Guideline of Trade Associations

Corrosion Protection of Steel Structures

Duplex Systems
Hot-dip Galvanized Coating plus Paint Coating

- Selection, Execution, and Application -

Jointly published by

Deutscher Stahlbau-Verband DSTV

Bundesverband Korrosionsschutz e.V.

Industrieverband Feuerverzinken

Verband der deutschen Lackindustrie e. V.

Foreword

The subsequent guideline for coating of hot-dip galvanized steel structure components by liquid and powder coating materials is intended to summarise the current knowledge as far it is confirmed for practical application. The guideline has been prepared to inform the user with regard to important relationships but is not intended to replace current standards which it may only supplement.

The guideline has been prepared by a common Working Group, consisting of experts of the following trade associations:

Bundesverband Korrosionsschutz e. V.
Neuköllner Straße 2
50676 Köln
GERMANY
E-Mail: info@bundesverband-korrosionsschutz.de
Internet: www.bundesverband-korrosionsschutz.de

Deutscher Stahlbauverband DSTV
Sohnstraße 65
40237 Düsseldorf
GERMANY
E-Mail: dstv@deutscherstahlbau.de
Internet: www.deutscherstahlbau.de

Industrieverband Feuerverzinken e. V.
Sohnstraße 70
40237 Düsseldorf
GERMANY
E-Mail: feuerverzinken@t-online.de
Internet: www.feuerverzinken.com

Verband der deutschen Lackindustrie e. V.
Karlstraße 21
60329 Frankfurt (Main)
GERMANY
E-Mail: vdl@vci.de
Internet: www.lackindustrie.de

This guideline should be used for steel structures within the field of application of EN ISO 12944 (Corrosion protection of steel structures by protective paint systems), but may also be used analogously for further coating of other steel parts provided with zinc coatings.

Düsseldorf, in June 2000

Contents

1 Field of application

This guideline is intended to inform customers, planners, consultants, companies carrying out hot-dip galvanizing and paint work as well as manufacturers of coating materials with regard to corrosion protection of steel structures by hot-dip galvanizing plus paint coating (duplex systems) in accordance with EN ISO 12944. Steel structures in accordance with these guidelines are steel building components of material thickness ≥ 3 mm for which an approved strength calculation is required. In the field of application of zinc coatings such steel structures will normally be protected by hot-dip galvanizing in accordance with EN ISO 1461.

The subsequent guideline describes requirements and tests for duplex systems, consisting of zinc coatings and coatings of liquid coating materials or powder coating materials respectively.

This guideline is applicable with restrictions for steel structures consisting of parts which have been zinc-coated by other hot-dip galvanizing methods (e.g. of continuously hot-dip galvanized strip and sheet in accordance with EN 10142 and EN 10147).

2 Standards

In this guideline the following standards are referenced. These standards are to be used in their actual version.

ISO 7253
Paints and varnishes – Determination of resistance to neutral salt spray

DIN 50017
Climates and their technical application - Condensed water containing climates

DIN 50018
Testing in a saturated atmosphere in the presence of sulfur dioxide

DIN 50021
Spray tests with different sodium chloride solutions

DIN 53167
Paints, varnishes and similar coating materials – Salt spray test on coatings

EN 10142
Continuously hot-dip zinc coated low carbon steel strip and sheet for cold forming - Technical delivery conditions

EN 10147
Continuously hot-dip zinc coated structural steel strip and sheet -Technical delivery conditions

EN 24624
Paints and varnishes – Pull-off test for adhesion

EN ISO 1461
Hot-dip-galvanized coatings on fabricated iron and steel articles

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EN ISO 2360
Non-conductive coatings on non-magnetic basis metals – Measurement of coating thickness – Eddy current method

EN ISO 2409
Paints and varnishes – Cross-cut test

EN ISO 2808
Paints and varnishes – Determination of film thickness

EN ISO 3231
Paints and varnishes – Determination of resistance to humid atmospheres containing sulfur dioxide

EN ISO 6270
Paints and varnishes –Determination of resistance to humidity (continuous condensation)

EN ISO 12944-1 to 8
Corrosion protection of steel structures by protective paint systems

EN ISO 14713
Protection against corrosion of iron and steel in structures – Zinc and aluminium coatings – Guidelines

3 Terms / Definitions

The following terms and definitions are of importance in connection with the subsequent guideline. They are therefore defined or explained in the following. As far as available, definitions given in existing standards have been used as the basis of the definitions.

Metallic coating/ paint coating:	Coats of metal are designated metallic coatings; coats of coating materials (paints and related products) are designated paint coatings (see DIN 50902)
Coating material:	Pigmented product in liquid or in paste or powder form, which, when applied to a substrate, forms an opaque film having protective, decorative or other specific properties (see EN ISO 12944-1)
Protective paint system:	Sum total of the coats of paints or related products which are to be applied or which have been applied to a substrate to provide corrosion protection (see EN ISO 12944-1)
Hydro coatings:	Paint coatings obtained by application of water-borne coating materials
Protective coating system:	Sum total of coats of metal materials and/or paints or related products which are to be applied or which have been applied to a substrate to provide corrosion protection (see EN ISO 12944-1)

