NORSOK STANDARD M-501

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Surface preparation and protective coating

Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum

Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are as far as possible intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

Annex A is normative, whilst Annex B is for information only.

Introduction

The main changes included in this revision of NORSOK M-501 are that

- ISO 20340 has been adopted as pre-qualification test standard for coating systems;
- fire testing of aged spray-on passive fire protection has been introduced;
- minimum requirements with respect to coating products, number of coats and coating thickness have been introduced also for coating systems that shall be pre-qualified;
- DNV classification testing has been accepted as an alternative qualification method for ballast water tank coatings (coating system 3B).

Other smaller changes and modifications are also made. All changes are highlighted with revision marks.

1 Scope

This NORSOK standard gives the requirements for the selection of coating materials, surface preparation, application procedures and inspection for protective coatings to be applied during the construction and installation of offshore installations and associated facilities.

This NORSOK standard cover both paints, metallic coatings and application of spray-on passive fire protective coatings.

The aim of this NORSOK standard is to obtain a coating system, which ensures

- optimal protection of the installation with a minimum need for maintenance;
- that the coating system is maintenance friendly;
- that the coating system is application friendly;
- that health, safety and environmental impacts are evaluated and documented.

This NORSOK standard is not applicable to pipelines and pipeline risers.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

2.1 Normative references

ASTM D4752	Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub.
DIN 8566-2	Zusätze für das termische Spritzen; Massivdrähte zum Lichtbogenspritzen; Technische Lieferbedingungen.
DNV Classification Note 33.1	Corrosion prevention of tanks and holds.
ISO 1461	Metallic coatings - Hot-dip galvanised coating on fabricated ferrous products - Requirements.
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ISO 2814	Paints and varnishes - Comparison of contrast ratio (hiding power) of paint of the same type and colour.
ISO 4624	Paints and varnishes - Pull-off test for adhesion.
ISO 4628-6	Paints and varnishes - Evaluation of degradation of paint coatings - Designation of intensity, quantity and size of common types of defect – Part 6: Rating of degree of chalking by tape method.
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. Informative supplement to part 1: Representative photographic examples of the change of appearance imparted to steel when blast-cleaned with different abrasives (ISO 8501-1:1988/Suppl:1994).
ISO 8502-3	Preparation of steel substrates before application of paints and related products - Test 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 - Test for the assessment of surface cleanliness – Part 6: Extraction of soluble contaminants for analysis - The Bresle method.
ISO 8502-9	Preparation of steel substrates before application of paints and related products - Test for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts.

ISO 8503	Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast cleaned substrates.
ISO 8504-2	Preparation of steel substrates before application of paints and related products - Surface preparation methods – Part 2: Abrasive blast cleaning.
ISO 12944-5	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 5: Protective paint systems.
ISO 20340	Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures.
NACE RP0188	Discontinuity (holiday) testing of protective coatings.
NORSOK M-001	Material selection.
NORSOK S-002	Working environment.
NS 476	Paints and coatings - Approval and certification of surface treatment inspectors.
SFS 8145	Anticorrosive painting, surface preparation methods of blast cleaned and shop primer coated steel substrates and preparation grades for respective treatments.
SSPC/SSPM Volume 2	Systems and Specifications, Fourth Edition

2.2 Informative references

DIN 32521	Acceptance test and quality control for thermal spraying equipment.

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1
can
verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.2
feathered
gradual taper in thickness from a coated surface to an uncoated surface

3.1.3
holiday
discontinuity in a coating, which exhibits electrical conductivity, when exposed to a specific voltage

3.1.4
may
verbal form used to indicate a course of action permissible within the limits of the standard

3.1.5
shall
verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.6
should
verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.7
shop primer
thin protective coating normally applied for protection during transport and storage

3.1.8
stripe coat
supplementary coat applied to ensure adequate protection of critical areas like edges, welds etc.

3.2 Abbreviations

CPS	coating procedure specification
CPT	coating procedure test
CSDS	coating system data sheet
MDFT	minimum dry film thickness
MEG	mono ethyl glycol
NACE	
NDFT	nominal dry film thickness
RAL	Colour definitions issued by RAL (Deutsches Institut für Gütesicherung und Kennzeichnung e.V.)
SSPC	Steel Structures Painting Council
SSPM	Steel Structures Painting Manual
QC	quality control

4 General requirements

4.1 General

Selection of coating systems and application procedures shall be made with due consideration to conditions during fabrication, installation and service of the installation.

Specific qualification requirements for products, personnel and companies are given in clause 10.

4.2 Planning

All activities shall be fully incorporated in the fabrication plan.

Details of management, inspectors, operators, facilities, equipment and qualified procedures shall be established and documented before commencing work.

Steel surfaces shall be blast cleaned and coated, i.e. metal sprayed or coated with primer and the succeeding coat of the applicable system, prior to installation.

4.3 Equipment protection and clean up

All equipment and structures shall be fully protected from mechanical damages, ingress of abrasives and dust from blast cleaning. Sags, droplets and paint over-spray (inclusive dry-spray) shall be avoided. Adjacent areas not to be painted or already finished shall be protected. On completion of the work in any area, all masking materials, spent abrasives, equipment etc. shall be removed.

4.4 Ambient conditions

No final blast cleaning or coating application shall be done if the relative humidity is more than 85 % and when the steel temperature is less than 3 °C above the dew point. Coating shall only be applied or cured at ambient and steel temperatures above 0 °C.

