

TECHNICAL SPECIFICATION

LIQUID REHABILITATION COATING OF ONSHORE PIPELINES

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for field-applied external liquid rehabilitation coatings on onshore buried pipelines. It includes coating materials, qualification of coating materials and their Applicator, surface preparation, coating application, quality assurance/control, and repair.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company and, where necessary, to Contractors and Manufacturers nominated by them.

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and, where applicable, supply/marketing installations.

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

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

1.3 DEFINITIONS

1.3.1 General definitions

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

The **Applicator** is the party that carries out the surface preparation and coating application.

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

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

adhesive failure	rupture of an adhesive bond such that the separation appears to be at the coating – steel substrate interface
ambient temperature	temperature of the surrounding environment in the field
applicator	party that applies the liquid pipeline rehabilitation coating system in the field
backfill time	time required for the paint to dry hard enough to resist mechanical damage by the backfill soil
batch	amount of materials produced within one uninterrupted production run of maximum 8 h under constant production conditions
cohesive failure	rupture of an adhesive bond such that the separation appears to be within the coating
damp surface	surface on which there are molecular layers of moisture without visible water droplets. The surface temperature is above but within 3 °C of the dew point.
delamination	separation of a coat or coats from the previous coat or from the substrate
disbondment	loss of adhesion between a coating and the substrate
dry film thickness (DFT)	thickness of an applied coating over the top of the peak of the anchor profile when dry
dry-to-touch time	time taken by the paint to dry until it becomes tack-free
epoxy	thermosetting resin capable of forming tight cross-linked polymer structures characterized by toughness, strong adhesion, and low shrinkage, used especially in surface coatings and adhesives
epoxy novolac	class of epoxy resin containing more than two functional groups to react with crosslinking agents to generate a high degree of crosslinking; generally for high temperature application
fingerprinting	method of identifying a coating material through laboratory analyses of coating density, solids content, pigment content, etc. Infrared (IR) spectroscopy is often used in the analysis
fish eye	defect in a coating film in the form of a small dimple resembling a fish's eye
holiday	discontinuity in a protective coating that exposes the unprotected surface to the environment, or a thin coating spot that cannot provide good barrier to the environment, normally detected by a low or high voltage holiday detector
MSDS	material safety data sheet
pinhole	hole or discontinuity through a coating film exposing the pipe surface, normally caused by solvent bubbling, moisture or foreign particles

plural component spray	application method that automatically proportions and mixes two or more components of a coating material in the process of delivering them to the spray gun. Plural component spray equipment is used to apply coatings with a pot life that is too short to permit mixing and application by conventional air and airless spray equipment
polyol	organic compound having more than one hydroxyl (-OH) group per molecule, used as reactant in polyurethane resin
pot life	time within which a coating can be effectively applied after all components of the coating have been thoroughly mixed
room temperature (RT)	indoor temperature generally between 20 ° and 25 °C
shelf life	amount of time a coating or other material remains in usable condition
wet film thickness (WFT)	thickness of a wet liquid coating film immediately after application
wet surface	surface with visible water

1.4 CROSS-REFERENCES

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

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com. Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards folder. The DEP Administrator and DEP Author monitor these folders on a regular basis.

2. GENERAL INFORMATION

2.1 GENERAL

Coating qualification shall be performed before the start of a specific pipeline rehabilitation project. With this qualification process, a list of qualified coating materials will be developed, from which the Principal may select a coating material for a specific project.

To facilitate the selection of suitable coating material, the coating shall be qualified at its maximum service temperature by going through the full coating qualification process. The coating Manufacturer may recommend the maximum service temperature for each coating material.

For a specific project, the Principal may require some additional testing to be performed.

2.2 CONTRACTOR RESPONSIBILITY

2.2.1 General

The Contractor shall be responsible for the health and safety of its workers, the maintenance of all the coating related equipment, and the quality of the work, which shall be performed in accordance with this DEP and all other relevant documents, such as site regulations, local or national requirements, safety rules and the coating Manufacturer's product data sheet.

The Contractor shall supply all the weather protection, access and any other equipment necessary to ensure that the work is carried out in accordance with this DEP.

The Contractor shall prepare appropriate work planning, which shall be in agreement with that of the Principal.

2.2.2 Health, safety and environment

The Contractor shall comply with the requirements of the Principal's HSE Management System, the product's MSDS and other requirements such as site regulations, safety rules, etc.

The Contractor shall ensure that updated MSDS are obtained from the Manufacturer before commencing coating.

The Contractor shall provide all painters with approved protective clothing including safety glasses, safety shoes, hard hats, goggles, respirators, earplugs, fresh-air-fed hood and any other necessary safety equipment. All the safety equipment shall be maintained in a good working condition. All blasting equipment shall be fitted with an operator-controlled, automatic "dead-man" device.

The Contractor shall be required to test work areas for flammable vapours, with an appropriate vapour tester, prior to and throughout abrasive blasting and coating operations.

The Contractor shall post appropriate warning signs and erect appropriate barriers in the work area.

The Contractor shall ensure that coatings to be used fully comply with any local and national regulations on safety and hazardous components.

2.2.3 Personnel

Contractor shall provide all competent personnel needed for satisfactory completion of the works. Blasters and painters shall be qualified in accordance with (5.2) prior to commencing the coating work.

2.2.4 Coating material

The Contractor shall be trained and /or certified by the coating Manufacturer about the coating material and its proper application procedure.

Unless otherwise specified by the Principal, the Contractor shall provide all coating and cleaning materials, tools, equipment, storage and competent personnel needed for satisfactory completion of the work.

2.2.5 Blasting and spraying equipment

The Contractor shall demonstrate that the blasting and spraying equipment to be used is in good condition and well maintained. The compressed air shall be free of water and oil. In no case shall air-compressors be allowed to work at a temperature in excess of 110 °C. Blasting nozzles shall be discarded and replaced when the nozzle diameter has increased through wear by more than 50 % of the original diameter. The rubber hose shall be anti-static. Spray guns, brushes, rollers, paint pots and the like shall be regularly cleaned.

