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Petroleum, petrochemical and natural gas industries — Qualification testing and acceptance criteria for protective coating systems under insulation

Industries du pétrole, de la pétrochimie et du gaz naturel — Essais de qualification des systèmes de revêtement protecteurs sous isolation

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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 documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

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

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

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

Unprotected carbon steel in insulated service with the presence of water and concentrating contaminants from the atmosphere or surrounding sources can cause accelerated corrosion and lead to severe metal loss. Additionally, unprotected austenitic and duplex stainless steels can suffer external chloride-induced stress corrosion cracking if contaminates, such as chlorides from the atmosphere and or the insulation, are present at the steel surface. Therefore, steel structures under insulation are normally protected to prevent corrosion-related damage during the operational life required of the equipment.

There are different ways of protecting steel structures from corrosion under insulation. This document deals with protection by use of coating when used as part of a system, including insulation and cladding materials, which can work together to prevent corrosion under insulation (CUI). All components of the corrosion prevention system are important in achieving adequate corrosion protection. This document only deals with the coating part of the corrosion protection system with focus on typical CUI coating environments. Further, this document focuses on accelerated testing protocols and acceptance criteria, so that interested parties can make informed decisions.

In order to ensure effective corrosion protection of steel structures and equipment, it is necessary for owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials to have at their disposal state-of-the-art information in a concise form on corrosion protection by coating systems. Such information has to be as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the interested parties with the practical implementation of protection work.

This document is intended to give the abovementioned information to people who have some technical knowledge of coatings and the process operations of the equipment. It is assumed that the user of this document is familiar with other relevant International Standards, in particular those dealing with surface preparation, inspection/testing of coatings, and relevant regulations.

Future parts of this document are planned to be developed and can include other subjects like higher temperature, cyclic and intermittent service, testing of coatings for maintenance and repair, tape-applied coating materials, etc.

Petroleum, petrochemical and natural gas industries — Qualification testing and acceptance criteria for protective coating systems under insulation

1 Scope

This document describes various corrosion under insulation (CUI) environments in refineries and other related industries and environments, and establishes CUI environmental categories including operating temperature ranges from −45 °C to 204 °C for topside and aboveground service only. This document specifies both established and other test methods for the assessment of coatings used for prevention of CUI for each given environment. This document also provides acceptance criteria for each CUI environment.

NOTE The test results and acceptance criteria can be considered an aid in the selection of suitable coating systems. For service or peak temperatures below −45 °C an optional cryogenic test can be incorporated and for over 204 °C testing acceptance criteria can be agreed between interested parties. Additional or other test and acceptance measures are possible, but require particular agreement between the interested parties.

This document covers spray-applied coatings applied on new carbon and austenitic stainless steel for use in CUI service. This document does not cover testing of sacrificial coatings, such as inorganic zinc, as these coatings can be consumed quickly in wet environments. Developing accelerated corrosion testing for what can be continuous wet service with sacrificial coatings is beyond the scope of this document.

“Non-through porosity” thermal spray aluminium coatings with greater than 250 µm dry film thickness can be tested and qualified in accordance with this document. This document does not cover tape and sheet applied products for use in preventing CUI.

This document does not deal with other aspects of coating degradation, such as those caused by abrasion, erosion, ultraviolet degradation or other methods that can exist given specific environment and construction methods.

