

# Industrial Coating of Metal Surfaces



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# 1. Corrosion

Corrosion means the erosion of metals, which causes changes in the properties of metals and leads to failures in the metal, its environment or the technical system as a whole. The corrosion of metals is a physical and chemical reaction between the metal and the environment.

Corrosion causes damage to the metal, it's immediate environment or the whole structure. Usually the nature of the reaction is electrochemical so that water in one form or another is always necessary for corrosion. Metals occur naturally mainly as ore minerals, e.g. oxides and sulfides. To extract pure metals from these requires large amounts of energy. The energy which has been bound into the metal during refinement from its natural state provides the driving force for the corrosion process.

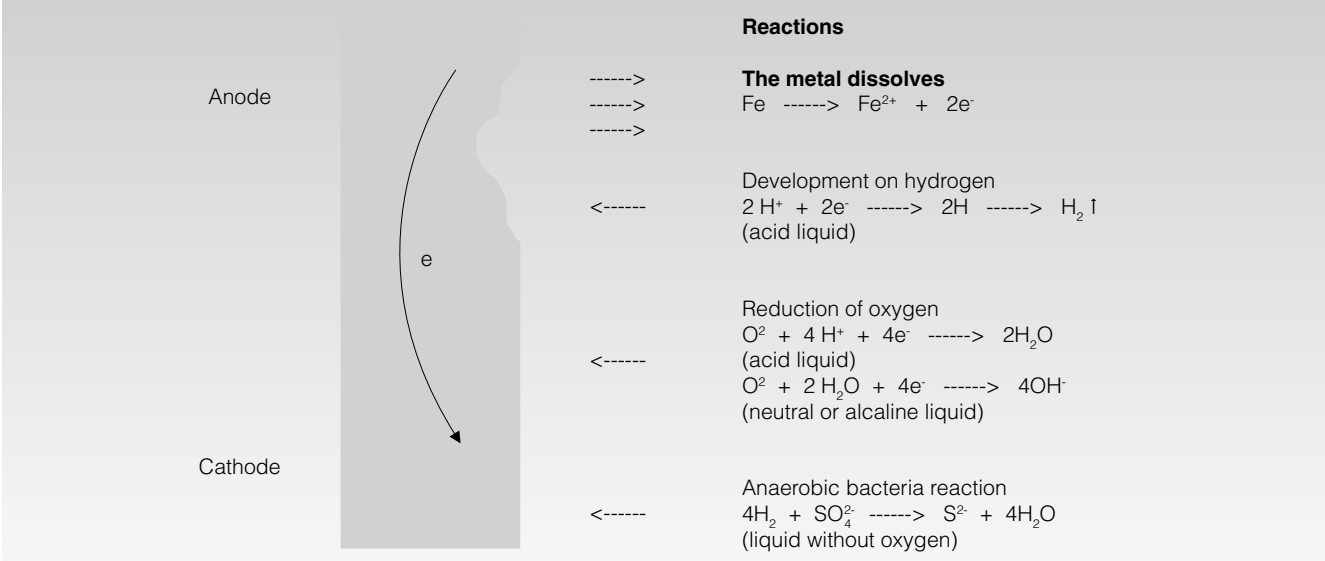
The corrosion of metals requires the formation of 'corrosion pairs' or local galvanic elements on the metal surface. A local corrosion cell can be formed at the joint between two different metals but also within the same metal surface, due to differences in the physical surface or its molecular construction. In addition, corrosion requires the presence of a conductive liquid or an electrolyte on the metal surface. Generally this electrolyte is water.

Local variations in the concentration of some components of the electrolyte, such as oxygen, can

cause the formation of galvanic cells. (Picture 1.) In the galvanic corrosion cell, the less precious metal, or part of the metal surface, acts as an anode, and the more 'noble' metal or area acts as a cathode. A common term for both areas is an 'electrode'. In the corrosion reaction the anode dissolves and the cathode is preserved. The intensity of the reaction depends on the difference in potential between the anode and the cathode and on environmental conditions.

Less reactive or more 'noble' metal (Cathode)
Platinum
Gold
Silver
Stainless steel
Nickel
Monel (2/3 Ni, 1/3 Cu)
Aluminium bronze
Copper
Brass
Tin
Lead
Cast iron
Low alloy steel
Carbon steel
Cadmium
Aluminium
Zinc
Magnesium
More reactive or less 'noble' metal (Anode)

Picture 2. The Galvanic series of metals in sea water, temperature +25C°.



Picture 1. Corrosion of iron in water solutions.



## 1.1 Atmospheric corrosion

The speed of atmospheric corrosion depends on a number of factors including: the relative humidity of the air, the temperature, chemical contaminants and the location of the surface. In order to estimate how severe atmospheric corrosion might become, atmospheric conditions are often categorised as rural, urban, industrial and marine.

**Wet time.** A necessary condition for the atmospheric corrosion of a metal is that the metal surface is covered by an electrolyte. The period when the metal surface is influenced by humidity is sometimes called the 'wet time'. Rain, condensation, mist or other forms of humidity can cause the surface to become wet. For most metals there is a critical value of relative humidity required for corrosion to proceed. If this is exceeded, then corrosion will occur.

The critical value of the relative humidity varies between 60-95%, depending on the quality of the metal and other factors. Once the corrosion has started, a much lower relative humidity can be enough to keep the process active. Steel can however corrode when the relative humidity of the air is below 40%, if there are chlorides or other chemical contaminants on the metal surface.

**Temperature.** Corrosion increases at higher temperatures. Below freezing point, corrosion proceeds slowly or not at all. On chemically contaminated surfaces, corrosion may however continue even at low temperatures.

**Atmospheric Contamination.** The two most important components of atmospheric contamination which accelerate the corrosion of metals are chlorides and sulphur dioxide. In coastal areas, salt from seawater is a major factor, but this effect decreases rapidly away from the coast. Inland, road salt applied to road surfaces to prevent freezing in winter is a major source of chloride contamination.

The amount of sulphur dioxide in the air, mainly arising from the burning of fossil fuels, varies greatly with location and time. Sulphur dioxide reacts with atmospheric moisture to form sulphuric acid. When sulphuric acid settles on metal surfaces, sulphate salts are formed. How the sulphate ions take part in the corrosion process varies depending on the metal concerned.

## 1.2 Corrosion in water

The speed of corrosion in water depends on how rapidly

oxygen reaches the metal surface. This depends on many factors such as the water flow, content of oxygen, the temperature, biological activity and dissolved salts. How corrosive naturally occurring waters are, depends on their chemical composition. The most corrosive type of water is sea water.

## 1.3 Corrosion in the ground

The rate of corrosion in the ground varies between that in air and that in water. As a corrosive environment, the ground is a heterogeneous and porous environment and the corrosion rate may vary considerably from place to place.

## 1.4 Different types of corrosion

The corrosion of metals can occur in several ways, such as an even corrosion all over the surface or in one specific area; pitting, crevice corrosion or tension corrosion.

Usually corrosion is relatively even, with the surface corroding, at a similar rate in all areas. Examples of this are the atmospheric corrosion of steel and metal surfaces exposed to chemical corrosion.

With pitting, the metal corrodes in small spots causing local cavities. E.g. the roughness of the surface, a powerful flow of liquid against the surface and the chloride ions in sea water may all cause pitting. Pitting occurs generally on metals for which corrosion resistance depends on the formation of a protective oxide coating forming on the surface. Examples would include aluminium and stainless steel.

Crevice corrosion occurs in narrow slits, holes etc., where the oxygen concentration is low. If chloride ions are present it will accelerate crevice corrosion. Stainless steel is particularly sensitive to this kind of corrosion. If a precious and a less precious metal are covered by the same electrolyte, e.g. sea water, and are electrically connected, a galvanic corrosion will occur, with the less precious metal corroding. The corrosion is more concentrated, the smaller the area of the less precious metal is compared to the precious metal, and the bigger the voltage difference between them e.g. in riveted joints, the rivets should not be made of less precious metal than the material they are connecting, or serious corrosion will result.

Tension corrosion, stress corrosion, erosion and cavity corrosion, all occur when the metal is exposed to corrosion and mechanical stresses at the same time.

## 2. Corrosion preventing by painting

The intention with protective coating is to protect the metal surface from corrosion and, at the same time, obtain the required degree of cosmetic finish for the object.

The ability of the paint coating to prevent corrosion depends on its anti-corrosive pigments and its adhesion to the substrate. Often the protective properties are a combination of the above factors.

Painting can prevent corrosion by:

- preventing the cathodic reaction
- preventing the anodic reaction
- presenting high resistance for the current circuit of the galvanic pair

The additives and pigments which are used in paints in order to increase their corrosion preventing properties usually prevent both the cathodic and the anodic reactions.

### 2.1 Preventing the cathodic reaction

The cathodic reaction is prevented when oxygen and water are prohibited from reaching the cathode. The paint coat acts as an insulating material and slows down the movement of oxygen and water to the metal substrate. Adhesion is also important – for example, epoxy paints form a very tightly bonded coat and therefore offer good protection in severe conditions. By increasing the coating thickness or by using laminar pigments, the corrosion preventing properties can be improved.

The cathodic reaction can also be prevented by using anti-corrosive pigments which contain zinc. The zinc ions precipitate as zinc hydroxide on the cathodic surfaces and this protective layer prohibits the cathodic reaction. These kinds of anti-corrosive pigments are called cathodic inhibitors.

### 2.2 Preventing the anodic reaction

In the anodic reaction, iron ions are formed under the paint coat. Depending on the conditions these ions form different kinds of iron compounds. In order to stop the anodic reaction, the dissolving of iron ions has to be prevented, e.g. by cathodic protection or by anodic

inhibitors which form a protective layer on the anodic area. A paint which offers cathodic protection must contain a lot of conductive pigments, less precious than iron, like the zinc found in zinc rich paints.

The anodic reaction can be prohibited when active anti-corrosive pigments take part in forming a protective layer, consisting of various oxides, on the anodic area. These anti-corrosive pigments also protect against corrosion by precipitating compounds, which do not allow iron ions to penetrate, on the anodic area. These kinds of anti-corrosive pigments are anodic inhibitors. Examples of these are red lead, zinc chromate and zinc phosphate. Due to health reasons, lead and chromate pigments are now rarely used.

### 2.3 Preventing the electric current

The paint coating has to form a sufficient resistance to the current circuit between the galvanic pairs. The corrosion preventing properties of paints which not contain active anti-corrosive pigments are based on their ability to prevent the ions moving between the electrodes. These kinds of paints, e.g. Temaline epoxy coatings, are used for the corrosion prevention of immersed or buried structures.

# 3.Consideration of surface treatment when planning steel constructions

The durability of the protective coating always depends on the entire decisions. A successful result depends on many more factors than a paint system and paints resistant against the actual exposures.

One of the most important factors, considering the corrosion resistance of the structure, is the planning of the steel construction. The base for an efficient surface treatment is often done already at the drawing board when appropriate decisions from surface treatment point of view are done.

In order to reach an optimum result, the corrosion resistance, the surface treatment employed, the whole construction and its behaviour during production and use have to be considered. Factors which have an influence on the corrosion resistance are, among others, the time, place and duration of surface treatment, the maintenance painting possibilities and furthermore the assembling method, time and place. The durability of the protective coating depends also on the surrounding of the structure, "micro climate", the season variations, interruptions or changes in the process.

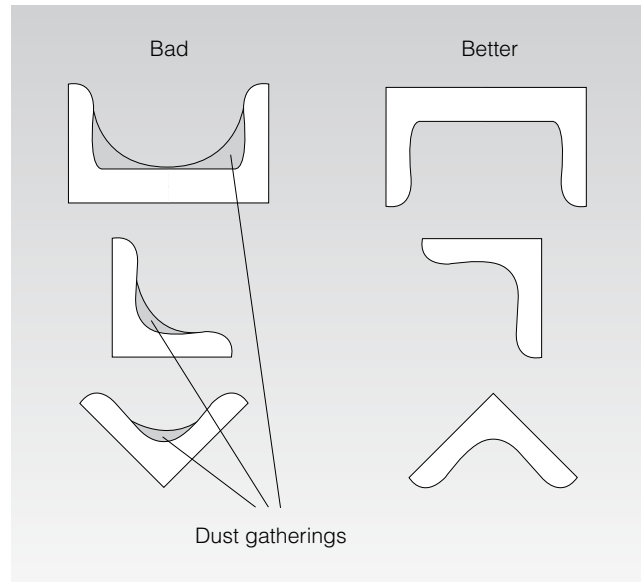
Standard EN ISO 12944-3 includes instructions about the planning of steel structures considering corrosion prevention and resistance.

The designer has many possibilities to influence the corrosion resistance of the construction. The correct solutions, which consider the corrosion prevention, should be technically and economically motivated. Pay attention at least to following facts:

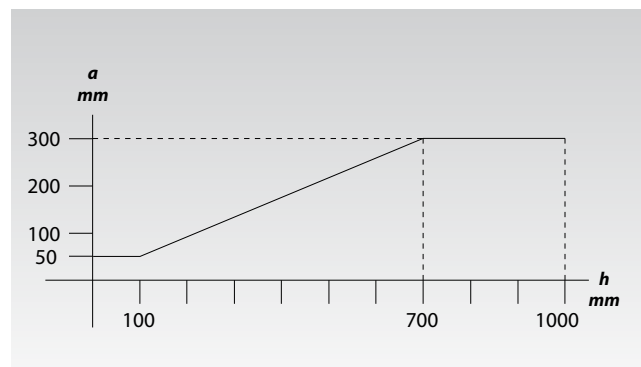
## 3.1. Avoiding corrosive conditions

The construction details should be located so that it is possible to keep the construction clean and dry. Ensure any water that might collect on any surfaces either by rain, splashes or condensation has the ability to flow away.

Section structures can gather dust, water and contaminations from the process etc. These rise the risk for corrosion and the exposure of the structure. If liquids collecting details cannot be avoided they should be drained at the lowest part of the structure. The waste water/liquid should be lead away from others parts of the construction.



Picture 3. Examples of structures which gather water, moisture and dirt and how the same structures can be designed better from the corrosion point of view.



Picture 4. Instructions for the minimum distance between surfaces, close to each other, standard EN ISO 12944-3. So that the pretreatment, painting and maintenance of the surface should be possible the worker has to see this surface and reach it with his tools. That is why it is important that the surface is visible and possible to reach.

### 3.2 Choosing the correct material and protection method

Harmful galvanic pairs can be avoided by choosing correct materials, keeping the area of the less precious material bigger than that of the precious material. Also by isolating metals from each others or by covering the less precious metal with another, more suitable metal or by an insulating coating, as an anti-corrosive paint.

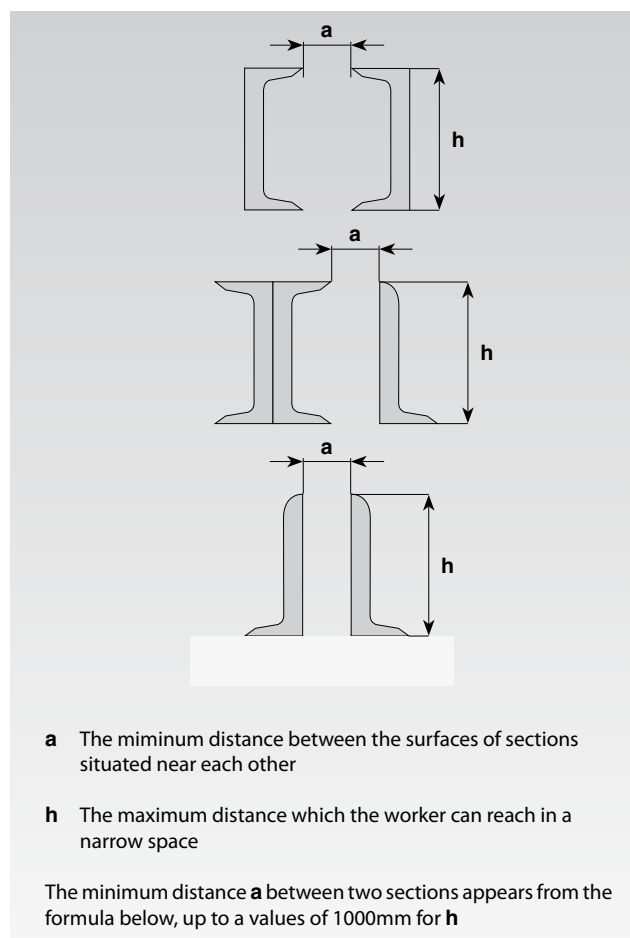
### 3.3 Avoiding corrosion sensitive structures and structures which are unfavorable from coating point of view

The possibilities to carry out protective coating and maintenance depend very much on the form and location of the structure. This has, of course, an influence on the durability of the painting. Every surface of a steel construction should be located so that it is possible to prepare, paint and inspect.

It is also essential that the forms of the structures are favorable from the corrosion point of view. A good designer chooses simple forms and tries to avoid sharp edges and other details which make the painting difficult.

### 3.4 Surface treatment before assembly

Surfaces which cannot be treated after the assembly and installation should be treated before or should be made of corrosion resistant material.



Picture 5. Instructions for the minimum distance between surfaces, close to each other, standard EN ISO 12944-3.

Action	The lenght of the tool (D2)	The distance between the substrate and tool (D1)	Working angle ( $\alpha$ )
	mm	mm	grades
Blast cleaning	800	200...400	60...90
Power tool cleaning			
-by needle-gun	250...350	0	30...90
-by wire-brushing/ grinding	100...150	0	-
Cleaning by hand tools			
- wire-brush/scraper	100	0	0...30
Paint application by spray	300	150...200	90
Paint application by			
-spray	200...300	200...300	90
-brush	200	0	45...90
-roller	200	0	10...90

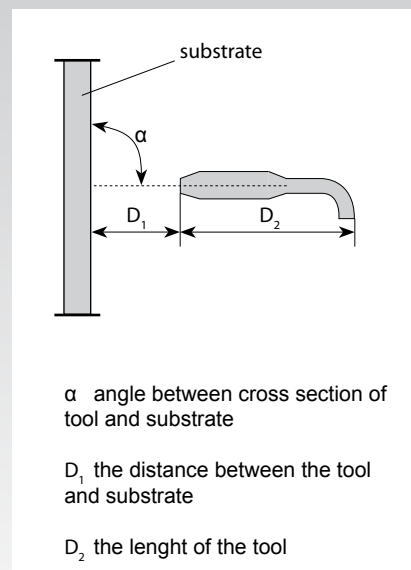


Table 1. Typical distances required for tools used in protective coating work, according to standard EN ISO 12944-3.

# Check list

## **considering corrosion preventing when constructions and machinery is designed**

- Choose the correct materials.
- Design a simple and practical construction, which remains clean.
- Check if the construction has to be treated with intumescent paint. Notice this in the dimensioning.
- Check the accessibility. All surfaces should be possible to be cleaned, painted and inspected. Consult standard EN ISO 12944-3 about the minimum interspaces.
- Avoid water and dirt collecting grooves.
- Necessary grooves should be drained.
- Avoid horizontal levels on which water and snow remain.
- Avoid sharp edges. N.B. cut plate has sharp edges over which the paint film has difficulty in covering satisfactorily.
- Remember, paint is not putty, it does not even fill the smallest notch.
- Avoid intermittent welding, it will surely corrode.
- Remember that a totally closed pipe or tube would not corrode from the inside, an open one does.
- Avoid not insulated joints between two different metals.
- Do not use corroding equipment, hinges, handles etc.
- Remember that in a screw joint the paint coat often is destroyed and the corrosion starts. Suitable plates may help.
- Avoid producing many small manholes, it is far better to produce a large single one, e.g. in tanks, the manholes are not only for movement, there is also a need for ventilation and for the removal of cleaning material.
- Define the quality grade of the steel work, ISO 8501-3.
- Choose a dark colour for parts which are exposed to hits, it is not so easy to see the damages.
- At every detail, ask yourself, is this exposed to corrosion? If so, is it necessary, has it to be like this etc. You will find that with fewer parts you will get a better structure.
- Do not be afraid of criticism. Go out in the field, by communicating with people in work and painting shops you will get abuses, but also know-how, which others don't have. You will become an expert.

## 4. Standards concerning protective coating

The purpose of standards for protective coating work is to ensure a better and more uniform quality of paint specification and application. Good standards can support the users expertise, but can never replace it.

### 4.1 The purpose of standards

Standards create a central frame of reference for all users, defining technical terms and making it easier to understand a particular technical field. The common language which is defined in the standards and the unitary methods of working makes planning easier, saves costs and helps to avoid duplication of work.

Generally, a standard is a recommendation of good practice. However, when standards are referred to in a specification document, they can become mandatory aspects of the work.

Both national and international standards concerning protective coating contain stipulations concerning paint systems, pretreatment, painting work and quality control. Generally they do not closely define the formulation of the paints themselves, but rather provide advice on certain properties of the coatings.

### 4.2 International standards

The **ISO** and the **EN ISO** standards described below cover protective coating work:

#### **EN ISO 12944: 1-8**

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

Part 1: General introduction

Part 2: Classification of environments

Part 3: Design considerations

Part 4: Types of surface 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

#### **ISO 8501: 1-3**

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.

Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings.

Part 3: Preparation grades of welds, cut edges and other areas with surface imperfections.

EN ISO 8501-4: Preparation grades of coated and uncoated steel substrates after removal of rust and previous coatings by high pressure water jetting.

#### **ISO 8503: 1-4**

Preparation of steel substrates before application of paints and related products. Surface roughness characteristics of blast cleaned steel substrates.

Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces.

Part 2: Method for the calibration of ISO surface profile of abrasive blast cleaned steel. Comparator procedure.

Part 3: Method for the calibration of ISO surface profile comparators and for the determination of surface profile. Focusing microscope procedure.

Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile. Stylus instrument procedure.

#### **ISO 8504: 1-3**

Preparation of steel substrates before application of paints and related products. Surface preparation methods.

Part 1: General principles

Part 2: Abrasive blast-cleaning

Part 3: Hand- and power-tool cleaning

#### **EN 10238**

Automatically blast-cleaned and automatically prefabrication primed structural steel products.

## 4.3 Standards concerning testing of paints and film thickness

### ISO 1520

Paints and varnishes. Cupping test.

### ISO 1521

Paints and varnishes. Determination of resistance to water. Water immersion method.

### ISO 1522

Paints and varnishes. Pendulum damping test.

### ISO 2178

Non-magnetic coatings on magnetic substrates. Measurement of coating thickness. Magnetic method.

### ISO 2360

Non-conductive coatings on non-magnetic electrically conductive basis materials. Measurement of coating thickness. Amplitude-sensitive eddy current method.

### ISO 2409

Paints and varnishes. Cross-cut test.

### ISO 2808

Paints and varnishes. Determination of film thickness.

### ISO 2810

Paints and varnishes. Natural weathering of coatings. Exposure and assessment.

### ISO 2812: 1-2

Paints and varnishes. Determination of resistance to liquids.

Part 1: General methods

Part 2: Water immersion method

### ISO 2813

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

### ISO 3231

Paints and varnishes. Determination of resistance to humid atmospheres containing sulphur dioxide.

### ISO 4624

Paints and varnishes. Pull-off test for adhesion.

### ISO 4628: 1-8

Paints and varnishes. Evaluation of degradation of coatings. Designation of quantity and size of defects, and of intensity of uniform changes in appearance.

Part 1: General introduction and designation system

Part 2: Assessment of degree of blistering

Part 3: Assessment of degree of rusting

Part 4: Assessment of degree of cracking

Part 5: Assessment of degree of flaking

Part 6: Rating of degree of chalking by tape method

Part 7: Assessment of degree of chalking by velvet method

Part 8: Assessment of corrosion around a scribe

### ISO 6270: 1

Paints and varnishes. Determination of resistance to humidity. Part 1: Continuous condensation.

