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Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 5: Protective paint systems

Peintures et vernis — Anticorrosion des structures en acier par systèmes de peinture —

Partie 5: Systèmes de peinture anticorrosion

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Foreword

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

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

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

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

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

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

This fourth edition cancels and replaces the third edition (ISO 12944-5:2018), of which it constitutes a minor revision.

The changes compared to the previous edition are as follows:

— correction of the former doubled category "G5.02" in Tables D.1 to read "G5.02a" and "G5.02b";

— correction of the table headlines of Tables B.3 and B.4;

— some editorial changes.

A list of all parts in the ISO 12944 series can be found on the ISO website.

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

Introduction

Unprotected steel in the atmosphere, in water and in soil is subjected to corrosion that may lead to damage. Therefore, to avoid corrosion damage, steel structures are normally protected to withstand the corrosion stresses during the required service life required of the structure.

There are different ways of protecting steel structures from corrosion. ISO 12944 (all parts) deals with protection by paint systems and covers, in the various parts, all features that are important in achieving adequate corrosion protection. Additional or other measures are possible but require particular agreement between the interested parties.

In order to ensure effective corrosion protection of steel structures, owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials need to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. It is vital that such information is as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

ISO 12944 (all parts) is intended to give this information in the form of a series of instructions. It is written for those who have some technical knowledge. It is also assumed that the user of ISO 12944 (all parts) is familiar with other relevant International Standards, in particular those dealing with surface preparation.

Although ISO 12944 (all parts) does not deal with financial and contractual questions, attention is drawn to the fact that, because of the considerable implications of inadequate corrosion protection, non-compliance with requirements and recommendations given in ISO 12944 (all parts) can result in serious financial consequences.

ISO 12944-1 defines the overall scope of ISO 12944. It gives some basic terms and definitions and a general introduction to the other parts of ISO 12944. Furthermore, it includes a general statement on health, safety and environmental protection, and guidelines for using ISO 12944 (all parts) for a given project.

This document gives some terms and definitions related to paint systems in combination with guidance for the selection of different types of protective paint system.

Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 5: Protective paint systems

1 Scope

This document describes the types of paint and paint system commonly used for corrosion protection of steel structures.

It also gives guidelines for the selection of paint systems available for different environments (see ISO 12944-2) except for corrosivity category CX and category Im4 as defined in ISO 12944-2 and different surface preparation grades (see ISO 12944-4), and the durability grade to be expected (see ISO 12944-1).

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 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 2063 (all parts), *Thermal spraying — Zinc, aluminium and their alloys*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 3549, *Zinc dust pigments for paints — Specifications and test methods*

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 8503-1, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*

ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12944-1 and the following apply.

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

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

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

3.1
compatibility
<for products within a paint system> ability of two or more products to be used together successfully as a paint system without causing undesirable effects

3.2
priming coat
first coat of a paint system

3.3
intermediate coat
coat between the *priming coat* (3.2) and the *topcoat* (3.6)

3.4
tie coat
coat designed to improve intercoat adhesion

[SOURCE: ISO 4618:2014, 2.262]

3.5
sealer
coating material applied to porous surface prior to painting to reduce the absorptivity

Note 1 to entry: An example for a porous surface is a thermal sprayed metal layer.

3.6
topcoat
final coat of a coating system

3.7
primer
paint that has been formulated for use as a *priming coat* (3.2) on prepared surfaces

3.8
pre-fabrication primer
fast-drying paint that is applied to blast-cleaned steel to provide temporary protection during fabrication while still allowing welding and cutting

[SOURCE: ISO 4618:2014, 2.204, modified — "primer" has been replaced by "paint", and "protect it" has been replaced by "provide temporary protection".]

3.9
dry film thickness
DFT
thickness of a coating remaining on the surface when the coating has hardened/cured

3.10
nominal dry film thickness
NDFT
dry film thickness (3.9) specified for each coat or for the whole paint system

3.11
maximum dry film thickness
highest acceptable *dry film thickness* (3.9) above which the performance of the paint or the paint system could be impaired

3.12
pot life
maximum time, at any particular temperature, during which a coating material supplied as separate components can successfully be used after they have been mixed together

3.13
shelf life
time during which a coating material will remain in good condition when stored in its original sealed container under normal storage conditions

Note 1 to entry: The expression “normal storage conditions” is usually understood to mean storage between +5 °C and +30 °C.

4 Classification of environments

The following five atmospheric corrosivity categories are relevant for this document:

— C1 very low;

— C2 low;

— C3 medium;

— C4 high;

— C5 very high.

The atmospheric environments defined in ISO 12944-2 are considered, except corrosivity category CX. Systems for offshore-CX environments are described in ISO 12944-9. For other CX environments, individual systems need to be defined according to the special needs of that environment.