The coating manufacturer shall specify the maximum and minimum application and curing temperature and other relevant limitations regarding application and curing conditions for each product in any coating system.

4.5 Coating materials

The selected coating materials shall be suitable for the intended use and shall be selected after an evaluation of all relevant aspects such as:

- corrosion protective properties;
- requirements to health, safety and environment;
- properties related to application conditions, equipment and personnel;
- availability and economics of coating materials.

All coating materials and solvents shall be stored in the original container bearing the manufacturer's label and instructions. Each product shall have a batch number showing year and month of manufacture and giving full traceability of production. Shelf life shall be included in the technical data sheet.

Applicable coating systems are tabulated in Annex A. Coating systems 1, 3B, 4, 5 and 7 shall be pre-qualified in accordance with clause 10.

Topcoat colours should be in accordance with Annex B. Light colours shall be used in ballast and fresh water tanks.

4.6 Steel materials

Steel subject to surface preparation on site shall as a minimum requirement be in accordance with rust-grade B according to ISO 8501-1. Shop primers shall be regarded as temporary corrosion protection and shall be removed prior to the application of the coating systems herein unless the requirements in 4.7 are fulfilled.

4.7 Shop primer

If a shop primer is considered left on the surface to form an integrated part of the final coating system, it shall be applied in accordance with the following requirements:

Blast cleaning shall comply with ISO 8501-1 Sa 2½ and the surface shall remain at Sa 2½ until application of the primer. The primer shall consist of 1 coat zinc ethyl silicate primer with 15 μm thickness. Measured on a plane polished steel or glass test plate, the dry film thickness shall be maximum 25 μm.

Use of shop primer as an integrated part of the final coating system, can only be considered for coating system no. 1, 3B, 4, 5, 7 and 8. For coating systems 1, 3B, 4, 5 and 7, the pre-qualification requirements in 10.1 shall apply.

Areas with intact shop primer shall be sweep blasted to minimum lightly in accordance with SFS 8145, table 1, prior to application of the final coating system. All other areas shall be treated in accordance with the requirements for bare steel.

4.8 Unpainted surfaces

The following items shall not be coated unless otherwise specified:

- aluminium, titanium, uninsulated stainless steel, chrome plated, nickel plated, copper, brass, lead, plastic or similar;
- jacketing materials on insulated surfaces.

If stainless steel is connected to carbon steel, the stainless steel part shall be coated 50 mm beyond the weld zone onto the stainless steel. For piping and pressure vessels, the coating for the stainless steel part shall not contain metallic zinc.

4.9 Handling and shipping of coated items

Coated items shall be carefully handled to avoid damage to coated surfaces. No handling shall be performed before the coating system is cured to an acceptable level. Packing, handling and storage facilities shall be of non-metallic type.

4.10 Pre-qualification of products, personnel and procedures

Pre-qualification requirements as described in clause 10 shall be fulfilled and documented prior to commencement of any work in accordance with this NORSOK standard.

4.11 Metal coating

Hot-dip galvanising shall be in accordance with ISO 1461. Minimum coating thickness for structural items and outfitting steel shall be 125 µm and 900 g/m^2. Structural items shall be blast cleaned before hot-dip galvanising. When additional painting is specified, coating system no. 6 shall be used.

Metal spraying shall be in accordance with the requirements in this NORSOK standard.

5 Health, safety and environment

The following documentation shall be provided and used when evaluating coating systems:

- chemical name of organic solvent, occupational air requirements (OAR) number according to Norwegian regulations, and volatile organic components content in g/l);
- percentage of low molecular epoxy (molecular weight < 700);
- content of hazardous substances, see NORSOK S-002;
- specification of hazardous thermal degradation components**;**
- combustibility;
- special handling precautions and personal protection.

All coating products shall as a minimum be in accordance with relevant Norwegian regulatory requirements regardless of where the coating operation takes place.

Content of quartz and heavy metals in blast cleaning media (see ISO 8504-2) shall be given.

6 Surface preparation

6.1 Pre-blasting preparations

Sharp edges, fillets, corners and welds shall be rounded or smoothened by grinding (minimum R = 2 mm).

Hard surface layers (e.g. resulting from flame cutting) shall be removed by grinding prior to blast cleaning.

The surfaces shall be free from any foreign matter such as weld flux, residue, slivers, oil, grease, salt etc. prior to blast cleaning. All surfaces should be washed with clean fresh water prior to blast cleaning.

Any oil and grease contamination shall be removed in accordance with SSPC/SSPM Volume 2, grade SP1, prior to blasting operations.

Any major surface defects, particularly surface laminations or scabs detrimental to the protective coating system shall be removed by suitable dressing. Where such defects have been revealed during blast cleaning, and dressing has been performed, the dressed area shall be re-blasted to the specified standard. All welds shall be inspected and if necessary repaired prior to final blast cleaning of the area. Surface pores, cavities etc. shall be removed by suitable dressing or weld repair.

6.2 Blast cleaning

Blasting abrasives shall be dry, clean and free from contaminants, which will be detrimental to the performance of the coating.

Size of abrasive particles for blast cleaning shall be such that the prepared surface profile height (anchor pattern profile) is in accordance with the requirements for the applicable coating system. The surface profile shall be graded in accordance with ISO 8503. Grit shall be used as blast medium.