### ISO 7253

Paints and varnishes. Determination of resistance to neutral salt spray (fog).

### ISO 9227

Corrosion tests in artificial atmospheres. Salt spray tests.

### EN ISO 2064

Metallic and other inorganic coatings. Definitions and conventions concerning the measurement of thickness.

### EN ISO 1518

Paints and varnishes. Scratch test.

## 4.4 Swedish standards BSK 99

Practice in Sweden follows the recommendations concerning the protective coating of steel structures which are published by Boverket. They are included in "Boverkets handbok om Stålkonstruktioner (BSK 99)", (Manual for planning and surface treatment of steel structures). BSK is mainly based on standard EN ISO 12944.

The paint systems in BSK 99 are marked according to tables 8:72 a-f. S-systems correspond to those in EN ISO 12944-5, the N-systems are national.

When needed, Tikkurila Oyj can provide information about approved paint systems.

**SSG standards**

Standard Solutions Group in Sweden has published painting standards for the paper and cellulose industry.

**SSG 1000, 2004**

General stipulations for planning and purchasing of surface protection by painting.

**SSG 1005, 2004**

Paint systems for new painting of metals.

**SSG 1007, 2004**

Colours for finish of metals. Colour card.

**SSG 1009, 2004**

Paint systems for galvanized steel.

**SSG 1010, 2004**

Paint systems for maintenance painting of metals.

**SSG 1012, 2004**

Choice of paint systems.

Paint systems according to SSG are marked such as:  
SSG 1005-GB40 TD160-SSG20.

This means:

SSG Skogsindustriella Standardiseringsgruppen

1005 Standard 1005

GB40 Temazinc 99, 40µm

TD160 Temacoat RM 40, 160µm

SSG20 Colour according to colour card SSG 1007

## 4.5 Finnish standards

In Finland some national standards have also been compiled to complement international standards for protective coatings. These standards have mainly been required by process and metal industry.

**SFS 5873**

Corrosion protection of metal structures by means of protective paint systems. Recommendation for use in process and metal industry.

**SFS 8145**

Anticorrosive painting. Quality grades of mechanical surface preparations for blast cleaned or blast-cleaned and prefabrication primed steel substrates.

**PSK 2701**

Corrosion protection of metal constructions by means of protective paint system. Procurement Documents.

**PSK 2702**

Procurement and Painting of Hot Dip Galvanized Steel Constructions. Recommendation for Use in the Process Industry.

SFS standards are available at Suomen Standardisoimisliitto SFS ry. P.O. Box 116, 00241 Helsinki, FINLAND, tel. 358 9 149 9331.

## 4.6 Manufacturer's own standards

Many manufacturers have developed their own standards which take into account the special demands concerning specific locations and conditions. These include specifications for specific projects where the paint systems and quality grade are defined. Tikkurila Oyj is ready to assist in developing manufacturers' own standards and paint specifications.



## 5. Cleaning and pre-treatment

The cleaning and pretreatment of the surfaces to be painted include a range of measures to improve the adhesion and durability of the paint film. A careful and appropriately chosen pretreatment operation is essential for a successful painting project, with around 50–70% of all painting failures being due to poor pre-treatment.

An appropriate and economical pretreatment method is chosen on basis of the original condition of the surface and the corrosion category of the environment relevant to the project. At the same time the requirements of the paint system, the type of structure and the place of the pre-treatment (i.e. shop or site) should be considered.

### 5.1 Symbols describing pretreatment methods

Distinctive symbols are used in paint specifications to describe which kind of pre-treatment should be carried out. These symbols are described in table 2.

Preatreatment method	Symbol
Pickling	Be
Wire brushing	St
Blast cleaning	Sa
Flame-cleaning	Fl
Spot blast cleaning	PSa
Spot cleaning with hand or power tools	PSt
Spot cleaning with power tools	PMa

Table 2. Surface preparation grades and signs.

### 5.2 Rust grades

In standard ISO 8501-1 the rust grades of unpainted, hot rolled steel, are described by text and by photographs). There are four rust grades; A, B, C, and D.

**A** Steel surface covered completely with adherent mill scale and with little or no rust.

**B** Steel surface which has begun to rust and from which the mill scale has begun to flake.

**C** Steel surface on which the mill scale has rusted away or from which it can be scraped, but with little pitting visible to the naked eye.

**D** Steel surface on which the mill scale has rusted away and on which considerable pitting is visible to the naked eye.

The inspection is done by naked eye in day light or equal illumination. The poorest rust grade of the substrate is recorded.

The rust grades of painted surfaces are specified in standard ISO 4628-3 according to the attached photos. The photos represent painted steel surfaces which have rusted to varying degrees. The grades are marked Ri 0 - Ri 5 and they correspond with percentages of rusty areas between 0% and 40/50% as follows (Table 3).

Grade	Rusty area (%)	European	ASTM D610
Ri 0	0	Re 0	10
Ri 1	0,05	Re 1	9
Ri 2	0,5	Re 2	7
Ri 3	1	Re 3	6
Ri 4	8	Re 5	4
Ri 5	40/50	Re 7	1-2

Table 3. Rust grades of painted surfaces according to standard ISO 4628-3 compared to similar standards.

## 5.3 Preliminary cleaning

Contamination which could interfere with preparation and painting operations is removed by various appropriate methods.

Solid contamination as ice, concrete, mortar, old paint coatings, thick salt and rust, should be removed by chipping, scraping or wire brushing. Salts and other water soluble contamination should be removed by water washing with brushing, high pressure spraying with water or steam, or alkaline treatment. Grease and dirt are usually removed by solvent, emulsion or alkaline washes. After emulsion and alkaline washing, surfaces must be rinsed thoroughly with clean, fresh water.

### 5.3.1 Removal of dirt and grease

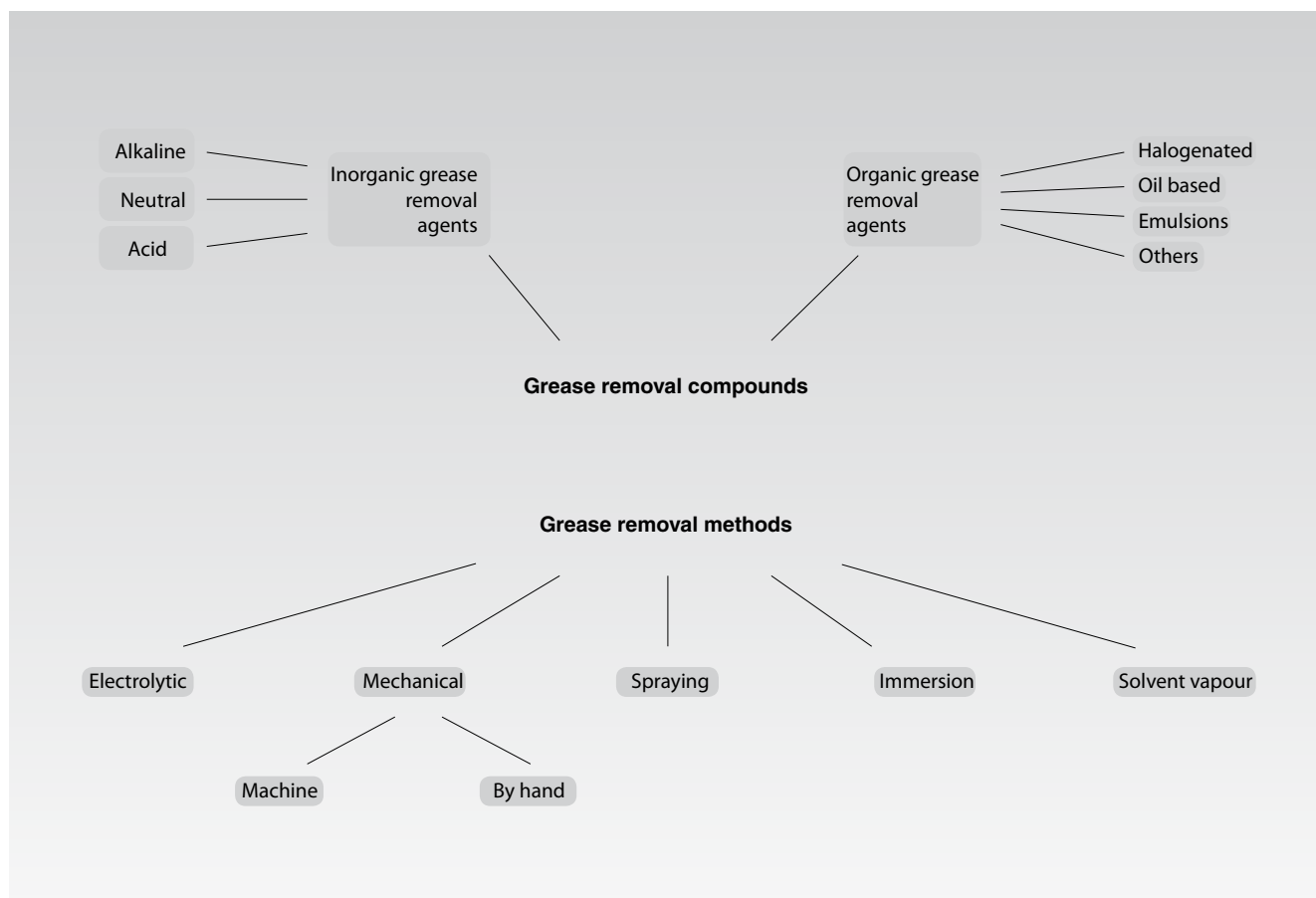
Methods and materials which are used for dirt and grease removal are shown in picture 6. There are many factors which have an influence on the choice of cleaning method and materials, such as the type and extent of the contamination, the type of structure or item

to be cleaned and the kind of surface treatment to be used following cleaning.

Water soluble compounds, such as salts and traces of acids, can be removed by water washing. The washing efficiency can be improved by using warm or hot water or by mechanical measures such as high pressure or scrubbing. 'Steam cleaning' can also be used, which employs high pressure steam, giving advantages of heat and rapid drying, and using relatively small amounts of water.

When water and steam cleaning are used, a detergent can be added which improves the removal of the dirt layer, but a water rinse to remove detergent residues is then necessary. In water cleaning, alcohol can also be used to improve cleaning efficiency and this removes the need for subsequent rinsing.

N.B. If salts and grease on steel surfaces are not removed, they can contaminate the blasting agent in a recyclable blasting system and then transfer this contamination to following items.



Picture 6. Grease and dirt removal methods and detergents.

### 5.3.2 Alkaline wash

Alkaline wash removes grease, oil and water soluble contamination. Alkaline detergents are most efficient at temperatures of around 60–90°C. There are different alkaline detergents available for different purposes. When cleaning zinc and aluminium surfaces, special detergents suitable for these metals have to be used in order to avoid attack of the metal substrate.

In addition to the type of metal substrate, the type of oil and grease contamination can have an influence on the choice of detergent. Very alkaline detergents may dissolve dirt layers selectively, so that some of contaminants dissolve, but others remain on the surface and are difficult to remove.

Alkaline washing is done by immersion or spraying. Because the washing liquids are warm it is essential that the surfaces do not dry before rinsing. All traces of alkalis must be removed before surface preparation. Sometimes there is a need for a treatment with a neutralizing solution after the alkaline wash. This can, for example, be done by adding phosphoric acid to the rinsing water.

### 5.3.3 Solvent washing

Solvent washing can be done with flammable or non-flammable solvents.

**Flammable** solvents are, among others, white spirit, thinners, turpentine and aromatic hydrocarbons such as xylene and toluene. Solvent washing with white spirit is often done by rubbing the surface with a rag. This method is not very efficient, as the grease is often being moved from one place to another. Flammable solvents should be used only in flame-proof areas with good extraction.

**Non-flammable** solvents include chlorinated hydrocarbons and today these are only used in fixed, permanent facilities. The cleaning is often done in a similar manner to steam cleaning. The solvent in the bottom of the box is heated and the vapours condense on the surfaces to be cleaned.

Solvent washing does not remove inorganic salts and heavy layers of grease. Solvent washing is often combined with immersion cleaning. The solvent is chosen according to the type of contamination. The most usual solvents are trichloroethylene (tri, 87°C), ethylene dichloride (per, 121°C), methylene chloride (40°C) and 1.1.1-trichloroethane (87°C). There is however some concern about the use of halogenated hydrocarbons for such procedures. One advantage of solvent washing is that there is no need for a water rinse following cleaning

### 5.3.4 Emulsion cleaning

In emulsion cleaning the cleaning solution contains water, solvents and emulsifiers. The emulsifiers act on the contaminants so that they lose adhesion to the surface. Emulsion cleaning is an efficient method to remove different layers of dirt but a thin coat of oil may remain on the surface. Emulsion cleaning is often used as preliminary cleaning before alkaline or solvent cleaning. Emulsifiers can also be added to lubricating oils which make it possible to rinse the surface with water after tooling.

### 5.3.5 Drying

When water based cleaning methods are used, objects should be dried before painting. Different drying methods include the following:

- A very common drying method is a drying convection tunnel. Hot air at about 150°C is circulated in the tunnel and blows away water drops from the object and makes any remaining moisture evaporate. A disadvantage with this method is the need for large facilities and the energy demand, especially if the objects are large or the speed of the line is high.
- Simple and light pieces can be dried by using hot water for the final rinse, the accumulated thermal energy will make the remaining water to evaporate. This is an economical method because there is no need for drying equipment. A further advantage is that savings of space and energy demand can be made.
- A more efficient method which also required less space is a combination of convection drying and infra-red radiation. By placing the infra-red radiators, which can be aimed very precisely, in the front end of the tunnel, it is possible to increase the temperature of large items rapidly, even at fast line speeds. At the end of the tunnel is a convection zone where hot air blows away remaining water from cavities and the accumulated thermal energy makes any remaining moisture evaporate.
- Infra-red drying can be used on its own for very large objects of simple configuration. The surface temperature of the object is increased rapidly to the boiling point of water, so that the thermal energy causes that the water evaporates. The method requires little space.

## 5.4 Pretreatment grades

The cleanliness of the surface is based on visual inspection, with the so called pretreatment grades (or preparation grades) being defined in standard ISO 8501-1. These are separated into to the most common surface preparation methods: wire-brushing (St); blast cleaning (Sa); flame-cleaning (Fl); and pickling (Be).

The pre-treatment grades are defined by description of the appearance of the surface after cleaning, together with illustrative photographs. The number after the symbol for the cleaning method defines the preparation grade, which are described in section 5.6, surface preparation methods. By also adding the original rust grade before the sign, you get a complete description of the steel surface before painting.

When only parts of the surface are prepared, the symbols of the preparation grades are:

- PSa spot blasting
- PMA power tool cleaning of spots
- PSt cleaning of spots with manual or power tools

Example:

**C Sa2½**  
└─┬─ Grade of blast  
   └─ cleaning  
   └─ Rust grade

N.B. For chemical pretreatment grades there are not yet any standardized preparation grades. Advice does exist however even for these methods on how to achieve a suitable surface for painting.

## 5.5 Quality grades of pretreatment

Cleaning and preparation measures before painting are not limited only to removal of rust, mill scale, grease, contamination and old paint. It is also necessary to consider the treatment of weld seams, cut faces and surface defects in the steelwork itself.

The mechanical preparation methods and quality grades for blast cleaned steel surfaces are defined in standard ISO 8501-3. The standard shows the appearance of the different quality grades of mechanical preparation in practice.

There are three preparation grades for making steel surfaces with imperfections suitable for application of paints and related products:

**P1** Light preparation: minimum preparation considered necessary before application of paint.

**P2** Thorough preparation: most imperfections are remedied.

**P3** Very thorough preparation: surface is free of significant visible imperfections.

## 5.6 Surface preparation methods

It is necessary to remove rust, mill scale, old paint layers and other solid contaminants from steel and cast iron surfaces prior to painting. Mill scale is a brittle oxide layer which is formed during the hot-rolling process for structural steelwork. Mill scale will usually detach from the steel surface within a few weeks or months and must therefore always be removed before painting.

The thickness of the steelwork, the size of the object, cleaning conditions, the type of the rust to be removed, the type of coating system to be applied and the degree of surface profile required are all factors which influence the choice of rust removal method. The surface preparation method and the quality grade are usually specified in the project specification, protective coating schedule or painting work manual.

Available surface preparation methods are: mechanical wire-brushing; blast cleaning; thermal methods and chemical methods.

### 5.6.1 Surface preparation by manual or power tools, (St standard)

Wire-brushing, grinding and scraping with manual or power tools are used for rust removal where more thorough methods such as blast cleaning are impractical or too expensive. These methods are described with the abbreviation "St". If only spot cleaning is being carried out the sign PSt is used. The tools required for these methods are easy to use and cheap to obtain but the cleaning result is poor compared with the quality of other surface preparation methods. Cleaning with manual and power tools is described in standard ISO 8501-1. An example is given below of an St 2 surface

#### St 2 Careful cleaning with manual or power tools

Dust, grease and dirt, loose mill scale, rust, paint or other contaminants should not be obvious on visual inspection.

## 5.6.2 Blast cleaning, Sa

Blast cleaning is generally used for rust removal from steel and cast iron, this method being the most efficient for the removal of mill scale and rust. Blast cleaning, which is described with the abbreviation Sa, is a mechanical surface cleaning method where contaminants are removed by abrasive which is propelled at the surface at very high speed. When only certain localised areas of the surface are to be cleaned, the sign P<sub>Sa</sub> is used (described earlier as "spot blasting"). Blast cleaning methods include: open blasting, vacuum blasting, water blasting (wet blasting) and fixed self-contained blasting machines (often called 'wheel abrators', due to the method of propelling the abrasive at the steel surface using large 'paddle wheels').

Light or sweep blast cleaning is used also for hot galvanized surfaces, aluminium surfaces and to clean and roughen old undamaged paint coatings immediately before painting. In these cases the abrasive material should be non-metallic and the pressure low in order to avoid damage to the surface. The particle size of the abrasive material should be 0.2-0.5mm and the pressure below 4 bar. The distance between the nozzle and the surface should be 0.5-0.8m.

### 5.6.2.1 Pretreatment grades of blast cleaning (ISO 8501-1)

#### Sa 1 Light blast cleaning

Dust, grease and dirt, loose mill scale, rust, paint or other loose contaminants should be removed.

#### Sa 2 Careful blast cleaning

Dust, grease and dirt, loose mill scale, rust, paint or other loose contaminants should be removed. Remaining contaminants must have good adhesion to the surface.

#### Sa 2½ Very careful blast cleaning

All dust, grease and dirt, mill scale, rust, paint or other contaminants should be removed. Only very slight traces of remaining contaminants should be visible, seen as light colorations or darker spots and shades.

#### Sa 3 Blast cleaning to white metal

Dust, grease and dirt, mill scale, rust, paint or other contaminants should be completely removed. The surface should have a homogenous metallic lustre.

#### SaS Sweep blast cleaning

Sweep blast cleaning to grade SaS (SFS 5873) (sometimes previously called 'sand wash') can be used

for cleaning hot dip galvanized and aluminium surfaces. It is also used to roughen old, undamaged, painted surfaces and to remove loose or flaking paint during maintenance. After treatment, the surface appearance should be evenly matt and rough but the original coating should be undamaged.

All dust, rubbish and abrasive agents should always be removed after blast cleaning. Most types of paint requires blast cleaning to grade Sa 2½, which today is the most common pretreatment grade. For objects which are to be immersed should always be cleaned to Sa 2½ standard. Standard Sa 3, which is very expensive and time consuming to achieve, is usually reserved only for extreme service conditions or prior to application of hot metal spray coatings, which demand very high surface cleanliness.

### 5.6.2.2 Blast cleaning agents

There are a lot of different materials which can be used as blasting agents. The form and type of the abrasive has an important influence on the appearance and profile of the cleaned surface.

For cleaning of metallic surface, the following materials are generally used:

#### Materials which can be used several times (re-usable abrasive)

- cast iron or steel grit, both round and sharp
- steel chopped wire or steel plate chips
- aluminium oxide and aluminium silicate are used in some special cases
- glass pellets are used for blasting of aluminium and stainless steel

#### Non-recurring materials

- different kinds of slag
- quartz sand
- natural sand

The use of natural sand is now usually avoided because of the risk of silicosis. The blasting material can also be mixed with water, to give wet blasting.

The durability and hardness of the blasting agents have an influence on which abrasive is chosen. The most durable abrasives are steel chopped wire and cast iron grit. Fast wearing abrasives include cast iron and natural sand. A common requirements for blasting materials is that they should not contain any water soluble salts or other contaminants which may contaminate the metal surface and reduce the life of the protective coating.

Demands on blasting materials are described in standard ISO 11124 (metallic grits) and standard ISO 11126 (non-metallic material).

### 5.6.2.3 Surface profile

The profile of the surface is the degree of roughness of the surface, left by the blasting abrasive, and is generally defined as the distance between the 'peaks' and 'troughs' of the profile. (Under a microscope, a typical blast profile looks very similar to a mountain range seen from the air, the shapes of the 'mountains' depending on the shape of the abrasive particle which was used. A sharp, angular grit will give a profile which looks like high, sharp-edged mountain peaks, whereas a rounded steel shot abrasive will give a profile which looks more like large rounded hillsides).

The blasting agent should be chosen according to its size, form and quality, so that a suitable surface profile is achieved from the coating's point of view. The surface profile can be measured by comparing it to the ISO surface profile models, attachments to standard ISO 8503 (definition of steel surface). With round agents (S=shot) a rather round profile is achieved and with sharp agents (G=grit) a sharper one. The standard classifies the surface profile in fine, medium rough and rough, separately for each type of abrasive. Using these surface comparators, the blasted surface can be compared visually or by touch.

### 5.6.3 Water jetting

Water can also be used as a blasting material. The properties of the method are:

- no dust
- removes very well thick layers of paint or rust but removing of thin paint layers (e.g. shop primer) is more difficult
- removes soluble salts, does not remove mill scale
- does not provide any surface profile
- blasted surface rusts very fast again (flash rust)

Standard EN-ISO 8501-4 defines initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting.

The pretreatment grades are:

- WA 1 Light high-pressure water jetting
- WA 2 Thorough high-pressure water jetting
- WA 3 Very thorough high-pressure water jetting

### 5.6.4 Thermal methods

One thermal method is, for example, flamecleaning, where old paint, mill scale and rust is removed from the steel surface by using a oxygen-acetylene flame.

After this the surface must be wire-brushed before an acceptable painting substrate cannot be achieved. The flame-cleaning is described with the abbreviation "FI".

### 5.6.5 Chemical methods

Chemical rust removal, or 'pickling', is done by immersing the object in a pickling bath filled with a suitable chemical, dependent on the actual metal being treated. The pickling bath can be acid or alkaline.

**Acid pickling** can be done using hydrochloric, sulphur or nitric acid. Which acid is chosen depends on which metal is to be treated. The intention is that the pickling solution should remove oxide layers without corroding the base metal. In order to protect the metal, inhibitors are added to the pickling solution. After pickling of steel, the surface should be neutralized and dried immediately. Alkaline pickling is usually done with a solution of sodium hydroxide, 50-80%. Rust removal with alkaline solutions is slower than with acids but an advantage is that organic contaminants are also removed. The pickling of aluminium is often done using alkaline solutions. The wetting properties of the solution is regulated using additives and the pickling efficiency by varying the alkaline concentration (pH).

### 5.7 Phosphating

Phosphating improves the adhesion of the coating to the metal surface and can also improve the corrosion resistance of the painted surface. Iron, steel, zinc and hot galvanized surfaces are suitable for phosphating, and in some cases, aluminium surfaces.

