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Oil and gas industries including lower carbon energy — Internal coating and lining of steel storage tanks

Industries du pétrole et du gaz y compris les énergies à faible teneur en carbone — Revêtement intérieur et doublure interne des réservoirs de stockage en acier

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Foreword

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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 document 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).

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This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16961:2015), which has been technically revised.

The main changes are as follows:

— inclusion of lining selection criteria (Clause 6);

— update of requirements for non-exposure and exposure tests (Clause 6);

— clarification of the requirements in a pre-production trial (Clause 6);

— update of the typical thicknesses based on industry standards (Clause 8);

— update of references throughout this document.

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 objectives of this document are to define technical requirements for the corrosion protection by coating and lining of internal surfaces of steel storage tanks, to provide technical guidance for developing local standards and specifications, and to ensure conformance in coating and lining material selection and performance with contract requirements.

Where an alternative is proposed, the specification issuer needs to identify any deviations from this document and provide details.

Oil and gas industries including lower carbon energy — Internal coating and lining of steel storage tanks

1 Scope

This document specifies requirements for surface preparation, materials, application, inspection and testing of internal coating lining systems that are intended to be applied on internal surfaces of steel storage tanks of crude oil, hydrocarbons and water for corrosion protection.

It covers both new construction and maintenance works of tank internal coating and lining as well as the repair of defective and deteriorated coating/lining.

This document also provides requirements for shop performance testing of the coated/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 2808, *Paints and varnishes — Determination of film thickness*

ISO 2812-1, *Paints and varnishes — Determination of resistance to liquids — Part 1: Immersion in liquids other than water*

ISO 4624, *Paints and varnishes — Pull-off test for adhesion*

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 7027 (all parts), *Water quality — Determination of turbidity*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 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)*

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

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

ISO 8503-2, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel — Comparator procedure*

ISO 8503-5, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 5: Replica tape method for the determination of the surface profile*

ISO 8573-1, *Compressed air — Part 1: Contaminants and purity classes*

ISO 11124 (all parts), *Preparation of steel substrates before application of paints and related products — Specifications 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 11127-7, *Preparation of steel substrates before application of paints and related products — Test methods for non-metallic blast-cleaning abrasives*

ISO 12944-3, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 3: Design considerations*

ISO 12944-9:2018, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures*

ISO 15234, *Paints and varnishes — Testing of formaldehyde-emitting coatings and melamine foams — Determination of the steady-state concentration of formaldehyde in a small test chamber*

ISO 15711, *Paints and varnishes — Determination of resistance to cathodic disbonding of coatings exposed to sea water*

ISO 19840, *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 29601, *Paints and varnishes — Corrosion protection by protective paint systems — Assessment of porosity in a dry film*

ISO 80000-1:2022, *Quantities and units — Part 1: General*

API RP 652, *Lining of Aboveground Petroleum Storage Tank Bottoms*

API Std 653, *Tank Inspection, Repair, Alteration and Reconstruction*

API Std 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*

ASTM A380, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

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

ASTM D570, *Standard Test Method for Water Absorption of Plastics*

ASTM D790, *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

ASTM D2240, *Standard Test Method for Rubber Property—Durometer Hardness*

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 Abrader*

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

ASTM D5402, *Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs*

ASTM D6943, *Standard Practice for Immersion Testing of Industrial Protective Coatings and Linings*

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

ASTM G42, *Standard Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures*

EN 14020 (all parts), *Reinforcements — Specification for textile glass roving's*

NACE TM0304, *Offshore Platform Atmospheric and Splash Zone Maintenance Coating System Evaluation*

NACE TM0404, *Offshore Platform Atmospheric and Splash Zone New C*

SSPC Guide 12, *Guide for Illumination of Industrial Painting Projects*

SSPC-Guide 15, *Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates*

PAINTING MANUAL VOL SSPC, 1

SSPC-SP 1, *Steel Structure Painting Council Surface Preparation Specifications — Solvent Cleaning*

SSPC-SP 11, *Surface Preparation Standard, Power-Tool Cleaning to Bare Metal*

3 Terms, definitions and abbreviated terms

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
application procedure specification
document describing procedures, methods, equipment and tools used for *coating* (3.1.7) application

3.1.2
applicator
contractor (3.1.8) or subcontractor having the technical capability, knowledge, equipment and qualified personnel that is approved by the *client* (3.1.5) for the *coating* (3.1.7) processes according to specific requirements

Note 1 to entry: The requirements are given in this document.

3.1.3
C glass
glass fibre that provides greater resistance to chemicals and is used in advanced composites

Note 1 to entry: C glass is mainly used in the form of surface tissue in the outer layer of laminates used in chemical and water pipes and tanks.

3.1.4
caulking
process of applying a 98 % to 100 % solid catalysed *epoxy* (3.1.13) material on tank internal surfaces to fill pores/pits or to cover weld seams, lap joints, large projections, connections, etc.

Note 1 to entry: This is to provide a uniform gradual transition and smooth surfaces.

Note 2 to entry: The 98 % to 100 % solid catalysed epoxy material is referred to as the caulking compound.

3.1.5
client
party or organization for which professional services are rendered or person that receives a product

3.1.6
coat
paint, varnish or lacquer applied to surface in a single application (one layer) to form an evenly distributed film when dry

3.1.7
coating
lining
material applied to the internal surfaces of a tank to serve as a barrier to corrosion and/or product contamination

3.1.8
contractor
vendor company or business that agrees to furnish materials and/or perform specific project/services to *client* (3.1.5)

3.1.9
curing
chemical process of developing the intended properties of a *coating* (3.1.7) or polymerized product in the lining system

Note 1 to entry: Curing is generally due to a reaction between two or more chemicals (e.g. resin and curing compound).

3.1.10
dew point
temperature of a given air/water vapour mixture at which condensation starts, since its maximum water content saturation is reached at that temperature

3.1.11
dry abrasive blast cleaning
surface preparation method that uses an abrasive propelled by air pressure, centrifugal force, to clean and provide a *surface profile* (3.1.21)

3.1.12
dry film thickness
DFT
thickness of a *coat* (3.1.6) or *coating* (3.1.7) system in its fully cured and dry condition

3.1.13
epoxy
resin containing epoxide functional groups that allow for *curing* (3.1.9) by polymerization with a variety of curing agents

3.1.14
fibreglass reinforced lining
resin lining, usually polyester, vinyl ester or epoxies, into which layers of fibreglass are incorporated to enhance the lining's structural capability, corrosion and chemical resistance performance

3.1.15
fibre mat
woven glass fibre that is used as reinforcement of the thermosetting resin [e.g. *epoxy* (3.1.13)] lining to repair and/or add strength to tank bottoms

3.1.16
gel coat
final *coat* (3.1.6) applied over the fibreglass lining laminate to seal the laminate surface and enhance water and hydrocarbon resistance

3.1.17
holiday
discontinuity in a lining or contamination in the *coating* (3.1.7) film that significantly lowers the dielectric strength of the coating

Note 1 to entry: Examples of a discontinuity in a lining are a *pinhole* (3.1.19), void, crack, thin spot, and inclusion of foreign material.

3.1.18
manufacturer
company responsible for the manufacture of *coating* (3.1.7) material(s)

3.1.19
pinhole
small film defect characterized by small pore-like flaws in the lining that will 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 to the substrate and lead to a *holiday* (3.1.17).