The Contractor shall ensure that blasting and coating equipment fully complies with any local and national regulations.

Blasting and coating application equipment shall be earthed to prevent the build up of static electricity.

2.2.6 Quality control

The Contractor shall be responsible for all quality control activities, including visual inspection, DFT measurement and holiday testing. The Contractor shall notify the Principal when these tests are to be performed to allow verification. A copy of all records of inspection results shall be made available to the Principal on a daily basis.

The Contractor is responsible for calibrating testing instruments.

2.2.7 Disposal of hazardous waste

The Contractor shall be responsible for disposal of all hazardous waste as defined by local and national legislative agencies. At the end of each workday, waste coating material such as unused coating, old coating, dirty clean-up solvents, and contaminated disposal items such as empty paint and solvent cans shall be removed from the job site and disposed of in accordance with applicable regulations.

2.2.8 Access

Easy and sufficient access shall be provided for surface preparation, painting and inspection of all surfaces. Ditches and bellholes shall be constructed in accordance with local regulations and the requirements of the Principal or as otherwise agreed with the Principal.

The Principal shall have access to the work at all times, with the right to inspect and approve the work and materials furnished by the Contractor.

2.2.9 Information to be submitted by the Contractor

The Contractor shall submit the following information to the Principal.

- coating material information (4.2);
- abrasive blasting media and anchor profile,
- coating application procedures;
- name of the proposed Applicator;
- Applicator's qualification information;
- quality control and assurance plan.

2.3 INFORMATION TO BE SUBMITTED BY THE PRINCIPAL

The Principal shall submit the following information to the Contractor regarding the project:

- project name;
- coating material selected and coating's nominal DFT;

- maximum operating temperature of the pipeline;
- existing coating material;
- geographical area;
- expected ambient temperatures and humidities during operation;
- soil and backfill conditions;
- voltage for holiday inspection;
- description of steel pipe;
- applicable specification;
- cathodic protection applied.

3. COATING MATERIALS

3.1 GENERAL

The coating material shall be selected according to the weather (ambient temperature, humidity), surface wetness, maximum service temperature of the pipeline, and backfill time. The coating material shall be prequalified according to the test protocol listed in (4). The coating Manufacturer shall present to the Principal the test report prepared by a 3rd party test laboratory and certified by Shell (witnessing the application and testing) to demonstrate that the coating material has passed the acceptance criteria of the qualification test specified in (4).

Thinners shall not be used unless specified by the coating Manufacturer.

In general, liquid coatings require a thorough surface preparation with a minimum near white metal finish (ISO 8501-1, Sa 2½). Otherwise, the coating performance is greatly compromised. For the sake of productivity, liquid coatings are formulated so that they can be applied in one coat to reach the minimum specified DFT. Possible rehabilitation coatings for various service conditions are listed in Table 1. Other coating materials that are not listed in the Table 1 may still be used if they pass the acceptance criteria and fulfil the local and national HSE regulations.

Table 1 Possible liquid coatings for various service conditions

Service condition	Maximum service temperature	Application method	Possible liquid coatings
Cold weather, (ambient temperature <10 °C)	< 80 °C	Spray, brush/roll	Vinyl ester, Polyurethane, fast cure epoxy
General use	< 80 °C	Spray, brush/roll	Epoxies
High temperature	> 80 °C	Spray, brush/roll	Epoxy novolac
High humidity ¹	< 40 °C	Spray, brush/roll	Damp surface tolerant epoxy
Wet surface ¹	< 40 °C	Brush	Wet surface tolerant epoxy
River crossing ¹	< 40 °C	Trowel	Underwater cured epoxy
¹ To be specified by the Principal.			

3.2 HSE REQUIREMENTS FOR COATINGS

The coating material shall contain no carcinogens such as methylene dianiline (MDA) curing agent, and shall contain less than 500 mg/kg of heavy metals (antimony, cadmium, chromium, copper, lead, mercury, nickel, selenium) in the paint.

The amount of volatile organic compounds (VOC) of the coating material shall be in accordance with the applicable regulations.

3.3 TYPES OF LIQUID COATING MATERIALS

3.3.1 Epoxies

Of all the types of pipe coatings used in the field, epoxies have the best adhesion and are the least susceptible to soil stress. They are often used for general rehabilitation when abrasive blasting can be used. But, being a relatively thin coating, they are susceptible to penetration damage by sharp rocks and impact damage during backfilling.

Epoxy pipeline coatings are either solvent free (100 % solids) or high solids. This allows the coating to be applied as a single coat. Epoxy coatings come in two parts, the epoxy material (Part A) and the curing agent (Part B). Both Part A and B must be thoroughly mixed prior to application. For high solids and solvent free epoxies, the viscosities are high and the pot lives are short. As a result, the application methods must be carefully considered. Coatings with pot lives of 30 min or less are usually applied by plural spray. For an epoxy coating with a pot life greater than 30 min, the airless spray method may be used.

High solid or solvent free epoxy resins used for pipeline rehabilitation are normally made of low molecular weight epoxy monomers. Generally speaking, they are brittle in nature. Epoxy may be modified with polyurethane polymer to increase its flexibility.

3.3.2 Epoxy novolacs

Epoxy novolacs are polyfunctional epoxy resins with a functionality higher than that of epoxy resin. The higher functionality results in a more close-knit network and is responsible for better performance at elevated temperatures.

3.3.3 Damp surface tolerant epoxy

The epoxy resin can be formulated with special additives (coupling agent) or curing agent (modified amidoamine) to tolerate the damp surface. This type of coating should not be considered for service temperatures above 40 °C.

3.3.4 Wet surface tolerant epoxy

For coating repair on wet surfaces, special epoxy formulated with modified amidoamine curing agent may be used. Normally, a brush is used to apply the coating material. The brushing action should help to displace water from steel surface to promote adhesion to steel surface. It is not good practice to apply spray coatings to wet surfaces.

