



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS COR 220

Three layer polyethylene external coating for pipelines

03	10/04	General review
02	10/03	General review – Change of Group name and logo
01	10/02	General review – Field joint coating out of this specification
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Contents

1. General	4
1.1 Scope	4
1.2 Definitions of main parties involved	4
2. Reference documents	4
3. Obligations of APPLICATORS and MANUFACTURERS	6
3.1 COMPANY requirements regarding coating products	6
3.2 Qualification of APPLICATOR's plant and coating system	7
3.3 Notification prior starting coating work	8
3.4 Acceptance certificates	8
4. Coating system and characteristics of the raw materials and repair products	8
4.1 Coating System	8
4.2 Marking and identification	9
4.3 Characteristics of epoxy primer	9
4.4 Characteristics of the adhesive material	10
4.5 Characteristics of the polyethylene	12
4.6 Characteristics of the repair product	13
4.7 Finishing coating for concrete weight coating	13
5. Application of the coating and repair products	14
5.1 Application of the coating	14
5.2 Application of repair products	15
6. Characteristics of applied coating	16
6.1 Aspect	16
6.2 Thickness	16
6.3 Electrical porosity	17
6.4 Cut-backs	17
6.5 Other characteristics	18
7. Inspection	18
7.1 Inspection of coating materials and repair product conformity	19
7.2 Inspection of the various application parameters of the coating materials	19



7.3	Systematic inspection of each coated pipe.....	21
7.4	Systematic inspection of pipe coating or test samples taken at pipe ends.....	21
8.	Handling, transport and storage rules	24
8.1	Handling.....	24
8.2	Transfer to storage yard	24
8.3	Storage yard of the APPLICATOR	24
8.4	Pipe loading for shipment	24
8.5	End caps.....	24
9.	Reporting	24
Appendix 1	Raw materials data base.....	25
Appendix 2	Summary of Qualification and Fabrication tests	26
Appendix 3	Thermal ageing test	29
Appendix 4	UV ageing test	30

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.

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,
- Handling, transport and storage rules,

Field joint coatings to be applied after girth welding of pipes and field repairs of 3LPE coated pipes are specified in [GS COR 420](#).

Requirements from [NF A 49-710](#) 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. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
CAN/CSA Z245-20	External fusion bond epoxy coating for steel pipes
NF A 49-710	External three layer polyethylene based coating
ISO 8130-6	Coating powders –Part 6- Determination of gel time of thermosetting coating powders at a given temperature
ISO 2811-1	Paints and varnishes-Determination of density-Part 1 : Pycnometer method
ISO 6964	Polyolefine pipes and fittings : Determination of carbon black content by calcinations and pyrolysis : Test method and basic principles
ISO 306	Plastics – Thermoplastic materials – Determination of Vicat softening temperature
ISO 1133	Plastics – Determination of the melt-mass flow rate (MFR) and melt-volume flow rate (MVR) of thermoplastics
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 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 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 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 2808	Paints and varnishes -- Determination of film thickness
ISO 868	Plastics and ebonite -- Determination of indentation hardness by means of a durometer (Shore hardness)
ISO 527-Part 1	Plastics -- Determination of tensile properties -- Part 1: General principles
ISO 527-Part 2	Plastics -- Determination of tensile properties -- Part 2: Test conditions for moulding and extrusion plastics
ISO 11357-1	Plastics -- Differential scanning calorimetry (DSC) -- Part 1: General principles

Reference	Title
ISO 11357-3	Plastics -- Differential scanning calorimetry (DSC) -- Part 3: Determination of temperature and enthalpy of melting and crystallization
ISO 4287	Geometrical Product Specifications (GPS) -- Surface texture: Profile method -- Terms, definitions and surface texture parameters

Professional Documents

Reference	Title
NACE RP 0274	High voltage electrical inspection of pipeline coatings prior to installation

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS COR 420	External field joint coating of pipelines

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 Chapter 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. 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 3 and Appendix 4 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.
 - For PE only : Tests results (from an independant laboratory) for ESCR resistance as per **ASTM D1693**, Cond B shall be submitted to COMPANY for approval. Test result shall not be older than three years.

Note : Based on feedback from projects and qualification process, the COMPANY updates a data base of typical raw materials to be considered for qualification (see Appendix 1). Whenever new raw materials are proposed for qualification (i.e. not listed in annex 1) a full application process shall be witnessed by COMPANY and coating properties measured. All data and measurements shall meet the requirements of this specification.