3.1.20
pre-production trial
application of *coating* (3.1.7) and inspection/testing of its properties, to confirm that the *application procedure specification* (3.1.1) is able to produce a coating with the specified properties

3.1.21
surface profile
micro-roughness of a surface

Note 1 to entry: Surface profile is generally expressed as the average height of the major peaks relative to the major valleys, and sometimes referred to as amplitude.

3.2 Abbreviated terms

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CV	curriculum vitae
DFT	dry film thickness
GRE	glass reinforced epoxy
GRUP	glass reinforced unsaturated polyester
GRVE	glass reinforced vinyl ester
HBE	high build epoxy
HSE	health, safety, and environment

ITP	inspection and testing plan
MSDS	materials safety data sheet
NACE	National Association of Corrosion Engineers
PPE	personal protective equipment
PPT	pre-production trial
PQT	procedure qualification trial
QA/QC	quality assurance/quality control
QP	qualification procedure
RH	relative humidity
RP	recommended practice
SSPC	the Society for Protecting Coatings
WFT	wet film thickness

4 Conformance

4.1 Rounding

Unless otherwise stated in this document, 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 80000-1:2022, Annex B, Rule A.

NOTE For the purpose of this provision, the rounding method of ASTM E29–08 is equivalent to ISO 80000-1:2022, Annex B, Rule A.

4.2 Conformance to this document

A quality system should be applied to assist conformance with the requirements of this document. ISO 29001 gives sector-specific guidance on quality management systems.

The applicator shall conform with all applicable requirements of this document. It shall be permissible for the client to make any investigations necessary in order to be ensured of conformance by the applicator and to reject any material that does not conform.

5 Pre-work requirements

5.1 General

5.1.1 All necessary health, safety and environment (HSE) procedures shall be employed to protect personnel and the surrounding environment during on-site/field works.

5.1.2 The contractor shall submit its HSE manual for client's approval. The contractor shall strictly follow the approved HSE manual for the safe lining processes.

5.1.3 Adherence to all relevant safety requirements are required while performing coating and lining works.

5.1.4 Materials safety data sheets (MSDS) for all chemicals to be used within operation areas shall be submitted for review and approval by the client. Health and safety precautions shall be clearly described on each chemical container/package.

5.1.5 All wastes resulting from supply and application shall be contained, collected and properly disposed of.

NOTE Environmental protection regulations can apply.

5.2 Safety precautions in flammable atmosphere

5.2.1 Where there is a risk of flammable atmosphere being present in a particular tank, the client may impose restrictions on methods of surface preparation.

5.2.2 The client shall advise on the hazardous area classification for plant design and construction/maintenance projects.

5.2.3 The contractor shall provide the client with all necessary data for the proposed coating/lining systems, solvents and coating procedure in order to permit area classification to be determined for the duration of coating work. Special care shall be observed when mixing resins to avoid fire hazards.

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

5.3 Qualification of coating/lining application and inspection personnel

5.3.1 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 procedure qualification trial (PQT) during pre-production trial (PPT).

5.3.2 Inspectors and applicator personnel carrying out the coating inspection shall be competent. 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.

5.4 Positive isolation and ventilation

5.4.1 All pipeline/piping shall be disconnected at the tank valves and the open ends of pipes shall be blanked off. All tubular housing and conduits connected to the tanks for gauging or other instrumentation purpose shall be disconnected. Cathodic protection system shall be disconnected only during the actual surface preparation and coating application works. The tank shall have provision to exhaust gases from the tank by at least two air changes per hour and vented at high level on the downwind side. Local and national HSE regulations on exhaust and ventilation can apply.

5.4.2 The tank should be lighted in accordance with SSPC Guide 12 and should be ventilated. Any client-related standards shall take precedence. All parts of the work shall be clearly visible.

6 Coating/lining materials

6.1 General

6.1.1 Typical coating and lining systems include, but are not limited to, high build solvent free glass-flake filled coating, hand lay fibreglass reinforced lining (e.g. GRE, GRVE, GRUP), solvent free epoxy, phenolic epoxy, epoxy novolac and high build epoxies.

6.1.2 All coating/lining materials shall be free of foreign elements and contaminants. The expiry date of materials components shall not exceed the recommended shelf-life as limited by the manufacturers.

6.1.3 The coating/lining materials shall be delivered to the site in original manufacturer's sealed un-opened containers with batch number, date of manufacture and expiry date clearly marked thereon.

6.1.4 Coatings/linings with proven performance and track record, in the intended service, can be used by agreement with the client and manufacturer.

6.1.5 The coating and lining systems to be used and the areas to be lined for each tank shall be identified/specified by the client project specification and equipment data sheet.

6.1.6 The following data shall be provided for the selection of the appropriate coating/lining for the service:

a) design and operating temperature range (i.e. minimum and maximum temperature), expressed in °C or F;

b) design and operating pressure range (i.e. minimum and maximum pressure), expressed in MPa;

c) substrate material (i.e. carbon steel or stainless steel);

d) extent of pitting for maintenance projects and existing coating/lining condition;

e) composition of tank fluid including all impurities, solids, sludges, gases, etc., and pH;

f) whether an internal cathodic protection is in operation.

6.1.7 The coating work shall be undertaken by applicators, approved by the client, with experience on installing the type of internal coating/lining specified as per manufacturer's instructions and product data sheets.

6.2 Approvals

6.2.1 All coating/lining materials and thinners in any (multi-coat) system shall be manufactured by a single manufacturer to avoid any incompatibility issues. For a particular project or maintenance work, the use of different materials shall be subject to the client's and manufacturers' written approval.

6.2.2 The contractor's submittal of coating/lining materials, for the client's review and approval, shall include details of the manufacturer, technical specifications/datasheets, and performance testing of the materials to be used.

6.2.3 The selected coating/lining materials, provided by the contractor, shall conform with the requirements in 6.3 to 6.12 and the relevant technical specification/datasheets.

6.2.4 Manufacturer's certificates, from approved certification authority, shall be furnished with all coating/lining materials and shall assure that the material conforms with the requirements of this document.

6.3 Prequalification of coating/lining system

6.3.1 Test methods and frequencies for a PQT are specified in 6.5 to 6.12. Acceptance criteria are given in the relevant subclauses.

6.3.2 The applicator may request the manufacturer's assistance during the PQT to ensure the correct use of the coating/lining material(s) and to train the applicator personnel.

6.3.3 Qualification tests shall be carried out on representative test plates having the same material specification and thickness of the storage tank plates to be internally coated/lined. All qualification test results shall be as per the coating/lining manufacturer's recommendations. The name of the applicator and the date the sample delivered to the site shall be printed or marked on the plates.

6.3.4 All tools and equipment (e.g. for abrasive blasting, coating/lining application and inspection) being used for the PQT shall be of the same type as those being used for the actual coating/lining.

6.3.5 The method/procedure of coating repairs and stripping of defective internal tank 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 their representative for approval.

6.4 Holding (blast) primer

If primer is used, a client approved primer shall be used as holding primer. The holding primer shall be spray applied but may be applied by brush on small surfaces in case of minor repair. The approved holding primer shall be compatible with the coating/lining system and as specified in the material datasheet.

6.5 Caulking (putty) and filler compounds

6.5.1 Caulking (putty) compound shall be a mixture of solvent-free resin and aggregates. The applied caulking shall provide a great strength and chemical resistance and shall be compatible with the coating/lining system.

