

GENERAL SPECIFICATION

CORROSION

GS EP COR 220

Three layer polyethylene external coating for pipelines

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08	01/2011	General review
07	10/2009	Changes in testing requirements
06	10/2008	Specification becomes limited to EP - Inclusion of pipe coating line velocity monitoring, change of acceptance criteria for epoxy primer
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1. General

1.1 Scope

This specification covers the manufacturing of 3 layer polyethylene (3LPE) external anticorrosion coatings for onshore or offshore pipelines transporting oil, gas, or water.

The coating shall be plant applied and suitable for service temperature from -40°C up to +80°C (depending on the type of epoxy primer used).

The purpose of this specification is to define the following:

- Applicator's obligations
- Composition of coating and characteristics of the epoxy primer, the adhesive and the polyethylene
- Application of the epoxy primer, the adhesive and the extruded polyethylene
- Characteristics of the finished coating
- Qualification testing
- Fabrication testing and Inspection.

Field joint coatings to be applied after girth welding of pipes and field repairs of 3LPE coated pipes are specified in **GS EP COR 420**.

Requirements from **NF A49-710** standard shall be followed when they are not in conflict with those of the present document.

1.2 Definitions of main parties involved

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

1.2.1 Manufacturer

The Company which produces and sells the products used for the coating shall be referred to herein as the "Manufacturer".

1.2.2 Applicator

The Company in charge of the plant coating application and quality control which is eventually sub-contracted by the Contractor shall be referred to herein as the "Applicator".

1.2.3 Inspector

The Company's representatives or members from Company elected Inspection Bodies for the time being or from time to time duly appointed in writing by the Company to act as its representatives for the purpose of the Contract shall be referred to herein as the "Inspector".

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

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External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
ASTM D 1693	Standard test method for environmental stress-cracking of ethylene plastics
ASTM D 4940	Standard test method for conductimetric analysis of water soluble ionic contamination of blasting abrasives
ASTM D 570	Standard Test Method for Water Absorption of Plastics
CSA Z245-20	External fusion bond epoxy coating for steel pipes
ISO 1133-1	Plastics - Determination of the melt-mass flow rate (MFR) and melt-volume flow rate (MVR) of thermoplastics – Part 1 Standard method
ISO 11357-1	Plastics - Differential scanning calorimetry (DSC) - Part 1: General principles
ISO 11357-3	Plastics - Differential scanning calorimetry (DSC) - Part 3: Determination of temperature and enthalpy of melting and crystallization
ISO 1183	Plastics - Methods for determining the density and relative density of non-cellular plastics
ISO 2808	Paints and varnishes - Determination of film thickness
ISO 2811-1	Paints and varnishes - Determination of density - Part 1: Pycnometer method
ISO 306	Plastics - Thermoplastic materials - Determination of Vicat softening temperature
ISO 4287	Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters
ISO 4892-2	Plastic - Methods of exposure to laboratory light sources - Part 2: xenon-arc lamps
ISO 527-1	Plastics - Determination of tensile properties - Part 1: General principles
ISO 527-2	Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics
ISO 6964	Polyolefine pipes and fitting: Determination of carbon black content by calcinations and pyrolysis: Test method and basic principles
ISO 8130-6	Coating powders - Part 6: Determination of gel time of thermosetting coating powders at a given temperature

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Reference	Title
ISO 8501-1	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 8502-3	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 8502-6	Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Part 6: Extraction of soluble contaminants for analysis - The Bresle method
ISO 8502-9	Preparation of steel substrates before application of paints and related products. Tests for the assessment of surface cleanliness. Part6: Field method for conductometric determination of water-soluble salts.
ISO 8503-4	Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates - Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile - Stylus instrument procedure
ISO 868	Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)
NACE RP0274	High-Voltage Electrical Inspection of Pipeline Coatings
NF A49-710	Steel tubes. External coating with three polyethylene based coating. Application through extrusion

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP COR 420	External field joint coatings of pipelines
GS EP PLR 410	Concrete coating for submarine pipelines

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3. Obligations of Applicators and Manufacturers

3.1 Company requirements regarding coating products

The Applicator shall, in his tender, submit the data sheets of its selected products concerning the epoxy primer material, the adhesive material, the polyethylene and the repair products for approval. He will also provide a written notice attesting that the epoxy primer material, the adhesive material, the polyethylene and the repair products delivered shall meet the required characteristics as set forth in § 4 according to the specified methods.

The Applicator shall inform by writing the Manufacturers of the epoxy, the adhesive and the polyethylene of the Company requirements related to:

- Test certificates, properties requirements and conformity certificates as detailed in the present document. A copy of this written notice shall be sent to Company
- The packaging of the epoxy powder: The Manufacturer shall deliver the product in waterproof plastic bags to prevent water contamination and absorption of humidity during storage and transportation.

Once approved the epoxy primer material, the adhesive material, the polyethylene and the repair products shall not be changed by the Applicator.

Approval of the products by the Company shall not, under any circumstances, be considered as a guarantee from the Company with respect to coating materials and repair products but simply as an authorisation for use.

3.2 Qualification of Applicator's plant and coating system

Qualification of the proposed application plant, personnel, coating method and products shall be carried out in due time through a Procedure Qualification Trial (PQT). Qualification shall be organised jointly by the Contractor and the Applicator, and witnessed by a Company representative. Qualification testing shall be organised at least 2 months before the works start in order to ensure that a suitable solution can be implemented in case of test results fail to meet the requirements of this specification.

Qualification shall consist of the following step:

- Raw materials (epoxy, adhesive, PE):
 - Conformity certificates (see § 4) and tests results for materials requirements (see § 4) shall be submitted to Company for approval prior to the start of qualification process of the coating.
 - Certificate of analysis (see § 4) for each batch of product used for qualification process shall be submitted to Company.
 - For PE only: Tests results (from an independant laboratory) for thermal and UV ageing resistance as per Appendix 2 and Appendix 3 shall be submitted to Company for approval. The tests results shall be coming from coated pipe samples. Tests results shall not be older than three years.