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Duplex system: Protective coating system, consisting of a zinc coating in combination with one ore more subsequent paint coatings (see EN ISO 12944-5)

White rust: White to dark grey corrosion products on zinc-coated surfaces (see EN ISO 12944-4)

Surface preparation: Any removing method of preparing a surface (examples: pickling, blast-cleaning) for coating (see EN ISO 12944-4)

Surface pretreatment: Any method of preparing a surface by which conversion layers are formed (example: phosphating) (see ISO 8044)

Sweep blast-cleaning: Light blast-cleaning for the purpose of cleaning and roughening surfaces (see EN ISO 12944-4)

4 Field of application and purpose of duplex systems

Duplex systems, consisting of a zinc coating obtained by hot-dip galvanizing + paint coating, are used where the following points of view have to be particularly considered:

- **High durability:**
  The durability of duplex systems normally is significantly higher than the sum of the individual durability of the zinc coating and that of the paint coating. One is talking here about a synergism effect. The resulting factor of prolongation is between about 1,2 and 1,5, depending on the system.

- **Colour design:**
  In addition to the metallic zinc coating it is possible in the case of duplex systems to utilize the full range of colours available by paint coatings.

- **Signalling/Camouflage/Adaptation:**
  For certain objects marking by colours for warning and identification purposes is necessary. By the use of suitable coating materials an adaptation of objects to the surrounding or a camouflage effect can also be achieved.

The duplex system meets the requirement of corrosion protection in the shop. It renders both hot-dip galvanizing and paint work in the shop under defined and optimum conditions possible. Work on site and influences of weather and temperature will be minimised.

The corrosive stress has been distinctly went down in Western Europe in the past years due to the lowered pollutant content of the atmosphere. As an average value the removal of zinc amounts to about 1 µm/a. From this a considerable higher durability of zinc coatings results which, in turn, makes in some cases the use of duplex systems for prolonging the effectiveness of the protective coating system not absolutely necessary. An increasing importance has, however, the architectural and colour design of steel building components. In the case of zinc-coated steel this is only possible by additional paint coatings.

The application of suitable coating materials is also then appropriate if, in certain cases, the delivery of zinc to the environment has to be avoided.

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5 Composition and properties of duplex systems

5.1 General

The aim of duplex systems – corrosion protection of high durability – will be achieved if both parties of the system fulfil their function and are optimally adapted to each other.

For this, the selection of suitable coating materials for the single or multi-coat paint coatings is particularly important. These materials shall have certain application-related properties such as UV resistance, resistance to chemicals, diffusion tightness etc.. Precondition for a high durability is, however, an unobjectionable and long-lasting adhesion on the hot-dip-galvanized zinc coating. As a matter of principle, only those systems should be used which have been proved in suitability tests as being suitable for use on hot-dip-galvanized zinc coatings (see clause 8).

5.2 Hot-dip-galvanizing

Hot-dip galvanizing is a melt dipping method in which building components, workpieces or sheets of steel are provided with a zinc or zinc alloy coating by dipping into a liquid zinc melt. The requirements and the test methods for the zinc coating are specified in EN ISO 1461.

5.2.1 Thickness of zinc coatings

In accordance with EN ISO 1461 the minimum thickness of zinc coatings is between 45 µm and 85 µm. In practice the zinc coatings are, however, distinctly thicker, depending on composition of the steel, material thickness, time period of dipping and other parameters. Minimum thicknesses are given in table 1. In practice higher coating thicknesses may be agreed.

Table 1: Minimum thickness of zinc coatings (EN ISO 1461)

Material thickness mm	**Coating thickness µm**
< 1,5	≥ 45
≥1,5 to < 3	≥ 55
≥3 to < 6	≥ 70
≥ 6	≥ 85

5.2.2 Properties of zinc coatings

Depending on the chemical composition of the steel to be zinc-coated and the mass of the steel part the zinc coating is formed differently (Figure 1). Zinc coatings may consist of a layer of an iron zinc alloy and a so-called pure-zinc layer above it (silvery appearance), but also completely of iron zinc alloy layers. The latter show a grey appearance and are slightly more rough than silvery zinc coatings. There are no differences with regard to corrosion protection between these possible variations in the case of weathering by the atmosphere. Both are suitable as substrate for a subsequent paint coating.