3.3.5 Underwater cured epoxy

For the coating repair of a pipeline crossing a river, specially formulated epoxy coating materials cured with modified amidoamine curing agents are available; these are able to displace water from the wet surface in order to bond to the steel surface. The formulation is normally solvent-free and incorporates Kevlar fibres for reinforcement and viscosity adjustment to hold the coating paste together under water before it is applied onto the steel pipe surface. Any attached biological matter and corrosion shall be removed by conventional abrasive blasting or high pressure water jetting with abrasive. The surface shall be thoroughly cleaned with the specified anchor profile. The coating may be applied by trowel. Details on surface preparation and coating application are available from the coating Manufacturers.

3.3.6 Polyurethanes

Polyurethanes used for external pipe coatings are typically two-component, high solids (>98 %) or 100 % solids. This type of coating has a fast crosslinking reaction between the isocyanate and polyol monomer, and limited pot-life after the two components are mixed. Because of their faster cure times, they can be applied in colder weather.

3.3.7 Vinyl ester

Vinyl ester resins are dissolved in styrene monomers to reduce their viscosity. The unsaturated group on the resins and styrene monomers is cured by free radicals generated from peroxides, such as methyl ethyl ketone peroxide. Metal salts such as cobalt naphthanate are used as accelerators. Cure rates are often adjusted by varying the amounts of accelerators and retarders. Since only a small amount of catalyst will be included in Part B, care shall be taken to ensure proper mixing of the vinyl ester coating. The styrene monomer is an irritant to human lungs, so care shall be taken in its use.

Vinyl ester resins may be cured very quickly and may be used for the rehabilitation coating of pipelines in cold climates.

4. QUALIFICATION OF COATING MATERIALS

4.1 GENERAL

The coating Manufacturers shall demonstrate the performance of their proposed coating materials in accordance with this qualification procedure. The coating material shall meet all the specified acceptance criteria before approval can be granted. Prequalification shall be carried out by a third-party test laboratory and witnessed by the Principal. The test report with fingerprinting shall be provided to the Principal. Any coating material for which a test report is submitted to the Principal for acceptance shall remain valid for a period of five years, provided that its formulation has not been changed. If the coating formulation is changed after qualification, the coating material shall be requalified in accordance with this DEP.

In general, liquid coatings are applied on dry steel substrate with a surface temperature of at least 3 °C above dew point. However, on rare occasions, the Principal may request certain specific coatings to be applied on a damp surface in very humid weather conditions, on a water condensing wet surface, or on a underwater pipe. The application procedure of the test specimens shall be identical to the field application procedure and the Principal shall witness the testing. The prepared test specimens shall be qualified with the same procedures as the ones prepared in dry conditions.

4.2 REQUIRED PRODUCT INFORMATION

When each coating material is subject to qualification testing, the coating Manufacturer shall provide the following information as part of the test report.

- (1) Product data sheet
- (2) MSDS
- (3) Fingerprinting—The requirements for fingerprinting of the coating material are listed in Table 2.

Table 2 Fingerprinting of coating materials

	Property	Component	Standard
1	Density	Part A and B, each component	ISO 2811-1
2	Solids content by weight	Mixed Parts A and B	ISO 3251
3	Pigment Content by weight	Part A and B, each component	ASTM D 2371
4A	Fourier transform infrared-attenuated total reflection (FTIR-ATR) scan with pigment or	Part A and B, each component	Equipment manufacturer's instruction
4B	Infrared (IR) scan without pigment	Part A and B, each component	ASTM D 2621

If the fingerprinting test is conducted by the Manufacturer, the fingerprinting test results shall be certified by the Manufacturer's quality assurance/quality control department or the senior technical manager.

- (4) All of the following information:

- manufacturer's name;
- product name;
- colour;
- material type;
- batch numbers, Parts A and B;

- manufacturing date;
- shelf life;
- surface cleanliness;
- anchor profile;
- volatile organic compounds (VOCs);
- cleaning solvent;
- thinner type;
- mixing ratio by volume or weight;
- application method;
- allowable application ambient temperature range;
- allowable pipe surface temperature range;
- allowable application humidity range;
- pot life at the allowable application ambient temperature range;
- dry-to-touch time at the allowable pipe surface temperature range;
- backfill time at the allowable pipe surface temperature range;
- maximum recoat time at the allowable pipe surface temperature range;
- solids content by percentage in volume;
- minimum WFT and DFT;
- storage conditions;
- required preheat temperature.

4.3 TEST PROTOCOL AND ACCEPTANCE CRITERIA

In addition to the coating performance, the ease of application of the liquid coating also plays an important role in successful field coating. Therefore, the test protocol includes both performance and ease of application. At least three test specimens shall be used for each test method. Each test specimen shall be abrasive blasted to at least Sa 2½ surface cleanliness. The anchor profile shall be the same as specified in (6.5). The test protocol and acceptance criteria are summarized in Table 3.

4.4 THICK FILM FORMATION

For productivity reasons, the liquid coating shall be applied by either an airless spray or a plural component spray in a single coat to reach a minimum 400 µm to 500 µm DFT. Normally, the liquid pipeline coatings shall be either solvent-free or high-solid coatings to form a thick film of smooth appearance without drips, running, sags, pinholes or fisheyes. A DFT of at least 500 µm shall be sufficient to provide an adequate barrier resistance to oxygen and water. For short pipe sections, the brush / roll application method may be used, but they still shall meet the above-mentioned requirements.

4.5 DRY-TO-TOUCH TIME

Dry-to-touch time shall be determined in accordance with ASTM D 1640. The dry-to-touch time shall be no longer than 4 h at RT.

4.6 BACKFILL TIME

The backfill time is that taken for the film to attain a Shore D hardness of 65. The Shore D hardness shall be measured with a pocket hardness meter in accordance with ISO 7619. The backfill time shall be as short as possible, particularly for pipeline rehabilitation work near populated areas. The backfill time for plural component sprayed coatings shall be less than 6 h. The backfill time for airless sprayed coatings shall be less than 12 h.

