TEKNOS

Paint with Pride

Handbook for Corrosion Protection

of Steel Surfaces by Painting


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Handbook
for Corrosion Protection
of Steel Surfaces by Painting

TEKNOS

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Corrosion protection by paint systems

Paints are liquid or powdery substances that are applied in thin coats on a substrate using a paint application method. The paint dries into a solid coating which bonds to the substrate.

The painting of metal substrates with protective paint systems is called *corrosion protection painting*.

The purpose of corrosion protection painting is to protect the metal substrate against atmospheric corrosivity, i.e. rust, and to give the surface the designed appearance and texture.

Corrosion protection painting is a process where quality cannot be fully assessed merely based on the acceptance inspection of the finished coating. Therefore, it is imperative that the process of corrosion protection painting is planned carefully. It is equally important to manage and monitor all parameters affecting the coating outcome during the painting process.

Teknos has compiled this handbook to provide clients, designers, employees and students with optimally comprehensive information on corrosion protection painting.

We hope that you will find this handbook useful.

Yours faithfully,

TEKNOS OY

Corrosion protection painting

1. Protective paint system as corrosion protection method

Introduction

Various engineered materials used for industrial purposes require protection against the effects of the environment. These materials comprise concrete composites and a number of different metals, for example. Concrete substrates need coating against carbonatisation and surface disintegration due to abrasion, among others things. Metals need protection against corrosion.

Corrosion is a physicochemical reaction occurring when a metal is exposed to its environment, which changes the properties of the metal and, in many cases, results in degradation of the metal, adjacent environment or technical system.

Rust is reaction product of iron and steel corrosion.

Corrosion damage is any change in the corrosion system due to corrosion and which is considered to cause degradation of the metal, the adjacent environment, or the technical system they constitute together.

Corrosion system comprises one or multiple metals and all of the parameters of the environment, which contribute to corrosion. Such parameters of the environment can also be the coating surface layer, electrode, and so forth.

Anti-corrosion or corrosion protection refers to the modification of the corrosion system in a way that retards or inhibits the formation of corrosion damage.

Corrosion protection painting refers to the coating of metal surfaces with corrosion protection paint.

Corrosion mechanism in metals

Metal corrosion is currently explained by the formation of local electrochemical electrode pairs on the metal surface. The electrode pair is called an anode-cathode pair. Positive metal ions are dissolved from the anode to the solution, and produce negative electrons in the metal lattice, which migrate in the metal to the cathode. In the cathode, the electrons are consumed in multiple cathode reactions. In acid solutions, hydrogen gas is produced, while in pH neutral solutions oxygen reduction produces hydroxide ions. The electrically conductive electrolyte between the anode and cathode closes the circuit. The anode and cathode sites can be next to one another, resulting in the formation of uniform corrosion or separated from one another resulting in localised corrosion. The anode site is the metal surface's less noble site or a site with a higher surface energy. **Image 1.1** illustrates the formation of local pairs onto a metal surface, and the anode and cathode reactions.

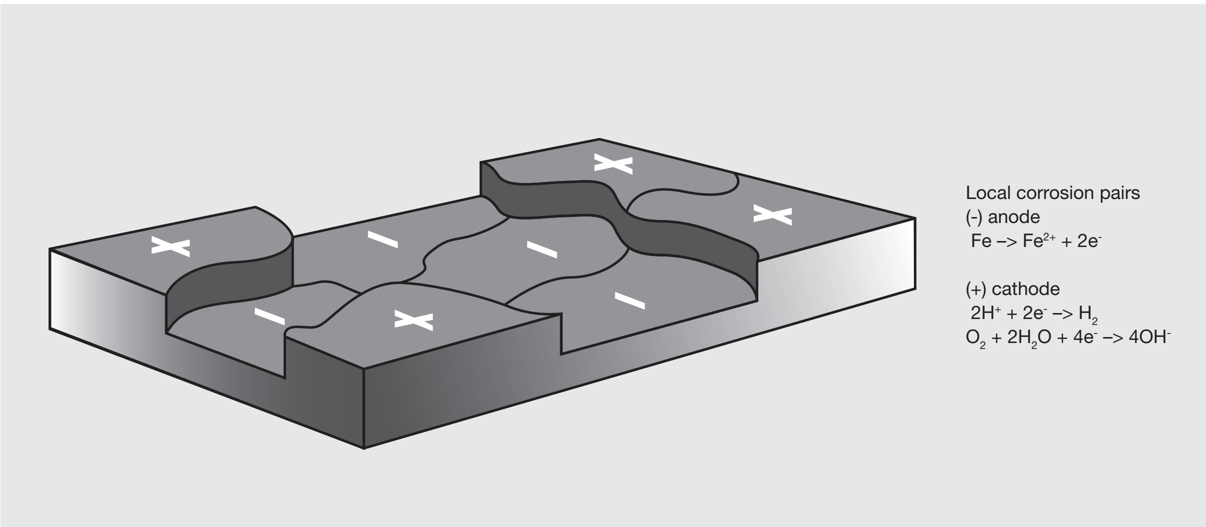


Image 1.1 The formation of local pairs onto a metal surface, and the anode and cathode reactions.

Combining the anode and cathode reactions provides the total reaction:

$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$
$4Fe(OH)_2 + O_2 \rightarrow 2H_2O + 2Fe_2O_3{*}H_2O$ hydrous iron oxide, i.e. rust

The corrosion protection mechanism in metal is based on
- the inhibition of formation of local pairs on a metal surface, and
- the inhibition or retardation of anode and/or cathode reaction

Protection mechanism of paint system

The overwhelmingly most popular corrosion protection method is the application of paint onto the metal surface. An impervious, intact and sufficiently thick coating will prevent ions from entering the metal surface, thus reducing the formation of local pairs. Epoxy paints provide an example of a type of paint based on imperviousness.

Corrosion protection paints used against atmospheric stress utilise corrosion protection pigments, which retard the dissolution of metal ions from the anode sites. Various phosphates and borates, for example, are used as corrosion protection pigments, which, together with water entering the coating, form protective layers at the anode sites.

The paint protects the steel surface cathodically, when it contains sufficient quantity of zinc dust. The zinc particles in the coating are in electrically conductive contact with the steel substrate, and, as electronegative metals, are sacrificial anodes that inhibit steel corrosion.

Water-borne paints also utilise corrosion inhibitors to inhibit corrosion during paint application or curing (flash rust).

In conclusion

Corrosion of the metal surface to be protected can be inhibited or retarded by applying:
- corrosion protection paint containing corrosion protection pigments, which passivates the anode and/or cathode reaction, or
- a coating, which generates sufficient resistance against an ion current
- a primer giving cathodic protection

2. Primary standards associated with corrosion protection painting

Standardisation

The purpose of standards is to promote trade and industry, increase safety, welfare and consumer protection as well as to facilitate domestic and cross-border commerce.

Pursuant to standard EN 45020, the standard resulting from standardisation work is defined as follows:
'A *standard* is a normative document, established by consensus and approved by a recognised body, that provides for common and repeated use, rules, guidelines, or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given content'.
A standard is usually a recommendation only. In certain cases, public regulatory bodies may reference the standards in the *regulations* and *directives*. These so-called r*eference standards or normative standards* are *legally binding documents.*

In Finland, the Finnish Standards Association SFS and its member industry bodies draft and issue the standards. Public bodies and professional, commercial, and industrial organisations take part in the drafting work. Standards drafting focuses currently on European (EN) and international (ISO) standards.

The Finnish standards relating to paints and coatings are drafted by the following SFS member organisations:
- Chemind, Chemical Industry Federation of Finland, Kemianteollisuus ry
- MetSta, Metalliteollisuuden Standardisoimisyhdistys ry

SFS endorses, issues and sells both Finnish and international standards. SFS also provides and disseminates information on standards and statutory regulations.

The standards relating to the planning and execution of painting work are a result of a long-term and systematic drafting effort. The standards provide users of paints all over the world with detailed information and knowledge of the relevant environment, structure, substrate, paint or paint work in any given situation.

EN and ISO standards

European Union member states constitute an internal market aimed at the free mobility of goods and services. Ensuring free mobility of goods requires harmonisation of the various technical standards of the member states.

The international standard EN ISO 12944 on corrosion protection of steel structures by protective paint systems, approved and adopted on 25 May 1998, is one further step toward this end.

ISO 12944 consists of the following parts:

Part 1	General introduction
Part 2	Classification of environments
Part 3	Design considerations
Part 4	Types of surfaces and surface preparation
Part 5	Protective paint systems
Part 6	Laboratory performance test methods
Part 7	Execution and supervision of paint work
Part 8	Development of specifications for new work and maintenance

Durability
Durability is indicated in ISO 12944-1 in terms of three ranges:

2 to 5 years	low (L)
5 to 15 years	medium (M)
more than 15 years	high (H)

The durability range is not a "guarantee range". Durability is a technical consideration that can help the owner set up a maintenance programme. A guarantee period is a major issue, and is subject to dedicated clauses in the contract. The guarantee time is usually shorter than the durability range. There are no rules that link these two periods of time.

Classification of environments
Atmospheric corrosivity and special corrosion stresses influence the durability of the structure's corrosion protection painting and the planning of paint work in an important way.

Pursuant to ISO 12944-2, atmospheric corrosivity is divided into six categories:
C1 very low
C2 low
C3 medium
C4 high
C5-I very high (industrial)
C5-M very high (marine)

The classification is based on the corrosion rate of steel and zinc during the first year in exposure.

ISO 12944-2 defines three corrosivity categories for structures immersed in water or buried in soil:
Im1 immersion in fresh water, such as structures in rivers, hydropower plants
Im2 immersion in sea or brackish water, such as port structures
Im3 burial in soil, such as subterranean containers, steel beams and similar structures

Structure and surface preparation
ISO 12944-3 provides instructions for the design of structures intended for coating.

ISO 12944-4 discusses a number of different substrates and surface preparation methods. In the definition of surface preparation methods and preparation grades, the standard references the following existing ISO standards: ISO 8504 Surface preparation methods, ISO 8501 Rust grades and preparation grades, and ISO 8503 Method of grading surface profile.

Paint systems
The protective paint system is composed of the substrate, surface preparation, and the combination of paints used for coating.
ISO 12944-5 presents the most common types of corrosion protection paints and protective paint systems.

The markings for the paint types are:

Acrylic	AY
Alkyd	AK
Epoxy	EP
Chlorinated rubber	CR
Polyurethane, aliphatic	PUR
Polyurethane combinations, purified urethane tar	PURC
Ethyl zinc silicate	ESI Zn (R)
Epoxy zinc	EP Zn (R)
Polyvinyl chloride	PVC

In 2007, a new edition of standard ISO 12944-5 was issued. Under ISO 12944-5:2007, the paint systems are marked as follows:

ISO 12944-5/A1.01, where
A1 = the table in which the system is included
01 = the sequence number of the paint system in the table

The standard has eight tables (A1 – A8), which present the paint systems for the various corrosivity categories for steel and zinc surfaces, thermally coated, sherardised, and zinc-electroplated steel surfaces. The table indicates for each paint system
- the number
- binder type of the primer, the number of coats, and nominal film thickness
- binder type for the intermediate and top coats
- total number of coats, and nominal dry film thickness of the paint system
- expected durability

The footnotes of the tables indicate the binder types and provide further information on the paints.

Testing of paints

Part 6 of ISO 12944 is designed to facilitate the suitability assessment of new paint systems. Suitability is assessed in laboratory conditions using the humidity condensation test (ISO 6270), the neutral salt spray (fog) test (ISO 9227), and the test method used for determining resistance to the effects of water and chemicals (ISO 2812-1 and 2812-2). The standards inform that the aforementioned methods are not applicable to the testing of water-borne paints. Nevertheless, some water-borne paint systems are amenable to testing and evaluation using the procedures described in the standards, and the results could be taken taken into account. Testing paints in real-life conditions is regarded as the optimum method, and using well-known conventional paint systems as a reference in all testing operations is highly recommendable.

Execution and supervision of paint work

Application methods, paint work, and the associated quality control are described in part 7 of ISO 12944.

Painting is one of the processes where quality cannot be fully assessed merely based on the acceptance inspection of the finished coating. Therefore, supervision and control during paint work over all parameters that may affect the coating outcome is imperative. Emphasis is also increasingly being placed on the qualification of personnel **(see form 186)**.

Reference areas

Upon a separate agreement, the contractor will prepare reference areas in conformity with the paint work specification in the presence of representatives of the purchaser and the manufacturer. The reference areas are used to establish the personnel's professional skills and the acceptable quality of the work while monitoring whether the specifications provided by the manufacturer and the contractor are correct. The performance of the coating can also be monitored by means of the reference area. The reference areas are not used for guarantee purposes, unless otherwise agreed to the contrary.

The reference areas are to be prepared in locations in which the corrosive stresses are typical for the structure concerned. The size and number of reference areas are to be selected in proportion to the total surface area of the structure and criticality of its components. Annex A of ISO 12944-7 contains informative instructions on the reference areas.

All reference areas are to be marked on the structure and the records must be stored **(see form 187)**.

Measurement of dry film thickness

On rough surfaces, dry film thickness should be measured using the method and procedure specified in ISO 19840 and, on smooth and galvanised surfaces, in compliance with ISO 2808, unless otherwise agreed to the contrary.

For dry film thickness measurements, the parties shall agree on the following:

a) the method to be used, the measurement instrument to be used, details of the calibration of the measurement instrument, and how to take into account the contribution of the surface profile to the result
b) the sampling plan – how and how many measurements are to be made for each type of surface
c) how the results are to be reported, and what further action they may necessitate.

Nominal dry film thickness (NDFT) refers to the dry film thickness of the coat indicated in the specification.

The arithmetical average (mean) of the measurements shall be equal to the NDFT or greater.

All individual measurements must be no less than 80 per cent of the NDFT or greater. Individual dry film thicknesses of no less than 80 per cent of the NDFT are acceptable provided that the number of such measurements does not exceed 20 per cent of the total number of individual measurements made. The maximum dry film thickness is to be agreed upon case-specifically with the contractor or manufacturer.

Planning of corrosion protection painting

Corrosion protection painting requires a plan, which indicates the structure's progress from raw material to the final structure ready for deployment **(see chapter 3)**.

The specification planning for new and previously painted surfaces is described in ISO 12944-8.

Health and safety

It is the duty of clients, specifiers, contractors, paint manufacturers, inspectors and of all other personnel involved in a project to carry out the work for which they are responsible in such a manner that they do not endanger the health and safety of themselves or others. In pursuance of this duty, they shall ensure that all statutory requirements, whether related to occupational safety or protection of the environment, or other, of the country in which their work is carried out are complied with.

Items that will need particular attention are, for example:

- measures against unnecessary or uncontrolled use of harmful substances
- measures against harmful effects of fumes, vapours and noise, as well as fire hazards
- protection of the body, including the eyes, the skin, the ears and the respiratory system
- premises used for the application or storage of explosive substances (known as ATEX provisions; for detailed instructions, see EU Directive 94/9/EC)

Where feasible, the requirements relating to health, safety and environmental protection should be described in the project specification.

Project specification

The project specification describes the project and associated requirements (ISO 12944-8). The party issuing the project specification can be the owner of the structure being coated, or the principal contractor, for example. The main headings in the project specification are:

1. General information
2. Type of project
3. Type of structure and constituent element
4. Description of each constituent element
5. Description of the environment of each constituent element
6. Durability

7.-10. Protective paint systems – particular constraints

11. Quality management
12. Inspection and assessment
13. Reference areas
14. Health and safety; environmental protection
15. Special requirements
16. Meetings
17. Documentation

Protective paint system specification

The protective paint system specification describes surface preparation and the protective paint system to be applied onto the structure in compliance with the project specification **(see forms 184 and 185)**. The specifier can be the paint manufacturer, for example, and the main items are:

1. General information (names of the project, owner and specifier)
2. Steel dressing
3. Surface preparation
4. Protective paint systems
5. Paint manufacturer
6. Quality control and quality assurance for paint materials

Paint work specification

The paint work specification describes execution of the paint work in compliance with the requirements of the project specification. The specifier can be the paint contractor, for example, and the main items are:

1. Project information and name of the specifier
2. Paint contractor/applicator qualifications
3. Planning of new and maintenance work
4. Execution of new and maintenance work
5. Quality control and quality assurance

Where necessary, a separate inspection and assessment specification will be issued, describing how the inspections and assessment are to be carried out.

The standards relevant to paint work are listed in section 11. LIST OF STANDARDS, (page 56).

3. Planning of corrosion protection painting

Prerequisites for good corrosion protection painting

Only good planning will provide a corrosion protection solution that is both technically optimal and economically sound. The entire process chain associated with the structure, from the raw material to a final structure ready for deployment, will be considered at the planning stage. Therefore, corrosion protection must be taken into consideration from the very start of designing a new structure. A corrosion protection specification is issued, which comprises all information on all parameters influencing the durability of the coating, such as
- designed function and service life of the structure
- corrosivity parameters of the environment and special corrosivity stresses for the structure
- design and shape of the structure
- surface cleaning and surface preparation
- paint materials
- site, time, and conditions for execution of the paint work
- supervision of paint work
- requirements for future maintenance

Based on the corrosion protection specification, the purchaser can issue a paint system specification. The paint system specification is the basis for a paint work specification, which describes how the designed service life of the corrosion protection painting is to be achieved.

For the specifier of the paint system specification and paint work specification, the corrosion protection standards are of great assistance. Using the standards allows for unambiguous determination of the corrosivity category of the environment, the state of the steel surface prior to painting, quality grade of preparation, paint work, supervision of paint work and so on. ISO 12944-8 provides guidance on the planning of paint work and drafting of the paint system specification.

Painting as a design consideration for steel structures

ISO 12944 provides the designers of steel structures with instructions on how to take the requirements and constraints of corrosion protection into consideration in structural design.

Corrosion protection starts from choosing suitable construction elements and establishing the measures designed to prevent corrosion. The shape and location of the structure are determinant parameters influencing the execution, inspection and maintenance of the corrosion protection painting, as well as its durability and service life.

In the visual design of the structure, shapes promoting corrosion resistance are to be preferred. The surfaces being coated should be as smooth and plain as possible to eliminate sharp edges, which hamper the application of paint. Positioning of the elements should allow for keeping the structure clean and dry, and in a way that rain, splash and condensation water has free passage off the surface.

The weld joints must be designed to eliminate formation crevices and traps between components, which cannot be coated. Interrupted welds are to be avoided. Unlike interrupted welds, a solid weld bead does not form crevices or traps in the structure, which are difficult to coat.

Riveted joints are poorly suited for structures to be protected by protective paint systems.