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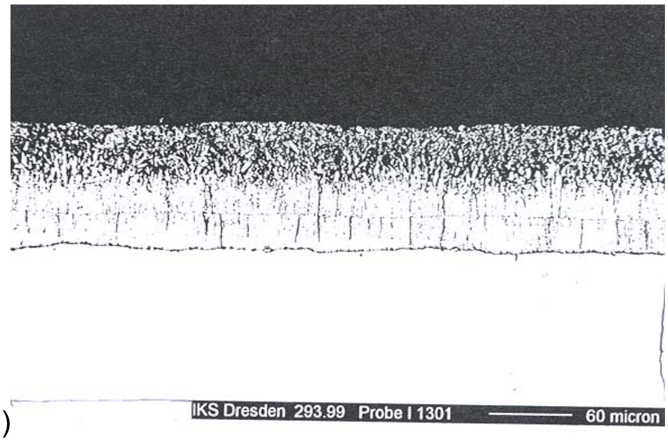
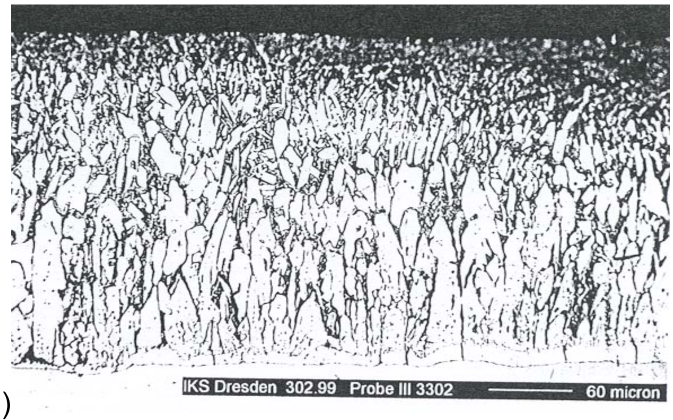
In the course of weathering corrosion products are formed on the surface of zinc coatings, predominantly consisting of zinc oxide and basic zinc carbonate. Depending on the chemical composition of the zinc coating, the corrosive stress and its duration whitish to grey or also brownish corrosion products may be formed in the course of time.



a)



b)

Figure 1: Zinc coatings in accordance with EN ISO 1461 on steel with different silicon content, metallographic transverse section with magnification 200:1, etched
a) with pronounced pure-zinc layer
b) with overalloyed iron-zinc-alloy layer

5.2.3 Requirements in accordance with EN ISO 1461

EN ISO 1461 contains the following statements regarding duplex systems:

Sub-clause 6.3 – Renovation Where a special requirement is advised by the purchaser, e.g. a paint coating to be applied subsequently, the proposed renovation procedure shall be advised in advance to the purchaser by the galvanizer.
Clause A.2 – Additional information The following information may be required for particular purposes and, if so, shall be supplied or specified, as applicable, by the purchaser ... . Any after-treatments or overcoating to be given to the galvanized coating ...
Clause C.4 – After-treatment

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To retard the possible formation of wet storage stain on the surface, articles that are not to be painted can be given a suitable surface treatment after hot dip galvanizing

If the articles are to be painted or powder coated after galvanizing, the purchaser should inform the galvanizer before the article is galvanized.

In addition, in the **National Supplement to EN ISO 1461** attention is drawn to the following:

Re: Annex A.2 - Abbreviations
Coating DIN EN ISO 1461 – t Zn b as well as
Coating DIN EN ISO 1461 – t Zn k.
The abbreviation "t Zn b" means „Hot-dip galvanizing and paint coating", the abbreviation "t Zn k" means hot-dip galvanizing and "no after-treatment to be carried out".

Re: Clause C.4 – After-treatment
Normally, no after-treatment of zinc coatings is carried out. In the absence of particular agreements relating to this, it is up to the supplier whether and, if so, which type of after-treament is chosen (abbreviation t Zn o). If hot-dip galvanized steel parts are intended to be painted afterwards, the attention of the galvanizing shop is to be drawn to this fact in order to avoid measures by the shop which adversely affect the adhesion and the properties of the paint coating. In these cases the abbreviation "t Zn k" (no after-treatment) is to be used.

It is recommendable to order for duplex systems a zinc coating having the abbreviation „t Zn k" so that no after-treatment is carried out in the galvanizing shop which adversely affects the adhesion of subsequent paint coatings.

5.3 Coating materials / Paint coatings for duplex systems

5.3.1 General notes: Liquid and powder coating materials

Paint coatings for duplex systems are obtained from liquid coating materials and powder coating materials of different binder basis. In the technical frame of selected binder basis they can be adapted to the methods of surface preparation and application as well as to the drying and curing conditions.

	Liquid	**Powder**	**Coating material**
Application	Brushing, roller coating, spraying	Electrostatic spraying	↓
Drying*, *curing	Depending on type physically or chemical reaction	Thermal curing by chemical reaction at 150 to 220 °C	
			Coating (solid and firmly adhering)

Whilst liquid coating materials are drying or curing at normal environmental conditions, powder coating materials are to be principally cured thermally.
Liquid coating materials for corrosion protection contain volatile matter (organic solvents and water). Powder coating materials are applied in the form of a dry free-flowing powder and practically contain no volatile matter.

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Properties of coatings such as thermoplasticity, hardness, mechanical resistance, UV resistance, resistance to heat and chemicals etc. are essentially influenced by the binder. Characterization of coating materials and coatings by statement of the binder basis is therefore meaningful, both in practice and standardization, and is also common practice.

Decisive for the suitability in duplex systems is, however, the special formulation with optimum adaptation of suitable binders from a large number of possibilities within the binder classes and the pigment composition.

Depending on the application case, priming, intermediate and top coats will be used, or top coats also directly.

Paint coatings on zinc coatings not normally require pigmentation with active pigments. The use of such pigments is, however, possible and may be advantageous in special cases. The coating materials for a coating system and their application are to be adapted to each other. The materials should, if possible, originate from one and the same manufacturer.

For duplex systems only such coating materials must be used for which a confirmation of the manufacturer on their suitability on a hot-dip galvanized zinc coating is available.

Coating materials with optimum formulation give coatings with good adhesion. The requirements to the surface preparation/surface treatment depend on the coating material.

