
**Petroleum, petrochemicals and
natural gas industries — Internal
coating and lining of carbon steel
process vessels —**

**Part 1:
Technical requirements**

*Industries du pétrole, de la pétrochimie et du gaz naturel —
Revêtement de protection interne et doublure des récipients de
production en acier au carbone —*

Partie 1: Exigences techniques



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

A list of all parts in the ISO 18796 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The objective of this document is to define the minimum technical requirements for the corrosion protection by coating/lining of internal surfaces of carbon steel process vessels used in the oil and gas industry and subject to marked pressure/temperature changes and/or acidic or other aggressive chemicals. In addition, this document provides technical guidance for developing project specifications and helps to ensure compliance in coating/lining material selection and performance with contract requirements.

Further or differing requirements can be specified for individual applications. This document does not limit the contractor and/or manufacturer from proposing, or the company from accepting, alternative engineering solutions for the individual application. This can particularly be applicable where there is an innovative or emerging technology. Where an alternative is proposed, the specification issuer will need to identify any deviation from this document and provide details.

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Petroleum, petrochemicals and natural gas industries — Internal coating and lining of carbon steel process vessels —

Part 1: Technical requirements

1 Scope

This document specifies the minimum technical requirements for surface preparation, materials, application, inspection and testing of internal coating and lining systems that are intended to be applied on internal surfaces of process vessels that are subject to marked pressure/temperature changes and/or potentially corrosive conditions or processes and aggressive chemicals, used in the oil and gas industry.

This document covers both new construction and maintenance works of process vessels as well as the repair of defective and deteriorated coating and lining systems.

This document also provides the minimum requirements for the coated and lined samples and the criteria for their approval.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2812 (all parts), *Paints and varnishes — Determination of resistance to liquids*

ISO 3233 (all parts), *Paints and varnishes — Determination of the percentage volume of non-volatile matter*

ISO 4624¹⁾, *Paints and varnishes — Pull-off test for adhesion*

ISO 7027, *Water quality — Determination of turbidity*

ISO 7619-1, *Rubber, vulcanized or thermoplastic — Determination of indentation hardness — Part 1: Durometer method (Shore hardness)*

ISO 8501-1²⁾, *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 8501-3, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 3: Preparation grades of welds, edges and other areas with surface imperfections*

ISO 8502-3, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

1) ASTM D4541 is equivalent to this document.

2) SSPC-SP5/NACE No. 1 is equivalent to this document.

ISO 8502-6³⁾, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 6: Extraction of soluble contaminants for analysis — The Bresle method*

ISO 8502-9⁴⁾, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 9: Field method for the conductometric determination of water-soluble salts*

ISO 10474⁵⁾, *Steel and steel products — Inspection documents*

ISO 11124 (all parts), *Preparation of steel substrates before application of paints and related products — Specifications for metallic blast-cleaning abrasives*

ISO 11125 (all parts), *Preparation of steel substrates before application of paints and related products — Test methods for metallic blast-cleaning abrasives*

ISO 11126 (all parts), *Preparation of steel substrates before application of paints and related products — Specifications for non-metallic blast-cleaning abrasives*

ISO 11127-6, *Preparation of steel substrates before application of paints and related products — Test methods for non-metallic blast-cleaning abrasives — Part 6: Determination of water-soluble contaminants by conductivity measurement*

ISO 16276 (all parts)⁶⁾, *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating*

ISO 19840⁷⁾, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

ISO 21809-3:2016⁸⁾, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 3: Field joint coatings*

ISO 29601⁹⁾, *Paints and varnishes — Corrosion protection by protective paint systems — Assessment of porosity in a dry film*

ISO 80000-1:2009, *Quantities and units — Part 1: General*

ASTM D522, *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*

ASTM D610, *Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces*

ASTM D714, *Standard Test Method for Evaluating Degree of Blistering of Paints*

ASTM D2583, *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*

ASTM D4060, *Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*

ASTM D4285, *Standard Test Method for Indicating Oil or Water in Compressed Air*

ASTM D4414, *Standard Practice for Measurement of Wet Film Thickness by Notch Gages*

3) SSPC-Guide 15 is equivalent to this document (together with ISO 8502-9).

4) SSPC-Guide 15 is equivalent to this document (together with ISO 8502-6).

5) EN 10204 is equivalent to this document.

6) ASTM D4541 is equivalent to this document.

7) SSPC-PA2 is equivalent to this document.

8) ASMT G42 is equivalent to this document.

9) NACE SP0188 is equivalent to this document.

ASTM F21, *Standard Test Method for Hydrophobic Surface Films by the Atomizer Test*

NACE/TM 0174, *Standard Test Method — Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials on Metallic Substrates in Immersion Service*

SSPC-SP1, *Steel Structure Painting Council Surface Preparation Specifications — Solvent Cleaning*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1.1

abrasive blast cleaning

surface preparation method that uses an abrasive propelled by air pressure, centrifugal force, or water pressure to clean and usually to profile a surface

3.1.2

application procedure specification

document describing procedures, methods, equipment and tools used for coating application

3.1.3

applicator

contractor or subcontractor having the technical capability, knowledge, equipment, qualified personnel that is approved by the client for the coating processes as required by this document

3.1.4

coat

one layer of protective coating or paint applied to the surface in a single application to form an evenly distributed film when dry

3.1.5

contractor

vendor or company that agrees to furnish materials and/or perform specific project/services to the client