The following three categories for water and soil are relevant for this document:

— Im1 immersion in fresh water;

— Im2 immersion in sea or brackish water;

— Im3 buried in soil.

The immersed environments defined in ISO 12944-2 are considered, except category Im4. Systems for offshore, related structures and Im4 environments are described in ISO 12944-9.

5 New work and refurbishment

5.1 New work and total refurbishment

The surfaces to be coated encountered in new structures are carbon steel of rust grade A, B and C as defined in ISO 8501-1, as well as hot dip galvanized steel and thermal-sprayed metallic coating (see ISO 12944-1). Possible surface preparation is described in ISO 12944-4. The substrate and the recommended surface preparation grade are given in Table B.1. The quality of the surface preparation is essential for the durability of a coating system. The paint systems listed in Annex C, Annex D and Annex E are typical examples of systems used in the environments listed in Clause 4 when applied to steel surfaces with rust grades A to C, as defined in ISO 8501-1, or to hot dip galvanized steel or thermal-sprayed metallic coating. Where the steel has deteriorated to the extent that pitting corrosion has taken place (rust grade D as defined in ISO 8501-1), the dry film thickness or the number of coats shall be increased to compensate for the increased surface roughness, and the paint manufacturer should be consulted for recommendations.

In principle, no corrosion protection is required for corrosivity category C1. If, for aesthetic reasons, painting is necessary, a system intended for corrosivity category C2 (with a low durability) may be chosen.

If unprotected steelwork destined for corrosivity category C1 is initially transported, stored temporarily or assembled in an exposed situation (for example, a C4/C5 coastal environment), corrosion will commence due to air-borne contaminants/salts and will continue even when the steelwork is moved to its final category C1 location. To avoid this problem, the steelwork should either be protected during site storage or given a suitable primer coat. The dry film thickness should be appropriate for the expected storage time and the severity of the storage environment.

5.2 Partial refurbishment

Systems for partial refurbishment should be specified and agreed separately for every object between the interested parties. The paint systems listed in Annex C, Annex D and Annex E may be used, if they are suitable. In special cases, other types of systems might be required for repair works.

The necessary surface preparation of any old coating and the compatibility of the coating system to be applied should be tested in an appropriate manner before starting the repair works.

Test areas can be prepared to check the manufacturer's recommendations and/or compatibility with the previous paint system.

6 Types of paint

6.1 General

Based on the corrosivity category, various examples of paint systems, which are informative in nature, are given in Tables C.1 to C.6, Table D.1 and Table E.1 in relation to the expected durability. The systems have been included because of their proven track record, but the list is not intended to be exhaustive and other similar systems are also acceptable. Only the generic types of binders mentioned in the systems in Tables C.1 to C.6, Table D.1 and Table E.1 are described in this clause. Pigments, fillers and additives are important ingredients of a paint as well. Depending on the composition of the paint, the performance of the coating can vary strongly within a given binder technology. The binder types described in Clause 6 are only examples, other generic types of coatings can be used as well.

In addition, new technologies are continually being developed, often driven by government legislation, and these should always be considered where appropriate and where performance has been validated by

a) the track record of such technologies, and/or

b) the results of testing at least in accordance with ISO 12944-6.

NOTE Information given in 6.2 concerns only the chemical and physical properties of paints and coatings and not the way they are used. Variations can be expected for each type of paint, depending on its formulation.

6.2 Examples of generic type of paints

6.2.1 Alkyd paints (AK)

In these single pack paints, the film hardens/forms by evaporation of solvent and/or water, and by reaction of the binder with oxygen from the atmosphere.

6.2.2 Acrylic paints (AY)

Acrylic paints are single pack coating materials; water-borne and solvent-borne types are available. The film of solvent-borne acrylic paints dries by solvent evaporation with no other change of form, i.e. the process is reversible and the film can be re-dissolved in the original solvent at any time. In water-borne acrylic paints the binder is dispersed in water. The film hardens by evaporation of water and coalescence of the dispersed binder to form a film. The process is irreversible, i.e. this type of coating is not re-dispersible in water after drying.

The drying time will depend, among other things, on air movement, relative humidity and temperature.

6.2.3 Ethyl silicate paints (ESI)

Ethyl silicate zinc primers are provided as single or two pack coating materials. Their films dry/form by solvent evaporation and chemical curing by reacting with moisture from the air. Two pack coating materials consist of a liquid (containing binder) and a powder (containing zinc dust) component. The mixture of liquid and powder has a limited pot life.

The drying time will depend, among other things, on temperature, air movement, humidity and film thickness. The lower the relative humidity, the slower the curing will be.