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- For PE only: Tests results (from an independent laboratory) for ESCR resistance as per [ASTM D 1693](#), Cond B shall be submitted to Company for approval. Test result shall not be older than three years.

Note: It is requested that Applicator provide the data listed in Appendix 4 to Company or its representative on site during either qualification or start up.

- Coating process: Witnessed by Company representative and in accordance with § 5. Coating process parameters shall be fully recorded during PQT. Same parameters shall be used for production, with a maximum discrepancy of 5% for each parameter. Of special interest here is the pipe travel speed for blasting and coating operations, which shall be strictly monitored to be equal during PQT and production (within a 5% margin).
- Coating properties: Witnessed by Company representative and in accordance with § 6.

A summary of Qualification tests as well as acceptance criteria and frequency is given in Appendix 1. The Contractor and Applicator shall submit a complete joint report of the Qualification test results to the Company for approval.

Once approved, the system (considered as the three components as a whole) will be considered as qualified on the corresponding coating line. Any change in the components of the system or the application of a qualified system on a new coating line shall lead to a new qualification process. The qualification of the system on the coating line is valid for a duration of three years. Renewal of the qualification is based on a technical visit and/or track record. A new PQT can be requested in case of quality issues noted on the line during the three years duration.

- At start of production a Pre-Production Trial (PPT) shall be carried out, consisting mainly of reinforced test frequency over the first pipes of the first shift of production, as described in Appendix 1 (typically five pipes, but can be more, subject to Company decision).

3.3 Notification prior starting coating work

The Contractor shall notify the Company, at least eight working days before production start up, for the dates of starting coating process to allow mobilisation of the Company designated Inspector.

The Inspector shall have free access to the workshops, storage yards and laboratory of the Applicator who shall also provide him with all the facilities necessary for the proper execution of his work (i.e. office, telephone and fax, handling equipment, measuring instruments with calibration certificates, etc.).

Upon arrival at the coating plant, the Inspector shall receive from the main Contractor the documents supplied by the Applicator.

3.4 Acceptance certificates

The Contractor and the Applicator shall sign jointly with the Inspector the coated pipes acceptance certificate including the results of all tests and inspection as set forth in this specification.

The acceptance certificate of coated pipes shall certify that all tests and inspections have been performed by the Applicator under the responsibility of the Contractor for all Company ordered pipes and have been witnessed by the Inspector.

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One copy of the acceptance certificates shall be transmitted to Company and one copy to the Inspector.

4. Coating system and characteristics of the raw materials and repair products

For each raw material (epoxy, adhesive and PE), the requirements are as follow:

- Nature and type of raw material
- Technical requirements
- Content of conformity certificate
- Content of certificate of analysis.

4.1 Coating System

The three layer polyethylene coating shall consist of:

- One epoxy primer
- One adhesive coat
- One extruded polyethylene coat.

4.2 Marking and identification

Raw materials shall be clearly identified with the following markings (whatever the packaging of the product):

- Name of Manufacturer
- Production plant
- Name of product
- Batch number
- Date of manufacture (epoxy only)
- Shelf life (epoxy only). For PE and adhesive, a shelf life of one year (starting at reception of material by Applicator) shall be considered, provided the product is stored according to Manufacturer's recommendation (To be found in Materials Safety Data Sheets).

4.3 Characteristics of epoxy primer

4.3.1 Nature and type

The epoxy primer shall be 100% solid powder form. The use of liquid epoxy is not allowed.

4.3.2 Technical requirements

The epoxy primer shall meet the technical requirements specified in Table 1.

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Table 1 - Technical requirements for epoxy primer

Characteristic	Methods	Units	Acceptable Values
Moisture content	Powder: 20 g Temperature: 105°C Time: 30 min	%	0.5 (max.)
Glass transition temperature*	Differential Scanning Calorimeter (DSC)	°C	No less than 100°C for fully cured material
Bend test	CAN/CSA Z245-20, Clause 12.11 2.5° at minimum temperature		No holiday
Water absorption (demineralised water)	ASTM D 570 on a free film of 500 microns ± 50 thickness	% wt	Less than 15% of weight uptake after 28 days at 80°C

* Tg shall be understood here as inflection point.

4.3.3 Content of conformity certificate

The conformity certificate is a document issued by the raw material Manufacturer (specific to each raw material). It is a list of physical or chemical characteristics controlled for every production batches. For each of these characteristics, a conformity range is reported by the Manufacturer.

The conformity certificate shall include the following information (as a minimum, but not limited to):

- Name of Manufacturer
- Name of product
- Manufacturing plant
- Date of issue
- Name, function and signature of the person issuing the document.

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Characteristics	Methods	Units	Conformity range
Gel time	ISO 8130-6	second	Manufacturer specification
Density	ISO 2811-1	g/ml	Manufacturer specification
Glass transition T°			
First heating		°C	Manufacturer specification
Second heating		°C	Manufacturer specification and as per Table 1
Enthalpy		J/g	Manufacturer specification
IR Spectra			Manufacturer specification
Particle size analysis	Manufacturer		Manufacturer specification
Moisture content	Manufacturer		Manufacturer specification and as per Table 1

Conformity certificate shall be considered valid for one year, provided there is no change of any kind for the product for that period.

When submitted to Company for approval during qualification, Company reserves the right to ask for changes with regards to Manufacturer's specification ranges for each characteristic.

4.3.4 Content of certificate of analysis

The certificate of analysis is issued by raw material Manufacturer with every batch of product. It reports all characteristics controlled on the corresponding batch.

The content of certificate of analysis shall be equivalent to the conformity certificate, except that measured values shall be reported instead of conformity range or Manufacturer specification.

4.4 Characteristics of the adhesive material

4.4.1 Nature and type

The adhesive shall be based on linear-type (i.e. low pressure manufacturing process) PE with grafted reactive sites. Both extruded and powdered adhesive applications are allowed.