All sections of the steel structure surface must be placed so that they allow access for surface preparation, application, inspection and maintenance work (ISO 12944-3 Annex A). Sufficient free space must be reserved for preparation and application equipment in front of the surface being coated. Surfaces exposed to corrosivity and which cannot be coated subsequent to assembly must be coated in advance or be constructed of corrosion-resistant material.

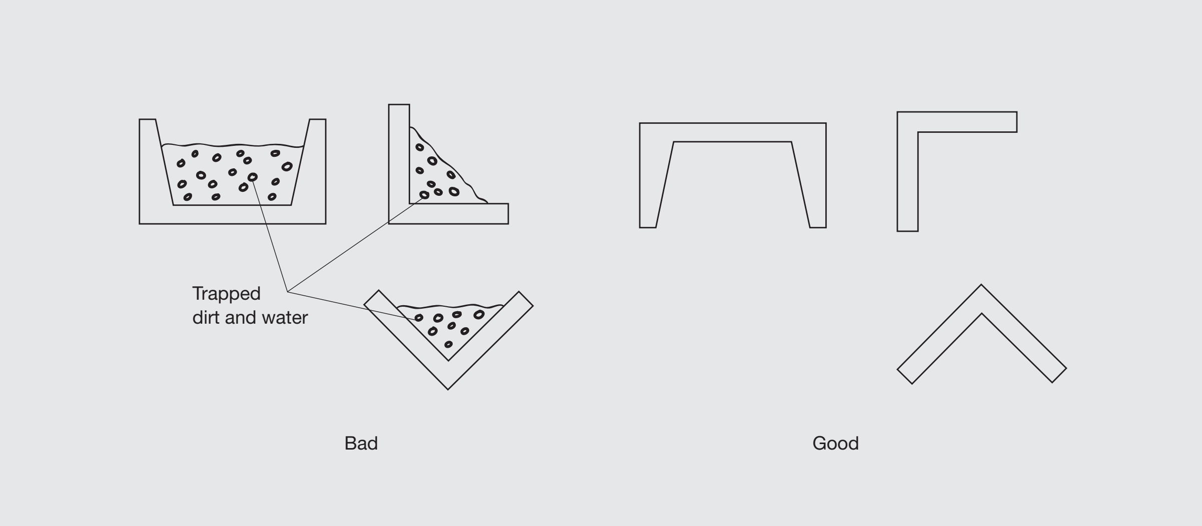


Image 3.1 On the left-hand side, examples of structures not suitable for corrosion protection painting. On the right-hand side, examples of suitable solutions (ISO 12944-3).

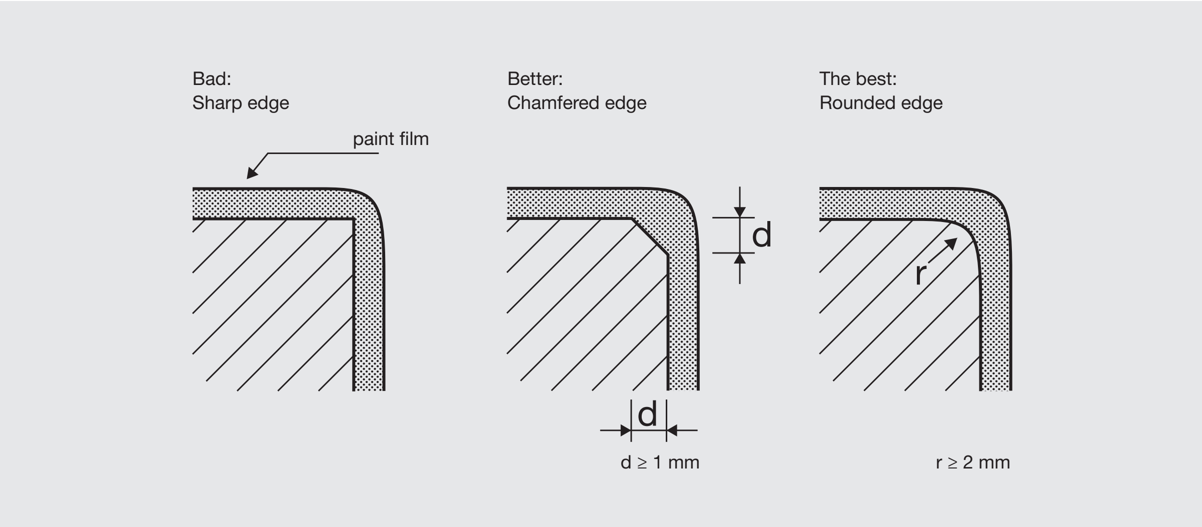


Image 3.2 In terms of painting, rounded corners and edges are ideal, since coating thickness is uniform (ISO 12944-3). Sharp corners are to be avoided.

Determination of the application site for corrosion protection painting

The determination of the application site depends on the paint system and the object being coated. The term shop application, or industrial painting, refers to an application undertaken in a workshop, or an adjacent industrial painting facility. The term field application, or on-site application, refers to painting undertaken on-site. Maintenance paint work on old structures is in almost all cases undertaken using the field application method.

Where feasible, corrosion protection painting should be finished under industrial painting conditions. In shop application, the conditions can be optimised for corrosion protection painting, and the paint systems and application methods ideally suited for the object can be utilised.

Field application performed at the assembly site or at the location of the structure is complicated and restricts the choice of available paint systems. For these reasons, the installation and assembly of the structure should be designed so that, at least, the shape or size of the object does not prevent the use of industrial painting for surface preparation and priming.

4. Substrate preparation

Determination of the preparation method and the quality grade for metal working and surface preparation

The surface preparation methods are described in parts 1 – 3 of ISO 8504 and in part 4 of ISO 12944.
The determination is based on the following parameters, among others:
- relevant working conditions
- state and condition of surface
- quality grade requirements of surface preparation
- surface preparation of the entire surface area or only part thereof
- economical considerations
- special requirements or constraints

The preparation degree and quality grade of surface preparation is determined based on the paint system to be used. The paint system is determined based on the protection requirements, taking into consideration surface preparation and surface preparation conditions.

The quality grade for metal working and surface preparation is indicated in the paint system specification. The mechanical surface preparation methods and associated quality grades for blast-cleaned and prefabrication primer-treated steel surfaces are described in ISO 8501-3.

If only the surface preparation quality for the metal working is being determined, the first part of the table can be applied: STEEL WORK.

Removal of grease and soil

Contaminants hampering rust removal and paint work are removed using grease and soil removal methods (ISO 12944-4). The grease and soil removal method is determined based on the surface contaminants and the working conditions.

Solid contaminants, such as ice and plaster or paint material residue, are removed by hammering, scraping or scrubbing.

Salts and other water-soluble contaminants are removed through washing and scrubbing, or high-pressure, steam or alkali washing.

Oils and greases are removed using alkali, emulsion or solvent washing. After alkali or emulsion washing, the surfaces must be rinsed clean.

Rust removal

Rust removal is used for removing rust and mill scale from metal surface. The rust removal methods are divided into mechanical, thermal and chemical cleaning methods.

The mechanical cleaning methods include wire brushing and blast cleaning, which are described in ISO 8504.

Wire brushing (St) is performed using hand tools, or wire-brush or grinder power tools (ISO 8504-3).

In abrasive blast cleaning (Sa), abrasive granular material is blasted onto the surface using pressurised air or water or a centrifugal blaster (ISO 8504-2).

In hydro-blast cleaning (Wa), ultra-high pressure water, over 70 MPa, is sprayed onto the surface. Hydro-blast cleaning is based on the impact energy of water directed against the surface. No abrasive material is used in hydro-blast cleaning (ISO 8501-4 and SSPC VIC-4).

The thermal method is the *flame cleaning*, where an acetylene-oxygen flame is used to remove previous paint coats, mill scale, and rust from steel surface. Hereafter, the surface is cleaned using wire brushing (ISO 9501-1).

In chemical rust removal, i.e. acid pickling, mill scale and rust is dissolved in a suitable acid or acid-mixture bath.

Determination and assessment of cleanliness and surface profile of steel surface

The state of steel surface immediately before cleaning can be indicated as *rust grade*. The state of steel surface immediately after cleaning is indicated as *preparation grade* or *preparation quality grade*.

Rust grades

The surface of hot-milled steel has a layer of mill scale generated during milling. The quantity of rust on steel surface varies according to how long, and in what environment, the steel has been unprotected.

The rust grade of an uncoated steel surface influences the determination of the rust removal method, cleaning costs and durability of the coating. ISO 8501-1 specifies four *rust grades* for hot-milled steel. The rust grades, designated and marked as A, B, C, or D, are defined verbally together with illustrative example photographs. In the photographs, the marking A depicts a steel surface covered largely by a firmly adherent layer of mill scale, and rust is minimal or absent. B depicts a steel surface where the formation of rust is at an initial stage and where the layer of mill scale has started to flake off. C depicts a steel layer where the mill scale has rusted off or can be scraped off, and where minor pitting corrosion can be detected through visual inspection. D depicts a steel surface where the mill scale has rusted off and where generalized pitting corrosion can be detected through visual inspection.

Preparation grades

Standard ISO 8501-1 specifies the surface preparation grades by describing verbally, together with illustrative photographs, the visual texture of the surface.

Surface preparation with hand or power tools – scraping or wire brushing manually, or wire brushing or grinding using power tools – is designated with the marking ”St”. The number following the marking indicates the degree of cleanliness from mill scale, rust, and previous coats. The most common preparation grades of wire brushing are St 2 and St 3. For example:

St 2 = Careful cleaning by hand or power tools.
With visual inspection, the surface may not contain dust, grease or oil, nor weakly adherent mill scale, rust, paint material or foreign substances. See photographs BSt 2, CSt 2 and DSt 2 in the standard.

Surface preparation performed using *abrasive blast cleaning* is designated with the marking ”Sa”. The preparation grades for abrasive blasting are Sa 1, Sa 2, Sa 2½ and Sa 3. For example:

Sa 2½ = Very careful abrasive blast cleaning. With visual inspection, the surface may not contain dust, grease, oil, mill scale, rust, paint material or foreign substances. The contaminants remaining on the surface must be firmly adherent to the substrate. See photographs ASa 2½, BSa 2½, CSa 2½ and DSa 2½ in ISO 8501-1.

The term ‘foreign substance’ refers to water-soluble salts and welding medium residue, for example. These contaminants cannot be entirely removed using dry blast cleaning. Standard ISO 8502 describes the test methods for detecting water-soluble iron salts and chlorides, dust and condensates.

Hydro-blast cleaning is a surface cleaning method, which uses only high-pressure water. Hydro-blast cleaning is based on the impact energy of water directed against the surface.
Advantages of hydro-blast cleaning include:
- no solid abrasive granules or associated dust
- removes soluble salts
- removes grease and oil
- leaves no granules or dust on the surface
- does not prevent simultaneous execution of other trades in the immediate vicinity

Disadvantages of the method include
- does not remove mill scale
- does not form surface profile

The following hydro-blast cleaning methods are in common use:
- high-pressure hydro-blast cleaning (34 MPa – 70 MPa)
- ultra-high pressure hydro-blast cleaning (over 70 MPa)

In the determination of rust grade, the least acceptable rust grade discovered is to be recorded. In the determination of the surface preparation degree, the degree corresponding most closely under visual inspection to the steel surface being assessed is to be recorded.

In cases where painting is carried out as patching and only part of the surface is prepared, the letter P can precede the marking for the surface preparation degree to indicate that the surface preparation is only partial, e.g. PSa 2½, surface cleaned partially to surface preparation degree Sa 2½, ISO 8501-2.

Grading of blast-cleaned steel surface profile

The surface profile refers to the surface micro-roughness, which is normally indicated as a ratio of the highest profile peak and the lowest profile valley (ISO 8503-1).

Irrespective of the procedures and the type of abrasives used, the surfaces after blast cleaning consist of random irregularities with peaks and valleys that are not easily characterised. Experts have therefore concluded that because of this random nature, no method is capable of giving a precise value for this profile. They have recommended that the profile should be identified either as *dimpled* (where shot abrasives have been used) or *angular* (where grit abrasives have been used)

Grading of the surface profiles is given in ISO 8503-1.
- Fine grade   Profiles equal to Segment 1 and up to, but excluding Segment 2
- Medium grade   Profiles equal to Segment 2 and up to, but excluding Segment 3
- Coarse grade   Profiles equal to Segment 3 and up to, but excluding Segment 4

ISO 8503-2 specifies the requirements for the ISO surface profile reference comparators used for visual and tactile comparison of blast-cleaned steel surfaces **(image 4.1)**, where shot (S) or grit (G) abrasives have been used.

All loose dust and debris is removed from the test surface. The appropriate surface reference comparator, either G or S, is selected and placed against the test surface. Then the test surface is compared, in turn, with each sector of the comparator. The two profiles on the comparator that are nearest to the profile on the test surface are assessed and, from these, the grade is determined: “fine grade”, ”medium grade” or ”coarse grade”.

Determination of surface profiles using the focusing microscope procedure and the stylus instrument procedure are specified in standards ISO 8503-3 and ISO 8503-4.

Also, other procedures for surface profile assessment are in use, such as the dial gauge procedure and the replica tape procedure.

Hydro-blast cleaning does not form a surface profile.

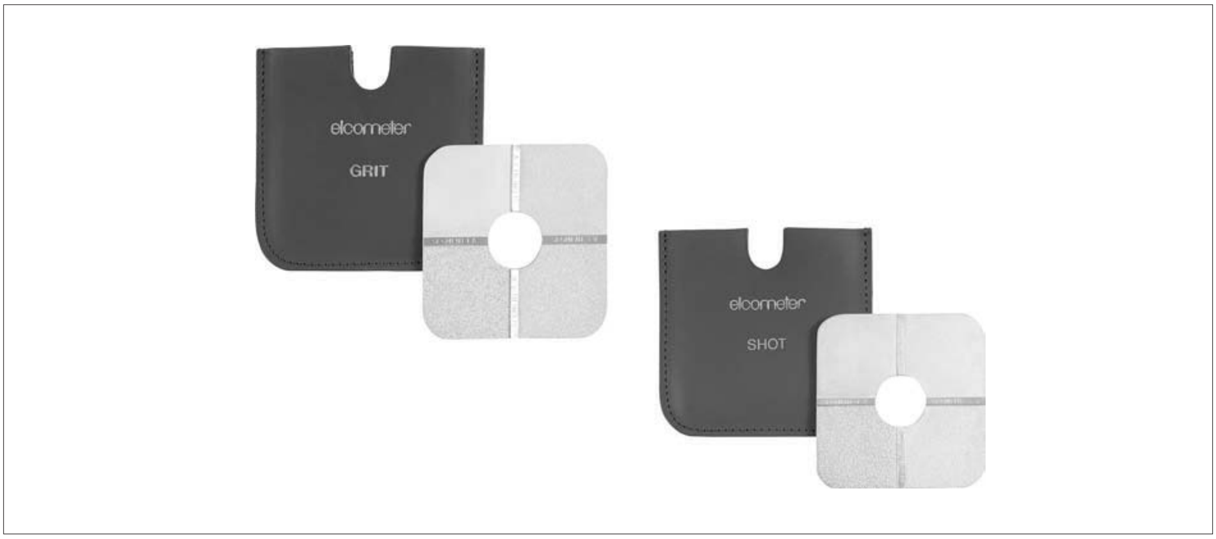


Image 4.1 ISO surface profile reference comparators for tests under ISO 8503-1 and ISO 8503-2.

Table 4.1 Nominal values and deviation range for the surface profiles of the different sectors of the ISO surface profile reference comparator.

a) Grit blast-cleaned steel surface comparator "G"

Segment	Nominal reading, $\overline{Ry5}$	Tolerance
1	25 µm	3 µm
2	60 µm	10 µm
3	100 µm	15 µm
4	150 µm	20 µm

b) Shot blast-cleaned steel surface comparator "S

Segment	Nominal reading, $\overline{Ry5}$	Tolerance
1	25 µm	3 µm
2	40 µm	5 µm
3	70 µm	10 µm
4	100 µm	15 µm

Prefabrication primer treatment

In terms of coating durability, surface preparation and paint work should preferably be performed once the final structure is complete. This is not possible in all cases, and the costs of surface preparation can be very high. Therefore, mill scale and rust are removed from steel plates or beams prior to the workshop stage. In such cases, rust is removed using automatic centrifugal blasting equipment, and the cleaning is inexpensive.

The steel surface is protected immediately after cleaning using a special paint material called the *prefabrication primer*. Formerly, the prefabrication primer went by the name of *shop primer*, which currently refers to the first subsequent priming coat. The purpose of prefabrication primer treatment is to protect the cleaned steel surface temporarily during transport and the various manufacture phases until the final corrosion protection paint can be applied.

The prefabrication primer must have the following properties (ISO 12944-5, Annex B):
- the primer must be suitable for application using automated coating equipment
- the primer must form a uniform coat with high opaqueness
- the primer must allow for the application of subsequent coats
- the drying time of the primer must not be so long that the coated pieces cannot be handled shortly after application
- the primer must protect the steel surface for a specified duration
- the primer film must not significantly hamper welding or torch cutting operations
- the saturation of the fumes and vapours from welding and cutting must not exceed the allowed exposure limits of the working site.

In the determination of the prefabrication primer, the subsequent paint system, stress during the temporary protection, and stress on the structure after the final coating must all be considered. The most common types of prefabrication primers and associated markings are:

	EN ISO 10238
Epoxy	EPF
Polyvinyl butyral	PVBF
Acrylic	AYF
Ethyl zinc silicate	ESIZ
Epoxy zinc	EPZ

Prefabrication primers based on ethyl zinc silicate or zinc epoxy are particularly suitable for application in cases where the steel remains in outdoor conditions for a lengthy period before subsequent coating, the structure is exposed to severe weather stress, and where the subsequent coat is of zinc powder paint **(see table 4.2)**. EN ISO 10238 provides information on the measurement of the dry film thickness of prefabrication primers.

Prefabrication priming must form a uniform film thickness. The best outcome is achieved using automatic spraying.

The data sheet of the paint product and the descriptions of paint systems indicate the type of prefabrication primer suitable in each case. **Tables 4.2** and **4.3** present a comparison of the various types of prefabrication primers.

Preparation of galvanised surfaces

Zinc is commonly used for corrosion protection of steel surfaces (i.e. galvanisation). The properties of zinc differ in many respects from those of steel. The differences must be taken into consideration in surface preparation, in choosing the paint system and the structure being coated.

Before mechanically coarsening the galvanised surface, which is recommendable in many cases, all contaminants and water-soluble salts hampering surface preparation and paint work must be first removed from the surface using soil and grease removal methods; see ISO 12944-4.

