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Thermal spraying — Zinc, aluminium and their alloys —

Part 1: Design considerations and quality requirements for corrosion protection systems

Projection thermique — Zinc, aluminium et alliages de ces métaux —

Partie 1: Considérations de conception et exigences de qualité pour les systèmes de protection contre la corrosion

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

This document, together with ISO 2063-2:2017, cancels and replaces ISO 2063:2005, which has been technically revised.

A list of all the parts in the ISO 2063 series can be found on the ISO website.

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Introduction

In order to protect iron- and steel-based structures (e.g. for steel construction, bridge construction, steel structures for water construction, onshore and offshore wind energy constructions, petrol and natural gas industry) against corrosion, protective coatings are usually deposited. Corresponding to type, shape and required functionality of the part, numerous procedures are available. The deposition of corrosion protection coatings or coating systems can be done by applying hot-dip galvanizing, organic coatings or thermal spraying of zinc, aluminium and their alloys. Using combinations of metallic and organic coatings, duplex corrosion protection coating systems can be produced.

Thermal-sprayed corrosion protection coatings made of zinc, aluminium and their alloys can be sprayed onto all steels which make up the components used in the relevant industrial application. This may be carried out on-site, as well as in the workshop, regardless of the article's size. Due to the usually low heat input into the surface of the part, only a slight thermal loading of the substrate occurs, so that changes in steel properties and deformation of the part do not occur.

Corrosion protection coatings can be used as repairs or rework of defects of other coatings (e.g. uncoated hot-dip zinc galvanized areas) or worn coatings where thermal spraying can be applied on the spot. Due to relative low investment costs, thermal spraying can also be economically applied for single parts.

The ISO 2063 series applies to thermal-sprayed metallic coatings to protect iron and steel against corrosion by deposition of zinc, aluminium or their alloys onto the uncoated surface to be protected.

This document targets designers of components. It covers the planning engineering of the corrosion protection system and deals with the basic rules for planning of corrosion protection systems and for the constructive design of the components to be protected, if the protection system is based upon a thermal-sprayed metallic coating.

ISO 2063-2 targets manufacturers of corrosion protection systems. It deals with the requirements for the execution of the corrosion protection works by thermal spraying in the workshop and on-site.

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Thermal spraying — Zinc, aluminium and their alloys —

Part 1:
Design considerations and quality requirements for corrosion protection systems

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1 Scope

This document specifies requirements for the protection of iron and steel surfaces against corrosion by applying thermal-sprayed metallic coatings of zinc, aluminium or their alloys.

In this document, requirements for the planning of the corrosion protection system and for the constructive design of the component to be protected are specified, where thermal spraying is intended to be the process for the deposition of the metallic corrosion protection.

Some field-related basic terms are defined and instructions for corrosion behaviour of the zinc and aluminium materials under different environment conditions are provided.

Characteristic properties of the coating, e.g. coating thickness, minimum adhesive strength and surface appearance, are specified and test procedures for thermal-sprayed corrosion protection coatings of zinc, aluminium or their alloys are determined.

This document is valid for applying thermal-sprayed zinc and aluminium protection coatings against corrosion in the temperature range between −50 °C to +200 °C, taking into consideration the service conditions of any sealants used. Heat-resistant protective coatings of aluminium are covered by ISO 17834 and are not in the scope of this document.

Other corrosion protection processes, e.g. hot-dip galvanizing (galvanic coating), sherardizing, electroplating or selection and deposition of organic coatings/paints are not in the scope of this document.

Requirements for the manufacturing of thermal-sprayed coatings are specified in ISO 2063-2.

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 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

ISO 2063-2:2017, *Thermal spraying —Zinc, aluminium and their alloys — Part 2: Execution of corrosion protection systems*

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

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

ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions*

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*

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

ISO 12671, *Thermal spraying - Thermally sprayed coatings - Symbolic representation on drawings*

ISO 14232-1, *Thermal spraying — Powders — Part 1: Characterization and technical supply conditions*

ISO 14916, *Thermal spraying — Determination of tensile adhesive strength*

ISO 14917, *Thermal spraying — Terminology, classification*

ISO 14919, *Thermal spraying — Wires, rods and cords for flame and arc spraying — Classification — Technical supply conditions*

ISO 14923, *Thermal spraying — Characterization and testing of thermally sprayed coatings*

EN 10163-2, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections — Part 2: Plate and wide flats*

EN 10163-3, *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections — Part 3: Sections*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14917, ISO 8044 and the following apply.

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

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

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

3.1
service life
expected lifetime of a product (e.g. a structure, component or part) or the acceptable period of use in service

Note 1 to entry: It is also the time that any manufactured item can be expected to be serviceable.

3.2
design life
period of time during which the item (e.g. a structure, component, part or product) is expected by its designers to work within its specified parameters

Note 1 to entry: In the case of series production, it is the period of time between the putting into service of a single item and that item's onset of wearing out.

3.3
life to first maintenance
durability
expected life of a coating system until first maintenance

Note 1 to entry: It is also the time interval that elapses after the initial coating before coating deterioration reaches the point that maintenance is necessary to restore protection of the base metal in accordance with ISO 12944-1.

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3.4
protective coating system
sum total of the coats of metal materials and/or paints (duplex coatings) or related products which are to be applied or which have been applied to a substrate to provide corrosion protection in accordance with ISO 12944-1

3.5
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 in accordance with ISO 12944-5

Note 1 to entry: In many languages, the term "pre-fabrication primer" does not have the same meaning in English.

3.6
maintenance
sum of all measures to ensure that function of protection of the steel structure against corrosion is maintained

Note 1 to entry: Maintenance includes, but is not limited to, paintwork. Such paintwork can be patch painting (repair included spots/areas of the coating system), patch painting followed by over-painting of the structure or total repairing in accordance with ISO 12944-8.

