



**STANDARD SPECIFICATION
FOR
3 LAYER POLYETHYLENE COATING
OF LINEPIPES**

API	American Petroleum Institute
APS	Application Procedure Specification
ASME	The American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CD	Cathodic Disbondment/ Compact Disc
CSA	Canadian Standards Association
<i>d</i>	Days
DFT	Dry film thickness
DIN	Deutsches Institut für Normung
DNVGL	Det Norske Veritas & Germanischer Lloyd
DSC	Differential Scanning Calorimetry
EN	European Standards
ESCR	Environmental Stress Crack Resistance
FBE	Fusion Bonded Epoxy
<i>h</i>	Hours
HDPE	High density polyethylene
ISO	International Organization for Standardization
MFR	Mass Flow Rate
PE	Polyethylene
PP	Polypropylene
ppd	per pipe diameter
PQT	Procedure Qualification Tests
RO	Reverse Osmosis
SSPC	The Society for Protective Coatings
<i>s</i>	seconds
UV	Ultraviolet



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1.0 SCOPE

This specification covers the minimum requirements for supply of all materials, plant, equipment, plant sites, consumables, utilities including all labour, supervision, inspection and tests etc. for plant-application of external anti-corrosion coating of pipes by using 'Three (3) Layer Side Extruded Polyethylene (3LPE)' conforming to ISO 21809 — 1: 2011 "Petroleum and natural gas industries — External coatings for buried and submerged pipeline transportation systems — Part 1: Polyolefin Coatings (3-layer PE and 3-Layer PP)" and the requirements of this specification.

2.0 REFERENCE DOCUMENTS

2.1 Reference has also been made to the latest edition (edition enforce at the time of issue of enquiry) of the following standards, codes and specifications. The edition enforce at the time of floating the enquiry shall be termed as latest edition.

API RP 5L1	: Recommended practice for railroad transportation of line pipe
API RP 5LT	: Recommended practice for truck transportation of line pipe
API RP 5LW	: Recommended practice for transportation of line pipe on barges and marine vessels
API Spec 5L	: Specification for line pipe
ASME B31.4	: Pipeline transportation systems for liquids and slurries
ASME B31.8	: Gas transmission and distribution piping systems
ASTM D149	: Standard Test Method of Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Frequencies
ASTM D257	: Standard Test Methods for DC Resistance or Conductance of Insulating Materials
ASTM D790	: Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D1603	: Standard test method for carbon black content in olefin plastics
ASTM D1693	: Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D3895	: Standard Test Method for Oxidative-Induction Time of Polyolefin's by Differential Scanning Calorimetric
ASTM D4940	: Standard Test Method for Conduct metric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives
CSA Z245.20	: Plant applied external coatings for steel pipe
DIN 30670	: Polyethylene coatings on steel pipes and fittings - Requirements and testing
DNVGL-ST-F101	: Submarine pipeline systems
DNVGL-RP-F102	: Pipeline field joint coating and field repair of line pipe coating

DNVGL-RP-F 106	: Factory applied external pipeline coatings for corrosion control
DIN VDE 0433-2	: Generation and measurement of high voltages; Specifications for voltage measurement by means of sphere gaps (one sphere earthed)
EN 10204	: Metallic products - Types of inspection documents
ISO 306	: Plastics - Thermoplastic materials - Determination of Vicat softening temperature (VST)
ISO 572	: Plastics - Determination of tensile properties\ Part 2 - Test conditions for molded and extruded plastics Part 3 - Test conditions for films and sheets
ISO 868	: Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)
ISO 1133	: Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics
ISO 1183	: Plastics - Methods for determining the density of non-cellular Plastics
ISO 2808	: Paints and varnishes - Determination of film thickness
ISO 3146	: Plastics - Determination of melting behavior (melting temperature or melting range) of semi-crystalline polymers by capillary tube and Polarizing-microscope methods
ISO 8501	: 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	: Preparation of steel substrate 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) Part 9 - Field method for the conductometric determination of water soluble salts
ISO 8503	: Preparation of steel substrates before application of paints and related products- Surface roughness characteristics of blast-cleaned steel Substrates Part 1 - Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces Part 2 - Method of grading of surface profile of abrasive blast cleaned steel - Comparator procedure Part 4 - Method for the calibration of ISO surface profile comparators and for the determination of surface profile - stylus instrument procedure

ISO 9001	: Quality Management Systems - Requirements
ISO 9002	: Quality management systems -- Guidelines for the application of ISO 9001: 2015
ISO 11124	: Preparation of steel substrates before application of paints and related products - Specifications for metallic blast-cleaning abrasives Part 1 - General introduction and classification Part 2 - Chilled-iron grit Part 3 - High-carbon cast-steel shot and grit Part 4 - Low-carbon cast-steel shot
ISO 11357	: Plastics - Differential scanning calorimetry (DSC)
ISO 15512	: Plastics - Determination of water content
ISO 21809	: Petroleum and natural gas industries External coatings for buried or submerged pipelines transportation systems Part 2 - Fusion-bonded epoxy coatings Part 3 - Field joint coatings
SSPC SP1	: Steel Structures Painting Council -Solvent Cleaning

2.2 The Applicator shall be familiar with the requirements of these documents and shall make them readily available at the coating plant to all persons concerned with carrying out the works specified in this specification.

2.3 In case of conflict between the requirements of this specification, ISO 21809 —1 and the codes, standards and specifications referred in clause 2.1 above, requirements of this specification shall govern.

3.0 COMPLIANCE

3.1 The Applicator shall be responsible for complying with all applicable requirements of ISO 21809-1: 2011 and this specification. The Company reserves the right to make necessary investigation and, in case of doubt, ask the applicator to conduct additional testing, batch sampling and manufacturing inspection in order to be satisfied of compliance by the applicator. Any materials/coating that does not comply with the requirements shall be rejected.

4.0 PLANT SCALE AND INSTALLATION

4.1 The Applicator shall size coating plant(s) after evaluating the scale of work and the time schedule required for the works. Coating plant(s), both new and existing, shall be installed into a yard whose geometry and dimensions are such as to allow the execution of a continuous work schedule. For this purpose, the Applicator shall ensure non-stop work execution owing to prohibitive adverse weather conditions and install requisite equipment and plant in roofed and adequately weather-protected areas.

4.2 Plant equipment, machinery and other facilities shall be in finest operating condition to at least meet the job requirements of quality and production. Worn out and improvised plants are not acceptable.

4.3 The epoxy spray booth shall be sized to accommodate the number of spray guns required for the application of required quantity of epoxy powder to be electrostatic ally sprayed on to the

- pipe to achieve specified thickness. Under no circumstances epoxy powder shall escape from the booth. This shall be clearly demonstrated by coating applicator during procedure qualification tests (PQT).
- 4.4** Plant shall have a powder storage room hermetically controlled with power back up for Air conditioning capable of storing the coating materials as per coating manufacturer's recommendations. Temperature and relative humidity shall be recorded continuously.
- 4.5** The powder system shall have an operational automatic fire suppressant system. Powder system shall have means to separate virgin and reclaimed powder.
- 4.6** Plant shall have pipe internal blow-out and debris collection system to remove loose scale, dirt and abrasive from the pipe interior.
- 4.7** The air used for the fluidization of epoxy powder shall be free from moisture. For this purpose dehumidifiers and /or air dryer, as necessary shall be provided along with necessary monitoring and control system. Fluidized bed shall have magnets adequate to remove iron and steel shaving contaminant from recycled powder.
- 4.8** The conductivity of RO water should be less than 35 micro-siemens and rinse water pressure shall be minimum 1000 psi.
- 4.9** The Applicator shall, at his own responsibility and cost, provide and prepare all necessary area for the storage of bare and coated pipe and all other materials, for coating yard, stock-piling and other temporary installation. For each area, Applicator shall provide necessary agreements, as required, with the land owner(s)/relevant Authorities, and, on work completion, to clean and pay settlement and claims for damages, as applicable.
- 4.10** The Applicator shall at its own responsibility and cost, provide for water supply, power supply and other utilities, consumables and obtain authorization regarding access roads and other permits required for the execution of works conforming to all the requirements of the governing Authorities.
- 4.11** The Applicator shall at its own expense provide a fully equipped laboratory and test facilities with adequate inventory to carry out tests required for the procedure qualification and regular production. Outside testing for qualification and regular production is not acceptable to Company.
- 4.12** The Applicator shall be fully responsible for adherence to all statutory regulations applicable for handling & disposal of the hazardous chemicals during the coating works and shall obtain all statutory approvals/ clearances from relevant Authorities including Pollution Control Board, as applicable for the coating plant(s).
- 5.0** **REQUIREMENTS FOR QUALITY**
- 5.1** The Applicator shall have established within his organization and, shall operate for the contract, a documented Quality System that ensures that the requirements of this specification are met in all respect. The Quality System shall be based upon ISO 9001/2 or equivalent.
- 5.2** The Applicator shall have established a Quality Assurance Group within its organization that shall be responsible for reviewing the Quality System and ensuring that it is implemented.
- 5.3** The Applicator shall submit the procedures that comprise the Quality System to the Company for agreement.
- 5.4** The Applicator's Quality System shall pay particular attention to the control of suppliers and

sub-contractors and shall ensure that the requirements of this specification are satisfied by the suppliers and sub-contractors operating Quality system in their organization.