It is important that the paint manufacturer's instructions regarding the limits for relative humidity and wet and dry film thickness are complied with in order to avoid bubbles, pinholes or other defects in the coating. In particular, limitations on NDFT have to be considered, due to the risk of cracking if the limits are exceeded.

6.2.4 Paints for epoxy coatings (EP)

Paints for epoxy coatings are two pack coating materials. The paint dries by evaporation of solvents, if present, and cures by a chemical reaction between a base and a curing agent component. The mixture of base and curing agent has a limited pot-life.

The binders in the base component are polymers having epoxy groups, e.g. epoxy, epoxy vinyl/epoxy acrylic or epoxy combinations (e.g. epoxy hydrocarbon resins).

The curing agent component can consist of e.g. polyamines, polyamides or adducts.

The drying time will depend, among other things, on air movement and on the temperature.

Formulations can be solvent-borne, water-borne or solvent-free.

Most epoxy coatings chalk when exposed to sunlight. If colour or gloss retention is required, a suitable topcoat should be applied.

6.2.5 Paints for polyurethane coatings (PUR)

Single pack polyurethane paints dry initially by solvent evaporation (where solvent is present) and by a chemical reaction with moisture from the air. The process is irreversible, meaning that the coating cannot be dissolved in the original solvent. Aromatic as well as aliphatic types of polyurethane coatings are available. Aromatic types are not recommended for top coats, as they tend to chalk.

Two pack paints for polyurethane coatings dry by evaporation of solvents, if present, and cure by a chemical reaction between a base and a curing agent component. The mixture of base and curing agent has a limited pot-life.

The binders of the base component are polymers with free hydroxyl groups e.g. polyester, acrylic, epoxy, polyether, fluoro resin, which react with suitable isocyanate curing agents. They can be combined with non-reactive binders, e.g. hydrocarbon resins.

The curing agent component contains an aromatic or aliphatic polyisocyanate.

A special type of PUR is based on fluoropolymers.

Paints for fluoropolymer/vinyl ether co-polymer (FEVE) coatings are two pack coating materials, and both water-borne and solvent-borne types are available. Solvent-borne paints dry by solvent evaporation and cure by a chemical reaction between a base resin and a curing component. Paints for FEVE coatings are ambient curable coating materials cross-linked with isocyanate hardener.

The resin of the base component is fluoropolymer with free hydroxyl groups which reacts with suitable isocyanate curing agents.

The drying time will depend, among other things, on air movement, relative humidity and temperature.

6.2.6 Paints for polyaspartic coatings (PAS)

The two pack paints for polyaspartic coatings dry by evaporation of solvents, if present, and cure by a chemical reaction between a base and a curing agent component. The mixture of base and curing agent has a limited pot life.

The process is irreversible, meaning that the coating cannot be dissolved in the original solvent.

The binders of the base component are aminofunctional aspartates which react with suitable polyisocyanates. They can be combined with non-reactive binders, e.g. hydrocarbon resins.

The curing agent component contains an aliphatic polyisocyanate.

The drying time will depend, among other things, on air movement, relative humidity and temperature.

6.2.7 Paints for polysiloxane coatings (PS)

Paints for polysiloxane coatings can be either one or two component coating materials.

Polysiloxanes are part inorganic using silicone resin and part organic using a modified resin that is typically acrylic, acrylate or epoxy based.

Single component paints dry initially through solvent evaporation and then chemical reaction with moisture from the air. As in the case of one component paints for polyurethane coatings the reaction is irreversible, meaning that the film cannot be dissolved in the original solvent.

Two component paints dry by a combination of solvent evaporation and a chemical curing reaction between the base component and curing agent. The mixed material will have a limited pot life.

7 Paint systems

7.1 Priming coats and type of primers

7.1.1 General

As the first coat of coating systems, priming coats shall provide adhesion to sufficiently roughened, cleaned metal. The priming coat shall also provide adhesion to the subsequent coats.

In Tables C.1 to C.6 and Table D.1 coating systems with a minimum of one coat are described. In these cases, the priming coat shall act as a topcoat too.

Annex A provides an overview of abbreviated terms and descriptions.

7.1.2 Types of primer

Tables C.1 to C.6 give information on the type of primer to be used. For the purposes of this document, two main categories of primer are defined according to the type of pigment they contain.

— Zinc-rich primers, Zn (R), are those forming a coat with a zinc dust pigment content equal to or greater than 80 % by mass in dry film.

— Other primers (miscellaneous) are all other categories of primers.

For pre-fabrication primers, see Annex F.

The zinc dust pigment shall comply with ISO 3549.

NOTE 1 Due to the potentially high margin of error in ASTM D6580 laboratory determination of metallic zinc content in zinc primers, it is acceptable for paint manufacturers to declare the theoretical zinc dust content based on formulation. This can be confirmed between partners by declaration of formulation (in confidence) or by audit.