3.1.6

curing

chemical process of developing the intended properties of a coating/polymerized product in the lining system, generally due to a reaction between two or more chemicals (e.g. resin and curative)

3.1.7

client

entity for which professional services are rendered or person that receives a product

3.1.8

dew-point

temperature of a given air/water vapour mixture at which condensation starts, because its maximum water content saturation is reached at that temperature

3.1.9

dry film thickness

thickness of a coat of paint, layer of tape or coating system in its fully cured condition

3.1.10

epoxy

resin containing functional epoxy groups that allow for curing by polymerization with a variety of curatives

3.1.11

grit abrasive

angular or irregularly shaped particles of abrasives

3.1.12

holiday

discontinuity in a lining or contamination in the coating film that significantly lowers the performance of a coating

Note 1 to entry: Examples of discontinuity in a lining are pinhole, void, crack, thin spot, and inclusion of foreign material.

3.1.13

lining

internal coating

Note 1 to entry: The term 'coating' is also used for the purposes of this document.

Note 2 to entry: Internal coating can be applied to the internal surfaces of a tank vessel to serve as a barrier to corrosion and/or product contamination, for example.

3.1.14

novolac

phenol-formaldehyde resin with formaldehyde to phenol molar ratio of less than 1

3.1.15

phenolic

resin of the phenol-formaldehyde type

3.1.16

pinhole

small film defect characterized by small pore like flaws in the lining that would permit corrosion of the substrate under the conditions for which the lining is designed

Note 1 to entry: A pinhole can extend entirely through the film and lead to a holiday.

3.1.17

surface profile

micro-roughness of a surface, generally expressed as the average height of the major peaks relative to the major valleys

3.2 Abbreviated terms

APS	application procedure specification
ASTM	American Society for Testing and Materials
BGAS	British Gas
BS	British Standard
CV	curriculum vitae
DFT	dry film thickness
GRUP	glass reinforced unsaturated polyester

GRVE	glass reinforced vinyl ester
GSO	Gulf Standardization Organization
HBE	high build epoxy
HSE	health, safety and environment
ISO	International Organization for Standardization
ITP	inspection and testing plan
MSDS	materials safety data sheet
NACE	National Association of Corrosion Engineers
NTU	nephelometric turbidity units
OSHA	Occupational Safety and Health Administration
PPT	pre-production trial
PQT	procedure qualification trial
QA/QC	quality assurance/quality control
QP	qualification procedure
RH	relative humidity
RP	recommended practice
SSPC	Society for Protecting Coatings
WFT	wet film thickness

4 Conformance

4.1 Rounding

Unless otherwise stated in this document, to determine conformance with the specified requirements, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with ISO 80000-1:2009, Annex B, Rule A.

NOTE For the purpose of this provision, the rounding method of ASTM E29-08 is equivalent to ISO 80000-1:2009, Annex B, Rule A.

4.2 Conformance to this document

Management systems based on ISO 9001 and ISO 14001 and good laboratory practice should be applied to assist conformance with the requirements of this document. ISO/TS 29001 gives sector-specific guidance on quality management systems.

The applicator shall be responsible for conforming to all of the applicable requirements of this document.

5 Pre-work requirements

5.1 General

5.1.1 All necessary HSE procedures shall be followed to protect personnel and the surrounding environment during on-site/field works.

5.1.2 The contractor/supplier shall submit their HSE manual for client's approval. The approved recommended procedures for safe lining processes shall be strictly followed.

5.1.3 All relevant requirements for fire safety, client's safety regulations for contractors and lifting equipment regulations shall be followed while performing work within the operation areas.

5.1.4 An MSDS shall be submitted as required.

5.1.5 All wastes resulting from supply and installation shall be contained, collected and properly disposed of in accordance with local HSE protection standards or regulations.

5.2 Safety precautions in flammable atmosphere

5.2.1 Where there is a risk of a flammable atmosphere being present in a particular vessel, the client may, with relevant safety authority, impose restrictions on methods of surface preparation based on area classification for plant design and construction/maintenance projects.

5.2.2 The contractor shall submit to the client, for approval, all necessary data for the proposed coating/lining systems, solvents and coating procedures in order to permit area classification to be determined for the duration of coating work.

5.2.3 All equipment used in surface preparation, coating/lining application and inspection, including floodlights or spotlights, shall be explosion-proof and spark-proof.

5.2.4 Prior to surface preparation, all scales shall be removed from the vessel and shall be properly weathered prior to disposal. The flammable atmosphere inside the vessel shall be monitored.

5.3 Safety precautions in confined space

The procedures for performing safe work in confined spaces shall be in accordance with the client's identified HSE regulations.

5.4 Safety precautions for blasting and coating works

5.4.1 The abrasive blast nozzle shall be bonded (grounded) to the work metal in order to prevent the build-up of electrostatic charges, which could cause a spark discharge.

5.4.2 Nozzle blast operators shall wear goggles and an approved helmet and shall be connected to a source of clean air. All other persons exposed to the blast dust and chemical fumes shall wear air-supplied respirators.

5.4.3 Any surface laps, scabs, or seams exposed by abrasive blasting shall be reported immediately to the client so they can take appropriate action.

5.4.4 Adequate fresh air ventilation shall be provided during all lining work.

5.4.5 The coating manufacturer's recommended precautions regarding toxicity and safe handling of all coating materials shall be followed. Special care shall be taken when mixing resins to avoid fire hazards. For coatings that use a promoter, catalyst and resin (such as polyesters and vinyl esters), the promoter and resin shall be mixed thoroughly before adding the catalyst.

