

GENERAL SPECIFICATION

CORROSION

GS EP COR 222

Fusion Bonded Epoxy (FBE) external coating for pipelines

05	06/2012	Update following the EP reorganization, March 2011
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1. Scope

This specification covers the minimum requirements to ensure proper application and performance of plant-applied fusion bonded epoxy powder coatings to the external surfaces of pipelines.

The purpose of such coatings is to prevent corrosion when used in conjunction with cathodic protection.

The coating shall be suitable for service temperature from -20°C up to +80°C (depending on the type of epoxy primer).

For higher temperature, high glass transition temperature epoxy powders are necessary. Specific requirements and qualification tests might be requested by Company on a case by case basis. Qualification dossiers specific to such product shall be submitted to Company before the epoxy powder is ordered, and in any case, two (2) months prior to the commencement of coating works, for formal approval based on the present specification to which high service temperature related performance characteristics shall be added.

2. Reference documents

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

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 570	Standard Test Method for Water Absorption of Plastics
ASTM D 4940	Standard test method for conductimetric analysis of water soluble ionic contamination of blasting abrasives
ASTM G 8	Standard test methods for cathodic disbonding of pipeline coatings
ASTM G 95	Standard test methods for cathodic disbonding of pipeline coatings (Attached Cell Method)
CSA Z245-20	External fusion bond epoxy coating for steel pipes
ISO 2811-1	Paints and varnishes - Determination of density - Part 1: Pycnometer method
ISO 4287	Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters
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 - Part 9: 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
NACE SP0490	Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 µm (10 to 30 mils)

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
Not applicable	

3. Obligations of Applicators and Manufacturers

3.1 Company requirements regarding coating products

Applicator shall, in his tender, submit the data sheets of the selected products both for Fusion Bonded Epoxy (FBE) and repair products for Company approval. He will also provide a written notice attesting that the FBE material and the repair products delivered shall meet the required characteristics as set forth in § 4 according to the specified methods.

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The Applicator shall inform by writing the Manufacturer, with a copy to Company, of Company requirements related to:

- Test certificates, properties and conformity certificates of FBE and repair products as detailed in the present document
- The packaging: Manufacturer shall deliver the products in waterproof plastic bags to prevent water contamination and absorption of humidity during storage and transportation.

Once approved by Company, the epoxy powder and the repair products shall not be changed by the Applicator.

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

3.2 Qualification of Applicator plant and coating system

Qualification of the proposed application plant, personnel, coating process, and products shall be carried out in due time through a Procedure Qualification Trial (PQT). Qualification shall be organised jointly by Contractor and 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 failing to meet the requirements of this specification.

Qualification shall consist of the following steps:

- Submission of information for Company approval for raw materials (epoxy, repair products) prior to the start of PQT:
 - Conformity certificates (see § 4.3.3) and tests results for materials requirements (see § 4.3.2)
 - Certificate of analysis (see § 4.3.4) for each batch of product used for PQT
 - For FBE, tests results (see § 4.3.5) on laboratory coated sample plates.
- Coating process: The PQT will be witnessed by Company representative and shall be in accordance with § 5. Coating process parameters shall be fully recorded during PQT and the same parameters shall be used for production, with a maximum discrepancy of 5% for each parameter, including the pipe travel speed for blasting and coating operations, which shall be strictly monitored during PQT and production (within the 5% margin).
- Coating properties: Tests shall be witnessed by Company representative and in accordance with § 6.
- An Inspection Test Plan for the PQT is given in Appendix 1. Contractor and Applicator shall submit a complete joint report of the PQT results to Company for approval.
- Once approved, the FBE coating will be considered as qualified on the corresponding coating line. Any change in the components of the coating or the application process of a qualified coating on a new coating line shall lead to a new qualification process. The qualification of the coating on the coating line is valid for three years duration. Renewal of the qualification is normally based on a technical visit and/or Company track record. A

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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 Test (PPT) shall be carried out, as described in Appendix 1.

3.3 Notification prior starting coating work

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

Company inspector shall have free access to workshops, storage yards, and laboratory of 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, Company Inspector shall receive from Contractor the documents supplied by Applicator.