4 Criteria for corrosion and corrosion protection by thermal-sprayed coatings

4.1 General

Thermal-sprayed coatings of zinc, aluminium and their alloys can significantly increase the effectiveness of the corrosion protection and the service life of the parts. Thermal-sprayed coatings are to be applied preference, if a long time effective corrosion protection is required.

4.2 Corrosivity categories and environment conditions

The corrosivity category provides a basic rule for selecting materials and corrosion protection measures in relation to requirements for the individual application, especially for the service life. Definitions of corrosivity categories and environment conditions are given in ISO 9223 and ISO 12944-2. Additional notes for measuring relevant environment parameters are given in ISO 9225.

Annex A contains a list of typical environments related to the estimation of corrosivity categories.

4.3 Corrosion rate

The corrosion rate of a material is given by the medium and by the exposure time of moisture, air pollution, temperature and contamination of the surface.

ISO 9224 contains information about corrosion rates for different metals. Additional information for metallic materials related to the likelihood of corrosion in the atmosphere environment is given in ISO 9223.

4.4 Coating materials and corrosion behaviour

4.4.1 General

The coating material and the required coating thickness are to be selected and specified in relation to the expected corrosivity, the required design life and construction design.

The corrosion rate of metals and alloys, are not constant over the course of the exposure time. For most metals and alloys, it decreases with time of the exposure due to the accumulation of corrosion products on the surface of the exposed metal.

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The corrosion rates of thermal-sprayed coatings are different from bulk materials and other types of metallic coatings due to porosity of thermal-sprayed coatings.

4.4.2 Zinc and zinc alloys

Zinc possesses a high resistance to corrosion due to its passive behaviour against atmospheric attack. However, the corrosion rate per year is affected by the composition of the atmosphere.

The rate of corrosion of zinc or zinc coatings in water depends mainly on the pH value, the carbon dioxide value and the salt and oxygen content of the water. In neutral or slightly alkaline water, zinc corrodes insignificantly only.

Alloying of aluminium up to a content of 15 mass % to the zinc base metal generates a higher corrosion resistance in maritime atmosphere compared to pure zinc metal in the case of lower pH values. It is evidently shown that the passive protection of the aluminium due to its oxidation can be combined with the cathodic protection of zinc.

NOTE Many applications of zinc and zinc alloys in the atmosphere indicate their favourable corrosion behaviour, e.g. the frequent use of thermal-sprayed zinc and zinc alloys for coatings on steel structures in industrial and marine environments and also in form of solid material for roofs and gutters and cast tubes in soils.

Details of the corrosion behaviour of zinc materials (Zn99,99 and ZnAl15) are shown in Annex B.

Further details for zinc, zinc alloys and their corrosion behaviour can be taken from ISO 14713-1.

4.4.3 Aluminium and aluminium alloys

The corrosion behaviour of aluminium materials is characterized by the protection behaviour of the electrical isolating aluminium oxide layer, which is rebuilt spontaneously even after mechanical damage to the surface. Aluminium shows a very high corrosion resistance in slightly acidic to slightly basic media and is particularly suitable for the corrosion protection of steel structures in SO_2-containing industrial atmospheres, as well as in marine environments.

Further details for aluminium, aluminium alloys and their corrosion behaviour in sea water and maritime atmosphere are to be taken from the literature.

A summary of the details for the corrosion behaviour of aluminium materials (Al and AlMg5) are shown in Annex B.

NOTE Aluminium coatings are successfully used in the building industry, where they are applied by electrolytic anodizing or thermal spraying. They have been proven in industrial and marine environments, as well as in seawater immersion.

5 Requirements for the corrosion protection systems and their planning

5.1 General rules — Technical requirements

Application of the thermal-sprayed corrosion protection system requires counter-intuitive design considerations as compared to other coating processes such as hot-dip galvanizing, which are not in the scope of this document. The most adequate corrosion protection system for the specific application should be specified according to the material used and the coating process before starting the design at any time. In the case of a more serious corrosion attack, an additional organic coating should be applied to the spray coating (duplex system), which can increase the corrosion protection significantly.

The following points of view shall be considered and stipulated in a specification, where required.

a) The corrosion protection system, e.g. a thermal-sprayed coating, sealed and covered by an organic coating, shall be selected in such a way that it complies with the required design life of the component. This is especially valid for surfaces, which are not accessible after assembly. A coating

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protection system, which is intended to survive the required design life of the construction with appropriate maintenance, shall be applied.

b) If there is no protection system available that is likely to survive for the full expected design life, the corrosion protection system shall be planned not to corrode or only corrode insignificantly until the first maintenance is planned. In that way, only the organic coating shall be renewed during maintenance. The adequate period of time to first maintenance shall be stipulated.

c) Thermal-sprayed metallic corrosion protection coatings may be sealed. The sealant to be used shall be stipulated in the coating specification or the manufacturing instructions. Comparability with further organic coatings and the thermal-sprayed metallic coating shall be considered.

d) Because thermal spraying can be applied in the workshop, as well as on-site, instructions as to the place of coating application shall be given, if applicable.

e) If bimetallic corrosion is possible, adequate organic coatings or foils as a barrier are to be stipulated. Organic coating systems can be chosen relative to the corrosivity category in accordance with ISO 12944-5.

f) ISO 12944-5 provides guidance for the selection of organic coating materials which are also suitable as topcoats for thermally sprayed coatings.

Details for applying the sealing and deposition of the organic coating to a thermal-sprayed coating can be taken from 6.5 and 6.6.