NOTE 2 The value of 80 % zinc dust by mass in the dry film for zinc-rich primers Zn (R) is the basis for the durability given for the paint systems in Annex C. Some countries have national standards with a minimum content of zinc dust for zinc-rich primers Zn (R) higher than 80 %.

7.2 Subsequent coats

7.2.1 General

Tables C.1 to C.6, Table D.1 and Table E.1 give information on the generic types of subsequent coats if the number of coats is higher than 1. For a better readability of Tables C.1 to C.6, Table D.1 and Table E.1 the term subsequent coats was introduced. It summarizes all additional coats as intermediates and topcoats applied on the primer.

7.2.2 Intermediate coats

Intermediate coats are used in paint systems with three or more coats between the primer and the topcoat mainly as a barrier for corrosive media.

7.2.3 Topcoats

Topcoats, as the last coat in a paint system, determine the design of a steel construction. Gloss and colour retention and resistance to chemicals have to be considered in selecting the binder type. 6.2 gives information on the generic types of paint mentioned in Annexes B to E.

7.3 Dry film thickness

The film thicknesses indicated in Tables B.2 to B.5 are nominal dry film thicknesses. Dry film thicknesses are generally checked on the complete paint system. Where judged appropriate, the dry film thickness of the priming coat or of other parts of the paint system may be measured separately.

NOTE Depending on the instrument calibration, measurement method and dry film thickness, the roughness of the steel surface will have a different degree of influence on the measurement result.

The method and procedure for checking the thicknesses of dry films on rough surfaces shall be in accordance with ISO 19840, and for hot dip galvanized surfaces in accordance with ISO 2808, unless otherwise agreed between the interested parties.

Acceptance criteria, as stated in ISO 19840 shall apply unless otherwise agreed.

Care shall be taken to achieve the dry film thickness and to avoid areas of excessive thickness. It is recommended that the maximum dry film thickness (individual DFT value) is not greater than three times the nominal dry film thickness. In cases when the dry film thickness is greater than the maximum dry film thickness, expert agreement shall be found between the parties. For some products or systems, there is a critical maximum dry film thickness. Information given in the paint manufacturer's technical data sheet shall apply to such products or systems.

The number of coats and the nominal dry film thicknesses quoted in Tables B.2 to B.5 are based on the use of airless spray application. Application by roller, brush or conventional spraying equipment will normally produce lower film thicknesses, and more coats will be needed to produce the same dry film thickness for the system. Consult the paint manufacturer for more information.

7.4 Durability

Definitions of durability and of durability ranges are given in ISO 12944-1.

The durability of a protective paint system depends on several parameters, such as:

— the type of paint system;

- the design of the structure;
- the condition of the substrate before preparation;
- the surface preparation grade;
- the quality of the surface preparation work;
- the condition of any joints, edges and welds before preparation;
- the standard of the application work;
- the conditions during application;
- the exposure conditions after application.

The condition of an existing paint coating can be assessed using ISO 4628-1, ISO 4628-2, ISO 4628-3, ISO 4628-4, ISO 4628-5 and ISO 4628-6, and the effectiveness of surface preparation work can be assessed using ISO 8501-1 and ISO 8501-3.

Recommendations regarding the first major maintenance are given in ISO 12944-1.

7.5 Shop and site application

To ensure maximum performance of a paint system, the majority of the coats of the system or, if possible, the complete system, should preferably be applied in the shop. The advantages and disadvantages of shop application are as follows.

Advantages

a) Better control of application

b) Controlled temperature

c) Controlled relative humidity

d) Easier to repair damage

e) Greater output

f) Better waste and pollution control

Disadvantages

a) Possible limitation of the size of the building components

b) Possibility of damage due to handling, transport and erection

c) Maximum overcoating time could be exceeded if subsequent coats are applied on site

d) Possible contamination of the last coat

After completion of fabrication on site, any damage shall be repaired in accordance with the specification.

NOTE Places where repairs have been carried out will always remain more or less visible. This is one reason why it is better to put a topcoat over the whole surface on site when aesthetic aspects are important.

Site application of the coating system will be strongly influenced by the daily weather conditions, which will also have an influence on the expected lifetime.

If preloaded bearing-type connections are to be painted, paint systems shall be used which do not lead to an unacceptable decrease in the preloading force. The paint systems selected and/or the precautions taken for such connections will depend on the type of structure and on subsequent handling, assembly and transportation.