The cleanliness of the blast cleaned surface shall be as referred to for each coating system in accordance with ISO 8501-1.

6.3 Final surface condition

The surface to be coated shall be clean, dry, free from oil/grease, and have the specified roughness and cleanliness until the first coat is applied.

Dust, blast abrasives etc. shall be removed from the surface after blast cleaning such that the particle quantity and particle size do not exceed rating 2 of ISO 8502-3.

The maximum content of soluble impurities on the blasted surface as sampled using ISO 8502-6 and distilled water, shall not exceed a conductivity measured in accordance with ISO 8502-9 corresponding to a NaCl content of 20 mg/m^2.

7 Paint application

7.1 General

Contrasting colours shall be used for each coat of paint.

Hiding power of topcoat for specified colours shall be tested in accordance with ISO 2814. Contrast ratio shall not be less than 94 % at the specified topcoat thickness.

The coating manufacturer shall provide a CSDS for each coating system to be used, containing at least the following information for each product:

- surface pre-treatment requirements;
- film thickness (maximum, minimum and specified);
- maximum and minimum re-coating intervals at relevant temperatures;
- information on thinners to be used (quantities and type);
- coating repair system (qualified in accordance with table 10.1).

7.2 Application equipment

The method of application shall be governed by the coating manufacturer's recommendation for the particular coating being applied.

Roller application of the first primer coat is not acceptable. When paints are applied by brush, the brush shall be of a style and quality acceptable to the coating manufacturer. Brush application shall be done so that a smooth coat, as uniform in thickness as possible, is obtained.

7.3 Application

For each coat, a stripe coat shall be applied by brush to all welds, corners, behind angles, edges of beams etc. and areas not fully reachable by spray in order to obtain the specified coverage and thickness.

Edges of existing coating shall be feathered towards the substrate prior to overcoating.

Each coat shall be applied uniformly over the entire surface. Skips, runs, sags and drips shall be avoided. Each coat shall be free from pinholes, blisters and holidays.

Contamination of painted surfaces between coats shall be avoided. Any contamination shall be removed.

8 Thermally sprayed metallic coatings

8.1 General

Relevant requirements provided in this standard are applicable for thermally sprayed metallic coatings. Specific requirements valid for thermally sprayed metallic coatings are provided below.

8.2 Coating materials

The materials for metal spraying shall be in accordance with the following standards:

Aluminium: Type Al 99.5 of DIN 8566-2 or equivalent.
Aluminium alloy: Aluminium alloy with 5 % Mg, DIN 8566-2 AlMg5 or equivalent.

All coating metals shall be supplied with product data sheets and quality control certificates, and be marked with coating metal manufacturer's name, manufacturing standard, metal composition, weight and manufacture date.

A sealer that fills the metal pores shall be applied. The sealer shall be applied until absorption is complete. There should not be a measurable overlay of sealer on the metallic coating after application.

The materials for sealing the metal coating shall be two-component epoxy for operating temperatures below 120 °C and aluminium silicone above 120 °C operating temperature. Volume solids in the sealers when applied shall be 10 % to 30 %.

8.3 Application of thermally sprayed coating

Each coat shall be applied uniformly over the entire surface. The coat shall be applied in multiple layers and shall overlap on each pass of the gun.

Equipment for application should follow guidelines given in DIN 32521.

For items that will be welded after spraying, 5 cm to 10 cm measured from the bevel area shall be left uncoated.

The coating shall be firmly adherent. The surface after spraying shall be uniform and free of lumps, loosely adherent spattered metal, bubbles, ash formation, defects and uncoated spots.

Before application of any further coat, any damage to the previous coat shall be repaired.

8.4 Repair, field coating of pipes and coating of in-fill steel

All requirements, including adhesion, applicable to metal spraying, shall apply.

The treating and handling of the substrate shall be done in such a manner that the product in its final condition will have a continuous and uniform coating.

Before the metal spraying operation starts, the area 30 cm to 40 cm in distance from the weld zone shall be sweep-blasted to ensure that all contamination is removed. The uncoated welding zone shall be blast cleaned as specified for coating system no 2. The metal coating shall be performed according to 8.3.

9 Sprayed on passive fire protection

9.1 General

Relevant requirements provided in this NORSOK standard are applicable for sprayed on passive fire protection. Specific requirements valid for sprayed on passive fire protection are provided below.

Information regarding selection of materials, thicknesses and areas to be protected is not covered by this NORSOK standard, but the passive fire protective material shall follow applicable requirements to fire protective properties.

9.2 Materials

The sprayed on fire protection shall be applied with wire mesh reinforcement. The wire mesh shall be mechanically fixed to the steel substrate by studs and be properly embedded into the passive fire protection material. The wire mesh shall be plastic coated for all types of fire protection, with the exception of epoxy based materials for which hot dip galvanised or stainless steel wire mesh shall be used. Alternative reinforcement and anchoring of the sprayed on fire protection shall be formally handled as a deviation.

Cement based fire protection shall be externally protected with a material which retards/stops the migration of carbon dioxide and humidity. The coating shall be accepted by the manufacturer.