5.2 Used spray materials and coating thickness

5.2.1 Spray materials

Primarily, spray materials of zinc, aluminium or their alloys for applications covered in this document are applied in wire form. In the case of smaller areas and for repairs, spray powders are also used. Usual spray materials are available

— in wire form:
  — Zn99,99 in accordance with ISO 14919, code number 2.1;
  — ZnAl15 in accordance with ISO 14919, code number 2.3;
  — Al99,5 in accordance with ISO 14919, code number 3.2;
  — AlMg5 in accordance with ISO 14919 , code number 3.3;
— in powder form:
  — Al 99 in accordance with ISO 14232-1;
  — Zn 99,5 in accordance with ISO 14232-1;
  — ZnAl15 (no standard available).

The spray material to be used shall be specified in the manufacturing instructions.

5.2.2 Coating thickness

Depending upon the service conditions of the construction, the corrosivity of the environment, the requested service life and the expected corrosion resistance of the coating, the composition of the coating and the thickness of the sprayed coating are critical considerations.

In relation to the corrosivity and the selection of the spray material, the minimum coating thickness mentioned in Table C.1 for coatings of zinc, aluminium or their alloys are recommended. The minimum coating thickness shall be specified in the manufacturing instructions.

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5.3 Construction design requirements for iron and steel components for thermal spraying

5.3.1 General

The corrosion protection system should be stipulated. This should be the most appropriate for a particular application. The coating should be specified before the design work is started. The design of the part and the specification of the coating should fulfil the instructions of this document and correspond to the recommendations in accordance with ISO 12679.

5.3.2 Recommendations for the design of the part — Avoidance of corrosion creating areas

Components, structures and constructions intended for spray metallizing should be designed considering the general possibilities for operation and limits of the thermal spray processes. The main principles are shown in Table D.1.

Favourable and unfavourable examples of the design for thermal spraying are shown in Figures D.1 to D.4. Further instructions for thermal spraying-related design are provided in Annex D or can be taken from ISO 12679. Further advice for general accessibility can be taken from ISO 12944-3.

5.3.3 Requirements for welding in combination with thermal-sprayed protective coatings

Welding works shall be done prior to thermal spraying. If a construction shall be welded later, the weld zone shall be masked and not be coated up to a distance of about 100 mm from the weld bevel.

If the welding can be applied after thermal spraying, only the area of the weld zone shall be prepared, in accordance with ISO 8501-3, and coated locally. The coating process, e.g. thermal spraying, zinc powder coating, deposition of solder, or an organic coating only, shall be stipulated in the manufacturing instructions.

5.3.4 Thermal spraying of corrosion protected fastenings

The corrosion protection for screws, nuts and other sorts of load-carrying fastenings shall be compatible with the corrosion protection system of the part and should be balanced for the required design life. The current product standards contain specific requirements.

6 Pre-conditions and requirements for the manufacturing process

6.1 General — Requirements

The surface to be corrosion protected by a thermal-sprayed coating shall be unambiguously indicated on the drawing resp. described in the manufacturing instructions. Also, the required minimum thickness and the final conditions of the surface, including the sealing, shall be indicated preferably in accordance with ISO 12671. If further organic coatings shall be deposited, instructions for the organic coating and its application shall be specified in the manufacturing instructions.

6.2 Reference areas

Coated reference areas shall show the durability of the coating system over the service life. Using these guidelines for inspection, the state of the coating shall be evaluated in this area in the presence of an independent supervisor, after a certain or specified service time has elapsed.

In case of spraying very large component surfaces, several reference areas can be required. Location and size of such areas shall be specified by the planning engineering. Selection of the reference area, thermal spraying of the metallic coating and its sealing should be carried out in the workshop, where the final organic coating can be applied on-site. Application of the entire coating work shall be

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supervised by an independent test or supervising body. Performance and results of the entire process shall be separately documented.

6.3 Preparation of the surface to be coated

The influence of acceptable surface imperfections (e.g. material depressions, seams, pores, notches) and repairs by grinding or welding for hot-rolled plates, wide flat steel and profiles in accordance with EN 10163-2 and EN 10163-3 shall be considered for surface preparation.

In order to achieve an adequate adhesive strength, the surface shall be pre-treated (degreasing, cleaning and removing of scale and coatings, if present).

For thermal spraying of coatings of zinc, aluminium or their alloys, the surface shall be prepared until the required level of surface cleanliness Sa 2 ½ G for Zn/ZnAl15 and Sa 3 G for Al/AlMg5 is reached. For further details, see ISO 8501-1. ISO 2063-2 contains the requirements for an adequate surface preparation.

A suitable abrasive grit shall be used for blasting prior to thermal spraying; that way, a roughening and enlarging of the substrate's surface will be achieved and the adhesion strength will increase due to mechanical anchoring.

To meet the requirements of the necessary roughness, the coating specification can contain the required surface roughness condition in accordance with ISO 8503-1; that way, the entire coating system shall be considered because by increasing the number of coat layers, the roughness decreases. ISO 2063-2 contains the roughness values usually applied.

6.4 Thermal spraying

Usually, wire flame (WFS) or arc spraying (AS) is applied for thermal spraying of zinc, aluminium and their alloys for corrosion protection. For smaller surfaces and for repairs, powder flame spraying (PFS) is also used. The procedures are described in ISO 14917.

Thermal spraying for corrosion protection covered by this document is usually manually applied; however, it can also be applied mechanically. In order to ensure reproducibility of the coating quality, mechanical or automatic spraying is recommended, where possible.

To ensure adequate quality of thermal spraying, supervision and testing in accordance with ISO 2063-2 shall be stipulated in the manufacturing instructions.

6.5 Sealing of thermal-sprayed coatings

Thermal-sprayed coatings can have a porosity level of up to 15 %, depending on the spray procedure and spray parameter utilized. In order to reduce the internal porosity of the sprayed coating and to close open pores on and near the surface of the sprayed coating, sealants should be applied. In some cases, sealing is used to improve the appearance and the ability to clean the sprayed coating. Sealing reduces the infiltration of dirt and other contaminations into the thermal-sprayed coating (e.g. aggressive salts, other corrosive contaminants).