8 Tables for protective paint systems for C2 to C5, Im1, Im2 and Im3

8.1 Reading the tables

The tables given in Annex C to E give examples of paint systems for different environments. The shading used in alternate lines is purely for ease of reading. The paints used for all these systems shall be suitable for the highest corrosion stress of the given corrosivity or immersion category. The specifier shall ensure that documentation, or a statement from the paint manufacturer, is available confirming the suitability or the durability of a paint system for use in a given corrosivity or immersion category.

NOTE The paint systems listed have been chosen as "typical systems". This has led to some systems being listed that are not necessarily typical or available in some countries. It has been concluded, however, that a simple overview cannot be given, nor can all options be covered.

8.2 Parameters influencing durability

In practice, some systems have a proven durability much longer than 25 years. Increasing the film thickness will increase its barrier properties (but can above a certain level have a negative effect due to worsened mechanical properties and increased solvent retention). Increasing the number of separate coats can decrease the internal stresses caused by solvent evaporation. Also, variations in film thickness caused by overspray tend to decrease with an increased number of coats. In addition, the choice of a system designed for a corrosivity category "higher" than the one envisaged will provide higher durability when such a system is used in a lower-corrosivity environment.

During their specified shelf life, paints can be used without their age having any influence on application of the paint or on the performance of the resulting coating.

8.3 Designation of the paint systems listed

A paint system given in Tables C.1 to C.6. and Table E.1 is designated by its system number given in the left-hand column in each table. The designation shall be given in the following form (example taken from Table C.1 for paint system No. C2.08): **ISO 12944-5/C2.08**.

In cases where coats with different binders are given under one and the same paint system number, the designation shall include the binder used in the priming coat(s) and that used in the subsequent coat(s) and shall be given in the following form (example taken from Table C.1 for paint system No. C2.06): **ISO 12944-5/C2.06-EP/PUR**.

If a paint system cannot be allocated to one of the systems listed in Tables C.1 to C.6, D.1 and E.1, full information regarding surface preparation, generic type, number of coats, nominal dry film thickness, etc., shall be given in the same way as indicated in the tables.

8.4 Guidelines for selecting the appropriate paint system

— Determine the corrosivity category of the environment (macroclimate) where the structure will be located, as described in ISO 12944-2.

— Establish whether special conditions (microclimate) exist which can result in a higher corrosivity category (see ISO 12944-2).

— Search in Annexes B to E for the relevant table. Annex B establishes a set of minimum requirements for protective systems in the various corrosivity and immersion categories and durabilities. Tables C.1 to C.6, D.1 and Table E.1 give proposals for different generic types of paint system for corrosivity categories C2 to C5 and Im1 to Im3.

— Identify in the table paint systems with the required durability.

— Consult the paint manufacturer in order to confirm the choice and to determine what commercially available paint system(s) correspond to the paint system selected.

Annex A
(normative)

Abbreviated terms and descriptions

Table A.1 gives an overview of abbreviated terms and descriptions.

Table A.1 — Abbreviated terms and descriptions

<table>
<tr><th></th><th>Abbreviated term</th><th colspan="4">Description</th></tr>
<tr><td rowspan="2">Type of primer</td><td>Zn (R)</td><td colspan="4">Zinc-rich primer, see 7.1.2 for further details. The usual nominal dry film thickness varies from 40 µm up to 80 µm.</td></tr>
<tr><td>Misc.</td><td colspan="4">All other categories of primers</td></tr>
<tr><td rowspan="6">Binder base for primers and subsequent coats</td><td></td><td>Main binder</td><td>Type</td><td>Water-borne possible</td><td>Additional remarks</td></tr>
<tr><td>AK</td><td>Alkyd</td><td>single pack</td><td>X</td><td></td></tr>
<tr><td>AY</td><td>Acrylic</td><td>single pack</td><td>X</td><td>Usually water-borne</td></tr>
<tr><td>EP</td><td>Epoxy</td><td>two pack</td><td>X</td><td>Poor UV-resistance</td></tr>
<tr><td>PUR</td><td>Polyurethane</td><td>single or two pack</td><td>X</td><td>Only aliphatic types for topcoats</td></tr>
<tr><td>ESI</td><td>Ethyl silicate</td><td>single or two pack</td><td></td><td>It is recommended to use a tie coat compatible with the next subsequent coat</td></tr>
<tr><td rowspan="4"></td><td>C2 to C5</td><td colspan="4">Corrosivity categories, see ISO 12944-2.</td></tr>
<tr><td>Im1 to Im3</td><td colspan="4">Immersion categories, see ISO 12944-2.</td></tr>
<tr><td>NDFT</td><td colspan="4">Nominal dry film thickness. See 7.3 for further details.</td></tr>
<tr><td>MNOC</td><td colspan="4">Minimum number of coats. Depending on the coating material, the application method and the design of the parts, it may be necessary to apply a higher number of coats.</td></tr>
</table>

Annex B
(normative)

Minimum requirements for corrosion protection systems

Tables B.1 to B.5 describe the minimum requirements (surface preparation, minimum number of coats (MNOC) and the NDFT) of protective coating systems for the given durabilities and corrosivity/immersion categories on carbon steel, hot dip galvanized steel and thermal-sprayed metallic coating.