5.5 The Applicator shall, prior to the commencement of work, prepare and issue a Quality Plan for all of the activities required satisfying the requirements of this specification. The plan shall include any sub-contracted work, for which the sub-contractors Quality Plans shall be submitted. The plan shall be sufficiently detailed to indicate sequentially for each discipline the requisite quality control, inspection, testing and certification activities with reference to the relevant procedures and the acceptance standards.

5.6 The Applicator's Quality system and associated procedures may, with due notice, be subject to formal audits. The application of quality control by the Applicator will be monitored by the Company Representatives who will witness and accept the inspection, testing and associated work required by this specification.

6.0 COATING CLASSIFICATION

6.1 General

The three layer coating as per this specification shall belong to coating Class B of ISO 21809-1: 2011 and shall be suitable for design temperature range of (-) 40 °C to (+) 80 °C.

6.2 Coating thickness

Minimum overall thickness of finished coating shall be as per Table 1 below:

Table 1- Minimum thickness of finished coating

Pipe Size (Specified Outside Diameter)	Minimum Coating Thickness (mm)
$\leq 10 \frac{3}{4}$" (273.1 mm)	2.5
$\geq 12 \frac{3}{4}$" (323.9 mm) to ≤ 18" (457 mm)	2.8
≥ 20" (508.0 mm) to ≤ 30" (762 mm)	3.0
≥ 32" (813.0 mm)	3.3

All coating thickness readings must meet the minimum requirements. However, localized coating thickness of less than the permissible minimum thickness can be tolerated on the condition that it does not attain a total extent of more than 5 cm² per meter length of coated pipe, and the actual coating thickness does not drop more than 10% below the permissible minimum coating thickness at these locations.

7.0 MATERIALS

7.1 The three layer coating system shall comprise of a powder epoxy primer, copolymeric or grafted adhesive and a high density polyethylene (HDPE) topcoat. Coating materials shall be suitable for the service conditions and the pipe sizes involved.

7.2 Pipe

Details of line pipe such as specification, diameter, wall thickness, length, material, grade etc., on which coating is to be applied as per this specification, shall be as given in Purchase Order.

7.3 Coating Material

- 7.3.1 The coating materials i.e. epoxy powder, copolymeric or grafted adhesive and polyethylene compound shall have proven compatibility.
- 7.3.2 Applicator shall choose brand of epoxy powder and adhesive as per 'Annexure I' of this specification that will achieve the functional requirements and properties of coating system as specified in clause 7.3.1 and Table 5 of this specification.

7.4 Qualification of coating materials

- 7.4.1 The coating system and materials shall be pre-qualified and approved by Company in accordance with provisions of Annexure I of this specification. Applicator shall obtain prior approval from Company for the coating system and coating materials.
- 7.4.2 The coating materials manufacturer shall carry out tests for all properties specified in Table 2, Table 3 and Table 4 of this specification for each batch of epoxy, adhesive and polyethylene compound respectively. In addition, the manufacturer shall also furnish infra-red scan for each batch of epoxy powder. The manufacturer shall issue Inspection Certificate 3.1B in accordance with EN 10204 for each batch of materials supplied to Applicator and same shall be submitted to Company for approval prior to their use.

7.4.3 Epoxy properties

Epoxy properties shall meet the properties listed in Table 2 below:

Table 2 — Epoxy properties

SI. No.	Properties	Unit	Requirement	Test Method
Raw material				
1.	Density	<i>g/l</i>	Within +/- 0.05 of the manufacturer's specified nominal value	ISO 21809-1 Annex N
2.	Gel time at 205° C ± 3° C	s	Within 20% of the nominal value specified by the manufacturer	ISO 21809-1 Annex J
3.	Particle size	--	Within manufacturer's specification	ISO 21809-2 Annex A.6
4.	Moisture Content	% mass	≤ 0.5	ISO 21809-1 Annex K
5.	Minimum glass transition temperature (<i>T_o</i>)	° C	≥ 95 and within manufacturer's specification	ISO 21809-1 Annex D
6.	Infrared scan	% transmittance	As per manufacturer's specification	—

As — applied				
7.	Hot water adhesion 24 h @ 65 °C	--	Rating of 1 to 2	ISO 21809-2, Clause A.16

Table 2 — Epoxy properties

SI. No.	Properties	Unit	Requirement	Test Method
8.	Hot water adhesion 28 d @ 65 °C	--	Rating of 1 to 3	ISO 21809-2, Clause A.16
9.	Flexibility at 0 °C	--	No cracking, tears, disbondment or delamination at 2.0° ppd length	ISO 21809-2, Clause A.13
10.	Impact resistance at 0 °C	J	≥ 1.5	ISO 21809-2, Clause A.14

The colour of epoxy powder shall be either green or dark red or any other colour approved by Company except grey colour.

7.4.4 **Adhesive material properties**

Copolymeric or grafted adhesive material shall meet the properties listed in Table 3 below:

Table 3 — Copolymeric or grafted adhesive material properties

SI. No.	Properties	Unit	Requirement	Test Method
Raw material				
1.	Density	kg/m ³	≥ 930 and within manufacturer's specification	ISO 1183
2.	Melt flow rate	g/10 minutes	≥ 1.0 and within manufacturer's specification	ISO 1133
3.	Water Content	%	≤ 0.1	ISO 15512
As — applied				
4.	Elongation at break at 23 °C ± 2 °C	%	≥ 600	ISO 527-2
5.	Tensile yield strength at 23°C ± 2 °C	MPa	≥ 8	ISO 527-2
6.	Vicat softening temperature A/50 (9.8 N)	°C	≥ 100	ISO 306
7.	Flexural Modulus	MPa	≥ 450	ASTM D790

7.4.5 PE (top coat) material properties

The topcoat polyethylene used shall be a black readymade compound, fully stabilized against influence of ultraviolet radiation (i.e. sunlight), oxygen in air and heat (due to environmental temperature upto + 80°C). No visible change shall occur during exposure to such environments up to atleast a period of 8,500 hours. The Applicator shall submit certificate from Manufacturer in this regard.

PE material shall meet the properties listed in Table 4 below:

Table 4 — PE (top coat) material properties

Sl. No.	Properties	Unit	Requirement	Test Method
Raw material				
1.	Density	g/cm ³	≥ 0.930	ISO 1183
2.	Melt flow rate	g/10 minutes	≥ 0.25 and within manufacturer's specification	ISO 1133
3.	Water content	%	≤ 0.05	ISO 15512
4.	Carbon black content	%	≥ 2	ASTM D1603
5.	Melting point	°C	≥ 120	ISO 3146
As — applied				
6.	Hardness	Shore D	≥ 55	ISO 868
7.	Elongation at break at 23°C ± 2 °C	%	≥ 600	ISO 527
8.	Tensile strength at 23°C ± 2 °C	MPa	≥ 17	ISO 527
9.	Vicat softening temperature A/50 (9.8 N)	°C	≥ 110	ISO 306
10.	Environmental Stress Cracking Resistance (ESCR) (50°C, F50, cond. B)	<i>h</i>	≥ 300	ASTM D1693
11.	Oxidative induction time (intercept in the tangent method) in oxygen at 220°C, Aluminium pan, no screen	minute	≥ 10	ISO 11357
12.	UV resistance and thermalageing	%	AMFR ≤ 35	ISO 21809-1 Annex G
13.	Indentation (mass 2.5 kg)	mm	≤ 0.2 @ 20 °C ≤ 0.4 @ 80 °C	ISO 21809-1 Annex F

14.	Impact resistance	J/mm	≥ 7	ISO 21809-1 Annex E
15.	Volume Resistivity @ 23°C±2 °C	Ohm-cm	$\geq 10^{16}$	ASTM D257
16.	Dielectric withstand, 1000 Volts/second rise @ 23°C 1 2°C	V/mm	$\geq 30,000$	ASTM D149

7.4.6 In addition to manufacturer's Certificate, the Applicator shall draw samples from each batch of epoxy, adhesive and polyethylene in the presence of Company Representative and test for the following properties at the coating yard at least one week prior to its use, to establish compliance with the manufacturer's Test Certificates.

a) Epoxy Powder

- i. Gel Time
- ii. Cure time
- iii. Moisture content
- iv. Thermal Characteristics (T_{91} , T_{92} , ΔH)

b) Adhesive

- i. Density
- ii. Melt flow rate
- iii. Vicat softening temperature
- iv. Water content

c) Polyethylene

- i. Melt flow rate (MFR)
- ii. Density
- iii. Water content
- iv. Thermal stabilization (as per ASTM D3895)

In case of failure of any of the above tests in a batch, that batch of material shall be tested for all other tests required as per Table 2, Table 3 and Table 4 of this specification including the tests which failed. If all tests pass, the batch shall be accepted for coating. If any of the tests fail, entire batch of material shall be rejected and shall not be used for the coating.