The sealants applied shall possess a low viscosity to achieve significant penetration. The chosen sealant shall be compatible with the thermal-sprayed coating. Sealants based on alkyd resins should not be applied to zinc and zinc alloys. The compatibility of the sealant with organic coating shall be considered, if applicable.

Sealing should be in accordance with ISO 2063-2.

Natural sealing of thermal-sprayed coatings is also possible and can be achieved by oxidation of the coating, as long as the coating is exposed to an adequate environment and the created oxides, hydroxides and/or basic salts are not soluble in this environmental conditions. However, care shall be taken to avoid rusting before the pores are closed.

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6.6 Metallic coatings and additional organic top coatings

ISO 12944-5 gives recommendations for additional organic coatings, which can be applied after sealing of the metallic spray coating, usually called duplex coating system.

ISO 12944-8 and ISO 12944-7 should be considered when planning and applying the organic coating. As long as they are appropriate for the order processing type and handling, organic coatings shall be stipulated in the manufacturing instructions.

6.7 Requirements for the tests — Test procedures

6.7.1 General

Checking the environment conditions (humidity, dew point, temperature of the surrounding and the component) is specified in ISO 2063-2.

Usual tests of the sprayed coatings are:

— non-destructive testing:

  — visual testing;

  — testing of coating thickness;

— destructive testing (test on the accompanying specimen):

  — adhesion testing (pull-off test in accordance with ISO 4624);

  — tensile adhesion testing in accordance with ISO 14916 (for procedure qualification only or, if required, to be specified in the coating specification or manufacturing instructions);

  — metallographic investigations (coating thickness, quality assessment).

Since specific tests cannot be applied non-destructively on the component, accompanying specimens are to be provided. The form of the accompanying specimens shall be suitable to enable destructive testing. Recommendations for the specimen's form are provided in ISO 2063-2:2017, Annex E. The type and number of specimens shall be stipulated in the manufacturing instructions.

The accompanying specimens shall be sprayed using the same spray parameters, which are stipulated in the spray procedure specification (TSPS) for the part. Differences in the spray position (preferably horizontal position, over-head, vertically down), the spray method (manually, mechanically) and the general spray conditions (in the workshop or on-site) shall be considered.

If a test for a specific location of the structure shall be required, a special test piece (e.g. by a mock up) representing the conditions shall be agreed upon between the contracting parties.

6.7.2 Visual inspection — Appearance

The surface of the coating shall be of uniform appearance without inclusions or bare patches and be free from non-adhering particles or defects, which could be detrimental to the service life and expected use of the protective coating. The appearance of surface imperfections and defects is described in ISO 14923. The execution of the visual inspection shall be in accordance with ISO 2063-2.

6.7.3 Coating thickness

Preferably, the coating thickness shall be electromagnetically measured using a mobile coating thickness measuring instrument in accordance with ISO 2178. Location and number of the measuring points are to be chosen such that the measuring results can be adopted as being representative for the entire sprayed coating.

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Such coating thickness measuring techniques measure the entire thickness including any sealers and further organic coats. Therefore, the thickness of the metallic layer can only be determined this way before any subsequent layers are applied.

The coating thickness can also be measured destructively on the accompanying specimens (metallographic investigations) (for details, see 6.7.5). This shall be stipulated in the manufacturing instructions, if required.

6.7.4 Adhesion strength

If required, the tensile adhesive strength shall be determined in accordance with ISO 2063-2, following ISO 4624. The mean values of the tensile adhesive strength shall be agreed upon between the contracting parties. Also, if another test procedure is to be applied, its use shall be agreed upon between the contracting parties.

The surface of the component to be coated or the accompanying specimen shall be plane and rigid enough to avoid deflection during testing. In the case of tensile adhesive testing on the component, the position shall be representative for the sprayed coating.

Usually, tensile adhesive testing in accordance with ISO 14916 is not used for quality control measures. If this measurement shall be required, e.g. for qualification matters, the number of accompanying specimens are to be stipulated in the coating specification or manufacturing instructions.

6.7.5 Metallographic investigation

If required, the coating thickness can be determined by metallographic means. A cross-section shall be taken out of a coated accompanying specimen. The investigation shall follow the instructions of ISO 1463.

The main conditions for the assessment of the coating quality are as follows:

— coating defects, e.g. cracks, pores, flaking, peeling, irregular appearance, insufficient coating thickness;

— excessively blasted substrate surface, too many grit residues or pores at the substrate-coating interface;

— oversize single pores or degree of porosity in the coating.

The limiting levels of imperfections to be accepted shall be agreed upon between the contracting parties, if necessary. Test procedure, assessment of the test results and their documentation are specified in ISO 2063-2.

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7 Requirements for the manufacturer

7.1 General

Requirements for qualification, manufacturing and testing are specified in ISO 2063-2. To ensure that these requirements will be fulfilled by the applicator, ISO 2063-2 shall be stipulated in the manufacturing instructions of the design engineering, e.g. in a specific manufacturing specification.

If a qualification of the spray procedure specification is required, this shall be stipulated in the manufacturing instructions.

7.2 Coating specification — Requirements for the spray coating

Due to technical operation demands on the components (e.g. mechanical loading, the corrosive conditions at the service location regarding the corrosivity category), the designer shall draw up a

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coating specification and define both the coating requirements and the expected service life of the corrosion protection.

That way, the coating specification can also contain requirements for the surface preparation and advices on applying a specific thermal spray procedure.

Usually, the following requirements are to be specified in the coating specification or in the manufacturing instructions for applications covered in this document, if the coating system shall not be selected by the manufacturer of the coating due to contractual agreements and instructions.

— Coating material or spray material.

— Stipulated spray procedure.

— Minimum coating thickness (occasionally, maximum coating thickness also).

— Minimum tensile adhesive strength (MPa) in accordance with ISO 2063-2.