5.5 Isolation and ventilation

5.5.1 All pipeline/piping shall be disconnected at the vessels valves and the open ends of pipes shall be blanked off and blinded. All tubular housing and conduits connected to the vessels for gauging or other instrumentation purpose shall be disconnected. Cathodic protection, if any, shall be disconnected only during the actual surface preparation and coating application works. The vessel should have provision to exhaust gases by at least two air changes per hour and vented at high level on the downwind side.

5.5.2 The vessel shall be lit and ventilated in accordance with the client's approved standards and local HSE regulations. All parts of the work shall be clearly visible.

5.6 Qualification of coating/lining application and inspection personnel

5.6.1 The coating/lining operatives shall be competent to undertake the coating application, inspection/testing procedures and repair work. The qualification may be obtained as agreed with the client or by demonstration at a PQT during PPT.

5.6.2 Inspectors and applicator personnel carrying out the coating inspection shall be competent (see [8.1.2](#)) to carry out the requirements of this document. The applicator shall request the manufacturer of the coating/lining material(s) and equipment to provide technical assistance to the coating/lining operatives, if necessary.

6 Coating/lining materials

6.1 General

6.1.1 The materials and equipment used for surface preparation, coating application, inspection and testing shall comply with the requirements of this document, the referenced standards and codes.

6.1.2 The coating/lining materials shall be delivered to the site in original manufacturer's sealed and previously unopened containers to assure the coating/lining materials are free from contaminants. The date of manufacture and expiry date shall be clearly marked thereon. The age of coating materials shall not exceed the recommended shelf life as limited by the manufacturers.

6.1.3 All coating/lining materials intended to be used should have a 5-years proven performance in the relevant service liquid or as agreed by the client. The details shall be submitted to the client for review and approval.

6.1.4 The coating work shall be undertaken by applicators, including supervisors and workers, with experience on installing the type of internal coating/lining specified, and in accordance with manufacturer's recommendations and approved by the client.

6.2 Approvals

6.2.1 All coating/lining materials and thinners in any multi-coat system shall originate from a single manufacturer. For a particular project or maintenance job, the use of different materials shall be subject to the client's written approval and the coating manufacturer's compatibility confirmation.

6.2.2 The contractor's submittal for coating/lining materials shall include details of manufacturer, composition, technical specifications and performance-based testing of the materials to be used, which complies with the requirements of this document. This shall be reviewed and approved by the client.

6.2.3 The proposed coating/lining system shall be based on the following aspects:

- a) analysis of product(s) to be stored including all major and minor constituents;
- b) temperature conditions and exposure intervals including the designed operating conditions and cyclic temperature conditions;
- c) procedures for cleaning the vessel at turnaround times (e.g. steam cleaning, and exposure time) as well as cleaning agents to be used;
- d) pressure or vacuum operation:
 - designed and operating,
 - cyclic, or
 - rapid (explosive) decompression from operating pressure;
- e) abrasion or erosion conditions including amount, particle size, and flow rates;
- f) possible damage caused by vibration, installation, welding operations, etc.;
- g) the intended internal inspection cycle (1 year, 5 years, 10 years, or other time period);
- h) condition of existing surface;
- i) coating/lining material curing time;
- j) previous experience on performance of coating system.

6.3 Procedure qualification trial (PQT)

6.3.1 Unless otherwise required by the client, the APS shall be qualified by a PQT. Test methods and acceptance criteria for the PQT are identified and specified in [6.8](#).

6.3.2 The applicator may request the manufacturer(s) to assist during the PQT to ensure the correct use of the coating/lining material(s).

6.3.3 Qualification tests shall be carried out on representative test plates.

6.3.4 All tools/equipment and material specifications used for the PQT shall be of the same type/specifications as those being used for the actual coating/lining.

6.3.5 Coating repairs of defective internal process vessel coating/lining shall be included in the PQT.

6.3.6 The applicator shall submit a complete report of the qualification test results to the client or his representative for approval.

6.4 Pre-production trial (PPT)

6.4.1 Unless otherwise required by the client, a PPT shall be performed on site to verify the following aspects:

- a) coating/lining system;

- b) coating/lining materials;
- c) coating/lining application procedure;
- d) qualification of equipment being used for surface preparation and coating application;
- e) application of the coating system;
- f) qualification of the coating operatives and inspectors that will actually be used in the field.

6.4.2 The aspects listed in [6.4.1](#) shall comply with the requirements of this document and the results of any previous PQT.

6.4.3 Test methods and acceptance criteria for the PPT are identified and specified in [6.8](#).

6.4.4 The PPT shall be carried out in the presence of the client and/or applicator (or their representative) at the start of operations when equipment and personnel are mobilized on site. The PPT shall be performed on the first test plate to be coated.

6.4.5 Unless there is previous long-term (5 years) experience demonstrating that a coating and lining is suitable for the specified process conditions, appropriate testing shall be conducted as directed by the client.

6.5 Thickness classifications of coatings

6.5.1 Thin-film coatings are applied coatings for which the total DFT is up to 250 μm (10 mils).

6.5.2 Thick-film coatings are applied coatings for which the total DFT is between 250 μm (10 mils) and 760 μm (30 mils).

6.5.3 Extra-heavy-film coatings are applied coatings for which the total DFT is greater than 760 μm (30 mils).

6.6 Holding (blast) primer

If a holding primer is to be used, it shall be part of a qualified approved coating system.