During phosphating a thin, crystalline phosphate layer forms on the metal surface, which improves the adhesion. The most usual phosphating methods are iron and zinc phosphating. Which method is chosen depends on the environment which the coated surface will have to withstand. The phosphating is done either by spraying or by immersion.

Zinc phosphating is usually considered to give the best surface for painting. The adhesion of the paint and the corrosion protective properties of the zinc phosphate are excellent. The thickness of the zinc phosphate coat is 2-4.5g/m<sup>2</sup>. The colour of the zinc phosphated surface is grey.

There are generally five treatment phases in zinc phosphating: cleaning of the surfaces; rinsing; phosphating; rinsing; and a passivating rinsing. The type of product being coated and the service requirements of the painted item can add to, or reduce, these phases. Zinc phosphating as a pretreatment is used for surfaces exposed to severe conditions, such as in the automotive

and transport vehicle industries.

In iron phosphating there is at least two phases, combined wash/phosphating and rinsing.

Iron phosphating is the simplest and cheapest of the phosphating methods. Iron phosphating improves the adhesion of the paint to the steel surface but its corrosion protective properties are not as good as for zinc phosphating. Depending on the method used, the thickness of iron phosphating is generally 0.1-1.0g/m<sup>2</sup>. The colour varies from blue to grey depending on the thickness of the iron phosphate layer. Iron phosphating is used for the pretreatment of so-called 'white goods', such as domestic washing machines, refrigerators, etc.

## 5.8 Chromating

Chromating is used as a pretreatment method for light alloys and galvanized surfaces. The treatment causes a thin colourless or yellowish coat. There are also chromating methods which form a substrate which is not suitable for painting.

## 5.9 Etching primer

To ensure the adhesion of paint on zinc, light alloy, lead, copper, stainless steel and cold rolled steel surfaces, etching primers can be used. Etch primers or wash primers are usually based on polyvinyl butyryl resins or two component modified epoxy binders. Phosphoric acid is typically used as an active etching ingredient in either technology. Etch primers are generally used for DIY car repairs.

## 5.10 Prefabrication primer

The intention in using a prefabrication primer is to temporarily protect the steel surface using a thin, fast drying coating. Generally the pretreatment is blast cleaning to Sa 2½. Prefabrication primers are often called shop-primers. The paints are usually zinc epoxy (EPZ), zinc silicate (ESIZ) or epoxy prefabrication primers (EPF). One and two component polyvinyl butyral prefabrication primers (PVBF) are also used.

It is an essential part of the overall coating specification that any prefabrication primer, the surface

pre-treatment prior to its application, and its compatibility with subsequent paint coatings, are all taken into account. Generally the prefabrication primer surface is cleaned from grease and dirt and sweep blasted prior to applying further coats of paint. For objects to be immersed, all the prefabrication primer is usually removed. If the subsequent primer is to be a zinc rich paint, a zinc based prefabrication primer must be used.

Descriptions of a range of prefabrication primers and their selection can be found in standard EN 10238. The compatibility of prefabrication primers with the final paint system and service conditions are described in standard EN ISO 12944-5.

Prefabrication primer	Type signs EN 10238	Further painting
Polyvinyl butyral	PVBF	AK, AY, CR
Epoxy	EPF	AK, AY, CR, EP, PVC
Zinc epoxy	EPZ	CR, EP, AY, PVC
Zinc silicate	ESIZ	CR, EP, AY, PVC

Table 4. Prefabrication primers, type signs.

# 6. Protective coatings - methods and equipment

## 6.1 Brush application

During maintenance and repair painting it is often impractical to use spray equipment and the coatings have therefore to be applied by brush. When paint is applied by brush, it penetrates a rusty surface much more efficiently than when sprayed, as the brushing action 'works' the paint into the surface profile. Brush is also used for 'stripe' painting of corners, edges and other difficult areas, in connection with spray application, to ensure adequate dft on all areas – paint tends to 'run away' from edges, and spray application cannot adequately coat all areas. The shape of the object, the required degree of finish and the type of the paint, are all factors which have an influence on which kind of brush is the most suitable. Most brushes are made of either natural bristles, or a wide range of different synthetic materials.

- Round paint brushes (sometimes called 'striker' brushes) are suitable for applying and rubbing thick primers onto the surface. The final smoothing can then be done by a flat brush.
- Varnish brushes are basic tools for applying and smoothing varnishes and paints. They are rectangular.
- Flat brushes are thin, rectangular brushes, meant for the final smoothing of surfaces painted with roller or spray gun. Solvent-borne Fireflex intumescent paint
- Special brushes with long, angled shafts are used for surfaces which are difficult to reach with normal equipment.
- Oil paint brushes are made of stiff, special bristles and are designed for applying thick oil paints. They are also suitable for the application of many anti-corrosive paints.
- Brushes made of synthetic material such as polyamide (nylon) or polyester, with bristles with thinned or split ends, are specially suitable for water-borne paints.

## 6.2 Roller application

Protective coatings are seldom applied by rollers. The rollers leave an uneven surface and some type of paints will 'froth' if they are applied by roller. Protective coatings are seldom formulated so that a good finish is possible to achieve by roller. Paint rollers are manufactured for several different purposes and of many materials

(polyester, acrylic, mohair, lamb pelt). When choosing a roller, as with choice of brush, you have to consider the properties of the product and the properties of the object, surface roughness, porosity, dimensions etc. Roller is often used a preliminary paint spreading, the final smoothing then being done by brush.

## 6.3 Conventional spray

It should be noted that the whole modern spray application technique began with the conventional spray method (also called low pressure, can, air etc. spraying). The principle of the method is that the paint is atomized using low pressure compressed air, and there are several different methods used to apply the paint in this way. Dr. Allen DeVilbiss is usually named as the inventor of this method, as he developed the first liquid spray gun as early as the nineteenth century. His intention was not to apply paint, but to spray medicine into the throat and nose of a patient. On basis of this spray guns for painting were developed some years later. The furniture and automotive industry were the first to use these spray guns.

### 6.3.1 The breakthrough of the spray application technique

However, the technical evolution of spray paint application was rather slow. The real breakthrough came when new, fast drying paints became available. When it was decided that the new fast dry paints, together with spray application, should be used in the production of a car model in Oakland in 1924, the conventional spraying method finally consolidated its position in industry. The demands of the automotive industry still strongly affect spray equipment development. Hardly any section of the metal painting industry has such high demands on the appearance and finish of a paint as the automotive industry. Conventional spraying is still one of the most common paint application method for cars. Many small companies also use conventional spray for industrial coating work, as the equipment is cheap to buy.



### 6.3.2 Advantages and disadvantages of conventional spraying

Below are some of the advantages of conventional spray:

- high quality of finish
- small amounts of paint can be sprayed, so only small quantities of special colours are needed
- can be used for different forms, types and dimensions of objects
- low investment and usage expenses
- fast regulation of the spray fan and the amount of paint used
- suitable for water-borne products

Disadvantages with conventional spraying include the following:

- low capacity, slower application
- can only spray thin paints (recommended spray viscosity 15–30 seconds DIN4 for solvent-borne paints, depending on the type of paint and spray gun)
- each application therefore gives a thin coat
- huge solvent use compared to airless spray
- heavy environmental disadvantage

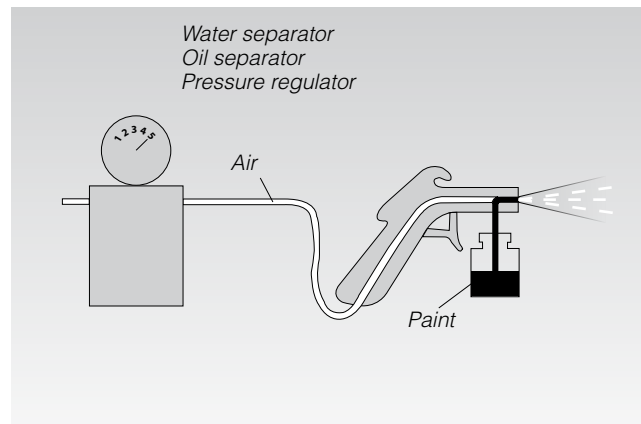
### 6.3.3 Conventional spray guns

Conventional spray guns can be divided into two groups depending on the way they are fed - by pressure or by suction. Equipment which is fed by suction is often called 'container spray' because the paint reservoir is fixed to the spray gun itself, either above the gun or below it. The nozzle of the spray gun is formed so that they create a low pressure area at the tip, which sucks the paint from the reservoir. The amount of paint which leaves the spray gun depends on the size of the nozzle, the quantity of air and the viscosity of the product.

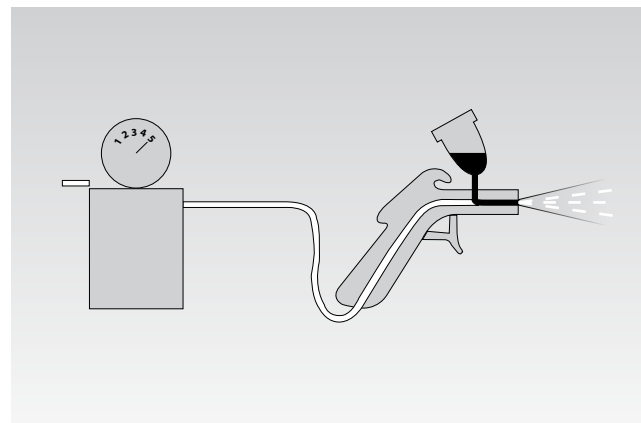
In pressure fed equipment the paint is "forced" into the spray gun by air pressure (so-called 'pressure pot') or by a pump. The relation between the flow of paint and the atomisation can then be regulated independently from each other. In continuous production pressure feed is recommended. A wide range of nozzle sizes are available for pressure fed spray guns, which give a range of different effects and are suitable for various paint types and viscosities.

### 6.3.4 Combination of nozzles for conventional spraying

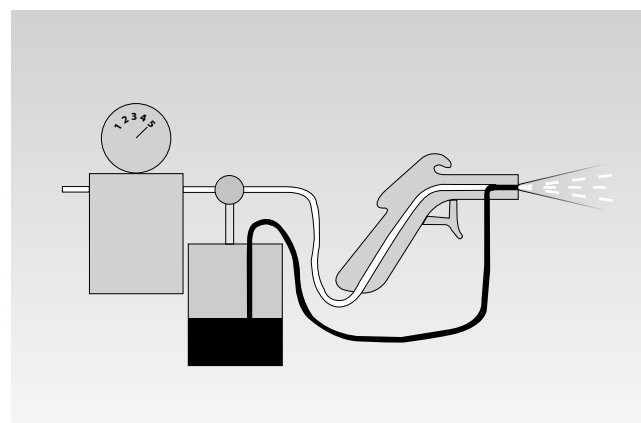
The most important part of the conventional spray gun is the combination of nozzles. It will determine what result you can achieve with the spray gun. The combination consists of the paint nozzle, the needle and the air nozzle. The properties of the paint and the dimensions



Picture 7. Suction fed spray gun, reservoir beneath gun.



Picture 8. Suction fed spray gun, reservoir above gun.



Picture 9. Pressure fed spray gun with a pressurized container. The paint flow is achieved by membrane, piston or gear pump.

and shape of the object will also affect the choice of paint nozzle.

If too much paint is fed through a small nozzle, the flow speed of the paint will be so high that the paint will not atomise correctly. The result is a paint fan which is heavy in the middle (this may also cause air bubbles in the coat). The opposite, too low a flow of paint through too big a nozzle, will cause too much atomisation and too 'thin' spray fan.

Which kind of air nozzle should be chosen is dependant on the amount of paint, its viscosity and its atomising properties. The efficiency of the air nozzle is dependant on the air flow, the number of air holes, the size of the angles, and the distance to the point where the air and the paint flows meet.

The closer to the paint nozzle that the air and the paint flow meet, the more efficient is the atomisation. This also means that the risk of contamination of the nozzle is greater. An efficient air nozzle consumes on average about 300–400 litres of air per minute when the pressure is 2–4 bar. For paints which atomise easily, a nozzle which consumes less air and therefore causes less paint mist, is suitable.

The choice of the air and paint nozzles have an effect both on the working environment and the application result. A correctly adjusted pressure spraying gun causes less paint 'overspray' (paint which has dried in the air before reaching the object being sprayed, and falls to the ground as dust) than a suction fed spraying gun. The amount of air can be separately adjusted to the lowest level possible in order to achieve the degree of finish required. There are also two adjustments possible on the spray gun. One regulates the width of the spray fan, while the other adjusts the degree of opening of the 'needle', which affects the paint flow.

A very common mistake is that the amount of the spray is decreased by the needle. This causes a friction between the nozzle and the needle which wears both of them rapidly. A better solution would be to use a smaller paint nozzle.

### 6.3.5 Improvement of transfer efficiency

In addition to the paints themselves, it is also necessary to continually develop application methods, in order to reduce the environmental impact of paint application.

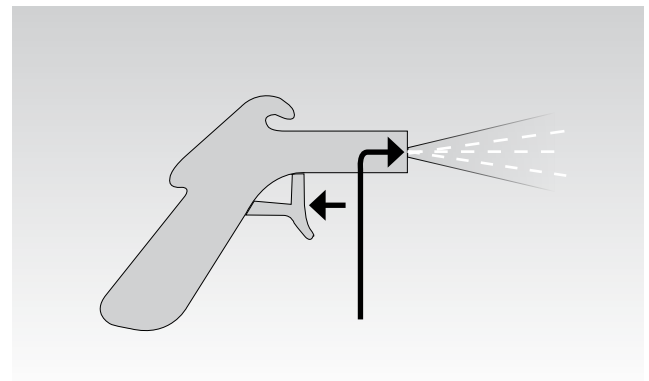
A disadvantage of conventional spraying is its low transfer efficiency. This is defined as the percentage of paint solids which end up adhering to the object.

The most efficient way to increase the transfer efficiency is to use electrostatic equipment. Another way is to use the so called HVLP (High Volume Low Pressure) spraying equipment, where the pressure is considerably

lower than in normal conventional spraying equipment. The transfer efficiency can also be improved by heating the paint and the air.

## 6.4 Airless spraying

Today, airless spray is the most common method in work shops, shipyards and the protective coatings industry generally. It is also used for painting wooden surfaces, product painting in the wood industry and for construction painting.



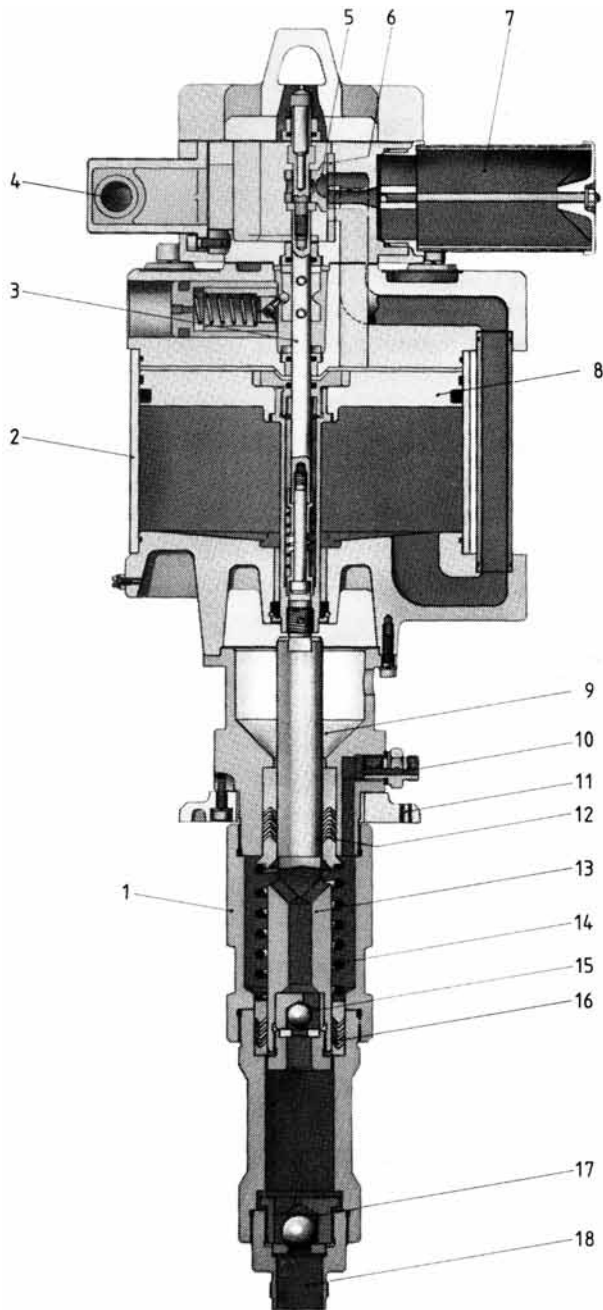
Picture 10. Airless spray gun.

### 6.4.1 The principle of airless spraying

In airless spraying the paint is fed by high pressure, through a pressure resistant hose, to the spray gun, where the paint is forced through a narrow, hard, metal nozzle. The paint is atomised due to the air resistance and arising pressure difference, and the shape of the nozzle orifice.

The paint pressure is achieved by a piston or membrane pump. The power can be pneumatic, electric, internal combustion engine or a hydraulic piston pump. Picture 11 shows an airless spraying outfit powered by a pneumatic piston pump. Because no compressed air is used in the atomising of the paint, as with conventional spray, the method is called 'airless'.

A pneumatic airless spray gun consists of an air motor and a feed pump for the paint. The relation between the cross-sectional areas of the plungers of the air motor and the paint pump describes the pressure relation of the spraying system. E.g. a pump with the pressure ratio of 40:1 gives a pressure of 200 bar at the spray nozzle when the pressure of the compressed air is 5 bar. The final pressure in the nozzle depends also on the length and diameter of the hose, the number and position of the filters (to remove any bits from the paint which may block the very fine spray nozzle), the size of the nozzle, the type of paint and its viscosity and temperature.



Picture 11. Airless spray gun, construction.

- |                            |                       |
|----------------------------|-----------------------|
| 1. Paint pump              | 2. Air motor          |
| 3. Direction reverse valve | 4. Air intake         |
| 5. Valve tap               | 6. Valve disk         |
| 7. Silencer                | 8. Air piston         |
| 9. Lubricating oil cup     | 10. Paint output      |
| 11. Clasp seat             | 12. Upper packing     |
| 13. Paint piston           | 14. Pressure spring * |
| 15. Output ball valve *    | 16. Lower packing     |
| 17. Input ball valve       | 18. Paint input       |

\* Size and weight of the ball has to be sufficient when using products with high viscosity.

When choosing the airless spray gun, attention should also be paid to the required throughput, measured in litres per minute. Too low a throughput limits the use of bigger nozzles even if the pressure relation is big enough. This is noticed as cyclic changes in the width of the spray fan. Also, if the litre capacity of the pump is small, it will wear out faster.

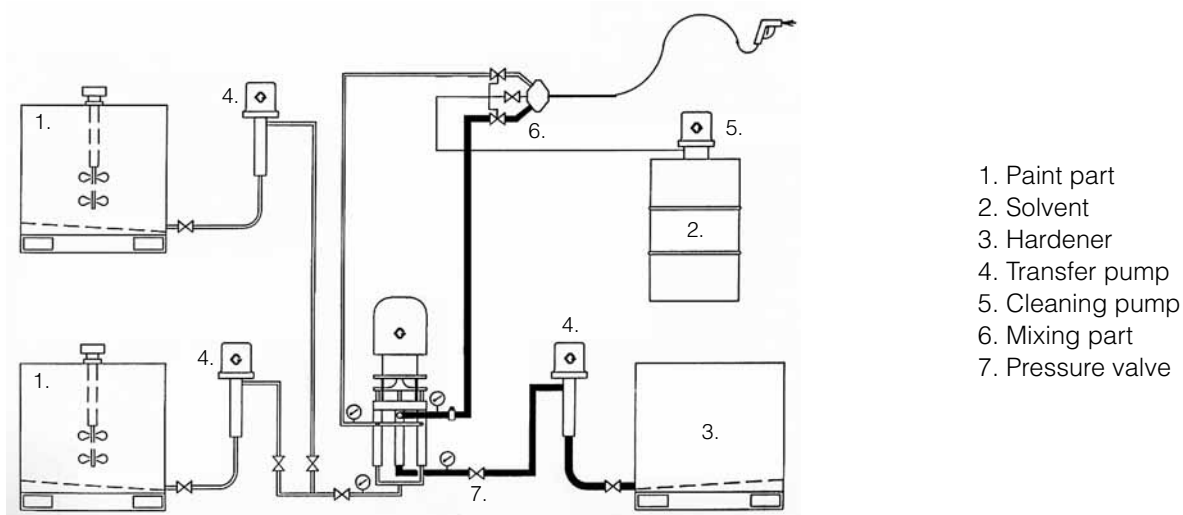
When adjusting the pressure you should always try to find the lowest pressure which is sufficient to atomise the paint. Too high a pressure stresses the gun and hoses and increases paint wasted as 'over-spray'. Thixotropic epoxy, coal-tar and chlorinated rubber paints also need higher pressures. Solvent-free epoxy, polyurethane and polyester coatings need very high nozzle pressures up to 200–300 bar in order to get good atomisation. Too low a pressure, or a too thick paint in relation to the pressure, will be clearly noticed by the spray fan having a stripy appearance, known as 'fingering'. By heating or thinning in accordance with the paint suppliers recommendations, the need for high pressures can be reduced to a more workable level.

#### 6.4.2 Two component airless spray equipment

When the solvent-free epoxy and polyurethane coatings appeared on the market, spray equipment manufacturers began to develop different types of two component airless spraying equipment. This was necessary because these kinds of products have a very short pot-life, perhaps only a few minutes. They are also too viscous, at room temperature, to atomise at normal pressures. Therefore the two component spray systems are often equipped with paint heaters. The fluid hoses are also insulated and kept as short as possible, to prevent the paint cooling before it reaches the spray gun. Only a few metres of fluid hose near the gun is left uninsulated and flexible, in order to make it possible to handle it. Two component spraying outfits should always be supplied with feed pumps.

Such 'twin feed' spray equipment saves material, because the two components only get mixed at the spray gun – up to then, they are separate, and therefore cannot react together. Because of this advantage, two component equipment is becoming more common even for the application of typical water-borne and solvent-borne epoxy and polyurethane paints, specially in painting shops where large volumes of paint are applied.

These two component spraying machines are based on firm mixing ratios, where the proportion is achieved by two or three cylinders of certain volume. By changing the volume of the cylinders, it is possible to choose the



Picture 12. Two component spraying equipment based on fixed mixing ratio, outline.

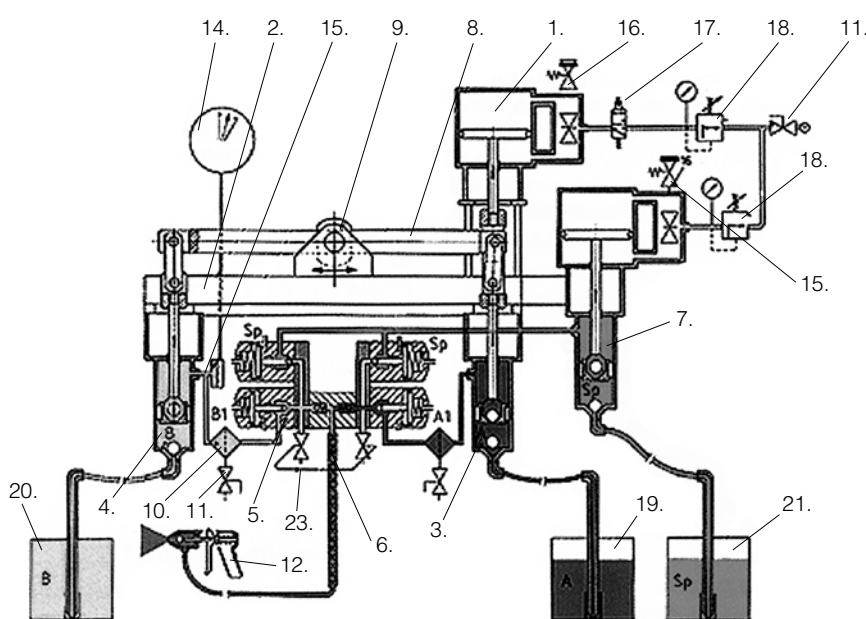
mixing ratio e.g. 1:1, 1:2, 1:3 and 1:4. Some models of equipment have an adjustable mixing ratio, which can be regulated by adjusting the length of the cylinder stroke. In both types, the cylinders are powered by a pneumatic motor of high efficiency.