Different hot dip galvanised structures must be prepared after cleaning as follows:

- hot dip galvanised steel structures are to be sweep blast-cleaned so that the entire surface becomes dull. Suitable cleaning agents are aluminium oxide, natural sand and quartz, for example. Painting is not recommended for galvanised structures intended for immersion.
- New galvanised steel-plate structures are sweep blast-cleaned lightly. For preparation of surfaces dimmed by oxidation, alkali wash emulgation and rinsing with fresh water is sufficient.

Surfaces coated with zinc-rich paint are prepared prior to subsequent coating according to the technical data sheet of the product.

Chemical conversion treatments and etching primers

The most commonly used chemical conversion treatments on the cleaned metal surface are; phosphating, chromating, chromium-free pretreatments, anodising of aluminium, etching, and painting with an etching primer. These treatments improve the paint material's adhesion to the metal surface and decelerate corrosion underneath the coating.

Iron and zinc phosphating are suitable for steel, zinc and aluminium surfaces. Phosphating is used primarily for sheet products, especially as a preparation method for stoving. The phosphating process forms a firmly adherent, thin and fine-grained layer of phosphates on the metal surface. Metal objects are treated after cleaning with a phosphate solution using either dipping, spraying or brush application.

Chromating is a surface preparation method used for alloys and galvanised surfaces. Metal objects are treated after cleaning with a chromating solution in accordance with the chemicals supplier's instructions. There are also chromium-free pretreatments that are suitable for cold-rolled steel and zinc and aluminium surfaces.

Anodising of aluminium is an electrolytic pretreatment. The object is immersed into an anodising bath, where the electric current forms a protective oxide layer on its surface. The oxide layer is very durable and gives excellent corrosion protection. Anodising of aluminium is commonly used as pretreatment in powder coating.

Etching is suitable for steel, zinc, aluminium, lead and copper surfaces as well as for stainless steel. Etching can be carried out by electrolysis, brush etching, immersion etching or spray etching.

Etching primers are usually two-pack PVB or epoxy paints containing phosphoric acid or special curing agents and pigments. The treatment forms a thin film on the metal surface improving adhesion of paint.

Table 4.2 Compatibility of pre-fabrication primers with paint systems (standard ISO 12944-5).

Pre-fabrication primer		**Compatibility of generic type of pre-fabrication primer with primer of paint systems [1]**						
Binder type	Anticorrosive pigment	Alkyd	CR	Vinyyl/PVC	Acrylic	Epoxy [2]	Polyurethane	Zinc silicate
1. Alkyd	Miscellaneous	+	–	–	+	–	–	–
2. Polyvinyl-butyral	Miscellaneous	+	+	+	+	–	–	–
3. Epoxy	Miscellaneous	+	+	+	+	+	+	–
4. Epoxy	Zinc dust	–	+	+	+	+	+	–
5. Silicate	Zinc dust	–	+	+	+	+	+	+ [3]
Acrylic (water-borne)	Miscellaneous	–	+	–	+	–	+	–

\+ = In principle compatible
– = In principle not compatible
[1] NOTE Paint formulations vary. Checking compatibility with the paint manufacturer is recommended.
[2] Including epoxy combinations, e.g. Hydrocarbon resisns
[3] Sweep-blasting is required

Table 4.3 Suitability of pre-fabrication primers, used with a related paint systems, in various exposure conditions (standard ISO 12944-5).

Pre-fabrication primer		**Suitability to exposure conditions [1]**						
Binder type	Anticorrosive pigment	C2	C3	C4	C5-I	C5-M	Immersion without cathodic protection	Immersion with cathodic protection
1. Alkyd	Miscellaneous	+	+	+	–	–	–	–
2. Polyvinyl-butyral	Miscellaneous	+	+	+	–	–	–	–
3. Epoxy	Miscellaneous	+	+	+	+	+	+	–
4. Epoxy	Zinc dust	+	+	+	+	+	+	–
5. Silicate	Zinc dust	+	+	+	+	+	+	+
Acrylic (water-borne)	Miscellaneous	+	+	+	–	–	–	–

\+ = Suitable
– = Not suitable
[1] NOTE Paint formulations vary. Checking compatibility with the paint manufacturer is recommended.

5. Protective paint systems

Composition of paints

As a rule, paints are composed of binders, pigments, fillers, solvents and additives.

Binders

A binder forms a coating which bonds to the substrate, containing pigments bound to one another by the binder. The binder largely determines the characteristics and performance of the coating, such as adhesion, cohesive strength and durability. The curing mechanism of the paint is a binder-dependent property.

The binders in paints are for the main part organic macromolecule polymers (plastics), or reactionable resins, which form polymers in the curing process. Synthetic polymers and resins are the most important group of binders. Based on the curing mechanism of the binder, paints are divided into reversible coatings (physically curing paint) and irreversible coatings. Irreversible coatings are further divided into air curing paints, water-borne dispersion paints and chemically curing paints. A paint product is named by the binder used, e.g. alkyd, epoxy, chlorinated rubber, polyurethane, acrylic or vinyl paints.

Pigments and fillers

Pigments are powders which produce the colour and hiding power of the coating. Corrosion protection pigments are also capable of retarding or inhibiting the corrosion reaction.

Fillers influence a number of characteristics of the coating, such as gloss, durability and brushability. The fillers also increase film density.

Solvents

The purpose of solvents is to dissolve the solid resins and polymers, and to reduce viscosity of the binder. In water-borne paints, solvent are also used for film formation.

Although solvents evaporate from the coating after application, they contribute in an important way to film formation and properties.

Solvents are flammable liquids, and most of them produce vapours and fumes harmful to health.

Based on the solvent's flash point, the paints are divided into flammable (and combustible) liquid classes as follows:

Extremely flammable (symbol F+):
flash point < 0°C

Flammable (symbol F+):
flash point 0 – 21°C

Ignitable: (no symbol)
flash point 21 – 55°C

If the flash point exceeds 55°C, the paint product is not classified as flammable liquid. If the flash point is in the range of 55 – 100°C, only the regulations on the warehousing permits of combustible liquids are relevant.

The EU's new regulation on classification, labelling, and packaging of substances and mixtures, the CLP Regulation (EC) No 1272/2008 specifies the classification criteria applicable to solvents in a new way. The Regulation enters into force in phases in 2010 and 2015.

Some of the solvents used in paints are classified as volatile organic compounds (VOC).

Thinner
Thinner is a volatile liquid added to paint for thinning, which can be either a solvent or water. Paints are also referred to as water-thinnable or solvent-thinnable.

In thinning a paint product, the instructions provided by the paint manufacturer must always be adhered to.

Additives
Paints usually contain a number of additives in small quantities. Additives are required to produce certain properties associated with shelf life, viscosity and curing. In water-borne paints, for instance, the usage of additives is very important.

Paint types

Paints can be classified in many ways, for example, by
- physical state (solid/liquid)
- film formation
- binder type
- pigment
- coat order in the paint system
- designed use

In this handbook, the paint types are classified according to binder types, and acronyms are used in accordance with ISO 12944-5.

Reversible coatings
In reversible coatings (formerly: physically curing paint), the binder is a complete polymer. Film is formed without any chemical reaction required when the molecules of the binder agent are attached to one another once the volatile paint component has evaporated from the film, or a fused film cools down. The film can be dissolved at any point using the original solvent contained in the used paint

Chlorinated rubber paint CR
In the chlorinated rubber paints, the binder is a mixture of either chlorinated rubber and chemical-resistant plasticizer or of chlorinated rubber and resin. Chlorinated rubber paints are used for priming, intermediate and top coats on metal and concrete composite substrates. The chlorinated rubber film withstands chemicals in splash form and water in immersion. Its weather resistance is good.

Acrylic paints AY
In acrylic paints, the binder is a mixture of acryl polymers and a suitable plasticizer. Acrylic paints are used for priming, intermediate and top coats in weather-resistant paint systems.

Polyvinyl chloride paints PVC
In polyvinyl chloride paints, the binder is a mixture of copolymers of polyvinyl chloride and plasticizers. Polyvinyl chloride paints are used for priming, intermediate and top coats in weather-resistant paint systems.

Irreversible coatings
Initially, the coating cures physically through the evaporation of volatile solvents (if a solvent is used), followed by a chemical reaction or coalescence of binder particles (in water-borne dispersion paints). The process is irreversible, which means that the film cannot be dissolved after curing using the original solvent or, in solvent-free paints, using a solvent typical for the paint type in question.

Air curing paints (oxidation)
In air curing paints (i.e. the curing mechanism is based on oxidative cross-linking), the binder is a curable oil substance or a derivative thereof. Oxygen in the ambient air binds to the double bonds of the binder, and the cross-linking process starts.

Alkyd paints AK
In alkyd paints, the binder is an oil-modified polyester, epoxy or urethane resin.

Alkyd paints (like epoxy esters and urethane oils) cure when exposed to oxygen in the ambient air once the solvent has evaporated from the film. Film formation requires a temperature of over +5°C. Alkyd paints can be either solvent-borne or water-borne.

Alkyd primers utilise corrosion protection pigments.

Alkyd paints are used both indoors and outdoors in environment classes C1 – C4.

Water-borne dispersion paints (one-pack)
In water-borne dispersion paints the binder is a polymer in aqueous dispersion form (minuscule balloons of ø 0,05 – 0,25 µm). Once water has evaporated from the film, the polymer balloons fuse together to form an integral film. The curing process is irreversible, and the coating cannot be dispersed or dissolved in water after hardening.

Paints designed for metal surfaces utilise corrosion protection pigments and corrosion inhibitors. The most commonly used polymers are acrylic resin (AY), vinyl polymers or polyurethanes (PUR).

The weather resistance of dispersion coating is good. The film is thermoplastic, and it has good resistance to solvents and water.

Chemically curing paints
Film formation in chemically curing paints results from a reaction where a liquid resin of small molecule size becomes cross-linked and increases in molecule size. The cross-linked coating does not dissolve after hardening in the original solvent and does not substantially soften when exposed to heat.

In two-pack paints, the cross-linking reaction of the paint components, the base component and the curing agent takes place

Two-pack epoxy paints EP
Two-pack epoxy paints are coatings where amine is used for cross-linking the epoxy resin. After combining the components, the coating mixture has a limited pot life. Film formation usually requires a temperature of over +10°C. Lower temperatures are also possible when special curing agents are used.

The epoxy film does not dissolve in solvents, has good adhesion to the substrate, and is hard, which signifies good mechanical properties. The coating withstands alkalis, salt solutions, weak acids, oils, greases and solvents well. When exposed to weather stress, the epoxy coating chalks easily on the influence of UV light.

Epoxy pains are available in solvent-borne, water-borne and solvent-free versions. Epoxy resin and a curing agent are used as binders in epoxy coatings, which are solvent-free or contain solvent only in minimal quantities. The coating has a short pot life. The coating is usually applied using a two-pack sprayer. A single application produces a dry film of 250 - 1000:µm in thickness

Epoxy coating reinforced with glass fibre is marked using the acronym EPGF.

Epoxy combinations (EPC) can be modified using, for example, hydrocarbon resin, coal tar, acryl or vinyl. Coal tar-based epoxy coatings are used for subterranean or submarine structures intended for an immersion environment.

Two-pack polyurethane paints PUR
Polyurethane coatings are two-pack paints. The binder is a resin containing hydroxyl groups (i.e. polyol), such as acrylic or polyester resin.

Using aliphatic isocyanate compounds as a curing agent will produce excellent durability of gloss and colour in outdoor conditions.

Using aromatic isocyanates allows for shorter curing times and better chemical resistance, but the coating turns yellow and chalks when exposed to UV light.

Film formation requires a temperature of over 0°C.

Polyurethane combinations (PURC) can be modified using, for example, hydrocarbon resin, or coal tar. The coatings are used for subterranean or submarine structures intended for an immersion environment.

Oxirane ester paints (national acronym OX)
Oxirane ester paints are solvent-borne coatings with a high content of solids. In two-pack oxirane ester paints, the binder is oil containing oxirane groups, cured using resin containing carboxylic acid groups. The film hardens at a slow rate at room temperature and, therefore, curing is usually accelerated by stoving the coating at a temperature of +60 – +150°C.

Adhesion of the oxirane ester coating to steel surfaces is good and, in combination with a primer, the paint is suitable for application on other metal surfaces. The chemical and weather resistance of the coating are rather good. The film is flexible and mechanically strong.

Oxirane ester paint applied without priming onto metal surface usually contains corrosion protection pigments.

Moisture curing paints
The film forms though the evaporation of the solvents. Chemical cross-linking occurs when the binder is exposed to ambient humidity.

Moisture curing polyurethane paints
Cross-linking takes place at or even below 0°C, if ambient humidity is sufficient.

Ethyl zinc silicate paints ESI (one or two-pack ethyl silicate)
The binder for ethyl zinc silicate paint is an organic silicate and the pigment is zinc powder.

Ethyl zinc silicate paint is able to withstand high temperatures, mechanical stress, and pH neutral solvents well. The paint is suitable for priming in environment classes C4, C5-I, and C5-M.

Stoving paints
The film formation of stoving paints takes place at a high temperature (+120 – +180°C), when the components of the binder react with one another.

Alkyd stoving paints
The binder is a short-oil alkyd resin and amino resin.

Polyester stoving paints
The binder is a polyester and amino resin.

Powder coatings
Powder coatings are paints in powder form. The binder for chemically curing powder coating is epoxy, acryl, polyester, polyurethane, or silicone. The powder is usually applied using an electrostatic spray. The final film forms in an oven, when the powder melts and polymerises into a coating at a temperature of +140 – +200°C (for 5 to 20 min).

Coil coatings
Coil coating is a continuous process for coating metal in an industrial coating line using stoving paints. The material to be coated is metal sheet: cold-rolled steel (CRS), hot dip-galvanised steel (HDG) or aluminium. Usually, a double-coat system, comprising the primer and topcoat, is used. The most commonly used binders are polyester (PE), polyurethane (PUR), and PVDF (domestic acronym PVF2). The sheet back is usually coated using epoxy paint. The coatings weather well and are highly pliable (e.g. profiled roofing sheets).

6. Paint systems

A paint system comprises the substrate, substrate preparation, and the coating formed by the protective paints applied to the substrate. A paint system can comprise only a single paint, which is applied one or multiple times until a sufficient film thickness is accomplished. In most cases, the paint system comprises multiple paints, which have properties supplementing one another. Based on the application sequence, the paints are divided into primers, intermediate coats and top coats.

The corrosion protection mechanism of a corrosion protection paint system is based on electric potential displacement inhibition, anodic or cathodic inhibition, or cathodic protection. The system paints usually utilise two of these three mechanisms. For example, a top coat can utilise electric potential displacement inhibition and the primer cathodic inhibition. In certain cases, corrosion protection pigments are used in all coats.

Markings of the paint systems

Part 5 of ISO 12944 describes the designation method for paint systems. The paint systems described in tables A.1 - A.8 of the standard can be marked as follows:

EN ISO 12944-5/A2.08

In cases where multiple or alternative generic paint types are included under the same system number, the identifier must contain the binder type, to be presented in the following form (system A2.06 of table A.2 as example):

EN ISO 12944-5/A2.06-EP/PUR

Tables A.1 – A.8 present the listed paint systems:
- substrate (Fe/Zn) and preparation grade of the surface
- generic paint types, number of coats, and nominal dry film thickness
- total number of coats, and total nominal film thickness of the paint system
- estimated service life category under the corrosivity category indicated in the table

In some countries, the paint system markings are more detailed. In Finland, for instance, it is recommended to mark the paint systems using a designation composed of the marking specified in part 5 of ISO 12944, supplemented (in brackets) by the paint type identifier, total nominal film thickness, number of coats, substrate material and the identifier for substrate preparation.

The binder type identifiers are presented pursuant to part 5 of ISO 12944. The substrate preparation grades are presented according to the grades specified in ISO 8501-1 (see Chapter 4 'Substrate preparation' of this document). Nominal dry film thickness is presented in micrometres.

Substrate material is presented using the chemical symbol for the main constituent compound of the metal structure, for example:
Fe = iron
Zn = zinc

Marking recommendation applicable in Finland:
SFS-EN ISO 12944 – 5/A2.02 (AK 120/2 – Fe Sa 2½)

ISO 12944 requires that if a paint system does not correspond to any of the combinations described in tables A.1 – A.8, the designation must contain all information on substrate preparation, general paint type, nominal dry film thickness and the number of coats. In such a case, the designation for the paint system can be presented using the designation method specified in the above recommendation (without reference to the identifier of the table).

Determination of the paint system

The paints of the paint system must be suitable for the environment and associated stresses at the location of the site. The paints must be compatible with one another, the surface preparation method used, and the painting work conditions. The paints must form a sufficiently thick protective coating and provide corrosion protection at a reasonable cost.

Corrosivity categories

The paint type is selected primarily based on the protection required in the environment of the structure. The paints must also withstand any stress due to manufacture or installation.

In the description of the environment relevant to the structure, the provisions in part 2 of ISO 12944 are to be used, where the environments are divided into corrosivity categories C1 – C5 and Im1 – Im3 based on the parameters contributing to corrosion in metals.

Indoor environments in most cases fall into corrosivity categories C1 and C2, unless corrosivity parameters other than humidity are present to a significant degree.

Outdoor environments fall into corrosivity categories C2 – C5. Based on the quality and quantity of atmospheric contaminants, local environments can be divided into rural, urban, maritime and industrial environments.

In addition to the aforementioned corrosivity categories, there are a number of special stresses, such as those associated with chemical plants, paper and pulp mills, bridges, and subterranean or submarine structures. Corrosivity parameters typical for special environments include corrosive gases, chemical dust, splashes, biological, mechanical and thermal corrosion, and immersion in water or burial in soil. The paint systems for special environments are described in the Teknos Manual 'Paint Systems for Industrial Coating and Corrosion Protection Painting'.

In particular, the corrosivity parameters in the structure's immediate environment must be considered in the determination of the relevant corrosivity category. This immediate atmospheric environment (microclimate) is more important in terms of corrosion protection than the general atmospheric environment of the locality (macroclimate).

For instance, the Finnish climate is cool and humid by nature and, in comparison to most industrialised counties, clean.

Because the performance and durability of coatings of the same type may, in principle, differ from one another, it is increasingly important to choose a time-proven paint system.

The most commonly used Teknos paint systems with a good service history are described in the Teknos Manual 'Paint Systems for Industrial Coating and Corrosion Protection Painting'.

Preparation and application conditions

In the determination of the paint systems, the surface preparation and application conditions must also be considered. In case the location of the structure, or economical reasons, set constraints on the surface preparation or application, the paint system should be chosen in a way that the paints are suitable for the intended surface preparation and application conditions and meet the corrosion protection requirements optimally. Teknos Oy provides paint systems both for shop and on-site application environments.