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4.4.2 Technical requirements

The Company requirements are given in Table 2.

Table 2 - Technical requirements for adhesive

Characteristics	Standards	Units	Acceptable values
Elongation at break	ISO 527	%	≥ 500
VICAT Softening point (9.8 N)	ISO 306	°C	> 90
Melting point	ISO 11357-1 and ISO 11357-3	°C	> 120

In addition:

- A full DSC spectra shall be provided once for each adhesive, from -40°C up to 200°C Heating rate 20°C/min, cooling rate 10°C/min (first and second heating)
- DMTA spectra shall be provided once at a frequency of one Hertz from -40°C up to 200°C.

4.4.3 Content of conformity certificate

The conformity certificate is a document issued by the raw material Manufacturer (specific to each raw material). It is a list of physical or chemical characteristics controlled for every production batches. For each of these characteristics, a conformity range is reported by the Manufacturer.

The conformity certificate shall include the following information (as a minimum, but not limited to):

- Name of Manufacturer
- Name of product
- Manufacturing plant
- Date of issue
- Name, function and signature of the person issuing the document.

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Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16 kg; 190°C)	ISO 1133-1	g/10 min	Manufacturer specification
Density	ISO 1183		Manufacturer specification
Reactive site content*	Manufacturer		Manufacturer specification
In addition, for powder adhesive			
Particle size analysis	Manufacturer		Manufacturer specification

* Reactive site content can be evaluated by indirect methods such as adhesion test over aluminium foil for instance, provided it is checked on every batch of product with corresponding conformity range. Method to be submitted to Company for approval.

Conformity certificate shall be considered valid for one year, provided there is no change of any kind for the product for that period.

When submitted to Company for approval during qualification, Company reserves the right to ask for changes with regards to Manufacturer's specification ranges for each characteristic.

4.4.4 Content of certificate of analysis

The certificate of analysis is issued by raw material Manufacturer with every batch of product. It reports all characteristics controlled on the corresponding batch.

The content of certificate of analysis shall be equivalent to the conformity certificate, except that measured values shall be reported instead of conformity range or Manufacturer specification.

4.5 Characteristics of the polyethylene

4.5.1 Nature and type

PE shall be based on a butene, hexene or octene comonomer type PE.

Blends of different PE type or grade shall not be allowed.

Additives (Carbon black, anti oxidants, etc.) shall be incorporated by means of a masterbatch. PE raw material Manufacturer shall be the only one authorized to perform this step. No additivation of any kind shall be allowed at the coating plant during extrusion.

4.5.2 Technical requirements

Company requirements are given in Table 3 below.

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Table 3 - Technical requirements for PE

Characteristics	Standards	Units	Acceptable values
Density (with carbon black)	ISO 1183		> 0.940
Carbon black content	ISO 6964	%	≥ 2.0
Carbon black particle size		nm	≤ 25 or (type P)
VICAT Softening point (9.8 N)	ISO 306	°C	> 110
Melting point	ISO 11357-1 and ISO 11357-3	°C	> 120
Thermal ageing*	Appendix 2		Result < 0.35
UV ageing*	Appendix 3		Result < 0.35
Stress cracking resistance*	ASTM D 1693, Cond B (10% Igepal)		F20 > 1000 hr

* Certificate from independent laboratory no older than three years.

4.5.3 Content of conformity certificate

The conformity certificate is a document issued by the raw material Manufacturer (specific to each raw material). It is a list of physical or chemical characteristics controlled for every production batches. For each of these characteristics, a conformity range is reported by the Manufacturer.

The conformity certificate shall include the following information (as a minimum, but not limited to):

- Name of Manufacturer
- Name of product
- Manufacturing plant
- Date of issue
- Name, function and signature of the person issuing the document.

Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16 kg, 190°C)	ISO 1133-1	g/10 min	Manufacturer specification
Density	ISO 1183		Manufacturer specification and as per Table 3
Carbon black content	ISO 6964	%	Manufacturer specification and as per Table 3

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Conformity certificate shall be considered valid for one year, provided there is no change of any kind for the product for that period.

When submitted to Company for approval during qualification, Company reserves the right to ask for changes with regards to Manufacturer's specification ranges for each characteristic.

4.5.4 Content of certificate of analysis

The certificate of analysis is issued by raw material Manufacturer with every batch of product. It reports all characteristics controlled on the corresponding batch.

The content of certificate of analysis shall be equivalent to the conformity certificate, except that measured values shall be reported instead of conformity range or Manufacturer specification.

4.6 Characteristics of the repair product

The repair products shall be:

- Suitable for the protection of the pipeline for the pipeline design conditions
- Compatible with the three layer polyethylene coating applied.

4.7 Finishing coating for concrete weight coating

Coated line pipes that are to be covered with concrete shall fully comply with the requirements of **GS EP PLR 410**. This surface processing shall not affect the minimum thickness given in § 6.2.

Surface treatment to increase surface roughness of coating shall be either granule or powder application before cooling of the top coat on the coating line.

5. Application of the coating and repair products

5.1 Application of the coating

5.1.1 Surface preparation

- Before abrasive blasting, the pipe surface shall be inspected and cleaned to remove all traces of oil, grease and loose deposits. Any visible trace of oil or grease shall be removed using an appropriate non-oily and non-toxic product.
- Salt contamination shall be checked as per [ISO 8502-6](#) and [ISO 8502-9](#) before and after abrasive cleaning at PQT and PPT stage, and after blast cleaning during production and shall be lower than 2 micrograms per square cm. Alternative methods such as SCM400 are acceptable.
- All pipes shall be preheated (40 to 70°C) before abrasive blasting. Temperature shall be checked continuously with infra red camera.
- The pipe surface shall be blast cleaned to Sa 3 as per [ISO 8501-1](#) using automatic blasting machine(s).
- The grit shall be selected so that the average roughness Ry5 (as per [ISO 4287](#)) obtained ranges from 60 to 90 microns (as per [ISO 8503-4](#)). The use of replica tape to assess the roughness is not allowed. At start of production, cleanliness and salt contamination of

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abrasives shall be checked as per [ASTM D 4940](#): Conductivity shall be lower than 1000 microSiemens/cm and no oil shall be visible after 30 minutes. No silica grit is allowed.

f) Immediately after abrasive blasting, all dust and traces of abrasives shall be removed from the pipe surface by brushing and vacuum cleaning. Maximum acceptable level shall be 2 according to [ISO 8502-3](#).

g) Each cleaned pipe shall be inspected for surface defects. Any defect shall be removed.