Usually the two outer cylinders pump the so called 'base' component of the paint, with the middle cylinder pumping the 'hardener' component, which usually has a lower viscosity. In this way the strain on the equipment is divided more evenly. From these cylinders, the paint components move into separate hoses, and travel to a mixing unit at the spray gun, where they are mixed together and the curing reaction begins. Because the pot-life of the products is short, especially for solvent-free products where the components are heated, no hold-ups can be allowed during the application work without immediately flushing out the mixing unit with solvent.

Advantages of two component spraying equipment:

- the mixing ratio is always correct
- the mixing is uniform
- less need for cleaning solvents
- shorter cleaning time
- because the system is closed the solvent emissions are smaller
- improvement in working safety
- possibility to supply paint in bigger containers
- less waste of paint
- two component outfits are very economic in large scale, routine production, especially if the same colours are used continuously

1. Air motor
2. Chassis
3. Base
4. Hardener
5. Valve unit
6. Mixing unit
7. Cleaning pump
8. Adjusting shaft for pumps
9. Bearing
10. Airless spraying filter
11. Ball valve
12. Spray gun
13. Mixing ratio control unit
14. Manometer (pressure gauge)
15. Pressure valve
16. Pressure relief valve
17. Compressed air valve
18. Air regulator
19. Paint container A (base)
20. Paint container B (hardener)
21. Container for cleaning agent



Picture 13. Infinitely variable two component spraying equipment, outline.

### 6.4.3 Advantages and disadvantages of airless spraying

Airless spraying has a higher production rate and less need of thinning when compared to other application methods. Coatings can be applied in thick coats (up to more than 500 microns) so that the specified total film thickness can be achieved in fewer coats than by conventional spraying or brush. Disadvantages include the difficulty in avoiding sagging, especially for complicated constructions, and the high investment cost for the equipment.

It is not possible to adjust the spray fan on the airless spray gun itself, this must be done by choosing a suitable nozzle. Finer adjustment is achieved by regulating the viscosity of the product and in adjusting the pressure. Adjustable nozzles are available where the width of the spray can be regulated immediately. They are however mainly suitable for application of high build coatings, for surfaces where the demands on the finish are not so high.

### 6.4.4 Heated airless spraying

The hot airless spray was patented by the Dane, James Bede, after the second world war. The American brothers Eric and Ewan Nord bought the rights to the patent in 1949 and developed the existing hot airless method during the 1950's. Most spray equipment manufacturers nowadays supply hot airless spraying equipment. They are very popular for product painting and protective coating contractors have also begun to use hot airless spray equipment.

The purchase price of hot airless spray equipment is about twice that of normal airless spraying equipment. The method can easily be complimented with electrostatic facilities.

#### 6.4.4.1 Why heat the paint?

By heating the paint the viscosity decreases, which reduces the need for thinning and spraying pressure, and improves the spraying efficiency. When the paint leaves the nozzle the solvents evaporate rapidly and at the same time the temperature of the atomized paint falls quickly. When the paint is heated, atomisation can be achieved with lower pressure when compared to usual airless spraying. When spraying with lower pressure, the speed of the heated paint is lower and it is easier to direct the spray. The paint also does not sag so easily and you can achieve higher builds than without heating. Below are some of the advantages of heating the paint for the user:

- you will save paint
- you will get a better painting result
- less cleaning of the paint reservoir
- the cleanness and the work safety increases
- less wear of the pumps
- longer life time for the nozzles

Sometimes it is a disadvantage to heat the paint too much. When painting large, complex constructions, e.g. cranes, the 'over spray' (paint dust) which falls down on already painted surfaces does not dissolve into the coat, but instead forms a "sand paper surface". This can be avoided by using slower evaporating solvents so that the surface remains wet during the painting work.

Also, when overheated, some paints may gel or pinholes may appear in the paint film. It is usually advisable to consult the paint supplier before heating any paint, particularly water-borne materials.

#### 6.4.4.2 The principle and use of heated airless spray

The essential parts of airless spray equipment consists of the paint pump, the paint heater, the filter and the paint circulating system. The filter should always be chosen in accordance with the size of the actual nozzle, in order to avoid blockages. There are two kinds of heaters, direct electric heaters, and indirect heaters, where a liquid (water) is heated by electricity and the liquid then heats the paint.

In high pressure systems the heaters should have good pressure resistance, and the maximum operating pressures vary, depending on different manufacturers and purposes, between 105–300 bar.

The temperature of the paint is regulated by a variable thermostat and paint temperatures are generally set between 30–90°C. The heaters are equipped with a mechanical overheating regulator, in order to prevent overheating of the paint in case of equipment breakdown.

In all spraying applications you should try to spray with the lowest possible pressure in order to avoid too much overspray. Too often you notice the attitude "all valves open". Where there is a need for more paint, a bigger nozzle should be chosen.

In a return-circulating system, there is a hose for the paint to flow back from the spray gun which will have a return valve, making it possible to adjust or shut as required. This circulation makes it possible to continue spraying immediately after a pause, as the paint keeps its temperature so there is no need to increase the pressure.

Compared to usual airless spray, the paint atomises at lower pressures when using heated airless spray.

### 6.4.5 Airless spraying nozzles

The type of paint, the coating thickness required and the size and shape of the object, all have an influence on the choice of nozzle. There are mainly two types of nozzles, fan nozzles and round nozzles. The round nozzles are generally used only in connection with electrostatic spraying.

The innermost part of the airless spraying nozzle consists generally of a hard metal, which makes it very resistant against wear. In the nozzle is a hole, the dimensions of which vary depending on the item being sprayed and the type of paint. The dimensions are stated as thousandths of an inch, or 'thou'. The size of the hole is chosen depending on the required film thickness and the type of paint; e.g. glossy topcoats are sprayed with nozzles of size 0.011"–0.015" (11–15 thou), but epoxy primers or high build materials use nozzles of size 0.015"–0.026" (15–26 thou). Larger nozzles would also be used for primers and topcoats with high viscosity such as chlorinated rubber, modified epoxy resin paints and vinyl tar paints. Special coatings which contain large, special pigments will also require larger nozzles.

Another important factor when the nozzle is chosen is the nominal angle of the nozzle, which will determine the width of the paint spray fan. (Table 5.) For painting of small cross items, nozzles with small angles, 20–30°, are used in order to avoid excessive overspray. Angles below 30° may cause air bubbles in the paint coating when glossy products are applied. When large flat surfaces are painted by automatic spray equipment, a nozzle with an angle of 90° is used. A good nozzle for general use has an angle of 40°.

Though a new spray nozzle may have acceptable properties when first used, its properties will change with time because of wear. It is therefore necessary to continually check the properties of the nozzle, e.g. by comparing it with a similar unused nozzle, and replace it when necessary. Painting with a worn nozzle can cause poor spraying and impairs the finish, especially when glossy products are applied.

Besides normal hard metal nozzles, adjustable nozzles are also available, which have variable orifices capable of adjustment within certain limits. In this case the amount of paint flow and the form of the spray fan can be changed according to the actual need. Most airless spray nozzles which are not variable, are made to be reversible. A reversible nozzle, installed into a ball or cylinder, can be turned around within the gun housing, so that by pressing the trigger, any blockage in the nozzle can be "blown away", after which the cleaned nozzle





Relative diameter of the nozzle	The nominal angle of the spray	The form of the spray	Painted surface
Ø 0,015" (0,380mm)	40°		 ①
Ø 0,015" (0,380mm)	80°		 ②
<ul style="list-style-type: none"> <li>• From the surfaces ① and ② you can notice how the spray angle affects the coat thickness when the spraying speed is the same, and the amount of paint is the same.</li> <li>• The larger the spreading angle, the tighter the filter should be.</li> <li>• E.g. the nozzles above, that with an angle of 40° needs a shaft filter of 0.310mm and that with an angle of 80° 0.150mm.</li> </ul>			

Table 5. The influence of the angle when spraying.

can be turned back to the spraying position. This type of nozzle is essential for most users, especially when rougher products are applied, because the cleaning of a reversible nozzle is fast and easy.

### 6.4.6 Air-assisted airless spraying

In air-assisted airless spraying, both the conventional and the airless spraying methods are utilized. In this method, atomising air is used to adjust the spray fan. Generally pumps with a pressure ratio of 25:1–60:1 are used. The pressure in the nozzle is 80–250 bar and the pressure of the atomising air about 1–3 bar. (Air consumption is around 50–100 l/min) The method can easily be improved further by using electrostatic spraying.

### 6.4.7 Spray application technique

The basic elements of the spray application are set through the choice of the spraying equipment and type of paint. Because airless spray causes less waste and overspray than conventional spraying, it is the general application method used for most protective coating work.

The parameters of the spray equipment should be set in accordance with what the particular coating requires. Before application you should confirm what pressure and nozzle the paint supplier recommends.

Before application, check which is the best way to direct the spray gun. A careful preliminary planning of working methods will save costs and can considerably improve application efficiency.

#### 6.4.7.1 Use of the trigger of the spray gun

You should pay special attention as to how to handle the trigger, so that the paint spray is interrupted at the appropriate moment. Paint will tend to accumulate at the

edges of the spray fan, so the edges of the fan are often positioned outside of the area to be sprayed when first triggering the gun.

#### 6.4.7.2 The relation between speed and distance of the spray gun

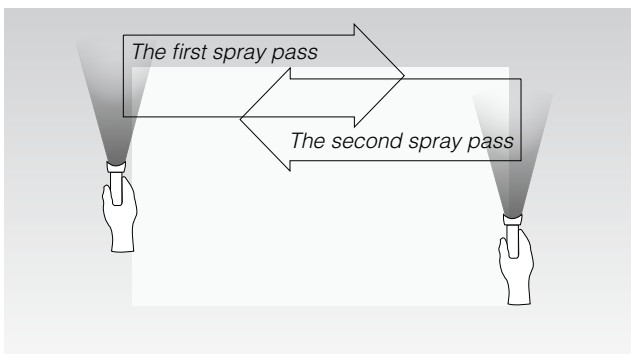
A correct relation between the distance from the surface and the spraying speed is something the painter learns only by training. For different painters, this relation will vary. It is important to check that there is enough paint all over the surface, as too little paint can cause a rough finish, with too much paint causing sagging on vertical surfaces.

#### 6.4.7.3 Spraying of plain, flat surfaces (sheets)

When spraying a plain sheet, start the spraying 'pass' just before the sheet edge, and stop the spraying pass just after the other sheet edge.

Usually the application is done as straight, even passes, so that one pass overlaps about 50% of the former pass. The nearer to the surface the spray gun is, the more paint is applied, so the spray gun has to be moved faster in order to avoid sagging. If the spray gun is held too far from the surface, it will cause a too much overspray and the paint may be too 'dry' when it hits the surface to form a proper film.

Appropriate use of the spray gun is essential in the spraying application technique. It is important to immediately hit the edge of the object and reach a sufficient paint coat without wasting paint.



Picture 14. Spraying of a plain surface. The later spray pass should always cover about 50% of the previous pass.

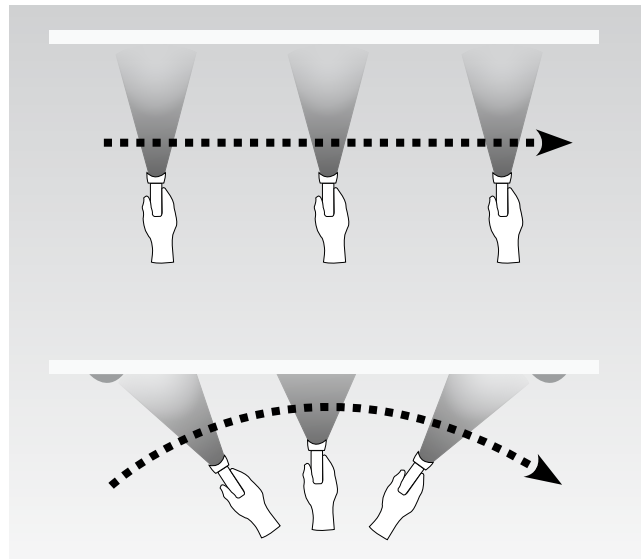
#### 6.4.7.4 Spraying long pieces

Long pieces are here defined as pieces which cannot be sprayed in one continuous pass, and where several overlapping passes are therefore required, end to end. Long pieces are divided into 0.6 – 1.5 metres sections and the same spraying technique as for other surfaces

is used, for every section, ensuring sufficient overlap. This application technique is also practised for large, uniform surfaces, as roofs and walls.

#### 6.4.7.5 The distance of the object and the spray gun

The spraying should be done keeping a so called 'standard distance' between the spray gun and the object. If the spray gun is too near the surface, too much paint will gather on a small area and cause sagging if the spray gun is not moved fast enough. The spraying distance for conventional spraying is about 150–300 mm, and about 200–400mm for airless spraying. The distance should be kept constant for the whole surface. The spray gun should not be moved in a curve, as this will constantly vary the spraying distance and give poor results.



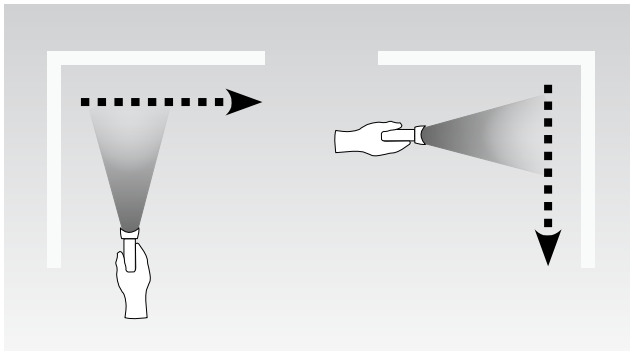
Picture 15. The spray gun should always be kept perpendicular to the surface (the upper picture). If the spray gun is turned so that the angle changes, the coat becomes uneven. Overspray occurs at the edges.

#### 6.4.7.6 Spraying corners and difficult areas

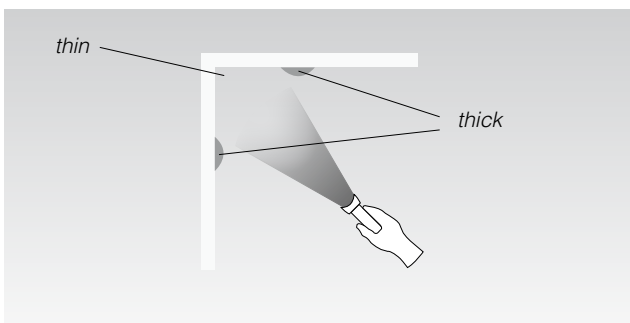
When a corner or cavity is painted, it should be done so that the plain surfaces are sprayed separately. If you try to paint a corner by directing the spray perpendicularly at the corner, the paint will spread unevenly and some sagging is highly likely.

Edges and corners (outer) are sprayed perpendicular and after that the plain surfaces as described above.

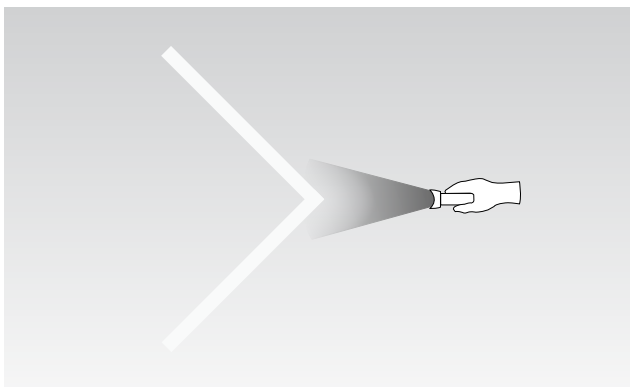




Picture 16. When painting a corner both sides should be sprayed perpendicularly advancing from the corner, or vertically according to the object.



Picture 17. Wrong direction of the spray gun, the result is not even.



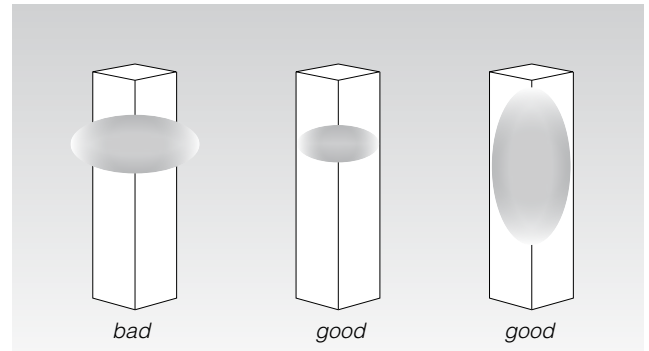
Picture 18. The correct direction when a corner is sprayed.

#### 6.4.7.7 Spraying narrow objects

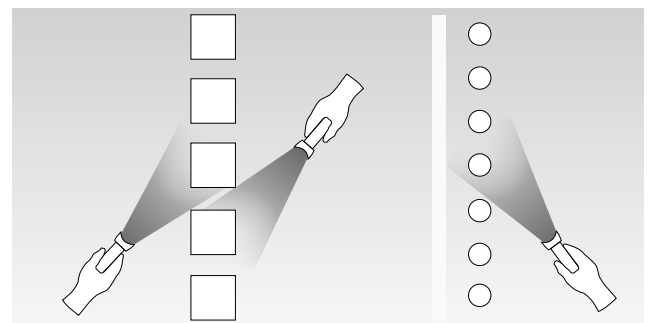
The spray fan width should be determined by the object. For a narrow vertical beam, a wide spray fan is not suitable, it should be a narrow spray fan, which will cover well and not cause unnecessary overspray. Very narrow spray fans should be avoided, as they require great skill to avoid frequent sagging.

#### 6.4.7.8 Spraying complicated objects

When spraying mesh-like surfaces, such as gratings or similar, the spraying direction should be chosen so that as large an area as possible would be covered by one



Picture 19. The waste overspray is reduced when the paint spray is set to be suitable for the actual object. The best technique is shown in the middle.



Picture 20. Spraying of a mesh-like object.

paint spray pass. When a mesh-like object is sprayed, a background sheet should be used, which will reduce overspray and partly direct some of the paint onto the back of the item. When big, complicated constructions are painted by spraying, it is important to plan in advance the sequence of application, in order to avoid overspraying and ruining freshly applied coating.

#### 6.4.8 Airless spraying – safety precautions

When airless spray equipment is used, it is necessary to carefully study all safety instructions and follow them strictly.

Stipulations according to location, space, ventilation, etc., should be checked with regulations laid down by local authorities.

In airless spraying, the flow of liquid causes friction, which can cause build up of electrostatic charge and the risk of sparking. In order to eliminate the risk of explosion you should always ensure that the equipment is connected to earth. If there is any doubt, the equipment, the item being sprayed and the spray gun, should all be earthed by a separate cable.

The exhaust air from the air pump should be lead away from the working spaces, in order to avoid oil mist in the working environment near the item being sprayed.



When airless spraying, there are always particles of paint and solvents in the air, which are harmful for the health. Suitable masks should always therefore be used, including when using water-borne paints.

Pay attention to the spray fan. NEVER direct it towards anybody or yourself, as the high pressure can cause severe injuries.

All components of the equipment, the hoses, the spray gun, the connections etc. should be suitable for use with the maximum working pressure which is used.

Handle the high pressure hoses with care, they should not be bent in a radius below 20cm in case they become cracked or split.

Before investigating any problems with airless spray equipment or when changing the nozzle, ensure that the pressure has been relieved from the spray gun, all the lines and other equipment, before trying to identify the problem.

## 6.5 Electrostatic spraying

In electrostatic spraying the paint is electrically charged in the spray gun. The object is connected to the earth and so it forms an anti-pole. The paint particles move along the electromagnetic power lines in the electric field towards and around the object. The advantages of this method are reduced waste and more efficient coverage of small pieces.

The power of the electric field depends on factors including:

**The distance between the spray gun and the object, and the voltage.** The object is connected to the earth and the voltage difference is attained by charging the paint particles at the tip of the spray gun. Depending on the equipment, a voltage of 30–90kV is adopted in the spray gun (manual spray guns ).

**The spraying distance.** In principle, the shorter the distance, the stronger the electric field. In practice however, it is not useful to put the spray gun too near the object, and the same distances as in normal spraying are used. In some equipment the voltage can be adjusted depending on the spraying distance.

**The kinetic energy of the sprayed paint.** The lesser the kinetic energy, the better possibilities the voltage difference has to overcome this kinetic energy and thus direct the paint particles 'around' the object. The paint particles should be as small as possible, that is, of minimum mass. More important is to slow down the speed of the paint particles, which will also improve the basic efficiency of the process.

**The electric properties of the paint.** The paint or varnish should conduct electricity fairly well, but should

also have sufficient resistance properties. Usually the conductive properties of the paint are determined by a resistance gauge, and when necessary, adjusted to the required value by adding special solvents.

**The form and the construction of the object.** Electrostatic spraying is influenced by the so called 'Faraday effect'. The paint particles try to move along the power fields to the nearest surface, and this causes difficulties for the paint to reach inner cavities, which tend to be 'sheltered' by their surroundings.

**The ventilation of the spraying space.** For electrostatic spraying the air current in the spraying booth should not exceed 0.5 metres per second. If the air current is too strong, the spraying efficiency decreases, because the flowing air removes the lighter paint particles.

**Earthing.** The earth connection should always be made efficiently. The spraying line and the hanging hooks should be cleaned often to prevent insulating paint build-up. Insufficient earthing decreases the application efficiency and may also cause danger of fire. Paints with highly flammable solvents are not recommended for electrostatic spraying.

### 6.5.1 Electrostatic centrifugal method

In this method the paint is fed into a rotating disk, with a speed of about 5000–80000rpm. Due to the centrifugal force, the paint moves to the edge of the disk where it atomises and is electrically charged. In this equipment compressed air is used to support to direct the paint mist into required direction. The transfer efficiency is very good, up to 95%. The method is generally used for production line application and is also suitable for water-borne products. In this case the whole system, including the paint hoses, should be isolated.

### 6.5.2 Electrostatic conventional spraying

Electrostatic conventional spraying is suitable for painting of smaller, mixed items. Normally you achieve an efficiency of 100–300ml/min together with the advantages of conventional spraying, e.g. a very good finish. Furthermore the static electricity reduces the waste overspray, which is a typical factor in conventional spraying. This method is also suitable for water-borne paints. In this case the whole system, including the paint hoses, should be isolated.

### 6.5.3 Electrostatic airless spraying

Electrostatic airless spraying is a suitable method for large painting operations and, compared to electrostatic conventional spraying, it gives better results when painting enclosed items. There are separate switches

on the spray gun, and the electricity can be switched off so that the equipment can then act like a normal airless spray. The method can be used with heating and air assisted airless spraying, to give an electrostatic, heated, air assisted airless spray. The method is also suitable for water-borne paints. In this case the whole system, including the paint hoses, should be isolated.