7.5 Storage and handling of coating materials

7.5.1 All materials to be used shall be supplied in sealed, damage free containers and shall be suitably marked with the following minimum information:

- a) Name of the manufacturer
- b) Type of material/ product description
- c) Mass/ Quantity of material
- d) Batch number
- e) Location of manufacture
- f) Date of manufacture
- g) Manufacturing identification number
- h) Temperature requirements for transportation and storage
- i) Shelf life or 'use by' date (DD/MM/YYYY)
- j) Qualified minimum flexibility test temperature
- k) Safety Data Sheets (to be included with delivery)

7.5.2 All materials noted to be without above identification shall be deemed suspect and shall be rejected by Company. Such materials shall not be used for coating and shall be removed from site/ store and replaced by Applicator at his own expense.

7.5.3 Applicator shall ensure that all coating materials are properly stored in accordance with the Manufacturer's recommendation at all times, to prevent damage and deterioration in quality prior to use.

7.5.4 Applicator shall be required to use all materials on a date received rotation basis, i.e. first-in-first used basis.

8.0 COATING SYSTEM QUALIFICATION

8.1 General

Properties of coating system and as-applied coating material shall comply the requirements indicated in Table 5 of this specification. In case the coating / material properties are tested as per test methods/ standards other than specified herein below, the same may be accepted provided the test procedures and test conditions are same or more stringent than the specified.

8.2 Application procedure specification (APS)

8.2.1 Upon award of the CONTRACT, the Applicator shall submit within two (2) weeks, for Company approval, a detailed report in the form of bound manual outlining, but not limited to, the following:

- a. Details of plant(s), location(s), layout, capacity and production rate(s).
- b. Details of process control and inspection equipment required for the coating process such as temperature control, thickness control, holiday testers, etc.
- c. Details of the equipment available to carry out the coating works including surface preparation, epoxy powder application and its recycling system, adhesive & polyethylene extrusion, moisture control facilities available for coating materials.
- d. Facilities in the yard for unloading, handling, transport, production, storage, stockpiling, loading of bare and coated pipes and warehouses for storage of other coating materials.
- e. Plant Organization Chart and availability of manpower including coating specialist
- f. Details of utilities/facilities such as water, power, fuel, access roads and communication etc.

After Company has given approval; no change in plant set-up shall be made. However, unavoidable changes shall be executed only after obtaining written approval from Company.

8.2.2 At least four (4) weeks prior to the commencement of production coating, a detailed procedure of the Applicator's methods, material proposed, etc., shall be formulated by the Applicator and submitted for Company approval in the form of a bound manual. The procedure shall include, but not limited to, the following information and proposals:

- a. Procedure for pipe inspection at the time of bare pipe receipt.
- b. Procedure for pipe tracking

- c. Procedure for steel surface preparation, including preheating, removal of steel defects, method of pipe cleaning, dust removal, abrasive blast cleaning and surface profile; methods of measurements and consumables.
- d. Procedure for pipe heating, temperatures and control prior to epoxy application.
- e. Complete details of raw materials for coating, repair and blasting operation including current data sheets showing values for all the properties specified together with quality control and application procedure recommendations from manufacturer(s).
- f. Procedure for application of FBE powder, adhesive and polyethylene, including characteristics, temperature, line speed, application window, curing time, gel time etc.
- g. Quenching and cooling procedure including time and temperature.
- h. Procedure for continuous temperature monitoring at various stages of coating.
- i. Procedure for preparation of coating cutback area.
- j. Quality Assurance System, Quality Plan, Inspection and Test Plan and reporting formats, including instrument and equipment types, makes and uses, etc
- k. Detailed method of repair of coating defects duly classified depending upon nature and magnitude of defects and repair thereof including coating stripping technique.
- l. Details of instrument and equipment calibration methods including relevant standards and examples of calibration certificates.
- m. Procedure for cleaning of all application equipment.
- n. Complete details and inventory of laboratory and equipment for procedure qualification and regular production.
- o. Coated pipe handling, stock piling and/or loading procedures including protection of pipe ends.
- p. Sample of recording and reporting formats (Daily log format), including laboratory reports, certificates and requirement as per clause 14.0 of this specification.
- q. Complete details of test certificates for raw materials including test methods and standards used.
- r. Test certificates from PE compound manufacturer for tests for thermal aging, volume resistivity and aging under exposure to light. These test certificates shall not be older than three years.
- s. Health, Safety and Environment Plans.
- t. Storage details of coating materials and chemicals.

8.3. Procedure Qualification Tests

- 8.3.1 Prior to start of production, the Applicator shall, at his expense, carry out a coating Procedure Qualification Tests (PQT), for each pipe diameter on max. wall thickness, for each type of pipe, for each coating material combination, and for each plant, to prove that his plant, materials, and coating procedures result in a quality of end product conforming to the properties stated in Table 5 of this specification, relevant standards, specifications and

material manufacturer's recommendations. Applicator shall give seven (7) working days' notice to witness all procedures and tests.

- 8.3.2 Procedure Qualification Tests (PQT) shall be carried out only after obtaining written approval of the above procedure from Company. No change in the procedure shall be made after the Company has given approval. However, unavoidable changes shall be executed only after obtaining written approval from Company.
- 8.3.3 A batch representing a normal production run, typically fifteen (15) pipes, shall be coated in accordance with the approved coating procedure and the coating operations witnessed by Company Representative. Out of these pipes, at least one pipe shall be coated partly with epoxy and partly with both epoxy and adhesive layers.
- 8.3.4 At least five (5) test pipes shall be selected by Company Representative for coating procedure approval tests and shall be subjected to procedure qualification testing as described hereinafter. Company Representative shall witness all tests. Out of five (5) test pipes, one (1) pipe partly coated with epoxy and partly coated with both epoxy and adhesive layers shall be included. Remaining four (4) test pipes shall have all three layers.
- 8.3.5 During PQT, the Applicator shall qualify various procedures forming a part of coating operations as detailed subsequently.
- 8.3.6 After completion of the qualification tests and inspection as per clause 7.4.6 and Table 5 of this specification, the Applicator shall prepare and issue to Company for approval a detailed report of the tests and inspection including test reports/certificates of all materials and coatings tested. Only upon written approval from Company, Applicator shall commence production coating.
- 8.3.7 On successful completion of PQT, coating of all five (5) test pipes shall be removed and completely recycled as per the approved coating procedure specification, at Applicator's expense. Remaining pipes will be accepted by Company provided they meet the requirements of this specification and need not be stripped and re-cycled.
- 8.3.8 The Applicator shall re-establish the requirements of qualification and in a manner as stated before or to the extent considered necessary by Company, in the event of, but not limited to, the following:
- Every time there is a change in the previously qualified procedure.
 - Every time there is a change in the manufacturer and change in formulation of any of the raw materials and change in location of raw material manufacture.
 - Every time the coating yard is shifted from one location to the other or every time the critical coating equipment (induction heater, epoxy spray system, extruder etc.) are shifted.
 - Any change in line speed during coating application.
 - Any time when in Company's opinion the properties are deemed to be suspect during regular production tests.

8.3.9 Company reserves the right to conduct any or all tests required for qualification through an independent laboratory or agency at the cost of Applicator when in Company's opinion, the results are deemed suspect. Company's decision shall be final.

84. Properties of As-applied Coating System

8.4.1 All pipes shall be subject to the following inspections:

- a. Surface cleanliness, surface roughness measurements and dust control immediately after second abrasive blast cleaning and salt test.
- b. Visual inspection of finished coating, cut back dimension, internal/external cleanliness, end sealing and bevel inspection.

Acceptance criteria for all inspection and testing shall be as specified in this specification.

8.4.2 Properties of as-applied coating system shall meeting the minimum requirements as per Table 5 below:

**Table 5 - Requirements for plant applied coating
(PQT and Production)**

Sl. No.	Properties	Acceptance Criteria	Test Method	Inspection Frequency	
				During PQT	During Production
A. Epoxy Layer					
1.	Pipe feed rate	As per APS	As per APS	Each pipe	Continuous monitoring ^{a)}
2.	Air pressure in epoxy spray guns	As per APS	As per clause 9.3.3.7 of this specification	Each pipe	Continuous monitoring & recording
3.	Induction coil setting	As per APS	As per APS and clause 9.3.2.2 of this specification	Each pipe	Continuous monitoring ^{a)}
4.	Pipe temperature	As per clause 9.3.2.3 of this specification	As per clause 9.3.2.4 of this specification	Continuous monitoring & recording	Continuous monitoring and recording
5.	Minimum epoxy layer thickness (DFT)	≥ 0.200 mm	ISO 2808 e ¹	One pipe ^{d)}	1/shift ^o
6.	Degree of cure - Percentage cure, A1-11 - AT _g	95% ≤ 5°C	ISO 21809-1 Annex D and clause 10.9 of this spec.	4 samples x 1 pipe ^{d)}	1/shift ^{b)}
7.	Holiday detection (test voltage set to exceed 5V per pm of epoxy thickness)	No holidays	ISO 21809-1, Annex B	Each pipe ^{d)}	Not required
8.	Dry adhesion	Rating 1 or 2	ISO 21809-2 Clause A.4 & clause 10.10 of this spec.	One pipe	1/shift