6.7 Coating and lining systems

6.7.1 There are many coating and lining systems that can be considered for the internal corrosion protection of carbon steel process vessels. Selection criteria for the suitable coating and lining system for tank internal corrosion protection should be identified and defined for guidance.

6.7.2 The coating and lining systems can be applied in multiple coats and can be ambient-temperature cured.

6.7.3 Coatings and linings are applied in the shop or field. The force curing procedure shall be strictly followed as provided by the coating/lining manufacturer and duly accepted by the client.

6.7.4 Ambient-temperature cured coatings shall not be force cured, unless the design and operation of such force curing procedure is approved by the client and the lining manufacturer.

6.7.5 The coating and lining materials shall be capable of withstanding operating conditions (e.g. service temperature, pressure and media) as specified by the client.

6.7.6 The HBE shall be capable of building up the recommended thickness without any film defects.

6.8 Material approvals — Coating and lining systems

6.8.1 Original certificates from a testing laboratory, operating in conformance with ISO/IEC 17025, shall be submitted to the client to prove that the lining, when applied in accordance with this document, meets the applicable acceptance criteria as given in [Table 1](#).

Table 1 — Acceptance criteria for approval of coating and lining systems

Properties	Test method	Acceptance criteria
Adhesion (after immersing the lining into media and temperature as specified by the client)	ISO 4624 ^a	10 MPa (1 160 psi) (under de-pressurization conditions). The rate of de-pressurization and pressure conditions for testing shall be based on requirement of the client's specific service conditions
Atlas cell testing	NACE/TM 0174, Method A (6 months)	ASTM D714 (no blisters) ASTM D610 (9 or better)
Cathodic disbondment	ISO 21809-3:2016, Annex G ^b	Maximum allowable radius of disbondment shall be 15 mm or by agreement
Solids content (non-volatile matter)	ISO 3233 (all parts)	As per coating manufacturer and client agreement
Immersion test	ISO 2812 (all parts) as applicable	No defects after the immersion of 6 months in relevant media and temperature
Flexibility test	ASTM D522	As per coating manufacturer and client agreement
Hardness, Barcol	ASTM D2583	As per coating manufacturer and client agreement
Hardness, shore-D	ISO 7619-1 ^c	As per coating manufacturer and client agreement
Abrasion resistance	ASTM D4060 (1 000 cycles, CS17 wheel, 1 kg load)	As per client's specific service conditions and by agreement
^a For the purpose of this provision, ASTM D4541 is equivalent to ISO 4624. ^b For the purpose of this provision, ASMT G42 is equivalent to ISO 21809-3. ^c For the purpose of this provision, ASTM D2240 is equivalent to ISO 7619-2.		

6.8.2 The quality of coating and lining work is subject to client's approval. The contractor shall submit a sample plate for client's testing and analysis.

6.8.3 For each different coating type, the applicator shall prepare a sample plate in accordance with this document for product and applicator qualification on each project. Upon curing of the lining, the sample shall be subjected to tests as specified in [Table 1](#) and to the client's satisfaction.

6.8.4 The sample plate, to which the coating and lining system will be applied, shall be steel plate measuring 900 mm (±5 mm) × 900 mm (±5 mm) × 6 mm (±0,5 mm), on which a vertical plate shall be welded at one side of height 300 mm (±5 mm). The plate shall be abrasive blasted and coated, in accordance with the technical specification of the lining system to be tested. Within a 150 mm square in one corner on the side that is not primed the name of the contractor and the date the sample is delivered to the client shall be clearly printed or marked. The client may request pre-qualifications of more samples of complex shapes as detailed in ASTM D4228.

6.8.5 Sample plates testing procedures.

Upon completion of coating and lining system application and the specified curing time, the sample shall be subjected to the following tests.

a) Non-destructive testing

1) Visual inspection

The sample plant shall be thoroughly inspected visually for general conditions of the surface finish and any recognized coating defects, for example, delamination, checking, cracking, pinholes.

2) Thickness measurements

The DFT shall be checked at the four corners of the plate using a micrometre and other random readings shall be measured by suitable thickness gauge.

3) Holiday detection test

Pinhole detection test of the lining shall be carried out by suitable high voltage holiday (spark) testing instrument at a set voltage as required by ISO 29601.

NOTE 1 For the purpose of this provision, NACE/SP 0188 is equivalent to ISO 29601.

b) Destructive testing

1) Adhesion test

The adhesion test shall be carried out in accordance with ISO 4624 after immersing the sample plate in media and temperature as specified by the client.

NOTE 2 For the purpose of this provision, ASTM D4541 is equivalent to ISO 4624.

2) Hardness test

The hardness of the coating/lining shall be checked at 10 different random locations using the instrument recommended by the coating/lining manufacturer. A minimum of 10 random readings shall be recorded in the test record. Barcol hardness testing and hardness Shore D are two different test methods recognized by the industry and each test has a different scale. Barcol hardness testing shall be in accordance with ASTM D2583 and hardness Shore D testing shall be in accordance with ISO 7619-1.

NOTE 3 For the purpose of this provision, ASTM D2240 is equivalent to ISO 7619-1.

6.8.6 Acceptable limits.

The results of the tests explained in 6.8.5 shall meet the acceptance criteria as given in [Table 1](#).