3.4 Acceptance certificate

Contractor and Applicator shall sign jointly with Company 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 Applicator under the responsibility of Contractor for all Company ordered pipes and have been witnessed by Company Inspector.

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

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

For each raw material (epoxy powder and repair product) the documentation requirements prior to the start of the work are as follows:

- Nature and type of raw material
- List of technical design and performance requirements of Company
- Certificate of conformity from Manufacturer
- Certificate of analysis from Manufacturer.

4.1 Coating system

The Fusion Bonded Epoxy external coating shall consist of one coat of powder epoxy of 400 to 500 microns DFT, with neither primer nor conversion chemical surface treatment such as chromatation.

Coating shall be plant applied in one coat.

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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
- Shelf life or expiry date.

4.3 Characteristics of epoxy powder product

4.3.1 Nature and type

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

4.3.2 Technical requirement for epoxy powder

The epoxy powder shall meet the requirements of Table 1.

Table 1 - Technical requirements for FBE powder

Characteristic	Test	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	Not less than 100°C for fully cured material
Water absorption (demineralised water)	ASTM D 570 on a free film of 500 microns ± 50 microns	%wt	Less than 15% of weight uptake after 28 days at 80°C

* For service temperature up to 80°C. For higher service temperature, high glass transition temperature materials are requested. They shall be submitted to Company for approval on a case by case basis. In all cases, Tg shall be understood as the inflection point on a DSC spectra.

4.3.3 Content of conformity certificate

The conformity certificate is issued by the raw material Manufacturer (specific to each raw material). It lists physical and chemical characteristics to be controlled for each production batch with conformity acceptance values set by Manufacturer.

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The conformity certificate shall include the following information:

- Name of Manufacturer
- Name of product
- Manufacturing plant
- Date of issue
- Name, function and signature of the person issuing the document
- All information as requested in Table 2 below.

Table 2 - Contents of Manufacturer's conformity certificate

Characteristics	Methods	Units	Conformity acceptance values
Gel time	ISO 8130-6	seconds	Manufacturer specification
Cure time	Manufacturer	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
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 before PQT, 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 the raw material Manufacturer with every batch of product and shall feature all characteristics which have been 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 acceptance criteria.

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4.3.5 Laboratory coated test plates qualification

The coating shall be qualified by the Manufacturer through testing of laboratory coated plates for each applicable test of Table 3 below.

Qualification is valid for three years. Company may, after this period of three years, extend the validity of the qualification, provided upon receipt from Manufacturer of a statement certifying that product formulation and manufacturing plant and process have remained unchanged.

4.3.5.1 Preparation of laboratory coated test samples

Steel plates shall be mild steel 6 mm thick, 100 x 100 mm (unless otherwise).

Salt contamination shall be checked prior to abrasive cleaning and shall be lower or equal to 2 micrograms/cm² as per [ISO 8502-6](#) and [ISO 8502-9](#).

Cleanliness after blast cleaning shall be Sa3 as per [ISO 8501-1](#).

Surface roughness shall be such as: 60 microns < Ry5 < 90 microns. It shall be measured as per [ISO 8503-4](#) (stylus method). The use of replica tape is not allowed.

Cured film thickness of the applied coating shall be 450 ± 50 microns.

4.3.5.2 Technical requirements

The selected epoxy powder applied as per § 4.3.5.1 shall fulfill the requirements of Table 3 below.

Before tests commence, DSC testing shall be used to clearly demonstrate that the epoxy powder is fully cured.

Table 3 - Technical requirements of laboratory coated test samples

Properties	Requirements	Number of test specimens	Test method
Thermal characteristics (curing and Tg) DSC	As per Table 1 ΔTg lower than 3° No residual enthalpy	1	DSC (see Appendix 2)
Water permeability	Value after three month at 23°C. For information, but mandatory	1 (free film)	As per Manufacturer. Film thickness to be noted
Water absorption	Value after three month at 23°C. For information, but mandatory	1 (free film)	As per Manufacturer. Film thickness to be noted
Cathodic disbondment 48 hr, 65°C	3 mm max radius	3	ASTM G 8
Cathodic disbondment 28 days, 23°C	5 mm max radius	3	ASTM G 8
Cathodic disbondment 28 days, 80°C	15 mm max radius	3	ASTM G 8