9.	Cross-section porosity	\leq compared with Fig. A.11 of ISO 21809-2	ISO 21809-2 Clause A.12	Each pipe ^{d)}	Not required
10.	Interface porosity	\leq compared with Fig. A.12 of ISO 21809-2	ISO 21809-2 Clause A.12	Each pipe ^{d)}	Not required
11.	Hot water adhesion 24 h @ 65 °C	Rating of 1 to 3	ISO 21809-2, Clause A.16	One pipe	Not required
12.	Flexibility at 0 °C	No cracking, tears, disbondment & delamination at 2.0° ppd length	ISO 21809-2, Clause A.13	One pipe ^{d)}	Not required

Table 5 - Requirements for plant applied coating (PQT and Production)

Sl. No.	Properties	Acceptance Criteria	Test Method	Inspection Frequency	
				During PQT	During Production
B.	Adhesive Layer				
13.	Minimum thickness	\geq 0.200 mm	ISO 2808 ^{e)}	One pipe ^{d)}	1/shift ^{f)}
14.	Extrusion temperature of adhesive	As per APS	As per APS & clause 9.3.3.8 of this spec.	Continuous monitoring & recording	Continuous monitoring & recording
C.	PE layer and all three layer				
15.	PE extrusion temperature	As per APS	As per APS	Each pipe	Continuous monitoring & recording
16.	Water quenching	As per APS	As per APS	Each pipe	Continuous monitoring
17.	Visual inspection	As per clause 10.2 of this specification	Visual	Each pipe 100% surface area	Each pipe 100% surface area
18.	Holiday detection (test voltage shall be min. 25 kV & travel speed shall not exceed 300 nun/s)	As per clause 10.4.2 of this specification	As per ISO 21809-1, Annex B and clause 10.4.1 of this spec.	Each pipe 100% surface area	Each pipe 100% surface area
19.	Coating thickness	Table 1 of this specification	ISO 2808 & clause 10.3 of this spec.	Each pipe	Each pipe ^{h)}
20.	Tensile strength @ 23°C \pm 2°C	\geq 17 MPa	ISO 527	One pipe	Not required

21.	Air entrapment test	$\leq 10\%$ & as per clause 10.8 of this specification	As per clause 10.8 of this specification	5 pipes x 1 sample from body & 1 sample from weld (if applicable)	1 sample from body & 1 sample from weld (if applicable)/ shift
22.	Bond Strength (Peel Strength) ■ @ 23°C ± 2°C (No peeling of FBE layer)	≥ 15 N/mm	ISO 21809-1 Annex C, (clause C.2 or C.5 hanging mass) and clause 10.5 of this spec.	5 pipes x 3 tests (@ both ends & middle) ^{d)}	2 h for pipe ends (cutback portion) & 4 h for middle of pipe
	■ @ 80°C ± 2°C (No peeling of FBE layer)	≥ 3 N/mm		5 pipes x 3 tests (@ both ends & middle) ^{d)}	2 h for pipe ends (cutback portion) & 4 h for middle of pipe

**Table 5 - Requirements for plant applied coating
(PQT and Production)**

Sl. No.	Properties	Acceptance Criteria	Test Method	Inspection Frequency	
				During PQT	During Production
23.	Coating Resistivity ^{k)}	$\geq 10^8 \Omega \cdot m^2$	Annex J of DIN 30670	One pipe	Not required
24.	Impact resistance (min. of 30 impacts on body located equi-distance along the length. No breakdown allowed when tested at 25 kV)	≥ 7 J/mm of coating thickness	ISO 21809-1 Annex E and clause 10.6 of this spec.	3 pipes	2 pipes/ shift ⁱ⁾
25.	Indentation resistance ■ @ 23°C ± 2°C	≤ 0.2 mm	ISO 21809-1 Annex F and clause 10.6 of this spec.	2 samples x 5 pipes ^{m)}	2 pipes/ shift ^{j)}
	■ @ 80°C ± 2°C	≤ 0.3 mm		2 samples x 5 pipes ^{m)}	2 pipes/ shift ^{j)}
26.	Elongation at break	$\geq 400\%$	ISO 527-3 & clause 10.12 of this spec.	6 samples x 3 pipes	Once per PE batch
27.	Cathodic disbondment test ■ 65 °C/ 24 h; - 3.5 V	(Average disbondment radius) ≤ 7 mm	ISO 21809-1 Annex H and clause 10.11 of this specification	One pipe	Once/ day
	■ 23 °C/ 28 d; -1.5 V	≤ 7 mm		One pipe ⁱ⁾	Not required
	■ 80 °C/ 28 d; -1.5 V	≤ 15 mm		One pipe ⁱ⁾	Not required
28.	Hot Water Immersion test	Avg. ≤ 2 mm & max. ≤ 3 mm, 48 hours	ISO 21809-1 Annex M and clause 10.13 of this spec.	One pipe	Once/ day

29.	Flexibility	No cracking at an angle of 2.0° ppd length	ISO 21809-1 Annex I	One pipe	Not required
30.	Hardness	≥ 55 Shore D	ISO 868	One pipe	Not required
31.	Residual magnetism of line pipe	Avg. of the four readings ≤ 2.0 mT (20 gauss) & no single reading ≥ 2.5 mT (25 gauss)	Hall - effect gaussmeter	One pipe x 4 readings approx.90° apart around the circumference of both ends of the pipe	1/shift
<p>Notes:</p> <p>a) Parameter shall be recorded at least once per shift.</p>					

Table 5 - Requirements for plant applied coating (PQT and Production)

<p>b) Lead pipe shall be subjected to this test and thereafter pipes shall be selected randomly by Company Representative during the middle of a shift. Suitable provisions/ arrangements as per the instructions of Company Representative shall be made by the Applicator for this purpose.</p> <p>c) Shift duration shall be maximum 12 hours.</p> <p>d) The value obtained from the test shall meet the specified requirement. None of the test value shall fail.</p> <p>e) Thickness shall be checked at every one metre spacing at 3, 6, 9 and 12 o'clock positions.</p> <p>f) Thickness of epoxy and adhesive shall be measured at the beginning of each shift and whenever the plant re-starts after any stoppage for compliance. Coating of epoxy and adhesive on portion of pipe required for this purpose, stripping and recoating of such partly coated pipes shall be at Applicator's expense.</p> <p>g) Epoxy film samples (minimum 4 no.) shall be scratched from the coated pipe. Care shall be taken to remove the samples of full film thickness avoiding inclusion of steel debris.</p> <p>h) The frequency may be reduced "Once in 10 pipes" depending upon consistency of results, at the sole discretion of Company Representative. Results of all measurements shall be recorded.</p> <p>i) Test shall be carried out at every change in batch of PE. Frequency of test may be reduced to one pipe per 2 weeks depending upon the consistently acceptable results at the sole discretion of Company's Representative.</p> <p>j) Test shall be carried out at every change in batch of PE. Frequency of test may be reduced to one test each on 2 coated pipes per week at random, after 1 week of consistently acceptable results.</p> <p>k) Test carried out in an independent laboratory of national international recognition on PE topcoat is also acceptable.</p> <p>l) In case of PQT necessitated for different pipe size with same coating material combination, 24 hours test shall only be conducted and 28 days test is not mandatory.</p> <p>m) If any one of these samples fails to satisfy the specified requirements, then the test shall be repeated on four more samples. In this case, none of the samples shall fail.</p>

8.5 Qualification of Procedures

8.5.1 Epoxy Powder Application & Recycling

During pre-qualification, air pressure in the epoxy spray guns, satisfactory functioning of monitoring system, line speed v/s coating thickness, etc. shall be established. Dew point of air used to supply the fluidized bed, epoxy spray system and epoxy recycling system shall be recorded during the PQT.

Also, the Applicator shall remove samples of reclaimed powder from the reclamation system. These samples of reclaimed powder shall be subject to a detailed visual examination, thermal analysis and moisture content tests. The properties of the reclaimed powder shall be within the range specified by the Manufacturer of epoxy powder. In case the properties of the reclaimed powder are out of the range specified by the Manufacturer, Applicator shall not use the reclaimed powder during the regular production. The proportion of the reclaimed powder in the working mix shall not exceed 10% at any time.

8.5.2 Pipe Pre-heating

The Applicator shall establish the temperature variation due to in-coming pipe temperature, line speed variation, wall thickness variation, emissivity, interruptions, etc. and document the same during the PQT stage. During PQT, proper functioning of pipe temperature monitoring and recording system including alarm/hooter shall be demonstrated to the Company Representative.

8.5.3 Surface Preparation

The procedure to clean and prepare the pipe surface shall be in accordance with the requirements of this specification. The ratio of shot to grit shall be established during procedure qualification testing, such that the resultant surface profile is not dished and rounded. The qualification shall be performed through a visual inspection, measurement of roughness and check of the presence of dust on the abrasive blast cleaned pipe surface.