Economical considerations

Corrosion protection by a paint system is an investment targeted to provide, at an optimal cost, a coating that will serve the designed purpose throughout the projected service life. Although the share of the paints is usually only 15 – 30 per cent of the overall costs, the determination of the paint system may have significant economical effects. For example, in industrial coating and shop application fast-curing paints shorten process times and thus increase the output capacity of the facility.

7. Execution of the painting work

How the paint is applied greatly influences the performance and durability of the coating. All painting work must be performed in a professional manner, in the application conditions according to the manufacturer's instructions provided in the technical data sheet.

Painting methods

Paints can be applied onto the surface using a number of different painting methods. Spraying, brush application, roller application, dipping, flow coating, industrial flow coating and industrial roller coating are the most common painting methods. In the determination of the painting method, the following must be considered, among others:
- painting site
- shape, size and number of structures being coated as well as manufacture process cycles
- paint type
- number of colours
- safety and environmental considerations
- compatibility of the painting tools and implements used with the paint system

Brush application

Brush application is the oldest painting method in common use today. The advantages of brush application include the paint's good penetration in the surface pores. Brush application is a slow process and a relatively expensive one. On large surfaces, brush application does not produce a sufficiently uniform and good-quality film. Film thickness is thinner than in airless spray coating.

Roller application

Roller application is often preferred to brush application because of the speed of the method. In roller application, the paint is rolled onto the surface instead of rubbing as in brush application. A paint roller is not an appropriate tool for painting small, poorly cleaned or uneven surfaces, especially in cases where the surface contains rust or dust. In such a case, the coating rests on the contaminants and cannot bond properly to the substrate. Furthermore, achieving a uniform and sufficient film thickness is rather difficult. Hence, the paint roller is primarily a paint application tool for the application of top coats on large and smooth board surfaces, and is not recommended for priming use.

Spraying

Spraying is the most commonly used painting method for large surfaces today. Different types of sprayers have been developed for various purposes of use.

Low pressure (conventional) air spray

The side mount gravity sprayer, i.e. air atomising sprayer, is the oldest of the sprayer types. This sprayer type is still in extensive use, for example, for painting cars and the top coating of small structures. **(image 7.1)**

In low pressure air spraying, the liquid is injected, either under hydrostatic pressure or slight overpressure, into the middle of the sprayer gun nozzle. The liquid from the nozzle is then atomised into fine mist by air jets directed at different angles to the paint material being ejected. The volume of the liquid flow to the nozzle can be adjusted using the needle valve or by adjusting the nozzle orifice size. The spray pattern is determined based on the angle and volume of the air jets.

The method requires the availability of pneumatic air and thinning of the paint material. The quality of the finish is uniform and smooth. The method is not suitable for forming thick coatings, since thinning in used to regulate the coating finish. Conventional spraying is not recommended for coating complex structures. Atomising prevents paint material from entering tight corners and the surface pores **(image 7.5)**. Air atomising spraying is also called low-pressure spraying because of the low operating pressure used.

The main advantages of low pressure air spraying include the following:
- adjustable spray pattern
- no movable parts
- high-quality finish
- low purchase price
- allows for rapid change of colours

Disadvantages include:
- not suitable for all paint types
- painting corners and other complex structures is difficult
- thinning of paint required

Image 7.1 Low pressure (conventional) sprayers

Airless i.e. high-pressure spraying
Airless spraying is the most commonly used painting method in corrosion protection painting **(image 7.2)**. The splitting of paint liquids in airless spraying is based on the great pressure difference induced by conveying the liquid under high pressure though a small nozzle orifice. The resulting paint mist is rather fine in quality and the droplets hit the surface at a high velocity. Because there is no “air lock” to overcome (see conventional spraying), the paint enters freely into corners and to the bottom of the surface pores.

The pressure required for airless spraying is supplied by a high-pressure pump, which increases the pressure by tens of times, depending on the surface area ratio between the air-side pistons and the liquid-side pistons. There are also sprayers supplied by diaphragm or piston pumps, powered by electricity or a combustion engine. These sprayers are used on sites where pneumatic air is not available.

The volume of sprayed paint (l/min) depends upon the nozzle size and the pressure used. The width of the spray pattern depends upon the split angle of the nozzle. Over the course of usage, the diameter of the nozzle orifice wears and becomes larger and, thus, the spit angle increases. The technical data sheets of the paint products describe the design nozzle sizes for the product used in airless spraying.

For spraying paint without thinning, a nozzle pressure of 120 – 250 bar is usually required. Using too high a spraying pressure should be avoided, since this will increase the volume of spray dust and, thus, the visual texture of the finish. As low a pressure as possible should be applied to achieve a cost-effective outcome. The operating pressure can also be significantly reduced by using an appropriate paint warmer as an auxiliary device.

The main advantages of airless spraying include:
- suitable for most paint materials
- high performance and capacity
- only minimal thinning required
- high dry film thickness
- minimum volume of paint mist

Disadvantages include:
- high hose pressure required
- visual texture of finish may not be as satisfactory as in low pressure air spray
- not suitable for application of small volumes of paint

Image 7.2 High-pressure pump and sprayer

Image 7.3 Electrostatic sprayer

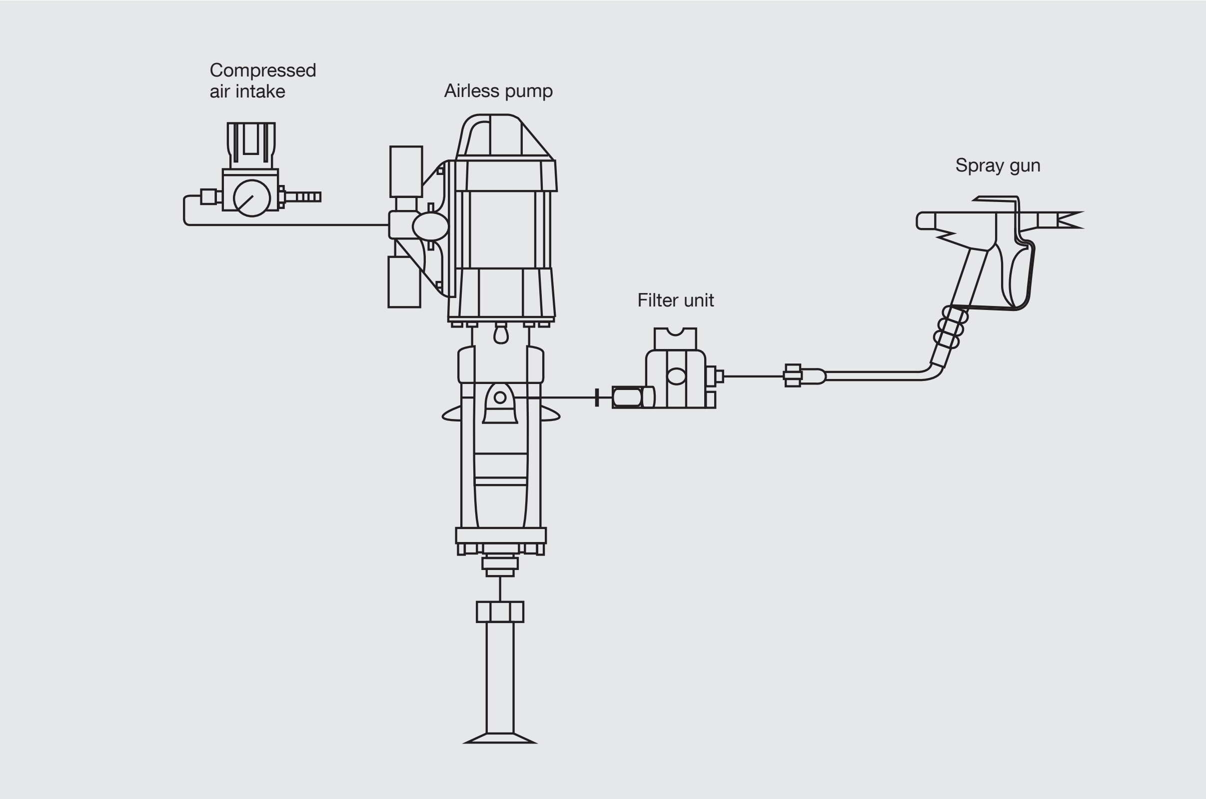


Image 7.4 Operation principle of airless sprayer, i.e. high-pressure sprayere.

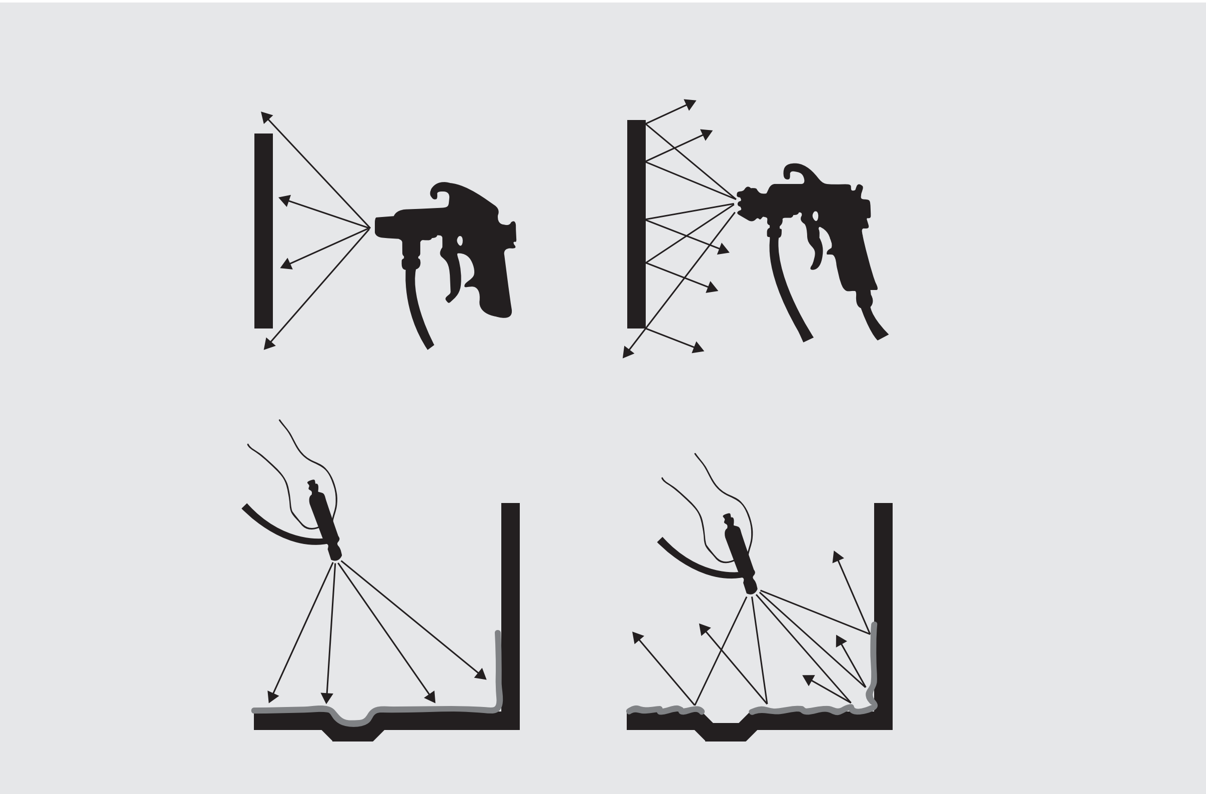


Image 7.5 High-pressure spraying (on the left) provides better finish than conventional spraying (on the right), especially in the corners.

Air-assisted airless spraying
The finish produced by airless spraying can be enhanced using a spray gun where compressed air is introduced into the spray from the airless nozzle to improve atomisation.

Various spray gun manufacturers offer air-assisted airless spray guns under different brand names, such as Airmix, Aircoat, Airflow, Airassistant, and so on.

They all share the same feature, namely that the characteristics of the spray fan generated by the gun can be adjusted and modified by separately adjusting the compressed atomisation air. This allows for an improved finish and high-viscosity paints can be sprayed without creating a stencilling effect.

These spray guns can be used as regular airless spray guns if compressed atomisation is not required. Because air-assisted spray guns allow for a reduction of spray pressure, they are well suited for electrostatic coating.

Electrostatic spraying
Electrostatic sprayers have been developed for the application of both liquid paint **(image7.3)** and powder coatings **(image 7.7)**. High direct-current field (60 – 100 kV) is formed using a transformer between the coated surface and the sprayer. The liquid paint or powder coating is atomised in the spray gun using centrifugal force, compressed atomisation air or high-pressure pneumatic air. The liquid or powder becomes electrically charged in the field and is attracted to the surface of the grounded structure.

Powder coating is charged using one of two methods, based either on high voltage (image 7.7) or triboelectricity **(image 7.8)**.

In powder coating, the powder drifting off target can be recovered and recycled for further use.

Two-pack spraying
In certain two-pack coatings, the curing reaction time is so short that dedicated two-pack spray applicators have been developed **(image 7.6.)**. The applicators pump the curing agent and the base component from separate containers and mix the components to the correct proportion before the liquid reaches the spray gun.

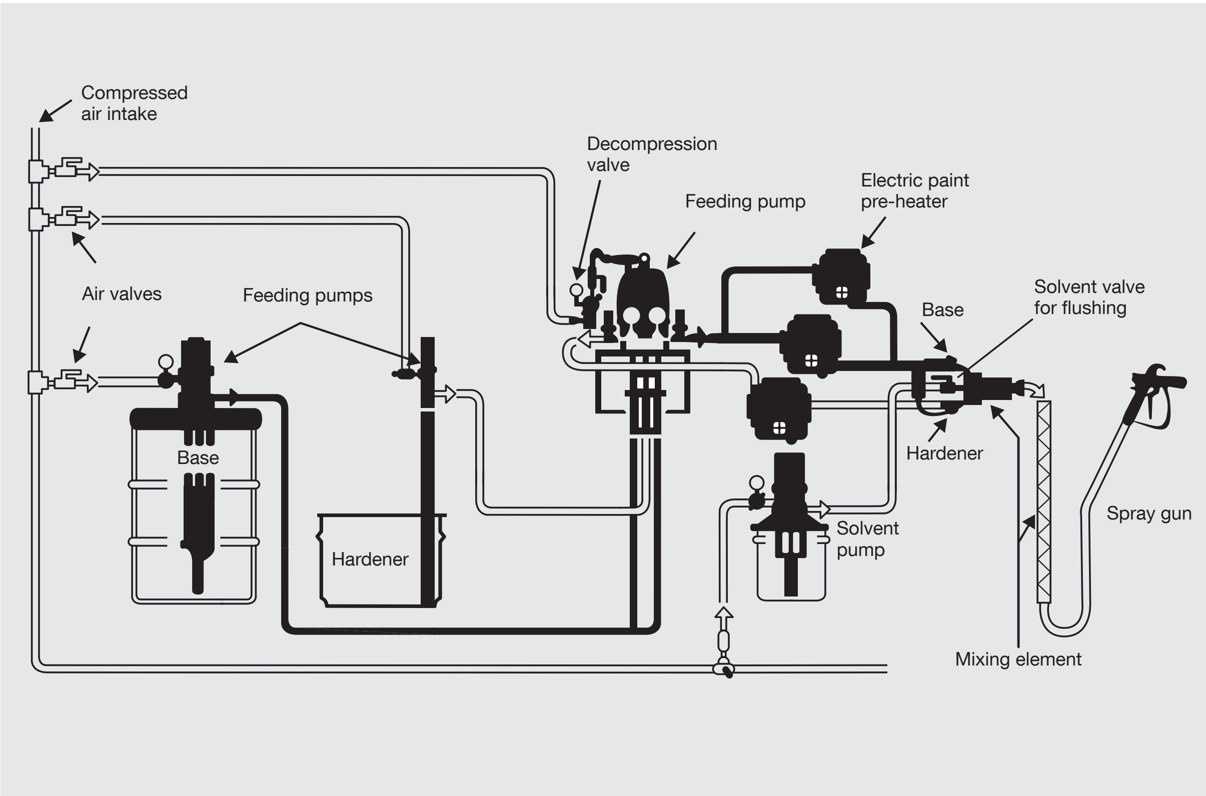


Image 7.6 Operation principle of two-pack sprayer.

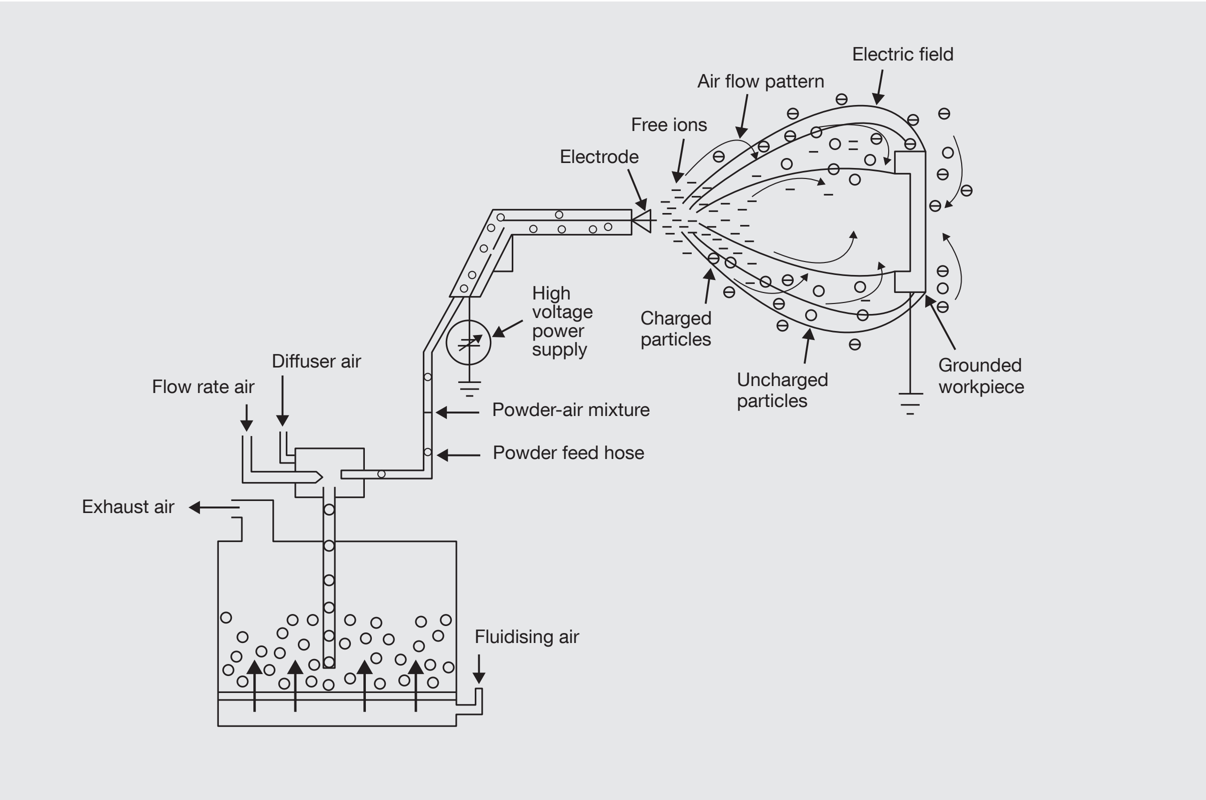


Image 7.7 High voltage powder sprayer.