Coating system no. 5 shall be used for sprayed on passive fire protection. Topcoats used on passive fire protection shall be pre-qualified for coating system 1. The sprayed on passive fire protection coating system without topcoat shall be pre-qualified in accordance with clause 10. During construction, other primers/substrates than the ones used in the pre-qualification test for the passive fire protection system may be used, provided the products are already pre-qualified in coating system 1. Under all conditions, surface preparation, primers/substrates and topcoats are subject to acceptance by the manufacturer of sprayed on passive fire protective coating.

The supplier of the sprayed on passive fire protection material shall document that the passive fire protection system as applied has good properties concerning relevant rapid temperature changes during construction and operation.

9.3 Application

Application of the sprayed on passive fire protective coating shall be in accordance with the recommendations given by the manufacturer of the material.

Studs shall be welded to the structural members, firewalls and fire rated decks with a maximum of 300 mm centres. Attention shall be paid to areas where mesh ends on the substrate. In these areas the maximum

distance shall be 200 mm between welded studs. On highly stressed structural steel, stud welding may not be allowed. In these areas, the studs may be glued to the substrate.

If several layers of passive fire protective coating are necessary, the material shall normally be sprayed wet to wet.

After the passive fire protective coating material has cured, and before application of topcoat, the thickness of the coating shall be checked. Holes shall be drilled down to the substrate on a spot check basis to measure that the thickness is correct. The holes shall be marked and filled with fresh material immediately after the readings. Where feasible, ultrasonic techniques may be used as an alternative to verify the thickness of the coating.

Topcoating shall be carried out in accordance with manufacturer's specification.

The surface finish shall conform to the reference sample prepared during the CPT (see 10.3) and manufacturers application guide. On horizontal surfaces and cavities, adequate water drainage shall be ensured. Areas, which are difficult to access for spraying of passive fire protective coating, shall to the extent possible, be boxed in before the passive fire protective coating is applied. Adequate water shedding shall be arranged for.

9.4 Repairs

The damaged area shall be removed and the edge around the area shall be cut back to solid materials. Adequate overlap with existing reinforcement shall be ensured. If the area is greater than 0,025 m^2, the mesh shall be replaced and secured to the substrate. If the corrosion protection is damaged, the area shall be blast cleaned to Sa 2½ and new corrosion protection applied.

10 Qualification requirements

10.1 Pre-qualification of products

The requirements for pre-qualification prior to use are applicable to coating system no.1 (applied on carbon steel) and to coating systems no. 3B, 4 and 7. In addition, any sprayed on fire protective coating to be used for outdoor or naturally ventilated areas shall be subject to pre-qualification testing.

Acceptance criteria in the pre-qualification testing are considered as minimum performance requirements. Coating systems should be selected among those systems fulfilling the acceptance criteria with the best margin, and which fulfils all other coating material selection criteria given in this NORSOK standard.

In a pre-qualified coating system, the approved topcoat may substitute another pre-qualified top-coat, provided the intermediate coating is the same and the film-thickness of the topcoats are equal.

When a shop primer is an integrated part of coating system no.1, 3B or 7, the following shall apply:

- one coating system, system no. 1 or 7, shall be tested with and without the shop-primer. Both systems must pass the test in table 10.1;
- the shop primer may then be used as an integrated part of a compatible coating system which has been pre-qualified in accordance with table 10.1 with or without shop primer.

To form an integrated part of system 4 and 5, the complete coating system with shop primer shall be pre-qualified according to table 10.1.

Table 10.1 - Pre-qualification tests for coating materials

Test	Acceptance criteria
Seawater immersion according to ISO 20340 Testing is required for the following coating systems: • Coating systems no 3B and 7. • Coating system no 1 when used in tidal or splash zones.	According to ISO 20340.
Ageing resistance according to ISO 20340, procedure A Testing is required for the following coating systems: • Coating systems no 1, 3B, 4, 5A and 5B. • Coating system no 7 when used in tidal or splash zones.	According to ISO 20340. Supplementary requirements: 1. Chalking (see ISO 4628-6): Maximum rating 2. Applicable to coating system no 1 only. 2. Adhesion (see ISO 4624): Minimum 5,0 MPa and maximum 50 % reduction from original value. 3. Overcoatable without mechanical treatment obtaining minimum adhesion of 5,0 MPa. 4. Adhesion (see ISO 4624) for system 5A and system 5B: Maximum 50 % reduction from original value, minimum 2,0 MPa for cement based products and minimum 3,0 MPa for epoxy based products. 5. Water absorption after complete ageing resistance test shall be reported for system 5A.
Cathodic disbonding according to ISO 20340. Coating systems no 3B and 7. Coating system no 1 when used in tidal or splash zones.	According to ISO 20340.

Notes:
1. Acceptance criteria are considered as minimum performance requirements. Coating systems should be selected among those systems fulfilling the acceptance criteria with the best margin, and which fulfils all other coating material selection criteria given in this document.
2. Adhesion testing shall be performed by using equipment with an automatically centred pulling force. For coating system 4, adhesion testing may be conducted on coating without non-skid aggregates on test panels not exposed to the above test environments.
3. The acceptance criteria to be used in this NORSOK standard for corrosion from scribe shall be corrosion from the 2 mm wide scribe. Thus, for this NORSOK standard, the 0,05 mm scribe specified in ISO 20340 may be omitted and the test plate dimensions may be reduced to 75 mm x 150 mm x 5 mm.
4. Coating systems for ballast water tanks approved to class B1 by DNV shall be considered as qualified. Accordingly, testing in accordance with this standard is not required.
5. The thickness of system 5A to be tested shall be 6 mm.
6. Tests on system 5A and system 5B shall be performed on material without reinforcement.
7. Tests on system 5A and system 5B shall be carried out on system without topcoat.