— Surface condition in the as-blasted condition.

— Surface condition in the as-sprayed condition.

— Surface condition in the final machined condition (if applicable).

— Sealing of the sprayed coating, instructions for the sealant.

— Further organic coatings (if applicable).

— Tests and scope of tests.

— Permit of repairs, repair procedures and size of defects or damages due to e.g. transportation, assembly or destructive testing or coating defects.

Details for final condition, storage, transportation, assembly, permit of repairs and testing may also be specified in the manufacturing instructions instead of the coating specification.

Necessary details for the surface preparation for thermal spraying and for the surface conditions prior to spraying can be taken from ISO 2063-2 or they shall be specified in the manufacturing instructions.

8 Documentation

Documentation shall be provided by the manufacturer of the thermal-sprayed coating. It shall contain the tests applied and test results, including those from job reference specimens of the thermal sprayers. Furthermore, designations of the parts, tracing back of the operation steps and quality assurance documents (e.g. work instructions, test instructions and reports, technical data sheets of the blasting grit, the spray material, other coating materials) are to be kept. These requirements are specified in ISO 2063-2.

Reports of maintenance and repair works shall be also documented.

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Annex A
(informative)

Corrosivity categories — Environment conditions — Exposure

Table A.1 — Corrosivity categories — Environment conditions — Exposure

CC[a]	Typical environment conditions		Exposure[b]
	Indoor	Outdoor	
C 1	Not relevant for this document	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, central Arctic/ Antarctica	VL
C 2		Temperate zone, atmospheric environment with low pollution (SO_2 < 5 µg/m^3), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas	L
C 3		Temperate zone, atmospheric environment with medium pollution (SO_2 between 5 µg/m^3 to 30 µg/m^3) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides, subtropical and tropical zones with atmosphere with low pollution	M
C 4	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution (SO_2: 30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water, exposure to strong effect of de-icing salts, subtropical and tropical zones with atmosphere with medium pollution	H
C 5	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones	Temperate and subtropical zones, atmospheric environment with very high pollution (SO_2: 90 µg/m^3 to 250 µg/m^3) and/or important effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline	VH

SOURCE ISO 9223, ISO 12944 (all parts) and ISO 14713-1.

[a] CC means corrosivity category.

[b] Corrosion exposure time: VL = Very low; L = low; M = Medium; H = high; VH = very high.

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Table A.1 *(continued)*

CC[a]	Typical environment conditions		Exposure[b]
	Indoor	Outdoor	
CX	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter	Subtropical and tropical zones (very high time of wetness), atmospheric environment with very high pollution (SO_2 higher than 250 µg/m^3), including accompanying and production pollution and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas with occasional contact with salt spray	extreme
Im1		Fresh water	
Im2		Sea water in temperature climate	VH
Im3		Soils	
Im4		Sea or brackish water	

SOURCE ISO 9223, ISO 12944 (all parts) and ISO 14713-1.

[a] CC means corrosivity category.

[b] Corrosion exposure time: VL = Very low; L = low; M = Medium; H = high; VH = very high.

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Annex B
(informative)

Summary of the corrosion behaviour of thermal-sprayed coatings of zinc, aluminium and their alloys

Zn99,99

— High corrosion resistance in alkali medium at pH 7 to pH 12.

— Excellent protection against atmospheric corrosion.

— High so-called “cathodic (long-distance protective) reaction”.

— High corrosion resistance in soil with organic coatings.

— Life cycle time proportional to coating thickness.

— Inadequate in the case of higher salt content in air, as for coastal regions.

— Corrosion behaviour similar to that of hot dip galvanizing.

ZnAl15

— Higher corrosion resistance against atmospheric corrosion than zinc.

— Higher corrosion resistance against chlorides and especially SO_2 containing atmospheres than zinc.

— Higher corrosion resistance in soil with organic coatings.

— Inadequate for applying in salt water without organic coating.

— Cathodic protection; however, smaller than for pure zinc.

Al99,5

— High corrosion resistance in media from pH 4 to pH 9.

— Especially sufficient for SO_2 containing industrial atmosphere.

— Well sufficient for marine atmosphere and in seawater.

— High heat resistance.

— Low cathodic protection in the atmosphere.

— Cathodic protection; high only in a strong electrolyte, e.g. sea water.

AlMg5

— As a sprayed coating, it is used in the same places as Al generally.

— As solid material, especially sufficient in marine atmosphere and in sea or brackish water.

— The loss rate in these corrosive media is significantly lower than for pure aluminium.

— Service is also given for environment conditions according to corrosiveness categories Im 2 and C5-M (salt water, offshore plants).

— Cathodic protection in the atmosphere is low.

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— Cathodic protection; high only in strong electrolytes, e.g. sea water.

— Levels of Mg in sprayed coating can vary between 1,5 % and 4,5 %, depending upon the spray process which shall also be specified, as these variances cause differences in corrosion behaviour.

— AlMg5 spray coatings have a higher hardness than aluminium and aluminium coatings and can be machined and polished easier.

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Annex C
(informative)

Recommended values for the thickness of the metallic coating

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Table C.1 — Recommended values for the thickness of the metallic coating — Life to first maintenance > 20 years

Dimensions in micrometres

Corrosivity category in accordance with ISO 12944-2		Metals — Coating materials											
		Zn99,99			ZnAl15			Al99,5			AlMg5		
		as	as+s	as+s+oc	as	as+s	as+s+oc	as	as+s	as+s+oc	as	as+s	as+s+oc
C1	very low	80	80	50	80	80	50	NR	NR	—	NR	NR	—
C2	low	150	80	50	150	80	50	150	150	150	150	150	150
C3	medium	150	100	80	150	80	80	150	150	150	150	150	150
C4	high	NR	150	100[c]	100	100	100[c]	200	200	150	200	200	150
C5	very high	NR	NR	100[c]	200	150	100[c]	250	200	200	250	250	200
CX	extreme	NR	NR	200[c]	250	150	100[c]	250	200	200	250	250	200
Im1		NR	NR	100	NR	NR	100	NR	NR	NR	NR	NR	NR
Im2		NR	NR	250[c]	NR	NR	150[c]	350	200	NR[b]	350	200	NR[b]
Im3		NR	NR	100	NR	NR	100	NR	NR	NR	NR	NR	NR
Im4[a]		NR	NR	250	NR	NR	150	350	300	NR	350	300	NR

Key

as = as sprayed; s = sealed; oc = organic coating; NR = not recommended

[a] In combination with galvanic CP.