Proper surface preparation is one of the preconditions for a long lasting protective coating system. The classification of the coating systems is based on the minimum requirement for surface preparation described in Table B.1. If not otherwise specified in the technical data sheets of the paints, these preparation grades should be a minimum requirement for surface preparation.

Table B.1 — Surface preparation

Substrate	Minimum preparation grade (if not otherwise specified)	First layer of protective system
Carbon steel rust grades A, B, C or D[a] according to ISO 8501-1	Sa 2 1/2 according to ISO 8501-1 medium (G) according to ISO 8503-1	Zn (R) primer
	Sa 2 1/2 according to ISO 8501-1 additional information should be given in the technical data sheets	Miscellaneous primer
	According to ISO 2063 (all parts)	Thermal-sprayed metallic coating and sealer (according to ISO 2063 (all parts))

[a] For rust grade D special care is needed to ensure proper surface preparation.

The minimum required surface preparation of hot dip galvanized steel according to ISO 1461 is sweep blasting (see ISO 12944-4), if not otherwise specified.

NOTE Other criteria are also important, such as presence of water soluble salts, dust, oil, grease, etc.

The NDFT as stated in Tables B.2 to B.5 for guidance in specific circumstances might not be appropriate to the end use. Increased DFT might be necessary.

New innovative coating technologies, if available, might provide equivalent corrosion protection at lower NDFT and/or reduced MNOC compared to the current coating technologies covered in this document (Table B.2 to Table B.5). The same applies to proven systems that have been performing well over long field experience, despite not fulfilling the requirements concerning minimum number of coats and minimum dry film thickness. Performance of these new coating technologies should be proven by a combination of experience (field applications which are periodically evaluated and product development trials) and laboratory testing according to ISO 12944-6, which should be carried out and reported by an independent test laboratory. Extended test durations from those stated in ISO 12944-6 could be used to further demonstrate performance; a well-established, proven coating system appropriate to the intended end use should be used as a reference to compare performance. It is accepted that for new technologies, a long track record may not be available; however, performance data from harsher environments and shorter durations can also be useful in establishing a coating systems fitness for use.

In the case of proven systems not fulfilling the MNOC and/or minimum dry film thickness, field performance evidence shall be documented with application and inspection data on field-exposed steel structures, respectively at the moment of application and after a number of years exposed in a known corrosivity environment (as defined in this document). Claims on durability expectation (l, m, h, vh as defined in this document) can only be made according to the number of years of proven performance according to criteria agreed between the parties.

Table B.2 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on abrasive blasted steel substrates

Durability		**Low (l)**			**Medium (m)**			**High (h)**			**Very high (vh)**		
Type of primer		Zn (R)	Misc.		Zn (R)	Misc.		Zn (R)	Misc.		Zn (R)	Misc.	
Binder base of primer		ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY
Binder base of subsequent coats		EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY
C2	MNOC	[a]			—	—	1	1	1	1	2	2	2
	NDFT				—	—	100	60	120	160	160	180	200
C3	MNOC	—	—	1	1	1	1	2	2	2	2	2	2
	NDFT	—	—	100	60	120	160	160	180	200	200	240	260
C4	MNOC	1	1	1	2	2	2	2	2	2	3	2	—
	NDFT	60	120	160	160	180	200	200	240	260	260	300	—
C5	MNOC	2	2	—	2	2	—	3	2	—	3	3	—
	NDFT	160	180	—	200	240	—	260	300	—	320	360	—

The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

[a] If a coating is desired, use a system from a higher corrosivity category or durability, e.g. C2 high or C3 medium.

Detailed examples for protective paint systems in different corrosivity categories and durabilities are given in Annex C, Tables C.1 to C.6.

Table B.3 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on hot dip galvanized steel according to ISO 1461

Durability		Low (l)		Medium (m)		High (h)		Very high (vh)	
Binder base of primer		EP, PUR	AY	EP, PUR	AY	EP, PUR	AY	EP, PUR	AY
Binder base of subsequent coats		EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY
C2	MNOC	a		a		1	1	1	2
	NDFT					80	80	120	160
C3	MNOC	a		1	1	1	2	2	2
	NDFT			80	80	120	160	160	200
C4	MNOC	1	1	1	2	2	2	2	—
	NDFT	80	80	120	160	160	200	200	—
C5	MNOC	1	2	2	2	2	—	2	—
	NDFT	120	160	160	200	200	—	240	—

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE 1 The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.