6.5.2 Filler compound shall be 100 % volume solids and compatible with the coating/lining system.

6.5.3 The selected putties and fillers shall be as specified in the coating/lining system material data sheet and approved by the client.

6.5.4 Surface preparation for better anchoring and maximum thickness of caulking (putty) and sealer compounds to be applied shall be identified/specified considering corrosion allowance of metal substrate and operating conditions (loading/unloading vibrations) of tank.

6.6 Fibreglass lining materials

6.6.1 Fibreglass resin compound

The resin compound for the fibreglass lining system shall be chemical and abrasion resistance type, which include bisphenol epoxy resin, epoxy phenolic or novolac epoxy, polyester and vinyl ester. The resin shall be of high quality to meet the performance requirements as described in this document. The epoxy resin should be type 1 Grade 1 as per ISO 3673-1 or ASTM D1763. The bisphenol epichlorohydrin epoxide resin shall be 100 % pure of low viscosity at normal room temperature. Epoxy resin may be an amine adduct cured subject to client approval. Epoxy base blends shall be of high molecular weight, resins of low viscosity at normal room temperature. Also, the resin shall be as per material manufacturer recommendation for specified storage services with coverage of proven performance assurance.

6.6.2 Glass fibre reinforcement

6.6.2.1 Glass fibre reinforcement shall be type E or C glass fibre roving, in accordance with the EN 14020 series, of size 0,4 mm in diameter of low alkali borosilicate glass, evenly distributed in a random pattern and bound together with a chemical binder highly soluble in the laminating resin. In addition, glass fibre reinforcement shall be as per material manufacturer's recommendation for specified storage tank services with coverage of proven performance assurance.

6.6.2.2 For laminated fibreglass reinforced lining (hand applied), the mat shall have a minimum weight of 30 g/m^2, shall have a minimum width of 1 250 mm and shall contain a high solubility binder. The fibreglass mat shall be of suitable lengths. The overlap between the fibreglass mats should be minimum 100 mm along the length of the mat.

6.6.2.3 The glass surface tissue (surface veil) shall be a lightweight glass fibre with a minimum weight of 30 g/m^2, if required.

6.6.2.4 Topcoat shall be applied over the fibreglass lining laminate to seal the laminate surface and enhance water and hydrocarbon resistance. This topcoat is also referred to as gel coat, seal coat or flood coat.

6.6.2.5 Glass reinforced schemes, where the fibre is incorporated via methods other than hand applied (e.g. chopped glass schemes), are permitted, if they can be shown to conform with the performance requirements of this document.

6.7 Glass flake filled coating/lining system

6.7.1 The resin compound for glass flake filled coating/lining system shall be as specified in 6.1.1

6.7.2 Other resin materials, such as bisphenol A/novolac vinyl ester and isophthalic/bisphenol A/ chlorinated unsaturated polyester may be used.

6.7.3 The C glass shall be in accordance with the EN 14020 series. The size of the flake shall be in the range of 2 µm to 7 µm thick and 400 µm to 600 µm wide for spray type products. For brush and trowel application, the size of flake can be 2 µm to 7 µm thick and 600 µm to 4 000 µm width.

6.7.4 The chemical resistance information shall state whether the material has been laboratory tested, e.g. according to ISO 2812-1, Method B, or another equivalent standard.

6.8 Epoxy coating/lining systems

6.8.1 The phenolic epoxy shall be amine cured and shall be capable to withstand a service/ operating temperature (immersed in service liquid as specified in the scope of this document). Also, the phenolic epoxy shall be as per material manufacturer's recommendation for specified storage services with coverage of performance guarantee.

6.8.2 The high build epoxy (HBE) shall be amine cured. The volume solids shall be minimum 70 %. HBE shall be capable to build up the recommended thickness in a single or maximum two coats without any film defects.

6.8.3 Solvent free epoxy shall be high build and suitable for using in storage items for which they are intended.

6.9 Material approvals — Fibreglass lining system

6.9.1 Original certificates from a testing laboratory, operating in conformance with ISO/IEC 17025, shall be submitted to the client to prove that the fibreglass lining meets the minimum specifications presented in Table 1 for non-exposure tests and Table 2 for exposure tests.

Table 1 — Requirements for coatings and linings for non-exposure tests

Property	Test method	Minimum specification
Fingerprint (all components)	ISO 12944-9:2018, Annex C	As per test standard
Total DFT of the system	ISO 19840	As per manufacturer's recommendation and as approved by the client
Low voltage holiday/pinhole detector at 90 V by wet sponge for DFT < 500 µm	ISO 29601	No holidays
High voltage holiday/pinhole detector at 5 V per microns for DFT > 500 µm	ISO 29601	No holidays
Adhesion of the system to steel – at minimum and maximum operating temperature	ISO 4624	Minimum 10 MPa Mode of failure to be recorded
Hardness, as per submitter's request method	Shore D (D0 indenter): ASTM D2240 Pencil: ISO 15234 Barcol: ASTM D2583	As per manufacturer's minimum value
Edge retention	NACE TM0304 and NACE TM0404	> 50 %
Thick film cracking (for linings > 70 % volume solids)	NACE TM0404	No cracking after 72 cycles
Flexibility	ASTM D790	Value to be recorded
Abrasion resistance	ASTM D4060 using 1 000 cycles, CS17 wheel, 1 kg load	As per coating manufacturer's and client's agreement

Table 2 — Requirements for coatings and linings for exposure tests

Property	Test method	Minimum specification
Thermal gradient immersion (for internally heated [crude oil storage tanks] only) [a] Note this test may not be appropriate for fibre glass reinforced linings	ASTM D6943, Method B using test solution L1 with minimum duration of 2 000 hrs. ISO 4624 (using post exposure adhesion after the panels have cooled to ambient under good ventilation) and ISO 4628-2, ISO 4628-3, ISO 4628-4, ISO 4628-5 for evaluation	To be conducted up to the maximum operating temperature Post exposure adhesion to be not less than 70 % of original value or to be > 7 MPa (A/B failure)
Chemical resistance (see list of immersion chemicals in Table 3)	ISO 2812-1, Method B with minimum duration of 4 200 h. ISO 4624 (using post exposure adhesion after the panels have cooled to ambient under good ventilation) and ISO 4628 (parts 2 to 5) for evaluation	To be conducted up to the maximum operating temperature Post exposure adhesion (after 48 h recovery) to be not less than 70 % of original value or to be > 7 MPa (A/B failure)
Water absorption	ASTM D570	As per coating manufacturer's and client's agreement
Cathodic disbondment resistance at 23 °C	ISO 15711, Method A	The equivalent diameter of the disbonded area shall be less than 20 mm.
Cathodic disbondment at maximum operating temperature (limited to 95 °C)	ASTM G42	As per coating manufacturer and client agreement

[a] Thermal gradient immersion testing is only an appropriate test where the tank is internally heated (so there is a thermal gradient to the external). This testing is not appropriate when the contents are warmed externally (e.g. by the sun).

Table 3 — Recommended immersion chemicals [a]

Service	Reference
Crude oil/5 % NaCl (1:1 ratio by volume)	L1
Gas condensate	L3
Seawater	L4
Glycol	L5
Aviation fuel	L6
Alcohol	L7
Gasoline	L8
Deionised/Demineralized water	L9

[a] Alternative immersion chemicals may be used as per client's approval.

6.9.2 The coating/lining thickness shall be considered depending upon the service conditions requirements, expected design life and as per the coating/lining materials manufacturer's recommendations.