8.5.4 Coating Application

The Company Representative will check the correctness of each coating application operation, values of the main parameters of each operation, pre-heating pipe surface temperature prior to epoxy powder application temperature, line speed, fusion bonded epoxy curing time, temperature and flow rate of copolymeric or grafted adhesive and polyethylene, etc. and the same shall be recorded. These values shall be complied with during regular production.

9.0 APPLICATION OF COATING

9.1 General

Unless specified otherwise, the pipes shall be supplied free from mill applied oils but may be subject to contamination occurring during transit.

9.2 Pipe Surface Preparation

9.2.1 Initial evaluation and surface preparation

9.2.1.1 Applicator shall visually examine the pipes as per Table 6 of this specification and shall ensure that all defects and irregularities (i.e. slivers and scratches), flats and other damages have been repaired or removed. Grinding of steel defects shall not reduce the wall thickness of the pipes below the specified wall thickness of the pipe.

9.2.1.2 Any oil, grease, salt or other contaminants detrimental to the formation of a good coating bond or coating quality shall be removed prior to coating application. Contaminants may be removed by the use of non-oily solvents. Gasoline or kerosene shall not be used for this purpose. Visible oil and grease spots shall be removed by solvent wiping in accordance with SSPC-SP 1. Steel surface shall be allowed to dry before abrasive blast cleaning.

9.2.1.3 The Applicator shall also remove marking stickers, if any, present within the pipe. Record shall be kept of such marking on the stickers to ensure traceability of pipe after coating.

- 9.2.2 **Abrasive blast cleaning**
- 9.2.2.1 All pipes shall be preheated to a temperature of 65°C to 85°C prior to abrasive blast cleaning. The external surface of the pipes shall be cleaned using two (2) no. dry abrasive blast cleaning units to achieve the specified surface cleanliness and profile as per Table 6 of this specification.
- 9.2.2.2 The abrasive blast cleaning units shall have an effective dust collection system to ensure total removal of dust generated during blast cleaning from the pipe surface. During abrasive blast cleaning, the metallic abrasive shall be continuously sieved to remove "fines" and "contaminants" and the quality checked at every four (4) hours. Abrasives used for blast cleaning shall comply ISO-11124 (all parts) and Table 6 of this specification. Silica sand or copper slag shall not be used as abrasive material.
- 9.2.2.3 Abrasive blast cleaning carried out shall be such that the resultant surface profile is not dished and rounded when viewed with 30X magnification. The standard of finish for cleaned pipe shall conform to near white metal finish as per Table 6 of this specification. This shall be measured by a suitable instrument such as surface profile depth gauge. In addition the pipe surface after blast cleaning shall be checked for the degree of cleanliness, degree of dust and shape of profile as per Table 6 of this specification. Tape used for assessment of degree of dust shall comply ISO 8502-3. Pressure shall be exerted on the applied tape using a 4 kg roller, prior to peeling-off to assess the degree of dust.
- 9.2.2.4 The blast cleaned surface shall not be contaminated with dirt, dust, metal particles, oil, water or any other foreign material, nor shall the surface or its anchor pattern be scarred or burnished. All blast cleaned pipe surface shall be kept in dust free enclosure prior to coating.
- 9.2.2.5 After blast cleaning, all surfaces shall be thoroughly inspected under adequate lighting to determine anchor pattern, quality of blasting and identify any surface defects prior to coating application. All surface defects such as slivers, scab, burns, laminations, welds spatters, gouges, scores, indentations, slugs or any other defects considered injurious to the coating integrity made visible during blast cleaning shall be reported to the Company Representative and on permission from Company Representative such defects shall be removed by filing or grinding. After any grinding or mechanical repairs, the remaining wall thickness shall be checked and compared with specified thickness. Any pipes having thickness less than specified wall thickness shall be kept aside and disposed-off as per the instructions of Company Representative.
- 9.2.2.6 The method employed to remove surface defects shall not burnish or destroy the anchor pattern or contaminate the surface. Pneumatic tools shall not be used unless they are fitted with effective air/oil and water traps. Wherever burnishing results in destruction of anchor pattern, the anchor pattern shall be restored by suitable means. Pipes having damages repaired by grinding and ground areas more than 50 mm in diameter shall be re-blasted.
- 9.2.2.7 Suitable plugs shall be provided at both pipe ends to prevent entry of any shot/grit into the pipe during blast cleaning operations. These plugs shall be removed after blast cleaning. Alternatively the Applicator may link the pipes suitably together to prevent the entry of any short/grit into the pipe.
- 9.2.2.8 At no time shall the blast cleaning be performed when the relative humidity exceeds 85%. The Applicator shall measure the ambient conditions at regular intervals during blast cleaning and coating operations and keep records of prevailing temperature, humidity and dew point as per Table 6 of this specification.
- 9.2.2.9 The total allowable elapsed time between completion of the blasting operations and commencement of the pre-coating and heating operations shall be such that no detectable oxidation of the surface occurs. Relative humidity readings shall be recorded every half an hour

during the blasting operations in the immediate vicinity of the operations. The maximum elapsed time shall not exceed the duration given below:

Relative Humidity %	Maximum elapsed time
>80	2h
70 to 80	3 h
<70	4h
Note: a) Any pipe not processed within the above time-humidity requirement shall be completely re-blasted. Any pipe showing flash rusting shall be re-blasted even if the above conditions have not been exceeded.	

9.2.2.10 All pipes shall be visually examined for presence of any shot/ grit/ loose material left inside the pipe during blast cleaning. Suitable mechanical means (stiff brush) shall be employed to remove the same before the pipes are processed further. In addition, inside surface of the pipe shall also be visually inspected for presence of any foreign material or shots and grit (free or embedded/ sticking to pipe inside surface). The pipe inside surface shall be examined using sharp floodlight focused at the middle of the pipe at one end while inspection is carried out visually from other end. Any foreign material or shots/grit present in the pipe shall be completely removed by mechanical brush, high pressure air jets, by tilting of pipe etc.

9.2.2.11 Upon Completion of the blasting operations, the quality control supervisor shall accept the pipe for further processing or return for re-blasting after removal of defects/ imperfections. In case imperfections are considered detrimental to the coating quality, the same shall be reported to Company's Representative for final decision on rejection or re-blasting/removal of defects. Re-blasting/ removal of defects or returning pipe to the yard shall be at the Applicator's cost. Company's Representative, in additions, reserves the right to initiate any of the above actions during periodic inspections for oil, dust, salt, imperfections, surface defects, lack of white metal finish, etc.

In order to ensure that pipe with defects are not processed further, provisions shall be available to lift the pipe from inspection stand.

9.2.2.12 Pipe handling between abrasive blasting and pipe coating shall not damage the surface profile achieved during blasting. Any pipe affected by the damage to the surface exceeding 200 mm² in area and/ or having contamination of steel surface shall be rejected and sent for re-blasting.

9.2.3 Surface dust contamination

9.2.3.1 Any dust or loose residues that have been accumulated during blasting and/or during filing/ grinding operations shall be removed by vacuum cleaning. The dust level shall be measured and acceptance requirements shall be in accordance with Table 6 of this specification.

9.2.3.2 If dust contamination of surface occurs, the quality of blast cleaning method and process shall be examined. If the surface roughness is outside the specified limit, the blast cleaning material shall be checked and replaced.

9.2.4 Surface cleanliness and salt contamination tests

9.2.4.1 All pipes shall be tested for salt contamination after blast cleaning as per Table 6 of this specification. An approved salt meter (SCM 400 or equivalent) shall be used to carry out salt tests and shall be calibrated in accordance with the equipment manufacturer's recommendations.

9.2.4.2 Any pipe having salt contamination exceeding the acceptable limits as per Table 6 of this specification shall be either re-blasted or washed by de-ionized water and then rechecked for salt contamination. In case salt level less than acceptable limit as per Table 6 of this

specification is consistently achieved, the frequency of salt contamination testing may be relaxed to at least one pipe per hour at the sole discretion of the Company Representative.

Table 6 Requirements for inspection of surface preparation of pipe

Sl. No.	Properties	Test Method	Requirement	Frequency	
				During PQT	During Production
1.	Surface condition of pipe before blasting	Visual Inspection	Free of contaminations and surface defects	Each pipe	Each pipe

Table 6 Requirements for inspection of surface preparation of pipe

Sl. No.	Properties	Test Method	Requirement	Frequency	
				During PQT	During Production
2.	Relative humidity	Measurement/ as required	Record (relative humidity shall be < 80%)	Every 1/2 h	Every 1/2 h
3.	Pipe temperature before blasting	Thermocouple	min. 3°C above dew point	Each pipe	Every 1/2 h
4.	Water soluble contamination abrasive	ASTM D4940	Conductivity ≤ 60 pS/cm	Once	1/ shift
5.	Soluble salt after blasting	Conductive measurement ISO 8502-9	Salt (Chloride) content as (NaCl) max. 20 mg/m ²	Each pipe	Each pipe
6.	Size, shape and properties of virgin abrasive	Visual + Certification as per ISO 11124-3	Conformity to certificate and compliance with manufacturing/ working procedure	Every batch	Every batch
7.	Surface roughness of blasted surface	ISO 8503-4	R _z /R _{ys} : 75µm to 100µm	Each pipe	Every 1 h
8.	Visual inspection of blasted surface	ISO 8501-1	Grade Sa 21/2	Each pipe	Each pipe
9.	Presence of dust after dust removal	ISO 8502-3	max. class 2 (for both size and quantity)	Each pipe	Every 1 h

10.	Visual inspection of pipes prior to introduction to coating line	Visual	No rust	Each pipe (100% surface area)	Each pipe (100% surface area)
11.	Preheating temperature before coating	Pyrometer	Compliance to APS	Each pipe	Each pipe

9.3 Coating application and curing temperature

9.3.1 General

The external surface of the cleaned pipe conforming to clause 9.2 of this specification shall be immediately coated with 3-layer extruded polyethylene coating in accordance with the procedures approved by Company, relevant standards and this specification.