## 6.6 Automatic spraying equipment

As with other production line methods, surface treatment can be carried out automatically. An automatic method of spray application is ideal when long series of similar objects have to be treated. The spraying method depends on the form and the material of the object and on which type of paint is used. The most important requirement for the automatic equipment is how reliable it is.

Advantages of automatic spraying include:

- big capacity
- uniform quality
- lower labour expenses
- low paint wastage
- a better working environment

The most common type of automatic spray plane is reciprocator beam spraying system. These can be used together with nearly all known spraying methods.

- An reciprocator beam is an apparatus which linearly moves the spray guns from side to side or up and down, with a fixed speed. The items to be painted pass on a conveyor below the spray guns. Usually the moving distance and the transfer speed of the reciprocator beam can be adjusted. Generally the distances of the spray guns are adjusted manually. The reciprocator beams are of two kinds, vertical and horizontal.

Generally one or two automatic spray guns are installed in the vertical reciprocator beam, of which there can be several, one after the other. Usually they are equipped with electrostatic facilities. The speed of the conveyor line varies, 1–3 metres per minute being typical.

Horizontal reciprocator beams are generally equipped with four spray guns and the speed of the line varies between 1.5 to 9 metres per minute.

## 6.7 Robot-operated spraying techniques

A spraying robot is a good solution for narrow spaces and when consistent, high quality finish is required. Nowadays there are robots which are purpose-built for painting. The robots are, as standard, supplied with software in order to assist the manual learning program. Usually, an experienced sprayer will program the robot how to spray a particular item best, and the robot's software will record this process. The programs can be adjusted as necessary.

The most important criteria when considering the use of robot-operated spraying techniques are their line accuracy, the repetition of speed, the work load and their reach.

## 6.8 Dip coating

The dip coating method is simple. It must however be expected that some sagging and dripping will occur in the dried paint film. The viscosity of the paint has an essential influence on the finish. The viscosity of paint in the dip tank should be checked daily. Water-borne paints, which are usually very suitable for dip coating, should also be checked for pH.

The advantages of this method are:

- good coverage
- rapidity
- suitable for items which cannot be sprayed
- water-borne dip coatings are safe and favourable from labour and environmental points of view
- saves paint

The disadvantages of this method are:

- the required tanks are huge and there is a need for big amounts of paint
- the paint circulates slowly, so there may be a risk of gelling
- you reach a dry film thickness of only 30–50µm by one dipping and the coat thickness is thinner at the upper parts of the object
- the paint can be contaminated by dirt and grease from the objects
- there should not be any cavities in the object which could retain liquid paint
- not suitable for two component products
- small, light pieces do not sink into the tank
- usually there should be a continuous circulation in the tank in order to avoid settlement of paint solids
- sometimes there is a need for a heater in order to keep an even temperature

## 6.9 Curtain coating

Curtain coating, or flood coating, is similar to very low pressure airless spray, but without a spray fan. Paint is simply pumped at low pressure through a simple orifice and essentially 'poured' over the item to be painted. The item is positioned in a container, from which excess paint can be recycled into the pumping system. The finish of curtain coating is almost the same as for dip coating. The application can be done manually or automatically. When solvent-borne paints are used, the curtain coating space should be isolated from the other working environments and equipped with sufficient ventilation.

## 6.10 Powder coating

Powder coating requires application equipment which is different to that required for wet paints. Powder coating also requires an oven treatment at a temperature of around 150–200C°.

During application, the powder particles are electrostatically charged in order to deliver powder particle onto the surface of the component. The waste sprayed powder can be recirculated and used again. The powder coating equipment consists of a powder container, a powder pump, a steering unit and a spray gun. The spray guns are high voltage or friction charged, and can be manual or automatic. The powder container has two functions, store the powder and to keep it 'fluid' as a mixture with air. The air which is used for the suspension and the circulation of the powder should be dry and free from oil in order to avoid packing of the powder.

Powder coating is the most expensive application method in terms of initial investment costs. The heat curing requires a lot of energy and it is not economically viable for large, complicated items, or for objects which cannot be heated. One major advantage however is that it is solvent-free.

# 7. Application conditions

The pretreatment and application work has to be done in accordance with the paint manufacturer's instructions. Application conditions depend on the temperature of the object to be painted and the ambient air, air conditioning and on the relative humidity of the air. These factors are also affecting the drying line and quality of the surface during the drying of the coating.

## 7.1 The influence of humidity and temperature

The influence of the relative humidity of the air on the application properties and the drying of a paint coating varies depending on the type of paint. A general rule is that the relative humidity and the temperatures of the air, the substrate and the paint itself should be at least equal to those given in the product data sheets. Generally the relative humidity should not exceed 80% when solvent-borne paints are used.

When water-borne paints are used the recommendation is that the relative humidity should be within the range of 20–70%. Too high humidity affects the drying of the paint and increases the sensitivity for sagging. Too low relative humidity may cause problems with the film forming properties of the coating.

On clean, shiny metal surfaces, water vapour condenses onto the surface when the relative humidity of the air is 100%. On rough or dirty surfaces, condensation can occur at a considerably lower relative humidity. A blastcleaned steel surface begins to corrode when the relative humidity of the air is 60–70%. That is why blasting should be done in conditions where the relative humidity of the air is low. A blast cleaned surface should be painted immediately after blasting in order to avoid surface corrosion.

When the temperature of a metal surface is lower than the temperature of the surrounding air, condensation can occur even if the relative humidity of the air is low. It is therefore important that the temperature of the metal surface exceeds the dew point by at least 3°C. The dew point is that temperature to which the air has to be chilled so that the relative humidity reaches 100%.

When the temperature of the air is below 0°C it must be ensured that there is no ice on the substrate. The humidity conditions in the environment can be improved by heating or by drying the air (dehumidification).

## 7.2 The influence of temperature on the film forming properties of the coating

Temperature has a considerable influence on the drying of a paint film and the formation of the coating layer. A rule of thumb is that the higher the temperature, the faster the drying. The drying of chemically cured paints in particular increases considerably at higher temperatures.

Low temperatures can cause problems which include:

- viscosity
- application properties (spray ability)
- drying and film formation
- cross-linking (curing)
- resistance or the protective properties of the coating

At lower temperatures, the viscosity of the paint increases considerably, and this can mean that the paint has to be diluted considerably in order to be applicable. This can lead to sagging and low dry film thickness. Especially with water-borne products, adding thinner may slow down the drying time.

Physically drying paints, such as chlorinated rubber, vinyl, bituminous paints and ethyl silicate paints, can dry even when the temperature is below zero. During such conditions however, the paints should be stored in a warm area prior to use in order to avoid thinning and low dft.

Alkyd and oil resin paints, which dry by oxidation, dry very slowly at low temperatures. Painting with alkyd paints should be avoided when the temperature is below +5°C.

The rate of cross-linking of epoxy paints is the slower the lower the temperature is. Many epoxy paints may appear dry when the solvents have evaporated, but full resistance will not be reached until the coating has chemically cured, which can take a very long time at lower temperatures. Overcoating times in multicoat systems should be extended at lower temperatures.

By using so called 'winter grade' quality hardeners, it is possible to get epoxy paints to cure in lower temperatures, down to -5°C.

Water-borne paints generally require a temperature of at least +15°C, and preferably +20°C, in order to allow water evaporate properly and therefore to achieve a good film formation.

Too high temperatures may also cause problems. At a high temperature and with effective ventilation, solvents may evaporate too rapidly from the paint surface. The coating therefore dries too fast and forms a surface 'skin', which traps some of the solvents into the coating. Entrapped solvents can cause cracking, blistering and pin-hole problems, changes in gloss or soft paint film. When using water-borne products, it is essential to use proper ventilation, which is sometimes even more important than elevating the temperature of the air.

## 8. Types of paint

Paint consists of resin, pigments, solvents and additives. They may be divided into types in several different ways. Generally, paints are classified depending on their resin, or in which way the resin dries. The resin has the most important influence on the properties of the paint. In this chapter the different types of paint based on their types of resin are described. Below each item, Tikkurila Oyj's trade names are given for reference.

### 8.1 Categorisation of paints

Paints can be divided into physically drying and chemically drying paints, depending on the way their resin hardens. The way in which the paint dries has an effect on their overcoating and maintenance painting. Chemically curing paints usually have a limited overcoating time, after which the surface has to be roughened in order to give good adhesion. Overcoating of physically drying paints does not generally require special attention.

Nowadays, paints are also often divided into water-borne and solvent-borne paints.

#### 8.1.1 Physically drying paints

The paint film of physically drying paints is formed when the solvents evaporate and the molecules of the resin coalesce to form a film. The drying is dependant on how fast the solvents evaporate and the coating thickness. These types of coatings will dissolve in their original solvents and soften at higher temperatures. Similarly, water-borne paints dry physically when the water and trace solvents evaporate. However, water-borne coatings do not dissolve in water after they have dried. Physically drying paints include chlorinated rubber, vinyl and acrylic paints.

#### 8.1.2 Chemically drying paints

The paint film of chemically curing paints is formed in a chemical reaction where the liquid resin, consisting of small molecules, cures to form larger molecules. If the paint contains solvents or water, the drying begins with the evaporation of these volatile components. The cured film is not thermoplastic. Neither does the film dissolve in solvents, but if the grade of curing is low, the coating may expand under the influence of solvents.

Chemically curing paints can also be divided as below:

- paints which dry by oxidation cure by reaction with oxygen in the air (e.g. alkyd paints).
- paints which are moisture curing dry by reaction with humidity in the air (e.g. moisture cured urethanes and ethyl silicate paints).
- two component paints, where the components react with each other (e.g. epoxy and polyurethane paints).
- stoving enamels, where the components react with each other under the influence of high temperature.

#### 8.1.3 Water-borne paints

The raw materials which are used for manufacturing of water-borne paints have only been developed in recent years. In combination with many other recent technical improvements, it is now possible to use water-borne protective paints for steel surfaces without compromising anticorrosive protection or other properties.

Water-borne paints use the same types of resins as solvent-borne paints, e.g. epoxy, acrylic, vinyl and alkyd. The properties of water-borne paints therefore tend to be similar to corresponding solvent-borne products.

There are more advantages to using water-borne coatings than the obvious environmental ones. They reduce fire and explosion risk and improve the working environment. Water can be used as thinner and cleaner instead of solvents.

There are also some disadvantages when using water-borne materials. They do not tolerate any degree of oil or grease on the surface being coated, so that cleaning has to be to a very high standard. Blast cleaning to Sa 2½ is the normal standard required for good performance.

### 8.2 Alkyd paints

Alkyds are polyesters which contain fatty acids derived from vegetable oils e.g., linseed oil, soya oil, castor oil or tall oil fatty acid. Drying oils (such as linseed or soya oil), or fatty acids from drying oils (such as tall oil fatty acid) are used in air-drying paints. Alkyd paints made from non-drying oils are used in stoving enamels. When alkyd paints dry, the solvents evaporate and the resin reacts with the oxygen in the air.

Drying by oxidation needs time and alkyd paints usually reach their protective properties within two

weeks. The drying slows down when the temperature falls. The forming of the film requires a temperature of at least +5°C. The solvents in alkyd paints are mostly white spirit or xylene.

The recoating time for different alkyd paints varies. If the recoating has been done too soon it can cause wrinkling, or even detachment of the initial coat from the substrate. This is called 'lifting'. Also grinding or too strong solvents in the topcoat may cause lifting of alkyd paints.

In the data sheets for alkyd paints the recoating times and suitable topcoats are recommended. Recoating interval is usually stated at a temperature of 23°C and a dry film thickness of 40-50µm. It should be understood that lower temperatures or higher film thicknesses will extend the recoating intervals.

Alkyd paints generally have good resistance to weathering and abrasion. They are one component, easy to spray and the relatively low in price. They often have good resistance to heat, and to splashes of oil, water and fuel, but they tend to have limited resistance to acids and alkalis.

Alkyd paints can be used indoors in modest gas and chemical dust exposure, and outdoors in urban, industrial and marine environments.

Epoxy esters and urethane alkyds are also resins which dry by oxidation and their properties are similar to alkyds. Their abrasion and chemical resistance is slightly better than alkyds. Epoxy esters are generally used only in primers. The properties of alkyd paints can be improved by adding vinyl, phenolic or acrylic resins.

### **8.2.1 Fontelac water-borne alkyd paints**

#### **Fontelac QD 80**

A water-borne, glossy, fast drying alkyd topcoat. Good gloss and colour retention in climatic stress. Suitable for painting machines and equipment with rapid production cycles. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.

### **8.2.2 Temaprime and Temalac solvent-borne alkyd paints**

#### **Temaprime AB**

A zinc-phosphate alkyd primer for steel surfaces. Especially suitable for painting on site. Brush and spray application. Colours: Grey and reddish brown.

#### **Temaprime EE**

A fast-drying zinc-phosphate primer with excellent anti-corrosive properties. Also suitable for galvanized and aluminium surfaces. Colours: TEMASPEED PREMIUM tinting.

#### **Temaprime EUR**

A fast-drying zinc-phosphate primer for steel surfaces. Economical, and ideal for use in workshops and painting stations with rapid production cycles. Spray application. Colours: TEMASPEED PREMIUM tinting.

#### **Temaprime GF**

A fast-drying zinc-phosphate special primer for steel, aluminium and zinc surfaces, especially for applications with high aesthetical requirements. Overcoatable with polyurethane paints. Recommended as a primer for haulage equipment, agricultural machines, and other machines and equipment. Excellent anti-corrosive properties. Colours: TEMASPEED PREMIUM tinting.

#### **Temaprime ML**

A fast drying zinc-phosphate primer for steel surfaces. Ideal for use in workshops and painting stations with rapid production cycles. Spray application. Colours: Grey and reddish brown.

#### **Temalac AB 70**

A glossy alkyd topcoat for alkyd systems. Especially suitable for the on-site painting of bridges, exteriors of storage tanks, etc. Brush and spray application. Colours: RAL, NCSS, SSG, BS and the Metallic Colour Card. TEMASPEED tinting.

#### **Temalac ML 90**

A high-gloss alkyd topcoat. Used as a semi-fast topcoat in painting stations and for product painting. Recommended as a topcoat for agricultural equipment, haulage and transport vehicles, etc. Spray application. Colours: RAL, NCS-S, SSG, BS. TEMASPEED tinting.

#### **Temalac FD 20**

A fast-drying, semi-matt alkyd paint containing zinc-phosphate pigment. Mainly for use as a single coat system for steel frameworks and structures. Ideal for use in machine shops with fast production cycles. Spray application. Colours: RAL, NCS-S, SSG, BS. TEMASPEED PREMIUM tinting.

#### **Temalac FD 50**

A fast-drying, semi-gloss alkyd topcoat. Ideal for use in fabricators works and painting stations with rapid production cycles. Recommended as a topcoat for steel frameworks and structures, machines, etc. Spray application. Suitable also for electrostatic painting. Colours: RAL, NCS-S, SSG, BS. TEMASPEED PREMIUM tinting.

**Temalac FD 80**

A fast-drying, glossy alkyd topcoat. Ideal for use in assembling shops and painting stations with rapid production cycles. Recommended as a topcoat for machines and equipment. Spray application. Suitable also for electrostatic painting. Colours: RAL, NCS-S, SSG, BS and the Metallic Colour Card. TEMASPEED PREMIUM tinting.

**Temalac SC-F 20**

A high solids, semi-matt, solvent-borne alkyd paints, containing anti-corrosive pigments. Recommended as a single coat system for steel surfaces both indoors and outdoors. Can be painted in thick films. Good application properties. Recommended for steel framework, service platforms and different types of machinery and equipment. Application by airless or conventional spraying. Colours: RAL, NCS, SSG, BS and SYMPHONY colour cards. TEMASPEED PREMIUM tinting.

**Temalac SC-F 40**

A high solids, semi-gloss, solvent-borne alkyd paints, containing anti-corrosive pigments. Recommended as a single coat system for steel surfaces both indoors and outdoors. Can be painted in thick films. Good application properties. Recommended for steel framework, service platforms and different types of machinery and equipment. Application by airless or conventional spraying. Colours: RAL, NCS, SSG, BS and SYMPHONY colour cards. TEMASPEED PREMIUM tinting.

**Temalac SC-F 80**

A high solids, gloss, solvent-borne alkyd paints, containing anti-corrosive pigments. Recommended as a single coat system for steel surfaces both indoors and outdoors. Can be painted in thick films. Good application properties. Recommended for steel framework, service platforms and different types of machinery and equipment. Application by airless or conventional spraying. Colours: RAL, NCS, SSG, BS and SYMPHONY colour cards. TEMASPEED PREMIUM tinting.

## 8.3 Epoxy paints

Epoxy paints are two component materials, the base containing epoxy resin and the hardener containing polyamide or polyamine, amide or amine adducts. The properties of the paint can be adjusted by the choice of the hardener and the type of epoxy resin. Solid epoxy resins are generally used in solvent-borne paints and liquid epoxy resins in solvent-free coatings.

The base and hardener are mixed together in the correct proportions and thoroughly stirred. After the paint has been mixed, there is a limited time, called the 'pot life', in which the product can be applied before the mixture becomes too thick to use due to the reaction of base and hardener. The pot life will always be given on the product data sheet. Following application, and as a result of the chemical reaction, the coating cures and forms a film which does not dissolve in the original solvents and has good heat resistance.

The chemical and mechanical resistance of epoxy paints are good. The coatings are hard and elastic and have good adhesion to metal surfaces.

Solvent-borne epoxy paints are used for metal and concrete surfaces exposed to mechanical and chemical stress in corrosion categories C2, C3, C4, C5-I and C5-M according to ISO 12944. When exposed to UV-light (sunlight), epoxy coatings will 'chalk', meaning they matt down and lose colour. Even so, they are often specified for exterior use in aggressive chemical environments. The colour should be chosen to minimise the effect of chalking.

Epoxy paints can be modified for different purposes. Modification with coal-tar was often used in the past, but in recent years this has been largely stopped for health & safety reasons and other, safer resins used in place of coal tar.

Usually epoxy paints require at least a temperature of +10°C for curing. New, low temperature curing, so called WG (winter grade) epoxies cure down to temperatures of -5°C. In normal temperatures the WG grades cure faster than ordinary epoxy paints. This reduces the recoating interval, which is an advantage in paint shops.

### 8.3.1 Fontecoat water-borne epoxy paints

**Fontecoat EP Primer**

A two-component water-borne epoxy primer. Used in epoxy and polyurethane paint systems. Recommended as primer for the exterior painting of, cranes, haulage equipment and other steelwork. Can be used on ships for surfaces above water line. Colours: Reddish brown and grey.

**Fontecoat EP 50**

A two-component, semi-gloss water-borne epoxy topcoat. Used as a topcoat or as a single-coat paint in epoxy paint systems on steel surfaces. Recommended for painting cranes, haulage equipment, electric motors, and similar machines and equipment. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.



### **Fontecoat EP 80**

A two-component glossy water-borne epoxy topcoat. Used as a topcoat in epoxy paint systems. Recommended for painting cranes, haulage equipment, electric motors, and similar machines and equipment. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.

### **8.3.2 Temabond and Temacoat solvent-borne epoxy paints**

#### **Temabond ST 200**

A two-component, high-solids aluminiumpigmented epoxy paint. Forms a very tough film due to its pigmentation. Also suitable for handprepared (St 2) steel. Especially suitable for various types of maintenance painting. High film building, application by brush or spray. Can also be applied on old alkyd surface. Colour: Aluminium grey.

#### **Temabond WG 200**

A two-component, high-solids aluminiumpigmented modified epoxy paint, which cures at low temperatures. Forms a very tough film due to its pigmentation. Also adheres well to hand-prepared (St 2) surfaces. Especially suitable for various types of maintenance painting. High filmbuilding properties, application by brush or spray. Can also be applied on old alkyd surface. Colour: Aluminium grey.

#### **Temabond ST 300**

A two-component high-solids epoxy paint. Suitable for blast-cleaned or hand-prepared steel providing excellent wetting properties. Recommended for ship hulls and ballast tanks, and for different types of steelwork, machinery and equipment in the wood-processing and chemical industry. A low solvent content and thus less VOC emissions than with traditional epoxy paints. High filmbuilding properties, application by brush or spray. Can also be applied on old alkyd surface. Colours: RAL, NCS-S, SSG and BS. TEMASPEED tinting.

#### **Temabond WG 300**

A two-component, at low temperatures curing, high-solid modified epoxy paint. Suitable for blast-cleaned or hand-prepared steel providing excellent wetting properties. Recommended for ship hulls and ballast tanks, and for different types of steelwork, machinery and equipment in the wood-processing and chemical industry. A low solvent content and thus less VOC emissions than with traditional epoxy paints. High film building properties, application by brush or spray. Can also be applied on old alkyd surface. Colours: RAL, NCS-S, SSG and BS. TEMASPEED tinting.

### **Temacoat GF Primer**

A two-component, polyamide-cured epoxy primer. Excellent adhesion to steel, galvanized and aluminium surfaces. Especially for use as a primer or an intermediate coat under a polyurethane topcoat. Recommended for painting transport and haulage equipment. Spray application. Colour: TEMASPEED PREMIUM tinting.

### **Temacoat GPL-S Primer**

A two-component, polyamide-cured epoxy primer. Excellent adhesion to steel, galvanized and aluminium surfaces. Used as a primer or an intermediate coat in epoxy and polyurethane systems, also as an intermediate coat on zinc-rich paints. Spray application. Colours: TEMASPEED PREMIUM tinting.

### **Temacoat GPL-S MIO**

A two-component, polyamide-cured epoxy containing micaceous iron oxide. Forms a very tough and durable film. Used as an intermediate coat in epoxy and polyurethane systems for objects exposed to severe climatic conditions and splashes, such as bridges, etc. Spray application. Colours: Grey.

### **Temacoat HB Primer**

A two-component, resin modified highbuild epoxy. Suitable for steel, galvanized and aluminium surfaces. Used as a primer or an intermediate coat in epoxy and polyurethane systems, also as an intermediate coat on zincrich paints. Spray application. Colours: Grey and reddish brown.

### **Temacoat SPA Primer**

A two-component high-solids polyamidecured high-build epoxy. Suitable for steel, galvanized and aluminium surfaces. Used as a primer or an intermediate coat in epoxy and polyurethane systems, also as an intermediate coat on zinc-rich paints. Spray application. Colours: Grey and reddish brown.

### **Temacoat SPA MIO**

A two-component high-solids polyamidecured high-build epoxy pigmented with micaceous iron oxide, zinc phosphate and aluminium flakes. Suitable for steel, galvanized and aluminium surfaces. Used as a primer or an intermediate coat in epoxy and polyurethane systems, also as an intermediate coat on zinc-rich paints. Spray application. Colours: Grey and light reddish brown.

### **Temacoat GPL**

A two-component, amine-adduct cured glossy epoxy topcoat. Used particularly as a finishing coat in epoxy systems for painting objects exposed to heavy abrasion

and chemical attack. Can also be used for the painting of concrete floors. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

#### **Temacoat GS 50**

A two-component, polyamide-cured semigloss epoxy topcoat. High film building properties. Can be used on galvanized and aluminium surfaces without a separate primer. Dries quickly for overcoating and handling. Especially suitable for the painting of steel frameworks, conveyors, tubular bridges, etc. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

#### **Temacoat HB 30**

A two-component, polyamide-cured highbuild epoxy. Suitable for steel, galvanized and aluminium surfaces. Used as a finish or an intermediate coat in epoxy paint systems. Can be used as a single-coat system for steel frameworks and structures. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

#### **Temacoat RM 40**

A two-component, resin-modified semigloss epoxy paint. Suitable as a primer and topcoat for steel, aluminium, galvanized and concrete surfaces exposed to mechanical and chemical wear. Also for underground and underwater structures. Recommended for construction frameworks, tubular bridges, ship hulls, etc. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

#### **Temacoat SPA 50**

A two-component, high-solids polyamidecured high-build epoxy. Suitable for steel, galvanized and aluminium surfaces. Used as a finish or an intermediate coat in epoxy paint systems. Can be used as a single-coat system for steel frameworks and structures. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

#### **Temaline LP Primer**

A two-component amine adduct cured epoxy paint. Used as a primer or intermediate coat for inside epoxy systems in kerosene and oil tanks. Spray application. Colours: Light grey and reddish brown.