- Coating process : Witnessed by COMPANY representative and in accordance with § 5
- 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 2. 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 constituents 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.

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.

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.

Table 1: Technical requirements for epoxy primer

Characteristic	Methods	Units	Acceptable Values
Moisture content	powder : 20 g temperature : 105°C time : 30 mn	%	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

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

Characteristics	Methods	Units	Conformity range
Gel time	ISO 8130-6	Seconds	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
Enthalpie		J/g	MANUFACTURER specification
IR Spectra			MANUFACTURER specification
Particle size analysis	MANUFACTURER		MANUFACTURER specification
Moisture content	MANUFACTURER		MANUFACTURER specification and as per table 1

- Name, function and signature of the person issuing the document

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.

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 -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

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

- Name, function and signature of the person issuing the document

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,...) 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.

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 -3	°C	> 120
Thermal ageing*	Appendix 3		Result<0.35
UV ageing*	Appendix 4		Result<0.35
Stress cracking resistance*	ASTM D 1693, Cond B (10% Igepal)		F20>1000 hrs

* : 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

Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16kg, 190°C)	ISO 1133	g/10min	MANUFACTURER specification
Density	ISO1183		MANUFACTURER specification and as per Table 3
Carbon black content	ISO 6964	%	MANUFACTURER specification and as per Table 3

- Name, function and signature of the person issuing the document

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 be supplied with the surface coating processed so as to obtain minimum shear strength of 5 kg/cm² between concrete coating and

extruded polyethylene coating. This surface processing shall not affect the minimum thickness given in § 6.2.

Tests may be requested by the COMPANY to check the shear strength between concrete and polyethylene coatings when the surface coating finishing process is not enough documented.

5. Application of the coating and repair products

5.1 Application of the coating

5.1.1 Surface preparation

- a) 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.
- b) If pipes have been in contact with marine or industrial atmosphere, they shall be cleaned before abrasive-blasting to remove any contamination. Cleaning shall be carried out using an adapted process. Salt contamination shall be lower than 2 micro grams per square cm as per ISO 8502-6.
- c) All pipes shall be preheated (40 to 70°C) before abrasive blasting. Temperature shall be checked continuously with infra red camera.
- d) The pipe surface shall be blast cleaned to A or B Sa 3 using automatic blasting machine(s) as per ISO8501-1.
- e) 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)
- 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.
- h) 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 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.

No chemical treatment of the surface of steel using chromates is allowed to improve adhesion. Required adhesion shall be obtained only by using suitable powder epoxy primer and surface preparation.

- 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.

The powder epoxy primer is sprayed using electrostatic spray guns. The thickness of the coat shall be between 80 and 150 microns (as per [ISO 2808](#), method 10), depending on the powder and the service conditions. It shall always be at least 20 microns higher than the measured roughness of steel pipes after sand blasting (see 5.1.1.e). The 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 MANUFACTURER recommendation, in order to obtain, as a minimum, adhesion values required in Table 5.

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 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) (for side extrusion).

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 of polyethylene may be sprayed on the hot extruded polyethylene surface (before quenching). The granules being not totally melted, they will provide a rough surface. Or the coating may be ended with an external wavy profile with thicker areas obtained by an extra polyethylene layer spirally applied.

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.

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 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.

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 RP 0274)

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.

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

For longitudinal or spiral welded pipes, coating thickness shall be measured on the pipe body as well as on the weld. The minimum total thickness may be reduced by a maximum of 10% of the minimum thickness on the seam weld for 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 RP 0274).

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.

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.

6.5 Other characteristics

Table 5 : Characteristics of applied coating

Characteristics	Methods	Units	Acceptable values
Impact resistance at 23°C +/- 2°C	NF A 49-710	Joules/mm	≥ 7
Shore D hardness	ISO 868	Shore D	≥ 50
Resistance to peeling	NF A 49-710 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 -2	%	> 500
Indentation	NF A 49-710 At 25 °C +/- 2°C (duration:2h) At 80 °C +/- 2°C (duration:4h)	Maximum depth (mm)	< 0.20 < 0.50
Homogeneity of the coating in the thickness	Visual		No microvoids or bubbles within the layers
Cathodic disbonding	NF A 49-710 after 28 days at 23 +/- 2°C After 48hr at 65 °C +/- 2°C After 28 days at 80 °C +/- 2°C (for information only)	mm	< 5 < 2 < 10

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 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,..) :
- Preheating pipe temperature,
- Finish of prepared surface,
- Dust level of prepared surface,
- Roughness (Ry5) of prepared surface,
- Pipe temperature when entering spraying machine,
- Intercoat time
- Pipe temperature after cooling.