Liquid and powder coating materials are listed in tables 2 and 3.

Epoxy resin coatings with high mechanical resistance and good resistance to chemicals are preferably used inside buildings because of their typical chalking under UV exposure, under natural weathering conditions normally together with UV-resistant top coats.

The colour stability and the remaining properties will be influenced by the binder basis, but exceptionally by the formulation of the products

Advice can be taken from the technical papers issued by the manufacturers.

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Table 2: Binder basis and film formation of the mainly used liquid coating materials for duplex systems

Liquid coating materials			
Binder basis		**Volatile matter**	**Type of film formation**
	Symbol		
1-pack (1K) coating materials			
Acrylic resins	AY	organic solvents [1]	physically drying
Acrylic resins	AY	water [2]	physically drying (by coalescence)
Vinyl chloride copolymers	PVC	organic solvents [1]	physically drying
2-pack (2K) coating materials			
Epoxy resins EP + Polyamino compounds	EP	organic solvents [1]	Curing by chemical reaction
Epoxy resin combinations EP/hydro-carbon resins + polyamino compounds	EP/ comb	organic solvents [1]	Curing by chemical reaction/physically drying
Polyurethane resins Acrylic resins + aliphatic poly-isocyanate	PUR	organic solvents [1]	Curing by chemical reaction

[1] Different composition , adapted to binder, application and drying conditions
[2] Low amounts of organic solvents technically required

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Table 3: Binder basis and film formation of the mainly used powder coating materials

Powder coating material			
Basis of the binder	**Symbol**	**Volatile matter**	**Type of film formation**
Epoxy resin	EP	none	Chemical reaction by thermal curing at 150 °C to 220 °C (depending on type)
Epoxy/polyester resin	EP/SP	none	
Polyester resin	SP	none	
Polyurethane-curing polyester resin	PUR	none or only small amounts of capro-lactam	

5.3.2 Special notes for liquid coating materials

As can be seen from table 2, for duplex systems liquid coating materials with different binder basis and film formation will be used.

1-pack (1K) coating materials:

These coating materials based on thermoplastic binders such as PVC and acrylic resin are physically drying by evaporation of the volatile matter. Particularly at elevated temperature the coatings obtained are more soft and more plastic than the chemically cross-linked coatings from 2-pack reactive coating materials

In the case of the solvent-containing PVC and acrylic resin systems the film formation is reversible, i.e. the solvent of the coating material will initiate the dissolution of the coating.

When using coating materials based on water-dispersed acrylic resins, coatings with very good adhesion and permanent elasticity will be obtained. These coating materials contain essentially water as volatile matter so that no or only low emissions of solvents will occur. The film formation takes place by evaporation of the water and coalescence (fusion of the polymer particles) of the dispersed binder and is not reversible.

2-pack (2K) coating materials:

In these reactive coating materials two different components react together, a so-called base component and a curing agent component (two-component coating materials). The two components will be supplied separately and mixed short time before use in the specified proportion. Application takes place within the “pot life” indicated by the manufacturer. After evaporation of the volatile matter the two components form the coating by chemical reaction.

Depending on the combined components, coatings with different cross-linking, hardness, UV stability etc. result which, in contrast to physically drying binders, are not soluble and not thermoplastic. Two-component coatings are therefore more resistant to mechanical stresses.

The application of the coating material normally takes place by brushing, roller coating and spraying. The mainly used spraying method is manual airless or air-mix spraying, in the case of shop application also automatic plants are used.

5.3.3 Special notes for powder coating materials

Duroplastic binders are almost used exclusively. Epoxy resin powder coating materials are normally characterized by particularly good adhesion as well as resistance to chemicals and corrosion. Epoxy polyester resin powder coating materials can often be used very economically. Polyester resin powder coating materials are suitable for exterior weathering. Less frequently polyurethane powder coating materials are used which are likewise resistant to exterior weathering, as well as thermoplastics, e.g. PVC.

The adhesion of coatings from powder coating materials on hot-dip galvanized steel is decisively determined by the condition of the surface, i.e. the surface preparation or surface treatment respectively.

As powder coating materials have to be stoved at 150 °C to 220 °C for film formation and curing, visual film defects such as blisters, craters etc. may occur due to gassing from the zinc coating. Here the use of powder coating materials with appropriate additives has been proved to minimise this problem. Partly, these additives will also be added by the applicator, in accordance with information given by the manufacturer. The appearance can also be improved by annealing at the stoving temperature or by application of two layers of the powder coating material, in the case of gassing also by sweep blast-cleaning.

6 Adhesion of the paint coating on the zinc coating

An unobjectionable adhesion of the paint coating on the zinc coating is precondition for duplex systems of high durability. If the state of the art is consequently observed by all parties, outstanding results will be achieved. In the same way as zinc coating and paint coating can supplement each other in an optimum manner when using suitable coating materials and complying with the technical rules, they can, on the other hand, also adversely influence each other distinctly.

Most of the defects due to insufficient adhesion, which occur again and again, can be avoided very simply by adaptation of the surface of the zinc coating to the subsequent paint system.

This can take place by:

- Selection or modification of the coating material for a given (defined) zinc coating, or
- Preparation of the required zinc surface by process engineering or surface preparation for the intended paint system.