Additional fire testing after ageing shall be performed for epoxy based sprayed on passive fire protection systems. Four test plates with minimum dimensions 400 mm x 400 mm shall be prepared in accordance with 9.2 and table 10.1. Two test plates shall be tested for ageing resistance in compliance with ISO 20340, procedure A. The other two plates shall be kept as reference. None of the plates shall have scribes. Minimum one test plate that has been subject to ageing testing and one reference test plate shall be fire tested in compliance with the requirements for hydrocarbon fire. Maximum 10 % increase in mean temperature read as oC of the aged test plate as compared to the simultaneously tested reference plate is accepted. This requirement refers to the recorded mean temperature increase from the two plates when fire tested for 60 min, or when the plate exceeds 400 oC within 60 min of the fire test.

10.2 Qualification of companies and personnel

10.2.1 Companies

Companies performing work in accordance with this NORSOK standard shall document experience in organizing, planning and execution of work with similar size and complexity.

10.2.2 Qualification of paint operators

Operators shall be qualified to tradesman level as blast-cleaner, painter, applicator etc. The personnel shall have relevant knowledge of health and safety hazard, use of protection equipment, coating materials, mixing and thinning of coatings, coating pot-life, surface requirements etc.

Personnel not qualified to tradesman level, shall document training and experience to the same level as a formalized tradesman education.

10.2.3 Qualification of metal spray operators

Prior to commencement of work in accordance with this NORSOK standard, the operator shall pass the pre-qualification test described in table 10.2. The results from the qualification test specified below are valid for maximum 12 months without regular coating work.

Table 10.2 - Qualification of metal spraying

Test	Acceptance criteria
Visual examination of coating All test panels shall be examined without magnification and with 10X magnification.	See 8.3.
Film thickness (see SSPC/SSPM Volume 2, SSPC-PA 2) and shape test (see NOTE 2)	Minimum 200 µm on all specimen surfaces.
Adhesion (see Note 3) ISO 4624. All test panels shall be tested. Examination of the test specimens shall be conducted after rupture to determine the cause of failure.	No single measurement less than 9,0 MPa. Re-testing is required if the failure occurred at the adhesive/coating interface. Test equipment with an automatic centred pulling force shall be used.

Notes:
1. General: Test materials shall be of a comparable grade to be used in production. The coating shall be applied in accordance with this NORSOK standard and the proposed procedure.
2. Specimens for shape test: One 1 500 mm long "T", "I" or "H" shaped profile approximately dimensions 750 mm high and 13 mm thick. Another specimen shall be cut from a 1 500 mm long 50 mm diameter pipe.
3. Specimens for adhesion test: Five specimens for the adhesion test shall be prepared according to the requirements of ISO 4624 using minimum 5 mm thick plates.

10.2.4 Qualification of passive fire protection operators

Operators, including pump machine operator, shall be qualified, trained and certified according to the manufacturer's procedures.

Before any stud welding, the welders and the procedures to be used shall be qualified in accordance with the coating manufacturer's procedures.

If the operators or stud welders have not been working with the type of application or material within a period of 12 months, the applicator shall document that necessary supplementary training have been given before start of any work.

10.2.5 Qualification of supervisors, foremen and QC personnel

Personnel carrying out inspection or verification shall be qualified in accordance with NS 476 (inspector level) or certified NACE coating inspector (level 3).

Assistant inspectors according to NS 476 may carry out the inspection work under the supervision of an inspector.

Supervisors and foremen shall be qualified to tradesman level and should be qualified as inspector in accordance with NS 476 or certified NACE coating inspector (level 3).

Supervisors, foremen or QC personnel involved in application of passive fire protection shall in addition, be trained and certified according to the procedures of the manufacturer of the passive fire protective material.

10.3 Qualification of procedures

Coating procedure specification (CPS)

A detailed CPS based on the requirements of this standard shall be established. The CPS shall contain the following:

- identification of equipment for surface preparation and application;
- information given on CSDS;
- personal protective equipment to be used;
- safety data sheets for each product;
- product data sheets.

For the sprayed on passive fire protection, the CPS shall, in addition, contain information regarding maximum allowable time between application of the different layers, method and frequency of measuring thicknesses, location of the reinforcement related to the different thicknesses and restrictions for use of solvents.

The qualified CPS shall be followed during all coating work.

The following changes in the coating application parameters requires the CPS to be re-qualified:

- any change of coating material;
- change of method and equipment for surface preparation and coating application.

Coating procedure test (CPT)

A CPT shall be used to qualify all coating procedures. A suitable location on the component to be coated may be selected on which the CPT shall be carried out. Alternatively, a test panel in accordance with 10.2.3 may be used for metal spraying and a test panel (minimum 1 m x 1 m) containing at least 1 pipe-end, 2 pipes, 1 angle and 1 flat bar may be used for other coating systems.

The coating procedures shall be qualified under realistic conditions likely to be present during coating application.