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 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 1513, *Coatings and varnishes — Examination and preparation of samples for testing*

ISO 2409, *Coatings and varnishes — Cross-cut test*

ISO 2812-2, *Coatings and varnishes — Determination of resistance to liquids — Part 2: Water immersion method*

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

ISO 4628-2, *Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 2: Designation of degree of blistering*

ISO 4628-3, *Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 3: Designation of degree of rusting*

ISO 4628-4, *Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 4: Designation of degree of cracking*

ISO 4628-5, *Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 5: Designation of degree of flaking*

ISO 4628-8, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 8: Assessment of degree of delamination and corrosion around a scribe*

ISO 7384, *Corrosion tests in artificial atmospheres — General requirements*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 12944-6, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 6: Laboratory performance test methods and associated assessment criteria*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurements of, and acceptance criteria for, the thickness of dry films on rough surfaces*

3 Terms and definitions

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

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

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

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

3.1
artificial ageing
procedure designed to accelerate the ageing of a coating system, i.e. to reduce the corrosion-protective efficiency more rapidly than by natural weathering

[SOURCE: ISO 12944-6:1998, 3.1, modified — 'paint system' has been changed to 'coating system'.]

3.2
corrosion under insulation
CUI
corrosion that is a result of the effect of moisture and contaminants, on the steel surfaces under thermal insulation

3.3
dry film thickness
DFT
thickness of a coating remaining on the surface when the coating has hardened

3.4
durability
expected life of a protective coating system to the first major maintenance coating

[SOURCE: ISO 12944-8:2017, 3.3, modified — 'paint system' has been changed to 'coating system' and 'maintenance painting' has been changed to 'maintenance coating'.]

3.5
nominal dry film thickness
NDFT
dry film thickness specified for each coat or for the whole coating system

3.6
peak temperature
maximum temperature for the designed system, including possible upsets and temperature reached as a result of maintenance efforts such as steam cleaning

3.7
sacrificial coating
coating that provides corrosion protection by sacrificing or being consumed in the act of protecting the substrate

4 Performance testing design

4.1 Relationship between artificial testing and natural exposure

The selection of a coating system for specific conditions should preferably be based on experience from the use of the system in similar cases. The reason is that the durability of a CUI coating system depends on many external factors, such as the environment, the design of the structure, the insulation material, the weather proofing (cladding), the surface preparation, the application, drying procedures, service temperature, thermal shock, thermal cycling, peak temperature, amount of moisture, contaminants and other variables.

The durability is also linked to the chemical and physical characteristics of the system, e.g. the type of binder, the dry film thickness. These CUI related performance characteristics can be evaluated by artificial tests. Resistance to water or moisture, boiling water, steam interface, electrolytes in the system, thermal exposure, thermal shock, and thermal cycling are of primary interest.

Artificial tests and durations specified in this document have been selected to help ensure that potential coating systems will have the characteristics needed for the durability required in the intended service. Results from artificial tests should be used with caution, because artificial testing will not necessarily have the same effect as natural exposure. Many factors have an influence on the progress of degradation and, in the laboratory, it is not possible to accelerate all of them using the most effective method. It is therefore difficult to make a reliable ranking of coating systems of very different compositions from artificial tests in the laboratory. This can sometimes lead to efficient protective coating systems being rejected because they cannot pass these tests.

4.2 Laboratory tests

As CUI environments are very specific and have special requirements, several tests are included so that coating products can exhibit performance in harsh environments typical of CUI exposure. These include thermal performance, boiling water, thermal shock, thermal cycling, peak temperature performance, and long term isothermal conditions. In addition, these coating products shall provide corrosion protection for long periods of time at ambient conditions, and in possibly wet conditions related to initial coating application prior to process start up, time associated with process shutdowns, and short term mothballing of the facility.

Standard weathering testing procedures shall be used to establish ambient related corrosion control test procedures and acceptance criteria. Both air dried and conditioned test samples and heat conditions test samples shall be evaluated.

Additional CUI and high temperature related tests shall also be used in order to verify the ability of a coating to work under insulation at the prescribed conditions.

Inorganic zinc primers or other sacrificial coatings are no longer recommended in CUI environments due to the accelerated corrosion related to wet environments. If testing and acceptance is required, additional testing, as agreed between the interested parties, can be performed. However, long term wet environments are difficult to accelerate and as such the specifier/owner should be careful with any acceptance criteria for sacrificial coatings.

4.3 Additional laboratory tests

Other test methods may also be used by agreement between interested parties.