7 Surface preparation

7.1 General

The surfaces to be coated/lined shall be prepared and cleaned in accordance with the requirements of [7.2](#) to [7.4](#) before any coating/lining work begins.

7.2 Preparations

The vessel shall be de-sludged and thoroughly cleaned to remove scale, salt, dirt, existing/temporary protective paint, and chalk and residues. Degreasing shall be carried out using vapour degreasing equipment or appropriate solvent in accordance with SSPC-SP1. Degreasing detergent shall be of an emulsifying type.

7.3 Patching, grinding, degreasing and washing (for new and rehabilitation works)

7.3.1 All welds shall be continuous. No skip welding is permitted. All existing skip welds shall be upgraded to continuous welds.

7.3.2 Surface irregularities, like weld spatter, sharp protrusions, slivers and porosity, shall be removed completely (made flush or ground smooth) in accordance with ISO 8501-3, (P3). All sharp outside corners and edges shall be rounded in accordance with ISO 8501-3, (P3). Any other observed defects in welds and base metal should be referred to client for disposition.

7.3.3 Prior final surface preparations, the steel substrate shall be tested for soluble salts contamination in accordance with ISO 8502-6 and ISO 8502-9, or client's approved standards and test equipment. In case of soluble salts contamination (residual soluble salts) on the surfaces that exceeds 20 mg/m² for new construction and 40 mg/m² for maintenance work, fresh water washing at minimum pressure, as agreed by client and manufacturer, shall be carried out, prior to take-up any coating works. This shall include sweep-blasting operation (fresh water conductivity reading of maximum 100 µS/cm). A chemical additive with demonstrated capability to remove salts can be used in the water wash, if agreed by the client.

NOTE For the purpose of this provision, SSPC-Guide 15 is equivalent to ISO 8502-6 and ISO 8502-9.

7.3.4 Those surfaces that are, or are likely to be contaminated with oil or grease shall be solvent cleaned with solvent using rags (for small areas), or a spray gun (for large areas), in accordance with SSPC-SP1. The solvent-cleaned surfaces shall then be thoroughly washed down with fresh water ensuring that the oil-water emulsion formed is completely removed from the metal.

7.3.5 Degreased and water-washed surfaces shall be checked for residual oil and grease using the atomized water spray test in accordance with ASTM F21, and further degreasing shall be carried out if residual oil or grease is found to be present. A black light test shall be used to check for oil contamination.

7.3.6 If required, washing shall be with fresh water containing an approved degreasing agent and even solvent washing of partially coated components shall take place between coats.

7.4 Dry abrasive blasting cleaning

7.4.1 Prior to the start of blasting, the contractor shall select an appropriate abrasive type and mesh size to attain the specified surface profile. Only approved garnet or grit abrasives shall be used. Sand or copper slag shall not be used as an abrasive material for blast cleaning. The abrasive shall be used in accordance with the manufacturer's specifications, shall contain no impurities and shall be in accordance with ISO 11124 (all parts), ISO 11125 (all parts) and ISO 11126 (all parts).

7.4.2 For environmental reasons, only garnet abrasive shall be used for offshore blast cleaning, unless approved by the client and local environmental regulations. If a recyclable abrasive is proposed, the recycling equipment, procedure and quality control testing measures to be employed shall be reviewed and approval by the client before its use can be required. Neither sand nor contaminated recycled abrasive are under any circumstances allowed for blast cleaning. If the abrasive is re-circulated, it shall be checked for contamination at least twice per shift, in accordance with [10.4.2](#).

7.4.3 The contractor may be requested to demonstrate to the client's satisfaction that the selected abrasive will provide the specified surface profile and visual standard. This shall be done by blasting a representative piece of steel, then measuring the surface profile in accordance with ISO 8503-5 (replica tape method) or ISO 8503-4 (stylus method) and comparing the surface finish to the appropriate visual standard. The blasted surface shall conform to the appropriate visual job site standard, when viewed without magnification.

NOTE For the purpose of this provision, NACE RP0287 and ASTM D4417 are equivalent to ISO 8503-5.

7.4.4 Unless otherwise specified by the coating manufacturer and the client, the metal substrate shall be abrasive blast cleaned to a visual standard Sa 3 in accordance with ISO 8501-1 for new constructions and to Sa 2½ for maintenance work. The surface profile height shall be as specified in coating system data sheet.

NOTE For the purpose of this provision, SSPC-SP5/NACE No. 1 is equivalent to ISO 8501-1.

7.4.5 Blast cleaning combined with vacuum collection at the nozzle can be used to reduce atmosphere contamination.

7.4.6 The compressed air used in any cleaning method shall be free of water and oil.

7.4.7 Adequate after cooler shall be fitted with suitable traps, separators and filters, which shall be regularly emptied of water and oil. Any accumulated moisture and oil in the air receiver vessel shall be removed by regular air purging. The air compressor shall under no circumstances be allowed to operate at temperatures in excess of 110 °C. The air supply shall be checked for water and oil contamination in accordance with the procedure specified in ASTM D4285 prior to blast cleaning and regularly throughout blast cleaning operations. The air supply shall be tested daily for cleanliness using a white absorbent paper or cloth test in accordance with [10.4.1](#). The compressed air supply used for dry blast cleaning shall be of sufficient pressure and volume to enable rapid and efficient cleaning rates to be achieved. Blast cleaning shall always be carried out at a minimum nozzle air pressure of 7 barg (100 psig), as measured with a hypodermic needle gauge.