In particular in the case of hot-dip galvanizing it is appropriate to test the adhesion of the paint coatings on the steel components or testplates with representative zinc coating surface. This test is an essential part when selecting suitable coating materials.

7 Condition and preparation / pretreatment of zinc surfaces

7.1 Surface of unweathered zinc coating

When hot-dip galvanizing individual steel components, an exactly defined and uniform surface condition will not be possible technically, even with the same composition of the melt and under appropriate execution of the work The surface may show irregularities which may adversely influence the application of subsequent coating materials.

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Examples of irregularities in the zinc coating are:

- runs or areas with high coating thicknesses;
- areas without zinc and areas with pores;
- lack of adhesion between zinc and steel;
- zinc peaks;
- adhering zinc ash and hard zinc.

Before applying paint systems, the applicator has to convince itself by visual assessment of the condition of the zinc coating and its suitability as substrate.

During storage after hot-dip galvanizing the fresh zinc surface reacts with the surrounding atmosphere. Zinc oxides, zinc hydroxides and partly also zinc carbonates will be formed. Because they can adversely effect the adhesion of paint coatings, at least in the case of usual 2-pack liquid coating materials as well as generally before the application of a powder coating material a complete and reliable removal of these surface layers is necessary. Zinc surfaces intended for powder coating materials are to be treated by phosphating, chromating or sweep blast-cleaning immediately before the application.

7.2 Surface of weathered zinc coating

In the course of storage the thickness of the formed surface layers (white rust) increases. These layers may contain further reaction products, e.g. zinc sulfate, zinc hydroxide and zinc chloride, depending on the environmental conditions and the duration of storage. As white rust the totality of such layers is understood. White rust will be formed in particular under the influence of condensed water and in the case of insufficient ventilation of hot-dip galvanized steel components. On zinc coatings with overalloyed iron-zinc alloy layer a brown colouration may occur, caused by oxidation of the ferrous constituents. All these zinc corrosion products have to be removed, either largely or completely. The surface preparation methods used for this purpose depend on the type and amount of the contaminants.

7.3 Methods of surface preparation/surface pretreatment of hot-dip galvanized steel building components

As surface preparation those working procedures are designated which are used to remove foreign contaminants, e.g. grease, fat, oil and other dirt, as well as characteristic layers, e.g. thin oxide layers, white rust or other zinc corrosion products. To obtain a defined surface on which a paint coating will adhere satisfactorily, normally a surface preparation of the zinc coating is necessary.

The type and amount of work to be carried out in the individual case depend on

- the condition of the surface,
- the technical possibilities,
- the coating material to be applied, and
- the later corrosive stress.

Both reducing methods (surface preparation) and methods which, for example, provide a conversion layer (surface pretreatment) are possible. The guidance given by the manufacturer of the coating material is to be considered.
Methods of technical importance are:

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Surface preparation:
- Washing
- Degreasing
- Brushing
- Water jetting
- Sweep blast-cleaning
- Ammonia solution wash with wetting agent (ANW)

Surface treatment:
- Chromating/Phosphating

A choice of methods can be taken from table 4.

Table 4: Type and application of surface preparation/surface treatment methods

Surface preparation/ treatment method	**Shop application**	**Site application**	**Liquid coating material EN ISO 12944**	**Powder coating material (shop)**	**Remarks**
without	x	-	x	-	
Washing	x	x	x	-	
Degreasing	x	x	x	-	only for small areas
Brushing	x	x	x	-	
Cleaning with water	x	x	x	-	
Water jetting	x	(x)	x	-	
Sweep blast-cleaning	x	x	x	x	observe conditions of sweep blast-cleaning
Ammonia solution wash with wetting agent (ANW)	(x)	x	x	-	only for smaller areas, observe safety at work
Chromating	x	-	-	x	
Phosphating	x	-	-	x	

x : suitable
(x): suitable with restrictions
- : not suitable

It is only possible to refrain from a particular surface preparation if immediately after hot-dip galvanizing the surface is coated with suitable coating materials, taking into account the later corrosive stress.

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- **Washing:**

The surface to be cleaned is to be washed down with fresh water by water cleaning or by using a plastics fleece with abrasive embedding. To remove oil or fat, detergents (surface active agents) can be added. Afterwards it is to be thoroughly rinsed with fresh water.

- **Degreasing:**

Degreasing is normally carried out by use of organic solvents. Care is to be taken that the cloth used is sufficiently often replaced to achieve a good degreasing result. The method is generally used for small areas only.
Degreasing by use of alkaline industrial cleaning agents is to be carried out in stationary plants in accordance with information given by the manufacturer. Afterwards it is to be rinsed with fresh water until the surface is neutral.

- **Brushing:**

Precondition for brushing are surfaces that are essentially free from grease. Brushing can take place manually using brushes with brass wire or plastics bristles, trowel, scraper, plastics fleece with embedded abrasive, abrasive paper as well as similar, mechanically driven tools. During the work polishing of the surface is to be avoided as the adhesion of paint coatings on such surfaces is insufficient.

- **Cleaning with water:**

In this method the surface to be cleaned is washed down with fresh water to which a wetting agent may have been added, if necessary. Afterwards, it is to be thoroughly rinsed with clean water.