[b] Overcoating with a thick organic layer is not recommended. However, a thin topcoat or a coloured sealer may be used for decorative purposes.

[c] An organic coating suitable for the environment; forms an essential part of this coating system.

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Annex D
(informative)

Examples of design and explanations

D.1 Crevices and narrow gaps which arise when back-to-back angles are used, or where stiffeners are welded on by short intermittent filler welds on alternative sides, shall be avoided as they are difficult to protect. Continuous welds are preferred.

D.2 Butt joints should be used in preference to lap joints unless the latter are sealed off by continuous, smoothened welds.

D.3 Corners should preferably be rounded as they are easier to protect than those that are square. They also simplify inspection, cleaning and maintenance and minimize dirt and moisture retention.

D.4 Rounded edges are desirable in order to provide greater surface area to take the protective coating uniformly and to overcome the difficulty of attaining coating thickness on sharp edges. Coatings on sharp edges are also more susceptible to damages.

NOTE Where there are large "edge areas" (e.g. on expanded metal) subject to atmospheric corrosion, it is generally considered to use zinc coating rather than aluminium because zinc gives better cathodic protection to iron and steel.

D.5 Blind crevices, narrow gaps, lap points, channels, and horizontal flat surfaces are potential subjects for corrosion attack arising from retention of moisture and dirt including the grit of the surface preparation. If possible an adequate number and location of drainage holes should be available to get rid of moisture by exhausting or run-off.

D.6 Overlapping surfaces to be joined by welding shall be totally sealed by weld seams to prevent entrapment of blasting grit and to prevent the ingress of moisture to not protected areas.

Further examples and figures are presented in ISO 12679.

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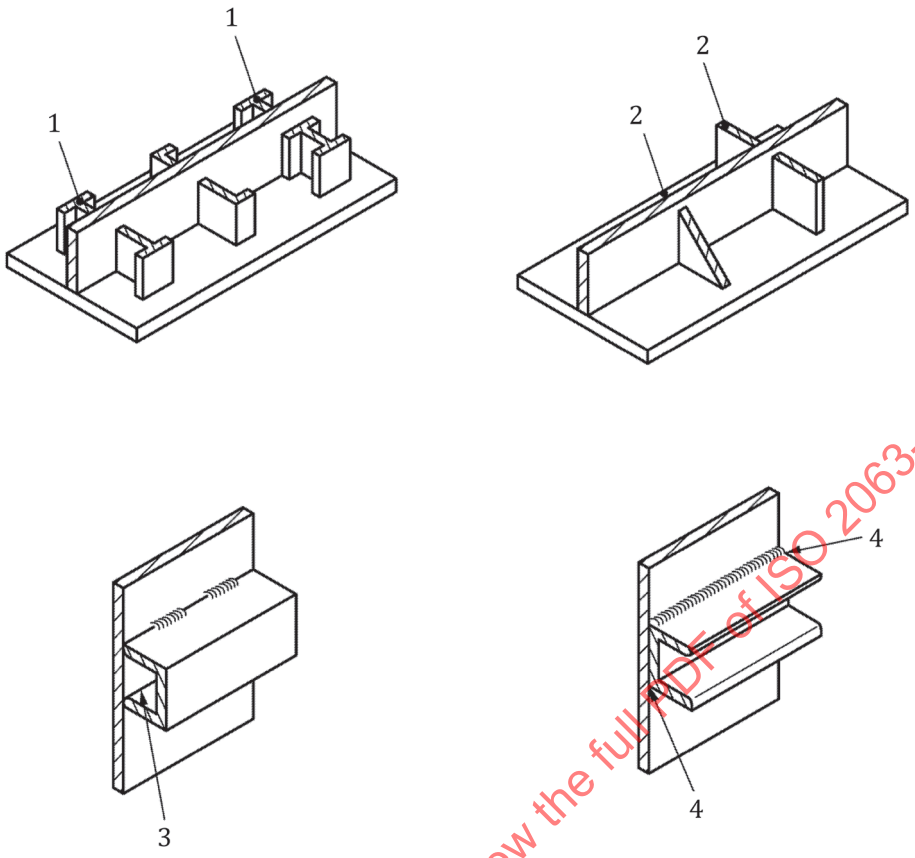