Table 3 Test protocol and acceptance criteria for liquid pipeline rehabilitation coatings

Coating properties	Test Method	Acceptance criteria
Thick film formation	Airless, Plural Component (PC) Spray, or Brush / Roll	One coat without coating defects for > 500 µm
Dry-to-touch time	ASTM D 1640	< 4 h at RT
Backfill time	ISO 7619	< 6 h PC spray at RT to reach > 65 Shore D hardness
		< 12 h airless spray at RT to reach > 65 Shore D hardness
Cathodic disbondment at maximum operation temperature	(4.7)	< 10 mm after 4 weeks and < 25 mm after 12 weeks, no blisters
Penetration resistance at maximum operation temperature	ASTM G17	< 10 %
Impact strength at RT	ISO 6272-2 or ASTM G 14	> 3 J
Impact strength at coldest ambient temperature	ISO 6272-2 or ASTM G 14	> 3 J
Aging stability at maximum operation temperature	(4.10)	75 % to 125 % of original flexure strain value

4.7 CATHODIC DISBONDMENT (CD)

4.7.1 General

The attached cell and electrolyte bath methods shall be used for laboratory testing of onshore pipeline coatings.

The CD resistance may be a function of coating DFT and microstructure. Thicker DFT may give a lower CD value. Therefore, the maximum coating DFT of the test specimens shall be in the range of 400 µm to 500 µm or no more than the minimum DFT specified by the Principal. Test specimens shall be prepared with the same coating application method to be used in the field.

Steel surface temperature shall be maintained to the required test temperature.

4.7.2 Test setup

Attached Cell Method

A plastic cylinder is attached to the test specimen with the holiday at the centre of the cylinder and sealed to the test specimen surface with a waterproof sealing material. This cylinder shall have an inside diameter of 75 mm to 100 mm and a height of at least 125 mm. Pour approximately 350 ml of electrolyte into the cylinder. Use a metal pan partially filled with a heat-transfer medium (e.g. sand) to ensure uniform heating of the test specimen. The metal pan is placed on a hot plate or in an oven to maintain the electrolyte test temperature. Immerse the thermometer and rest it on the test specimen.

Electrolyte Bath Method

The circular tank is made of non-conducting material, such as glass, ceramic or plastic, and provided with thermostatic temperature control. The capacity of the tank shall be such that it contains not less than 7.5 L of electrolyte per 1 m² of panel surface exposed. The tank

may have a cover plate with radial slot openings to suspend test panels vertically in the tank with at least 25 mm clearance from the bottom. The minimum panel separation shall be 30 mm, with 50 mm minimum clearance from the tank walls. Each specimen shall be separated from the anode by at least 40 mm.

4.7.3 Test specimen

Each specimen shall be labelled with a water-resistant marker which will not fade during the test.

Attached Cell Method

The minimum dimensions of the specimen shall be 100 mm square x 3 mm thick. The test specimen shall be either a flat panel or a cut-out from a pipe. A 3 mm or 6 mm diameter holiday, as specified by the Principal, shall be drilled into the coating at the centre of the specimen.

Electrolyte Bath Method

The minimum panel dimensions shall be 150 mm x 75 mm x 3 mm. All surfaces shall be coated. A 3 mm or 6 mm diameter holiday, as specified by the Principal, shall be drilled through the coating at the centre of the specimen on both panel surfaces.

4.7.4 Electrolyte

The electrolyte shall consist of potable tap water with the addition of 1 % (by mass) of each of the following salts, calculated on an anhydrous basis:

- sodium chloride;
- sodium sulphate; and
- sodium carbonate.

Freshly prepared solution shall be used for each test.

4.7.5 Anode assembly

The anode shall be platinum wire [0.5 mm diameter (24 gauge)], titanium or some other material that shows sufficient resistance to anodic polarization in electrolyte salt solution. The anode shall be inserted into a commercial glass or polyethylene filter tube with fritted disk of 30 mm in diameter with a pore size of 10 µm to 15 µm. The tube shall have a length of 180 mm and a diameter of 8 mm. The anode assembly shall be suspended inside the tank so that the tip of the anode assembly closest to the holiday is 25 mm above, and the edge of the anode assembly is 13 mm offset from, the holiday. The filter tube shall separate the chlorine gas generated in the anodic reaction, preventing it from entering the electrolyte and bleaching the coating.

4.7.6 Reference electrode

A saturated Cu/CuSO₄ reference electrode shall be used. If a calomel electrode is used, it shall be converted to the Cu/CuSO₄ reference by adding –0.072 V to the observed reading. When measurements are taken, the reference electrode shall be placed in the electrolyte solution, at least 40 mm away from the specimen and anode.

4.7.7 DC power supply

The positive lead of the current source shall be attached to the anode and the negative lead to the cathode (test panel). A potential of -1.50 ± 0.10 V shall be set with respect to the saturated Cu/CuSO₄ reference electrode. At least twice each week, a reference electrode shall be placed between the anode and the holiday to read the voltage and adjust the power supply output, so that a negative 1.50 V potential is maintained between the reference electrode and the test specimen.

4.7.8 Test duration

The test shall be conducted for 28 days at RT and for 112 days at the maximum operating temperature.

4.7.9 Evaluation

After the test is done, the specimen shall be taken out of the electrolyte and rinsed with tap water, then proceed as follows:

- use a utility knife to make four diagonal cuts;
- insert the blade of a utility knife under the coating at the holiday edge;
- use a levering action to chip off the coating;
- continue until the coating demonstrates a noticeable resistance to the levering action;
- measure the diameter of the disbonded area.

The average cathodic disbondment is equal to the average disbondment diameter minus the holiday size, and then divided by two.

The specimen surface shall also be examined for any pinhole formation, blistering, cracking, and discoloration. The pinhole shall be examined by means of a wet sponge holiday detector and confirmed with a 30x stereo microscope. For acceptance, the coating shall exhibit no defects. The allowable average CD at RT shall be less than 10 mm. At the maximum operating temperature, the allowable average CD shall be less than 10 mm for the 28-day test and 25 mm for the 112-day test.

