
- minimum coating thickness
- generic type of polymeric film with typical properties
- generic type of reinforcement material with typical properties
- generic type of adhesive with typical properties
- mechanical properties (elongation, tensile strength, etc)
- storage conditions

5.3.5.2 Mechanical outer wrap

- Colour
- minimum coating thickness
- generic type of polymeric film with typical properties
- generic type of reinforcement material with typical properties
- generic type of adhesive with typical properties
- mechanical properties (elongation, tensile strength, etc)
- storage conditions

5.4 COATING SYSTEM QUALIFICATION

Before a field joint coating system can be specified for a specific application it shall be qualified. Qualification shall be carried out according to the following procedures, which are also applicable for General qualification requirements.

The Contractor or the coating Manufacturer shall submit all data specified in (5.2) and (5.3).

The Contractor or the coating Manufacturer shall show that samples of the coating system applied on pipe joints of the specified pipe material have been successfully subjected to the tests as specified in Table 14. The tests shall be carried out by an independent test laboratory or, if approved by the Principal, by the coating Manufacturer. The Principal shall witness the application and the tests.

The number of pipe joints to be tested and the test procedures are given in Table 14.

If agreed by the Principal, previous qualification data developed in accordance with the requirements of this DEP may be used provided that the tests were performed using the same field joint coating system (5.2) and the same coating application process as specified in the contract.

With the approval of the Principal, tests carried out in accordance with other coating standards may be used insofar as the procedures are equal or more stringent than the procedures in this DEP. Such information shall include full reports on test procedures and results and be signed by the laboratory representatives and certification body.

6. APPLICATOR QUALIFICATION

6.1 GENERAL

Before application of a field joint coating system may commence, the Applicator shall be qualified to apply the coating system. The qualification shall be carried out according to the following procedures:

6.2 FIELD JOINT COATING APPLICATION PROCEDURE

The Contractor shall submit to the Principal information on the required coating application process and recommended applicators. Prior to start of production and any qualification testing, the Contractor shall prepare a detailed application procedure specification including:

- quality plan;
- Inspection and Test Plan (ITP);
- description of the coating application process, tools and equipment;
- pipe cleaning and surface preparation (cleanliness, profile, chemical pre-treatment, etc.);
- required surface and material application temperatures;
- recommended applicators;
- repair and testing procedures;
- marking, traceability and documentation;

6.3 APPLICATOR QUALIFICATION

After approval of the coating application procedure and before field application starts, the Applicator shall submit evidence that he has successfully applied the field joint coating system before on pipes of the specified material, and that the product complied with the requirements of this DEP for the tests indicated in Table 14, last column.

Regardless of whether the Applicator has applied the particular type of field joint in the past, the Applicator shall make a number of joints in order to:

- Prove the quality plan
- Prove the application procedures (both main and repair)
- Prove the ITP

This should cover at least 5 field joints. If different procedures are required for different sizes of joints, this should be 5 test joints for each procedure. All joints offered shall be tested in accordance with Table 14. After the Applicator has satisfactorily demonstrated that he can apply the field joint coating, his application workers shall be required to qualify by applying the required 2 joints (below) and having them tested to Table 14.

At least 2 welded pipe pups with the factory line pipe coating shall be coated by the applicator worker with the proposed field joint coating system and shall be subjected to the tests given in Table 14. These tests may be carried out in the Applicator's own laboratory, or by an independent laboratory to be agreed by the Principal. The Principal, or his representative, shall witness the application and testing. The results of the tests shall be reported to the Principal, signed by the head of the laboratory and the witness.

Table 14 Number of joints required during qualification

Property	Test method (section)	Number of joints required	
		Coating system qualification	Applicator qualification
Cleanliness of blast cleaned surface	(7.1)	5 joints	2 joints
Surface roughness	(7.1)	5 joints	2 joints
Pipe surface temperature	-	5 joints	2 joints
Coating application temperature	-	5 joints	2 joints
Appearance	visual	5 joints	2 joints
Coating thickness	(7.2)	5 joints	2 joints
Holiday detection	(7.3)	5 joints	2 joints
Adhesion	(7.4)	5 joints	2 joints
Impact	(7.5)	5 joints	2 joints
Indentation	(7.6)	3 joints	
Flexibility	(7.7)	3 joints	
Hot water soak	(7.8)	3 joints	
Cathodic disbonding	(7.9)	3 joints	
Thermal ageing	(7.10)	3 joints	
Lap shear	(7.11)	5 joints	
Degree of cure of FBE	(7.12)	3 joints	
Microscopic examination	(7.13)	3 joints	
Self-healing	(7.14)	3 joints	
Drip resistance	(7.15)	3 joints	
Peel to outer layers	(7.16)	3 joints	
Destructive testing	–	3 joints	2 joints
System identification/ Manufacturer's data	–	Available to Principal	–
Coating application process	–	–	Approved by Principal

7. INSPECTION AND TEST PROCEDURES

7.1 SURFACE FINISH AFTER BLAST CLEANING

The surface finish after blast cleaning shall be inspected as follows:

- surface cleanliness shall be determined in accordance with ISO 8501-1;
- chloride contamination shall be determined in accordance with ISO 8502-6 or by using Elcometer 130, SCM 400 Salt Contamination Meter;
- dust levels shall be determined in accordance with ISO 8502-3;
- surface profile shall be determined by means of a digital Surface Profile Gauge or Surface Roughness Tester which shall be calibrated before every unit of production.