7.4.8 All surfaces to be lined shall be cleaned to remove any dust, sand, debris, etc. by using industrial vacuum cleaner just prior to lining application. The surfaces shall be tested for the presence of residual particulate matter in accordance with the procedure specified in ISO 8502-3. The maximum acceptable size and quantity of retained matter shall be Class 2, rating 2. All reasonable steps should be taken to keep the metal surfaces dry and to prevent contamination or damage of the blast cleaned surface as they are subject to client's approval prior to priming.

7.4.9 Blast cleaned surfaces shall be coated within four hours of cessation of blast cleaning and before any visible rusting, discoloration, or other surface contamination occurs. The work shall be planned to ensure that this requirement is always met. The time before coating can be extended, if adequate dehumidification is used. Blasting shall be accomplished so that previously coated surfaces are not contaminated by abrasive or rust.

7.4.10 Weather conditions shall be monitored prior to and periodically according to the approved ITP throughout the work period. Dry blast cleaning shall only be carried out if the RH of the air is less than 85 % and the metal temperature is 3 °C above the dew point.

7.5 Humidity control

7.5.1 Appropriately sized dehumidification equipment may be installed and operated from the beginning of abrasive blasting operation and kept in continual operation until the final coat of the lining has passed the hardness reading as required by the lining manufacturer. The RH inside the vessel shall be maintained below 50 % at all times when dehumidifier is used.

7.5.2 In the event of a breakdown or interruption of the dehumidification equipment that results in the RH rising above 50 %, any surface area that exhibits flash rusting shall be re-blasted to achieve the required condition of ISO 8501-1 (Sa 3), unless otherwise specified and agreed by coating/lining manufacturer and client.

NOTE For the purpose of this provision, SSPC-SP5/NACE No. 1 is equivalent to ISO 8501-1.

7.5.3 The dehumidification equipment shall be capable of operating with connected heaters and ventilation when necessary to maintain a temperature range between 15 °C and 35 °C during blasting and lining operations. Guidelines for the use of such equipment are included in SSPC-TR3/NACE 6A192.

7.6 After blast cleaning

7.6.1 Following completion of abrasive blasting, the surface shall be brushed with a clean hair bristle or fibre brush, blown with compressed air and then vacuumed. The dust embedded on the cleaned surface shall be tested in accordance with [10.5.3](#).

7.6.2 The blast-cleaned surface shall be checked for the presence of soluble salts in accordance with [10.5.4](#).

7.6.3 A surface holding primer can be applied, in accordance with manufacturer's recommendation and client agreement, in order to hold the blasted surface for a short period until the blasting and cleaning is completed, unless dehumidification equipment is operated with a RH less than 50 % during the entire surface preparation operation. Only a primer approved by the manufacturer of the coating/lining material can be used based on the project needs.

7.6.4 All personnel entering the vessel after abrasive blasting shall wear rubber-soled shoes with clean, disposable shoe covers, sweatbands and lint-free gloves.

7.6.5 No acid washes or other cleaning solutions or solvents, including inhibitive washes intended to prevent rusting, shall be used on metal surfaces after being blasted, unless a written client's approval is obtained.

7.6.6 A minimum of 100 mm (4 inches) around the edges of blasted areas shall be left un-primed if the entire surface to be coated cannot be blasted and primed on the same day. Subsequent blasting shall continue a minimum of 25 mm (1 inch) into the primed surfaces. The rough edge shall then be feather edged by power tool or hand sanding with heavy grit wheel or sandpaper. The surface to be coated shall be free of loose and/or burnt coating.

8 Coating/lining application

8.1 General requirements

8.1.1 Coating/lining works shall be in accordance with the requirements specified by this document and the recommendations of the coating manufacturer.

8.1.2 The contractor shall verify that craft workers show proof of formal training and demonstrate that they are experienced and qualified to carry out the required work. All persons that carry out the work shall possess proof of competency from the lining system manufacturer. The applicator shall appoint a competent coating inspector (such as NACE/BGAS/I-Cor/SSPC/FROSIO) to be responsible for the proper application of the lining system.

8.1.3 The surfaces to be coated shall be inspected and approved prior to any coating being applied. This shall be done after surface preparation and between each subsequent coating. No primer or coating shall be applied without approval.

8.1.4 The application shall be carried out under controlled conditions and all necessary precautions shall be taken to ensure that water does not come in contact with uncured coatings. This is to obtain best adhesion and ultimate chemical resistance of the coating.

8.1.5 The quality of lining work is subjected to client approval. The contractor shall submit a sample plate for client's shop testing and analysis, as described in [6.8.5](#).

8.1.6 The coating and lining systems to be used and the areas to be coated and lined for each vessel should be specified by the client's project specification.

8.2 Application of environmental conditions

Coatings/lining shall be applied in the following weather conditions:

- a) ambient temperatures as per coating manufacturer's written parameters, typically above 10 °C for conventional lining;
- b) RH: less than 85 %;
- c) dew-point: steel temperature is 3 °C above the dew-point for prevailing environmental condition.

8.3 Primer application

8.3.1 The surfaces to be coated shall be clean, dust free and dry before application of any coating and shall meet the specified anchor pattern and surface finish before application of specified primer.

8.3.2 The entire blast cleaned area shall be sprayed with a primer coat. Primer application shall be in accordance with the manufacturer's instructions with respect to application conditions, thickness and suitability for topcoats.