#### **Temaline LP 60**

A two-component amine adduct cured epoxy finish. Used as a finishing coat for inside epoxy systems in kerosene and oil tanks. Spray application. Colour: White.

#### **Tematar TFA**

A two-component modified epoxy paint, coaltar free.

Suitable for steel, galvanized and concrete surfaces exposed to abrasion and chemical attack, especially for underground and underwater structures. Used for sludges and sewage tanks, pontoons, crude oil tanks, etc. Colour: Black.

### **8.3.3 Temaline epoxy coatings**

#### **Temaline EPL 100**

A two component epoxy phenolic paint. Resistant to dilute solutions of non-oxidizing acids, alkali and salts in immersion. Suitable for immersion of hot water from 65°C-100°C. Withstands dry heat up to 150°C, but discolouration possible. Recommended for tank linings. Application by spray or brush. Colour: White.

#### **Temaline NL**

A two component epoxy coating with a low solvent content. Excellent resistance to abrasion. Suitable for navigation markers, sluices, interiors of coal, wood chip and peat containers, and other surfaces exposed to heavy mechanical abrasion. Can be applied by standard airless spray equipment. Colours: white, black, grey and shades of MKH.

## **8.4 Polyurethane paints**

The base in two component polyurethane paints consists generally of polyester, acrylic, polyether or epoxy resins containing reactive hydroxy groups. The hardener consists of aromatic or aliphatic isocyanate which forms the polyurethane when reacting with the base. Two pack polyurethanes have a similar useful 'pot life' to epoxy paints.

The properties of the paint can be adjusted by choice of the components. By using an aliphatic hardener, a weatherproof and non yellowing paint can be produced. Aromatic hardeners are used only for indoor use. Polyurethane paints are chemically resistant. They are generally used as topcoats in all kinds of exterior environments.

The polyurethane paints give an easy-to-clean finish with good gloss and colour retention, and they do not chalk like epoxies. They are often used as topcoats over epoxy build coats e.g. external surfaces of cisterns, steel masts, transport equipment, machines etc.

### **8.4.1 Fontedur water-borne polyurethane paints**

#### **Fontedur HB 80**

A two-component water-borne high-build glossy polyurethane topcoat. Excellent weather and UV-light resistance. Recommended as a topcoat for paint systems outdoors. Typical uses: Machines and equipment. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.

## 8.4.2 Temadur and Temathane solvent-borne polyurethane paints

### Temadur 20

A two-component semi-matt acrylic polyurethane paint containing anticorrosive pigments. Recommended as a primer for polyurethane systems or as a semi-matt topcoat in epoxy systems exposed to weather and/or chemical attack. Can also be used as a one-coat coloured primer/finish for steel, zinc and aluminium surfaces. Colours: RAL, NCS-S, SSG and BS. TEMASPEED tinting.

### Temadur 50

A two-component, semi-gloss acrylic polyurethane topcoat. Excellent resistance to weather and abrasion. Gives a high-quality, non-chalking finish with good gloss and colour retention. Recommended as a topcoat in epoxy systems for painting objects exposed to weather and chemical attack. Colours: RAL, NCS-S, SSG, BS and the Metallic Colour Card. TEMASPEED tinting.

### Temadur 90

A two-component, high-gloss acrylic polyurethane topcoat. Excellent resistance to weather and abrasion. Gives a high-quality, non-chalking finish with good gloss and colour retention. Recommended as a topcoat in epoxy systems for objects exposed to weather and chemical attack. Typical uses: Haulage equipment, agricultural machines, and other machines and equipment. Colours: RAL, NCS-S, SSG, BS and the Metallic Colour Card. TEMASPEED tinting.

### Temadur Clear

A two-component, high-gloss clear polyurethane lacquer. Excellent weather and abrasion resistance. Forms a durable, nonchalking and easy-to-clean finish with good gloss and colour retention. Also suitable for copper, brass, aluminium and zinc surfaces.

### Temadur SC 50

A two-component, semi-gloss, high-solids polyurethane paint containing anticorrosive pigments. Recommended use as a single coat system or as a topcoat for painting agricultural, construction and earth moving machinery and other equipment. Suitable also as a topcoat in epoxy systems for painting objects exposed to weather and chemical attack. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

### Temadur SC 80

A two-component, glossy high-solids polyurethane paint

containing anticorrosive pigments. Recommended use as a single coat system or as a topcoat for painting agricultural, construction and earth moving machinery and other equipment. Suitable also as a topcoat in epoxy systems for painting objects exposed to weather and chemical attack. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

### Temadur SC-F 80

A two component fast drying gloss polyurethane paint, containing anticorrosive pigments, hardener aliphatic isocyanate. Recommended especially to be used as a single coat finish for agricultural and earth moving machinery and other machinery and equipment. Also suitable to be used as a topcoat in epoxy/polyurethane systems exposed to weathering and chemical stress, e.g. storage tank exteriors, steel framework and other steel structures. Excellent weathering and abrasion resistance. A durable, easy to clean and non-chalking topcoat with good gloss and colour retention.

### Temathane PC 50

A two-component, semi-gloss, high-solids acrylic polyurethane topcoat. Good resistance to weather and abrasion. Gives a non-chalking finish with good gloss and colour retention. Recommended as a topcoat in epoxy systems for painting construction frameworks, tubular bridges and similar objects exposed to weather and chemical attack. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

### Temathane PC 80

A two-component, high-gloss, high-solids acrylic polyurethane topcoat. Good resistance to weather and abrasion. Gives a non-chalking finish with good gloss and colour retention. Recommended as a topcoat in epoxy systems for painting construction frameworks, tubular bridges and similar objects exposed to weather and chemical attack. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

## Various additives for polyurethane paints:

### Temadur Accelerator

An accelerator solution to make Temadur polyurethane paints to cure faster.

### Temadur HF-Extra

A hammer finish additive used with Temadur polyurethane aluminium base paints.

#### **Temadur Structure Extra**

An additive used with Temadur polyurethane paints in order to roughen the finish.

### **8.5 Oxirane ester paints**

Oxirane ester paints are two component paints, which consist of modified oils and polyester, with high acid content. The film is formed when the oxirane and the carbonyl groups in the resins react with each other. The drying and elasticity properties of the paints can be adjusted within a certain range by changing the relation between the resins.

Oxirane ester paints are resistant to a wide range of chemicals, except alkalis. The paints are resistant to grease, oil and splashes of solvents. They are also resistant to nonoxidising acids and salt solutions. They have good resistance to sulphuric acid and to water immersion.

Oxirane ester paints have good gloss and gloss retention. They are often used instead of epoxy and polyurethane paints as a more environmentally friendly and labour-safe alternative.

#### **8.5.1 Duasolid solvent-borne oxirane ester paints**

##### **Duasolid 50**

A two-component oxirane ester glossy topcoat. Recommended as a topcoat for oxirane ester systems or a single coat system. Typical uses: Machines and equipment. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

### **8.6 Stoving enamels**

Stoving enamels are paints which dry only at high temperatures, usually between 120 and 180°C. The time they require to be heated to these temperatures ('stoving time') varies between 15 minutes and one hour.

Stoving enamels are made of many different kinds of resin. The most common are alkyd amino, acrylic amino, silicone and polyester. They can be either solvent-borne or water-borne.

A stoving enamel surface is hard and it has good resistance to chemicals and impact damage. Stoving enamels are used in industrial product painting and e.g. for painting of cars.

#### **8.6.1 Fontetherm water-borne stoving enamels**

Water-borne polyester resin based stoving enamels for metal industry.

#### **8.6.2 Tematherm solvent-borne stoving enamels**

Solvent-borne alkyd amino resin based stoving enamels for metal industry.

### **8.7 Chlorinated rubber paints**

The main resin of chlorinated rubber paints is chlorinated rubber which has been softened with chlorine paraffin and the solvents are generally aromatic hydrocarbons.

Chlorinated rubber paints have good water and chemical resistance. They are fast drying and it is also possible to apply them in cold conditions, down to -10°C. Chlorinated rubber paints are used for protective coatings exposed to chemicals and for objects exposed to atmospheric stress, e.g. bridges and ships.

Chlorinated rubber paint systems are recommended for steel and cast iron surfaces exposed to moderate chemical stress, e.g. bridges, cranes, haulage equipment, harbour equipment and outside surfaces of cisterns. The coatings withstand +80°C dry heat, but are not usually recommended for temperatures above +60°C. Chlorinated rubber topcoats are also suitable as vapour barrier coatings on concrete surfaces.

#### **8.7.1 Temachlor solvent-borne chlorinated rubber paint**

##### **Temachlor 40**

A high-build semi-gloss topcoat, based on chlorinated rubber. Used as a topcoat for bridges, cranes, harbour installations, etc. Can be used as a vapour barrier on concrete surfaces. Colours: RAL, NCS-S, SSG and BS. TEMASPEED tinting.

### **8.8 Acrylic paints**

Solvent-borne acrylic paints are used to replace chlorinated rubber and vinyl paints to avoid the strong solvents required for vinyls and the environmentally unfriendly chlorinated rubber resins. The resistance and application properties of acrylic paints are generally equivalent to chlorinated rubber paints.

Acrylic paints are used for cisterns, pipe linings, bridges and other steel surfaces exposed to atmospheric stress.

#### **8.8.1 Fontecryl water-borne acrylic paints**

##### **Fontecryl 10**

A water-borne, matt fast-drying acrylic paint. Anti-corrosion pigmented. Used as a primer or as a single-coat system. Overcoatable with a wide range of products, also with solvent-borne products. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.

### **Fontecryl 10 Dipp**

A water-borne, matt fast-drying anticorrosion pigmented acrylic primer. Especially suitable for application by dipping. Overcoatable with a wide range of products, also with solvent-borne products. Colours: Green, red, black and brown.

### **Fontecryl AP**

A water-borne, matt fast-drying acrylic paint. Anti-corrosion pigmented. Used as a primer or as a single-coat system. Application by dipping or spraying. Colours: Black, grey, yellow, iron oxide red, green and dark grey and TEMASPEED FONTE tinting.

### **Fontecryl PP**

A water-borne, matt fast-drying acrylic paint. Anti-corrosion pigmented. Especially recommended to use as a primer for powder coatings. Application by dipping or spraying. Colours: Grey, yellow.

### **Fontecryl 25**

A water-borne, semi-matt fast-drying acrylic paint. Anti-corrosion pigmented. Used as a single-coat system or as a semi-matt waterborne topcoat. Colours: RAL, BS, NCS-S and SSG. TEMASPEED FONTE tinting.

### **Fontecryl SC 50**

A water-borne, one component fast drying alkyd modified acrylic paint which contains active anticorrosive pigments. Suitable for product painting in metal industry and painting stations. Drying times can be shortened by using higher temperatures. Not suitable for immersion or constant humidity. Recommended especially as a single coat paint system for steel structures indoors and outdoors. Typical uses are e.g. steel frameworks, machinery and equipment. Application by conventional or airless spray. Colours: RAL, NCS, SSG, BS and SYMPHONY colour cards. TEMASPEED FONTE tinting.

## **8.8.2 Temacryl AR solvent-borne acrylic paint**

### **Temacryl AR 50**

A physically-drying semi-gloss topcoat based on acrylic resin. Can be applied at low temperatures. Recommended for surfaces exposed to marine or industrial climates and mild chemical attack, such as bridges, cranes, conveyors, harbour installations and tank exteriors. Colours: RAL, NCS-S, SSG and BS. TEMASPEED PREMIUM tinting.

## **8.9 Zinc-rich paints**

Zinc-rich paints or zinc dust paints are coatings where the zinc dust exceeds 75% of the solids by weight.

Various standards give different levels for the amount of zinc required for a 'zinc-rich' coating, with levels varying between 75 and 90 percent by weight.

A zinc dust paint film gives cathodic protection to the steel. The difference compared with galvanizing is the resin in the paint. The resins in zinc dust paints are usually epoxy, alkyl silicate or some physically drying resin. The choice of resin for zinc dust paints is important because properties such as hardness, elasticity, adhesion to the substrate and overcoating depend mainly on the resin. Zinc also reacts with most alkyd resins, so zinc coatings are not made using alkyd resins.

Zinc silicate paints are two component paints based on ethyl or alkali silicate resins. Ethyl silicate paints are solvent-borne and alkali silicate paints are water-borne. Ethyl silicate paints are the most common. Ethyl silicate paints cure by reaction with atmospheric moisture. Therefore the relative humidity of the air has to be relatively high (~80%) in order to ensure curing. Ethyl silicate paints can also be applied at low temperatures. They are used for solvent resistant coatings and as primers for long term exterior exposure systems.

## **8.9.1 Fontezinc water-borne zinc-rich paint**

### **Fontezinc 85**

A two component, water-borne zinc-rich epoxy paint. Offers cathodic protection for steel. Used as a primer in epoxy, polyurethane and acrylic systems for steel surfaces exposed to severe climatic conditions. Can be used without a topcoat on surfaces exposed to weathering. Recommended for bridges, cranes and steel frameworks as well as steelwork and equipment in the forest and chemical industries; such as tubular bridges, conveyors etc. Application by airless spray or brush. Colours: Reddish grey.

## **8.9.2 Temazinc and Temasil solvent-borne zinc-rich paint**

### **Temazinc 77**

A two-component, polyamide-cured zinc-rich epoxy primer. Used as a primer in epoxy, polyurethane, acrylic and chlorinated rubber systems for steel surfaces exposed to severe climatic conditions. Colour: Grey.

### **Temazinc 88**

A two component, polyamide cured zinc-rich epoxy primer. Used as a primer in epoxy, polyurethane, acrylic and chlorinated rubber systems for steel surfaces exposed to severe climatic conditions. Colour: Grey.

**Temazinc 99**

A two-component, polyamide-cured zinc-rich epoxy primer. Used as a primer in epoxy, chlorinated-rubber and polyurethane systems for steel surfaces exposed to severe climatic conditions. Colour: Grey.

**Temazinc EE**

A one-component matt zinc dust paint. Used as a primer for steel surfaces exposed to weathering and chemical stress. Ideal as a touch-up primer on damaged areas of zinc primed steel. Colour: Grey.

**Temasil 90**

A two-component, ethyl zinc-silicate paint. Excellent resistance to abrasion, weather and high dry temperature (+400°C). Can be overcoated with a wide range of protective coating systems. Colour: Greenish grey.

**8.10 Silicone paints**

Silicone resins are used for silicone paints. To form a film, the temperature must exceed +5°C, with final curing needing a temperature of 200-230°C.

Silicone paints are used as weatherproof topcoats and, when pigmented with aluminium, for painting of hot surfaces. Stoving enamels based on silicone resin can be used in urban, industrial and marine environments.

Pure silicone paints withstand +650°C dry heat on their own, and when applied over zinc silicate primers, up to +400°C. Silicone paints are used indoors and outdoors for hot surfaces. Silicone paints are also available in colours, but in a very limited colour range.

**8.10.1 Temal solvent-borne silicone paints****Temal 400**

A silicone-based heat-resistant paint, which withstands +400°C dry heat on steel. Application with airless spray equipment. Colour: Black.

**Temal 600**

A silicone-based heat-resistant paint, which withstands +650°C dry heat on steel. Application with conventional air equipment. Colour: Aluminium.

**Temal HB 600**

A high-build silicone aluminium paint, which is resistant to temperatures up to +650°C dry heat on steel. Application with airless or conventional spray equipment. Colour: Aluminium.

**8.11 Prefabrication primers**

These are often two component materials based on epoxy or silicate resin. They are mainly used for temporary protection of metal surfaces.

**8.11.1 Temablast and Temaweld solvent-borne prefabrication primers****Temablast EV 110**

A two-component, epoxy iron-oxide shop primer. Used as a preconstruction primer on blast-cleaned steel surfaces. Does not affect welding, cutting, drilling or other machinetooling. Colours: Red.

**Temaweld ZSM**

A two component modified zinc silicate shop primer, which has excellent resistance against abrasion, heat and corrosion. Can also be used for automatic shop priming of blasted steel material. Does not affect welding, gas cutting or other working processes in a steel shop. Colour: Grey.

**8.12 Vinyl paints**

The resin in vinyl paints is plasticized polyvinyl chloride (PVC) and xylene is the most usual solvent.

These paints are used for the same applications as chlorinated rubber paints, where good chemical and weather resistance is required. Vinyl paints can be applied down to 0°C.

**8.12.1 Temanyl MS solvent-borne vinyl paint****Temanyl MS Primer**

A modified vinyl primer, which has good abrasion, immersion and atmospheric resistance. Used as a primer under vinyl, chlorinated rubber and acrylic topcoats. Also suitable for underwater structures like ship bottoms etc. Can also be applied at low temperature conditions. Colour: Aluminium grey.

**Temanyl PVB**

A one component, polyvinyl butyral adhesion primer. An adhesion primer for steel, zinc, stainless steel and aluminium surfaces. Can also be used as a primer under powder coatings. Colours: Grey, light grey (TVT 4004), yellow and black.

**8.13 Bituminous paints**

Various bituminous extracts are used as resin in bituminous paint. Bituminous paints have good moisture and water resistance but their mechanical properties are poor. Bituminous paints are usually used for objects exposed to moisture or water in low wear areas. Nowadays bituminous paints are quite often replaced by resin modified epoxies.

## 8.14 Intumescent paints

Intumescent paints are used to protect the substrate from the effects of fire. Intumescent painting of structural steel retards the heating of the steel and gives additional time before the steel reaches a temperature at which it loses load bearing capacity. This extra time allows evacuation of the building and a chance for the emergency services to control the fire.

Depending on the fire resistant time and the object the constructions are divided in classes, R30, R60, R90 etc. With intumescent paint it is possible to reach fire retarding class R60.

Intumescent coatings are paints which swell under the influence of heat to form a protective, insulating and porous char. This insulating char can be up to 50 times the original thickness of the applied coating. Intumescent paints can be solvent-borne, water-borne and solvent-free.

Most single pack Intumescent paints are only used in dry interior areas. A typical system would be: blast clean to Sa 2½, approved anticorrosive primer to around 75 microns, the Intumescent coating, and usually a topcoat to around 40 microns dft. The dry film thickness (generally 0.5-3.0mm) of the Intumescent paint is determined by the size and weight of the steelwork and the period of fire protection required.

### 8.14.1 Water-borne Nonfire intumescent paints

#### Nonfire S104

A waterborne one component intumescent coating. When subjected to heat it expands and forms an insulating layer of foam. Used as a fire retardant paint on interior steel structures. Recommended to be applied on-site during dry conditions. Components painted in workshops must be topcoated before taken outdoors. Fulfills requirements R15-R60 (NT FIRE 021), F30-F60 (DIN 4102). Properties and dimensioning requirements are described in the certified product declaration, TRY-95-2005, published by Teräsrakenneyhdistys ry. (The Finnish Constructional Steelwork Association). Brushing, rolling or airless spraying. Colour: white.

### 8.14.2 Solvent-borne Fireflex intumescent paint

#### Fireflex

An intumescent coating. When subjected to heat it expands and forms an insulating layer of foam. Used as a fire retardant paint on interior steel surfaces. Fulfills Finnish requirements R15 and R30 (NT FIRE 021). The properties

of fire endurance have also been represented to match with the fire endurance class R45. Application on-site during dry conditions is recommended. Components painted in workshops must be topcoated before taken outdoors. Properties and dimensioning requirements are described in the certified product declaration, TRY-69-2007, published by Teräsrakenneyhdistys ry. (The Finnish Constructional Steelwork Association). Brushing, rolling or airless spraying. Colour: white.

## 8.15 Powder coatings

Powder coatings are paints in powder form. Chemically curing resins, such as epoxy polyester, acrylic and polyurethane, are used as powder coatings.

Powder coatings are mainly used for product painting in the metal industry. Typical objects are light fittings, domestic appliances, furniture, and bicycles.

Powder coatings are generally applied by electrostatic spraying. The powder adheres to the metal item, which is connected to earth. The final coat is formed by a chemical reaction at a temperature of 150 -200°C.

Powder coatings form a tightly adherent, mechanically and chemically resistant surface.

Polyamide, polyethylene or polyvinyl chloride are used as resins for thermoset powder coatings. The powder is spread over the surface by a floating method and it forms a film when heated, when the powder melts and sticks to the substrate.

## 9. Solvents and thinners

The purpose of solvents in paint is to dissolve the resin and to make the paint able to be applied. A resin dissolved in solvent is able to wet the substrate and form a protective film.

### 9.1 Type of solvents

On the basis of their chemical characteristics, solvents can be divided in separate groups, e.g. crude oil based aliphatic and aromatic solvents, oxygen-containing ketones, alcohols, esters and water. The dissolving properties of the solvents in each group are similar but there are differences in the evaporation rates.

### 9.2 Solvent efficiency

The capacity to dissolve the resin is an important property of the solvent. Different types of resins dissolve in different ways in different solvents.

Oils and long-oil alkyds dissolve easily in aliphatic hydrocarbon solvents such as white spirit. For short-oil, fast drying alkyds, xylene has to be used because the dissolving capacity of white spirit is not enough.

For chlorinated rubber and vinyl paints aromatic hydrocarbons are used. For epoxy paints a mixture of alcohols, ethers, ketone and aromatic solvents has to be used because the epoxy resins dissolve poorly in each of them alone.

Polyurethane paints are also dissolved in mixtures of solvents because aromatic solvents individually do not dissolve effectively enough. The most used solvents are esters. Alcohols cannot be used because the isocyanate would react with the hydroxyl groups in the alcohol and affect the performance and pot life of the coating.

On basis on their dissolving capacity, solvents can be divided in three separate groups:

- active solvents
- latent solvents
- diluents

An active solvent is a liquid which dissolves the resin without the presence of other solvents, e.g. esters and ketone.

Latent solvents are a kind of supporting solvent and they have effect only in combination with active solvents. This kind of solvent includes alcohols such as propyl and butyl alcohol.

Diluents are solvents which are mixed with the active solvents in order to reduce the use of the expensive active solvents. Diluents have to be used sparingly because their dissolving capacity is limited. If too much diluent is added the resin may precipitate. Diluents include hydrocarbon solvents, white spirit, xylene and toluene. Xylene and toluene have a better dissolving capacity than white spirit.

### 9.3 Evaporating value

Another important property for the solvent is the evaporating value. The evaporating properties of the solvent adjusts the application properties of the paint, the forming and leveling of the coat, viscosity and drying. The evaporating value is stated as a relative quantity. The evaporating value of butyl acetate is defined as 1. The evaporating value is comparable to the boiling point: the lower the boiling point, the higher the evaporating value.

The role of the solvents in a paint is critical in achieving a good coating. Every type of paint requires its own solvent mixture. The main component is a solvent which efficiently dissolves the resin, with other solvents to give good application properties to the paint. During spray application, part of the solvents evaporate on the way between the spray gun and the substrate, but sufficient solvent, of the right mixture, must remain in order for the paint to form a defect free film and dry correctly. An incorrect solvent blend can cause the surface of the coating to dry too quickly, thus trapping slower solvent within the coating, leading to wrinkling and other defects.

If the solvent mixture evaporates too slowly, sagging may occur. Too fast evaporation may prevent the surface flowing out giving an uneven finish.