7.2 COATING THICKNESS

The coating thickness shall be measured by means of a thickness meter based on eddy current or electromagnetic techniques, in accordance with ISO 2808, method 6A or 6B.

Magnetic thickness gauges shall not be used, either for qualification testing or for quality control purposes.

The thickness gauge shall be calibrated at least once per shift. Calibration shall be carried out on a steel plate of a similar thickness to the pipe wall by means of plastic shims of the same thickness as the nominal coating system.

For quality control purposes the coating thickness shall be measured at two locations per joint, at both sides of the weld. At each location, the thickness shall be measured at four positions, equally spaced around the circumference of the pipe. In addition four measurements shall be taken on the weld.

7.3 HOLIDAY TEST

A holiday test shall be carried out by means of an adjustable high voltage holiday tester having an audible and visual alarm. The scanning electrode shall consist of a metal brush or coil spring, adjusted to the diameter of the coated pipe.

The earth connection shall be made directly on the pipe.

The test voltage shall be as specified for the coating type described in the previous sections of this DEP.

The test voltage shall be checked at least once per shift by means of a special high voltage meter.

When the holiday test is carried out the external pipe surface shall be free of moisture.

The electrode shall be moved over the pipe surface at a speed of not more than 0.3 m/s. The entire pipe surface shall be covered by the test.

When used in conjunction with the impact resistance test (7.5), a suitable metal brush shall be used to inspect the impacted surface.

7.4 COATING ADHESION

7.4.1 General

The coating adhesion shall be measured by different methods, depending on the coating type used. For liquid coating types and FBE, the adhesion shall be measured by dolly pull-off measurements and the X-cut method. For the polymeric coatings (shrink sleeves, polyethylene/polypropylene and visco-elastic self-healing coatings), the peel test method shall be used.

7.4.2 X-cut method

The adhesion test shall be done at $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ unless otherwise agreed.

The test area shall consist of any coated area on the component or test sample that is free from all defects and with the correct dry film thickness.

Using a sharp-bladed utility knife against a steel rule, straight 30 mm to 50 mm cuts shall be made in the coating through to the metal surface to form an X with an angle of approximately 30° at the intersection point.

The point of the utility knife shall be inserted horizontally (i.e. the flat of the blade) under the coating at the point of intersection of the cuts such that the blade point is at the metal surface.

A levering action against a fulcrum (such as a steel rod) shall be used to force the flat point of the blade up from the metal surface describing a single, vertical (i.e. at 90° to the surface) motion in an attempt to prise the coating off.

The adhesion of the coating shall be determined by the following rating system (see Figure 1).

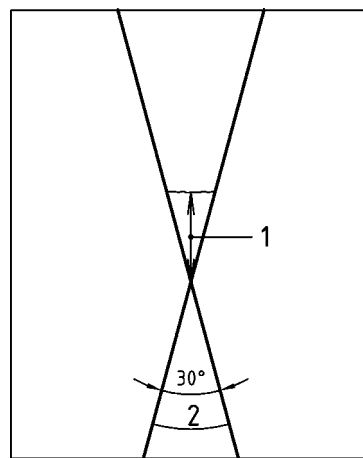


Figure 1 Adhesive loss of coating (rating 1 to 5)

Key

- 1 Adhesive loss of coating (rating 1 to 5) ^a
- 2 Cuts

NOTE ^a	Rating 1:	No removal of coating other than that caused by insertion of the flat point of the knife blade at the intersection point (nominally less than 1 mm).
	Rating 2:	Not more than 2 mm of adhesive loss of coating from the metal surface.
	Rating 3:	Not more than 3 mm of adhesive loss of coating from the metal surface.
	Rating 4:	Not more than 5 mm of adhesive loss of coating from the metal surface.
	Rating 5:	More than 5 mm of adhesive loss of coating from the metal surface.

The rating of the coating adhesion is determined by adhesive failure. Limited cohesive rupture within the coating shall be considered a pass, if there is satisfactory adhesion.

Cohesive rupture caused by excessive interface or cross-section porosity leaving a noticeable "honeycomb" structure on the sample surface shall constitute a failure, when the foaming degree is larger than degree 2 according (7.13).

An adhesive breakaway from the point of intersection of more than 2 mm, or brittle breakaway of flakes of more than 2 mm constitutes a failure.

Refusal to peel, or a cohesive break less than 2 mm long entirely within the coating, constitutes a pass.