8.3.3 Prior to the application of the full coat of specified primer and each succeeding coat of paint, all edges, corners, crevices, welds, holes, bolts, rivets and pitted areas shall be stripe painted with the appropriate paint material by brush, ensuring that the material is worked firmly into the metal surfaces. These stripe-coated areas shall extend a minimum of 25 mm from the relevant feature. Rollers shall not be used for strip coating.

8.4 Coating/lining thickness

8.4.1 Each individual coat should be checked for WFT, during application in accordance with ASTM D4414. After application and curing, DFT shall be measured with an approved magnetic or eddy current film thickness gauge as applicable to the substrate. Stainless steel substrates require different testing equipment. The measurement shall be in accordance with ISO 19840. The DFT gauge shall be calibrated at the beginning of coating work, and then at least daily or whenever required by the client. DFT shall be recorded and submitted to the client for primer coat as well as for the total thickness of coating/lining system.

NOTE For the purpose of this provision, SSPC-PA2 is equivalent to ISO 19840.

8.4.2 The DFT shall be checked after each coat for conformance with [10.6.2](#).

8.4.3 The number of coats shall not be less than the specified agreed, and the film thickness of individual coats shall be within the specified thickness range. All coating film thicknesses shall be checked, and coating films shall be free of voids, bubbles, runs or sags, and other visible defects.

8.4.4 Where coating film thickness does not meet the client's approved standards, or defects (holidays) are found, the contractor shall take corrective action in accordance with the client's agreed procedure.

9 Coating/lining application

9.1 The surface preparation shall be carried out in accordance with the requirements of [Clause 7](#) before coating application. Prior to the application of any coat, all damage to previous coats shall be repaired.

9.2 The coating manufacturer's recommended pot life shall not be exceeded. When this limit is reached, the spray pot shall be emptied and cleaned, materials shall be destroyed, and new material shall be mixed.

9.3 The coating shall be mixed in proper ratios in accordance with the manufacturer's recommendations and no part mixing shall be allowed. Multi-component shall be accurately measured and mixed in accordance with the manufacturer's directions. No more thinning shall be used than the manufacturer's recommendations.

9.4 Each coat (primer, first coat, and topcoat) shall be applied uniformly and completely using contrasting colours over the entire surface according to the accepted good coating practice. Care shall be taken to prevent over spray, spillage or application of coatings to surfaces for which the coatings are not intended. Each coat shall be inspected before applying further coats.

9.5 Stripe coats shall be applied by brush on all weld areas and sharp corners. All inaccessible areas where it is not practical to apply by spray can be coated by brush.

9.6 Spray coat shall be applied with the recommended pressure and the thickness controlled by measuring WFT in proper intervals. The manufacturer's recommended over coating or recoating intervals shall be strictly followed.

9.7 After application of the complete coating system, it shall be allowed to fully cure in accordance with the manufacturer's recommendations before the component is handled or moved. If the paint does not cure within the recommended period, a sample shall be removed to ascertain the cause of the problem.

9.8 The coating/lining shall be allowed to cure in well-ventilated dry conditions and in accordance with the manufacturer's instructions for curing, after successful inspection and before the vessel comes into service. Dehumidification should be used as required.

9.9 Curing time shall be dependent on the ambient temperature and shall be in accordance with the manufacturer's recommendations.

9.10 The forced curing procedure shall be strictly followed and shall be as recommended by the coating/lining manufacturer and duly accepted by the client.

10 Inspection and testing

10.1 General requirements

10.1.1 The applicator shall perform inspection and testing during the application in accordance with the client's approved ITP to verify the surface preparation, coating/lining application and the specified properties of the applied coating/lining. The ITP shall be prepared by the applicator and shall be reviewed and approved by the client prior to the start of the coating work. The ITP shall identify all inspection activities and tests, their frequency and the relevant inspection authorities. The plan shall include all activities in chronological order and shall have columns for marking up client, witness (W), hold (H), surveillance (S) and review (R) points.

10.1.2 Inspection and testing at all stages of surface preparation and coating/lining application shall be conducted as agreed by the applicator and client to ensure that the coating/lining work complies with the requirements of this document.

10.1.3 Surface preparation and coating/lining application may be subjected to inspection at any stage to ensure compliance with all requirements of this document. All records, inclusive of products and procedures used during the installation of the coating/lining, shall be kept current and shall be submitted to the client on a daily/weekly basis or upon request, and at the completion of the job for the client's verification.

10.1.4 A client's representative shall have the right to inspect at all times any tools, materials or equipment used in the performance of surface preparation and coating/lining application. This is to ensure compliance with the requirements of this document.

10.1.5 The coating manufacturer's representative shall have access to the work site during the progress of the work for any inspection and testing deemed to be necessary to ensure that coating/lining system is properly applied.

10.2 Environmental conditions testing

At the beginning of each day's operation and prior to the commencement of any coating/lining application work, and twice every shift, ambient temperature, metal surface temperature and RH shall be measured and recorded. Readings shall comply with [8.2](#). The surface to be coated/lined shall be inspected to verify that no moisture is present.

10.3 Materials and equipment inspection

10.3.1 Abrasive blasting and coating/lining application equipment (airless spray pump, hoses, etc.) shall be inspected to ensure compliance with the requirements of this document and the manufacturer's recommendations.

10.3.2 The contractor shall submit a list of QA/QC equipment intended to be used for coating/lining along with valid calibration certificates.