If the shop primer is intended to form an integrated part of the final coating system, and the requirements of 4.7 and 10.1 are fulfilled, the CPT shall be conducted on shop primed steel sweep blasted to grade lightly or more in accordance with SFS 8145 and on steel blast cleaned to the agreed standard for steel without shop primer.

Inspection and testing requirements for the CPT, including acceptance criteria, shall be as given in clause 11. For metal spray, additional acceptance criteria provided in table 10.2 shall also apply.

Curing time prior to carry out the adhesion test shall be according to time for fully cured in coating supplier’s data sheet.

For sprayed on passive fire protection, the CPT shall be performed on an area accepted by the parties involved. The area shall be clearly marked, and will serve as a reference area throughout the project. The application of the fire protection shall comply with the applicable procedures, and be subject to approval by the parties involved. The surface finish on the CPT area, and quality of the work, shall be used as a reference with respect to the quality of the work to be done during further production work.

11 Inspection and testing

Testing and inspection shall be carried out in accordance with table 11.1. Surfaces shall be accessible until final inspection is carried out.

Table 11.1 - Inspection and testing

Test type	Method	Frequency	Acceptance criteria	Consequence
Environmental conditions	Ambient and steel temperature. Relative humidity. Dew point.	Before start of each shift + minimum twice per shift.	In accordance with specified requirements	No blasting or coating
Visual examination	Visual for sharp edges weld spatter slivers, rustgrade, etc.	100 % of all surfaces	No defects, see specified requirements	Defects to be repaired
Cleanliness	a) ISO 8501-1 b) ISO 8502-3	a) 100 % visual of all surfaces b) Spot checks	a) In accordance with specified requirements b) Maximum quantity and size rating 2	a) Reblasting b) Recleaning and retesting until acceptable
Salt test	ISO 8502-6 and ISO 8502-9	Spot checks	Max conductivity corresponding to 20 mg/m^2 NaCl.	Repeated washing with potable water and retesting until acceptable
Roughness	Comparator or stylus instrument (see ISO 8503)	Each component or once per 10 m^2	As specified.	Reblasting
Curing test (for Zn silicate).	ASTM D4752	Each component or once per 100 m^2	Rating 4-5	Allow to cure
Visual examination of coating	Visual to determine curing, contamination, solvent retention, pinholes/popping, sagging and surface defects	100 % of surface after each coat.	According to specified requirements	Repair of defects
Holiday detection	NACE RP0188 voltage, see table 1	As per system specification	No holidays	Repair and retesting.
Film thickness	SSPC/SSPM Volume 2, SSPC-PA 2, calibration on smooth surface	SSPC/SSPM Volume 2, SSPC-PA 2	SSPC/SSPM Volume 2, SSPC-PA 2, and coating system data sheet.	Repair, additional coats or recoating as appropriate.
Adhesion	ISO 4624 using equipment with an automatic centred pulling force, and carried out when system are fully cured	Spot checks	See notes below.	Coating to be rejected

Notes:
1. For system no 2, adhesion during qualification shall be minimum 9,0 MPa. Adhesion measured during production shall be minimum 7,0 MPa for any single measurement.
2. For system 3A, 3C, 3D, 3E, 3F and 3G, maximum 30 % reduction from the CPT is acceptable. Absolute minimum value is 5 MPa.
3. For sprayed on passive fire protection, maximum 50 % reduction from CPT value read as cohesion is acceptable. Absolute minimum values are 2,0 MPa for cement based products and 5,0 MPa for epoxy based products.
4. For the remaining coating systems, 50 % reduction of average adhesion value from the CPT is acceptable as minimum adhesion during production coating. Absolute minimum value is 5 MPa.

Annex A
(Normative)
Coating systems

A.1 Coating system no. 1 (Shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system	MDFT (µm)
Carbon steel with operating temperature < 120 °C – Structural steel – Exteriors of equipment, vessels, piping and valves (not insulated)	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	1 coat zinc rich primer: Number of coats: MDFT of complete coating system (µm):	≥ 60 µm Minimum 3 coats 280

General notes:
1. If the second coat is not applied immediately after a zinc rich primer has cured, or if the primer is exposed to humid or outdoor conditions prior to application of the second coat, a tie-coat shall be applied on top of the primer immediately after the primer has cured.
2. When this coating system is used for accessible deck areas, a non-skid aggregate shall be added to the second last coat. Prior to applying the coating where the non-skid aggregates are added, the primer and the succeeding coat(s) shall be applied to a MDFT of 175 µm and fully cured.
3. In ventilated and heated rooms, the topcoat may be omitted.
4. Chalking rating 1 (see table 10.1) or better should be preferred for externally exposed surfaces.
5. For the splash zone area, the system shall also fulfil the pre-qualification requirements for system 7.
6. Zinc rich primer shall be in accordance with ISO 12944-5.
7. Specialized coating systems with at least two coats and without zinc rich primers, may be selected for particularly exposed areas on installations provided the system is pre-qualified in accordance with 10.1, the coating thickness is ≥ 1000 µm NDFT and provided relevant successful field experience is documented.

A.2 Coating system no. 2

Application (if not specified under others)	Surface preparation	Coating system	Thickness (µm)
Carbon steel: – Operating temperature > 120 °C. – All insulated surfaces of tanks, vessels, piping. – Flare booms. – Underside of bottom deck, included piping, jacket above splash zone, crane booms, lifeboat stations are optional areas (to be decided in each project).	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	Thermally sprayed aluminium or alloys of aluminium. Sealer	Minimum 200 µm See notes below.