7.2.1 Climatic conditions, surface cleanliness and preheating temperature

Pipes before sand 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 sand 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 sand blasting.

Pre heating temperature: 40 to 70°C

Salt contamination equivalent to 2 micrograms per square cm max (ISO 8502-6) and temperature 3°C above dew point for pipes after sand 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 A or B Sa 3 as per [ISO 8501-1](#).

7.2.3 Dust level of grit blasted surface

Frequency:

Each of the first 10 pipes at the end of surface preparation at the beginning of the job shall be checked, then 4 pipes per shift shall be checked.

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.

Frequency:

Each of the first 10 pipes at the end of surface preparation at the beginning of the job shall be checked, then 4 pipes per shift shall be checked.

Specification requirements:

Ry5 values shall be between 60 and 90 microns

7.2.5 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.

Specification requirements :

Temperature shall be in accordance with § 5.1.2.a

7.2.6 Intercoat time

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

Frequency:

Twice per shift

Specification requirement:

The measured intercoat time shall be in accordance with § 5.1.2.a and b.

7.2.7 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:

Each 10 pipes during production.

Specification requirement :

As per Table 4.

7.3.2 Cut-back

At both ends of each coated pipe.

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 RP 0274**.

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
- Adhesive layer thickness
- Impact resistance,

- Shore D hardness,
- Peeling speed,
- Peeling force,
- Indentation,
- Visual inspection of homogeneity of the coating within its thickness (samples used for peeling tests can be used for that purpose).

7.4.1 Epoxy layer thickness

Frequency:

One per shift

Specification requirements:

Results shall be in accordance with § 5.1.2.a. It shall correspond, as a minimum, to Ry5 of the controlled pipe plus 20 microns.

7.4.2 Adhesive layer thickness

Frequency:

One per shift

Specification requirements :

Measured value shall be 200 microns minimum.

7.4.3 Impact resistance

Frequency:

One test per shift or every 60 pipes starting from the first pipe.

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 RP 0274).

7.4.4 Shore D hardness

Frequency:

One test per shift.

Specification requirements :

Average equal or more than 50 (Shore D).

7.4.5 Resistance to peeling:

Frequency:

Two pipes at the start of each shift then one test every 60 pipes on the end to be cut back. If one test does not satisfy the requirements given here after, tests shall be performed on 10 pipes coated since the last check, and none of them shall be defective. As per NFA 49 710.

Specification requirements:

More than 1000/50 mm at $23 \pm 2^\circ\text{C}$ and 200N/50 mm at $80 \pm 2^\circ\text{C}$.

7.4.6 Indentation

Frequency:

One sample per shift, but 3 tests minimum. If one fails, 5 new samples shall be tested, none of them shall be defective.

Specification requirements:

Penetration shall be less than :

- 0.20 mm at $25^\circ\text{C} \pm 2^\circ\text{C}$ (duration: 2h)
- 0.50 mm at $80^\circ\text{C} \pm 2^\circ\text{C}$ (duration: 4h)

7.4.7 Homogeneity of the coating

Frequency:

One test every 30 pipes on one coated pipe sample. If the test does not satisfy the requirements, 2 other tests shall be made on pipes coated since the last check, and none of them shall be defective.

Specification requirements:

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

7.4.8 Cathodic disbonding

Equipment:

As per [NF A 49-710](#) Appendix K.

Frequency:

One test every 2 shifts at $65 \pm 2^\circ\text{C}$ during 48 hours.

Specification requirements:

The increase of the radius shall be less than 2 mm after 48 hours at $65 \pm 2^\circ\text{C}$.

7.4.9 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,
- 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 otherwise stated, 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 Raw materials data base

Typical raw materials to be considered for qualification:

Epoxy primers:

- Eurokote 71441 BS Coating
- Scotchkote 226N 3M
- Basepox 50-7179 BASF Coatings

Adhesives:

- Orevac 18350 Atofina
- NCPE 0420 Borealis
- Fusabond EM 158 D Dupont

Polyethylene:

- Lacqtene 2006PBK35 Atofina
- HE 3450 Borealis
- Lupolen 3652D-SW00413 Basell

This list is for information only. This shall not be considered as an exemption of qualification process. Other products can be proposed.