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Properties	Requirements	Number of test specimens	Test method
28 days hot water soak test, 65°C	Rating of 1-2	3	Appendix 3
Cross-section porosity	Rating 1-2	1	CAN/CSA Z245.20-98 Chap 12.10
Interface porosity	Rating 1-3	1	CAN/CSA Z245.20-98 Chap 12.10
Flexibility	2.5° at -20°C	3	CAN/CSA Z245.20-98 Chap 12.11
Impact	1.5 J at -30°C	3	CAN/CSA Z245.20-98 Chap 12.12
Strain polarization	No cracking or disbonding	3	CAN/CSA Z245.20-98 Chap 12.13

5. Application of the coating

5.1 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 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 as per [ISO 8502-6](#) and [ISO 8502-9](#). Alternative methods such as SCM400 are acceptable.
- All pipes shall be preheated (40 to 70°C) before abrasive blasting. Pipe temperature shall be checked continuously using an infra red camera.
- The pipe surface shall be blast cleaned to Sa 3 as per [ISO 8501-1](#) using automatic blast cleaning 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 abrasives shall be checked as per [ASTM D 4940](#): Conductivity shall be lower than 1000 µSiemens/cm and no oil shall be visible after 30 minutes.
- Immediately after abrasive blast cleaning, all dust and traces of abrasives shall be removed from the pipe surface by brushing and vacuum cleaning. Maximum acceptable dust level shall be 2 according to [ISO 8502-3](#).
- Each cleaned pipe shall be inspected for surface defects. Any defect shall be removed.

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- 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 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.

5.2 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 line speed) of the values measured during PQT.

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.

5.2.1 Application and curing temperatures

Application and curing temperature of the external pipe surface shall be as selected by the Applicator within the Manufacturer recommendation and shall not exceed 275°C.

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.

5.2.2 Coating thickness

Coating thickness: 450 microns $\pm$ 50 microns.

5.2.3 Cutback

Dimensions of cutbacks shall be as specified in the purchase order.

5.2.4 Recycling

Use of recycled powder is permitted only when collected and processed through a closed system, which controls the ratio of recycled to virgin powder. Sieving equipment of 350 microns or finer and a magnetic particle separator shall be used. The dew point of high pressure air supply to the fluidized bed and electrostatic gun shall be lower than 30°C.

The ratio of recycled powder to virgin powder shall not exceed 20%.

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5.2.5 Cooling

The pipe shall cool in a manner as to avoid damage to the newly applied coating. After cure is completed in accordance with the powder Manufacturer recommendations, the pipe may be quenched with running water or forced air cooling to facilitate pipe handling, and coating inspection and repair.

Curing time before quenching shall be monitored to ensure compliance with Manufacturer recommendation for minimum curing requirements and properties of Table 4. For safety reasons, temperature after cooling shall not exceed 60°C.

6. Characteristics of applied coating

The coating shall meet the properties detailed below:

6.1 Aspect

The coating shall be of uniform aspect and colour, and free of any surface defects detrimental to its quality. It shall not show any cracks, blisters, lamination, wrinkles, disbonding or sagging.

6.2 Thickness

Coating thickness specified: 450 microns $\pm$ 50 microns.

The coating thickness shall be measured at three random locations along each pipe length using a coating thickness gauge that is calibrated at least once every working shift (maximum of 12 hours) against a thickness standard that is within 10% of the nominal coating thickness specified. Such measured thickness values shall be recorded.

If individual measured thickness values are less than 400 microns, the coating thickness of the affected pipe shall be measured along the pipe length at intervals not exceeding 10 meter. The average of such values for each pipe shall be at least 4000 microns with no individual values below 3500 microns.

When they fail to meet these requirements, pipes shall be stripped and re coated.

6.3 Holiday inspection

The entire coated surface of each length of pipe shall be inspected with a holiday detector in accordance with [NACE SP0490](#).

Maximum temperature of pipe for inspection shall be 60°C.

Pipe containing holidays shall be re coated or repaired in accordance with the requirements of § 7.

The maximum number of repairs allowed before stripping and recoating of the entire pipe is 1 per meter of pipe length, whatever the diameter.