Cleaned pipes shall then be coated before degradation of surface preparation. They shall not be left in a moist and/or salt contaminated atmosphere. The metal temperature shall always be 3°C above the ambient dew point temperature. Any pipe which has not been coated before degradation of its surface preparation shall be completely re-blasted before coating.

5.1.2 Coating

The pipes shall be coated on a continuous coating line without any risk of deterioration (external pipe wall, bevels, coating) during the various heating, powder spraying, curing and quenching operations. All the process parameters shall be recorded during PQT. For PPT and production, these parameters shall strictly remain within a 5% error margin (especially pipe travel speed).

Conversion chemical treatment of the surface of steel (e.g. using chromates/phosphate/Acid wash or any kind of treatment) to improve adhesion or durability is subject to Company approval. In all cases, the required adhesion and CD test in this specification shall be obtained only by using suitable powder epoxy primer and surface preparation process. This shall be demonstrated during PQT by coating some linepipes with and without conversion chemical treatment, in order to show that required adhesion and CD properties of the present specification are obtained without treatment. The opportunity to implement a surface chemical treatment shall be based on specific requirements such as high temperature and/or high durability in hot/wet environment. In that case, additional specific tests to assess the durability of such treatment will be required.

a) Powder epoxy primer application:

The pipes shall be preferably heated by induction. The temperature of the pipe and the intercoat time (between primer and adhesive) shall be set according to the gel time of the epoxy primer and following the epoxy Manufacturer recommendation, in order to obtain, as a minimum, adhesion values required in Table 5 (and within 5% of recorded value during PQT).

After induction heating, the supporting wheels shall be designed so that they do not degrade the freshly blasted surface by leaving wheels marks or pollutions. As a consequence, plain steel wheels at that location are not acceptable. The preferred option is wire brushes-type steel wheels.

The powder epoxy primer is sprayed using electrostatic spray guns. The thickness of the coat shall be between 150 and 250 microns (as per [ISO 2808](#), method 10), depending on the powder and the service conditions Proposed value shall be documented by the Applicator.

b) Adhesive application:

The adhesive shall be applied in a time frame (after epoxy application) compatible with the gel time of the epoxy primer. Extrusion parameters shall be set following adhesive

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Manufacturer recommendation, in order to obtain, as a minimum, adhesion values required in Table 5 (and within 5% of recorded value during PQT).

The adhesive thickness shall be 200 microns minimum.

c) Polyethylene application:

The polyethylene top coat shall be applied by extrusion exclusively.

At that stage, no addition of additives of any kind to the PE is allowed.

No air entrapment, micro voids and/or micro bubbles is allowed within the layer thickness of the PE top coat. A cut through the thickness of the PE shall be performed to visually inspect the homogeneity of the layer.

The extrusion temperature, at the die, shall be in accordance with the PE Manufacturer's recommendation.

The coating shall be smoothed by pressure roller(s) (if side extrusion).

At this stage, there shall be no inter-layer mixing of adhesive and PE extrudates.

d) Surface preparation for concrete coating:

As specified in § 4.6, if a concrete weight coating is required, the polyethylene surface shall be processed to improve the friction coefficient between the concrete and the polyethylene surface. Granules or powder of polyethylene shall be sprayed on the hot extruded polyethylene surface (before quenching). The granules being not totally melted, they will provide a rough surface. The coating shall comply with the requirements of **GS EP PLR 410**.

5.1.3 Cooling

When coating is completed, the tube shall be sprayed with water in order to obtain a pipe temperature of +60°C maximum. Temperature shall be such that handling of the coated pipe leaves no marking or degradation on the coating.

5.2 Application of repair products

All defects detected by holiday detection (see § 6.3) and damaged coating areas less than 50 cm² resulting from destructive testing or mechanical accidents shall be repaired at the Applicator's expense as follows.

- If any individual damaged area is greater than 50 cm², the pipe will be completely re-coated.
- A maximum of three repairs per pipe joint is allowed, but in no case the total repaired areas shall exceed 150 cm².
- Defects originating from the coating process itself and not from subsequent handling and storage shall be addressed separately and immediately reported to CPY representatives.

The following procedures should be applied for the repairs:

5.2.1 Surface preparation

The part of the coating which is not bonded satisfactorily in the faulty area shall be removed. If the bare metal is exposed, it shall be carefully cleaned by brushing. The edges of the coating

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shall be bevelled. The area shall be made free of dust and degreased with appropriate products.

5.2.2 Repair

The repair method shall be submitted by the Contractor to the Company for approval before production begins. PQT for each repair type shall be performed at same time as PQT of coating line.

5.2.3 Inspection

The repaired area shall be 100% checked with a holiday detector set to 10 kV per mm of coating thickness (25 kV max, [NACE RP0274](#)).

6. Characteristics of applied coating

The coating shall meet the characteristics below according to the following methods and acceptance values.

6.1 Aspect

The coating shall be of a uniform colour and aspect, and free of any surface defect detrimental to its quality. It shall not show any crack, blister, lamination, wrinkle or disbonding.

6.2 Thickness

Coating thickness is dependent on pipe laying method, service constraints and pipe weight.

"Normal thickness" is used for low mechanically aggressive buried conditions or on lines with additional anti-rock protection.