Cohesive failure caused by voids in the coating leaving a honeycomb structure on the steel surface also constitutes a failure.

At least 3 X-cuts shall be made on one test piece.

The rating shall be recorded.

7.4.3 Dolly pull-off test

The adhesion strength of the coating shall be tested by a pull-off test according to ISO 4624.

7.4.4 Peel strength test

The coating adhesion shall be determined by measuring the peel strength, i.e. the force required to peel a strip of coating from the pipe surface.

The test method shall not use a force gauge of the spring balance type.

For testing at elevated temperatures, a sample of pipe shall be conditioned for at least 1 h at the test temperature. The test shall be carried out under conditions that ensure that the temperature of the outer steel surface is maintained at the required test temperature. The surface temperature shall be monitored during the test and the results reported.

The procedure and the type of heating equipment shall be proposed by the test laboratory and approved by the Principal.

A strip of coating with a width of between 20 mm and 50 mm shall be peeled off the pipe surface in the circumferential direction over the full pipe circumference or at least 300 mm length, by means of a tensile machine and the stripping arrangement shown in Figure 2. Apparatus in the relevant test method of ISO/DIS 21809-3 may be used.

The coating shall be peeled at an angle of 90° to the pipe surface with a pulling rate of 10 mm/min. The force required for the peeling shall be continuously recorded. The peeling force shall be the mean value of this recording, disregarding the first and last 20 mm. The recording shall not show any section of more than 20 mm length having a peeling force less than 75 % of the mean value.

The peel strength is calculated as:

$$\frac{F_m \times 10}{W} \quad (\text{N/10 mm})$$

where: F_m is the mean pulling force in N
 W is the width of the strip in mm.

The peel tests shall be carried out on the steel body, the weld and on the overlap with the existing line pipe coating.

The test strips shall be at least 50 mm apart.

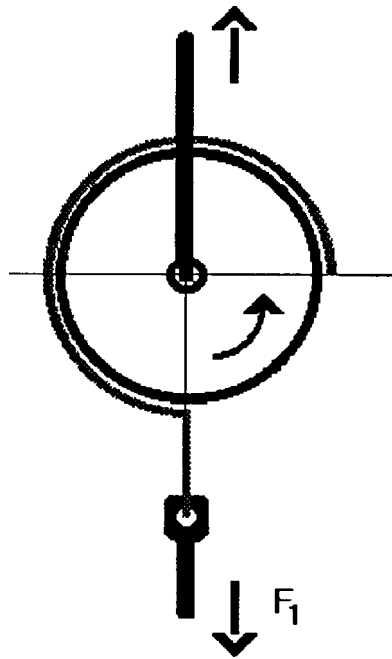


Figure 2 Arrangement for the peel strength test

7.5 IMPACT RESISTANCE

The impact test shall be performed by means of a free falling weight impact testing machine comprising the following:

- a straight guide made of steel, aluminium or plastic, rigid and non-deformable, inside diameter between 40 mm and 60 mm, length at least 1.30 m, with a smooth and even inside surface.
- a support and levelling device (for example, two spirit levels for the horizontal plane and a plumb line for the vertical plane);
- a graduated rod which makes it possible to determine the drop height to an accuracy of 5 mm;
- a hard steel punch, with a hemispherical head, free from notches, porosity or other surface irregularities and with a diameter of 25 mm. A small metal rod with a diameter of 6 mm shall be fixed perpendicular to the flat face of the head and in its centre; this rod shall be long enough to hold the additional weights required for the tests. The punch shall be equipped with a system for raising to the required height; the mass of this assembly shall be $1 \pm 0,005$ kg;
- a number of weights, formed by metal discs (preferably made of stainless steel) with an outside diameter of approximately 24 mm and incorporating a central hole of diameter 6,5 mm. The mass of each disc shall have an accuracy of ± 5 g.

Other guides may be used if agreed by the Principal.

Before the test, the pipe surface shall be tested for the absence of holidays.

The pipe sample shall be placed horizontally, supported directly under the impact area to avoid the effect of the elastic response of the pipe. The testing machine shall be placed in a vertical plane perpendicularly on the top of the pipe surface.

When tested at low temperatures (at or below 0 °C), the pipe sample shall be conditioned at that temperature for at least 12 h, and the test performed before the coating temperature rises more than 2 °C above the test temperature.

Each test shall comprise a series of 10 impacts, using a combination of weight and height corresponding to the predetermined impact energy. The impacts shall not be on pipe welds, coating overlaps or within $1.5 \times \text{DN}$ or 300 mm, whichever is smaller, from the edge of the coating. The impacts shall be at least 50 mm apart. After the impacts have been made, each point of impact shall be tested for the presence of a holiday in accordance with (7.3). The number of holidays shall be noted.

When no defects can be found, this value shall be rated as the minimum impact resistance.

The hard steel punch shall be checked every 30 impacts. If damaged, it shall be replaced.