1 Small section stiffeners or small U beams or channels are to be avoided.

2 Flat steels are to be preferred.

3 Shall be avoided, as far as the interior of the U beam had been corrosion protected prior to welding.

4 Continuous welds, smooth and cleaned of slag and weld spatter are to be preferred.

Figure D.1 — Acute interior angles and blind crevices

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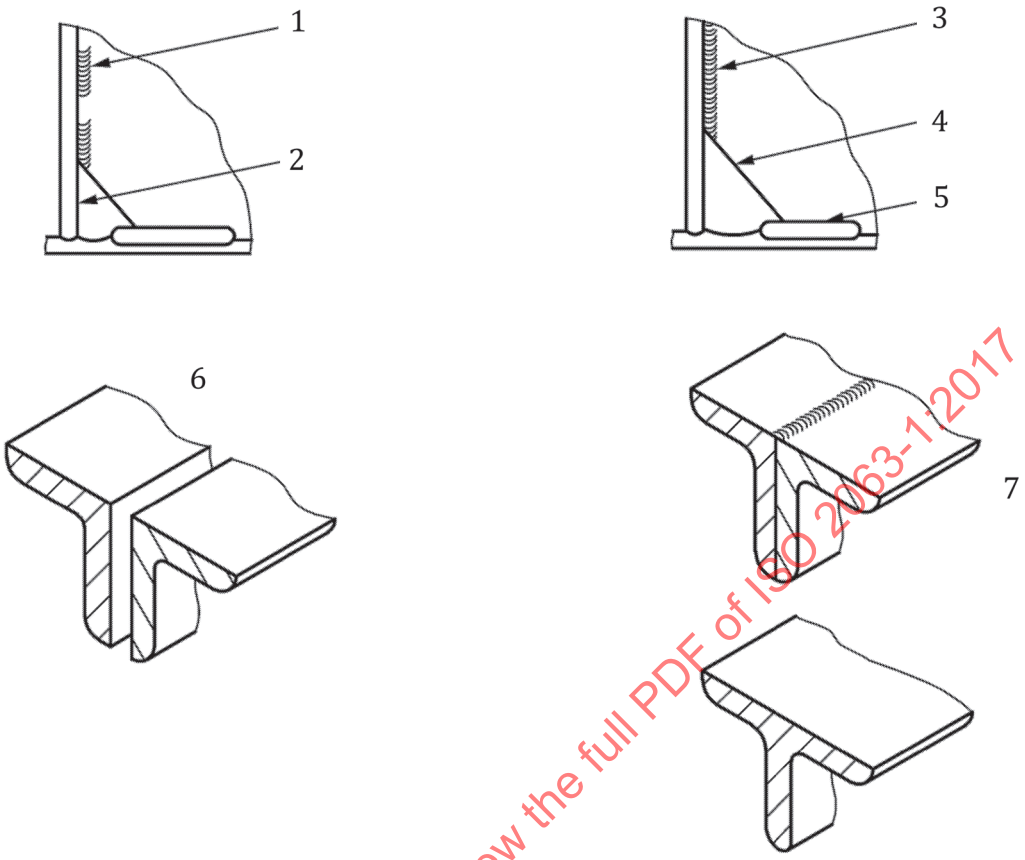

1 Intermittent stiffener welds are to be avoided.
2 Stiffening plate close to the flange corner shall be avoided because the gap cannot be coated sufficiently.
3 Continuous weld to be preferred.
4 Long snipe to give access is to be preferred.
5 Packing well away from the weld is to be preferred.
6 Back-to-back angles are to be avoided because the gap cannot be coated sufficiently.
7 Continuous welds or similar section T-bars are to be preferred.

Figure D.2 — Narrow gaps and crevices

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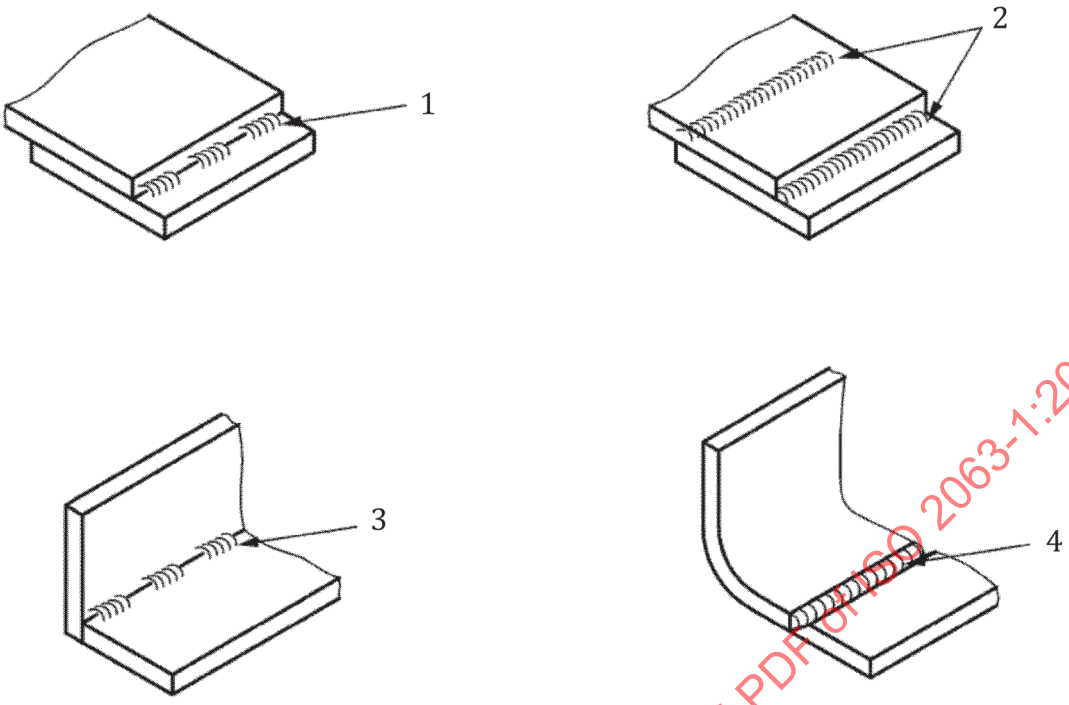

1 Overlapping joints with discontinuous welds are to be avoided.
2 Overlapping fully sealed by continuous welds, smooth and free from slag and weld spatter are to be preferred.
3 Sharp corners and discontinuous welds are to be avoided.
4 Rounded corners and continuous butt welds are to be preferred.