6.9.3 The quality of applied coating/lining work is subjected to client's approval. The contractor shall submit a coated/lined sample panel for client's testing and analysis if requested.

6.9.4 For all new products, the manufacturer and applicator shall prepare qualification test samples. Fully cured samples test panels shall be subjected to performance tests as per requirement of this document as well as to the satisfaction of the client.

6.9.5 Sample test panels shall be prepared in accordance with ISO 12944-9:2018, 9.1. The number of test panels required shall be in accordance with the referenced standards in Tables 2 and 3. Unless stipulated in the test standard, these test panels shall be supplied in triplicate for each test.

6.9.6 For fibreglass lining shop application, the lining and caulking shall be applied as per this document. The mat overlap shall be at the minimum 100 mm and should be made at the middle of the test panel.

6.9.7 Test panel testing procedures shall be as specified in 6.9.7.1 to 6.9.7.4.

6.9.7.1 Upon completion of the coating/lining system application and the specified curing time, the test panel shall be subjected to the tests described in 6.9.7.2 and 6.9.7.3.

6.9.7.2 Non-destructive testing

a) Visual inspection:

The test panel shall be thoroughly inspected visually for general conditions of the surface finish, scattered pockets among fibreglass cross section, shrinkage, pinholes, cracks, etc.

b) Thickness measurements:

The DFT of the coating/lining shall be checked in accordance with ISO 2808 on the panel using micrometer. Another four readings shall be randomly measured by suitable thickness gauge. The DFT readings shall be recorded in the test report. The minimum measured DFT shall always be as per the minimum specified DFT of the coating/lining system.

c) Holiday detection test:

Pinhole detection test of the coating/lining shall be carried out by suitable high voltage holiday (spark) testing instrument at a set voltage as recommended by ISO 29601, NACE SP0188 or manufacturer's recommendations.

6.9.7.3 Destructive testing

a) Adhesion test:

Adhesion test shall be carried out as per ISO 4624 or ASTM D4541 at minimum and maximum operating temperatures.

b) Hardness test:

The hardness of the applied lining shall be checked at 10 different locations using a Barcol hardness tester in accordance with ASTM D2583. The minimum, maximum and average readings shall be recorded in the test report.

c) Test panel preparation:

Upon completion of the non-destructive testing of 6.9.7.2, the panel should be machined cut by the contractor for destructive testing. A total of eight test panels shall be machine cut, each of 50 mm × 400 mm dimension. Four samples shall be cut parallel to one edge and the other four samples shall be perpendicular to this edge.

d) Test procedure shall be as per ASTM D522:

Two samples of each group shall be subjected to bending test as follows:

— Two samples shall be placed on the machine bending guides with lining upward. The plunger of 100 mm width and 50 mm thickness shall be compressed in the middle of the sample supported on a span of 350 mm until it is lowered 50 mm from the top line of the guides. The condition of lining shall be checked for any cracks or splitting from the steel panel.

— Two samples shall be placed on the machine bending guides with lining downward. The plunger of 100 mm width and 50 mm thickness shall be compressed in the middle of the sample supported on a span of 350 mm until it is lowered 25 mm from the top line of the guides. The condition of lining shall be checked for any cracks or splitting from the steel panel.

6.9.7.4 The results of the tests described in 6.9.7.2 and 6.9.7.3 shall clearly show the following acceptable limits:

a) a good quality smooth surface finishes without any evidence of shrinkage or air pockets or any other defects among fibreglass cross section;

b) the minimum lining DFT of the final coat shall be as specified in the lining systems requirements in Table 5;

c) the lined sample panel shall be free from any pinholes, voids, or other defects;

d) the hardness shall be as recommended by the lining manufacturer;

e) all test samples for bending tests shall be free of any surface cracks or splitting (separation) from the steel base;

f) the caulking shall be free of any cracks and voids;

g) the minimum adhesion value shall not be less than 10 MPa.

6.10 Material approvals — Glass flake filled coating/lining system

6.10.1 Original certificates from a testing laboratory, operating in conformance with ISO/IEC 17025, shall be submitted to the client to prove that the glass flake lining meets the minimum lining specifications presented in Tables 1 and 2.

6.10.2 The quality of coating/lining work shall be subjected to the client's approval. The contractor shall submit a coated sample panel to the client's shop for testing and analysis.

6.10.3 For all new products, the manufacturer and applicator shall prepare qualification test samples and production test samples. Fully cured test samples shall be subjected to performance tests as per the requirements of this document as well as to the client's satisfaction as detailed and applicable in 6.9.7.

6.11 Material approvals — Thin film epoxy coating/lining systems

6.11.1 Original certificates from a client approved independent testing laboratory, operating in conformance with ISO/IEC 17025, shall be submitted to the client, to prove that the lining meets the minimum specifications as presented in Tables 2 and 3.

6.11.2 The quality of applied coating/lining work shall be subjected to client's approval upon quality inspection and surveillance, stage wise inspection and approval, reports and documentation with daily sign-off and then final inspection before box-up or handover of tank.

6.11.3 For all new products, the manufacturer and applicator shall prepare qualification test samples and production test samples. Fully cured test samples shall be subjected to performance tests as per the requirements of this document as well as to the client's satisfaction, as detailed and applicable in 6.9.7. The minimum thickness shall meet the guidelines given in 8.8.

6.12 Pre-production trial

6.12.1 If specified or otherwise required by the client, a PPT shall be performed on site to verify the:

a) coating/lining system;

b) coating/lining application procedure;

c) qualification of equipment being used for surface preparation and coating application;

d) application of the coating system;

e) qualification of the coating operatives and inspectors that will be used in the field.

6.12.2 The PPT work and performance shall conform with the requirements of this document and the results of any previous PQT.

6.12.3 Test methods, frequencies, and acceptance criteria for PPT shall be in accordance with Table 4.

Table 4 — Minimum test requirements for pre-production trial

Property	Test method	Minimum specification
Surface cleanliness	ISO 8501-1	Sa 2½
Soluble salts	ISO 8502-6	As per supplier
Surface profile	ISO 8503-2	As per supplier
Coating/lining application characteristics	As agreed between all parties	As per product datasheet
Holiday/pinhole testing	ISO 29601	No holidays
Cure via solvent rub tests	ASTM D5402	As per supplier
Hardness		As per manufacturer's details
Adhesion of the system to steel at minimum and maximum operating temperature.	ISO 4624	Minimum 10 MPa

6.12.4 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.

7 Surface preparation

7.1 General

7.1.1 Design, fabrication, and surface finish requirements for steel tanks to be lined shall be in accordance with ISO 12944-3 and ISO 8501-3, unless otherwise specified by the client's specification. Repair of tank bottom (maintenance work) shall be mechanically accepted in accordance with API RP 652 and API Std 653.

7.1.2 The surfaces to be coated or lined shall be prepared and cleaned by the coating applicator in accordance with the requirements of 7.2, 7.3, 7.4 and 7.5 before any coating/lining work begins. If this work specified is part of the scope of the contractor, a third-party inspector with approval by the client shall be engaged by the contractor. The inspector shall test to ensure that the surface cleanliness meets the requirements of 8.4 and 8.5 before lining.

7.2 Tank pre-cleaning and residue removal (for rehabilitation work)

7.2.1 The internal surfaces of the tank shall be de-sludged and thoroughly cleaned to remove scale, salt, dirt, existing/temporary protective paint, chalk and oil residues. The cleaning shall be in accordance with API Std 2015. Degreasing shall be carried out using vapour degreasing equipment or appropriate solvent in accordance with SSPC-SP 1. Degreasing detergent shall be of an emulsifying type. Cleaning is usually followed by a freshwater rinse to ensure complete removal of cleaning chemicals.