Appendix 2 Summary of Qualification and Fabrication tests

Tests / Checks	Requirements	Qualification and start-up fabrication	Fabrication
1. Preheating	40 to 70°C	10 pipes	IR camera monitoring - All
2. Surface preparation			
➤ Degree of cleanliness	A or B Sa 3 No oil, grease contaminations	10 pipes	All
➤ Salt contamination	Lower than 2 micrograms per square cm	5 pipes	Once per shift
➤ Dust level	Equal or less than 2	10 pipes	10 first pipes and 4 per shift
➤ Roughness	$60 \leq Ry5 \leq 90 \mu m$	5 pipes	10 first pipes and 4 per shift
➤ Steel temperature	+ 3°C above dew point	1 pipe	4 per shift
3. Coating application			
➤ Pipe temperature after induction heating	See § 5.1.2.a	All	All
➤ Intercoat time	See § 5.1.2.a	All	Twice per shift
➤ Extrusion temperature	See § 5.1.2.b and c	5 pipes	Once per shift
➤ Cooling	$\theta \leq 60$ no marking of the coating.	All	All
4. Raw materials			
Conformity certificate	See § 4	Each Raw materials	N/A

Tests / Checks	Requirements	Qualification and start-up fabrication	Fabrication
<u>Tests results</u> ➤ Epoxy primer ➤ Adhesive ➤ Polyethylene ➤ UV and thermal resistance ➤ Stress cracking resistance	See § 4 See § 4 See § 4 Appendix 3 and 4 ASTM D1693, Cond B (10% Igepal) F20>1000	Each raw materials For PE only, One certificate no older than three years For PE only, One certificate no older than three years	N/A N/A N/A
Certificate of analysis	See § 4	Every batch	Every batch
5. Coating ➤ Thickness ➤ Epoxy thickness ➤ Adhesive thickness ➤ Holiday detection ➤ Cut-back ➤ Impact resistance ➤ Shore D hardness ➤ Peeling force	Visual aspect : Homogeneous colour See § 6.2 80 to 150 microns 20 microns above Ry5 minimum. 200 microns minimum 10 kV/mm (25 kV max) 150 +20 / -0 mm No less than 7J/mm - Holiday detection : 10 kV/mm (25 kV max) No less than 50 > 1000N/50 mm at 23°C ± 2°C > 200 N/50 mm at 80°C ± 2°C	All All 2 pipes 2 pipes All All at both ends 2 pipes 2 pipes 2 pipes 2 pipes	All Every 10 pipes One per shift One per shift All All at both ends Every 60 pipes One per shift Every 60 pipes

Tests / Checks	Requirements	Qualification and start-up fabrication	Fabrication
➤ Homogeneity of the coating	Visual inspection. No micro voids or micro bubbles.	2 pipes	Every 30 pipes
➤ Indentation	<0.20 mm at 23°C ± 2°C	1 pipe	One per shift
	< 0.50 mm at 80°C ± 2°C	1 pipe	
➤ Flexibility	No defect	1 pipe	N/A
➤ Cathodic disbonding	Test at 28 days at 23°C ± 2°C	1 pipe	
	Test at 28 days at maximum operating 80°C ± 2°C (for information)	1 pipe	
	Test at 65°C ± 2°C during 48h. Not more than 2 mm	1 pipe	1 every two shifts
➤ Residual magnetic intensity	< 3 milliTesla (30 gauss)	All at both ends	All at both ends

Notes:

- Shift is one team production

Appendix 3 Thermal ageing test

Test samples: Polyethylene sample taken from coated pipe.

Temperature of test: 100°C (+/- 2°C)

Duration of test: 4800 hrs

Procedure:

On sample taken from coated pipe, first measure the initial MFI according to [ISO 1133](#) (2,16kg, 190°C) : MFI (0).

Place the sample in a pulsed air oven at a temperature of 100°C (+/-2°C) for 4800 hrs.

After 4800 hrs, stop the test and measure the MFI according to [ISO 1133](#) (2,16kg, 190°C) : MFI (4800).

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

Results are expressed as variation of MFI with time :

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

Each MFI shall be the average value of three measures.

Appendix 4 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 +/-3°C
- Relative humidity : 65 +/-5%
- Cycle : 18 +/-0.5min humid; 102 +/-0.5 min dry
- Total radiant energy : 5 JG/m²
- Continuous exposure

Procedure:

On sample taken from coated pipe, first measure the initial MFI according to [ISO 1133](#) (2,16kg, 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 1133](#) (2,16kg, 190°C): MFI (5GJ/m²).

Results are expressed as variation of MFI with time :

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

Each MFI shall be the average value of three measures.