"Reinforced thickness" is used for mechanically aggressive ground (rock or clay), for submerged pipelines, with or without concrete, and in depths not greater than 200/300 m. In depths more important, the value may be modified by a job specification or by long duration documented tests.

Higher thickness may be acceptable as per particular specification.

The minimum thickness according to line pipe diameter is given in the following Table 4 for each of the thickness classes.

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Table 4 - Minimum thickness for the coating

Pipe weight (kg/m)	Minimum thickness (mm)	
	"Normal"	"Reinforced"
$w \leq 15$	1.3	2.3
$15 < w \leq 50$	1.5	2.7
$50 < w \leq 130$	1.8	3.1
$130 < w \leq 300$	2.2	3.5
$300 < w$	2.5	4.2

Procedure for thickness measurement is described in Appendix 6. The real measured total thickness may be reduced by 10% on the weld seam of SAW pipes.

6.3 Electrical porosity

The finished coating shall be free of porosity. It shall be demonstrated using a holiday detector set to 10 kV per mm of coating thickness (25 kV maximum, [NACE RP0274](#)).

6.4 Cut-backs

As a minimum, a 150 mm +20/-0 mm cut-back shall be provided at each pipe end unless otherwise specified. In case concrete weight coating is applied on top of the polyethylene the cut back may be longer in order to accommodate the rollers of the concrete coating machine. In any case the cut back length shall be determined by the pipe laying Contractor in relation with the coating Applicator(s) to take into account the coating yard requirements and the welding process heat input effect on the coating.

The coating shall be cut just after cooling and removed manually or mechanically with power brushes. The stripped steel ends shall be brushed clean. Epoxy primer shall be visible for 5 millimeters minimum at cut back to avoid any disbonding during storage.

The ends of the polyethylene coating shall be bevelled in order to ensure a satisfactory bonding of field joint material on site. The bevel angle shall be approximately 30 to 45°.

The cut backs shall be protected by peeling varnish in order to avoid rusting of the bare metal during storage/transportation.

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6.5 Other characteristics

Table 5 - Characteristics of applied coating

Characteristics	Methods	Units	Acceptable values
Impact resistance at 23°C ± 2°C	NF A49-710	Joules/mm	≥ 7
Shore D hardness	ISO 868 (15 seconds)	Shore D	≥ 50
Resistance to peeling At least 80% of peeled surface to be cohesive No bare steel after peeling	NF A49-710 At 23 ± 2°C At 80 ± 2°C	N/50 mm	> 1000 > 200
Elongation at break at 23°C ± 2°C for PE top coat	ISO 527-1 and ISO 527-2	%	> 500
Indentation	NF A49-710 At 25°C ± 2°C (duration: 2 h) At 80°C ± 2°C (duration: 4 h)	Maximum depth (mm)	< 0.20 < 0.50
Homogeneity of the coating in the thickness	Visual		No microvoids or bubbles within the layers
Curing of epoxy	DSC (Appendix 6)	°C J	ΔTg lower than 3°C No residual enthalpy
Cathodic disbonding	NF A49-710 and Appendix 7 After 28 days at 23°C ± 2°C* After 48 hr at 65°C ± 2°C After 28 days at 80°C ± 2°C*	mm	< 5 < 3 < 15

* Cathodic disbonding tests at 28 days are mandatory during **qualification process** described in § 3.2. Test result shall be known before start of production.

7. Inspection

Coating inspection shall be carried out by the Applicator in the presence of the Inspector from the beginning of the work and throughout production. It shall include the following four operations:

- Inspection of the epoxy powder, adhesive material and polyethylene deliveries and conformity with the requirements
- Verification of the various application parameters of the epoxy primer, the adhesive and the polyethylene coat
- Systematic inspection of pipe coating or test samples taken from pipe end
- Inspection of coated pipes.

The Inspector may take samples of the coating materials or repair product and test specimens of coated pipe(s) for testing in laboratories selected by the Company in order to check the quality of the tested products. These tests will be at Company cost if their results are

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satisfactory but they will be back charged to the Contractor/Applicator if the coating material and/or repair product are not in accordance with this specification requirements.

7.1 Inspection of coating materials and repair product conformity

Inspection shall be performed upon delivery of the coating materials and repair product in order to check packaging, markings and ensure that certificates of analysis for all materials fall within certificate of conformity.

Packaging and storage shall be in accordance with the Manufacturer's instructions and this specification and markings shall be in conformity with this specification.

Non-conformity with any of the specified requirements shall cause the immediate rejection of the delivery.

In order to cater for any dispute arising at a later stage, three 50 g three samples of each raw coating material shall be taken from each production batch. One shall be reserved for the Applicator, one shall be transmitted to the Company and one shall be kept as a check sample in the Applicator's laboratory for six months, away from humidity at a temperature below and close to 20°C.

7.2 Inspection of the various application parameters of the coating materials

Inspection shall be performed during coating application in order to check the following parameters:

- Climatic conditions (Air and steel temperatures, dew point, etc.)
- Preheating pipe temperature
- Finish of prepared surface
- Dust level of prepared surface
- Roughness (Ry5) of prepared surface
- Pipe travel speed for blasting and coating process
- Pipe temperature when entering spraying machine
- Intercoat time
- Pipe temperature after cooling.

7.2.1 Climatic conditions, surface cleanliness and preheating temperature

Pipes before grit blasting shall be checked for oil, grease and loose deposit contaminations. Pre heating temperature of the pipes shall be checked by IR camera on a continuous process. After grit blasting, pipes shall be checked for storage conditions and temperature.

Frequency:

Continuously and/or 100% of surface of the pipes.

Specification requirements:

No contamination of pipe surface before grit blasting.

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Pre heating temperature: 40 to 70°C.

Salt contamination equivalent to 2 micrograms per square cm max ([ISO 8502-6](#) and [ISO 8502-9](#)) and temperature 3°C above dew point for pipes after grit blasting.

7.2.2 Finish of prepared surface

Frequency:

100% of the prepared surface of each pipe shall be inspected.