7.2.2 Roof legs and supports shall be lifted to drain oil accumulations. Roof legs shall also be jacked up during lining application while open ends and covered with plastic bags or any other acceptable method to prevent drip page on blasted or primed surfaces.

7.2.3 Plastic bags, for covering larger areas plastic tarpaulins, or any other acceptable method shall be used to protect against overhead drip page from counterweights, supports, etc.

7.3 Preparatory patching and grinding (for new and rehabilitation work)

7.3.1 Isolated corroded areas below minimum thickness shall be repaired/replaced steel plate as per the client's requirements and contractor's recommendations.

7.3.2 All welds shall be smooth and continuous. No skip welding is permitted. All existing skip welds shall be upgraded to continuous welds.

7.3.3 The weld integrity between shell and annular or sketch plates shall be checked for welding defects and shall be repaired.

7.3.4 Surface irregularities, such as weld spatter, sharp protrusions, slivers, and porosity, shall be removed completely (made flush or ground smooth) as per ISO 8501-3, preparation grade P3. All sharp outside corners and edges shall be treated as per ISO 8501-3, preparation grade P3. Any other observed defects in welds and base metal shall be marked and discussed with the client.

7.3.5 Prior to final surface preparations, the steel substrate shall be tested for chloride contamination in accordance with ISO 8502-6 and ISO 8502-9, or SSPC Guide 15, or client-approved standards and test procedure. Fresh water (conductivity reading of maximum 100 µS/cm) washing at minimum pressure of 210 bar[1)] (3 045 psi) is highly recommended prior to any coating work including sweep blasting operation. A chemical additive with demonstrated capability to remove salts can be used in the water wash if agreed by the client.

7.3.6 The surfaces, which are likely to be contaminated with oil or grease, shall be cleaned with a biodegradable water-soluble liquid in accordance with SSPC-SP 1, followed by thorough freshwater wash. The surface shall be inspected for presences of any residual oil and grease in accordance with ASTM F21 with atomized water spray test. A black light test in accordance with ASTM A380 shall be used for inspection and presence of any oil and grease is not acceptable.

7.3.7 Washing with fresh water containing a suitable degreasing agent of partially painted components shall take place between coats if surface is found to be contaminated.

7.4 Dry abrasive blast cleaning

7.4.1 Prior to the start of abrasive blasting, the contractor shall select an appropriate abrasive type and mesh size to attain the specified surface profile. Only approved garnet or grit type abrasives shall be used. Sand or silica-based abrasives shall not be used. The abrasive shall be used in accordance with the manufacturer's specifications. The abrasive shall contain no impurities and shall be tested in accordance with the ISO 11124 series, the ISO 11126 series and ISO 11127-7, or other test method accepted by the client. For environmental reasons, only garnet abrasive shall be used for offshore blast cleaning. Neither sand nor contaminated recycled abrasive is allowed under any circumstances for blast cleaning.

7.4.2 The contractor may be asked to demonstrate, to the client 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 using replica tape as per ISO 8503-5, NACE SP0287 or

1) 1 bar = 0,1 MPa = 105 Pa; 1 MPa = 1 N/mm^2.

ASTM D4417 and comparing the surface finish to the appropriate visual standard; when viewed without magnification, the blasted surface shall conform to the appropriate visual standard.

7.4.3 The metal substrate shall be abrasive blast cleaned to near white metal finish (Sa 2½) for maintenance works, and white metal finish (Sa 3) for new steel. The surface profile height shall be as specified in 7.4.9.

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

7.4.5 The compressed air used in any cleaning method shall be free of water and oil. An after cooler shall be fitted with appropriate traps, separators and filters. The traps, separators and filters 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 operate at temperatures more than 110 °C. The air supply shall be checked for water and oil contamination as per the procedure specified in ISO 8573-1 prior to blast cleaning and regularly throughout blast cleaning operations. The air supply shall be tested daily for cleanliness using a white cloth or white blotting paper test as per 9.4.1. The compressed air supply used for dry blast cleaning shall be of sufficient pressure and flow rate to enable rapid and efficient cleaning rates to be achieved. Blast cleaning shall be carried out at a minimum air pressure of 7 bar (101 psi). Air pressures close to the nozzle may be measured using a hypodermic needle on a manometer inserted into the rubber blast hose close to the nozzle.

7.4.6 All surfaces to be lined shall be cleaned to remove any dust, sand, debris, etc. by using industrial vacuum cleaner/grit recovery unit just prior to lining application. The surfaces shall be tested for the presence of residual particulate matter in accordance with ISO 8502-3. The maximum acceptable size and quantity of retained matter shall be Class 2 Rating 2. All reasonable steps shall 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 approval prior to priming.

7.4.7 Blast cleaned surfaces shall be coated certainly within at most 4 h of cessation blast cleaning and before any visible rusting, discoloration or other surface contamination occurs. In case of any flash rust found on the surface, the same shall be removed by light sweep blasting. Dehumidification equipment is recommended to avoid any flash rust formation. However, the first coat application shall always be performed within 4 h of the blast cleaning. Blasting shall be accomplished so that previously coated surfaces are not damaged or contaminated by abrasive or rust.

7.4.8 The weather conditions shall be monitored prior to and constantly throughout the work period. No dry blast cleaning operation and coating work shall be carried out when the temperature of the surfaces is less than 3 °C above dew point or the relative humidity of the air is greater than 85 % or the air or substrate temperature is below the coating manufacturers recommendations.

7.4.9 For fibreglass lining, the surface profile shall be 75 µm to 100 µm or as specified by the lining manufacturer.

7.4.10 For glass flake filled coating/lining, the surface profile shall be 75 µm to 100 µm or as specified by the lining manufacturer.

7.4.11 For phenolic epoxy/high build epoxy/solvent free epoxy/solvent free elastomeric polyurethane systems, the surface profile shall be 50 µm to 100 µm or as specified by the lining manufacturer.

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 tank lining has achieved full cure as per by the lining manufacturer.

7.5.2 In the event of a breakdown or interruption of the dehumidification equipment that results in the relative humidity rising above 50 %, any surface area that exhibits flash rusting shall be re-blasted to be in accordance with ISO 8501-1 Sa 3.

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 dry air, and then vacuumed. The dust embedded on the cleaned surface shall be tested as per 9.5.5.

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

7.6.3 The blast-cleaned surface shall be checked for the presence of soluble chlorides and other salts as per 9.5.4.

7.6.4 A surface holding primer or surface inhibiting treatment shall be applied in order to hold the blasted surface for a short period till the blasting and cleaning is completed, unless dehumidification equipment is operated with a relative humidity less than 50 % during the entire surface preparation operation. Only a primers and inhibiting washes approved by the coating manufacturer of the tank coating/lining material may be used based on the project needs.

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

7.6.6 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. Proven and demonstrated environmentally-friendly acidic washes and coating-compatible flash rust passivation washes may be used if agreed by the client and coating manufacturer.

7.6.7 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 at 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.

7.7 Removal of existing laminate linings prior to abrasive blasting

7.7.1 The use of induction coil heating machines to destroy the bond of the existing laminate lining followed by lifting and removing segments of the laminate during maintenance lining/re-lining work may be approved in lieu of removal by abrasive blasting, subject to client approval.