4.8 PENETRATION RESISTANCE

Hard and sharp rocks that lie next to the pipeline can slowly penetrate into the coating under heavy soil loading. The penetration test is the measurement of the creep deformation of the coating materials under compression load. If the coatings suffer too much creep thinning, the barrier protection of the pipeline will be reduced. The penetration resistance shall be measured in accordance with the ASTM G 17. For higher temperature penetration tests, a heated aluminium block under the steel panel shall be used to obtain the required steel temperatures. The acceptable penetration shall be less than 10 % of the coating DFT at RT and maximum service temperature.

4.9 IMPACT STRENGTH

Impact strength is necessary to protect the coating from damage by rocks during backfill. Impact strength shall be measured in accordance with ISO 6272-2 or ASTM G 14. The test shall be conducted at RT and the coldest field ambient temperature. The impact strength shall be at least 3 J at both temperatures.

The impact strength is a function of coating DFT and microstructure. Thicker DFTs can give a higher impact strength value. Therefore, the maximum coating DFT of the test specimens shall be 500 µm. The coating application method for test specimens shall be the same method as that to be used in the field.

4.10 AGEING STABILITY

4.10.1 Test Specimen

At least twelve carbon steel test specimens, each 150 mm x 25 mm x 6 mm, shall be prepared. Each specimen shall be abrasive-blasted to at least Sa 2½ with an anchor profile of 50 µm to 100 µm. Only one side of each of the twelve steel specimens shall be coated. Of the twelve test specimens, the back side of six test specimens shall remain bare and shall not be exposed to the salt solution; these are the six control test specimens. The back

side of the six other test specimens shall be brushed with one coat of immersion-grade coating to protect the steel from rusting; these are the six aged test specimens.

4.10.2 Test Procedure

The coating on the back side of the six aged test specimens shall be allowed to cure at room temperature for at least one week and shall then be immersed in the same salt solution used for the CD test at the maximum operating temperature for 12 weeks.

The flexure strain for the coating material shall be measured on a fixed-radii mandrel bending test fixture as described in NACE RP0394 for the measurement of the flexibility of fusion-bonded epoxy coating material.

The coating DFT shall be measured prior to testing. The bare side or brush-coated side of the test specimen shall be bent over the fixed-radii steel mandrel. The deformed coating shall be examined for signs for cracking by means of a stereo microscope and a low-voltage wet sponge holiday detector. If no cracking is detected, the test specimen shall be bent over a mandrel with a smaller radius. The procedure shall be repeated until cracking is detected. To reduce the percentage of error, the radii of two consecutive steel mandrels shall generate less than 0.2 % difference in their flexure strains. The flexure strain of the coating shall be calculated by means of Equation (1):

$$\text{Flexure strain of coating} = (t/2 + c) / (R + t/2) \quad (1)$$

Where t = steel specimen thickness

c = coating DFT

R = mandrel radius

Because discrete bending radii are used, the true flexure strain is actually somewhere between two consecutive mandrel radii. For practical purposes, the flexure strain of the coating shall be reported as the average of these two values.

The coating flexure strain of the six control test specimens and the six aged test specimens shall be measured. The flexure strain retention ratio for the average of the six aged test specimens relative to the average of the six control test specimens shall be calculated as the measure of the aging stability.

If the coating becomes more brittle after aging, the flexure strain ratio is lower than 1. On the other hand, if the coating becomes softer after aging, the flexure strain ratio is higher than 1. The acceptable aging stability shall be in the range of 75 % to 125 %.

4.11 MAXIMUM SERVICE TEMPERATURE DETERMINATION

The cathodic disbondment test and penetration test are the two test methods used to determine the maximum service temperature for a given pipeline coating material. Within the maximum service temperature, the coating's CD and penetration resistance shall pass the performance acceptance criteria in Table 3.

5. QUALIFICATION OF COATING APPLICATOR

5.1 GENERAL

The coating Applicator shall be qualified in the presence of the Principal. Qualification may be waived if the Applicator can demonstrate the capabilities through documentation approved by the Principal.

5.2 APPLICATOR QUALIFICATION

The Applicator shall prepare the spray equipment and test steel specimen, which is a piece of steel pipe with similar pipe OD as the one to be rehabilitated. The steel pipe specimen shall be abrasive blasted to near white metal finish, Sa 2½, with the specified anchor profile and sprayed with the specified coating to the specified coating thickness. After the coating has hardened, it shall be visually inspected to detect any discolouration, sags, running, drips, blisters, fisheyes or pinholes. The pinholes shall be detected with a wet sponge holiday detector and be confirmed with a 30× hand-held microscope. None of the above-mentioned defects shall be observed. A knife adhesion test in accordance with ASTM D 6677 shall be conducted to inspect for adhesion to steel. Make an X-cut through to the steel on the panels and peel off with the pocket knife. If a rating above 8 or a cohesive failure mode is detected, the adhesion is acceptable. No holiday shall be detected by the test method specified in NACE RP0188. In general, the coating requires 7 days to harden at room temperature prior to the adhesion test. If a fast cure is applied to speed up the adhesion test, the Applicator shall consult with the coating Manufacturer to select the fast curing temperature and time. The acceptance criteria are listed in Table 4.

Application shall be identical to production coating in the field.

Table 4 Acceptance criteria for qualification of applicators

Property	Test Method	Acceptance Criteria
DFT	ISO 2808, method 6A,	> 500 µm
Appearance	Visual examination, wet sponge holiday detector and 30x microscope	No discolouration, drips, running, sags, blisters, pinhole, fisheyes
Holiday detection	NACE RP0188	Zero holidays
Adhesion	ASTM D 6677 knife test	Rating > 8 or cohesive failure

6. SURFACE PREPARATION

6.1 GENERAL

Before coating, the pipe surface shall be abrasive blast-cleaned to a minimum of Sa 2½ finish and made free of dust and foreign matter by means of clean dry compressed air or vacuum cleaning. The compressed air shall be free of any trace of oil or water.

6.2 EXISTING COATING REMOVAL

Before blast cleaning, the old coating on the designated pipe sections shall be scraped off. The Contractor shall remove the old coating in a manner that does not cause an unsafe condition or damage the pipe. Any method of coating removal that may scar, dent, or damage the pipe surface is strictly prohibited. The Contractor shall comply with all company, local, and national environmental rules and regulations regarding the removal, handling, and disposal of any coating.