NOTE 2 The durability is in this case related to the paint system adhesion to the hot dip galvanized surface. In case of damaged paint system, the remaining hot dip galvanized layer delivers further protection to the steel.

[a] If coating is desired, use a system from higher corrosivity categories or durability, e.g. C2 high or C3 medium.

Detailed examples for protective systems in different corrosivity categories and durabilities are given in Table D.1.

Table B.4 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on thermal-sprayed metallic coating according to ISO 2063 (all parts)

Durability		High (h)	Very high (vh)
Binder base of subsequent coats		EP, PUR	EP, PUR
C3	MNOC	1	2
	NDFT	120	160
C4	MNOC	2	2
	NDFT	160	200
C5	MNOC	2	2
	NDFT	200	240
Special care should be taken when overcoating thermal-sprayed aluminium in a chloride environment as premature failure have been documented. See also Reference [13].			
NOTE For abbreviations see Table A.1.			

Detailed examples for protective systems in different corrosivity categories and durabilities are given in Table E.1.

Table B.5 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint systems for carbon steel for three immersion categories of two different durabilities on abrasive blasted steel substrates

Durability	High (h)			Very high (vh)		
Type of primer	Zn (R)	Misc.	—	Zn (R)	Misc.	—
Binder base of primer	ESI, EP, PUR	EP, PUR	—	ESI, EP, PUR	EP, PUR	—
Binder base of subsequent coats	EP, PUR	EP, PUR	EP, PUR	EP, PUR	EP, PUR	EP, PUR
MNOC	2	2	1	2	2	1
NDFT	360	380	400	500	540	600
Minimum requirements for lower durabilities shall be agreed upon between the interested parties.						
NOTE For abbreviations see Table A.1.						

Detailed examples for protective systems in different corrosivity categories and durabilities are given in Table C.6.

Annex C
(informative)

Paint systems for carbon steel

Following the requirements given in Annex B, specific formulations for paint systems for carbon steel have been proven by a combination of field experience and laboratory testing according to ISO 12944-6. General generic examples whose specific formulations have not necessarily been tested are given in Tables C.1 to C.6. Other paint systems having the same performance are possible. If these examples are used, it shall be ensured that the paint systems chosen comply with the indicated durability when execution of the paint work takes place as specified. See also 7.4.

The coating system numbers consist of the corrosivity category and a sequential number. Due to the individual and extreme type of corrosive stress defined in corrosivity category CX, no general recommendations for paint systems can be given. Suitable paint systems and assessment criteria for CX have to be specified by the contractors.

Table C.1 — Paint systems for carbon steel for corrosivity category C1

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
For C1 any system used for a higher corrosivity category, preferably for C2, may be used.											

Table C.2 — Paint systems for carbon steel for corrosivity category C2

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C2.01	AK, AY	Misc.	1	40 to 80	AK, AY	1 to 2	80	X			
C2.02	AK, AY	Misc.	1	40 to 100	AK, AY	1 to 2	100	X	X		
C2.03	AK, AY	Misc.	1	60 to 160	AK, AY	1 to 2	160	X	X	X	
C2.04	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 3	200	X	X	X	X
C2.05	EP, PUR, ESI	Misc.	1	60 to 120	EP, PUR, AY	1 to 2	120	X	X	X	
C2.06	EP, PUR, ESI	Misc.	1	80 to 100	EP, PUR, AY	2	180	X	X	X	X
C2.07	EP, PUR, ESI	Zn (R)	1	60	—	1	60	X	X	X	
C2.08	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X	X	X
In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)]. NOTE For abbreviations see Table A.1.											

Table C.3 — Paint systems for carbon steel for corrosivity category C3

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C3.01	AK, AY	Misc.	1	80 to 100	AK, AY	1 to 2	100	X			
C3.02	AK, AY	Misc.	1	60 to 160	AK, AY	1 to 2	160	X	X		
C3.03	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 3	200	X	X	X	
C3.04	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 4	260	X	X	X	X
C3.05	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X		
C3.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X	X	X	
C3.07	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X	X	X
C3.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60	X	X		
C3.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X	X	
C3.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X	X	X

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE For abbreviations see Table A.1.

Table C.4 — Paint systems for carbon steel for corrosivity category C4

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C4.01	AK, AY	Misc.	1	60 to 160	AK, AY	1 to 2	160	X			
C4.02	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 3	200	X	X		
C4.03	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 4	260	X	X	X	
C4.04	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1 to 2	120	X			
C4.05	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X	X		
C4.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X	X	
C4.07	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2 to 4	300	X	X	X	X
C4.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60	X			
C4.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X		
C4.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X	X	
C4.11	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	260	X	X	X	X

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE For abbreviations see Table A.1.