7.6 INDENTATION

For liquid epoxy and polyurethane, FBE and polyethylene/polypropylene coating systems the indentation depth shall be measured and for heat shrink sleeves and visco-elastic self-healing wrappings the remaining thickness shall be measured.

The applied test pressure for the indentation test shall be 10 N/mm^2 . Tests are performed at ambient temperatures and at elevated temperatures and the duration shall be 24 h.

The test shall be performed three times on one coating sample.

The test sample, held within the penetrometer assembly, shall be placed in the thermostatically controlled chamber and set to the test temperature. The test sample shall be kept in the chamber for at least 1 h.

The following readings shall be made;

- a) T_0 is the reading on the dial gauge placed on an uncovered part of the steel plate or pipe; where T_0 is the thickness of the steel specimen.
- b) T_1 is the reading on the dial gauge with the indenter without the mass positioned centrally over the sample; where T_1 is the (specimen + coating) thickness before testing.
- c) T_2 is the reading of the dial gauge after the mass giving the total desired pressure on the indenter for a minimum duration of 24 h; where T_2 is the (specimen + coating) thickness after testing.

If sampling of the test piece is impractical (e.g. in the case of large diameter components), the test may be carried out directly on the coated component in air, provided that;

- (i) the surface temperature of the coating is in the range of $(20 \pm 5) ^\circ\text{C}$; and
- (ii) the experimental assembly (component and apparatus) is not exposed to heat radiation or vibration during the testing.

The following quantities can be calculated on the basis of the measurements;

$$T_3 = T_1 - T_0$$

where

T_3 is the coating thickness

$$T_4 = T_2 - T_0$$

where

T_4 is the residual thickness of the coating

$$T_5 = T_1 - T_2$$

where

T_5 is the indentation into the coating

The arithmetic mean of the three indentation measurements shall be calculated and recorded.

7.7 FLEXIBILITY

Samples shall be cold-cut from a coated pipe and shall be subjected to a bend test.

For pipe diameters of 300 mm and above, four strips (300 mm long x 50 mm wide) shall be cut in the longitudinal direction of the pipe.

For pipe diameters less than 300 mm, four rings shall be cut with a width of 50 mm.

The samples shall be free from holidays when tested in accordance with (7.3).

At 0 °C a 2 % strain, and at 20 °C a 3 % strain, shall be induced in the coating of the sample or otherwise agreed by the Principal.

Two tests shall be carried out at each temperature.

The deflection loading rate during bend testing shall be (25 ± 2) mm/min.

Strip samples shall be bent by means of a mandrel, using either a 3-point bending or a cantilever arrangement.

The mandrel sizes shall be selected according to the following formula:

$$D = \frac{t(1 - s)}{s}$$

where:

- D = mandrel diameter (mm)
- t = specimen metal wall thickness (mm)
- s = 2 % at 0 °C
3 % at 20 °C

The ring samples shall be squeezed in accordance with ASTM G 70 to obtain a strain of 2 % and 3 % respectively.

As a guide, the length of the reduced axis after squeezing shall be:

$$d_2 = \frac{d}{\left(\frac{s}{t} \times d\right) + 1}$$

where:

- d = the pipe diameter (mid-wall to mid-wall) before squeezing, mm
- d₂ = the length of the reduced axis (mid-wall to mid-wall) after squeezing, mm
- t = the pipe wall thickness (mm)
- s = 2 % at 0 °C
3 % at 20 °C

After bending, the pipe coating surface shall be examined for the presence of holidays in accordance with (7.3). The coating shall be deemed to have failed the test if any holiday is detected.

7.8 HOT WATER SOAK

A coated sample of 200 mm x 100 mm machined from a ring of the coated pipe shall be immersed in tap water at the test temperature specified in Table 15. The sample shall consist of the coating applied on steel and overlap with existing line pipe coating. The bare edges of the sample shall be coated to prevent ingress of moisture at the pipe-coating interphase. When agreed by the Principal, other sized coated samples may be used.

The exposure time shall be 28 days.

Immediately after the exposure, the coated sample shall be removed from the water bath and allowed to cool to ambient temperature. The coating shall then be examined visually and the adhesion shall be tested and judged in accordance with (7.4). i.e the X-cut and dolly pull-off test for the liquid and FBE coating systems and the peel tests for the other coating systems. Adhesion tests shall be performed on the field joint coating over both the steel substrate and the existing line pipe coating.

For the liquid and FBE coating systems the flexibility according to (7.7) shall be measured at ambient temperature after the exposure. The sample sizes for the flexibility test shall be as specified in section 7.7.

Table 15 Hot water soak test temperature

Maximum design temperature, °C	Test temperature, °C
< 20	20 ± 2
20 to 60	60 ± 2
60 to 80	80 ± 2
> 80	Maximum design temperature ± 2

7.9 CATHODIC DISBONDING RESISTANCE

The cathodic disbonding resistance of the coating shall be tested as follows:

The test sample shall be free of holidays when tested in accordance with (7.3).