6.3 ABRASIVE BLAST-CLEANING

Only the area to be coated in the same day shall be blast-cleaned. All surfaces to be blast-cleaned shall be free of oil, grease, dirt, soil, and contaminants, which shall be removed by cleaning with environmentally friendly solvent in accordance with SSPC SP 1. All the pipe surface including the underside, weld bead, and pits shall be blast-cleaned to achieve a minimum near-white surface cleanliness of Sa 2½ in accordance with ISO 8501-1. Pits generally require more blast repetitions or dry/water wash cycles to clean the surface to acceptable levels. A smaller particle size mix of abrasive is usually an effective means to scour the base of the pits. If blasting encounters recently rehabilitated coating, the blasting nozzle should be directed at an angle of 30° to 45° from the coated surface to the adjacent substrate to achieve feathering over a length of 50 mm to 100 mm. All surfaces shall be free of blasting abrasives and dusts. During blast-cleaning the pipe surface temperature shall be at least 3 °C above the dew point with relative humidity less than 85 %.

6.4 ABRASIVE BLASTING MATERIALS

Only pre-approved abrasives that meet all local and national regulations shall be used to prepare surfaces by open abrasive blasting. Abrasive blasting materials shall not be recycled unless automatic reclaiming equipment is used. Abrasives shall be a blend of particle sizes to reach optimum cleaning efficiency. Abrasives shall be as specified in Table 5.

Table 5 Abrasives specifications

Type	Generic Name	Characteristics	Standard
Natural Mineral	Olivine	Magnesium/iron silicate	ISO 11126-8
	Staurolite	Iron/aluminium silicate	ISO 11126-9
	Specular haematite	Crystalline Fe ₂ O ₃	Manufacturer specification
	Garnet	Calcium iron silicate	ISO 11126-10
Synthetic Mineral	Coal slag	Aluminium silicate	ISO 11126-4
	Aluminum oxide	Crystalline corundum	ISO 11126-7
Note: There is a wide variation in performance between products within a given generic class of abrasives. These variations are usually the result of varying raw material sources and / or the manufacturing process.			

6.5 ANCHOR PROFILE

The anchor profile shall meet the coating Manufacturer's specification. If not specified by the Manufacturer, the anchor profile shall be in the range of 50 μm to 100 μm , measured by means of replica tape in accordance with ISO 8503-5.

6.6 SOLUBLE SALT CONTAMINATION

Among soluble salts, chlorides are the most harmful followed by nitrates and then sulfates. Chloride levels shall be measured in the field, either in accordance with ISO 8502-6 and ISO 8502-9 or by using the Chlor-Test kit or the Elcometer 130, SCM 400 Salt Contamination Meter. The maximum allowable chloride ion content shall be 20 mg/m^2 .

6.7 FEATHERING OF MAINLINE PIPE COATINGS

If the mainline pipe coating is FBE, 3 LPE, 3 LPP, coal tar enamel, or asphalt enamel, at the transition to bare steel, the mainline pipe coatings shall be feathered over a length of 75 mm to 150 mm. If the mainline pipe coating is a polyolefin tape, a special procedure shall be presented to the Principal for approval.

7. COATING APPLICATION

7.1 GENERAL

The coating Applicator shall submit the coating application procedure to the Principal for approval.

Surfaces to be coated shall be abrasive blast-cleaned, dust free and dry. Blast-cleaned pipes shall be coated within the same day. Pipes delayed beyond this period, or pipes showing any visible rust stains, shall be blast cleaned again.

Either airless or plural component spray is the preferred coating application method. For short sections, brush or roll may be used. Liquid coating materials should be applied in a multi-pass to build to the specified film thickness in one coat. The substrate temperature shall be a minimum of 3 °C above the dew point and the relative humidity shall be below 85 % except for special coating services specified by the Principal. Under no circumstances should rehabilitation coating be applied in the field during periods of rain.

7.2 COATING PACKAGING AND LABELING

All coating materials shall be packaged in closed containers. Each container shall be clearly labelled to indicate the coating material's name, batch number, colour, Manufacturer name, manufacturing date, and shelf life.

7.3 COATING DELIVERY, STORAGE AND HANDLING

The coating shall be delivered to the job site in sealed containers. The coating material shall be stored in covered enclosures out of direct sunlight in a ventilated and dry area. Coating materials past the coating Manufacturer's specified shelf life shall not be used.

7.4 APPLICATION METHODS

7.4.1. Airless spray

The airless spray uses relatively simple and less expensive equipment to apply coatings in the field. Long potlife coatings are more convenient for the coating Applicator. However, coatings with long potlife will also have long dry-to-touch and backfill time.

Airless spray coatings usually contain solvents to reduce their viscosity during spraying. The mechanical mixing of Part A and Part B will introduce air into the liquid paints and the solvent and air bubbles may not escape fully due to high viscosity and thick film. Therefore, airless spray coatings will contain some voids, which reduce their blister resistance.

Airless spray equipment shall be properly earthed to avoid build-up of static charge on the gun.

7.4.2 Plural component spray

High performance liquid rehabilitation pipeline coatings are all applied by plural component spray. Normally, these coating materials require preheating by in-line heaters, heated hoses, or other methods to facilitate the application of the coating. The advantages are fast dry-to-touch and backfill time and higher quality film. Their service temperatures are normally high too.

7.4.3 Brush and roll

Spray is the preferred application method. However, for short sections, brush and roll may be used. For wet surfaces, brushing is the only acceptable application method. When using a roller, it is best to move the roller in a spiral around the pipe without removing it from the pipe surface. This minimizes "nubs or fingers" on the surface of the overlaps of the roller.

7.5 WFT

The wet film thickness shall be checked by means of a wet film gauge in accordance with ISO 2808 Method 1A (comb gauge) to ensure the minimum film thickness specified.

7.6 PREHEATING THE PIPE SURFACE

If the pipe surface temperature is below the minimum surface temperature specified by the coating Manufacturer, the Applicator shall consult the coating Manufacturer to select a proper preheating method, which may be a quartz radiation heating lamp, induction heating coil, or direct flame heating. If direct flame heating is used, the flame shall not be allowed to contaminate the surface to be coated or damage the coating being repaired.