- **Water blast-cleaning:**

High-pressure water cleaning (water jetting) is carried out using a pressure between 70 MPa and 170 MPa. If detergents are added to the water, afterwards thorough rinsing with clean water is necessary. The cleaned part should become dry without delay.

- **Sweep blast-cleaning:**

The aim of sweep blast-cleaning is to clean and roughen paint coatings and metallic coatings on the surface only. The required surface condition shall be agreed between the parties concerned, together with the thickness of the zinc coating to remain. Sweep blast-cleaning is, however, a strong mechanical stress for the zinc coating which, if not properly carried out, may lead to defects in the coating (cracks, detachments). Important parameters are, for example, hardness and density of the blast-cleaning abrasive, attack angle, distance between nozzle (or rotating wheel) and surface, working pressure (throwing-off speed) and particle size of abrasive (see, for example, EN ISO 12944-4).

Proved parameters for sweep blast-cleaning when using manual compressed-air blast-cleaning are:

- Abrasive: non-metallic slag abrasives, corundum, glass beads
- Abrasive particle size: 0,25 mm to 0,50 mm
- Pressure at the nozzle: 2,5 bar to 3 bar
- Attack angle: <30° (observe geometry of the building component)

If centrifugal blast-cleaning equipment is used, the throwing-off speed of the abrasive at the rotating wheel is to be controlled so that no damage of the zinc coating occurs and that the abrasive is completely removed again from the surface. Sweep blast-cleaned surfaces shall appear mat.

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- **Ammonia solution wash with wetting agent (ANW):**

This method is using an aqueous solution of ammonia (NH_4OH). A mixture of about 1 ¼ litre of ammonia solution, 10 % by mass, and 10 litres of water, with addition of 1 to 2 “crown corks” of wetting agent has been proved suitable.

The surface to be cleaned is to be grinded with corundum inbedded plastics fleece and the above mixture until a grey foam is formed which should be allowed to react for about 10 minutes. Afterwards it is to be thoroughly rinsed with fresh water.

Caution: Legislation regarding waste water is to be considered.

For protection of the skin rubber gloves during the grinding work are appropriate; in the case of interior work good ventilation is to be provided. In no case steel wool shall be used for grinding.

- **Chromating:**

Chromating will normally be used in connection with the application of powder coating materials. This method, to be carried out in shops or stationary plants only, comprises at least the following process steps: Degreasing – Rinsing – Pickling - Rinsing – Chromating – Rinsing – Rinsing with deionised water – Drying.

- **Phosphating:**

Analogously to chromating also phosphating of hot-dip galvanized surfaces is possible, in particular before application of powder coating materials. The process steps to be carried out are similar, the measures with regard to protection at work are significantly less. Phosphating is preferably to be carried out using zinc phosphating solutions.

Chromated and phosphated surfaces are to be provided with paint coatings immediately after the pretreatment. Also in the case of preparation by sweep blast-cleaning a short time period between preparation and application of the coating material is advantageous.

Valid legislation regarding health, safety, and protection of the environment must be considered for all methods.

8 Test methods for paint coatings

8.1 General

Impairment of adhesion of paint coatings of duplex systems may normally occur after stress by humidity, e. g. during natural weathering, by condensation etc.. Testing the adhesion of paint coatings exclusively in dry or unstressed condition is therefore meaningful at most in the case of interior applications without condensation conditions.

On site a paint coating on a hot-dip galvanized surface (zinc-coated article) can be tested as follows:

- Film thickness in accordance with EN ISO 2808 in connection with EN ISO 2360
- Adhesion in accordance with EN ISO 2409 and EN 24624

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8.2 Basic tests / Testing in the laboratory

Besides the tests listed in 8.1 further tests are necessary. In EN ISO 12944-6 „Corrosion protection of steel structures by protective paint systems“ the adhesion of paint systems on zinc-coated steel is tested after they have been aged in accordance with **EN ISO 6270**. The time period of ageing is at least 240 h and is prolonged for high corrosive stress and high durability to 720 h.

During the ageing the painted side of the test panels is exposed to condensed water vapour from a water bath heated to 40 °C, whilst the reverse side of the panels is in contact with a standard atmosphere of 23 °C. Due to the resulting temperature difference condensation at the painted side and water transfer within the paint coating into the direction of the phase boundary paint coating/zinc coating takes place which in turn leads to internal stresses in the paint coating. The adhesion is evaluated in accordance with EN ISO 12944-6 at standard atmosphere 24 h after the ageing. The test is passed if no more than classification 1 results in the cross-cut test and no blisters, cracks, flaking or rust has become visible.

For certain fields of application the above tests are not sufficient. Therefore, further test methods (e.g. ISO 7253 and EN ISO 3231), in particular for atmospheric stresses > C3, can be agreed.

9 Examples of paint systems for practical use

For structures consisting of carbon or low-alloy steel of at least 3 mm thickness which are designed using an approved strength calculation EN ISO 12944 deals with possible corrosion protection measures, in particular those using liquid coating materials, also on hot-dip galvanized substrates.

In Table 5 examples of paint systems consisting of liquid coating materials are given for use on hot-dip galvanized surfaces (zinc-coated articles), in analogy to EN ISO 12944-5, likewise in table 6 for powder coating materials, although there is not yet a standard dealing with such systems.