General notes:
1. All metallized surfaces shall be sealed in accordance with the following requirements: The sealer shall fill the metal pores. It shall be applied until absorption is complete. There should not be a measurable overlay of sealer on the metallic coating after application. The materials for sealing the metal coating shall be two-component epoxy for operating temperatures below 120 °C and aluminium silicone above 120 °C. Volume solids in the sealers when applied shall be 10 % to 30 %.
2. For items that will be welded after coating, 30 cm to 40 cm measured from the bevel area shall be left without sealer coat.
3. For insulated surfaces of tanks, vessels, piping and equipment operating at temperatures < 120 °C, two coats of immersion grade epoxy phenolic (each 150 µm NDFT) may be applied as an alternative. MDFT shall be 300 µm. Surface preparation shall be as defined above.

A.3 Coating system no. 3 (system 3B shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system
Internal surface of carbon steel vessels **3A** Potable water tanks **3B** Ballast water tanks/internal seawater filled compartments **3C** Tanks for stabilised crude, diesel and condensate **3D** Process vessels < 3 bar_g, < 75 ^oC **3E** Process vessels < 70 bar_g , < 80 ^oC **3F** Process vessels < 30 bar_g , < 130 ^oC **3G** Vessels for storage of methanol, MEG etc.	<u>System 3A:</u> Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5}) <u>System 3B:</u> According to pre-qualification <u>Other systems:</u> As for system 3A or according to coating manufacturers recommendation.	Lining materials for carbon steel vessels are subject to special evaluation, and shall always be approved by the purchaser. As a minimum the following shall be evaluated: • Medium • Operating temperature • Operating pressure • Experience with product • Properties with respect to explosive decompression

General notes:

1. 100 % holiday inspection in accordance with NACE RP0188 (table 1) is required for all tanks, except for system 3B and 3C where the tank tops and upper 1 m of walls shall be inspected. System 3G shall not be holiday tested.
2. Adhesion test shall be carried out on separate test plates, minimum adhesion values in accordance with ISO 4624 shall be 5,0 MPa when using automatically centred test equipment.
3. When solvent based coating is used, the maximum coating thickness given on the paint manufacturer's technical data sheet shall not be exceeded.
4. External of lined vessel shall be marked clearly in black letters: LINED VESSEL, NO HOT WORK

Specific notes:

<u>System 3A:</u>

1. All products used internally in potable water tanks and fresh water tanks shall be approved for such use by the Norwegian health authorities.
2. Internal lining to be applied in minimum three coats each 100 µm when solvent based epoxy is used.
3. Internal lining to be applied in minimum two coats each 300 µm when solvent free epoxy is used.

<u>System 3B:</u>

1. Internal lining to be applied in minimum two coats.
2. The coating system is subject to pre-qualification in accordance with table 10.1.
3. Coating systems for ballast water tanks approved to class B1 in according to DNV Classification Note 33.1 shall also be considered as qualified.

<u>System 3C:</u>

System to be applied to the flat bottoms and lower 1 m of walls, and to the roofs and upper 1 m of walls.

<u>System 3D:</u>

1. 2-component solvent free or solvent based epoxy is recommended.
2. The coating should be cured as close to operating temperature as possible.

<u>System 3E:</u>

2-component solvent based or solvent free epoxy or modified novolac epoxy is recommended.

<u>System 3F:</u>

2-component solvent free novolac epoxy is recommended.

<u>System 3G:</u>

Zinc ethyl silicate to be used NDFT 50 µm to 90 µm, or in accordance with manufacturer's technical data sheet.

A.4 Coating system no. 4 (Shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system (example)	NDFT (µm)
Walkways, escape routes and lay down areas. Coating system 1 may be used on other deck areas.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	Non-skid epoxy screed.	3000

General notes:
1. Light colour non-skid aggregates shall be used.
2. Particle size of non-skid aggregate to be 1 mm to 5 mm.
3. Aggregates shall have a uniform spread.
4. Coating systems for escape route and lay down areas shall have adequate properties related to water absorption, impact resistance, coefficient of friction, hardness and flexibility.

A.5 Coating system No. 5

A.5.1 Coating system no. 5A (Shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system (example)	NDFT (µm)
Under epoxy based fire protection.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	1) 1 coat epoxy primer: or 2) 1 coat zinc rich epoxy: 1 x epoxy tie coat: MDFT (µm):	50 60 25 85

General notes:
1. Stud welding shall be done before final blast cleaning.
2. If the passive fire protection material is not applied immediately after the primer has cured, or if the primer is exposed to humid or outdoor conditions prior to application of the passive fire protection material, coating alternative 2) shall be used.
3. Coating system no. 2 may be used as substrate for epoxy based passive fire protection, provided this is approved by the manufacturer of the passive fire protection coating.
4. The coating system and products shall be approved by the manufacturer of the passive fire protection coating.
5. Top-coating on top of the passive fire protection shall be in accordance with the passive fire protection manufacturer's recommendation.