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6.4 Other characteristics

Table 4 - Characteristics of applied coating

Test	Requirements	Test method
Thermal characteristics (curing and Tg) by DSC	ΔT_g Lower than 3°C in absolute value. No residual enthalpy	DSC as per Appendix 2
Adhesion	Rating 1-2	Appendix 4
Impact	1.5J minimum at -30°C	CAN/CSA Z245.20-98 Chap 12.12
Flexibility	2.5° at -20°C	CAN/CSA Z245.20-98 Chap 12.11
Cathodic disbonding test 28 days at 23°C	5 mm Max	ASTM G 95
Cathodic disbonding test 28 days at 80°C	15 mm Max	ASTM G 95
Cathodic disbonding test 48 hr at 65°C	3 mm Max	ASTM G 95
28 days hot water soak test 65°C	Rating 1-2	Appendix 3
Cross section porosity	Rating 1-3	CAN/CSA Z245.20-98 Chap 12.10

7. Repair products and procedure

7.1 Repair product qualification

Repair products shall be submitted to Company for approval prior to use.

Technical Data Sheets, Safety Data Sheets, Certificates of analysis, Certificates of conformity of each product shall be provided.

As a minimum, the following testing shall be performed on sample plates representative of the repair process either in the coating plant and/or in the field (both process shall be tested). At least one interface between the parent coating and the field joint shall be incorporated in the testing programme in order to assess compatibility of the repair technique with field joint interfaces.

PQT for repair materials and procedure shall be performed at the same time than PQT for line pipe coating.

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Table 5 - Repair product characteristics

Test	Requirement	Test method
Adhesion	1-2 (to steel and parent coating)	Appendix 4
Hot water soak test, 28 days at 65°C	Rating 1-2	Appendix 3
Cathodic disbonding test 28 days at 23°C	5 mm max	ASTM G 95

7.2 Repair procedure

The repair procedure shall be proposed jointly by Applicator and Manufacturer and submitted to Company for approval. All characteristics and tests results requested in § 7.1 shall be submitted.

The preferred option for repairs is the use of two component liquid epoxy material.

Defects originating from the coating process itself and not from subsequent handling and storage shall be addressed separately and immediately reported to CPY representatives.

8. Inspection

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

- Inspection of epoxy powder batches delivery and conformity with the requirements specified in this document
- Verification of the application process, in accordance with the requirements specified in this document
- Systematic inspection of pipe coating at pipe ends or of test samples taken from pipe end
- Inspection of coated pipes.

Company Inspector may take samples of the coating materials or repair products and test specimens of coated pipe(s) for testing in laboratories selected by Company in order to check their quality.

Such supplementary tests will be at Company cost if the results are satisfactory but will be back charged to Contractor/Applicator if the coating material and/or repair products are not in accordance with the requirements of the present specification.

8.1 Inspection of coating materials and conformity of repair products

Inspection shall be performed upon delivery of the coating materials and repair products in order to check packaging, markings and to ensure that certificates of analysis for all materials are compliant with certificates of conformity.

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

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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 samples of each raw coating material shall be taken from each production batch. One shall be kept by the Applicator in case third party testing becomes necessary, one shall be given to Company, and one shall be kept as a reference sample in Applicator's laboratory for six months, protected against humidity, and at a temperature below and close to 20°C.

8.2 Inspection of the various application parameters

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
- Degree of cleanliness of prepared surface
- Dust level of prepared surface
- Roughness (Ry 5) of prepared surface
- Pipe travel speed for blasting and coating process
- Pipe temperature when entering spraying machine
- Pipe temperature after cooling.

8.2.1 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 basis. After grit blasting and before coating, storage conditions of the pipes shall be checked.

Frequency:

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

Specification requirements:

No contamination of pipe surface before grit blasting.

Pre heating temperature before blasting: 40 to 70°C.

Salt contamination: 2 micrograms/cm² maximum ([ISO 8502-6](#) and [ISO 8502-9](#)).

Storage temperature: 3°C above dew point for pipes after grit blasting.

8.2.2 Finish of prepared surface

Frequency:

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

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Specification requirements:

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

8.2.3 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](#).

8.2.4 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.