Specification requirements:

Surface preparation shall be Sa 3 as per [ISO 8501-1](#).

7.2.3 Dust level of grit blasted surface

Frequency:

PQT and PPT: All pipes, Production: 4 pipes per shift.

Specification requirements:

Maximum acceptable level shall be 2 according to [ISO 8502-3](#).

7.2.4 Average roughness Ry5 of grit blasted surface

Surface profile roughness required -Ry5- (as per [ISO 4287](#)) shall be measured with electronic apparatus according to [ISO 8503-4](#). No replica tape allowed.

Frequency:

PQT and PPT: All pipes both ends, Production: every 10 pipes both ends.

Specification requirements:

Ry5 values shall be between 60 and 90 microns.

7.2.5 Pipe travel velocity

Pipe travel velocity shall be recorded for blasting and coating processes during PQT. Then, it shall be checked during PPT and production.

Frequency:

PQT: Record. PPT and production: checked twice per shift.

Specification requirement:

Within 5% of recorded value during PQT for PPT and production.

7.2.6 Pipe temperature before spraying cabinet

Control of pipe temperature shall be made with optical pyrometer (Infra red camera) and temperature recorder.

Frequency:

Control is continuous over total pipe length.

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Specification requirements:

Temperature shall be in accordance with § 5.1.2.a and within 5% of PQT recorded value.

7.2.7 Intercoat time

The time between spraying of epoxy primer and application of adhesive layer is called intercoat time.

Frequency:

PQT and PPT: All pipes, Production: twice per shift.

Specification requirement:

The measured intercoat time shall be in accordance with § 5.1.2.a and b and within 5% of PQT recorded value.

7.2.8 Extrusion temperature for adhesive and PE layers

Frequency:

Once per shift.

Specification requirements:

The extrusion temperature shall be in accordance with § 5.1.2.b and c.

7.3 Systematic inspection of each coated pipe

The following inspection shall be performed after coating application on each dry coated pipe cooled down to ambient temperature:

- Visual aspect, homogeneous colour
- Thickness with electromagnetic gauges (individual thickness print and general histogram / one per shift)
- Cut-backs length with ruler or specific gauge
- Electrical porosity.

7.3.1 Thickness

Frequency:

PQT and PPT: All pipes, Production: One every 5 pipes.

Specification requirement:

As per Table 4 and according to Appendix 6.

7.3.2 Cut-back

At both ends of each coated pipe.

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7.3.3 Electrical porosity

Adjustable DC holiday detector with voltage indicator - maximum voltage 25 kV and annular electrode covering 100% of pipe surface circumference is operated over the dry surface of coating. Control shall be made in automatic process after cooling in accordance with [NACE RP0274](#).

Total contact of electrode has to be ensured with the coating and pipe travel speed below or equal to 0.2 to 0.3 metre per second. The holiday detector shall be calibrated once per shift.

7.4 Systematic inspection of pipe coating or test samples taken at pipe ends

The inspection shall be performed upon completion of coating application on dry coated pipes cooled down to ambient temperature in order to check the following characteristics:

- Epoxy layer thickness
- Epoxy curing
- Epoxy adhesion to steel
- Adhesive layer thickness
- Impact resistance
- Shore D hardness
- Peeling force
- Indentation
- Visual inspection of homogeneity of the coating within its thickness (samples used for peeling tests can be used for that purpose)
- Cathodic disbondment
- Residual magnetic intensity.

7.4.1 Epoxy layer thickness

Frequency:

PQT and PPT: 2 pipes, Production: at start of each shift.

Specification requirements:

Results shall be in accordance with § 5.1.2.a (150-250 microns).

7.4.2 Epoxy curing (see Appendix 6)

Frequency:

PQT and PPT: 2 pipes, Production: at start of each shift.

Specification requirements:

ΔT_g (in absolute value) shall be lower than 3°C. No residual enthalpy.

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7.4.3 Adhesive layer thickness

Frequency:

PQT and PPT: 2 pipes, Production: at start of each shift.

Specification requirements:

Measured value shall be 200 microns minimum.

7.4.4 Impact resistance

Frequency:

PQT and PPT: 1 pipe, Production: 1 pipe per shift.

Specification requirements:

Energy shall be equal or more than 7 Joules per mm of specified nominal coating thickness.

The coating shall be examined with a holiday detector, over the points of impact, at a voltage of 10 kV per mm of coating thickness (maximum 25 kV, [NACE RP0274](#)). Pipe shall be repaired from impact after tests.

7.4.5 Shore D hardness

Frequency:

PQT and PPT: 2 pipes, Production: One test per shift.

Specification requirements:

Average equal or more than 50 (Shore D) (after 15 seconds).

7.4.6 Resistance to peeling

Frequency:

PQT and PPT: 3 pipes at both ends and in middle, Production: Both ends at cut back at start of shift and then every hour. If one test does not satisfy the requirements given here after, tests shall be performed on 10 pipes coated since the last check, two of them at middle of pipe also, and none of them shall be defective. As per [NF A49 710](#).

Specification requirements:

More than 1000/50 mm at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 200 N/50 mm at $80^{\circ}\text{C} \pm 2^{\circ}\text{C}$. More than 80% of peeled surface to be cohesive in both cases.

No bare steel allowed after peeling.

7.4.7 Indentation

Frequency:

PQT and PPT: 2 pipes, Production: One test per shift.

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Specification requirements:

Penetration shall be less than:

- 0.20 mm at 25°C ± 2°C (duration: 2 h)
- 0.50 mm at 80°C ± 2°C (duration: 4 h).

7.4.8 Homogeneity of the coating**Frequency:**

Same as peel test.

Specification requirements:

Samples used are from peeling tests. Within the thickness of the layer, there shall be no microvoids and/or microbubbles. The inspection is visual.

7.4.9 Cathodic disbonding**Equipment:**

As per Appendix 7.