Paint	First choice solvent	Also usable
Alkyd paint, medium and long-oil	white spirit	benzene, xylene
Alkyd paint, short-oil	xylene	butyl asetate
Acrylic, chlorinated rubber and vinyl paints	xylene	Aromatic solvent benzene, C9 - C10 and C10 - C11
Epoxy paints	Mixture: xylene, butyl, alcohol, propylene glycol methyl ether	As parts of the mixture the solvent benzene C9 - C10 and C10 - C11, toluene, ethanol
Polyurethane paints	Mixture: xylene, butyl asetate (Not ethanol or butyl alcohol or other polar solvents)	As parts of the mixture toluene, the solvent benzene C9 - C10 and C10 - C11, propylene glycol methyl ether acetate
Stoving enamels	Mixture: xylene, butyl alcohol	As parts of the mixture the solvent benzene C9 - C10 and C10 - C11, toluene, acetate
Zinc silicate paints	ethanol	As parts of the mixture acetone, propyl alcohol

Table 6. Types of paint and solvent.

Defect in the coat	Reason	Correction measures
Rough surface Changes in gloss Dry spray	Too fast thinner Too high spraying pressure Wrong position of the spray gun Too wide spray fan	Use slower thinner Reduce the pressure Spray perpendicular to the surface Change to a smaller tip
The paint levels poorly Orange peel	Too little or too fast solvent Wrong nozzle or pressure	Use more and/or slower solvent Test one point smaller nozzle, or higher pressure
Matt areas caused by pinholes	Too little and/or too fast solvent	Use more and/or slower solvent Apply first a thin layer, then later a full coat
Wrinkling occurs	The primer swells and deforms	Paint the primer and topcoat "wet on wet" or let the primer dry thoroughly Check if the primer and topcoat are compatible Is the solvent correct?
Sagging	Too thick film and/or slow thinner Too much thinner Cold paint, surface or thinner	Check the film thickness, thinner and the amount of thinner Check the temperatures

Table 7. Defects in the coat caused by solvent at spray application .

## 9.4 Water

Water is used as the thinner in emulsion, dispersion and water-borne paints. The atmospheric conditions, the relative humidity of the air and the temperature have a major influence on the evaporation rate of water compared to organic solvents. Also, the surface tension of water is so high that water-borne paints wet the surface less effectively than many solvent-borne coatings.

Spray equipment and paint containers should always be earthed when using flammable solvents, to minimise the danger of ignition from sparks caused by static discharge.

## 9.5 Explosion risk

The ignition risk of solvents limits their use, storage and transport. Flammable liquids are classified in different ignition classes on the basis of the temperature at which their vapours will ignite.

# 10. Paint systems for new-building and maintenance

A paint system consists of the pretreatment of the substrate and the coatings which are used to protect the surface. The paint system can consist of one paint, applied in one or more coats, but usually several different types of paint are used within a coating system.

## 10.1 The purpose of each paint coat

The paints are often named according to the order in which they are applied: e.g. primer, intermediate and top coat. The corrosion protection mechanism is based on high electrical resistance, anti-corrosive pigments or cathodic protection. The different coats in the paint system may protect the surface in different ways, e.g. the topcoat may have a high electrical resistance and the primer may contain anti-corrosive pigments.

The primer is the first coat of the system. The primer should have good adhesion to the substrate and in addition usually provides protection to the metal substrate with anti-corrosive pigments and high electrical resistance.

The intermediate coat is a mid-coat in the system. The intermediate coat should have good adhesion to the primer, even after prolonged periods, such as when the primer is applied in the shop and the next coat is not applied until site painting, weeks or months later. The intermediate coat can be a primer or a topcoat. It could also be a special high build paint, designed to increase the total film thickness.

The topcoat acts as a cosmetic, corrosion preventing finish, which reduces the possibility of oxygen, water and chemicals reaching the intermediate and primer coats. Topcoats usually require excellent colour and gloss retention, as they provide the painted item with its immediate appearance.

## 10.2 The choice of paint system

When choosing a paint system, several factors need to be considered:

- The corrosion category of the environment.
  - The material (substrate) to be painted.
  - The coating costs over the whole life time of the object.
- If parts of the construction cannot later be maintained, it will be necessary to choose a system which will last the design life of the structure. In other areas, the coating

system should last to the planned maintenance interval of the structure. Maintenance painting is generally much more expensive than the initial coating work, so a consideration of the total painting costs of a structure over its lifetime can greatly influence the choice of the new build coating system, especially where maintenance is difficult or impossible.

- Transit damage and exposure e.g. sea transport as deck cargo.
- Where will painting be carried out – is preparation and painting to be done in-shop, in controlled conditions, or on site during the winter?
- If the structure is exposed to special conditions e.g. abrasion, back-fill, heating, immersion in water or splashes with chemicals etc. In such cases, systems recommended in standard EN ISO 12944-5 are not always suitable, and a customized paint system recommended by a paint supplier may be advisable.
- Possible fire protection requirements.
- Aesthetic factors e.g. the possibility of getting the specified colour in the required topcoat, the gloss level, weather resistance, etc.

## 10.3 Environmental corrosion categories

EN ISO 12944-2 defines six atmospheric corrosion categories and three immersion categories.

### Atmospheric corrosion categories

**C1** (very mild) Dry, interior atmospheres, free from condensation e.g. apartments, schools, offices etc.

**C2** (mild) Exterior dry, clean atmosphere, such as rural locations, and interior, unheated buildings where condensation may occur, e.g. stores, sport halls, warehouses, etc.

**C3** (moderate) Exterior atmospheres such as towns and industrial areas where the sulphur dioxide levels are modest, and coastal regions where salinity is low. Interior atmospheres with high humidity some pollution, e.g. food industry, production plants, laundries, breweries and dairies.

**C4** (severe) Exterior environments with high sulphur dioxide levels and coastal areas with high salinity. Interior atmospheres such as chemical production plants, swimming pools and ship building facilities in coastal areas.

**C5-I** (very severe industrial environment) Exterior atmospheres with high humidity and corrosive pollution, such as industrial areas. Interior of buildings with almost continuous condensation and chemical contamination.

**C5-M** (very severe marine environment) Exterior coastal environments with high salinity and interior areas with continuous humidity and corrosive saline atmospheres.

## Corrosion categories for immersed and buried structures

### Im1

- Fresh water
- River constructions, hydro-electric plants

### Im2

- Sea and brackish water
- Harbour area constructions, such as sluice gates, quays, offshore constructions etc.

### Im3

- Soil
- Under ground cisterns, steel beams, pipelines of steel

When considering the corrosion category for a project, not only should the final environment be noted, but also the transport and storage conditions of steelwork prior to arriving on site, e.g. sea transport as deck cargo, storage outdoors etc.

EN ISO 12944-2 does not consider coating systems for special conditions, such as contact with food stuffs and potable water. It also does not take into consideration service requirements where exposure to chemicals, solvents, oils and areas of high mechanical abrasion. It is therefore often necessary,

even in the light of this standard, to consult a paint manufacturer for specific advice about particular service conditions, where the manufacturer's expertise and specialist coating knowledge may be required.

## 10.4 Durability of coating system

EN ISO 12944-1 divides the durability of paint systems into three categories.

**Low (L)** 2-5 years

**Moderate (M)** 5-15 years

**High (H)** over 15 years

These time periods indicate life to first maintenance and should not be interpreted as times for which a coating could be guaranteed.

## 10.5 The limitation of standard systems

EN ISO 12944 deals only with the corrosion protection properties of coating systems. Other protective properties, such as protection against micro organisms, chemicals (acids, alkalines, solvents etc.), abrasion or fire, are not considered by the standard. It also deals only with constructions where the steel thickness is at least 3mm and which are made of steel qualities including uncoated, galvanized, sherardized or pre-fabrication primed steelwork.

The standard does not deal with constructions made of iron sheets, aluminium or stainless steel. Also the range of coatings are limited - the standard does not for example deal with powder coatings and other heat-curing paints. Because the scope of this standard is therefore limited, Tikkurila Oyj offers a range of specialist coating systems which are not included in the standard. These specialist systems are based on Tikkurila's track record and experience of difficult coating environments, and lifetimes are usually hard to estimate due to the range of aggressive conditions which may be encountered.

## 10.6 Marking of the paint system

The recommendation is that the marking should be done according to instructions in standard EN ISO 12944-5. The marking is recommended to complete with sign of paint type, nominal DFT, number of coats, the material of the substrate and the marking of pretreatment of the substrate. In Tikkurila Oyj's system of marking, the product sign has been added. If the paint system is not included in above mentioned standard the EN ISO standard number and paint system number are excluded. Below you will find an example of Tikkurila Oyj's paint system coding.

Because of the limitations of the standard EN ISO 12944-5, many coating systems which are not described in the standard are used. In these cases, the standard's reference and the number of the paint combination are left out. Otherwise the coding remains the same.

### Coding of the substrate

Fe = Iron (steel)

Zn = Zinc

Al = Aluminium

If some part is missing from the coding of the paint system, as in the example below, this can act as a reminder to check why the code is incomplete by consulting standard EN ISO 12944-5 or the person who defined the code.

Information about Tikkurila Oyj's paint systems, recommended uses and properties, can be found in the paint system data sheets. Tikkurila Oyj also publishes reference tables for different metals, objects, application conditions and corrosion categories.

## 10.7 The nominal dry film thickness, NDFT

(EN ISO 12944-5 5.4)

The nominal dry film thickness, NDFT, is the dry film thickness at which the coat, or system, should be applied to meet the required degree of performance.

The commonly accepted standard is that dry film thicknesses less than 80% of the NDFT are not acceptable. Thicknesses between 80 and 100% of the NDFT are acceptable if the overall average thickness is equal to or greater than the NDFT.

The following important parameters are not defined in the standard and agreement is therefore required on how these items are to be evaluated:

- The method and 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.
- The sampling plan – how and how many measurements are to be made for each type of surface.
- How the results are to be reported and how they are to be compared with acceptance criteria.

### Dry film thickness (DFT) determination

The thickness of a coating remaining on the surface when the coating has hardened.

## 10.8 Maintenance painting

The condition of painted surfaces in service should be regularly inspected, using methods such as those described in standard ISO 4628, in order to decide when maintenance painting is required. The inspection interval will depend on the corrosion category. In particular, immersed objects and those exposed to severe conditions should be inspected more frequently. Repair of small damage points should also be carried out frequently, to prevent rapid spread into more severe breakdown.

In the corrosion categories C2-C5, touch-up painting is recommended when the degree of breakdown has reached Ri2-Ri3. As well as the repair of damage points, it is advisable to overcoat the whole area with an additional topcoat, to improve cosmetic appearance and increase the overall level of protection. The whole area should be washed and either abraded or sweep blasted, this latter process requiring great care so as not to damage intact coatings. When the degree of breakdown has reached Ri4-Ri5, removal of the entire coating and reapplication of a fresh system is recommended.

Maintenance painting is usually done using the original paint system. If this is not possible due to the weather conditions or the requirements of the original paint system, a maintenance painting system, which complements the original system, should be used. Maintenance systems are often a combination of high build paints, fewer coats, and with lower requirements for pretreatment and application conditions.

	TP 20-	SFS-EN ISO 12944 - 5/	A3.17	(EPPUR)	160/ 2 -	Fe	Sa 2½
Tikkurila Oyj's code							
The standard's reference							
The number of the standard system							
The paint types in the system							
Nominal film thickness, µm							
Number of paint coats							
Substrate							
Grade of pretreatment							

Table 8. Example of Tikkurila Oyj's paint system marking.

## 10.9 Distinctive marks of paint types

The marking of the paints in the paint system code is in accordance with the table 9 in standard EN ISO 12944.

Type of paint	Mark
Alkyd paint	AK
Acrylic paint	AY
Epoxy paint	EP
Resin modified epoxy paint	EP
Chlorinated rubber paint	CR
Polyurethane paint	PUR
Polyvinyl butyral paint	PVB
Silicone paint	SI
Zinc-rich silicate paint	ESIZn (R)
Vinyl paint	PVC
Zinc-rich epoxy paint	EPZn (R)
Ethyl zinc silicate	ESI

Table 9. Marks of paint types.

# 11. Protective coatings

## - costs and economy

Protective coating systems are expensive to apply. Not using protective paint systems is even more expensive. However, the most expensive route is to use poorly applied or wrongly specified systems, as in these cases you pay out large sums without getting any benefit for your investment.

In most cases maintenance painting at the construction site is many times more expensive than the original paint treatment in-shop. The longer the life time of the construction and the more difficult maintenance painting is, then the more profitable it is to invest in the correct treatment at new building.

When choosing a protective coating system you have to consider the maintenance costs during the whole life time of the construction. In the longer term, a more expensive system may prove to be the best investment.

The costs for painting work rises during the separate phases of the work. The costs consist of direct, indirect and unforeseen factors.

Direct costs in connection with protective coating are:

- the pretreatment of the surface (labour and cleaning equipment and material etc.)
- the paints, solvents, tools and the protection of the environment during the work
- wages
- labour management
- insurance and guarantee
- inspection
- administration
- paint shop

More difficult to calculate are the indirect costs such as:

- the creating of good application conditions (ventilation, removing of humidity, need of heating)
- scaffolding, labour safety, transport and transferring costs
- touch-up painting of damage on already painted surfaces

Unforeseen costs can be caused by:

- interruption of the painting work (bad weather, delays etc.)

- poorly or wrongly done work or defective material, which cause repainting
- interruption of the production

The place and method of the painting work also have an effect on painting costs and the quality of the work. Painting in a paint shop is generally cheaper, and the quality better, than painting carried out in the field. Often the pretreatment and primer application are done in the shop but touch-up of damage and final coating are carried out on site. In this case the costs are an average of the costs of painting in paint shop and painting at the installation site.

Painting can also be done at the construction site, in a paint shop which has been built for that purpose, but this is profitable only for large projects (over 100 000m<sup>2</sup>).

### 11.1 Calculation of costs

When the decision about the investment is to be taken, paint systems can be economically compared to each other e.g. by comparison with the present value. When comparing with the present value, one has to know the costs and the life time of the paint system.

The present value of the protective coating of the construction is that amount of money which now has to be reserved to cover the new painting and the maintenance painting during the life time of the construction.

The present value can be calculated as below:

$$K_0 = K_n \times (1 + r/100)^n$$

$K_n$  = actual cost

$K_0$  = present value ( $K_n$  after  $n$  years)

$r$  = calculation interest (%)

$n$  = number of years

For calculating the extra rise of the cost following formula can be used:

$$K_n = K_0(1 + p/100)^n$$

$K_n$  = the capital after  $n$  years

$K_0$  = the capital after 0 year

$p$  = percentage, inflation and the annual increasing of costs

$n$  = number of years

If the annual increase of costs including inflation is 5% the primarily euro, calculated by formula above, has risen to 1.629 euro in ten years.

The real costs of protective coating are not known when the initial painting work is done. Not until the maintenance painting is carried out can the total costs be estimated. The life time of the paint system has a vital importance on the economy of the paint system. Among others, the factors listed below have an influence on the life time:

- the form of the construction
- the paint systems
- efficient planning of time table and work
- careful agreements
- use of skilled employees
- correctly planned and organized quality control

# 12. Protective coatings - a matter of quality

## 12.1 Quality

‘Quality’ is all the characteristics and properties which a product or service must have in order to fulfil all the assumed and stipulated requirements.

There are many factors on which the surface treatment contractor has no influence, which can have an effect on the surface treatment quality, including:

- the planning of the construction
- the quality grade of the steel work
- the time and place of surface treatment
- choice of paint system and colours
- the time available to carry out the work and the schedule
- shortcomings and lack of clarity in agreements and regulations

The surface treatment contractor should bring any such issues to the client’s notice, in writing, as soon as possible.

## 12.2 The agreements

Piecework contracts and other agreements which concern surface treatment should be considered very carefully. In the event of unforeseen costs, contracts need to be very clear as to who must take responsibility, in order to avoid costly disputes.

For example: The piecework contract concerned the painting of big cargo tanks in a wine tanker using epoxy paints, when the vessel was laid up in unheated dry dock facilities during the winter. The agreement stipulated that the yard should supply a heating unit for the contractor’s use. The yard offered one (1) oil heater, exhaust type. The yard therefore fulfilled the agreement, but the heating offered was completely inadequate for good coating work to be carried out.

Any agreement should include a written quality program settled by supplier or contractor alone or together with the client. The quality program should be in accordance with the normal quality program procedures for the firm.

In the planning, consideration should be given to the following items:

- quality standards which can be achieved
- to whom the responsibility and authority belongs
- applicable procedures and working instructions
- quality control measurements and remedial procedures
- the procedure to be followed when the plans change during the course of the project

## 12.3 Personnel, professional skills and equipment

The employees which deal with the protective coating programme should have the required professional skills and access to suitable equipment. In certain cases evidence of a professional qualification or a certificate from an approved institution should be presented.

Skilled men should be provided with good equipment which is well maintained. They should also be provided with all the necessary information concerning use of the paint materials at the time of application, to ensure that all required conditions are met. It is too late to study the product data sheets when the work has already been done.

## 12.4 The type of steel construction

Before starting pre-treatment work the type of steel construction should be considered with regard to surface treatment – are all surfaces accessible for surface preparation work, can they be adequately illuminated, etc.

Also, the quality of the steelwork should be checked with regard to: has mill scale been removed, are corners, edges, imperfections and welding seams etc. ground to the specified grade? When painting previously painted surfaces, the degree and extent of breakdown of corroded areas needs to be assessed. For steelwork which has corroded to rust grade D, a separate section is included in these notes.

## 12.5 Pre-treatment

Remove obvious dirt and contamination to make subsequent preparation easier and more effective. Remove salts, grease and oil with an alkaline or emulsion



wash. Rinse the surfaces thoroughly with water and allow to dry. If not removed, dirt and contamination can seriously affect the performance of the subsequently applied coating system, and possibly also contaminate the blasting media in an enclosed blast cleaning system.

Removal of rust to the specified pre-treatment grade should then be carried out. Dust and blasting abrasive should be thoroughly removed from all surfaces. The preparation standard should be inspected according to standard ISO 8501-1 or ISO 8501-2 (spot blasting) and the surface profile, if necessary, according to standard ISO 8503. When spot blasting is done, this should be carried out so as not to damage the sound existing coating, and all edges of existing coating should be 'feathered' (abraded, so as to give a smooth transition from bare area to sound coating, rather than an abrupt 'step' edge, which could lift or curl when further paint coating are applied).

Cleaned surfaces should be primed as soon as possible in order to avoid oxidation and/or contamination.

## 12.6 Application conditions

The pre-treatment and painting work should be done in conditions as given in the specification and Product Data Sheets. If necessary, steps should be taken to provide the required conditions of temperature, humidity and ventilation, or work should be stopped.

The following environmental factors should be measured and recorded:

- the temperature of the air
- the temperature of the substrate (pay attention to shadow side)
- the relative humidity
- the dew point
- the wind conditions (for spray mist)
- the temperatures of paint and thinners
- the lighting
- other activities in the neighbourhood which may disturb the painting work

## 12.7 Painting methods and equipment

The painting methods should be in accordance with the requirements of the paint specification and the equipment should be in good condition. Bad or unsuitable equipment can cause higher costs and may give poor results. With efficient equipment, the work will proceed faster and material consumption will be minimized.

## 12.8 Paints and thinners

Paints and thinners are specified in the paint specification. The paints and thinners should be stored in a proper way. Original packages should be in good condition and carefully closed and the labels should be readable. Instructions mentioned in labels, data sheets and safety data sheets, regarding safety and application conditions, pot-life restrictions, etc. should be observed.

Before paints and thinners are used, they should be at an appropriate temperature – products may need to be stored in a warm area for several days before use in very cold conditions. Paint should also not be applied at too high a temperature, or excessive dry spray and too rapid drying may give a poor paint film. The names, product codes and batch numbers of the paints and hardeners should be recorded.

## 12.9 Painting work

The painting work should be done according to the painting specification and standard ISO 12944-7. Instructions regarding methods, application conditions and overcoating times should be observed. The data sheets and safety data sheets should be available for the employees and should be studied before starting the work.

The application should be done on a clean, pre-treated surface as soon as possible after the pre-treatment work in order to avoid contamination, corrosion or oxidation of the surface.

The paint and the hardener, if it is used, should be stirred so that it reaches an even consistency, for two component products the correct amount of hardener should be added and, if necessary, the paint should be thinned to a suitable viscosity. The temperature of the paint should be as recommended. Settlement in 200 litres barrels or containers can be difficult to stir with a normal pneumatic mixer, and premixing with more efficient tools may be required. After this, a normal mixer can keep the paint to an even consistency.

The paint should be applied in an even coat to the specified film thickness. The film thickness is checked with a wet film gauge.

Sharp edges, corners, nooks, welding seams and other similar critical areas should be stripe coated.

After each coat, the dry film thickness should be measured when the paint has dried. If the coat is too soft, use a suitable calibration film between the paint film and the gauge. The results should be recorded and, if necessary, also marked on an actual drawing. This

control is essential because it is difficult and expensive to increase the dry film thickness with the topcoat in the event of low areas, and this is sometimes forbidden (e.g. for intumescent coatings).

In order to ensure the hiding power of the topcoat, especially concerning red and yellow shades, it is advisable to use a primer or intermediate coat of a similar colour to the required topcoat shade.

The next coat should always be applied within specified overcoating times. If the maximum overcoating time has been exceeded the surface has to be prepared, e.g. by abrading.

## 12.10 Inspection of completed painting work

When the topcoat is dry enough the surface should be checked for parameters including:

- sagging
- blistering, pinholes
- dry spray
- orange peel
- cracking
- missed areas
- differences in gloss

Problem areas should be recorded and repaired when possible.

Measure the dry film thickness according to the specified method. Record the results and make a measurement drawing if necessary.

According to standard EN ISO 12944-5, film thickness readings below 80% of the nominal film thickness are not approved. Unless otherwise agreed, values between 80–100% are approved providing that the total average value is the same or greater than the specified nominal film thickness.

In other standards you will find different definitions for the nominal film thickness, measurement methods and scope. In each case the method which is specified in the agreement should be followed.

Control of pinholes is often required for immersed objects, where coating thicknesses exceed 300µm. The intention is to identify and repair pinholes in the coating, which could cause premature breakdown. A suitable measurement voltage for epoxy coatings is 0.5kV/100 µm + 1kV.

Example: The nominal film thickness of the coat is 500µm. Check with  $5 \times 0.5 \text{ kV} + 1 \text{ kV} = 3.5 \text{ kV}$  voltage.

The adhesion can be checked by a cross-cut test.

Generally this test is used only for coats below 200µm. According to the standard ISO 2409 the method is not suitable for film thicknesses over 250µm. For thicker coatings, a pull-off adhesion test can be carried out, although results must often be carefully interpreted, as problems using the pull-off tester can give misleading results.

## 12.11 Inspection equipment

The paint inspector should have access to at least following items:

- the painting specification and necessary drawings
- the product data and safety data sheets for the paints
- colour cards or colour samples
- applicable standards
- film thickness gauges
- thermometers for measuring the temperature of paints, air and the substrate
- gauge for measuring the humidity of the air
- actual records for documentation of the results

Furthermore, depending on the situation, a control mirror, a torch, a magnifying glass, a knife or a spatula, a marking crayon and perhaps measurement equipment mentioned in part 12.10 are also useful.

## 12.12 The behaviour of the paint inspector

The purpose of the supervision work is to assure that the surface treatment is in accordance with the painting specification. When the inspector looks at a finished surface, it is almost impossible to assess the degree of surface preparation lying beneath the coating. Seldom it is possible for the supervisor to be present all the time and lack of understanding or incorrect procedures by the applicators can give poor results.