5 CUI classification environments

Table 1 provides a list of CUI classification environments including the minimum and maximum temperatures for all environments. These descriptions include both isothermal and cyclic conditions.

Table 1 — CUI classification environments

Classification	Minimum temperature	Peak temperature
CUI-1	−45 °C	to 60 °C
CUI-2	−45 °C	60 °C to 150 °C
CUI-3	−45 °C	150 °C to 204 °C

Further, each coating should be qualified for each specific CUI classification where it is intended to be used. A coating that meets the requirements of a CUI-1 classification does not necessarily meet the requirements of a CUI-3 classification, and a coating that meets the requirements of a CUI-3 classification does not necessarily meet the requirements of a CUI-1 classification. By consolidating testing some tests can be used for more than one classification.

For insulated service for temperatures above 204 °C, additional testing may be performed as agreed by interested parties.

An optional classification for cryogenic cycling exposure ("-Cryo") may be added to each of the classifications in Table 1, when cryogenic testing and acceptance are included. In such cases the classifications as presented in Table 2 are appropriate.

Table 2 — CUI classification cryogenic environments

Classification	Minimum temperature	Peak temperature
CUI-1-Cryo	−196 °C	to 60 °C
CUI-2-Cryo	−196 °C	60 °C to 150 °C
CUI-3-Cryo	−196 °C	150 °C to 204 °C

6 Test samples

6.1 Test panels

This document requires the use of test panels and other testing surfaces that are available as standard shapes typically available on the market place. Both A-36 or S275 carbon steel and 316 (316L) austenitic stainless steel test panels shall be incorporated in testing and also shapes as described in 6.2 to 6.7.

6.2 Steel substrates

Test panels will be as follows unless otherwise agreed to and documented.

6.2.1 Carbon steel test panels shall be made of A-36 or S275 carbon steel. The minimum panel size shall be 3 mm × 150 mm × 70 mm or as agreed and documented by the parties. The thickness of the test panels shall not allow for bending as a result of heating and quenching. Unless otherwise agreed, the panel surface shall be prepared by abrasive blast-cleaning to meet the requirements of the corresponding technical product data sheet as per the coating manufacturer's instructions. In all other respects, test panels shall comply with ISO 7384.

6.2.2 Austenitic stainless steel test panels shall be used when stainless steel panels are specified. The grade shall be 316 or 316L stainless steel or as agreed and documented by the parties. The minimum panel size shall be 3 mm × 150 mm × 75 mm. Unless otherwise agreed, the panel surface shall be prepared by abrasive blast-cleaning to meet the requirements of the corresponding technical product data sheet as per the coating manufacturer's instructions. In all other respects, test panels shall comply with ISO 7384.

6.2.3 Square carbon steel tubing (A-36, ASTM A-500, or S275) ASIC standard shape HSS4X4X1/4 measuring approximately 101,4 mm by 101,4 mm, 406,3 mm long with a wall thickness of 6,35 mm shall be used for the multi-phase CUI cyclic test. Each coating sample area shall be a minimum of 101,4 mm long, on all four sides of the square tube with just the front face scribed with an X-cut. Each tube shall have an endcap welded on each end with a 25,4 mm pipe 101,5 mm long with a threaded connector. The two pipes shall be centred horizontally and shall be vertically attached with a centre 25,4 mm down from the top of the square tube. The completed tube should be tested to ensure that the welds do not leak. Figure 2 provides a general layout (see 7.4.2). Unless otherwise agreed, the tube's exterior surfaces shall be prepared by abrasive blast-cleaning to meet the requirements of the corresponding technical product data sheet as per the coating manufacturer's instructions.

6.2.4 A standard black carbon steel pipe (A-36 or S275), approximately 600 mm long, with 50 mm outside diameter with typical wall thickness of 5 mm shall be used for the optional vertical insulation pipe test. Unless otherwise agreed, the test surface shall be prepared by abrasive blast-cleaning to surface preparation to meet the requirements of the corresponding technical product data sheet as per the coating manufacturer's instructions.