8.2.5 Pipe travel speed

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

Frequency:

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

Specification requirement:

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

8.2.6 Pipe temperature before spraying cabinet

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

Frequency:

Control is continuous over total pipe length.

Specification requirements:

Temperature shall be in accordance with Manufacturer's recommendations and within 5% of values recorded during.

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8.3 Systematic inspection of each coated pipe

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

- Visual aspect, homogeneous colour
- Thickness
- Cut-backs dimensions
- Electrical porosity.

8.3.1 Thickness

Frequency:

All pipes.

Specification requirement:

Thickness shall be measured using an electromagnetic gauge. Individual measurements shall be recorded, and an histogram shall be prepared for each shift. Thickness shall be as per Table 4.

8.3.2 Cut-back

Frequency:

At both ends of each coated pipe.

Specification requirement:

The cut-backs dimensions shall be measured using a ruler or a purposely built gauge. The dimensions of the cut-backs shall be within the requirements of the Contract.

8.3.3 Electrical porosity

Frequency:

100% of the length of each coated pipe.

Specification requirements:

An adjustable DC holiday detector with voltage indicator set at 5 V / micrometer and an annular electrode covering 100% of pipe surface circumference shall be used over the dry surface of the coating after cooling. Control shall be automated and in accordance with [NACE SP0490](#).

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

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

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 curing
- Impact resistance
- Adhesion
- Porosity
- CD test
- Residual magnetic intensity.

8.4.1 Epoxy curing (see Appendix 2)

Frequency:

PQT and PPT: 2 pipes. Production: At the start of each shift.

Specification requirements:

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

8.4.2 Impact resistance

Frequency:

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

Specification requirements:

Energy shall be 1.5 J minimum.

Coating to be repaired if necessary after testing.

8.4.3 Porosity

Frequency:

PQT and PPT: One pipe. Production: Once per shift.

Specification requirements:

Rating 1-2 as per [CAN/CSA Z245.20-98](#).

8.4.4 Adhesion

Frequency:

PQT and PPT: 3 pipes. Production: at the start of shift and every hour thereafter.

Specification requirement:

Rating 1-2 as per Appendix 4.

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8.4.5 Cathodic disbonding

Equipment:

As per [ASTM G 95](#).

Frequency:

PQT: One pipe, 28 days at room temperature and 80°C for 48 hr at 65°C. PPT: first two pipes, 48 hr at 65°C. Production: One test every 2 shifts at 65 ± 2°C during 48 hours.

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.

8.4.6 Residual magnetic intensity

Frequency:

Both pipe ends on each coated pipe.

Specification requirements:

The residual magnetic intensity shall be below 3 milliTesla (or 30 gauss).

9. Handling, transport, and storage

9.1 Handling

Coated pipes shall be handled in a manner that avoids damage to the pipe and coating. The Applicator shall submit details of the handling procedure to Company for approval. Such procedures shall include loading requirements where the Applicator is responsible for loading.

Coated pipe shall have full encirclement separators around each length. Such separators shall be sized and located to prevent damage to the coating.

9.2 Storage

The Applicator shall submit details of the facilities and the methods to be used for yard storage for Company approval.

10. 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 any corrective action implemented for rejected pipes.

Appendix 1 Summary of qualification and production tests

Tests / Checks	Requirements	PQT	PPT	Production
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 at PQT	Once	Within 5% of PQT	Within 5% of PQT 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 § 5.2.1 Lower than 275°C	All	5 pipes	All
• Cooling	$\theta \leq 60$ no marking of the coating.	All	5 pipes	All
4. Raw materials				
Conformity certificate	See § 4	Each raw materials	Each raw materials	N/A
Tests results for FBE (laboratory coated samples)	See § 4	Each raw materials	N/A	N/A
Certificate of analysis	See § 4	Every batch	Every batch	Every batch