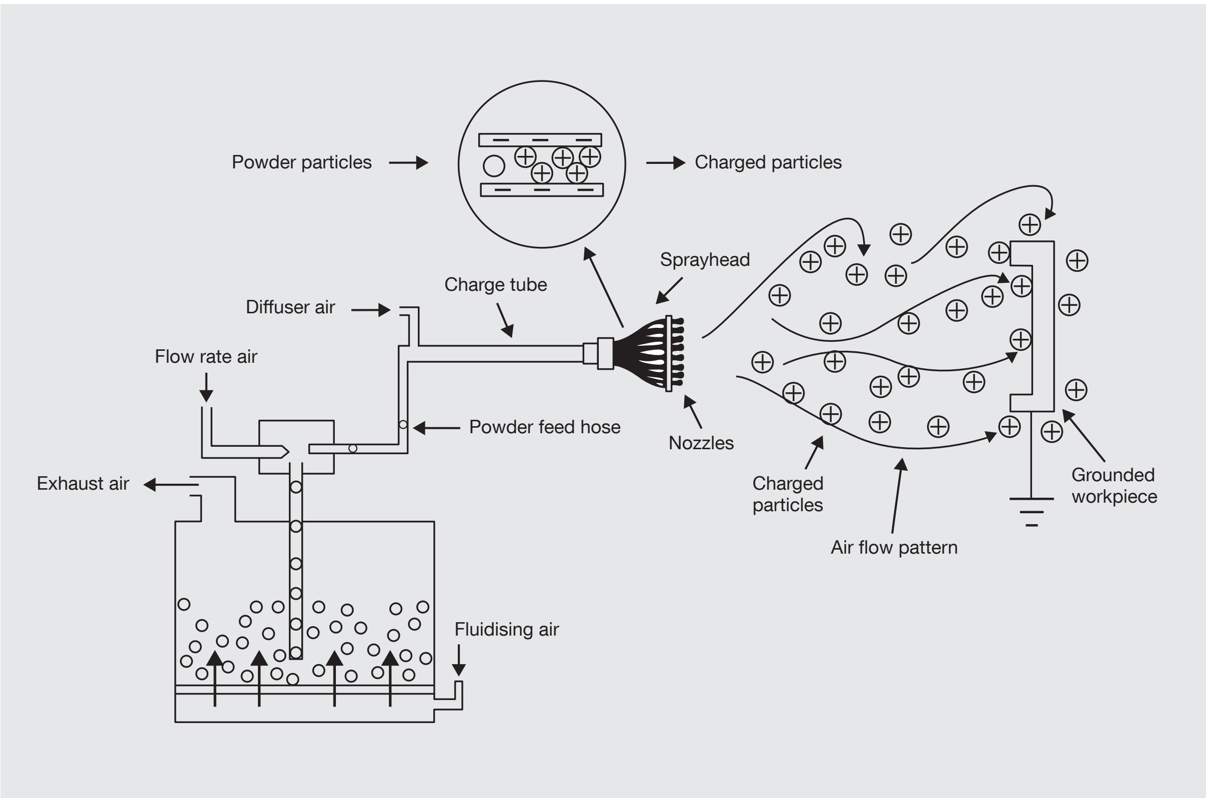


Image 7.8 Triboelectric powder sprayer.

Dipping

Dipping is a method used for serial products, providing short cycle times and minimal waste of coating material. The objects being coated are dipped into the dipping pool individually, in bundles, coating racks or smaller objects in a mesh basket or similar configuration.

The dipping pool is sized according to the size of the objects being coated. Larger dipping pools are equipped with pumps, which keep the coating material in constant flow so as to prevent settling of the paint.

Dipping requires special paints designed for the purpose, curing either physically or through oxidation, or stoving paints. Two-pack reaction paints are not usually used because of the limited pot life.

In most cases, film thicknesses varying at about 30 µm are achieved in one dip. If the object is very complex, dipping does not usually produce a fine finish because of sagging due to holes, cantilevers and other similar shapes.

Electric dip coating

Electric dip coating (electrophoresis, i.e. cathaphoresis) is a coating method where the object being coated is connected to a DC circuit either as an anode or a cathode and the basin being the opposite pole. The coating material is water-borne paint designed for the purpose. The paint particles become charged and are attracted to the surface being coated, then precipitate and form a uniform film of approximately 30 µm in thickness. The method is used for priming in the automotive and white consumer goods industries.

Electrostatic fluidized bed coating

The object being coated is dipped into a pool of fluidised powder. The pool has electrodes, creating an electrostatic charge to fluidized powder which attaches to grounded object run through the cloud of charged powder. Film thickness can be controlled by adjusting the voltage.

Application conditions

Surface preparation and coating must be performed under the conditions specified by the manufacturer's instructions. For instance, application onto a moist, wet or icy surface can cause peeling of the paint surface. The ambient temperature during application and drying must be sufficiently high to allow for curing.

Relative humidity and dew point

Water vapour present in the ambient air can condensate on the surface being coated. On clean metal surfaces, condensation occurs when relative humidity reaches 100 per cent, e.g. when the temperature falls below the dew point. On the surfaces containing contaminants, condensation can occur significantly earlier.

In practical terms, corrosion reaction starts on blast-cleaned steel surface when relative humidity reaches 60 - 70 per cent. For this reason, relative humidity must be low during blast cleaning. Coating must be applied immediately after cleaning, when the surface is dry and the corrosion reaction has not yet started.

The effects of relative humidity on the curing and film formation properties vary according to the paint types. The design limit values of allowed relative humidity are specified in the technical data sheet.

When the metal surface is colder than the ambient air, condensation can also occur in certain cases in low relative humidity. Therefore, in the determination of painting conditions, it is more important that the temperature of metal surface exceeds the dew point of ambient air by a sufficient margin (3°C) than relying on a given relative humidity percentage.

The dew point (dew point temperature) is the temperature at which the relative humidity of water in gaseous form is 100 per cent.

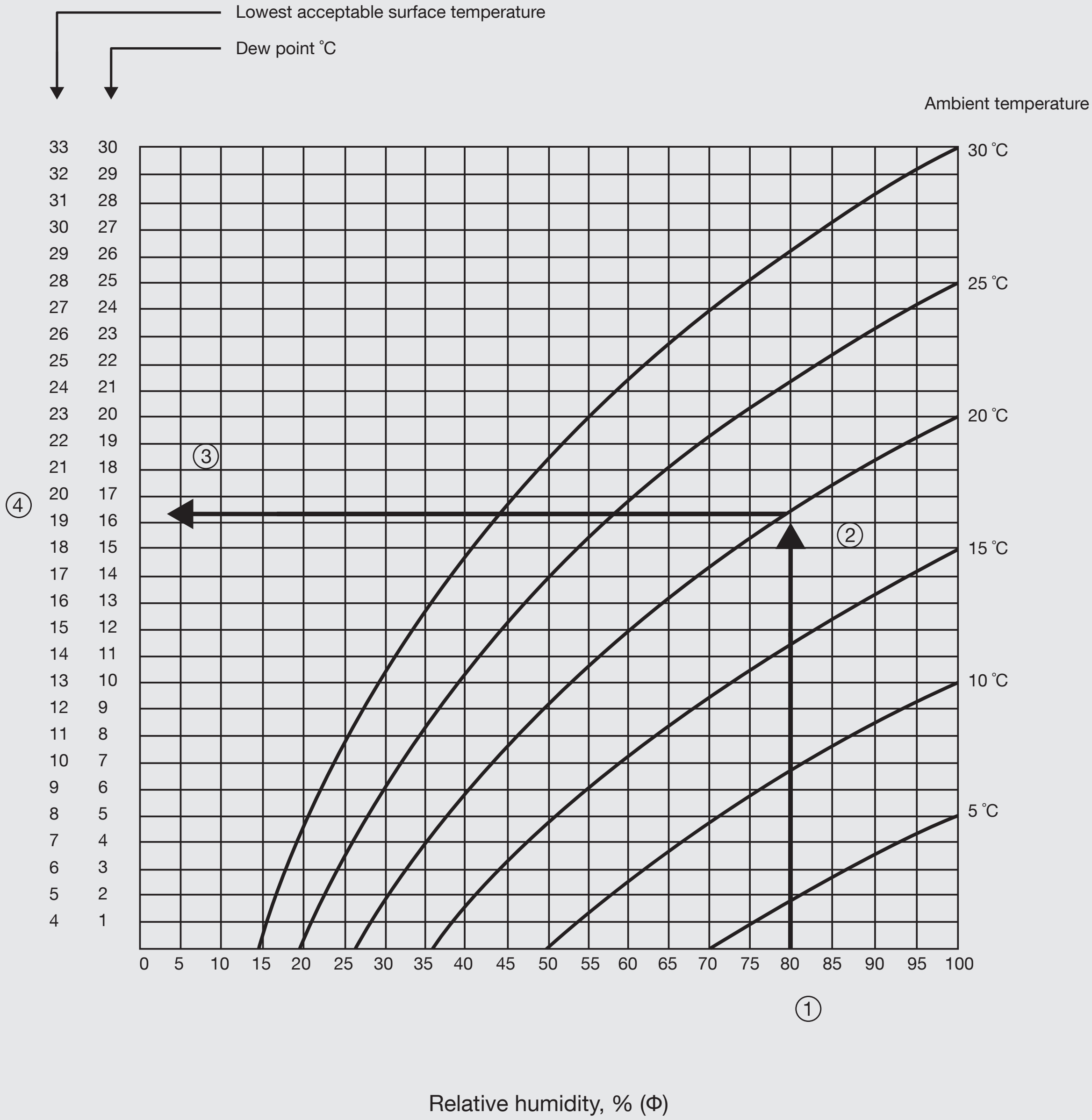
Relative humidity, ambient temperature and surface temperature are the starting points for the determination of dew point (potential condensation) on the surface being coated. In practical terms, the relevant parameters also include thermal conductivity of the surface, solar radiation, air flow on the surface, and type and volume of any hygroscopic substances present on the surface.

When ambient temperature is below 0°C, the surface must be checked for ice. A surface thermometer is the best device for measurement of surface temperatures.

Generally, the temperature of the surface being coated should exceed the dew point of ambient air by at least 3°C immediately before, and during, application and during curing, unless otherwise specified by the manufacturer. By using a dewpoint dial **(Image 7.9)** it is easy to make sure that the painting work can be carried out, if the ambient temperature, relative humidity and surface temperature are known.

Image 7.10 presents, as a function of ambient temperature and relative humidity, the lowest acceptable surface temperature for the structure, as well as the respective dew point.

Image 7.9 Dew point dial



Example calculation for determination of the lowest acceptable surface temperature using the table above:

①	Measure relative humidity in ambient air:	80 %
②	Measure temperature of ambient air:	20 °C
③	Read the dew point in the table:	16,4 °C
④	Surface temperature must exceed the dew point by at least 3 °C immediately prior to and during application and curing, i.e. in the example:	19,4 °C

Image 7.10 Ratio between ambient temperature, relative humidity, dew point, and acceptable surface temperature.

Effect of ambient temperature on curing

Ambient temperature influences the curing time and film formation of coatings. The curing rate of chemically curing and air curing paints accelerates significantly when ambient temperature rises. The technical data sheets indicate the minimum temperatures for ambient air, the surface and the coating material during application and curing.

The physically curing paints based on reversible binders, such as acryl, chlorinated rubber, vinyl, and bitumen can also be used in below zero degree conditions.

Air curing paints, such as oil and alkyd paints, cure at a very slow rate in low temperatures. Application should be avoided when the ambient temperature is below +5°C.

Cross-linking occurs in epoxy paints and other chemically curing paints at a very slow rate when the ambient temperature is below +10°C. In a temperature of below +10°C, only special epoxy paints suitable for application at low temperatures should be used. The special epoxy paints designed for low temperatures cure even in temperatures of -5°C. Although many epoxy coatings may seem hard after the evaporation of solvents is complete, they will achieve final resistance properties only after cross-linking terminates.

The accelerated evaporation of solvents due to a high ambient temperature can generate blisters and pinholes in the coating and cause poor bonding to the substrate

The source for information in **image 7.10** is ISO 8502-4:1993, which specifies the determination of potential condensation on the surface and of acceptability of application conditions.

Film thickness and associated measurement

Film thickness

Film thickness refers to the thickness of an individual wet or dry film, and to the thickness of a paint system. Film thickness is presented as micrometres (µm) or millimetres (mm).

The corrosivity category, the paint type, and the desired durability time specify the film thickness of a paint system. In the painting standards, paint system specifications and technical data sheets, the film thickness is indicated as the *nominal dry film thickness (NDFT)*. EN ISO 12944-5 (section 5.4) specifies the nominal dry film thickness. Wet film thickness is determined using a wet film thickness gauge. The thickness of dry film can be measured applying either a destructive or non-destructive method.
As the standards specify the inclusion of the surface profile in the dry film measurement in different ways, it is important to agree upon the applicable standard and specification. The film measurement methods are described in ISO 2808.

Measurement of wet film thickness

Film thickness can be monitored during application using a wet film measurement gauge. Wet film measurement is carried out using a wet film comb **(image 7.11)** or wheel immediately after application or before solvent evaporation. The measurement method is described in ISO 2808. The wet film thickness value (K_m) can be read directly from the comb/wheel.

Dry film thickness (K_k) can be calculated using the formula:

$$(1) \quad K_k = K_m \frac{V}{100} \quad (\mu m)$$

where V is the percentage of solids by volume. The percentage of solids content in the paint (V) is given in the technical data sheet, and the wet film thickness K_m is provided by the measurement.

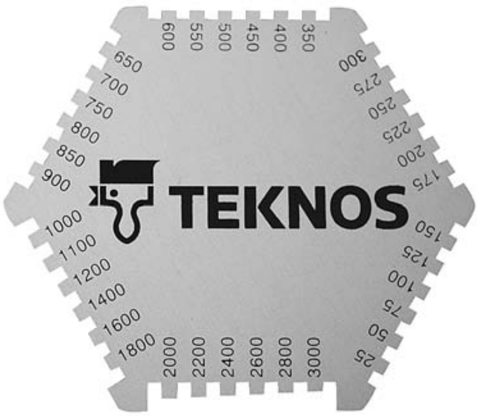


Image 7.11 Comb-type wet film thickness metering device. The measurement is read from the furthermost tooth coming into contact with the paint when the comb is pressed through the paint film so that the first and last tooth come into contact with the substrate.

Measurement of dry film thickness

Once the film is cured, dry film thickness will be measured. The dry film measurement method can be either destructive or non-destructive of the film.

Non-destructive methods

Magnetic film thickness gauges are used to determine the dry film thickness on metal substrates. If the metal substrate is ferrous, the magnetic gauges use one of two principles of operation: magnetic/electromagnetic induction or magnetic pull-off using a permanent magnet as the source of the magnetic field **(images 7.12a** and **7.12b)**.

Eddy current coating thickness gauges are used for non-ferrous metal substrates. The substrate characteristics and the distance of the probe from the substrate, i.e. the coating thickness, affects the magnitude of the eddy currents.

The metering device is to be used in accordance with the manufacturer's instructions. The parameters having an effect on the measurement results are described in ISO 2008. The paint film must be sufficiently cured before measurement.

Before application, the gauge is calibrated using appropriate calibration standards and in accordance with the manufacturer's instructions. The calibration standards in common use are for plastic membranes or coated panels.

Gauge calibration is carried out, as agreed, using either a smooth (e.g. cold-rolled) or rough (coarsened) steel surface. Calibration must always be validated on-site before measurement and at regular intervals during usage.

Any effect on the results due to the person carrying out measurement can be thwarted by using a fixed-pressure probe. The probe is always placed vertically against the metal surface. The gauge based on magnetic pull is used in a horizontal or upside-down position. The gauge must be separately adjusted for each operational position.

Film thickness is measured on a surface typical for the structure, i.e. a surface that is substantial enough in terms of visual appearance or operation of the structure. Depending on the total surface area of the typical surface, the number of test areas is determined in a way that will provide correct information on the overall film thickness distribution. The test area is the area of the typical surface, on which a number of separate measurements are made. The location of the test area where an individual measurement is made is called the measurement point. Because of the inaccuracy and insensibility of the measurement methods and inadequate repeatability and reproducibility of the measurements, multiple readings should be obtained for each measurement point. The arithmetical average (mean) of the readings for the measurement point is to be considered to establish the film thickness for the measurement point. The lowest film thickness measured for the typical surface is also the lowest localised film thickness.

Image 7.12a The dry film metering gauge is used for the tests under ISO 1461, ISO 19840, ISO 2063, ISO 2360, ISO 2808-7C, ISO 2808-7D and ISO 2808-12.

Image 7.12b The magnetic pull-off film thickness gauge is used on explosive sites, such as oil-drilling platforms, refineries and other similar facilities. The gauge is also known as the banana and is suitable for tests in accordance with ISO 2178 and ISO 2808-7A .

The standards, e.g. ISO 19840, specify the number of measurements by test area and the tolerance for deviation from the NDFT. For example: For each 100 m² of the total area of the typical surface, one test area of 10 m² is to be determined and 20 measurement points specified for such test area. Three readings are to be obtained for each measurement point. Film thickness may be no less than the NDFT in all but one of the measurement points of the test area. Such downward deviation may not exceed 20 per cent of the NDFT.

The measurement record must indicate the standard(s) applied, agreed or other deviation from the standard, test measurements (arithmetical mean, maximum and minimum values), the measurement method and the metering device.

Destructive measurement methods
The dry film thickness can also be measured using a destructive method where desired. ISO 2808 describes the measurement of dry film thickness using a micrometre (method 3A), rollback dial (method 3B), and cutting tool making a V-groove incision (method 5B). All the methods cut through the film into the substrate.

On-site measurements are made using a cutting device, which comprises an illuminated scaled magnifier and cutting tip. The tool's hardened steel tip makes a V-groove though the coating. The scale of the magnifier can be used to determine the film thickness of the coating, because the tip angle of the blade is a known constant. The number of the coats can also be studied **(images 7.13a, 7.13b**, and **7.13c)**.

Image 7.13a The cutting tool making a V-groove incision is used for tests in accordance with ISO 2808-6B.