A sample of coated pipe shall be taken of sufficient length and with approximately the same diameter as the production pipe. The exact set-up of the test may depend on the diameter of the pipe.

A 6 mm hole shall be drilled in the coating, by means of a flat-faced mill. The hole shall not penetrate more than 0.5 mm into the pipe steel. The hole shall be at least 50 mm from any weld.

The sample shall be placed inside an electrolytic cell or an electrolytic cell shall be constructed on the pipe surface. All metallic parts other than the test defect shall be sealed from the electrolyte by means of a resin or other suitable compound. The volume of the cell shall be at least 250 ml.

The cell shall be filled with a 3 % sodium chloride solution.

An inert auxiliary electrode (e.g. platinum wire or mesh) shall be placed in the electrolyte, remote from the test defect.

A saturated calomel reference electrode (SCE) shall be placed in the electrolyte with the tip 10 mm from the test defect.

Using a potentiostat, the electrochemical potential of the steel shall be polarised to a value of -1500 ± 10 mV with respect to the SCE. This potential shall be maintained throughout the test.

The current required to maintain the potential shall be continuously recorded.

The duration of the test shall be 28 days, after which the sample shall be removed from the cell and examined.

For tests at elevated temperatures, the temperature shall be controlled as follows:

- When the sample is immersed in the cell, the solution and sample shall be kept at the test temperature by the cell being placed in a thermostatically controlled water bath.
- When the cell has been constructed on the pipe sample, the steel sample shall be placed in a thermostatically controlled furnace or sand bath that also covers the top

surface of the sample with at least 1 cm of sand. The furnace or bath shall be adjusted to maintain the required test temperature on the pipe surface in the test defect.

- During tests at elevated temperatures, suitable reflux coolers shall be used to prevent evaporation of the test electrolyte.
- The maximum test temperature shall be 95 °C even if the maximum design temperature is more than 95 °C. At higher temperatures, the electrolyte in direct contact with the steel surface in the coating defect will start to boil.

At the end of the test period, the sample shall be rinsed with fresh water and wiped dry.

Two cuts shall be made through the coating in the longitudinal direction of the pipe and two similar cuts shall be made in the circumferential direction, each pair of cuts being 5 mm apart and approximately following the tangent of the test defect. The length of the cuts shall extend to approximately 20 mm each side of the defect; see Figure 3.

By means of a knife, the strips of coating between the cuts shall be peeled from the pipe surface as far as possible, starting at the test defect. The distance over which the coating is detached and the metal is exposed, measured from the edge of the original test defect, shall be recorded for all four directions. The maximum radius of disbonding shall be within the requirements set for each coating type. A photograph of the test sample after testing, showing the disbonded area, should be included in the test report.

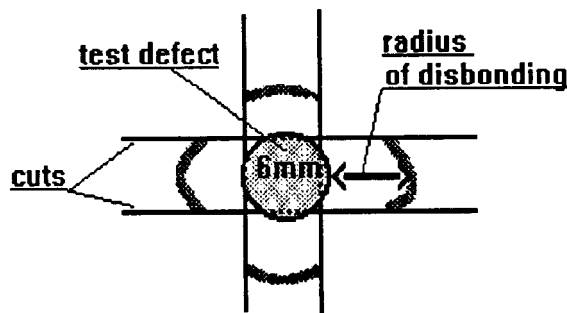


Figure 3 Radius of disbonding

7.10 THERMAL AGEING

A rectangular shaped sample, length 200 mm x width 100 mm, machined from a ring section, cut from the coated pipe shall be exposed to air in an oven at the test temperature specified in Table 16. The sample shall consist of the coating applied on steel and overlap with existing line pipe coating. The bare edges of the sample shall be coated to prevent delamination of the coating. When agreed by the Principal, other sized coated samples may be used. When subsequently flexibility testing is required, the sample size shall be as such that flexibility testing according (7.7) can be performed.

The exposure time shall be 100 days.

Immediately after the exposure, the coated sample shall be removed from the oven and allowed to cool to ambient temperature. The coating shall then be examined visually and the adhesion shall be tested and judged in accordance with (7.4). i.e the X-cut and dolly pull-off test for the liquid and FBE coating systems and the peel tests for the other coating systems. Adhesion tests shall be performed on the field joint coating over both the steel substrate and the existing line pipe coating.

For the liquid and FBE coating systems the flexibility according (7.7) shall be measured at ambient temperature after the exposure. The sample sizes for the flexibility test shall be as specified in (7.7).