Frequency:

PQT: 28 days at 23°C and 80°C plus 48 hr at 65°C, average of three samples on one pipe.
PPT: first two pipes, 48 hr at 65°C. Production: One test every 2 shifts at 65 ± 2°C during 48 hours (average of three samples).

Specification requirements:

28 days at 23°C: 5 mm

28 days at 80°C: 15 mm

The increase of the radius shall be less than 3 mm after 48 hours at 65 ± 2°C.

7.4.10 Residual magnetic intensity

The residual magnetic intensity shall be below 3 milliTesla (or 30 gauss), measured on the cut-backs at each coated line pipe end. 100% of coated pipes shall be tested.

8. Handling, transport and storage rules

The Applicator shall be responsible for any damage occurring to the pipes from unloading at reception of the pipes to loading of the coated pipes for shipment.

The Applicator shall consequently:

- Inspect the bare pipes upon delivery to check that they have not suffered previous damage

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- Take all necessary precautionary measures to prevent any deterioration during the following operations:
 - Handling
 - Transfer to storage yard
 - Storage
 - Loading of pipes for shipment.

All repairs and inspection shall be at the Applicator's expense.

8.1 Handling

The pipes shall be handled without causing damage to the pipe bevels and coating.

8.2 Transfer to storage yard

During transport of pipes to a storage yard, the Applicator shall take all the required actions to avoid pipe and coating damage.

8.3 Storage yard of the Applicator

Stockpiling of coated pipes shall be made so as to avoid any deterioration of coating. If coated pipes are to be stored for more than 6 months, they shall be protected against ultraviolet rays.

8.4 Pipe loading for shipment

During loading the coated pipes for shipment, the Applicator shall take all necessary actions to avoid the deterioration of pipes and coating during handling and transport.

8.5 End caps

If the bare pipes have been delivered to the Applicator with end caps, these end caps (or new ones) should be fitted again on the pipe ends after coating if required in the Contract.

Except if stated otherwise, temporary protection with varnish shall be applied on the cut-backs.

9. Reporting

The coating Applicator shall deliver, at the end of the coating application, a report containing all the coating material certificates, inspection results including pipe reference number, the list of all rejected coated pipes reference numbers, the reason for rejection and what was eventually the corrective action for these pipes.

Appendix 1 Summary of Qualification and Fabrication tests

Tests / Checks	Requirements	PQT	PPT	Fabrication
1. Preheating	40 to 70°C	10 pipes	All	IR camera monitoring - All
2. Surface preparation				
• Abrasive cleanliness	Conductivity lower than 1000 microSiemens No oil after 30 minutes in water	At start	At start	At start
• Degree of cleanliness	Sa 3 No oil, grease contaminations	10 pipes	All	All
• Salt contamination	Lower than 2 micrograms per square cm	5 pipes	2 pipes	Once per shift (at start)
• Dust level	Equal or less than 2	10 pipes	5 pipes	4 per shift
• Roughness	$60 \leq Ry5 \leq 90 \mu m$	10 pipes (both ends)	5 pipes (both ends)	Every ten pipes, both ends
• Pipe travel speed	Record during PQT During production, within 5% of recorded PQT value	Once	Once	Twice per shift
• Steel temperature	+ 3°C above dew point	1 pipe	1 pipe	4 per shift
3. Coating application				
• Pipe temperature after induction heating	See § 5.1.2.a	All	5 pipes	All
• Intercoat time	See § 5.1.2.a	All	5 pipes	Twice per shift
• Extrusion temperature	See § 5.1.2.b and c	5 pipes	5 pipes	Once per shift
• Cooling	$\theta \leq 60$ no marking of the coating.	All	5 pipes	All
4. Raw materials				
Conformity certificate	See § 4	Each raw material	Each raw material	N/A
<u>Tests results</u>				N/A
• Epoxy primer	See § 4	Each raw materials	Each raw material	
• Adhesive	See § 4			
• Polyethylene	See § 4			

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Appendix 1

Tests / Checks	Requirements	PQT	PPT	Fabrication
UV and thermal resistance	Appendix 3 and Appendix 4	For PE only, One certificate no older than three years	N/A	N/A
Stress cracking resistance	ASTM D 1693, Cond B (10% Igepal) F20 > 1000	For PE only, One certificate no older than three years	N/A	N/A
Certificate of analysis	See § 4	Every batch	Every batch	Every batch
5. Coating	Visual aspect: Homogeneous colour	All	5 pipes	All
Thickness	See § 6.2	All	5 pipes	Every 5 pipes
Epoxy thickness	150-250 microns	2 pipes	2 pipes	One at start of each shift
Curing of epoxy	Delta Tg < 3°C See Appendix 6	One pipe	One pipe	One at start of each shift
Adhesive thickness	200 microns minimum	2 pipes	One pipe	One at start of each shift
Holiday detection	10 kV/mm (25 kV max)	All	5 pipes	All
Cut-back	150 +20/-0 mm	All at both ends	5 pipes	All at both ends
Impact resistance	No less than 7 J/mm - Holiday detection: 10 kV/mm (25 kV max)	2 pipes	1 pipe	One at start of each shift
Shore D hardness	No less than 50	2 pipes	2 pipes	One at start of each shift
Peeling force	> 1000 N/50 mm at 23°C ± 2°C	3 pipes (both ends and middle)	3 pipes (both ends and middle)	Both ends at start of shift and then every hour
	> 200 N/50 mm at 80°C ± 2°C	3 pipes (both ends and middle)	3 pipes (both ends and middle)	Both ends at start of shift and then every hour
Homogeneity of the coating	Visual inspection. No micro voids or micro bubbles	As peel test	As peel test	As peel test
Indentation	<0.20 mm at 23°C ± 2°C	2 pipe	2 pipes	One per shift
	< 0.50 mm at 80°C ± 2°C	2 pipe	2 pipes	One per shift

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Appendix 1

Tests / Checks	Requirements	PQT	PPT	Fabrication
Cathodic disbonding	Test after 28 days at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ Less than 5 mm	1 pipe (mandatory at qualification)	N/A	N/A
	Test after 28 days at maximum operating $80^{\circ}\text{C} \pm 2^{\circ}\text{C}$ Less than 15 mm	1 pipe (mandatory at qualification)	N/A	N/A
	Test after $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$ during 48 h less than 3 mm	1 pipe	1 pipe	1 pipe every two shifts
Residual magnetic intensity	< 3 milliTesla (30 gauss)	All at both ends	All both ends	All at both ends

Note: Shift is one team production.