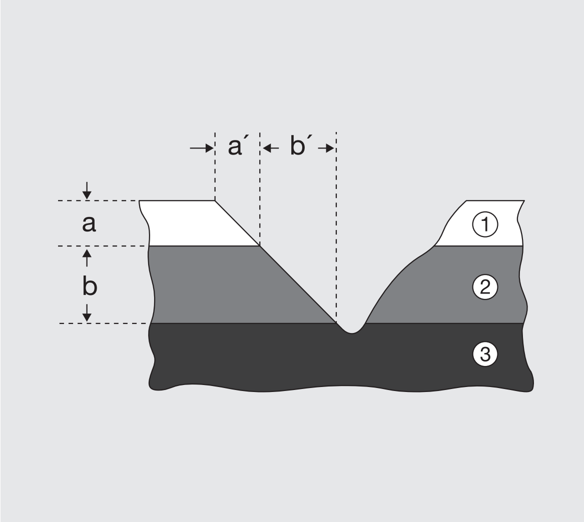


Image 7.13b Film thickness is determined by cutting a V-groove through the coating into the substrate and, then, measuring the width a´ (or b´), which is in relation to film thickness a (or b).

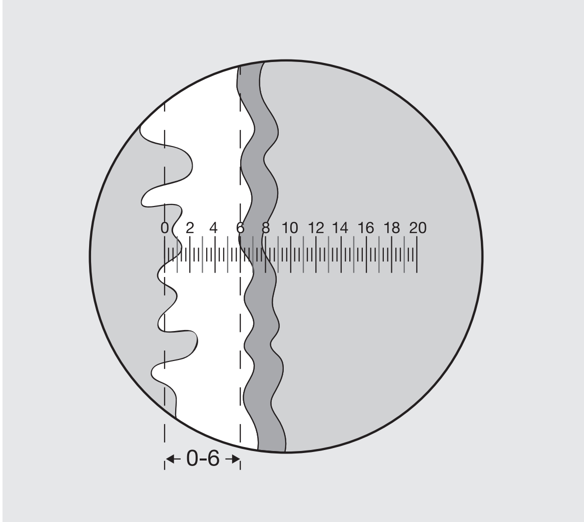


Image 7.13c Scaled magnifier.

Calculation of paint consumption

The theoretical paint consumption Mt (l) is calculated using the formula:

$$(2)\quad M_t = \frac{K_k * A}{10 * V} \quad (l)$$

where M_t = theoretical paint consumption (l)
K_k = dry film thickness (μm)
A = surface being coated (m^2)
V = percentage of solids by volume (%)

The quantity of paint material required for painting is in all cases greater than the theoretical consumption indicated in the technical data sheet. In real-life conditions, paint material is consumed for filling profile valleys, non-uniform coating and overspray. Small quantities of paint material remain in the containers, pots, tools, and implements.

The effective material consumption M_k can be calculated using the formula:

$$3)\quad M_k = \frac{10 * K_k * A}{V\,(100 - H)} \quad (l)$$

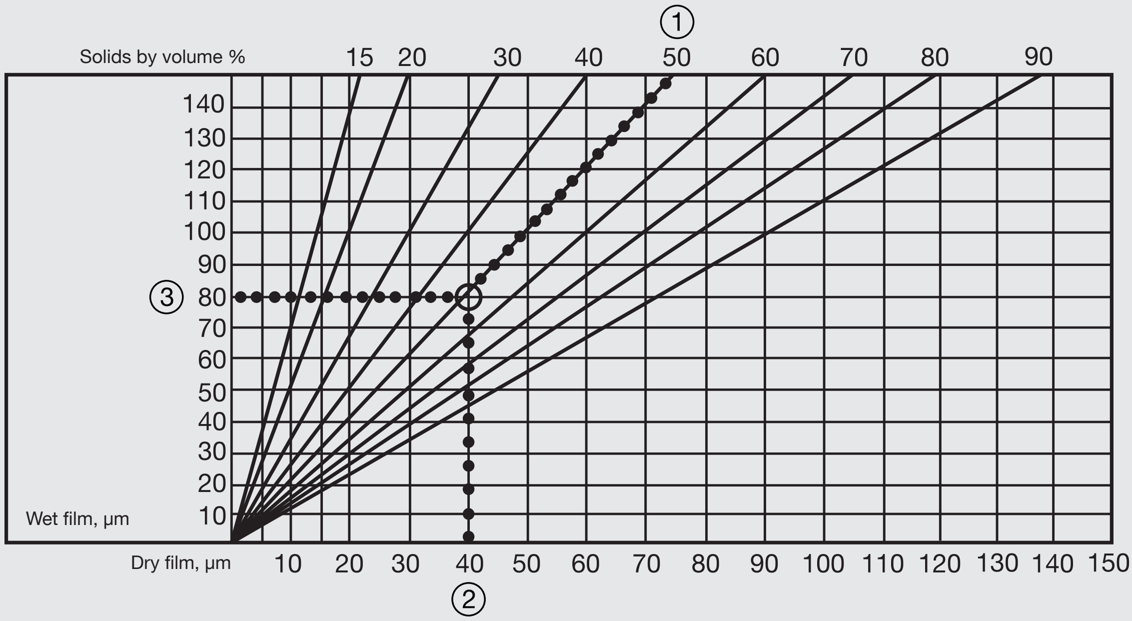
H = waste percentage of material (%)

In actual painting work, the waste percentage is approximately 40 – 70 per cent. In other words, effective material consumption Mk is 1.7 – 3 times theoretical consumption.

Tables for estimation of paint consumption

All values in the tables are for reference only, and may vary according to actual circumstances.

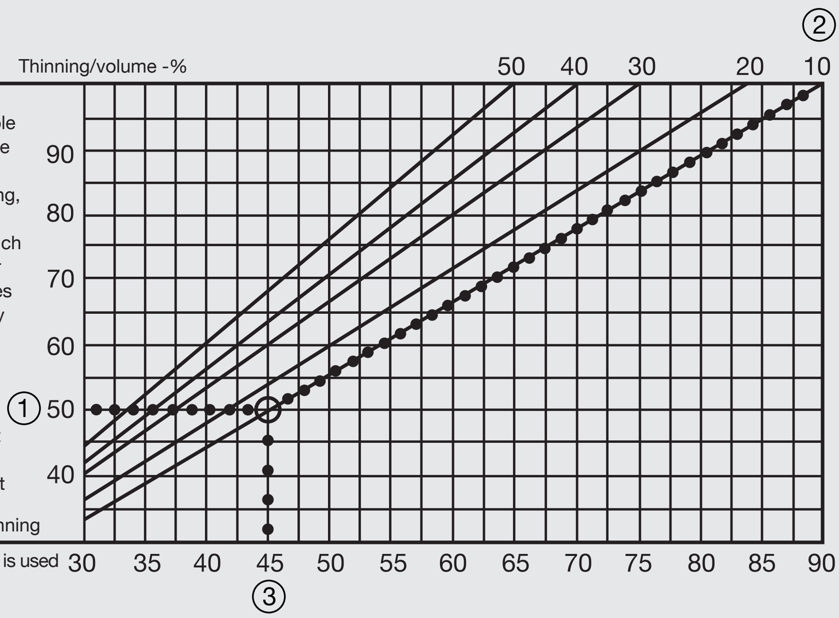
Table 7.1 Determination of coating thickness based on the percentage of solids by volume.



Traversal lines represent examples of the solids by volume. Start from the top of the relevant solids by volume. Follow the line downward until it meets the vertical line representing the required dry film thickness (at the bottom). Then, from the point where the traversal and vertical lines meet, follow the horizontal line to the left-hand side and read the value that corresponds to the required dry film thickness.

Example:
1. Solids by volume 50 per cent
2. Dry film thickness 40 µm
3. Yields 80 µm wet film thickness.

Table 7.2 Relative change of solids by volume when thinner is used.



Traversal lines represent example thinning percentages. Follow the horizontal line, which indicates solids by volume prior to thinning, starting from the left-hand side edge until the traversal line, which indicates the quantity of thinner added. The vertical line indicates the new percentage of solids by volume.

Example:
1. Solids by volume 50 per cent
2. Thinner by volume 10 per cent
3. Yields the new percentage of solids by volume = 45 per cent

8. Quality control of corrosion protection painting

Painting is a process where quality cannot be fully assessed merely based on the acceptance inspection of the outcome, i.e. the coating finish. Therefore, careful planning of corrosion protection work as well as supervision and control during execution over all parameters that may have an effect on the final coating is imperative. Purchasers increasingly request reference and certification information in writing, or other similar permanent form, i.e. quality control and assurance information on the quality of the painting and on all relevant parameters.

In corrosion work, a number of different parameters have an effect on the painting quality. The process steps are divided into planning, execution and quality assurance, i.e. monitoring and inspection activities at various levels. Qualifications and commitment of personnel is emphasised in all process phases.

The parameters having an effect on the required quality level of the corrosion protection work are presented below in tabular form. To facilitate assessment of the quality of the finished painting, the table also illustrates, in the proceeding order of the process, the significance of the various steps and associated parameters for the qualitative outcome.

An *inspection and assessment* plan is to be drafted, taking all the aforementioned considerations in mind. When writing the inspection and assessment specification, or the project specification, it should be noted that failure in the performance any of said parameters (the table), during any process step, may result in failure or qualitative deterioration of the entire outcome of the corrosion protection work (see standard 12944-8).

Successful corrosion protection work requires that
- personnel are qualified and target-oriented
- all process steps are executed in compliance with the paint work specification
- the required inspections are carried out and documentation issued during all process steps

Parameters having an effect on successful paint work

Paint system implemented
Quality assurance tests, e.g. film thickness, magnetic pull-off test, and other agreed tests and measurements
Performance of the coating, visual inspection
Patching
Application conditions
Application
Surface preparation
Quality degree of metal working
Appropriate design and structure
Qualified and target-oriented personnel
Planned paint system

The purpose of *quality assurance* of corrosion protection work is to provide the painting under the agreement (EN ISO 8402).

Quality control comprises the inspection and recording of all operations, materials, implements, methods and procedures, conditions relating to corrosion protection work, and the associated corrective action and elimination of deviations.

The quality control of corrosion protection work is made easier if the supplier or contractor has a quality system in place (see ISO 9001 and ISO 9002).

The quality assurance of corrosion protection work and the main parameters to be taken into account therein are described in part 7 of ISO 12944.

Inspection and assessment specifications

The supplier or contractor applying a quality system will issue an inspection and assessment specification for the painting project in writing, which is in compliance with the quality system and quality control applied by the company. The supplier or contractor also issues a report on the required qualifications of the applicators (see ISO 12944-7).

The inspection and assessment specification specifies:
- the target-quality parameters, such as the designed colour, visually satisfactory painting and agreed film thickness
- detailed allocation of duties and authorities during all project phases
- the specific methods, procedures and instructions to be applied
- the quality inspection procedures for the process steps, and the procedures to be applied to corrective action and elimination of deviations.
- the procedure for amending and endorsing the specification during the progress of the project.

If the supplier or contractor does not apply a quality system, the purchaser and the supplier or contractor can agree upon a quality plan in writing, which by form and content corresponds to the aforementioned inspection and assessment specification.

The parties can also stipulate that the quality inspections of the paint work are carried out by a third party, e.g. a certified quality inspector. The third party acts as agent for the parties. When such a third party is contracted, it may be necessary to execute a separate agreement, which specifies the targets, scope, time, place, measurement methods, and the number and time of inspection visits associated with the quality control. The agreement must also specify how the inspector records the anomalies discovered, and when, how, and to whom the inspector reports the defects and deficiencies and required corrective action and elimination of deviations.

Targets of quality assurance

The main targets and items associated with quality assurance of corrosion protection work are described in the following:

Personnel

The applicators of corrosion protection paint must be qualified for the work. Work requiring particular care can be performed only by personnel who have appropriate professional training or are certified by a recognised organisation, unless otherwise agreed by the parties

Where necessary, a meeting is convened prior to commencing paint work. The purchaser, the supplier, and the paint manufacturer must be represented in the meeting. The parties discuss in the meeting, among other subjects:
- the paint system specification, the paint work specification, and the standards applicable to the paint work
- the supplier must demonstrate its capability of delivering, during all process steps, the specified quality level
- the diary maintained during the paint work and the party responsible
- any ambiguities or conflicts of the specifications or standards, e.g. how to paint a difficult spot, which cannot be painted on-site in compliance with the paint system specification

Steel structure
If the parties agree that the structure is manufactured according to the structural requirements of part 3 of ISO 12944, this will be verified where necessary.

The rust grade of an uncoated steel surface is determined based on ISO 8501. Unless otherwise agreed to the contrary, only surfaces of rust grades A, B, or C are acceptable.

The quality of metal working is inspected pursuant to standards, while validating that the welds and edges are finished to the agreed quality degree.

The applicators must have unobstructed access to the work object (ISO 12944-3) and surface illumination must comply with the paint work specification.

The inspection results are recorded.

Surface preparations
The surface must be cleaned to the required surface preparation grade under the paint system specification.

Contaminants hampering rust removal, such as salts, oils, and greases must be washed from the surface before wire brushing or blasting.
Where necessary, the parties agree on the type, size, and purity of blasting abrasives (ISO 11124 - ISO 11127).

The cleaning equipment must comply with the agreement and be in good operational condition, the output of the air compressor must be sufficient and the pneumatic air free of contaminants.

Ambient temperature, the temperature of the work object and relative humidity must be in compliance with the agreement during cleaning. The readings obtained are recorded.

The surface preparation grade is assessed using ISO 8501-1, and the results are recorded.
Where necessary, the surface profile is determined based on ISO 8503.

After blast cleaning, the surfaces of rust grades C and D may contain water-soluble ferrous salts, chlorides, and dust not visible to naked eye. ISO 8502 describes the methods for the determination of such contaminants. A number of salt measurement devices are depicted in **image 8.1**.

The surface preparation grades of coated structures are specified in ISO 8501-1 and ISO 8501-2. In blast cleaning, disturbing an intact coat is to be avoided. The borderline between the cleaned surface and the intact coating must be feathered.

The surface preparation work must be scheduled so that the surface can be coated as soon as possible after preparation, before it becomes soiled. Work lighting must be sufficient.

Conditions
Surface preparation and painting must be performed under the conditions specified in the paint working specification or the applicable standards. The conditions during surface preparation, application and curing must not deviate from the ambient air and surface temperature range indicated by the paint supplier. Where necessary, the conditions are reorganised to comply with the requirements, or the work is suspended until requirements are met.

The following parameters of the environment must be measured, monitored and recorded to the agreed extent:
- ambient temperature
- substrate temperature
- relative humidity in ambient air
- dew point
- wind conditions
- temperature of paint material
- lighting conditions
- any operations in the vicinity disturbing application

Application methods, tools and implements

The application methods and procedures as well the tools and implements, in good operating condition, specified in the paint work specification or applicable standards must be adhered to in the paint work.

The selected application method must be appropriate for the structure and may not cause harm or hazard to the environment. The application methods and the execution of paint work are described in ISO 12944-7.

Substances used in coating

Only paints and thinners specified in the paint system specification may be used in painting, and such substances must be available in sufficient quantities.

The paints and thinners must be warehoused appropriately. The containers and other packaging must be original and in good condition. The labels must be legible. In the warehousing of paints, the requirements and constraints associated with safety and usage conditions provided in the material safety data sheets and technical data sheets must be taken into account, as well as the limitations to shelf life. Paint products should ideally be warehoused in constant, cool indoor conditions. Paints warehoused in colder conditions should be brought to the site conditions sufficiently in advance to ensure the appropriate temperature of the materials.

The brand names and production batch numbers of the paints, curing agents, and thinners are recorded in the protocol.

Application

Application must be performed in compliance with the requirements of the paint work specification and the applicable ISO 12944-7. The applicators must be familiar with the usage instructions and the material safety data sheets of the paints used.

The surface being painted must be prepared to the required surface preparation grade, and the surface may not be exposed to contaminants or oxidation before painting.

Any paint skinning must be removed, and the paint must be blended until uniform. The components of two-pack paints must be mixed in correct proportion, and the permitted pot life of the mixture may not be exceeded.

Where a thinner is used, the quality and added quantity of the thinner must comply with the paint system specification and the technical data sheet.

During application, it must be ensured that the required film thickness is achieved, that no sagging is produced or unpainted areas remain. The volume of applied paint is verified using a wet film measurement gauge.

Sharp edges, corners and welds must be reinforced by extra overcoating, where required.

Before application of a subsequent paint, the previous coat must be dry. If the time between applications exceeds the maximum overcoating interval allowed for the paint, the surface must be prepared using solvent washing or be sanded to ensure adhesion.

Surfaces remaining hidden after assembly are painted before assembly. Surfaces to be placed against one another must be dry to handle before installation.

A structure may not be handled after painting until the paint is dry to handle.

Patch painting refers both to corrective action during the application process and to patching damages caused to pre-painted surfaces during transport. Patch painting must take into account the paint system specification and the technical data sheets.

Finished coating

After curing, the coating is checked for unpainted areas or other defects deteriorating the performance of the coating, such as sagging, craters, pinholes, cracking, orange peel effect, or unbonded spray dust. Both the gloss and colour of the finish must be in compliance with the agreement.

The agreements require in many cases thickness measurement of the finished coating. The film thickness requirements are presented as the required *nominal dry film thickness*. The definition of nominal film thickness varies to some extent in the different standards. Measurement of film thickness is described in Chapter 7 (pp 40-42).
Carrying out a *porosity inspection* is recommended for insulating coatings exposed to immersion or burial corrosivity stress. The inspection is used to discover any pores, pinholes or other weak spots in the coating. A porosity inspection requires a minimum coating thickness of 300 µm **(image 8.2)**.

The film thickness can also be measured using a destructive method. The film thickness measurements are described in ISO 2802. Bonding of the coating is tested using the pull-off test under ISO 4624 (image 8.3), or validated using the cross-cut test of ISO 2409 **(image 8.4)**.

Inspection tools and implements

The inspector must have access to the valid paint work specification, all required designs and drawings, technical data sheets, material safety data sheets, colour charts, applicable standards and the required tools and implements, such as
- film thickness measurement gauge
- thermometers and humidity meters **(image 8.5)**.

Flashlights, flexible-arm inspection mirrors, knives and magnifying glasses are examples of the other tools required in inspections.

Reference areas

Where necessary, the supplier prepares a reference area in accordance with the paint system specification, and the purchaser accepts the coating of the reference area, the paints and coating equipment used, the applicators and application methods.

The reference area is used to establish the minimum acceptable quality of the paint work, to verify the information provided by the manufacturer or supplier (contractor), and to enable validation of the performance of the coating at any time after application (ISO 12944-7).

All reference areas must be recorded meticulously, and can also be marked permanently on the structure (ISO 12944-8).