Table 16 Thermal ageing test temperature

Maximum design temperature, °C	Test temperature, °C
< 20	20 ± 2
20 to 60	60 ± 2
60 to 80	80 ± 2
> 80	Maximum design temperature ± 2

7.11 LAP SHEAR

For each test specimen, two steel plates of 100 mm length and 50 mm width shall be blast cleaned to Sa 2½. Both plates shall be coated on one side over a distance of 25 to 30 mm in the longitudinal direction with the primer to be used for the shrink sleeve system. One plate is coated similarly with the shrink sleeve adhesive to obtain the same thickness as with the finished product. The second plate shall be positioned with the primer onto the adhesive layer on the first plate in such a way that the longer sides are parallel and that the overlap of the two plates is 20 mm. The specimen shall be treated at the application temperature for 15 minutes, applying a gentle pressure to obtain the same adhesive thickness as for the applied shrink sleeve. The maximum time between blast cleaning and this treatment shall be 4 h. The test specimens shall be stored for not less than 24 h at 23 °C. The adhesive that has oozed out at the sides of the plates shall be removed.

When no primer is used, the adhesive shall be directly applied to the plates.

The specimen shall be clamped in a tensile testing machine which complies with ISO 5893 equipped with a thermostatically controlled chamber to maintain the specimen at the required test temperature. The specimen shall be conditioned at the test temperature for at least 1 h before testing is started.

A tensile load shall be applied in order to maintain a constant shear rate of 10 mm/min until the specimen breaks. The maximum force (F) shall be recorded.

The shear strength is calculated as:

$$F / A \quad (\text{N/mm}^2)$$

where

F is the maximum force to shear the specimen, in Newtons

A is the surface area of the overlap of the two plates used in the test specimen, in mm².

7.12 DEGREE OF CURE OF FBE

The degree of cure of a FBE coating (stand alone sytem or primer) shall be measured by means of differential scanning calorimetry (DSC) in accordance with ASTM D 3418, to determine the glass transition temperature (Tg) and the enthalpy (Hr) of the curing of the powder.

For the samples of the applied coating, two scans shall be made to determine the glass transition temperatures Tg₁ and Tg₂, respectively. The degree of cure is related to the difference between Tg₁ and Tg₂, which shall be determined as:

$$\Delta Tg = Tg_2 - Tg_1$$

7.13 MICROSCOPIC EXAMINATION

A cross-section and the coating-steel interface of the cured film shall be examined using a microscope with a magnification of 30x to 40x. This may be done on chips of coating removed from test pipes for production quality control. The presence of foaming and voids through-film (section perpendicular to the pipe surface) and across-film (section parallel to the pipe surface) shall be rated according to the visual scale in Figure 4. Any other contamination at the coating interface shall be reported.

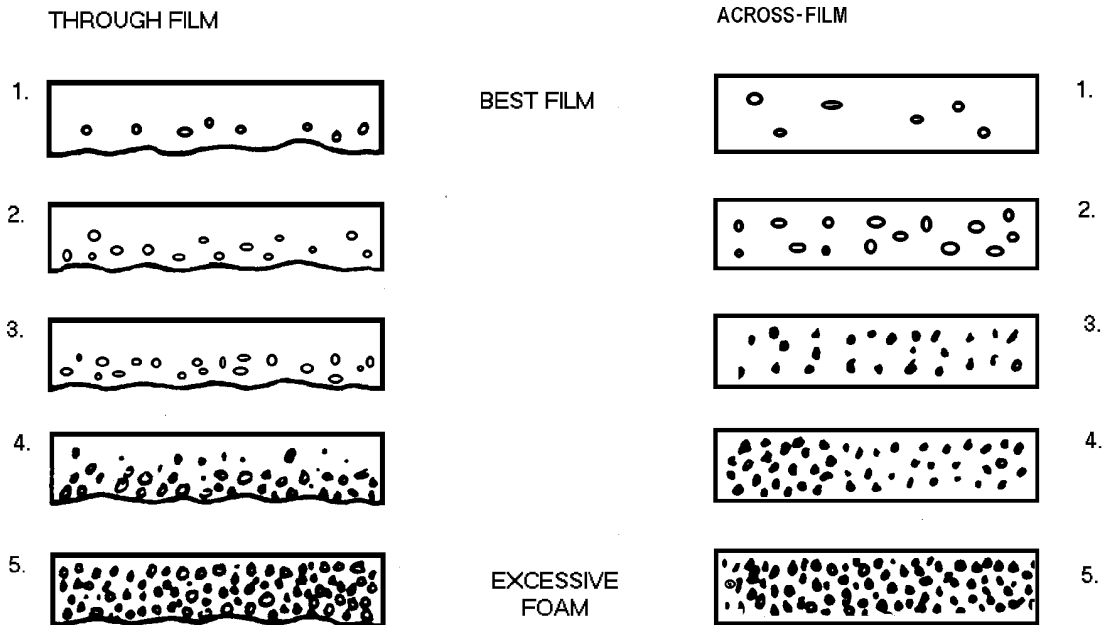


Figure 4 Degree of foaming of FBE film

7.14 SELF-HEALING

The self-healing performance of the coating shall be tested as follows:

The test sample shall be free of holidays when tested in accordance with (7.3).