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Appendix 2

Appendix 2 Thermal ageing test

Test samples: Polyethylene sample taken from coated pipe

Temperature of test: 100°C (± 2°C)

Duration of test: 4800 hr

Procedure:

On sample taken from coated pipe, first measure the initial MFI according to [ISO 1133-1](#) (2.16 kg, 190°C): MFI (0).

Place the sample in a pulsed air oven at a temperature of 100°C (± 2°C) for 4800 hr.

After 4800 hr, stop the test and measure the MFI according to [ISO 1133-1](#) (2.16 kg, 190°C): MFI (4800).

Intermediate measurements (every 1000 hr) can be performed to evaluate the evolution of the MFI with time.

Results are expressed as variation of MFI with time:

$$\text{Result} = \left| \frac{\text{MFI}(4800) - \text{MFI}(0)}{\text{MFI}(0)} \right|$$

Each MFI shall be the average value of three measures.

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Appendix 3 UV ageing test

Test samples: Polyethylene samples taken from coated pipes

Test conditions:

- Artificial weathering (Table 1 - Method A of [ISO 4892-2](#))
- Black panel temperature BST: $65 \pm 3^{\circ}\text{C}$
- Relative humidity: $65 \pm 5\%$
- Cycle: 18 ± 0.5 min humid; 102 ± 0.5 min dry
- Total radiant energy: 5 JG/m^2
- Continuous exposure.

Procedure:

On sample taken from coated pipe, first measure the initial MFI according to [ISO 1133-1](#) (2.16 kg, 190°C): MFI (0).

Expose the sample to the test conditions described above.

After total radiant energy is reached, stop the test and measure the MFI according to [ISO 11338-1](#) (2.16 kg, 190°C): MFI (5 GJ/m^2).

Results are expressed as variation of MFI with time:

$$\text{Result} = \left| \frac{\text{MFI}(5 \text{ GJ/m}^2) - \text{MFI}(0)}{\text{MFI}(0)} \right|$$

Each MFI shall be the average value of three measures.

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Appendix 4**Appendix 4 List of data to be provided by Applicator**

- Qualification or production
- Project reference
- Date
- Applicator/Location
- Pipe characteristics (diameter, WT, seamless or not etc.)
- Speed of coating line
- Adhesive and PE extrusion output
- Type of coating and thickness (provide data sheet, certificate of analysis and conformity for each product)
- Steel roughness (Ry5)
- Salt contamination
- Peeling strength at RT and 80°C
- Shore D
- CD test: 28 days at 23 and 80°C, 48 hr at 65°C

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Appendix 5

Appendix 5 Curing of epoxy layer

- Take a sample of epoxy from a coated pipe at cut back (where top coat was applied with no adhesive) by scratching with any tool.
- Weight about 10-15 mg and put in DSC pan.
- After calibration of DSC, run a first scan at 20°C/min up to 280°C (or any other max temperature as advised by Manufacturer).
- Cool down to ambient at 40°C/min. Wait at ambient for the temperature in the cell to stabilize (i.e. 2-3 minutes).
- Run a second scan at 20°C/min up to $T_g + 20^\circ\text{C}$.
- Calculate the ΔT_g in absolute value between first and second run.
- The T_g is understood here as the inflection point in the DSC curve.

Should a pre-heating of the sample before the first scan is proposed for homogeneising, it is requested to demonstrate that ABSOLUTELY NO CURING OCCURS.

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Appendix 6 Thickness measurements on the coating

The test consist of measuring, by means of a non destructive process, the thickness of the applied coating

A magnetic, electromagnetic or ultrasonic measuring instrument with 10% accuracy shall be used. The instrument shall be calibrated for the range of coating thickness to be measured.

The instrument reading shall be verified on a steel pipe surface using a calibrated shim of the same thickness range as the coating. The surface profile and cleanliness of the steel pipe surface shall be representative of the process (for measuring thickness of over 1 mm, the surface profile of the pipe is not relevant).

On each pipe to be tested, a total of 12 single readings shall be carried out in accordance with [ISO 2808](#). If any of these 12 readings is below the minimum coating thickness, an additional 4 readings shall be taken around this area. The average of the additional 4 readings and the initial reading shall be higher than the minimum thickness.

The measurements shall be taken at point distributed along 4 equally spaced longitudinal lines at the pipe length with three equally circumferential lines on the middle of the pipe at a distance of at least 300 mm from the end of the coating.

For SAW pipes, 4 thickness measurements shall be undertaken on the weld area.

An arithmetic average of all measurements shall be calculated and recorded.

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Appendix 7 CD test procedure

CD test general set up and equipment shall follow [NF A49-710](#). For temperature check, thermocouple shall be positioned inside the cell at contact to the steel.

For interpretation of test result, the following procedure shall be followed:

- 1) Once the test is finished, abrade the top coat and adhesive layer, until only the FBE layer is visible on the whole area under the cell during the test.
- 2) Make twelve radial incision using a sharp knife through the FBE down to the steel, extending outwards from holiday for a distance of at least 40 mm. Make the incision approximately 30° angle of each others.
- 3) Insert the knife point into the centre portion of the holiday down to the metal substrate. Using a gentle levering action, peel away slowly a radial section of coating continuing until firm action is encountered. Record distance up to which coating is disbonded (and not discoloration of the steel).
- 4) Repeat with each segment.
- 5) Calculate the average of the twelve measurements. Record the value.