The size and number of the reference area must be in reasonable proportion, both in practical and economical terms, to the total surface area of the structure (ISO 12944-8).

Documentation of paint work and conditions

Two types of documents are used in corrosion protection work. Documents of the first type exist prior to commencement of the work, while those of the second type are issued when the work is in progress.

Documents existing prior to commencement of paint work
For the purposes of quality assurance and quality control of the paint work, a number of different documents are issued and obtained, such as the specifications, drawings, inspection guidelines, work instructions, quality assurance procedures, technical data sheets and material safety data sheets. All the documents must be legible, dated, in good condition and maintained in an orderly fashion. Documents management is used to ensure that up-to-date versions of the relevant documents are available on all sites, where process steps substantial to coating quality are being performed.

Documents issued during paint work
The person responsible for the paint work maintains a *site log*. The daily conditions, events and measurements are entered in the log, such as
- weather conditions of the day, both on the application and surface preparation sites
- tool and equipment checks
- rust grade and surface preparation grade of the substrate
- the brand names and production batch numbers of the paints, curing agents and thinners, as well as the pot lives and application times of two-pack paints
- readings of film thickness measurements

The actions taken due to defects discovered and notices submitted, as well as the results of the re-inspection, are entered in the site log. The name of the person responsible for the paint work and the inspection time are recorded.

Inspection records
An inspection record is issued for all inspections, such as the final inspection, the acceptance inspection and other similar inspections.

Image 8.1 Salt content measurement devices for the tests under ISO 8502-6 and ISO 8502-9.

Image 8.2 Porosity probe for the tests under ISO 2746.

Image 8.3 Adhesion probe for measurement of film adhesion using the pull-off test under ISO 4624 and ISO 16276-1.

Image 8.4 Cross-cutting tool for determination of film adhesion under ISO 2409

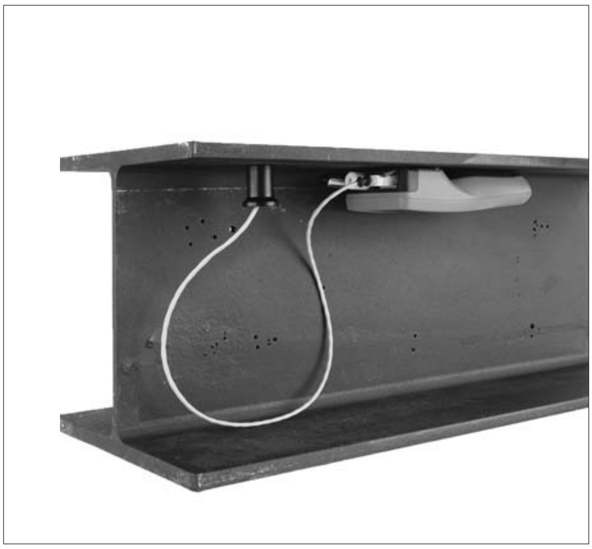


Image 8.5 Probe for determination of relative humidity, ambient temperature and dew point under ISO 8502-4.

9. Maintenance painting

Maintenance painting refers hereinafter to patch painting and overcoating of metal structures.

Evaluation of coating degradation

The coating has a limited service life. The coating degrades through exposure to weather, corrosive gases and similar atmospheric parameters. In the course of time coated metal structures may chalk, crack, blister, rust, and flake.

ISO 4628 outlines the general principles for designation of the quantity and size of the defects in coatings. The degradation classification has six categories, where category 0 signifies a defect-free coating and category 5 signifies a condition where no further classification is required. ISO 4628 also provides pictorial standards for evaluation of the blister and rust grades of coatings.

ISO 4628-3 specifies the coating rust grade Ri 0 – Ri 5. The rust grades and respective rust surface areas are presented in **table 9.1**. In rust grades Ri 1 – Ri 3, maintenance requires patch painting, while in rust grades Ri 4 and Ri 5 the corrosion protection capacity of the coating has been depleted, and the structure requires total repainting.

Table 9.1 Coating rust grades and respective rust surface areas.

Rust grade	Rusted surface area
Ri 0	0 %
Ri 1	0,05 %
Ri 2	0,5 %
Ri 3	1,0 %
Ri 4	8,0 %
Ri 5	40-50 %

Time for maintenance work

The more corrosive the environment, the more often the degradation of the coating must be evaluated. If the structure is exposed to special corrosion stresses or an immersion/burial environment, even a minor defect in the coating causes pitting corrosion, which can degrade the structure into an inoperative status in a very short time. Therefore, maintenance work on these structures must commence immediately upon discovery of defects, i.e. when rust grade is Ri 1 is reached and, at the latest, when corrosion of rust grade Ri 3 is discovered.

In corrosivity categories C2 – C5, patch painting must commence once the rust grade of the surface reaches rust grades Ri 2 - Ri 3.

The parties must jointly determine the degradation category of the coating or paint system before the first major maintenance work and carry out the evaluation pursuant to ISO 4628-1 – ISO 4628-5.

The durability of the coating is by definition the service life at the end of which the corrosion protection capacity of the coating has been depleted and must be replaced by a new protective paint system.

For the determination of rust grade, the pixel charts of ISO 4628-3 can be utilised, where the size and number of the pixels depicting the defects vary, while the degradation percentage and the rust grade Ri are constants **(Images 9.1** and **9.2)**.

The durability range is not a ”guarantee range”. Durability is a technical consideration that can help the owner set up a maintenance programme. A guarantee period is a major issue and is subject to dedicated clauses in the contract. The guarantee time is usually shorter than the durability range. There are no rules that link these two periods of time.

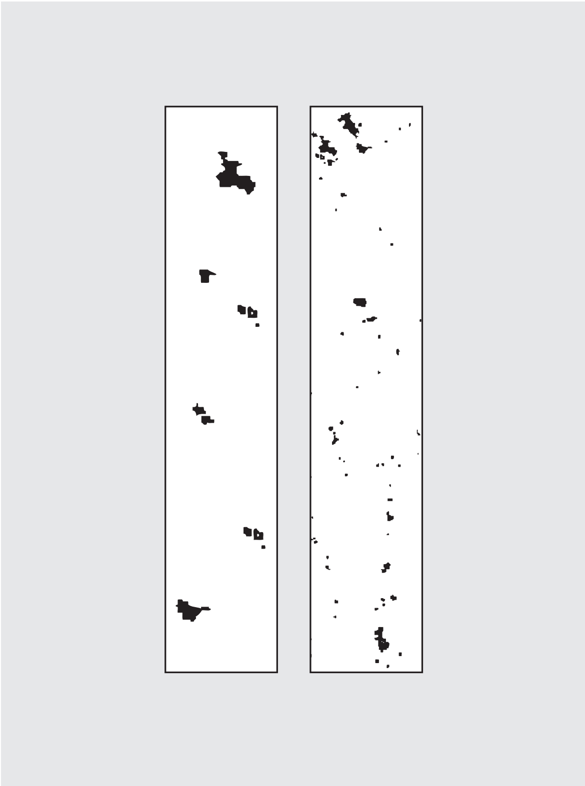


Image 9.1 Rust grade Ri 3.

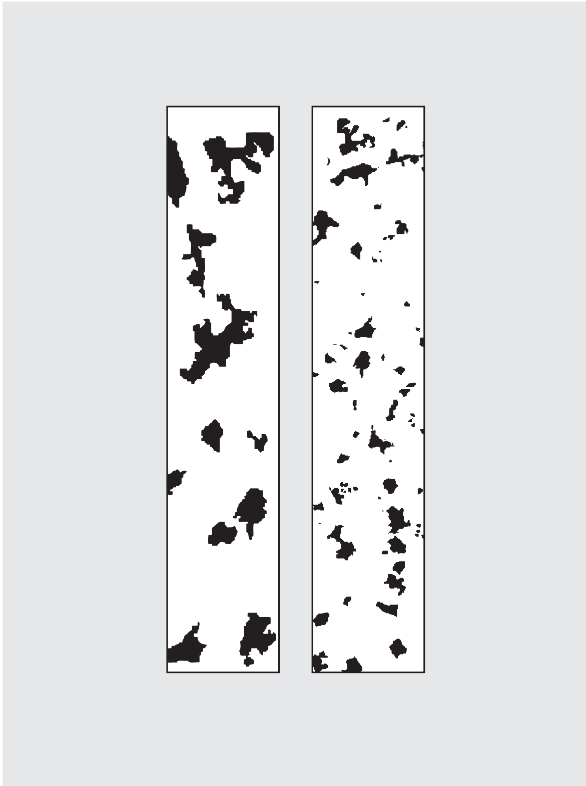


Image 9.2 Rust grade Ri 4.

Determination of the maintenance paint

The same type of paint is used in maintenance work as in the original coating, unless the performance of the original paint system is poor, or application conditions or other similar reasons justify a change in the generic paint type.

If the paint type of the original coating is not known, this can be determined on-site by exposing the coating to epoxy thinner for approximately ten minutes.
- The epoxy thinner has no effect on epoxy and polyurethane paints. Epoxy and polyurethane paints can be used for maintenance painting.
- Alkyd paints “lift” or become tacky when exposed to epoxy thinner. Alkyd paint is used for maintenance painting.
- Chlorinated rubber and vinyl paints dissolve in the epoxy thinner solution. In many cases, acrylic paint can be used for maintenance painting.
- Paints containing dispersion binder agents become tacky when exposed to epoxy thinner. In many cases, dispersion-type paint can be used for overcoating.

In ambiguous cases and where the structure is large, the old coating can also be studied by analytical means. Where necessary, a test painting is carried out, which can be studied by applying a number of different methods.

If the application conditions for maintenance painting cannot be organised in compliance with the requirements of the paint type, the option of changing the generic paint type should be discussed with the paint supplier.

If the original coating was not capable to resist the atmospheric environment, the suitability of the paint system must be checked and, where necessary, a more suitable paint system selected for the specific environment.

Execution of maintenance work

Maintenance work is carried out by either patch painting or repainting.

When the rust grade of the surface is Ri 2 – Ri 3, patch painting is used. The surface is cleaned of grease, oil, and soiling. Loose paint and rust is removed, either by scraping, wire brushing or blasting, from the areas being coated to prepare the surface to the required surface preparation grade for the paint system used. The borderline between the cleaned surface and the intact coating must be feathered.

ISO 8501-2 provides example images on surface preparation prior to maintenance work.

When blast cleaning is used in connection with patch painting, disturbing the intact coating is to be avoided. The angle, distance and abrasive material applied must be appropriate.

The patching areas are coated to the film thickness specified for the paint system used.

Where uniform visual appearance is preferred, the entire surface of the structure can be overcoated using the paints of the same system. In such a case, the intact original coating surface must be treated for better adhesion of the new coating. High-gloss alkyd and epoxy surfaces are washed using a suitable detergent and then sanded.

If the rust grade of the substrate is Ri 4, the structure must be entirely repainted using a protective paint system. The entire surface is first blast-cleaned from old coating and rust and then the surface is repainted using the original protective paint system.

10. Occupational safety guidelines applicable to paint work

Many paint materials contain substances harmful to health and, therefore, paints must be handled with care and all applicable precautions and safeguards must be taken. When handling flammable paints, particular attention must be paid to earthing to prevent fire and explosion hazards due to static electricity.

In the planning and implementation of appropriate working methods and precautions, local circumstances, working methods and paint types used, and the requirements of the objects being coated, must be taken into consideration. Site-specific occupational safety guidelines can be drafted, based of the general occupational safety principles described below.

The material safety data sheets must always be studied before commencing paint work. The technical data sheets provide relevant information on the following matters, for example:
- correct safety equipment
- requirements and constraints set for the work environment
- information on any hazards the product may induce
- action guidelines for accident or injury

Site arrangements
Organisation of site arrangements can be used to promote general occupational safety:

- *Cordoning-off the workstation* can be used to allow only authorised access.

- *Cleaning aptitude of the workplace* can be facilitated by using disposable paper or similar covers. Tight-locking and otherwise appropriate waste containers make cleaning work easier.

- *Warehousing of materials;* materials should be warehoused only in small quantities in the vicinity of the workstation. *In the warehousing of combustible liquids the constraints and regulations by the public bodies must be adhered to (for more detailed information; ATEX Directive 94/9/EC). Open containers and pots must not be warehoused on the premises where work is performed.*

- *Ventilation of the workplace* is one of the most central parameters having an effect on occupational safety in industrial coating facilities and other fixed workstations. The overall general ventilation can be supplemented using appropriately designed local extraction equipment or flexible extraction arms, either fixed or movable.

- *For washing purposes*, detergent agents, skin cream and eye cleaning kits must be available in addition to the regular washing accessories.

Application
Paint dosage, thinning, and stirring are carried out near the painting point. Splashes are to be avoided. Where necessary, a splash guard can be used when stirring. In connection with industrial coating lines, automatic or encased equipment can be used. In the dosage operation of combustible liquids, the formation of static electricity is to be avoided by earthing.

Application by brush, roller or putty knife produces less exposure than spraying. Appropriate safety clothing and gloves must be used to avoid the exposure of skin to splashes and residues. Where necessary, suitable safety glasses and face protection masks must be used. In roller application, appropriate ventilation keeps the VOC content in fumes and vapours at a sufficiently low level. If the VOC content in fumes and vapours becomes too elevated, respirators with fume filtration must be worn when performing paint work.

In spraying, the strength of exposure can vary extensively. In such a case, using a respiratory mask is necessary. Respirators must also be used when spraying water-borne paints. In such a case, the respirator must comprise at least dust filtration, preferably both dust and fume filtration. When spraying solvent-borne paints, the respirator must comprise both dust and fume filtration. If spraying is performed in premises where mechanical ventilation is insufficient or missing, supplied-air respirators can be used, either in the form of a mask or hood, the latter also providing protection for the skin areas on the face and neck.

In spraying, the skin is easily exposed. Protective clothing and safety gloves can be used to reduce exposure.

Safety gloves must be thin cotton gloves. Skin cleaning is easier when suitable skin creams are used.

Fire and explosion hazards are often present in spray painting operation. The hazards can be eliminated by using appropriate earthing both during application and when washing the sprayer.

Sanding
All sanding dust, especially of fresh paint, can irritate the respiratory tract, skin and eyes. Well-designed flexible extraction arms or extraction connected directly to the sander significantly reduce the generation of dust. Wet sanding also substantially reduces the quantity of dust. Where necessary, respirators featuring dust filtration must be used as well as suitable protective clothing.

Blast cleaning
In blast cleaning work, a protective helmet-cape configuration featuring a window and supplied-air function must be used.

Exposed areas of skin must be protected using heavy protective clothing, special safety gloves and safety boots.

Dust from abrasive material should be prevented from entering underneath the clothing, e.g. by taping or tightening the sleeve and trouser leg openings.

Personal protective equipment
In painting work, the areas of the body to be protected are usually the eyes, respiratory tract and skin:

- Safety glasses: If no air-purifying respirator providing protection for the eyes is used in painting work, using safety glasses is recommended.

- Safety gloves: When handling paints, thinners or resins, chemical-resistant gloves must be used, made either of nitrile or butyl rubber. Underneath the safety gloves, the use of thin cotton gloves is recommended to prevent skin irritation due to perspiration. In blast cleaning, special gloves designed for the purpose must be used.

- Protective clothing: In most cases, regular protective overalls can be used and in premises where fire or explosion hazard is present, preferably those made of cotton. Where necessary, impermeable aprons, safety helmets and knee or wrist safeguards can be applied. Where necessary, a disposable protective suit can be used on top of the working overalls.

- Protective creams: Use of protective cream is recommended where skin may be exposed. Protective creams make skin cleaning easier and prevent skin from becoming too dry.

- Respirators: To be used if harmful dust and fume contents cannot be eliminated sufficiently by ventilation at the workstation.
  - in sanding work, air-purifying respirator with dust filtration, type P2 or P3
  - in washing work and brush, roller and putty knife application, air-purifying respirator with fume filtration, type A
  - in spraying work, air-purifying respirator with combined filtration, e.g. type A2P3
  - in spraying, pneumatic or gravitational supplied-air respirator mask or hood; in blast cleaning, a blast cleaning helmet

Detailed information on the safety and protection equipment required when handling the products is available in the relevant material safety data sheet.

Personal hygiene
Good personal hygiene forms an integral part of occupational safety. When transferring from the workstation to another space, personal cleaning and a change of clothes is recommended. Use of protective creams makes skin cleaning easier. At the end of the working day, clean hands should be lubricated with skin cream so as to prevent skin from becoming too dry.

Further information
For further information on safe handling of chemicals;
ECHA, European Chemicals Agency (www.echa.europa.eu)

11. List of standards

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

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

ISO 12944-3
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 3: Design considerations

ISO 12944-4
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 4: Types of surface and surface preparation

ISO 12944-5
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 5: Protective paint systems

ISO 12944-6
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 6: Laboratory performance test methods

ISO 12944-7
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 7: Execution and supervision of paint work

ISO 12944-8
Paints and varnishes. Corrosion protection of steel structures by protective paint systems
Part 8: Development of specifications for new work and maintenance

Standards for substrate preparation
ISO 8501-1
Preparation of steel substrates before application of paints and related products
Visual assessment of surface cleanliness
Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings

ISO 8501-2
Preparation of steel substrates before application of paints and related products
Visual assessment of surface cleanliness
Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings

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 8501-4
Preparation of steel substrates before application of paints and related products.
Visual assessment of surface cleanliness.
Part 4: Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting

ISO 8504-1
Preparation of steel substrates before application of paints and related products
Surface preparation methods
Part 1: General principles

ISO 8504-2
Preparation of steel substrates before application of paints and related products
Surface preparation methods
Part 2: Abrasive blast-cleaning

ISO 8504-3
Preparation of steel substrates before application of paints and related products
Surface preparation methods
Part 3: Hand- and power-tool cleaning

Standards for the determination of substrate characteristics (roughness, and presence of dust, salts or other contamnants)
ISO 8502-3
Preparation of steel substrates before application of paints and related products
Tests for the assessment of surface cleanliness
Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)

ISO 8502-6
Preparation of steel substrates before application of paints and related products
Tests for the assessment of surface cleanliness
Part 6: Extraction of soluble contaminants for analysis. The Bresle method

ISO 8502-9
Preparation of steel substrates before application of paints and related products
Tests for the assessment of surface cleanliness
Part 9: Field method for the conductometric determination of water-soluble salts

ISO 8503-2
Preparation of steel substrates before application of paints and related products
Surface roughness characteristics of blast-cleaned steel substrates
Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel. Comparator procedure

Standards for the determination of film thickness, adhesion and other performance properties
ISO 19840
Paints and varnishes. Corrosion protection of steel structures by protective paint systems Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces

ISO 2808
Paints and varnishes. Determination of film thickness

ISO 2409
Paints and varnishes. Cross-cut test

ISO 4624
Paints and varnishes. Pull-off test for adhesion

ISO 2813
Paints and varnishes. Determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees and 85 degrees

Standards for the determination and evaluation of the degradation of coatings
ISO 4628-1
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 1: General introduction and designation system

ISO 4628-2
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 2: Assessment of degree of blistering

ISO 4628-3
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 3: Assessment of degree of rusting

ISO 4628-4
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 4: Assessment of degree of cracking

ISO 4628-5
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 5: Assessment of degree of flaking

ISO 4628-6
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 6: Assessment of degree of chalking by tape method

ISO 4628-7
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 7: Assessment of degree of chalking by velvet method

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

ISO 4628-10
Paints and varnishes. Evaluation of degradation of coatings
Designation of quantity and size of defects, and of intensity of uniform changes in appearance
Part 10: Assessment of degree of filiform corrosion

Standards in use in Sweden
BSK-07 Boverkets handbook om stålkonstruktioner

In Sweden, the process industry applies the standards adopted by Skogsindustriella Standardiseringsgruppen (SSG).
SSG 1000E-8
Design and procurement of protective paint systems. General regulations

SSG 1001E
Instructions for the design and procurement of protective paint systems

SSG 1005E
Systems for initial painting of metallic materials

SSG 1006
Färger för korrosionskydd av metalliska material.