7.7.2 Contractors wishing to use induction coil heating machines to remove old laminate linings shall provide complete information on the equipment and the methods of removal to client as part of their submittals for approval prior to commencing the work.

7.7.3 Abrasive blasting shall be conducted after all the laminate is removed and shall meet the requirements of 7.4, 7.5 and 7.6.

7.8 Striker plates, steel legs, risers, down comers and supports

7.8.1 When required striker plates shall be placed directly under each gauge hatch.

7.8.2 The striker plates shall be lined on both sides.

7.8.3 The lined striker plates shall be fixed over fibreglass lined reinforcing pad using epoxy resin that is compatible with lining materials.

7.8.4 Roof support legs, risers, down comers, filling lines, roof drain lines, steel supports, etc., shall receive coating of 100 % solids epoxy at a minimum of total DFT 750 µm or as specified in 8.7.2, up to a height as specified by the project specifications/data sheet.

7.8.5 All the reinforcement pads (even where the striker plates are kept above) shall have a full lining system.

7.8.6 The roof support legs shall be jacked up and supported to apply the full lining system on reinforcement pads. Temporary supports shall be designed in such a way that it will not damage the roof plates. Only alternate legs shall be lifted.

7.9 Safety precautions

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

7.9.2 The blast operators shall wear appropriate clothing and safety equipment. The blasting hoods shall be connected to a source of clean air (as per client requirements). All other persons exposed to the blast dust and chemical fumes shall wear air supplied respirators.

7.9.3 Adequate lighting in accordance with SSPC Guide 12 shall be used to provide good visibility during surface preparation works.

8 Coating/lining application

8.1 General requirements

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

8.1.2 The contractor or applicator shall use only experienced and qualified personnel to carry out the required works. The coating/lining applicator shall have approval from the client on the adequacy, experience and qualification of the personnel. The applicator shall appoint a certified coating inspector, approved by the client, to be responsible for the proper application of the lining system.

8.1.3 As part of the pre-preparation of the surface the underside of steel, floating roofs shall be sweep abrasive blast cleaned or water blasted to remove loose dirt and prevent it from falling and contaminating the wet coating.

8.1.4 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 client approval. The over coating interval time for application of intermediate coat or topcoat shall be followed at minimum time as per manufacturer's recommended time interval given in the product data sheets. Delay in over coating on primer/first coat/intermediate coats should be avoided. If any such situation occurs in any unforeseen conditions, a mild roughening of the surface by zero grade emery paper will enhance the inter-coat adhesion.

8.1.5 Degreasing and high-pressure fresh water washing of partially painted components shall take place between coats of paint at the discretion of the client engineer. This is particularly important in offshore situations or in onshore situations where either over coating has been delayed for more than 36 h or the partially painted are seen to be contaminated with dust, oil, grease or particulate matter.

8.1.6 Manufacturer's recommendations, as specified in data sheets, shall be followed. The contractor shall have copies of product data sheets and MSDS available at the site where the coating work is being performed.

8.1.7 The client may, at its option, require the contractor to have a technical representative from the coating manufacturer be present to assist and witness the initial and successive application of each coating system. The contractor shall obtain further technical assistance from the coating manufacturer when problems arise or when client requests such assistance at identified key stages.

8.1.8 The coating/lining application shall be carried out under completely dry conditions. All necessary precautions shall be taken to ensure that water does not come in contact with uncured resin. This is to obtain best adhesion and ultimate chemical resistance of the laminate.

8.1.9 The quality of fibreglass lining work is subjected to approval by client. The contractor shall submit a sample panel for client's shop testing and analysis, as detailed in 6.9.7.

8.1.10 Hand-applied/spray applied glass fibre mat on the shell shall extend 30 cm minimum on the tank bottom. The lap joint on the tank shell shall be at least 75 cm or by agreement with the client.

8.2 Safety precautions

8.2.1 Adequate fresh air ventilation shall be provided during all work and for at least 4 h after coating application, to keep solvent concentrations within safe, non-explosive limits. Vapours shall be removed by use of an explosion proof air educator rather than by air blown into the tank.

8.2.2 The coating manufacturer's recommended precautions regarding toxicity and safe handling of all coating materials shall be followed as outlined in MSDS. Special care shall be observed 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.

8.2.3 All the personnel involved in the coating work, blasting operators, coating applicators, helpers to operators, supervisors and inspectors shall wear necessary personal protective equipment (PPE). The PPE include hard hats, nose masks, coverall, safety shoes and hand gloves. The gas detectors, H_2S detectors and oxygen monitoring instruments shall be always used before entering the tanks. Any other equipment and instruments shall be used at site as required.

8.2.4 The contractor shall have a qualified and experienced safety supervisor in the team and available all the time during the execution of the blasting and coating work.

8.3 Fibreglass lining

8.3.1 Fibreglass lining shall be installed to the following internal surfaces of tank:

a) bottom plates of the entire floor except for potable water tanks;

b) shell plates, up to a height as specified in the project specifications/datasheet;

c) reinforcing plates under roof support legs and striker plate;

d) both sides of the striker plates.

The remaining surfaces shall be coated in accordance with client's specification.

8.3.2 Proper coating that is compatible and suitable for services shall be applied with a brush on a nozzle neck to flange weld. The coating shall cover a maximum of 10 mm on the flange face. It is recommended to have 100 mm (4 inch) minimum diameter nozzle for adequate internal coating application.

8.3.3 No sacrificial anodes shall be installed on the fibreglass lining.

8.4 Weather conditions

8.4.1 Fibreglass lining shall not be applied in the following weather conditions:

a) ambient temperature: below 10 °C;

b) relative humidity (RH): above 85 %;

c) dew point: steel temperature is less than 3 °C above the dew point for prevailing environmental condition.

8.4.2 Dew point determination for various ambient air temperatures is explained in Annex A.

8.5 Primer application

8.5.1 If the blasted surfaces cannot be lined completely on the same day, the entire blast cleaned area shall be spray primed with a specified holding primer, before any rust bloom occurs. The DFT shall not exceed the coating manufacturer's recommendation.

8.5.2 All coating/lining materials shall be supplied by the same manufacturer and shall be applied under the conditions specified by manufacturer.

8.5.3 The relative humidity determines the maximum allowable time between blasting and priming.

8.6 Caulking (putty) application

8.6.1 The caulking (putty) compound and seam sealer used shall be as described in 7.4 and specified in the coating system datasheets.

8.6.2 Shallow pits and other sharp irregularities shall be filled with approved putty to a level flush with the plate surface [see Figure B.1 a)].

8.6.3 The putty shall be applied over the primer and shall be compatible with both the primer and the lining system to be applied over it.

8.6.4 Caulking (putty) compound shall be applied on weld seams and lap joints to provide uniform gradual transition [see Figure B.1 b)].

8.6.5 Large projections and thick plate edges shall be filled with caulking compound in order to smooth out the surface and permit intimate contact with the glass reinforcement.

8.6.6 Caulking compound shall also be applied at the shell to bottom junction to produce a smooth surface on which the fibreglass system is applied without bridging. The applied material at this corner shall have a throat (leg dimension) of 100 mm × 100 mm [see Figure B.1 c)].

8.6.7 The above-mentioned caulking work can be carried out by spray/brush/trowel, subject to work requirement and technical datasheet.