9.3.2 Pipe heating and curing

9.3.2.1 Immediately prior to heating of pipe, all dust and grit shall be removed from inside of the pipe by a combination of air blast, brushing and vacuum cleaning. Suitable arrangement shall be made to protect the bevel ends from getting damaged during the coating operation.

9.3.2.2 Induction heater shall be used for heating the pipe. The method shall be capable of maintaining uniform temperature along the total length of the pipe, and shall be such that it shall not contaminate the surface to be coated. Appropriate frequency shall be used to ensure 'deep heating' and intense skin heating is avoided. This shall be demonstrated on bare pipes prior to start of PQT.

9.3.2.3 External surface of the pipe shall be heated to about 190°C or within a temperature range (min. to max.) as recommended by the epoxy powder manufacturer. However, application and curing temperature shall not exceed 250°C in any case. Required pipe temperature shall be maintained as it enters the coating chamber.

Any deviation from the application temperature range recommended by manufacturer shall be rectified. If immediate rectification is not feasible, the production shall be stopped until cause of deviation has been removed. Any pipe coated during the period of temperature deviation shall be identified by marking and rejected. Such rejected pipes shall be stripped, re-cleaned and recoated.

9.3.2.4 Temperature of the pipe surface shall be continuously monitored & recorded by using suitable instruments such as infrared sensors, contact thermometers, thermocouples etc. The recording method shall allow to correlate each line pipe. The monitoring instrument shall be able to raise an alarm/ activate audio system (hooter) in the event of tripping of induction heater or in the event of pipe temperature being outside the range recommended by the manufacturer.

Temperature measuring & monitoring equipment shall be calibrated twice every shift and/or as per Company Representative's instruction.

9.3.2.5 Applicator shall ensure that pipe surface emissivity variations are minimized during pipe heating. To avoid significant variance, more than once blasted pipes should be coated at the same time and not mixed with pipes blasted only once.

9.3.3 Pipe Coating Application

9.3.3.1 Coating materials shall be inspected in accordance with the manufacturer's recommendation prior to coating application and it shall be ensured that the materials are moisture free. In case

- the relative humidity exceeds 80%, the adhesive and polyethylene material shall be dried using hot dry air as per the directions of Company Representative.
- 9.3.3.2 Only those coating materials which are pre-qualified and approved by Company in accordance with provisions of Annexure I of this specification and qualified in accordance with the requirements of clause 7.4 i.e. Table 2, Table 3 and Table 4 of this specification shall be utilized for coating. All coating application processes shall be carried out as per manufacturer's recommendations and procedure qualification tests (PQT) as per clause 8.3 and Table 5 of this specification.
- 9.3.3.3 Subsequent to pipe heating, coating consisting of following layers shall be applied onto the pipe.
- i. Electrostatic application of epoxy powder of minimum film thickness as per Table 5 of this specification, unless otherwise specified. The maximum thickness shall not exceed the epoxy thickness specified by epoxy powder manufacturer.
 - ii. Copolymeric or grafted adhesive application by extrusion of minimum thickness as per Table 5 of this specification.
 - iii. Polyethylene application by extrusion.
- Minimum overall thickness of finished coating shall be as per Table 1 of this specification.
- 9.3.3.4 The coated pipe shall be subsequently quenched and cooled in water for a period that shall sufficiently lower the temperature of pipe coating, atleast upto 80°C, to permit handling and inspection.
- 9.3.3.5 Prior to starting the application of fusion bonded epoxy powder, the recovery system shall be thoroughly cleaned to remove any unused powder remaining from a previous line pipe coating application. The use of recycled powder *shall* be permitted subject to:
- a) Satisfactory qualification of the reclaimed system during PQT stage.
 - b) The proportion of the reclaimed powder in the working mix does not exceed 10% at any one time.
 - c) The quality of the recycled powder being routinely checked during production, at a minimum frequency of once per shift and consistently meets the requirements stated at clause 7.4.3 and Table 2 of this specification.
- 9.3.3.6 Dry air, free of oil and moisture shall be used in the coating chamber and spraying system and filters, dehumidifier/dryer as required along with control & monitoring system shall be provided for this purpose. Dew point of air used to supply the fluidized bed, epoxy spray system and epoxy recycling system shall be at least (-)40°C and this shall be monitored during the regular production.
- 9.3.3.7 Air pressure in the epoxy spray guns shall be controlled, continuously monitored and recorded by using suitable instruments. The air pressure shall be controlled within the limits established during coating procedure qualification. The monitoring system shall be able capable of raising an alarm / activate audio system (hooter) in the event of change in air pressure beyond the set limits. Any deviation from the pre-set limits shall be rectified. If immediate rectification is not feasible, the production shall be stopped until cause of deviation has been removed. Any pipe coated during the duration of air pressure deviation shall be identified by suitable marking and rejected. Such rejected pipes shall be stripped and recoated.
- 9.3.3.8 Extruded adhesive layer shall be applied before gel time of the epoxy coating has elapsed and within the window recommended by the manufacturer. The Applicator shall establish, to the

satisfaction of the Company Representative, that the adhesive is applied within the gel time window of epoxy and at the temperature recommended by the adhesive manufacturer. The Applicator shall state the minimum and maximum time interval between epoxy and adhesive application at the proposed pre-heat temperature and line speed.

9.3.3.9 Extruded polyethylene layer shall be applied over the adhesive layer within the time limit established during PQT stage and within the time/temperature range recommended by the manufacturer. The extrusion temperatures of the adhesive and polyethylene shall be continuously recorded. The monitoring instruments shall be independent of the temperature control equipment. The instruments shall be calibrated prior to start of each shift.

9.3.3.10 Applicator shall ensure that there is no entrapment of air or void formation along the seam weld (where applicable) during application of coating. Air entrapment below the coating and also along the coating overlap shall be prevented by forcing the coating on to the pipe using high pressure roller of suitable design during coating application. In case it is not adequately achieved, Applicator shall supplement by other methods to avoid air entrapment. The methods used shall be witnessed and approved by Company.

9.3.3.11 Resultant coating shall have a uniform gloss and appearance and shall be free from air bubbles, wrinkles, holidays, irregularities, discontinuities, separation between layers of polyethylene & adhesive, etc.

9.3.3.12 **Coating cutback**

Coating and/or adhesive shall terminate 120 mm (+) 20 / (-) 0 mm from pipe ends. The adhesive shall seal the ends of applied coating. Applicator shall adopt mechanical brushing for termination of the coating at pipe ends. Edge of the coating shall be shaped to form a bevel angle of 30° to 45°.

Wherever specified the cut back shall be 150mm (+) 20 / (-) 0 to facilitate automatic welding.

9.3.3.13 Failure to comply with any of the above applicable requirement and of the approved procedure shall be cause for the rejection of the coating and such coating shall be removed in a manner approved by Company at Applicator's expense.

10.0 INSPECTION AND TESTING

10.1 General

The Applicator shall establish and maintain such quality assurance system as are necessary to ensure that goods or services supplied comply in all respects with the requirements of this specification. The minimum inspection and testing to be performed shall be as indicated subsequently herein.

10.2 Visual Inspection

Immediately following the coating, each coated pipe shall be visually checked for imperfections and irregularities of the coating. The coating shall be of natural colour and gloss, smooth and uniform and shall be blemish free with no dust or other particulate inclusions. The coating shall not show any defects such as blisters, pinholes, scratches, wrinkles, engravings, cuts, swellings, disbanded zones, air inclusions, tears, voids or any other irregularities. Special attention shall be paid to the areas adjacent to the longitudinal weld (if applicable), adjacent to the cut-back at each end of pipe and within the body of the pipe.

In addition inside surface of the pipe shall also be visually inspected for presence of any foreign material or shots and grit (free or embedded/sticking to pipe inside surface). The pipe inside surface shall be examined using sharp floodlight focused at the middle of the pipe at one end while inspection is carried out visually from other end.

10.3 Coating Thickness

03.1 Coating thickness shall be checked by taking atleast 10 measurements at locations uniformly distributed over the length and periphery of each pipe. In case of welded pipes, five of these readings shall be made at apex of the weld seam, uniformly distributed over the length of the coated pipe.

10.3.2 Coated pipes not meeting the requirements shall be rejected. Rejected coated pipes shall be stripped and re-coated in accordance with approved procedure, at Applicator's expense.