Figure D.3 — Lap joints and corners

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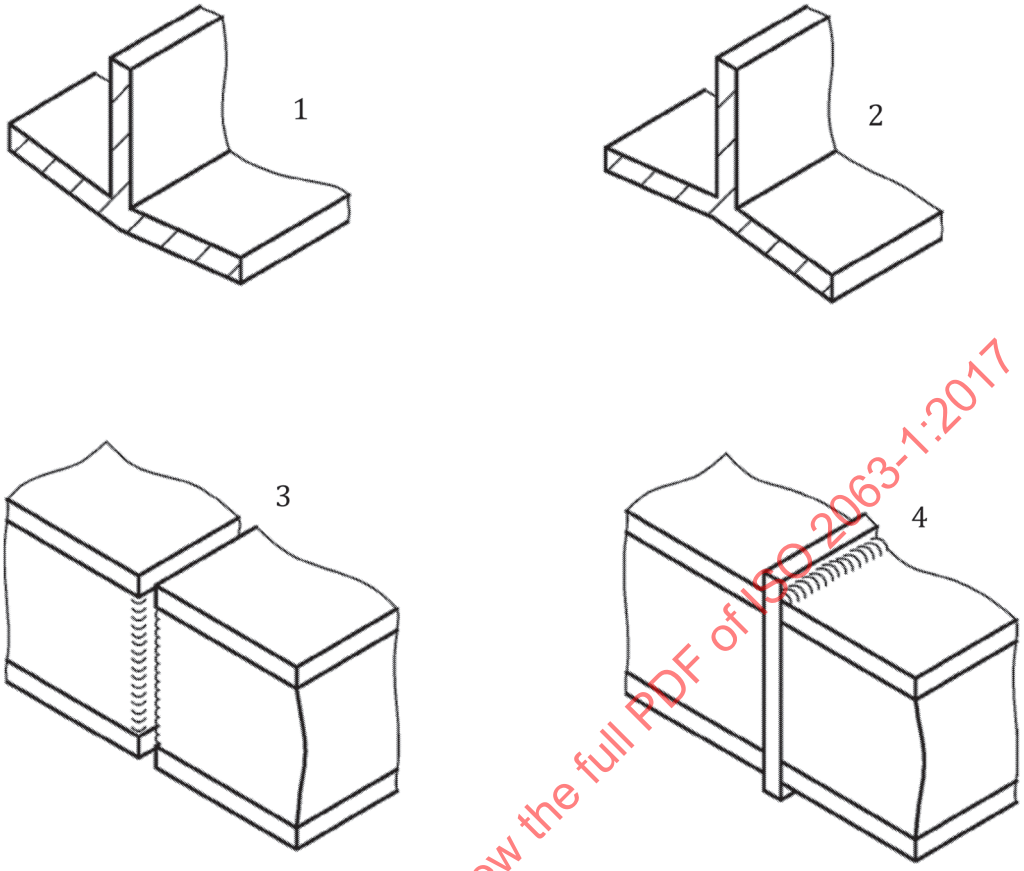

1 Such design details that dirt and moisture can remain are to be avoided.
2 Pre-bended plate, that water can run-off are to be preferred.
3 Lap joints with discontinuous welds and narrow gaps are to be avoided.
4 End plate with excess and fully sealed continuous welds is to be preferred.

Figure D.4 — Flat surfaces and pockets

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Table D.1 — Design considerations for the parts

Item	To be considered — Solution of problem	To be avoided
Accessibility	For the surface preparation, cleaning degreasing, grit blasting, testing.	Inaccessible areas
	Removal of grit residues.	Deposition of grit residues
	For the thermal spraying.	Inaccessible areas
	For sealing.	Inaccessible areas
	For the deposition of further organic coatings (paints).	Inaccessible areas
Possibility to get to	Areas to be coated shall be visible and reachable for the spray jet or tools independent whether the gun or torch is moved manually or by a handling system.	Narrow or not visible areas
Available space for motion	Minimum distance of about 300 mm to the surface. (Spray distance, dimension of the spray gun, space for motion of the hose assembly). Spraying can be applied using special deflecting tools.	
Spray distance	100 mm to 300 mm.	
Blasting distance	200 mm to 400 mm (depends on blasting parameter, gun, and nozzle).	
Blasting angle	Blasting grit shall approach the surface vertically, if possible. The approach blasting angle shall not be less than 60°.	
Spray angle	The spray angle of the spray jet to the surface to be coated should be around 90° and no less than 45°.	
Smooth outer contours	Makes the deposition of a corrosion protection system easier to apply.	Recesses, sharp corners
Main causes for rust are moisture and dirt	Design of smooth surfaces so that collections of moisture and dirt can be avoided. Supervision, cleaning and maintenance are easier to do.	Residues of moisture and dirt
Detail geometries, where water and dirt can collect	See Figures D.1 to D.4.	Narrow gaps, recesses, pockets, channels and horizontal flat surfaces
Sharp edges and sharp inner radii	Rounded or chamfered edges and open L, wide U or T profiles are to be applied preferably for reinforcements.	Sharp corners and sharp inner radii
Inside located corners and small inner radii	Neither the required surface preparation nor the spraying of the coating can be carried out efficiently. Swirling of the jet when grit-blasting resp. spraying. Use of larger inner radii.	Sharp corners and sharp inner radii
Enclosed spaces, e.g. tanks and containers	Manholes for adequate access. A second outlet for adequate ventilation and exhausting of the considerable volume of spray dust and heat.	Unacceptable working conditions, surfaces contaminated by dust
Enclosed spaces and hollow parts properly closed	Usually, the inner surfaces will be without corrosion protection. Drainage shall be prepared to take seeped water away, if these hollow parts are not hermetically sealed.	Weathering of not tight enclosed spaces
Dividing walls, baffles, crash plates, and fittings, etc. inside tanks and enclosed spaces	They shall be removable. If this is not possible, it shall be decided, whether a reduced quality can be accepted.	Thermal spraying may not be an adequate procedure

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