8.7 Fibreglass laminate application

8.7.1 A production sample plate shall be prepared in line with the application. The plate shall be blasted and primed on the commencement day of internal blasting. The final mat and gel coat application shall be on the last day of application.

8.7.2 The glass mat shall be cut to conveniently sized pieces and applied in a staggered seam (patchwork) pattern. Each seam shall overlap a minimum of 100 mm (4 inches). Seams on all vertical surfaces shall overlap the previously applied mat on the bottom. Seams of the second layer (and any successive layers) shall be staggered from the previous layer. Seams of the second layer (and any successive layers) shall be staggered diagonally opposite from the previous layer.

8.7.3 After each mat layer is laid down and saturated with resin, it shall be rolled thoroughly to remove all entrapped air and bubbles and to force the mat down smoothly. A serrated aluminium roller or short bristle brush wet with styrene may be used for this purpose. The direction of rolling or brushing shall be from the centre of the saturated mat outward to prevent trapping air bubbles beneath the mat. If the upper walls (above the fibreglass lining) shall be lined, the intersection area shall be prepared in such a way that the epoxy shall be lapped over the fibreglass lining at minimum 50 mm.

8.7.4 The fibre mat shall cut just before the weld of gusset plate or any other structure welded to shell or bottom plate. The weld joint and the structure part shall be coated with the resin to a height of minimum 600 mm. The intersection area of this resin to phenolic epoxy coating shall be in such a way that always phenolic epoxy shall be coated above the resin.

8.7.5 The resin may be applied either by a special mixing gun or by brush or roller. The first resin coat shall be tinted to indicate coverage over the steel plate. The mixed lining shall be spread, uniformly, on all areas to be covered caulked (e.g. repaired holes, plate overlaps, seams, welds, metal pinholes).

8.7.6 If a surfacing veil is specified, one 25 µm layer of the resin manufacturer's approved veil shall be applied as a final additional layer over the laminate.

8.7.7 When specified on the coating system data sheet, a final wax or gel coat shall be applied over the laminate system.

8.7.8 A final gel coat shall be applied over the laminate system after the complete inspection and repair of the lining.

8.8 Coating/lining thickness

8.8.1 Each individual coat shall be checked for wet film thickness (WFT), during application, in accordance with ISO 2808. After application and curing, DFT shall be measured with a magnetic/ electromagnetic/eddy current film thickness gauge or another equivalent instrument. The measurement shall be in accordance with ISO 19840. The DFT gauge shall be calibrated at the beginning of inspection work, and then at least three times in a shift of 12 h in a day or whenever recommended by the client. The DFT readings shall be recorded and submitted to the client for each coat as well as for the total thickness of coating/lining system.

8.8.2 The DFT of the coated primer shall be as per the manufacturer’s recommendation and by agreement with the client.

8.8.3 The first layer of fibre mat with resin should achieve a minimum thickness of 1 200 µm.

8.8.4 The second layer of fibre mat with resin (1 200 µm) should achieve a minimum thickness of 2 430 µm.

8.8.5 The tissue layer with resin (400 µm) should achieve a minimum total thickness of 2 830 µm.

8.8.6 The final gel coat of 250 µm should achieve a minimum total thickness of 3 080 µm.

8.8.7 Alternative coating sequences and thicknesses as per manufacturer's recommendation may be used by agreement with the client.

8.9 Glass flake filled coating application

8.9.1 The surface preparation shall be carried out as per Clause 7.

8.9.2 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 primer.

8.9.3 No coating shall be applied on damp surfaces; manufacturer's guidelines in its datasheet or written procedure shall be followed. The contractor shall have copies of datasheets available at the site where the coating work is being performed. Coatings shall be applied as per manufacturer's recommendations for the ambient temperature. The contractor shall obtain and follow the manufacturer's recommendations for over coating, drying, and curing times at all temperatures.

8.9.4 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.

8.9.5 Multi-component systems shall be accurately measured and mixed according to the manufacturer's recommendations. Mixing shall be done with an air-driven explosion-proof mixer for such time as necessary to ensure that the pigment, vehicles, and thinners are thoroughly mixed.

8.9.6 Mixing shall be done in clean containers, free from traces of grease, other types of coatings or other contaminants. Containers shall be cleaned regularly to remove partially reacted solids. All containers shall be kept covered to prevent contamination by dust, dirt or rain.

8.9.7 Prior to the application of the full coat of primer and each succeeding coating/lining by whatever method, all edges, corners, crevices, welds, holes, bolts, rivets, and pitted areas shall be stripe coated 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. Roller shall not be used for strip coating.

8.9.8 Each coat shall be applied uniformly and completely using contrasting colour shades over the entire surface according to SSPC Painting Manual Vol. 1 and accepted good coating practice. Care shall be exercised to prevent over spray, spillage or application of coatings to surfaces for which the coatings are not intended.

8.9.9 The glass flake lining shall be applied as per the manufacturer's recommended thickness as specified in the approved data sheet.

8.9.10 DFT shall be checked after each coat is applied and cured to minimum over coating interval time. The DFT shall not be measured on soft coating surface to avoid erroneous readings.

8.9.11 Coatings shall be applied in no fewer than the number of coats specified. The DFT of individual coats shall be within the specified thickness range. All coating film thicknesses shall be checked. The coating shall be free of pinholes, voids, bubbles, runs or sags and other detrimental defects. Film thickness shall be measured with a wet film gauge during application. Film thickness shall be checked and maintained during and after each application of each individual coat. Thickness requirements shall be met with each coat and total thickness shall not be achieved in any one coat.

8.9.12 Where film thickness does not meet the client requirements' specifications and or defects (holidays) are found, the contractor shall take corrective action. These corrections shall be to the satisfaction of the client.

8.9.13 All coatings shall be allowed to dry thoroughly for at least the minimum time recommended by the coating/lining manufacturer, considering temperature and humidity, before the application of succeeding coats. When a maximum overcoat time is recommended by the coating/lining manufacturer, it shall not be exceeded before the succeeding coat is applied.

8.9.14 Prior to the application of any coat, all damage to previous coats shall be repaired.

8.9.15 Each coat (primer, intermediate coats, and topcoat) shall be inspected before applying further coats.

8.9.16 Glass flake reinforced coatings shall be spray-applied in accordance with the coating system data sheet and the client approved application procedure. The coating shall be applied in two or more coats to obtain the specified thickness. The airless spray method/plural component airless equipment is the recommended method to provide the best adhesion of coating on the metal surface. Brush can be used only for repair of small areas.

8.9.17 Spray-applied coatings can be rolled, if approved by the client or stated in the coating system data sheet.

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

8.9.19 A sample test panel shall be prepared simultaneously and handed over to the client for further tests after marking the name of contractor and the date of application punched on the same.

8.10 Thin film coating application

8.10.1 The surface preparation shall be carried out as per Clause 7.

8.10.2 The coating/lining shall be mixed in proper ratios as per the manufacturer's recommendations and no part mixing shall be allowed.

8.10.3 No thinning shall be allowed more than the manufacturer's recommendations. For potable water tank lining, thinner shall not be used at any case. Stripe coat shall be applied on all weld areas, sharp corners and all the areas where it is not practical to apply by spray.

8.10.4 Spray coat shall be applied at recommended pressure using the right spray tip size in order to be able to control the WFT thickness. Manufacturer's recommended over coating or recoating intervals shall be strictly followed.