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Appendix 1

Tests / Checks	Requirements	PQT	PPT	Production
5. Coating	Visual aspect: Homogeneous colour	All	All	All
• Porosity	Rating 1-3	All	5 pipes	All
• Thickness	450 ± 50 Microns	All	5 pipes	Every five pipes
• Holiday detection	Max 1 holiday per meter length (to be repaired)	All	All	All
• Thermal characteristics	ΔTg lower than 3°C. No residual enthalpy	All	One pipe	One per shift at start
• Adhesion	Rating 1-2	3 pipes	3 pipes	At start of shift and every hour
• Cut-back	As per purchase order	All at both ends	All both ends	All at both ends
• Impact resistance	No less than 1.5 J at -30°C - Holiday detection: No holiday	2 pipes	1 pipe	One at start of shift
• 28 days hot water soak test at 65°C	Rating 1-2	2 pipes	1 pipe	N/A
• Flexibility	2.5° at -20°C No cracks	2 pipes	1 pipe	N/A
• Cathodic disbonding	Test at 28 days at 23°C ± 2°C Less than 5 mm	1 pipe (mandatory for qualification)	N/A	N/A
	Test at 28 days at 80°C ± 2°C Less than 15 mm	1 pipe (mandatory for qualification)	N/A	N/A
	Test at 65°C ± 2°C during 48h. Not more than 3 mm	1 pipe	1 pipe	1 every two shifts
• Residual magnetic intensity	< 3 milliTesla (30 gauss)	All at both ends	All both ends	All at both ends

Note: • Shift the production of one team, for 12 hours maximum.

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Appendix 2

Appendix 2 Check for curing of FBE by DSC

- 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 maximum temperature as advised by Manufacturer).
- Cool down to ambient temperature at 40°C/min. Hold at ambient for the temperature in the cell to stabilize (i.e. 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 defined here as the inflection point in the DSC curve.

Should pre-heating of the sample before the first scan be proposed for homogenisation of the sample, it shall be demonstrated that ABSOLUTELY NO CURING OCCURS during this operation.

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Appendix 3

Appendix 3 Hot water soak test

Heat fresh tap water up to $65^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

Place the specimen in the water bath for 28 days, fully immersed.

Upon removal from the bath, and while the specimen is still warm, use the utility knife to make a rectangle scribe, approximately 30 mm x 15 mm, through the coating to the substrate, then air cool the test specimen to $20^{\circ}\text{C} \pm 3^{\circ}\text{C}$. Within one hour removal from the water bath, insert the tip of the knife blade under the coating at a corner of the scribed rectangle. Use a levering action to remove the coating. Continue inserting the tip of the knife and levering it under the coating until either all of the coating in the rectangle is removed or the coating demonstrates a definite resistance to the levering action.

Rate the adhesion as follows:

- Rating 1: Cannot be removed
- Rating 2: less than 50% is removed
- Rating 3: More than 50% is removed, but coating shows a definite resistance to levering action
- Rating 4: The coating is easily removed in strips or large chips
- Rating 5: The coating is removed as a single piece.

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Appendix 4

Appendix 4 Adhesion test

Make a V-shaped scribe with two 20 mm lines intersecting approximately 5 mm from their ends at 30° to 45°.

Insert blade of the knife at the point of the V-cut. Then with an upward flicking action attempt to dislodge the coating within the V. If little or no coating is removed, repeat this action within the V at least 4 times to confirm the integrity of the coating.

Examine the appearance of the disbonded surface and compare with the following descriptive ratings below:

- Rating 1: No coating removed
- Rating 2: Coating removed in small chips with difficulties
- Rating 3: Coating removed in chips, slightly larger in area than the tip of the knife blade inserted under the coating. Some of the coating remains adherent to the surface of the steel within the V-cut
- Rating 4: Coating removed with no chipping of the coating and minimal resistance
- Rating 5: No coating remains adherent to the steel within the V-cut.

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Appendix 5

Appendix 5 CD test procedure

CD test general set up and equipment shall follow [ASTM G 95](#). For temperature check, a thermocouple shall be positioned inside the cell in contact with the steel.

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

- 1) Once the test is finished, make twelve radial incisions using a sharp knife through the FBE down to the steel, extending outwards from the holiday for a distance of at least 40 mm. Make the incisions approximately at 30° angle of each others.
- 2) Insert the tip of the knife blade into the center 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 the distance up to which the coating is disbanded (and not discoloration of the steel).
- 3) Repeat with each segment.
- 4) Calculate the average of the twelve measurements. Record the value.