6.3 Sampling of coatings

A representative sample of the product to be tested (or of each product in the case of a multi-coat system) shall be taken in accordance with ISO 15528. Each sample for testing shall be examined and prepared in accordance with ISO 1513.

6.4 Number of test panels

At least three panels shall be prepared for each test, unless otherwise specified. Each tube shall have the coating applied three times with the fourth space for a control coating.

6.5 Coating systems

6.5.1 Coating application

The test panels/surfaces shall be dry and free of dust, grease and any other foreign matter, immediately prior to coating application and in keeping with the coating manufacturer's recommendations. The test panels/surfaces shall be coated (preferably by spraying), air dried and cured in strict accordance with the coating manufacturer's recommendations. Each coat shall be homogenous in thickness and appearance and free from runs, sags, misses, pinholes, wrinkling, gloss variation, cissing, particle inclusions, dry overspray and blistering. If the manufacturer's drying requirements are in conflict with 6.5.4, the requirements of 6.5.4 shall take precedence, unless agreed to by all parties. Appropriate protection shall be applied to the edges and back side of test panels.

6.5.2 Dry film thickness

The method and procedure for checking dry film thickness shall be in accordance with ISO 19840 for rough surfaces. After each coat is sufficiently hardened, the dry film thickness of the applied coating shall be measured on the test surface of the test panel/surface at five locations (in the centre and each corner, at least 15 mm to 20 mm from the panel edge or rounded surface of the square tube) and these measurements shall be recorded as the minimum, arithmetic mean and maximum. The dry film thickness shall be within the range of the manufacturer's specifications and shall not exceed 20 % of the specified value.

6.5.3 Overcoating interval

For each layer of coating application, the overcoating interval shall comply with the coating manufacturer's recommendations.

6.5.4 Conditioning

Unless otherwise agreed, the coated test samples shall be conditioned for three weeks in a standard atmosphere of 23 °C ± 2 °C with 50 % ± 5 % relative humidity or 20 °C ± 2 °C with 65 % ± 5 % relative humidity, as defined in ISO 554, before testing, and in accordance with the requirements of the corresponding technical product data sheet as per the coating manufacturer’s recommendations.

6.5.5 Heat conditioning

Heat conditioning of the test samples shall be performed on applied and conditioned test samples. Heat conditioning shall consist of heating the conditioned test panels to the maximum temperature of the classification for 20 h in a muffler oven or other similar device. The test panels shall then be removed and air cooled for 4 h. This process shall be repeated a total of 5 times, providing for a total of 100 h exposure at maximum temperature of the classification and 20 h of air cooling time.

6.6 Scribe

If a scribe is required for testing of coatings on steel substrates, the scribe shall be in accordance with ISO 12944-6. Special care should be taken to ensure that potentially hot and small metal fragments do not affect the sample. Individual test procedures will indicate the need of a scribe for testing.

6.7 Reference system

It is recommended to use a coating system that has been in successful use for years on site and whose performance as indicated by laboratory testing is well known, as a reference system. This system shall be as similar as possible in composition and/or generic type and dry film thickness to the coating system being tested.

7 Test procedures and assessment

7.1 Assessment and acceptance

All tests shall be conducted in triplicate. At least two of the three tests shall comply with the requirements specified in this document. Triplicate for the multiphase CUI cycle test shall be three separate tubes run in three separate test cycles. Triplicate for the optional vertical pipe test shall be three separate tubes.

7.2 Assessment of adhesion and artificial ageing

7.2.1 Adhesion testing before artificial ageing

The applied and conditioned coating sample panels and the heat conditioned coating sample panels shall be tested for adhesion. This includes both the carbon steel test panels and the stainless steel test panels. Table 3 provides list of testing and acceptance criteria.