8.10.5 If the thickness found more than the manufacturer's recommended range, the lining system shall be re-blasted and reapplied to the specification. Where film thickness does not meet the client's requirements and or defects (holidays) are found, the contractor shall take corrective action. These corrections shall be to the satisfaction of the client.

8.10.6 A sample test panel shall be prepared simultaneously and handed over to the client for further tests after marking the name of contractor and the date of application punched on that.

8.10.7 Typical thicknesses for linings used in the oil and gas industry are shown in Table 5. The client can always specify the coating/lining type and thickness based on the tank liquid and maximum operating temperature.

Table 5 — Typical thicknesses based on industry standards

Generic coating/ lining system	Typical application	Maximum immersion temperature [a]	Typical no. of coats	Typical thickness
Thin film linings solvent-based coatings/linings				
Epoxy	Crude oil, refined products (gasoline, diesel, etc.), potable water	60 °C	2 to 3	250 µm to 350 µm
Phenolic epoxy	Crude oil, refined products (gasoline, diesel, etc.), solvents	90 °C	2 to 3	250 µm to 350 µm
Epoxy novolac	Crude oil, refined products (gasoline, diesel, etc.), solvents	≥ 90 °C	2 to 3	250 µm to 350 µm
Inorganic zinc silicate	Pure solvents including methanol xylene, toluene and acetone	50 °C	1	60 µm to 90 µm
Thick film linings				
Solvent free epoxy	Crude oil, refined products (gasoline, diesel, etc.), potable water	60 °C	1 to 2	500 µm to 1 000 µm
Solvent free phenolic epoxy	Crude oil, refined products (gasoline, diesel, etc.), solvents	90 °C	1 to 2	500 µm to 1 000 µm
Solvent free epoxy novolac	Crude oil, refined products (gasoline, diesel, etc.), solvents	≥ 90 °C	1 to 2	500 µm to 1 000 µm
Glass flake vinyl ester	Crude oil, acidic materials	90 °C	2 to 3	500 µm to 1 000 µm
Solvent free polyurethanes	Water and wastewater treatment	60 °C	1	500 µm to 1 000 µm
Thick film reinforced linings				
Solvent free epoxy	Crude oil, refined products (gasoline, diesel, etc.), potable water	60 °C	2 layers to 4 layers typically	1 500 µm to 3 000 µm
Solvent free phenolic epoxy	Crude oil, refined products (gasoline, diesel, etc.), solvents	90 °C	2 layers to 4 layers typically	1 500 µm to 3 000 µm
Vinyl ester	Crude oil, acidic materials	90 °C	2 layers to 4 layers typically	1 500 µm to 3 000 µm

[a] The maximum temperature varies by cargo and shall be verified by testing in accordance with Clause 6.

9 Inspection and testing

9.1 General requirements

9.1.1 The applicator shall perform inspection and testing during the application in accordance with client's approved inspection and testing plan (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 manner and shall have columns for marking up client, witness (W), hold (H) and review (R) points.

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

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

9.1.4 The client representative shall have the right to always inspect any tools, materials or equipment used in the performance of surface preparation and lining application.

9.1.5 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.

9.1.6 Any surface preparation or coating/lining work that does not satisfy the requirements of this document shall be re-done by the contractor or applicator.

9.2 Environmental conditions testing

At the beginning of each day's operation and prior to the commencement of any coating/lining application work, ambient temperature, metal surface temperature and relative humidity shall be measured and recorded. Readings shall conform with 7.5. The surface to be coated/lined shall be inspected to verify that no moisture is present.

9.3 Materials and equipment inspection

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

9.3.2 The contractor shall submit a list of QA/QC equipment intended to be used for internal coating/lining along with calibration certificates. The client shall confirm accurate working of inspection tools available at tank worksite.

9.4 Compressed air and abrasive

9.4.1 The cleanliness of each compressed air supply shall be verified daily by blasting without abrasive or coating onto blotting paper for 20 s. If oil or water appears on the blotting paper, all traps and separators shall be blown down until subsequent 20-s blotting tests in accordance with ASTM D4285 show no more oil or water.

9.4.2 Abrasives used for blasting shall be dry and free from dirt, oil, grease and suitable for producing the standard of cleanliness and profile specified.

9.4.3 Re-circulated abrasives shall be tested for oil contamination via test at least twice per shift by the immersion of a small amount of abrasive in a vial of water which is shaken vigorously. If any oil floats to the surface, the abrasive shall be discarded. Also, dust shall be removed from re-circulated abrasives and to improve cutting efficiency. Recycled abrasive shall be tested for chlorides.

9.4.4 Cleanliness of the abrasive shall be tested in accordance with the ISO 7027 series. Maximum reading for turbidity is 25 NTU.

9.5 Surface preparation inspection

9.5.1 Surfaces to be coated/lined shall be inspected to verify that specified surface preparation requirements have been achieved as per 9.5.2 to 9.5.5.

9.5.2 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, weld slag).

9.5.3 After abrasive blast cleaning, the steel surface shall be inspected for visual standard (surface cleanliness) and surface profile. The visual standard shall be Sa 3 white metal for new steel and Sa 2½ near white metal for maintenance work in accordance with ISO 8501-1. The surface profile shall be as per manufacturer's recommendations or this document. Testing of surface profile height shall be in accordance with ISO 8503-2. The measurements and results shall be recorded and submitted for the client's approval.

9.5.4 The blast cleaned surface shall be checked for the presence of soluble chloride in accordance with ISO 8502-6 and ISO 8502-9, or as per client approved standards and test equipment. The chloride contamination shall not exceed 20 mg/m^2 or as specified by coating system datasheet. Presence of sulphates shall be tested in accordance with client's approved methods. If the surface exceeds the above limits or recommend limits of manufacturer's data sheets, the blast cleaned surface shall be water washed in accordance with 7.3.5 or repeated.

9.5.5 The dust embedded on the cleaned surface shall not exceed grade 2 of ISO 8502-3.

9.6 Coating/lining inspection and testing

Coated/lined surfaces shall be inspected/tested in accordance with 9.7 to 9.11 to verify that the specified coating/lining quality and thickness have been achieved. Test methods, frequencies and acceptance criteria are specified in 9.7 to 9.11.

9.7 Coating/lining film thickness

9.7.1 The DFT of coats/lining shall be measured in accordance with ISO 19840.

9.7.2 The recommended minimum DFT of each system shall be as presented in Table 5.

9.8 Holiday detection test

9.8.1 The fully applied and cured fibreglass and glass flake lining system shall be electrically (spark) tested for pinholes and holidays using an approved high voltage spark type holiday detector. This shall be carried out over the entire (100 %) lined surface. The holiday testing shall be carried out in accordance with ISO 29601 and manufacturer's recommendations. This testing shall be carried out before gel coat is applied.

9.8.2 The applied fibreglass lining shall be 100 % porosity free. Small and limited number of pinholes may be permitted for repair in accordance with 9.10, provided that the contractor and client agree on the acceptable level within contract documents.

9.8.3 The thin film coating shall be pinhole tested by wet sponge method as per ISO 29601 or NACE SP0188.

9.9 Curing hardness test

9.9.1 The fibreglass lining layer shall be tested for curing by Barcol hardness tester in accordance with ASTM D2583, at 10 different locations or as required by client prior to the application of gel coat. The average reading shall be as recommended by the manufacturer. The minimum, maximum and average readings shall be recorded in the test report.

9.9.2 The surface cure shall also be tested. If the resin surface is still soft or tacky, the surface is un-cured.