8. QUALITY ASSURANCE AND CONTROL

8.1 GENERAL

All measurement and test equipment used for prequalification, quality assurance and control requirements shall be calibrated.

The minimum quality assurance and control tests to be performed shall be as indicated in Table 5.

The Contractor shall present to the Principal the qualification or certification of its coating Applicator and quality control personnel for approval. The Principal may hire qualified 3rd party coating inspector(s) to conduct the coating inspection, but the coating inspector(s) shall not absolve the Contractor from its quality assurance responsibility.

During application of the coating, the Applicator shall carry out the quality assurance activities needed to ensure that the coating is applied and stored in accordance with the approved coating application procedures and that the final product complies with the requirements of this DEP.

Coating materials older than the Manufacturer's recommended shelf life shall not be used.

8.2 COMPRESSED AIR

The water and/or oil content of the compressed air for surface preparation and coating operations shall be measured in accordance with ASTM D 4285. If moisture or contamination is detected, the problem shall be corrected and the test repeated for verification prior to use of the compressed air.

The compressed air shall be evaluated at least once daily.

8.3 BLAST ABRASIVES

During manufacturing, coal slag abrasives may be quenched with contaminated water and this contamination of abrasives may transfer to the steel surfaces being blasted, where it may accelerate corrosion. A visual inspection and bottle test shall be used to evaluate contamination and/or oil in the abrasive media.

Visual inspection of the abrasives for the absence of contamination and debris shall be conducted with 10x magnification.

The bottle test for evaluating oil contamination of abrasives shall be performed as follows:

Fill a small clean bottle half full of abrasive particles. Fill the remainder of the bottle with distilled water. Cap and shake the bottle for one minute. Inspect the water for oil sheen or other contamination.

Soluble salt contamination shall be measured in accordance with ASTM D 4940. The conductivity of the blasting abrasives shall be less than 50 pS/m.

If the abrasives are contaminated by oil, soluble salt or other substances, the abrasives shall not be used.

The abrasives shall be evaluated at least once per batch.

The abrasives shall be stored in a clean and dry location.

8.4 AMBIENT CONDITIONS - DEW POINT, AMBIENT TEMPERATURE AND RELATIVE HUMIDITY

The dew point and relative humidity shall be measured at least once per day and after obvious weather changes by means of wet/dry bulb type thermometers and psychrometric tables, or approved equivalent. The steel surface temperature shall be at least 3 °C above the dew point and the relative humidity shall be less than 85 %. The Applicator shall measure the ambient conditions at regular intervals during blasting and coating and keep

records of prevailing temperature, humidity and dew point. If the conditions are outside the limits specified in this DEP, the process shall be suspended until the required conditions are met.

8.5 SURFACE CLEANLINESS

The pipe surface finish shall be visually inspected by comparison with a certified surface finish standard and shall comply with ISO 8501-1, Sa 2½.

A transparent pressure-sensitive tape test shall be performed on the prepared surface in accordance with ISO 8502-3. Surfaces showing dust/particulates greater than or equal to rating 2 shall require additional cleaning prior to coating operations.

Surface finish and cleanliness shall be evaluated at least every 10 m², or as required, to maintain the required standard of surface preparation and coating performance. The cleaned surfaces shall be examined by means of optical magnifying instruments.

8.6 ANCHOR PROFILE

The anchor profile shall be measured by means of Testex Press-O-Film, X-Coarse replica tape or approved equivalent, and a surface profile comparator (ISO, or KTA comparator) in accordance with ISO 8503-2 and ISO 8503-5.

At least one anchor profile measurement shall be taken for every 10 m² of blasted surface.

The anchor profile shall follow the coating Manufacturer's specification or shall be in the range of 50 µm to 100 µm.

8.7 SOLUBLE SALT CONTAMINATION

The chloride content shall be less than 20 mg/m². The chloride ion content shall be measured in accordance with ISO 8502-6 and ISO 8502-9, Elcometer 130, SCM 400 Salt Contamination Meter or the Chlor® test kit. The chloride salt shall be measured once on the first 10 m² blasted surface and then every 100 m² thereafter.

8.8 COATING THICKNESS

The thickness gauge shall be calibrated at least once daily. Calibration shall be carried out on a steel plate of similar blast cleaning and anchor profile as the pipe by means of plastic shims of the similar thickness as the nominal coating system.

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

Magnetic thickness gauges (banana gauge) shall not be used for qualification testing or quality control purposes.

A minimum of five thickness measurements shall be made randomly for every 10 m² of coated surface and at the 3, 6, 9 and 12 o'clock positions around the pipe; at least one of these positions shall be on top of the weld. Any single coating DFT shall be more than 500 µm.

8.9 APPEARANCE

The finished coating shall be uniform colour, smooth, free of drips, running, sags, pinholes, blisters, fish-eyes, etc.

8.10 HOLIDAY INSPECTION

The coated surface shall be 100 % holiday-free prior to backfill. A holiday test shall be performed by means of an adjustable high-voltage holiday tester having an audible and

visual alarm. The scanning electrode shall consist of a metal brush or coil spring, fitting the diameter of the coated pipes. The earth connection shall be made directly on the pipe.

The holiday inspection shall be in accordance with NACE RP0188. The location of the holidays shall be marked on the surface for repair.

8.11 COATING ADHESION

The adhesion of the coating on a pipe shall be determined for every 100 m² of coated area at an easy repair location by the ASTM D 6677 knife test: A rating above 8 or a cohesive failure constitutes a pass. The coating should be allowed to cure for at least four days prior to the adhesion test.

8.12 HARDNESS

Shore D hardness tester in accordance with ISO 7619 shall be used to measure the degree of cure. The Shore D hardness shall be a minimum of 65 prior to backfill.

8.13 FINGERPRINTING OF COATING MATERIAL

Prior to coating application, the coating Manufacturer shall submit the fingerprinting documentation of the coating material to the Principal. The Principal may pick randomly a sample of the liquid coating delivered and send it to a 3rd party laboratory to conduct the fingerprinting test to match the test results with the Control.