10.4 Holiday Detection

10.4.1 The holiday detector shall be a low pulse D.C. full circle electronic detector with audible alarm and precise voltage control complying with DIN VDE 0433 Part 2. Applicator shall calibrate the holiday detector at least once every 4 hours of production. Applicator shall have necessary instruments or devices for calibrating the holiday detector.

10.4.2 Any pipe coating shall be rejected if more than one (1) holiday & area more than 100 cm² in size are detected in its length attributable to coating process.

10.4.3 Holidays, which are lesser in size than those mentioned in 10.4.2 above, shall be repaired in accordance with an approved procedure and shall be at Applicator's expense.

10.5 Bond Strength (Peel Test)

10.5.1 Applicator shall carryout bond strength test for applied coating as per Table 5 of this specification. A minimum of 65 mm length shall be peeled. First 20 mm and last 20 mm length shall not be counted for assessment of bond strength.

10.5.2 In case of non-grafted adhesive, the system shall disbond/ separate cohesively either in adhesive layer or in polyethylene layer. Majority of the peeled off area on the pipe shall show presence of adhesive. Disbondment/separation at epoxy to steel interface or epoxy / adhesive interface or adhesive/ polyethylene interface shall not be permitted. The failure mode shall be recorded for each test.

In case of grafted adhesive, cohesive failure mode is not applicable. However, the disbondment is not permitted in the epoxy layer and at the interface of epoxy & steel.

10.5.3 In case the test fails to comply the specified requirement, the Applicator shall test the preceding and succeeding coated pipe. If both pipes pass the test, then the remainder of the pipe joints in that shift shall be deemed satisfactory. If either pipe fails to meet the specified requirements, all pipes coated during that shift shall be tested until the coating is proved acceptable. Rejected coated pipes shall be stripped and re-coated in accordance with approved procedure, at Applicator's expense.

10.6 Impact resistance test

Minimum thirty (30) impacts located equidistant along the length of coated pipe shall be performed. Immediately after testing, the test area shall be subjected to holiday detection at the

same voltage as used prior to impact strength test. The pipe shall be rejected if any holiday is noted in the test area. In case of test failure, retesting and disposal of coated pipe shall be as per clause 10.5.3 above.

10.7 Indentation Hardness

Two samples for each temperature shall be taken from the cut back portion of coated pipe and one in the middle of the pipe for this test. In case of test failure, retesting and disposal of coated pipe shall be as per clause 10.5.3 above.

10.8 Air Entrapment Test

10.8.1 Strips from bond strength tests (peel test) or coated pipe may be used to help determine the porosity of the finished coating. Strip shall be also cut from longitudinal weld (if applicable) at cut back portion and examined for the presence of voids.

10.8.2 Bond strength strip shall be viewed from the side and at the failure interface. At the pipe bond strength test location, utility knife shall be used to cut the edge of the coating to a 45° angle and view with a microscope. Similar examination shall be done in the coating cut back area.

10.8.3 Strips shall be viewed from the side. All examination shall done using a 30X magnification hand-held microscope. The polyethylene and adhesive layers shall have no more than 10% of the observed area taken up with air entrapment (porosity or bubbles). Air entrapment shall not occupy more than 10% of the thickness in each case. Bubbles shall not link together to provide a moisture path to the epoxy layer.

10.8.4 In case of test failure, retesting and disposal of coated pipe shall be as per clause 10.5.3 above.

10.9 Degree of Cure

10.9.1 Epoxy film samples shall be scratched from cut back portion of the coated pipe using hammer and cold chisel and the samples shall be taken for cure test using DSC procedure. Silicon coated sulphite paper shall be placed between the epoxy layer and adhesive layer immediately after epoxy application, to ensure physical separation of epoxy & adhesive as well as to prevent contamination of epoxy with adhesive layer, at a location from where the epoxy samples are to be removed for the test. Care shall be taken to remove the samples of full film thickness avoiding inclusion of steel debris. Glass transition temperature differential (AT_g) and % cure (MI) shall comply the specified requirements.

10.9.2 In case of test failure, production carried out during the entire shift shall be rejected, unless the Applicator proposes a method to establish the compliance with the degree of cure requirements of all pipes coated during that shift.

10.10 Dry Adhesion Test (for epoxy)

The test shall be carried out at the cut back portion on the pipe from which the Degree of Cure test has been carried out as per clause 10.9 above. In case of test failure, retesting and disposal of coated pipe shall be as per clause 10.9.2 above.

10.11 Cathodic Disbondment Test

In case the test fails to conform to the specified requirement, at the option of the Applicator, all pipes coated after the previous acceptable test and prior to next acceptable test shall be rejected or the test shall be repeated using two additional samples taken from the same end of the affected pipe.

When both retests conform to the specified requirement, the lot of pipes shall be accepted.

When one or both the retests fail to conform to the specified requirement, all coated pipes after

previous acceptable test and prior to next acceptable shall be rejected. All rejected pipes shall be stripped, re-cleaned and re-coated. Company may consider a further retest program to determine whether any of the affected pipe meet the criteria for acceptance upon written request by the Applicator.

10.12 Elongation at break

In case the test fails to comply the specified requirement, the Applicator shall test the two preceding and two succeeding coated pipe. If both pipes pass the test, then the remainder of the pipe joints in that batch shall be deemed satisfactory. If either pipe fails to meet the specified requirements, all pipes coated with that batch of PE shall be tested until the coating is proved acceptable. Rejected coated pipes shall be stripped and re-coated in accordance with approved procedure, at Applicator's expense.

10.13 Hot water immersion

In case the test fails to comply the specified requirement, the Applicator shall test the two preceding and two succeeding coated pipe. If both pipes pass the test, then the remainder of the pipe joints in that day shall be deemed satisfactory. If either pipe fails to meet the specified requirements, all pipes coated in that day shall be tested until the coating is proved acceptable. Rejected coated pipes shall be stripped and re-coated in accordance with approved procedure, at Applicator's expense.

10.14 Damages occurring to pipe coating during above tests shall be repaired in accordance with approved coating repair procedure.

10.15 Repairs occurring on account of the production tests are however excluded from above mentioned limitations at clause 10.4.2 above.

10.16 Company reserves the right to perform inspection and witness tests on all activities concerning the pipe coating operations starting from bare pipe to finished coated pipe ready for despatch and also testing of raw materials. Applicator shall give reasonable notice of time and shall provide without charge reasonable access and facilities required for inspection to the Company's representative. Inspection and tests performed or witnessed by Company's representative shall in no way relieve the Applicator's obligation to perform the required inspection and tests.

10.17 In case rate of defective or rejected pipes and/or samples tests are 10% or more for a single shift (typically 8 hours), Applicator shall be required to stop production and carry out a full and detailed investigation and shall submit findings to Company for approval. Applicator shall recommence the production only after getting the written permission from Company.

Under no circumstances any action or omission of the Company's Representative shall relieve the Applicator of his responsibility for material and quality of coating produced. No pipes shall be transported from the coating plant unless authorized by Company in writing.

11.0 REPAIR OF COATING

11.1 General

Applicator shall submit to Company, its methods and materials (as per clause 8.2 of this specification) proposed to be used for executing a coating repair and shall receive approval from Company prior to use.

11.1.2 In open storage the repair coating materials must be able to withstand a temperature of at least(+) 80°C without impairing its serviceability and properties. Applicator shall furnish

- manufacturer's test certificates for the repair materials clearly establishing the compliance of the repair materials with the applicable coating requirements indicated in this specification.
- 11.1.3 All pipes leaving coating plant shall have sound external coating with no holiday or porosity on 100% of the surface.
- 11.1.4 Defects, repairs and acceptability criteria shall be as follows:
- Pipes showing porosities or very small damage not picked up during holiday test and having a surface less than 0.5 cm² or linear damage (cut) of less than 3 cm shall be repaired by stick using material of same quality.
 - Damages caused to coating by handling such as scratches, cuts, dents, gouges, not picked up during holiday test, having a total reduced thickness on damaged portion not less than 2 mm and an area not exceeding 20 cm² shall be rebuild by heat shrink patch only and without exposing to bare metal.
 - Defects of size exceeding above mentioned area or holidays of width less than 300 mm shall be repaired with heat shrink repair patch by exposing the bare metal surface.
 - Defects exceeding the above and in number not exceeding 2 per pipe and linear length not exceeding 500 mm shall be repaired using heat shrinkable sleeves of HTLP 80 or equivalent.
 - Pipes with bigger damage shall be stripped and recoated.
 - In case of coating defect close to coating cut back, Applicator shall remove the coating throughout the entire circumference of the pipe down to the steel surface and increase the coating cut back length. Now if the coating cut back exceeds 140 mm of linear length of pipe then the coating shall be repaired by the use of heat shrink sleeves thereby making up the coating cut back length of 120 mm.
- 11.1.5 Notwithstanding the above, if any defect exceeds 70 mm from the original coating cut back length, the entire coating shall be removed and the pipe shall be recycled through the entire coating procedure.
- 11.1.6 Irrespective of type of repair, the maximum numbers of repair of coating shall be as follows:
- Holiday repair of size 100 cm² attributable to process of coating application shall be maximum one number per pipe.
 - In addition to the above, defects to be repaired by heat shrink patch/sleeve shall be maximum 2 (two) per pipe.
- 11.1.7 Defects exceeding the above limits shall cause pipe coating rejection, stripping and recoating. The above is exclusive of the repairs warranted due to testing as per this specification. All repairs carried out to coating for whatever reason shall be to the account of Applicator.
- 11.1.8 Cosmetic damages occurring in the polyethylene layer only need not be repaired by exposing up to steel surface, as deemed fit by the Company Representative. In any case the Applicator shall establish his material, methods and procedure of repair that result in an acceptable quality of product by testing and shall receive approval from Company prior to use.
- 11.1.9 Testing of repairs shall be in the same form as testing coating. All repairs shall result in a coating thickness no less than the parent coating thickness. Applicator shall test repairs to coating as and when required by Company.