SSG 1007E-6
Colours of finishing paint on metallic materials

SSG 1008E-2
Project planning and procurement of single item hot dip galvanising

SSG 1009E-9
Systems for initial painting of hot dip zinc coated steel

SSG 1010E-8
Systems for maintenance painting (repainting) of metallic materials

SSG 1011E-6
Maintenance painting on metallic materials. Cleaning methods for surface treatment prior to painting

SSG 1012E-9
Choice of painting system

SSG 1017E-5
Recommendations for the inspection of painting

SSG 1021E-5
Paints for protection of metallic materials. Two-pack epoxy or polyurethane primer GA, GK, GS

SSG 1022E-5
Paints for protection of metallic materials. Zinc powder pigmented epoxy primer GB, GZ

SSG 1023E-5
Paints for protection of metallic materials. Acrylic or vinyl primer GE, GL

SSG 1024E-5
Paints for protection of metallic materials. Surface tolerant oil or long-oil alkyd primer GM, GP

SSG 1025E-4
Paints for protection of metallic materials. Two-pack oxirane ester primer GR

SSG 1026E-4
Paints for protection of metallic materials. Two-pack epoxy or polyurethane top paint TA, TB, TD

SSG 1027E-4
Paints for protection of metallic materials. Acrylic or vinyl top paint TE, TL

SSG 1028E-4
Paints for protection of metallic materials. Alkyd top paint TM, TP

SSG 1029E-4
Paints for protection of metallic materials. Two-pack oxirane ester top paint TR

SSG 1030E-4
Paints for protection of metallic materials. Solvent-free epoxy, vinyl ester or polyester top paint TF, TG

12. Painting problem – troubleshooting

The listing under the heading 'Potential cause' does not include the defects in the paint material itself.

PROBLEM	POTENTIAL CAUSE	CONSEQUENCE	SOLUTION TO PROBLEM
Liquid paint material			
Settling	Shelf life exceeded or storage temperature too high. Exposure to vibration during transport. Thinning.	Negligence in blending results in: - uneven pigment distribution - uneven gloss - striping - poor film formation and opaqueness.	Paint must be stored in a cool place. The paint must be stirred carefully before use, including at the bottom. During the painting work, the settling sensitivity must be monitored.
Skinning	Paint warehoused in a non-vacuum container for too long Storage temperature too high.	Part of paint wasted. Unsatisfactory finish, if skinning becomes mixed with paint. Clogging of sprayer filters.	Storage of ready-to-paint material in a closed, full container. If an opened container is not full, pour a minimal quantity of thinner onto the paint before closing. Paint must be stored in a cool place. The paint is sieved before application.
Application and film			
Orange peel	Inappropriate thinner, method or viscosity applied in spraying.	The film is not smooth.	After selecting a thinner suitable for spray application, apply the thinner in a quantity that provides suitable spraying viscosity and thus results in appropriate atomisation.
Porosity Pinholing	Unsuitable thinner. Air in the paint, Humidity in the sprayer supply air. Film thickness too thin or thick. Accelerated drying. Porous/pinholed substrate.	The pores in the film degrade coating performance and the coating stains more easily.	Use a suitable thinner in a suitable proportion, taking into account the application method, conditions and film thickness. On a porous substrate, apply primer with thinner using the shrouding technique.
Uneven gloss	Unsuitable thinner. Uneven substrate (filled spots). Uneven application. Porous, absorbent substrate.	The finish has stripes.	Use a suitable thinner in a suitable proportion. Filled or otherwise more porous spots must be patch painted before overcoating. Uniform application.

PROBLEM	POTENTIAL CAUSE	CONSEQUENCE	SOLUTION TO PROBLEM
Too fast drying	Thinners used are too fast. Relative humidity too low (water-borne paints).	Film formation disturbed; checkering or uneven gloss. Paint dust.	Add retarding thinner to the paint. Increase relative humidity (water-borne paints).
Too slow drying	Curing agent missing or incorrect quantity thereof. Film thickness too thick. Applied onto a fresh coating. Rain, fog, humidity or cold weather. Uneven or greasy substrate. Substrate contains plasticisers.	The film remains tacky. The film binds dirt. Poor durability.	The paint must be stored, blended and applied in accordance with the manufacturer's instructions. Allow the priming cure to dry well. Apply the paint in the correct viscosity onto a dry substrate and under the required conditions.
Flash rusting during painting	Cool or humid application conditions, film thickness too thick or insufficient inhibition in the paint used.	Immediately after application, water-borne film may cause slight spot rusting in steel, which becomes visible in the film as brown spots.	Adhere to the instructions on application conditions and film thickness. Apply the shrouding technique. Increase volume of ventilation.
Lifting	The primer cannot withstand the thinners of the topcoat, swells, and works loose from the substrate.	Paint film loosens from the substrate.	Use the correct type of topcoat. Do not use thinners that are too strong.
Rough surface	Unclean paint and/or painting tools used. Unclean, dusty substrate. Unsuitable thinner used, which can cause flocculation of the paint components. Spray coating applied to a previously coated surface. Sand-blasting dust or similar in the environment. Too fast drying.	Unsatisfactory visual appearance.	Sieve the paint. Wash the tools properly. Clean the substrate. Use suitable thinner. Stir the paint thoroughly before application. Avoid spraying mist from drifting to the surface being coated.
Wrinkling	Film thickness too thick.	Strong staining, Poor film formation.	Use the correct type of primer. Apply the correct film thickness and curing time.
Sagging	Film thickness too thick. Temperature of paint too low. Excessive thinning.	Unsatisfactory visual appearance.	Apply a thinner film. Store the paint in warm conditions before application. Apply less thinner to the paint.
Bleeding	Dissolving dye or pigment migrates from primer to topcoat. Bitumen bleeding.	The film changes hue or becomes speckled.	Select a suitable topcoat or apply an insulating coat. Bituminous coating must not be overcoated using any other type of paint.

PROBLEM	POTENTIAL CAUSE	CONSEQUENCE	SOLUTION TO PROBLEM
Durability and performance			
Cracking	The paint is too hard (fragile) for the specific substrate. Temperature variation. Unsuitable paint system.	The film cracks into the substrate or into the previous coat.	Check the suitability of the selected paint system with the paint manufacturer.
Flaking	The paint has been applied onto a moist or greasy surface. The paint has been applied onto mill scale or rust. Application has been performed in poor conditions. The paint has been mixed or thinned incorrectly. The paint system is unsuitable for the substrate.	The film, or part of it, works loose from the substrate and corrosion protection capacity of the coating is compromised	Clean the surface well. Apply paint on a dry substrate at a sufficiently high ambient temperature. Comply with the paint manufacturer's instructions on mixing ratio, application interval and film thickness. Select a paint system suitable for the substrate.
Delamination	The previous coat has been soiled or the hardening process is excessive. Unsuitable paint. Incorrect application interval.	The film becomes entirely loose from the precedent coat. Appearance and durability are degraded.	Before application of a subsequent coat, clean the surface form soil, grease and salts. Hard or glossy surfaces must be sanded to a dull finish. Select a topcoat suitable for the primer. Apply the required application intervals.
Blistering - in coating other than fresh	Unsuitable thinner. Humid conditions. Film thickness too thick or too thin. Moisture has permeated underneath the film. Rust formation under the coat. Blistering due to cathodic protection. Unclean substrate.	The film works loose from the substrate in blister form.	Apply paint only in good conditions. Clean the surface carefully. Use paints that withstand the relevant environment or special stresses well. In connection with cathodic protection mechanism, only paints compatible with said protection mechanism can be used.
Chalking	UV exposure too powerful for the paint.	The pigments become loose from the surface due to decomposition of the binder agent.	Choose a paint capable of weathering the UV exposure.
Weak corrosion protection	Unsuitable paint system. Film thickness too thin. Inadequate surface preparation. Poor application conditions.	Premature rust formation.	Choose a suitable paint system for the structure and comply with the manufacturer's instructions on surface preparation, application and application conditions.
Weak early water resistance	Unsuitable paint system. Drying time too short.	Raindrops, for example, produce fading and speckling in the film.	Choose a suitable paint system for the structure and comply with the manufacturer's instructions on surface preparation, application and application conditions.
Coating causes staining	The film chalks. A property of the pigment (e.g. certain bright red hues).	The film causes staining when rubbed with a piece or cloth or similar.	Select a suitable paint type/hue for the structure being coated.

13. Future of corrosion protection painting

In the coming years, the corrosion protection painting industry will face both the customer expectations of increasingly faster throughput and cycle times and the statutory constraints imposed on the coating industry, such as the VOC directives and regulations.

Shorter curing times, which would enable the transport and packaging of products sooner after coating, are a serious challenge for the research and development of paint materials. Positive outcomes have been achieved for a number of paints, but, for example, in water-borne paints much remains to be done in this respect. On the other hand, the concept of adjusting the number and/or film thickness of coats, without simultaneously compromising the corrosion protection performance of the paint system, provides a different potential way of shortening the throughput times.

The European Union directive (1999/13/EC), adopted in 1999, holistically regulating the emissions of volatile organic compounds (VOC) and associated emission restrictions, required member states to implement corresponding national regulations with the intent of reducing solvents emissions.

The VOC decree requires that the industrial coating facilities calculate their total annual emission of solvents. If the annual emission volume is 5,000 to 15,000 kilograms, the facility is obliged to register with the information system of the environmental administration. If the annual emission volume exceeds 15,000 kilograms, the facility is obliged to apply for an environmental permit in addition to registration.

The facility can reduce its VOC emission in an effective way by deciding to use either powder paints or solvent-free, water-borne, or high-solid wet paints.

Water-borne and high-solid paints

The VOC content of paints can be compared based on the VOC content (g/l) indicated in the product data sheet. The values required in the VOC decree can be calculated based on the content of solids in the paint (g/l).

Water-borne corrosion protection paints and coatings have been available on the market over 20 years. For example, the water-borne TEKNOPOX AQUA PRIMER 3 manufactured by Teknos is an epoxy primer designed for corrosion protection. The paint is also available in the tinted MIOX version.

The water-borne polyurethane topcoats of the TEKNODUR AQUA 3390 range are suitable for application in connection with water-borne epoxy primers.

Teknos has also been very active in the development of one-pack water-borne corrosion protection paints and coatings for industrial use. The TEKNOCRYL AQUA COMBI 2780 range could be mentioned here by way of example. The paint provides for easy spraying and excellent protection for any steel surface.

The high-solid paints and coatings are becoming increasingly prominent in the world of corrosion protection painting.

The high-solid polyurethane paints of the TEKNODUR COMBI 3560 range are the state of the art in the product development of the paint industry. The paints have a short curing time, are easy to apply, and the VOC emission values are extremely low.

Powder coatings

The entirely solvent-free and environmentally friendly INFRALIT powder coatings have been on the market for over 40 years. The INFRALIFT powder coatings contain no organic volatile compounds, and are fully compliant with the VOC directive of the European Union (1999/13/EC).

The INFRALIT powder coatings are also in compliance with European Union directive 2002/95/EC, as amended and endorsed by directive 2005/618/EC, which sets forth restrictions applicable to the products of the electrical industry, concerning the content of lead, chromium (VI) compounds, mercury, cadmium, polybrominated biphenyl (PBB), and polybrominated diphnenyl ether (PBDE).

Zinc-rich powder coatings, as they are known (INFRALIT EP 8026-05 and INFRALIT PE 8316-05) are an exception to the above, since they can contain, in the form of zinc impurity, cadmium over 0.01 weight per cent and/ or lead over 0.1 weight per cent.

As well as in industrial coating, the INFRALIT powder coatings are a cost-effective and high-quality option in corrosion protection painting. Teknos Oy has developed powder coating paint systems that have been tested accordant with Standard ISO 12944. The foregoing Teknos powder coating paint systems offer a true alternative to a number of recognized wet paint systems in domestic and international use.

Protective paint system specification – New work	**FORM 184** Version 1/0599 Page 1 (1)

Project			
Name of owner			
Location			
Constituent element			
Environment			
Drawing No./area			
Protective paint system			
Paint system No.: (ISO 12944-5)		Required durability (ISO 12944-5)	

SHOP APPLICATION

Surface preparation grade:

Type of prefabrication primer (if used):

Paint manufacturer: Area, m²:

PROTECTIVE PAINT SYSTEM	Nominal dry film thickness µm	Overcoating interval		Drying time at ....°C,h
		min., h	max., h	
1st coat				
2nd coat				
3rd coat				
4th coat				
Total				

NOTE: For touch-up of damage, see "site application" below.

SITE APPLICATION

Surface preparation grade:

Touch up:

Complete:

Paint manufacturer: Area, m²:

PROTECTIVE PAINT SYSTEM	Nominal dry film thickness µm	Overcoating interval		Drying time at ....°C,h
		min., h	max., h	
1st coat				
2nd coat				
3rd coat				
4th coat				
5th coat				
6th coat				
Total				

Protective paint system specification – Maintenance	**FORM 185** Version 1/0599 Page 1 (1)

Project		
Name of owner		
Location		
Constituent element		
Environment		
Drawing No./area		
Original paint system		
Condition of substrate (see ISO 12944-8, Annex K)		
Protective paint system for maintenance		Paint system No.: (ISO 12944-5)
		Required durability (ISO 12944-5)

MAINTENANCE

Surface preparation grade of damaged surface:	Area, m²:
Surface preparation of undamaged surface:	Area, m²:
Touch-up:	Area, m²:
Complete:	Area, m²:
Paint Manufacturer:	

PROTECTIVE PAINT SYSTEM	Touch-up	Complete	Nominal dry film thickness µm	Overcoating interval		Drying time at ....°C,h
				min., h	max., h	
1st coat						
2nd coat						
3rd coat						
4th coat						
5th coat						
6th coat						
		Total				

Paint work progress and application conditions

FORM 186
Version 1/0599
Page 1(1)

Project				Position No.	
Drawing No.		Corrosion protection plan No.		Area	
Constituent element				Inspected by	
Comments				Painted by	

Date	Time	Type of work (i.e. surface preparation application of priming coats, intermediate coats, top coats)	Method used	General weather conditions	Temperature		Relative air humidity	Dew point	Blast cleaning abrasive (abrasive designation/ material No.)	Paint batch No.	Colour	Remarks (e.g. ISO standard, surface preparation, grade, irregularities)	Signature/ initials
					Air °C	Structure/ constituent element °C	%	°C					

Place	Date	1st signature	2nd signature	3rd signature

Recommended form for a report on reference areas	**FORM 187** Version 1/0599 Page 1 (2)

Owner		
Specifier		
Project		
Constituent element		
	Company	Vastuuhenkilö
Surface preparation:		
Paint work:		
Supplier of paint materials:		
Reference area [1] Location and marking:		Size, in m²

Original condition of the surface:

Uncoated surface (information in accordance with ISO 8501-1)

Rust grade ☐ A ☐ B ☐ C ☐ D

Supplementary information:

Zinc-coated steel surface, if any:

☐ Hot-dip-galvanized surface
☐ Thermally sprayed surface
☐ Electroplated surface

Zinc corrosion (e.g. white rust) ☐ YES ☐ NO

Supplementary information:

Painted surface

Type(s) of coat (including thickness and age, if known):	
Degree of rusting in accordance with ISO 4628-3:	
Degree of blistering in accordance with ISO 4628-2:	
Degree of cracking in accordance with ISO 4628-4:	
Degree of flaking in accordance with ISO 4628-5:	
Supplementary information:	

Surface preparation:

Preparation grade (ISO 8501-1 / ISO 8501-2)
☐ Sa 1 ☐ Sa 2 ☐ Sa 2½ ☐ Sa 3 ☐ PSa 2
☐ PSa 2½ ☐ PSa3 ☐ St 2 ☐ St 3 ☐ PSt 2
☐ PSt 3 ☐ PMa ☐ FI

Other information relating to preparation method and grade achieved [2]

Remarks:

[1] Fill in a new sheet for each reference area.
[2] For example for preparation grades St 2 and St 3, whether hand tools or power tools were used.

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	1	2	3	4	5	6
	Prefabrication primer	**Priming coat**	[3]	[3]	[3]	**Top coat**
Paint material — Manufacturer — Brand name — Batch and/or production No.						
Colour [4]						
Application method [5]						
Air temperature, ˚C						
Relative humidity, %						
Surface temperature, ˚C						
Dewpoint, ˚C						
Weather conditions (brief description)						
Thinner (type and amount) of paint material, if added						
Average film thickness, µm [6] — wet instrument used — dry instrument used						
Other measurements, if specified [6]						
Date Time						
Location of paint work [7]						
Company name(s)						
Signature(s) of person(s) responsible						

[3] Possible further operations, e.g. application of further coats, edge protection.
[4] See ISO 12944-8, sub-clause 5, table 1
[5] See ISO 12944-7, sub-clause 5.3.
[6] List the individual measurements on a separate sheet.
[7] E.g. steel mill, workshop or on site.


NESTE OIL
Truck

Teknos is an innovative paint manufacturer and a pioneer in anti-corrosive paints and coatings. High-quality Teknos products are held in high esteem by both the wood and metal industry, and the retail and architectural coating market.

Our ability to produce cost-effective solutions providing clear added value has formed the basis of our guarantee of customer satisfaction for over 60 years. Teknos is a family-owned business. Our background as a family-run enterprise is reflected in our long-term business relations and customer-oriented approach.

Our technical competence and continuous investments in research and product development will continue to boost our status as one of the leading European operators in our industry.