10.4 Compressed air and abrasive

10.4.1 The cleanliness of each compressed air supply shall be verified daily before blasting and coating operations in accordance with ASTM D4285.

10.4.2 The abrasive used shall be tested for the presence of contaminants such as water soluble salts, dirt, clay, oil, grease and other foreign materials in accordance with ISO 11127-6. Water used for cleanliness of the abrasive shall be tested in accordance with ISO 7027. Maximum reading for turbidity is 25 NTU.

10.4.3 Re-circulated abrasives shall not be used.

10.5 Surface preparation inspection

10.5.1 Surfaces to be coated/lined shall be inspected to verify that the specified surface preparation has been achieved as described in [10.5.2](#) to [10.5.5](#).

10.5.2 Prior to abrasive blasting, the steel surface shall be checked for the presence of defects and contaminants (e.g. oil/grease, sand/dust, weld spatter, and weld slag).

10.5.3 After abrasive blast cleaning, the steel surface shall be inspected for surface cleanliness in accordance with ISO 8501-1 and surface profile shall be measured in accordance with ISO 8503. The measurements and results shall be recorded and submitted for client's approval.

10.5.4 Blast cleaned surfaces shall be checked for the presence of soluble salts in accordance with ISO 8502-6 and ISO 8502-9, using approved methods and test equipment. The soluble salts contamination shall not exceed 20 mg/m² for new construction and 40 mg/m² for maintenance work.

NOTE For the purpose of this provision, SSPC-Guide 15 is equivalent to ISO 8502-6 and ISO 8502-9.

10.5.5 The dust embedded on the cleaned surface shall not exceed Class 2 and rating 2 in accordance with ISO 8502-3.

10.6 Coating/lining inspection and testing

10.6.1 General

Coated/lined surfaces shall be inspected/tested in accordance with [10.6.2](#) to verify that the specified quality and thickness have been achieved.

10.6.2 Lining film thickness

The DFT of coats/lining shall be measured in accordance with ISO 19840. The minimum required DFT of each system shall be as presented below in [Table 2](#). The manufacturer can recommend alternate DFT subject to performance of the coating system and the client's agreement.

NOTE For the purpose of this provision, SSPC-PA2 is equivalent to ISO 19840.

Table 2 — Minimum required number of coats and DFT for epoxy coating/lining (as example)

System	No. of coats	Minimum thickness per coat μm	Minimum total thickness ^a μm
Phenolic epoxy	2	125	250
Novolac epoxy	2	250	500
High build epoxy	2	200	400
Solvent free epoxy	2	200	400

^a Without the thickness of surface holding primer.

10.6.3 Holiday detection test

The fully applied and cured lining system shall be tested for pinholes and holidays using an approved type holiday detector in accordance with ISO 29601 and manufacturer's recommendations. This shall be carried out over the entire (100 %) lined surface.

NOTE For the purpose of this provision, NACE/SP 0188 is equivalent to ISO 29601.

In case of any required repair, the repaired areas shall be re-tested for holidays. Detected holidays, correction, and final holiday-free inspection shall be recorded and submitted for approval.

10.6.4 Curing test

Test for cure shall be in accordance with the manufacturer's recommendation. Generally, thicker films are tested for cure by Shore D hardness readings while thin film coatings can be tested for cure by solvent rub test. If using the solvent rub test, it shall be in accordance with ASTM D5402. Precautions shall be taken when selecting solvents for flammability hazards, especially if used in a confined space.

10.7 Adhesion test

Adhesion testing on the prepared sample plate during the application of the coating/lining shall be carried out in accordance with ISO 16276-1 after immersing the sample plate in water (60 °C) for 24 hours.

NOTE For the purpose of this provision, ASTM D4541 is equivalent to ISO 16276-1.

11 Quality requirements

11.1 The manufacturer/contractor should operate a quality management system to satisfy the requirements of this document. ISO 9001 or ISO/TS 29001 can be considered as guidance.

11.2 Prior to commencement of work, the contractor shall submit its QA/QC documentation for approval in accordance with the requirements of the client. This shall include the quality plan and quality control system including inspection and testing methods and reporting/recording formats.

11.3 The contractor shall prepare and submit to its client for approval a detailed procedures manual of all work, sufficiently in advance before commencement, outlining at least the following.

- a) Manufacturer's details, equipment full details, characteristics, data sheets and test certificates.
- b) Full details of past projects, records of proposed surface preparation and lining applications. Such information shall include the name of the project, service conditions and any other details required by the client.
- c) Certificates from a testing laboratory operating in accordance with ISO/IEC 17025, indicating that the materials and equipment used in surface preparation and coating/lining application comply with an internationally recognized standard and the client requirements.

11.4 Inspection and testing plans for surface preparation and coating/lining applications shall satisfy the client's requirements.

11.5 Sample log sheets of material receipts, measurements, logging and dispatches shall be provided by the contractor for the client's approval.

11.6 The work/supply shall commence only after approval of the quality system procedures, manual and supply datasheets. After approval, any changes made shall be authorized in writing by the client.

11.7 Only qualified skilled and experienced personnel shall be employed to meet the required duties in this document. CVs of these personnel shall be provided for the client's approval. Adequate supervision shall be employed at all times.

11.8 The client reserves the right to conduct a quality audit at the manufacturer's/suppliers'/contractors' facilities at any stage during work execution or supply.

12 Documentation

12.1 General

12.1.1 All dimensions, units of measurement, physical constants, etc. shall be in SI units, unless otherwise specified.