The table indicates

- the surface preparation method to be used for the coating material;
- the composition of the coating system (priming coat/top coat);
- the required number of coats to be applied;
- the total nominal film thickness and
- the durability which can be achieved, related to the respective corrosivity category.

  low (l): 2 to 5 years
  medium (m): 5 to 15 years and
  high(h): >15 years

This corresponds to the durability of the paint coating but not to the durability of the total duplex system. The durability in accordance with EN ISO 12944-5 exclusively refers to the adhesion of the paint coating on the zinc coating. The corrosion protection efficiency of the zinc coating will be further maintained. The remaining durability of the zinc coating is dependent on the respective corrosivity category.

The corrosivity categories C2 to C5 (EN ISO 12944-2) mean:

C2 low
C3 medium
C4 high
C5-I very high (industrial atmosphere)
C5-M very high (marine atmosphere)

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Hot-dip galvanizing Surface preparation		Priming coat(s)			Top coat(s) incl. intermediate coat (1st top coat)			Paint system		Expected durability (see ISO 12944-1) Corrosivity category														
Cl	Sw	Binder	Number of coats	NDFT. µm	Binder	Number of coats	NDFT µm	Number of coats	Total-NDFT µm	C2			C3			C4			C5-I			C5-M		
										L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
x			---	---		1	80	1	80	x	x	x	x											
x			1	40		1	80	2	120	x	x	x	x	x										
x		PVC	1	80	PVC	1	80	2	160	x	x	x	x	x	x	x	x		x			x		
x			1	80		2	160	3	240	x	x	x	x	x	x	x	x	x	x	x		x	x	
x			---	---		1	80	1	80	x	x	x	x											
x			1	40		1	80	2	120	x	x	x	x	x										
x		AY	1	80	AY	1	80	2	160	x	x	x	x	x	x	x	x		x			x		
x			1	80		2	160	3	240	x	x	x	x	x	x	x	x	x	x	x		x	x	
	x	---	---	---		1	80	1	80	x	x	x	x											
	x	---	---	---		2	120	2	120	x	x	x	x	x	x	x	x		x					
	x	EP	1	40		1	80	2	120	x	x	x	x	x	x	x	x		x					
x		EP/comb.	1	40	EP	1	80	2	120	x	x	x	x	x	x	x	x		x					
x		AY hydro	1	40	or	1	80	2	120	x	x	x	x	x	x	x	x		x					
	x	---	---	---	PUR	2	160	2	160	x	x	x	x	x	x	x	x	x	x			x	x	
	x	EP	1	80		1	80	2	160	x	x	x	x	x	x	x	x	x	x			x	x	
x		EP/comb.	1	80		1	80	2	160	x	x	x	x	x	x	x	x	x	x			x	x	
x		AY hydro	1	80		1	80	2	160	x	x	x	x	x	x	x	x	x	x			x	x	
x		---	---	---	EP/comb.	1	80																	
					+ PUR	1	80	2	160	x	x	x	x	x	x	x	x	x	x			x	x	
	x	EP	1	80	EP	2	160	3	240	x	x	x	x	x	x	x	x	x	x	x		x	x	x
x	o	EP/comb.	1	80	or	2	160	3	240	x	x	x	x	x	x	x	x	x	x	x		x	x	x
x	o	AY hydro	1	80	PUR	2	160	3	240	x	x	x	x	x	x	x	x	x	x	x		x	x	x

Key: Cl = Cleaning, Sw = Sweep blast-cleaning or alternative preparation method of same efficiency
NDFT = nominal dry film thickness

Table 5: Examples of duplex systems obtained from liquid coating materials (hot-dip galvanizing + paint coating)

Zurück zum Inhaltsverzeichnis

Hot-dip galvanizing Surface preparation/ pretreatment		Priming coat(s)			Top coat(s)			Paint system		Expected durability (see ISO 12944-1)														
										Corrosivity category														
										C2			C3			C4			C5-I			C5-M		
Sw	Ch	Binder	Number of coats	NDFT µm	Binder	Number of coats	NDFT µm	Number of coats	Total NDFT µm	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
X		--	--	--	SP or EP/SP	1	80	1	80	X	X	X	X	X	X	X								
	X		--	--		1	80	1	80	X	X	X	X	X	X	X	X	X						
X			--	--		2	60	2	120	X	X	X	X	X	X	X	X							
X		EP	1	60		1	70	2	130	X	X	X	X	X	X	X	X							
	X		1	60		1	70	2	130	X	X	X	X	X	X	X	X	X	X	X		X	X	X

Key: Ch = Yellow chromating, Sw = Sweep blast-cleaning or alternative preparation method of same efficiency
NDFT = nominal dry film thickness

Table 6: Examples of duplex systems obtained from powder coating materials (hot-dip galvanizing + paint coating)

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10 Use of duplex systems in steel construction

Duplex systems consisting of hot-dip galvanizing + paint coating are used in many fields of steel construction.

Examples:

- Lattice masts for power lines
- Structures for transformer stations
- Radio and transmitter masts
- Railway traction line masts
- Steel components for hall construction
- Facade steel structure
- Conveyor and loading equipment
- Structures for platform roofing
- Equipment for protection against noise in railway and road construction
- Traffic safety equipment
- Steel components for bridge construction
- Railway signal bridges
- Pipelines and rails
- fencing, gates etc.