A sample of coated pipe shall be taken of sufficient length and with approximately the same diameter as the production pipe. A 6 mm hole shall be drilled in the coating, by means of a flat-faced mill. The hole shall not penetrate more than 0.5 mm into the steel substrate. Distance between the hole and any weld shall be at least 50 mm. For each test specimen, 3 holes shall be drilled at least 50 mm apart and at least 50 mm distance from any weld or pipe end.

The self-healing test shall be performed at room temperature and at the maximum design temperature. The test specimen shall be kept at the specified temperature for 24 h. After this period the holes shall be inspected by holiday detection (7.3) and the thickness in the hole shall be measured.

The test shall be considered passed if no holidays are present and the thickness in the hole is more than 0.6 mm.

7.15 DRIP RESISTANCE

The drip resistance of the coating shall be tested as follows:

Three samples of the coating (wrap, tape) of 150 mm in length and 50 mm wide shall be cut and shall be exposed in the oven for 48 h at the maximum design temperature. The samples shall be freely hanging vertically. After this period, it shall be determined if any

components of the coating system has dripped on the bottom of the oven. If any material has dripped, the coating system fails this test.

7.16 PEEL TEST FOR OUTER WRAP

The test consists of measuring the peel strength (peeling force per unit width) between two layers of tapes or wrapping bands.

Peel strength shall be determined for:

- inner layer to inner layer;
- outer layer to inner layer;
- outer layer to outer layer.

The equipment shall comprise the following:

- a tensile testing machine in accordance with ISO 5893 allowing the peeling force to be recorded and capable of operating at a constant rate of separation of 100 mm/min;
- equipment for the tensile testing machine allowing the sample to be maintained at the test temperature;
- lower rigid support plate (e.g. glass plate) about 50 mm x 300 mm x 5 mm;
- rigid upper plate (e. g. steel plate about 50 mm x 200 mm x 5 mm) with a smooth cellular rubber on its lower side (thickness of the rubber 1 mm to 3 mm);
- a load which produces a combined pressure of 0,01 N/mm² together with the upper plate;
- pipe sections of diameter 100 mm;
- release paper.

The test samples shall be prepared as follows (the numbers in brackets correspond to the items in Figure 5):

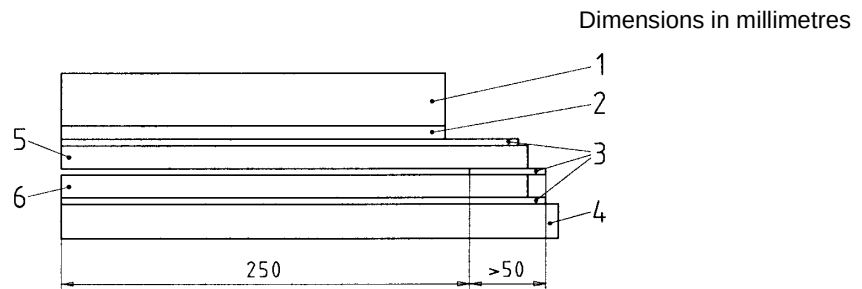
Discard the three outer turns from the roll. Cut strips 250 mm to 280 mm in length, 50 mm wide or of tape width in the case of narrower tapes. Locate one strip of the first tape (6), adhesive side down on release paper (3) on the lower plate (4). Apply the second tape strip (5) with the same dimensions exactly over the first. At one end insert a piece of release paper between the two tape strips for 50 mm to 80 mm. Place release paper (3), the rubber coating (2) and the upper plate with the load onto the sample (1) [pressure 0,01 N/mm²] and store for seven days at 23 °C ± 2 °C.

It is permissible to apply additional supporting films to the outer surfaces of the samples to prevent excessive elongation during the test.

Wrap the pipe section of diameter 100 mm, 100 mm long circumferentially with two layers of the shrinkable material one after another in accordance with the manufacturer's instructions. Store for at least 24 h at 23 °C ± 2 °C.

Key

- 1 plate with load
- 2 rubber coating
- 3 release paper
- 4 plate
- 5 tape 2
- 6 tape 1



Key

- 1 sample
- 2 rubber coating
- 3 release paper
- 4 lower plate
- 5 second tape strip
- 6 first tape strip

Figure 5 Assembly of the test sample for testing the peel strength between layers

The peel strength test shall be carried out at 23 °C at the maximum design temperature of the coating material.

Clamp the end of the two tapes into the grips of the tensile testing machine. Precondition the test sample at the specified test temperature for at least 0,5 h and maintain the specified test temperature throughout the test.

Set the tensile testing machine in operation at a constant rate of separation of 100 mm/min. Record the peeling force continuously.

Calculate the mean value of the peel strength in N/mm width using at least 20 points at regular intervals. Disregard the first and last 50 mm of the peeling length. If any values are less than 75 % of the specified peel strength, test a further three samples. No further failure is allowed.

The values of the three test samples shall be recorded and the minimum peel strength shall be larger than the specified value.