120 MARKING

Applicator shall place marking on the outside surface of the coating at one end of the coated pipe, and marking shall indicate, but not limited to the following information:

- a. Pipe number, Heat number
- b. Diameter & Wall thickness
- c. Coated pipe number
- d. Colour band
- e. Any other information considered relevant by Company.
- f. Pipe Manufacturer Name
- g. Inspection Mark/ Punch

Applicator shall obtain prior approval on marking procedure to be adopted from the Company.

13.0 HANDLING, TRANSPORTATION AND STORAGE

- 13.1 The Applicator shall be fully responsible for the pipe and for the pipe identification marking from the time of "taking over" of bare pipe from Company until such time that the coated line pipes are 'handed over' and/or installed in the permanent installation as the case may be according to the provisions of the CONTRACT.
- 13.2 At the time of "taking over" of bare pipes, Applicator shall inspect and record all the relevant details referred above including pipe defects in the presence of Company. All pipes shall be checked for bevel damages, weld seam height, dents, gouges, corrosion and other damages. Company Representative shall decide whether pipe defects / damages are suitable for repair. Damage to the pipes that occur after the Applicator has taken delivery such as dents, flats, or damage to the weld ends shall be cut off or removed and pipes rebevelled and repaired again as necessary. The cost of this work, as well as that of the pipe lost in cutting and repair shall be to the Applicator's account. All such works shall be carried out after written approval of the Company. Any reduction in length shall be indicated in the Applicator's pipe tracking system.
- 13.3 The Applicator shall unload, load, stockpile and transport the bare pipes within the coating plant(s) using suitable means and in a manner to avoid damage to pipes. The Applicator shall stockpile the bare pipes at the storage area of the coating plant. The Applicator shall prepare and furnish to Company a procedure/ calculation generally in compliance with API RP 5L1 for stacking of pipes of individual sizes, which shall be approved by Company prior to commencement.
- 13.4 The bevel protectors shall be removed and stored for reuse after completion of coating application. The ends of the pipes during handling and stacking shall always be protected with bevel protectors.
- 13.5 The Applicator shall load, unload, transport and stockpile the coated pipes within the coating plant using approved suitable means and in a manner to avoid damage to the pipe and coating. The Company shall approve such procedure prior to commencement of work.
- 13.6 Coated pipes may be handled by means of slings and belts of proper width (minimum 60 mm) made of non-abrasive/ non-metallic materials. In this case, pipes to be stacked shall be separated row by row to avoid damages by rubbing the coated surface in the process of taking off the slings. Use of round sectional slings is prohibited. Fork lifts may be used provided that the arms of the forklift are covered with suitable pads, preferably rubber
- 13.7 Bare/ coated pipes at all times shall be stacked completely clear from the ground, at least 300mm, so that the bottom row of pipes remains free from any surface water. The pipes shall be stacked at a slope so that driving rain does not collect inside the pipe. Bare/ coated pipes may be stacked by placing them on ridges of sand free from stones and covered with a plastic

- film or on wooden supports provided with suitable cover. This cover can be of dry, germ free straw covered with plastic film, otherwise foam rubber may be used. The supports shall be spaced in such a manner as to avoid permanent bending of the pipes.
- 13.8 Stacks shall consist of limited number of layers such that the pressure exercised by the pipe's own weight does not cause damages to the coating. Applicator shall submit calculations for Company approval in this regard. Each pipe section shall be separated by means of spacers suitably spaced for this purpose. Stacks shall be suitably secured against falling down and shall consist of pipe sections having the same diameter and wall thickness. The weld seam of pipes shall be positioned always in a manner so as not to touch the adjacent pipes.
- 13.9 The lorries used for transportation shall be equipped with adequate pipe supports having as many round hollow beds as there are pipes to be placed on the bottom of the lorry bed. Total width of the supports shall be at least 5% of the pipe length and min. 2 no. support shall be provided. These supports shall be lined with a rubber protection and shall be spaced in a manner as to support equal load from the pipes. The rubber protection must be free from all nails and staples where pipes are in contact. The second layer and all following layers shall be separated from the other with adequate number of separating layers of protective material such as straw in plastic covers or mineral wool strips or equivalent, to avoid direct touch between the coated pipes.
- 13.10 All stanchions of Lorries used for transportation shall be covered by non-abrasive material like rubber belts or equivalent. Care shall be exercised to properly cover the top of the stanchions and other positions such as reinforcement of the truck body, rivets, etc. to prevent damage to the coated surface. Slings or non-metallic straps shall be used for securing loads during transportation. They shall be suitably padded at the contact points with the pipe
- 13.11 Materials other than pipes and which are susceptible of deteriorating or suffering from damages especially due to humidity, exposure to high thermal excursions or other adverse weather conditions, shall be suitably stored and protected. Deteriorated materials shall not be used and shall be replaced at Applicator's expenses. These materials shall always be handled during loading, unloading and storage in a manner so as to prevent any damage, alteration and dispersion. When supplied in containers and envelopes, they shall not be dropped or thrown, or removed by means of hooks, both during the handling operations till their complete use. During unloading, transport and utilization, any contact with water, earth, crushed stone and any other foreign material shall be carefully avoided.
- 13.12 Applicator shall strictly follow Manufacturer's instructions regarding storage temperature and methods for volatile materials that are susceptible to change in properties and characteristics due to unsuitable storage. If necessary the Applicator shall provide for a proper conditioning.
- 13.13 In case of any marine transportation of bare/coated line pipes involved, the same shall be carried out in compliance with API RP 5LW. Applicator shall furnish all details pertaining to marine transportation including drawings of cargo barges, storing/stacking, sea fastening of pipes on the barges/marine vessels to the company for approval prior to undertaking such transportation works. In addition, Applicator shall also carry out requisite analyses considering the proposed transportation scheme and establish the same is safe and stable. On-deck overseas shipment shall not be allowed.
- 14.0 **MEASUREMENT AND LOGGING**
Applicator shall maintain records in computer using MS ACCESS database Software containing all the relevant data of individual pipe and pipe coating including pipe number, heat number, diameter, length, wall thickness, defects, coating number, batches of materials, sampling, testing, damages, repairs, rejects and any other information that Company considers

to be relevant and required for all incoming bare pipes and Company approved outgoing coated pipes as applicable. Applicator's documentation shall be designed to ensure full traceability of pipe and coating materials through all stages of coating and testing. Applicator shall submit this information in the form of a report at the agreed intervals. The above data shall also be provided in MS ACCESS format in Compact Disc (CD)/ pen drive . Applicator shall provide one Computer Terminal to Company Representative for monitoring/tracking of the above. The Applicator shall also submit the material balance details to Company for information at the end of each shift.

ANNEXURE I

List of Acceptable Combinations of Coating Materials

The following combinations of coating materials are considered acceptable. In case any of the combinations listed below are offered, details regarding properties of the offered materials need not be furnished with bid. However, In the event of award of contract, Applicator shall furnish the combination(s) proposed as per Table below and re-confirmation of compatibility of the proposed combination (s) from the raw materials Manufacturers. Only straight line combination of epoxy, adhesive and PE compound is acceptable.

Epoxy Powder (Manufacturer)	Adhesive (Manufacturer)	PE Compound (Manufacturer)
CORRO-COAT EP-F 2001 (JOTUN)	FUSABOND 158D (DUPONT)	SCLAIR 35 BP HDPE (NOVACOR)
CORRO-COAT EP-F 2002HW (JOTUN) or SCOTCHKOTE 226N (3M)	LUCALEN G3710E (LYONDELLBASELL)	LUPOLEN 4552 D SW 00413 (LYONDELLBASELL)
PE 50-6109 (BASF) or CORRO-COAT EP-F 2001/ 2002HW (JOTUN) / JOTAPIPE AC 1003 (JOTUN) or SCOTCHKOTE 226N (3M)	ME 0420 (BOREALIS)	HE 3450H (BOREALIS / BOROUGE)
CORRO-COAT EP-F 2001 (JOTUN)	LE — 149 V (HYUNDAI ENGINEERING PLASTICS)	ET 509 B (HYUNDAI ENGINEERING PLASTICS)

Although the above combinations would be acceptable to Company, the responsibility of suitability for application, performance and compliance to the coating system requirements shall unconditionally lie with the Applicator.