Table 5 Quality control requirements for pipeline rehabilitation coatings

Property	Test method	Test frequency	Acceptance criteria
Compressed air	ASTM D 4285	Once per day	No water, no oil contamination
Blast Abrasives	ASTM D 4940	Once per batch	No oil contamination and conductivity < 50 $\mu\text{S}/\text{cm}$ ¹⁾
Ambient conditions	(8.4)	Once per day and weather change	3 °C > dew point, ambient temperature and relative humidity fall within specified range
Surface Cleanliness	ISO 8501-1	Every 10 m ²	Sa 2½
Surface dusting	ISO 8502-3	Every 10 m ²	Rating 1
Anchor profile	ISO 8503-2 and ISO 8503-5	Every 10 m ²	Coating Manufacturer specification or 50 μm to 100 μm if not specified
Chloride salt	ISO 8502-6 and ISO 8502-9, SCM 400, Chlor® Test kit	First 10 m ² and every 100 m ² thereafter	< 20 mg/m ²
DFT	ISO 2808, method 6A	Every 10 m ²	>500 μm
Appearance	Visual examination	All surface	Smooth, no drips, running, sags, pinhole, fisheyes
Holiday detection	NACE RP0188	All surface	Zero holidays
Adhesion	ASTM D 6677 knife test	Every 100 m ²	Rating $\geq$ 8 or cohesive failure
Hardness	ISO 7619	Every 100 m ²	>65 Shore D hardness prior to backfill
Fingerprint check	Table 2	Principal to decide	Match with the control
¹⁾ 1 S = 1 Ω^{-1}			

9. COATING REPAIR

9.1 GENERAL

Any low DFT area, holiday, or other defect area shall be repaired. The repair coating should be either the same coating as the pipeline rehabilitation coating or the brush grade of the rehabilitation coating. The DFT after repair shall meet the minimum DFT requirement for the mainline rehabilitation coating.

9.2 LOW DFT COATING REPAIR

If the coating at a low DFT area is still within the maximum recoat time, the same coating should be applied onto the low DFT area. If the coating has exceeded the maximum recoat time, the area shall be abraded or slightly blasted before additional coating material is applied.

9.3 SMALL AREA ($\leq 1 \text{ m}^2$) REPAIR

A small defect area shall be roughened with coarse sandpaper, or a surface grinder prior to recoating. Wipe the surface with a clean cloth to remove dust. A brush may be used to apply the repair coating.

9.4 LARGE AREA ($>1 \text{ m}^2$) REPAIR

At a large defect area, light abrasive blasting should be applied to roughen the surface and overblasting damage shall be prevented by means of a tarpaulin or other necessary measures. The mainline rehabilitation coating shall be sprayed onto the repair area.

9.5 UNDERCURE COATING REPAIR

Coated areas in which the coatings have not been cured properly shall be stripped and recoated in accordance with the procedures in (6) and (7) of this DEP. The edges of the original coating shall be feathered around the area to be coated and all dust wiped off before applying the patch coating.

10. REFERENCES

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

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

AMERICAN STANDARDS

Standard test methods for drying, curing, or film formation of organic coatings at room temperature ASTM D1640

Standard test method for pigment content of solvent-reducible paints ASTM D 2371

Standard test method for infrared identification of vehicle solids from solvent-reducible paints ASTM D 2621

Standard test method for indicating oil or water in compressed air ASTM D 4285

Conductimetric analysis of water soluble ionic contamination of blasting abrasives ASTM D 4940

Standard test method for evaluating adhesion by knife ASTM D 6677

Standard test method for impact resistance of pipeline coatings (falling weight test) ASTM G 14

Standard test method for penetration resistance of pipeline coatings (blunt rod) ASTM G 17

Issued by:

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

Standard recommended practice on discontinuity (holiday) testing of new protective coatings on conductive substrates NACE RP0188

Standard recommended practice on application, performance, and quality control of plant-applied, fusion-bonded epoxy external pipe coating NACE RP0394

Issued by:

*NACE International
1440 South Creek Drive
Houston, TX 77084-4906
USA*

Solvent cleaning SSPC SP 1

Issued by:

*Society for Protective Coatings
40 24th Street, 6th Floor
Pittsburgh, PA 15222-4656
USA*

INTERNATIONAL STANDARDS

Paints and varnishes - Determination of film thickness ISO 2808

Paints and varnishes - Determination of density – Part 1: Pycnometer method ISO 2811-1

Paints, varnishes and plastics – determination of non-volatile – matter content	ISO 3251
Paints and varnishes – rapid – deformation (impact resistance) tests – Part 2: Falling-weight test, small-area indenter	ISO 6272-2
Rubber-determination of indentation hardness by means of pocket hardness meters	ISO 7619
Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness –	
Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings	ISO 8501-1
Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)	ISO 8502-3
Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness –	ISO 8502-6
Part 6: Extraction of soluble contaminants for analysis – The Bresle method	
Part 9: Field method for the conductometric determination of water-soluble salts	ISO 8502-9
Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates –	ISO 8503-2
Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel - Comparator procedure	
Part 5: Replica tape method for the determination of the surface profile	ISO 8503-5
Preparation of steel substrates before application of paints and related products – specifications for non-metallic blast-cleaning abrasives – Part 4: Coal furnace slag	ISO 11126-4
Preparation of steel substrates before application of paints and related products. Specifications for non-metallic blast-cleaning abrasives. Part 7 : fused aluminium oxide.	ISO 11126-7
Preparation of steel substrates before application of paints and related products – specifications for non-metallic blast-cleaning sbrasives – Part 8: Olivine sand	ISO 11126-8
Preparation of steel substrates before application of paints and related products – specifications for non-metallic blast-cleaning sbrasives – Part 9: Staurolite	ISO 11126-9
Preparation of steel substrates before application of paints and related products – specifications for non-metallic blast-cleaning sbrasives – Part 10: Almandite garnet	ISO 11126-10

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Switzerland

Copies can also be obtained from national standards organizations.