Table C.5 — Paint systems for carbon steel for corrosivity category C5

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C5.01	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X			
C5.02	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X		
C5.03	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2 to 4	300	X	X	X	
C5.04	EP, PUR, ESI	Misc.	1	80 to 200	EP, PUR, AY	3 to 4	360	X	X	X	X
C5.05	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X			
C5.06	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X		
C5.07	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	260	X	X	X	
C5.08	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	320	X	X	X	X

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE For abbreviations see Table A.1.

Table C.6 — Paint systems for carbon steel for immersion categories Im1, Im2 and Im3

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
I.01	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR	2 to 4	360	X	X	X	
I.02	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR	2 to 5	500	X	X	X	X
I.03	EP, PUR, ESI	Misc.	1	80	EP, PUR	2 to 4	380	X	X	X	
I.04	EP, PUR, ESI	Misc.	1	80	EP, PUR	2 to 4	540	X	X	X	X
I.05			—	—	EP, PUR	1 to 3	400	X	X	X	
I.06			—	—	EP, PUR	1 to 3	600	X	X	X	X

Depending on mechanical and abrasive loads, it can be necessary to increase the NDFT of the systems to ensure the durability. For abrasive loads, NDFT of up to 1 000 µm are recommended, and for extreme abrasive loads even up to 2 000 µm.

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE 1 Water-borne products are not yet suitable for immersion.

NOTE 2 The immersion categories deal with external exposure only. Confined spaces and tank internals are outside the scope of this document (see ISO 12944-2).

NOTE 3 For abbreviations see Table A.1.

Annex D
(informative)

Paint systems on hot dip galvanized steel

Following the requirements given in Annex B, specific formulations for paint systems on hot dip galvanized steel according to ISO 1461 have been proven by a combination of field experience and laboratory testing according to ISO 12944-6. General generic examples whose specific formulations may not have been tested are given in Table D.1. Other paint systems having the same performance are possible. If these examples are used, it shall be ensured that the paint systems chosen comply with the indicated durability when execution of the paint work takes place as specified. See also 7.4.

The coating system numbers consist of the leading letter "G", the number of the corrosivity category and a sequential number. Due to the individual and extreme type of corrosive stress defined in corrosivity category CX, no general recommendations for paint systems can be given. Suitable paint systems and assessment criteria for CX have to be specified by the contractors.

Table D.1 — Paint systems on hot dip galvanized steel for corrosivity categories C2 to C5

System No.	Corrosivity category	Priming coat			Subsequent coat(s)	Paint system		Durability[a]			
		Binder type	No. of coats	NDFT in µm	Binder type	No. of coats	NDFT in µm	l	m	h	vh
G2.01	C2	EP, PUR, AY	1	80		1	80	X	X	X	
G2.02		AY	1	80	AY	2	160	X	X	X	X
G2.03		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X	X	X
G3.01	C3	EP, PUR, AY	1	80		1	80	X	X		
G3.02		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X	X	
G3.03		AY	1	80	AY	2	160	X	X	X	
G3.04		EP, PUR	1	80	EP, PUR, AY	2	160	X	X	X	X
G3.05		AY	1	80	AY	2 to 3	200	X	X	X	X
G4.01	C4	EP, PUR, AY	1	80		1	80	X			
G4.02		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X		
G4.03		AY	1	80	AY	2	160	X	X		
G4.04		EP, PUR	1	80	EP, PUR, AY	2	160	X	X	X	
G4.05		AY	1	80	AY	2 to 3	200	X	X	X	
G4.06		EP, PUR	1	80	EP, PUR, AY	2 to 3	200	X	X	X	X
G5.01	C5	EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120	X			
G5.02a		AY	1	80	AY	2	160	X			
G5.02b		EP, PUR	1	80	EP, PUR, AY	2	160	X	X		
G5.03		AY	1	80	AY	2 to 3	200	X	X		
G5.04		EP, PUR	1	80	EP, PUR, AY	2 to 3	200	X	X	X	
G5.05		EP, PUR	1	80	EP, PUR, AY	2 to 3	240	X	X	X	X

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE For abbreviations see Table A.1.

[a] The durability is in this case related to the paint system adhesion to the hot dip galvanized surface. In case of a damaged paint system, the remaining hot dip galvanized layer delivers further protection to the steel.

The use of paint systems on hot dip galvanized steel for immersion service is possible but special care is needed before confirming suitability. Paint systems applied on hot dip galvanized surfaces do not automatically prevent early failure causes and, in some situations, can contribute further to premature breakdown of the protective system. Choosing to specify a paint system over hot dip galvanized