A.5.2 Coating system no. 5B (Shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system (example)	NDFT (µm)
Under cement based fire protection.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	1 coat zinc rich epoxy: 1 coat two component epoxy: MDFT (µm):	60 200 260

General notes:
1. Stud welding shall be done before final blast cleaning.
2. If the epoxy is not applied immediately after the primer has cured, or if the primer is exposed to humid or outdoor conditions prior to application of the epoxy, a tie-coat shall be applied on top of the zinc rich epoxy primer immediately after the primer has cured.
3. The 200 µm epoxy may be applied as 2 µm x 100 µm.
4. The coating system and products shall be approved by the manufacturer of the passive fire protection coating.
5. Top-coating on top of the passive fire protection shall be in accordance with the passive fire protection manufacturer's recommendation.

A.6 Coating system no. 6

Application (if not specified under others)	Surface preparation	Coating system	NDFT (µm)
Un-insulated stainless steel when painting is required. Aluminium when painting is required.	Sweep blasting with non-metallic and chloride free abrasive to obtain anchor profile of approximately 25 µm to 45 µm.	1 coat epoxy primer: 1 coat two component epoxy: 1 coat top coat: MDFT (µm):	50 100 75 225
Galvanised steel.	Cleaning with alkaline detergent followed by hosing with fresh water.		
Insulated stainless steel piping and vessels at temperatures < 120 °C.	Sweep blasting with non-metallic and chloride free abrasive to obtain anchor profile of approximately 25 µm to 45 µm.	2 coats immersion grade epoxy phenolic: MDFT (µm):	2 x 125 250

General notes:
1. Coatings for stainless steel shall not contain zinc.
2. 6Mo and 25Cr duplex stainless steel valves may be left uncoated. When such valves are welded into the piping system, the coating shall cover the weld zone and an additional 40 mm of the valve.
3. When coating stainless steel with operating temperatures above 120 °C, 30 µm (NDFT) of a high temperature modified silicone paint suitable for the operating temperatures shall be used.
4. Aluminium handrails located in living quarter shall be anodised.

A.7 Coating system no. 7 (Shall be pre-qualified)

Application (if not specified under others)	Surface preparation	Coating system (example)	NDFT (µm)
Submerged carbon steel and carbon steel in the splash zone. Submerged stainless steel and stainless steel in the splash zone.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm - 85 µm, R_{y5})	Two component epoxy Number of coats MDFT of complete coating system (µm):	Minimum 2 coats ≥350

General notes:
1. The system shall always be used in combination with cathodic protection.
2. The system is aimed at ambient operating temperatures and maximum 50 °C. For higher operating temperatures, a specific evaluation and performance documentation is needed.
3. For the splash zone, corrosion allowance in accordance with applicable regulatory requirements shall always be used in addition to the coating system, see NORSOK M-001.
4. Anti-fouling may be required.
5. Piping embedded in concrete shall be corrosion coated at least 300 mm into concrete.
6. Application using an additional number of coats with lower film thicknesses is acceptable provided each coat is applied and cured in accordance with the coating manufacturer's recommendation and provided all other requirements in this document are fulfilled.
7. For the splash zone area, the system shall also fulfill the pre-qualification requirements for system 1.
8. Specialized coating systems with at least two coats, may be selected for particularly exposed areas on installations provided the system is pre-qualified in accordance with 10.1, the coating thickness is ≥ 1000 µm NDFT and provided relevant successful field experience is documented.

A.8 Coating system no. 8

Application (if not specified under others)	Surface preparation	Coating system (examples)	NDFT (µm)
Structural carbon steel with operating temperature ≤ 80 °C in internal and fully dry and ventilated areas.	Cleanliness: ISO 8501-1 Sa 2½	1. 1 coat two component epoxy 2. Zinc rich epoxy + epoxy tie coat	150 60 + 25

General notes:
1. This coating system shall only be used if the areas are only exposed to fully dry indoor conditions during fabrication, intermediate storage, installation and operation. The system shall not be used on surfaces where water condensation may occur.
2. Reduced requirements (maximum 50 mg/m^2) to salt on surface prior to coating is acceptable.
3. Surface preparation to minimum St 2 may be used for touch-up.
4. Topcoat may be applied if specific colours are specified.
5. Equipment to be installed in non-corrosive areas as defined in the first note above, for example electrical rooms, control rooms, living quarters, etc., may normally be coated with suppliers standard coating system and colour. All such coating systems shall be subject to written acceptance from the purchaser.

A.9 Coating system no. 9

Application (if not specified under others)	Surface preparation	Coating system	NDFT (µm)
Bulk supplied carbon steel valves with operating temperature up to 150 °C.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, R_{y5})	2 coats immersion grade epoxy phenolic: MDFT (µm):	2 x 150 300

General notes:
1. When it is possible to identify the operating conditions (temperature, insulation, exposure conditions, etc.) at the time the order is placed, the bulk ordered valves shall be supplied coated with one of the relevant coating systems in this annex.
2. Tagged items shall always be supplied coated with one of the relevant coating systems in this annex.

Annex B
(Informative)
Colours

The below topcoat colours should be selected:

Colour	RAL-1K designation
White	RAL 9002 (Grauweiss)
Blue	RAL 5015 (Himmelblau)
Grey	RAL 7038 (Achalgrau)
Green	RAL 6002 (Laubgrün)
Red	RAL 3000 (Feuerrot)
Yellow	RAL 1004 (Goldgelb)
Orange	RAL 2004 (Reinorange)
Black	RAL 9017 (Verkehrsschwarz)

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