7.17 CONDUCTIVITY MONITORING OF BLASTING MATERIAL EXTRACTS

This method describes the procedure for monitoring the quality of the blasting material in machines that recycle the blasting material. An increased conductivity level may indicate that an ionic contaminant has been introduced into the blasting material from the pipe surface. The procedure to determine conductivity of the blasting material shall be in accordance with ISO 11127-6.

8. COATING REPAIR

The Contractor shall submit detailed procedures for coating repairs.

All coating repair procedures shall be qualified under both coating system (5.4) and Applicator qualification (6).

These procedures shall cover at least:

- repair of surface defects (e.g. by means of a melt stick);
- repair of pinholes, scratches and small defects);
- removal of rejected coating and cleaning the pipe to the required standard for recoating;
- testing to prove the effectiveness of the repairs.

All pipes that have been repaired shall be fully re-examined in accordance with the quality control procedures (4.3).

Records shall be kept of all repaired pipes and shall include the repair and re-test details.

9. DOCUMENTATION

9.1 QUALIFICATION RECORDS

The Contractor shall keep accurate records of all relevant data concerning the field joint coating qualification process.

This information shall consist of:

- Copies of pre-qualification information as requested in (5.2)
- Records of all samples as specified in (5.4)
- Records of all qualification tests carried out including test equipment data, test conditions and identification of samples used
- Records of all test results
- Names of persons that carried out and / or witnessed the tests.

All information shall be compiled into a test report which shall be approved and signed by the responsible person of the test laboratory and by the Inspector.

9.2 FIELD RECORDS

During field application of the coating system the Contractor shall keep accurate records of all information related to the coating application. This information shall include at least the following, all of which should be included in the Applicator's ITP:

- Copies of, or reference to, all procedures for the application of the coating
- Copies of, or reference to, the field joint coating qualification report.
- Results of qualification tests for field joint coating Application workers including names and dates of qualification; number of application workers required for each applicable pipe diameter.
- Identification of the pipe joints where coatings have been applied, by reference to the joint numbers in the pipeline construction record book.
- Batch numbers of all coating components that have been applied, date/time of application and the name of the Application worker(s)
- The results of all quality control testing
- Identification of field joint coatings that have been subjected to peel strength tests and destructive testing) with date/time of the test and all test results.
- Records of any process changes needed to comply with the specifications.
- Names and signatures of the responsible persons for the application process and quality control.

All results shall be compiled into a report in a format agreed between the Contractor and the Principal.

10. REFERENCES

In this DEP, reference is made to the following publications:

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell users on the SWW (Shell Wide Web) at <http://sww05.europe.shell.com/standards/>.

SHELL STANDARDS

Thermal sprayed aluminium coatings	DEP 30.48.40.31-Gen.
Elastomer coatings and monel sheathing for offshore riser protection	DEP 31.40.30.36-Gen.

AMERICAN STANDARDS

Standard test method for transition temperatures of polymers by differential scanning calorimetry	ASTM D 3418
Standard test method for indicating oil or water in compressed air	ASTM D 4285
Standard test method for ring bendability of pipeline coatings (squeeze test)	ASTM G 70

Issued by:
American Society for Testing and Materials
100 Barr Harbor Drive, West Conshohocken
PA 19428-2959
USA

INTERNATIONAL STANDARDS

Plastics and ebonite – Determination of indentation hardness by means of a durometer (shore hardness)	ISO 868
Paints and varnishes – Determination of film thickness	ISO 2808
Paints and varnishes – Pull-off test for adhesion	ISO 4624
Rubber and plastics test equipment – Tensile, flexural and compression types	ISO 5893
Coating powders	
Part 1: Determination of particle size distribution by sieving	ISO 8130-1
Part 2: Determination of density by gas comparison pyknometer (referee method)	ISO 8130-2
Part 3: Determination of density by liquid displacement pyknometer	ISO 8130-3
Part 6: Determination of gel time of thermosetting coating powders at a given temperature	ISO 8130-6
Part 7: Determination of loss of mass on stoving	ISO 8130-7
Part 8: Assessment of the storage stability of thermosetting powders	ISO 8130-8
Preparation of steel substrates before application of paints and related products - visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings	ISO 8501-1

Preparation of steel substrates before application of
paints and related products – Tests for the assessment of
surface cleanliness –

Part 3: Assessment of dust on steel surfaces prepared
for painting (pressure-sensitive tape method) ISO 8502-3

Part 6: Extraction of soluble contaminants for analysis
– The Bresle method ISO 8502-6

Preparation of steel substrates before application of
paints and related products – Test methods for
non-metallic blast-cleaning abrasives –
Part 6: Determination of water-soluble contaminants by
conductivity measurement ISO 11127-6

Petroleum and natural gas industries – External coatings
for buried and submerged pipelines used in pipeline
transportation systems – Part 3: Field joint coatings ISO/DIS 21809-3

Issued by:
ISO Central Secretariat
1, ch. de la Voie-Creuse
Case postale 56
CH-1211 Genève 20
Switzerland

Copies can also be obtained from national standards organizations.