10.1 Application

Duplex coating materials are either applied stationary in the shop or on site, using the known methods of application (spraying, brushing, roller coating) for liquid coating materials as well as spraying for electrostatic powder coating materials.

10.2 Application in the shop

Coating of hot-dip galvanized building components in stationary plants becomes more and more important. Duplex systems including the sturdy zinc coating are particularly suitable for the so-called corrosion protection from the shop.

In the case of structural members with high assembly effort and/or high risk of damage it is recommendable to apply a part of the whole paint system in the shop and the top coat(s) after assembly. Powder coating materials are to applied principally in the shop.

It is advantageous to apply at least one priming coat already in the shop because the formation of zinc corrosion products during transport, intermediate storage and assembly will be avoided. Expensive work for the surface preparation of the hot-dip galvanized structure on site will not be necessary.

Priming and top coats obtained from hydro coating materials, mostly based on acrylic copolymer, belong already since years to the proved systems and are particularly suitable for duplex systems including shop application. In the stationary plants the measures for complying with the required application conditions can be carried out particularly effective, and a considerable reduction of solvent emissions will be achieved. In addition, priming coats obtained from hydro coating materials can be further coated with different 1-pack and 2-pack paints so that paint systems with a broad field of application for atmospheric corrosive stresses will result.

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

11 Particular notes

11.1 Determination of dry film thickness

In accordance with EN ISO 12944-5 the procedure for checking nominal dry film thicknesses (instruments, calibration, any allowance for the contribution of the surface roughness to the result) is to be agreed between the parties concerned .

In accordance with the specifications in EN ISO 1461 the thickness of the zinc coating has to be checked prior to the paint work.

Film thickness values for individual coats as well as for paint coatings to be applied in the shop and on site should principally be specified as nominal film thicknesses in accordance with EN ISO 12944-5.

Unless otherwise indicated in the technical literature of the paint manufacturer, „...individual dry film thicknesses of less than 80 % of the nominal dry film thickness are not acceptable. Individual dry film thicknesses between 80 % and 100 % are acceptable, provided that the overall average (mean) is equal to or greater than the nominal dry film thickness and no other agreement has been made" (ISO 12944-5, sub-clause 5.4).

For the maximum dry film thickness the information in the technical data sheet of the paint manufacturer applies. If no information is given in the technical data sheet of the paint manufacturer, the maximum dry film thickness should not be greater than 3 times the nominal film thickness. "In the case of excessive dry film thickness, expert agreement shall be found between the parties. For products or systems which have a critical maximum dry film thickness or, in special cases, information given in the manufacturer's technical data sheet shall be observed."(ISO 12944-5, sub-clause 5.4).

The thickness of paint coatings on zinc is to be determined on representative areas, based on a statistically sufficient number of individual measurements and using measuring instruments working by the eddy current method described in EN ISO 2808 in connection with EN 2360. If individual measurements are below the acceptable range of the nominal dry film thickness, additional measurements are to be carried out in order to limit the area concerned with regard to the extent of any additional work required.

It is not permitted to compensate the nominal film thickness of the paint coating with excessive thicknesses of the zinc coating, whilst maintaining the total thickness of the whole system (zinc coating + paint coating).

11.2 Reference areas

Reference areas are suitable areas on the structure used to establish an acceptable standard for the work, to check that data provided by a manufacturer or contractor is correct and to enable the performance of the coating to be assessed at a later time.

If reference areas are intended to be used for guarantee purposes, this is to be agreed between the parties concerned together with the criteria to be used in their evaluation.

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They are to be prepared in representative locations of the structure and should also include welds, bolt connections, edges, corners and other areas of the structure at which an increased corrosive stress is to be expected.

The size and number of reference areas shall be in a reasonable proportion to the type of the complete structure, both technically and economically.

Detailed information regarding execution, supervision and documentation of reference areas is given in EN ISO 12944-7 and 8 (Annex B).

11.3 Corrosion protection-proved design

The shape of structures and their corrosion protection-proved design have decisive consequences for the execution and efficiency of corrosion protection works.

If friction areas of 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 the structure and on subsequent handling, assembly and transportation.

Basic information is given in EN ISO 12944-3 and EN ISO 1461 in connection with Supplement 1 and EN ISO 14713.

Safety relevant particulars for hot-dip galvanizing such as

- avoidance of sealed hollow components or provision of vents
- avoidance of large overlapping areas
- ensuring an unhindered inflow and outflow of the zinc melt

are to be observed.

If required, the hot-dip galvanizing shop is to be consulted.

Already in the planning and design stage of steel structures accessibility during execution, checking and maintenance is to be taken into account. Accessibility means that the space between structures and/or building components is sufficient to be accessed by persons. It also means that all areas are within reach manually for preparing, coating and checking them by using appropriate tools.

11.4 Contractual agreements

The trade association guideline “Duplex systems” is to be considered as a technical guideline for the user. Particular contractual agreements, especially regarding acceptance, touching up, elimination of defects and testing are not dealt with here. They are to be particularly agreed when a contract is made.

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