Part of the paint inspectors job is to discuss the specification requirements with the workforce before the job starts, to make sure they understand what is required and to identify any training requirements before work commences.

The paint inspector will have to decide at various stages throughout the work whether he will approve or reject the coating work. The following advice may be helpful:

- Discuss requirements in advance with the employees.
- Decide your standards and keep to them throughout the whole project.
- Remember the judge's rule: What is not reasonable cannot be right.

# 13. Labour safety and care of environment

## 13.1 Health hazards in connection with painting work

The below mentioned factors are the most common which may cause hazards to health:

- Evaporation of solvents which can be inhaled and damage the respiratory organs.
- Inhalation of paint mists and dusts can lead to ingestion of resins and pigments into the body.
- Absorption through the skin of hazardous substances from paint splashes.

The degree of hazard resulting from these factors will depend on:

- the composition of the paints which are used
- the amount of paint used and method of application
- the conditions in the work place e.g. ventilation
- how strictly safety measures are observed
- the working methods of the employees

## 13.2 Information about hazards

Safety data sheets and label markings give information about substances which may be hazardous or dangerous to health. On basis on this information, users can decide whether special precautions are required when handling the products and what possible dangers they need to be aware of.

### 13.2.1 Label markings

Warning signs on the labels provide information about any hazards associated with the products. Reactivity, health hazards and environmental dangers are described in both symbols and text which describe any dangers (R) and protective measures (S). The EU's new CLP Regulation governs the classification, labelling and packaging of substances and mixtures. CLP Regulation introduces the United Nations globally harmonised system (GHS) for classification and labelling of chemicals into Europe and new hazard pictograms and the signal words 'Danger' and 'Warning' to be used in hazard labelling. The R- and S-phrases have been replaced by hazard statements (H-phrases) and precautionary statements (P-phrases). Substances (like thinners and some hardeners) must be classified and labelled in accordance with CLP by 1st of December

2010 or December 2012 if substances are already on the market and likewise for mixtures (like paints) by 1st of June 2015 or 1st of June 2017 if mixtures are already on the market.



Picture 21. Old and new hazard pictograms.

### 13.2.2 Safety data sheets

For all paints, a safety data sheet should be available in accordance with the prevailing regulations. The safety data sheet shall be dated and shall contain the following headings:

1. identification of the substance/preparation and of the company/undertaking
2. hazards identification
3. composition/information on ingredients
4. first-aid measures
5. fire-fighting measures
6. accidental release measures
7. handling and storage
8. exposure controls/personal protection
9. physical and chemical properties
10. stability and reactivity
11. toxicological information
12. ecological information
13. disposal considerations
14. transport information
15. regulatory information
16. other information

The painting contractor must keep records of all paints and chemicals used and ensure that the safety data sheets of all products are available in the work place for employees to easily access.

Safety data sheets for Tikkurila's products may be ordered on the internet at [www.tikkurila.com](http://www.tikkurila.com)

### 13.3 Choice of products and planning of the work

For every painting project, it would be preferably to choose a type of paint which, considering the quality demands, is as harmless as possible. When planning the work it is necessary to consider the measures which have to be taken in order to carry out the work in a safe way.

The ventilation at the work place should ideally be so effective that no other protective measures are necessary. If this is not possible, other steps have to be taken in order to minimize the exposure of the employees.

If, despite of these arrangements, the content of dangerous substances in the work area is still likely to be too high, personal safety equipment must be used by all operatives. The use of personal safety equipment will vary from project to project, and actual measurements of hazardous substance levels may sometimes be required.

### 13.4 Legislation

The manufacturing, storage and handling of chemicals are regulated by a wide range of legislation within the EU. This legislation covers labour safety and the handling of chemicals, e.g. warning signs and the information in Safety data sheets.

More information:

[www.eurunion.org/legislat/chemadd](http://www.eurunion.org/legislat/chemadd)

### 13.5 Environmental protection – Licenses

Many industrial processes today require to be licensed to ensure they conform to strict environmental controls. Licenses will usually cover emissions to the air, to water and the handling of waste. Licenses required for painting operations vary from country to country and should be checked with local authorities.

#### 13.5.1 Emission of solvents

Solvents are the principal hazard for both personal safety and the environment in connection with industrial painting. Strict controls exist for minimising the emission of solvents to the environment and this has caused changes to both painting processes and the materials used. Solvents can damage the atmosphere in three main ways:

- They stimulate the production of ozone close to the earth's surface, which is harmful to both plants and people.
- Some solvents reduce the content of ozone in the upper atmosphere and reduce its ability to filter out harmful UV radiation.
- Solvent emissions promote global warming or the so-called 'greenhouse effect'.

Solvents can also cause problems of smell in the areas around large painting shops, which may affect local residents.

On the basis of the EU regulations concerning VOC's, approved in spring 1999, laws and regulations have been introduced in the member states to further reduce solvent emissions from industrial activities. The limits depend on the total amount of solvents used by the paint consumer, including thinners and cleaning solvents.

These regulations will, after a certain introductory period, apply to industrial painting operations where the total amount of volatile solvents used are:

- painting of metal and other surfaces, above 5 t/a year
- painting of transport vehicles always
- industrial painting of wood, above 15 t/a year

Limits for content of solvents in the exhaust air and for so called diffuse emissions are specified in the regulations. In practice, the limits imposed mean that paint applicators who use solvent-borne products have to treat their emissions or, alternatively, reduce them by changing coating methods and materials. When calculating the necessary reductions, the volume solids of all materials used is taken into account, not just the solvent content of any one material – the important factor is to reduce the total amount of solvent used. Applicators who use significant quantities of water-borne or solvent-free materials could therefore still use the occasional high solvent content paint if they needed to, and still easily comply with solvent emission regulations.

More accurate information about VOC regulations is given by local organisations and in environmental legislation.

The primary method of avoiding solvent hazards and solvent emissions is to use products which contain little or no solvent. The kind of products developed for metal surfaces are mainly:

- water-borne products
- solventless or solvent-free products (epoxies etc.)
- powder coatings
- products which contain reactive resins or solvents

Paint materials cannot of course be chosen purely on their low solvent content – their technical merits, price, and health & safety aspects also have to be suitable. It is important to realise however that today, solvent hazards associated with painting cannot simply be solved by just increasing the ventilation.

EU VOC legislation:

[www.europa.eu.int/comm/environment/air/stationary](http://www.europa.eu.int/comm/environment/air/stationary)

## 13.6 Paint waste

General instructions on the disposal of paint waste can be found on can labels and on the Health & Safety data sheets for paint products. The amount of paint waste can usually be minimised by careful organization of painting work and optimising technical aspects such as correct choice of spray tip.

There are various local and national regulations regarding the disposal of paint waste, and it is always

advisable to discuss this with the local authorities to get the best advice.

Among others, the following aspects have to be considered:

- It may sometimes be necessary to ask a recognised professional body for written advice on the disposal of some types of waste.
- The content of heavy metals and solvents may cause problems.
- Dust from alkyd and oil resin paints, sanding dust and other fine, particulate waste, can form an explosive dust cloud where the risk of spontaneous ignition is high. This kind of waste should be washed with water, dried outdoors or burned immediately.
- The disposal of water which has been used for cleaning of painting equipment is also a matter which has to be dealt with by the local authorities.
- The rules on how waste should be handled are changing all the time, and the main aim is that the amount of waste should be kept to a minimum.

## 13.7 Packaging waste

There are EU regulations concerning the disposal of packaging waste, with the aim of minimising the amount of waste taken for dumping at a waste tip.

E.g. in Finland, measures are in place for the disposal of empty paint containers, and there are now specialist companies who are working with paint manufacturers and applicators. Waste disposal will become increasingly important in the future and will cover more and more industries and processes.

For further information see:

[www.apeal.org/contents/base05](http://www.apeal.org/contents/base05)

[www.europa.eu.int/comm/environment/waste/packaging\\_index](http://www.europa.eu.int/comm/environment/waste/packaging_index)

## 14. Tinting system

For tinting of solvent-borne industrial paints Tikkurila Oyj uses the Temaspeed tinting system. This system is very advanced, consisting of two standard base paints for each type of paint and 13 colourants. For some types of paint there is a third base paint, which is aluminium pigmented. From this it is possible to tint colours with metallic lustre and by adding an additive (Temadur HF-extra) also a hammer finish.

The new, advanced TEMASPEED FONTE tinting system is especially developed for water-borne industrial paints. By using two different tinting systems it is possible to ensure that the best properties of each paint type are maintained for every colour, both for solvent and water-borne paints.

Tikkurila's formula register contains tinting formulas for the common international colour ranges, including: RAL Effect, RAL Classic, British Standard, NCS-S and SSG. There are thousands of shades and their number increases continuously. Formulas for special colours are easily achieved by using Tikkurila's Temaspeed spectrophotometer.

The tinting systems provide considerable advantages for users of industrial paints. Distributors are able to provide a wide colour range very quickly. By using distributors, customers can avoid unnecessary and expensive storage of large quantities of finished product. It is easy for the user to get new stock without holding up production or carrying large stocks.



Picture 22. Temaspeed HA-450 tinting machine.

# 15. Protective coatings, terms and words

In order to correctly describe the painting process, a range of industry-specific terms and vocabulary are used in standards, working instructions, data sheets and package labels etc. concerning protective coatings.

The intention with the terms and definitions in the glossary below is to make it easier to understand the purpose of the words and improve the communication between those who are involved. It is also a kind of data bank which helps to find further information. (References to standards or other documents).

**Adhesion promotor** A coating which improves the adhesion between different coats and/or prevents certain problems in connection with overcoating. (EN ISO 12944- 5)

**Airless spray** Airless spray is a method where paint under high pressure is sprayed through a nozzle onto the substrate.

**Anti-corrosive paint** (anti-corrosion paint) A paint containing active pigments, e.g. zinc phosphate, which prevent corrosion.

**Application viscosity** The viscosity the paint should have when applied, after any necessary thinner has been added. Generally, the viscosity is stated as the time, in seconds, it takes for the paint to pour through a viscometer. (ISO 2431) **Artificial ageing test** A method developed to accelerate the ageing of a paint system, e.g. to degrade the corrosion protective properties faster than in the natural environment. (EN ISO 12944-2)

**Atmospheric corrosion** Corrosion caused by the atmosphere. (ISO 8044)

**Automatic shot blasting** A mechanical blasting method where the blasting agent is propelled against the material to be cleaned. The material moves along a conveyor in a closed space.

**Be** The marking of pickling treatment.

**Blasting Grit (Shot)** A solid grit (shot) which is used as an abrasive for blast cleaning. (Natural sand or steel grit, round or sharp, are the most common) (ISO 11124-1; ISO 11126-1)

**Blasting** Blast cleaning (grit blasting, sand blasting, shot blasting, depending on the blasting agent). A method where the blasting agent is propelled at high speed (pneumatic, high pressure water or rotating wheels) against the surface to be cleaned. With this method it is possible to achieve a white metal surface. (ISO 8501-1)

**Certification** To prove, by the presentation of official, signed documents, that stated demands have been observed. The quality system, which ensure manufacturer's quality control is confirmed by a certificate.

**Chalking** A fine, powdery layer on the paint surface, caused by UV attack of the coating surface, which will have a pale, whitish appearance.

**Classification standard concerning environmental conditions** In the standard EN ISO 12944-2 the atmospheric environment is classified into six corrosion categories:  
C1 very mild  
C2 mild  
C3 moderate  
C4 severe  
C5-I very severe (industrial)  
C5-M very severe (maritime)

Objects in immersion are divided in three categories:  
Im1 fresh water  
Im2 sea and brackish water  
Im3 soil

**Climate** The weather in a certain place or region, statistically specified on the basis of meteorological factors over a long period. (EN ISO 12944-2)

**Coat** A uniform layer of paint which is achieved by one application. (EN ISO 12944- 1)

**Coating** A layer of resin based material applied to a surface for protection or decoration.

**Colour** A sense observation caused by light reflected from a surface. The colour can be described by three properties; hue, chromaticness and brightness.

**Compatibility** 1. Products in paint systems: the possibility to use two or more products in a paint system so that no problems occur; 2. The product and the substrate: The properties of the product should be such that it can be applied on the substrate without causing any harm.

**Confirmation of quality** Confirmation of quality includes all planned and systematic measurements which are necessary to ensure that the product or service fulfils stipulated demands. Confirmation of quality is a management method of the organisation. (EN ISO 8402).

**Construction** A steel construction (e.g. a bridge, a factory, a storage tank, an offshore platform) consisting of more than one determining part of construction. A project may include one or several constructions. (EN ISO 12944-8).

**Corrosion** Corrosion is a physical/ chemical reaction between a metal and the environment which changes the properties of the metal and often causes damage to the metal, its environment or the technical system. (ISO 8044)

**Corrosion damage** That affect of corrosion which is functionally harmful to metals, environment or technical systems. (ISO 8044)

**Corrosion prevention** To change the corrosion system, e.g. by painting, in order to reduce the damage caused by corrosion. (SFS 8044)

**Corrosion system** A system which consists of one or several metals and all the environmental factors which have a corroding influence.

**Corrosion strain (stress)** Those environmental factors which cause corrosion. (EN ISO 12944-1)

**Coverage** 1. The practical coverage: The practical coverage depends on the application method and application conditions, the shape of the construction and the surface quality and the skill of the painter. 2. Theoretical coverage: The theoretical coverage (TC) is stated as  $\text{m}^2/\text{litre}$  and it can be calculated on the basis of volume solids (VS-%) and specified dry film thickness (DFT-  $\mu\text{m}$ ).  $\text{TC} = 10 \times \text{VS\%/DFT}$

**Curtain coating (flow coating)** A painting method, suitable for serial production, where the paint is poured onto the painting object. The size and the shape of the object and the quality of the paint limit the use.

**Degreasing** Grease, oil and contamination, which make rust removal and painting difficult, are removed by degreasing.

**Degree of paint protection efficiency** Protection grade, corrosion protection grade.

**Demands** The values a paint system must reach in tests so that it can be considered suitable for rust protection.

**Density** The density is the weight of one litre of paint at 23°C (kg/l). ISO 2811-2

**Determination part of the construction** A part of the construction which is exposed to a certain environment and because of this needs a special protective paint system. E. g. in a storage tank there are several determination parts because there are internal and external surfaces, possible also supporting constructions of steel. (EN ISO 12944-8).

**Dew point** The temperature at which the humidity in the air condenses onto the surface. (ISO 8502-4).

**Dry film thickness DFT.** The thickness of the remaining coat on the substrate when the paint/coating has dried. (EN ISO 12944-5).

**Drying time** The drying times are stated, if not otherwise mentioned, at a temperature of 23°C, relative humidity 50% and sufficient ventilation. A lower temperature, too thick coats, bad ventilation and high relative humidity extend the drying time. By raising the temperature the drying and overcoating times can often be reduced. In most paint data sheets the following drying times are stated; dust dry, touch dry, overcoatable and fully cured. (ISO 1517).



**Durability** The expected life of a protective paint system to the first major maintenance painting. Important additional information, see the standard EN ISO 12944-1.

**Dust** A fine powder, caused by blast cleaning, other pretreatment work or from the neighbourhood, which lays on the surfaces which shall be painted. (ISO 8502-3)

**Emulsion wash** A cleaning method with a solution containing organic solvents, water and detergents which binds grease and oil particles and removes them together with the rinsing water.

**Evaporating time** See: flash-off time

**Film** A uniform layer of metal or a homogeneous coat of paint which has been received by one application. (EN ISO 12944-1)

**Finishing paint (finish, topcoat)** The last coat in a paint system. For this the colour and gloss grade are usually specified in accordance with the demands for the object.

**FINNCORR** An association in Finland dealing with corrosion prevention.

**FI** See: flame cleaning.

**Flame cleaning** A thermal cleaning method where old paint, mill scale and rust are removed from the steel surface by using a oxygen-acetylene flame. After the flame cleaning the surface has to be cleaned by wire brushing. (ISO 8501)

**Flash-off time** Flash-off time is the time after application during which the majority of the solvents evaporate, before more thorough drying occurs. The flash-off time depends on the type of paint, the solvent composition, the film thickness, the temperature and the ventilation.

**Flash rust** The thin rust layer which is formed very quickly on a prepared surface. (EN ISO 12944-2)

**Gloss (gloss level, limit, value, group, grade)** The gloss grade is the relative gloss of the paint surface or the capacity to reflect light. The relative gloss is usually specified at an angle of 60° (EN ISO 2813). According to their capacity to reflect light, paints are divided in gloss groups. The definition below is used in the RAL EFFECT colour collection by RAL Institute.

Nominal marking	Gloss level
Full gloss	$x \geq 90$
High gloss	$80 \leq x < 90$
Gloss	$60 \leq x < 80$
Semi gloss	$35 \leq x < 60$
Semi matt	$10 \leq x < 35$
Matt	$5 \leq x < 10$
Full matt	$x < 5$

**Grade of pretreatment** See: preparation grades.

**Hardener** That part of a two component paint which, when added to the base, causes the curing process. By choosing the type of hardener it is possible to adjust the properties of the paint.

**High-build coat** A property of the coating which allows for a thicker coat than would generally be the case for that kind of paint to be applied. In the standard EN ISO 12944 this means dry film thicknesses over 80µm.

**High-solid paints** High solid paints are paints with a high content of volume solids. Generally the volume of solids exceeds 70% by volume.

**Hot spraying** An airless spraying method in which the temperature of the paint is risen, in a way or another, to a higher temperature than usual. Generally a temperature range of 30-60°C is used, depending on type of paint and kind of equipment.

**Industrial environment** (atmosphere, climate) An atmosphere which contains pollution, mainly sulphur dioxide, from local and regional industries. (EN ISO 12944-2).

**Influence of corrosion** (corrosive) The corrosion caused by the surrounding atmosphere in a certain corrosion system. (ISO 8044).

**Inhibitor** An inhibitor is a material which slows down the rate of metal corrosion. There are several types of inhibitors.

**Intermediate paint** A paint between the primer and the topcoat, used to increase the film thickness. Generally a primer or a topcoat is used as an intermediate paint.

**ISO 9000** A standard concerning quality management and verification. Instructions for how to choose and how to use are found in ISO 9000, 9001 and 9004.

**Lining** A protective coating for inside surfaces of tanks (storage cisterns) (EN ISO 12944-1).

**Local environment** The conditions in the near neighbourhood of the construction. These conditions determine the corrosion category and include both atmospheric and contamination factors. (EN ISO 12944-2).

**Maintenance** The entirety of all factors in standard EN ISO 12944 which ensure that the corrosion prevention of the steel construction can be maintained.

**Maritime environment** The atmosphere at sea and in coastal areas. The maritime environment reaches a certain distance inland, depending on the shape of the landscape and current winds. The salinity, mainly chlorides, is high. (EN ISO 12944-2).

**Marking of paint system** The recommendation is that the marking should be done according to instructions in standard EN ISO 12944-5. The marking is recommended to complete with sign of paint type, nominal DFT, number of coats, the material of the substrate and the marking of pretreatment of the substrate. The signs of paint type in accordance with EN ISO 12944 part 5 and the marking of pretreatment according to part 4 and the nominal dry film thickness in microns. In Tikurila Oyj's system of marking, the product sign has been added. If the paint system is not included in above mentioned standard the EN ISO standard number and paint system number are excluded. E.g. TP20-EN ISO 12944-5/A3.08 (EPPUR160/2- FeSa2½) or TE4-EP500/2-FeSa2½.

**Maximum dry film thickness** The thickest dry film which can be approved. If it is exceeded it is possible that the properties of the paint or the paint system may deteriorate. (EN ISO 12944-5).

**Micro environment** Environmental conditions close into the surfaces of the construction. The micro environment is an important factor when the corrosion strains are estimated. (EN ISO 12944-2)

**Mill scale** A thick layer of iron oxides on hot-rolled steel, or steel which has been thermally treated.

**Mixing ratio** Information about the mixing ratio is found in the data sheets and the labels. The mixing ratio is the relation between base and hardener, generally the mixing ratio is stated as parts by volume, in exceptional cases in parts by weight.

**Nominal dry film thickness (NDFT)** The dry film thickness which is specified for each layer or the whole paint system. The dry film thickness ensures that the paint system achieves the durability which is required. (EN ISO 12944-5).

**Ocular estimation method** A method to do an ocular estimation of a paint system according to some part of standard ISO 4628.

**One-component paint** A paint which does not need any additive to start the drying and curing process. One component paints include e.g. alkyds, chlorinated rubber paints and vinyl.

**Paint** A pigmented liquid, paste or powderlike coating material, which applied on the substrate forms a hiding, opaque coat, which has protective, cosmetic or other special properties. (ISO 4618)

**Paint system** A paint system consists of the pretreatment and the paint film formed by the protective paints used. The paint system can consist of only one paint applied one or several times. Usually the paint system consists of several paints which have each complimentary properties.

**Painting** Painting is a surface treatment where one of the treatment components are paint.

**Phosphating** Phosphating is a method where the phosphate liquid is applied on the cleaned surface by dipping, spraying or brush. This forms a thin, fine crystalline layer which adheres to the substrate. Phosphating is mainly used as a pretreatment of thin metal sheets.

**Phosphatising** See above.

**Pickling** A chemical method to remove mill scale and rust from the substrate by immersion of the metal in a suitable pickling agent. At pickling a white metal surface should be achieved.

**Pigment** Pigments are pulverized dyestuff which gives the paint hiding power and colour. Furthermore the pigments protect the paint and the substrate from ultra-violet radiation. Anti-corrosive pigments can prevent or retard the corrosion process.

**Planning of constructions** The manner of construction, shown in detailed drawings, where the attention is paid to the corrosion prevention.

**Pot-life** The pot-life is the time within which it is possible to use a two component paint after mixing.

**Prefabrication primer** A prefabrication primer is a temporary protection for cleaned steel surfaces. The primer is applied in thin coats, 15–20µm. There are several different types of prefabrication primers.

**Preparation grades** In standard ISO 8501-1 several pretreatment grades are specified. Rust removing methods and preparation grades are described. The preparation grades are specified by a photographic description of the appearance of the surface after the treatment has been completed. Every preparation grade is marked with a sign for the pretreatment method. "Sa", "St", or "Fl". The number after the sign describes the preparation grade. (Removal of mill scale, rust or earlier coating).

**Pretreatment** The cleaning of the surface and other steps taken in order to protect the surface to be painted or to promote the adhesion and durability of the coat is called pretreatment.

**Primer** The first layer in a paint system and this determines the quality demands on the preliminary cleaning and the preparation grade.

**Project** A project is a complete programme of work for which the specification is made. A project can include one or several constructions. (EN ISO 12944-8)

**Project specification** The specification describes the project and the special demands which are included. The writer of the specification may be the owner or the main contractor. (EN ISO 12944-8)

**Protective coating system** The total coating, formed by metallic material and/or paints or similar products which are applied on the substrate in order to protect it from corrosion. (EN ISO 12944-1)

**Protective paint system** The total coat, formed by paints or similar products which are applied on the substrate in order to protect it from corrosion. (EN ISO 12944-1)

**Protective paint system specification** In the specification is described how the construction should be pretreated and which protective paint systems should be applied in accordance with the project specification. The writer of the specification can be, for instance, the paint manufacturer.

**Quality** The quality includes all the properties of a product or service which are necessary so that they fulfil stated or presumed demands. (ISO 9000)

**Quality control** Quality control of corrosion prevention is supervision and inspections of methods, material, equipment and application conditions. The contractor is responsible for the quality of the painting work and executes the quality control. The customer may, in addition to the quality control done by the contractor, make his own inspection if he finds it necessary. (EN ISO 12944-7)

**Quality grade of pretreatment** (ISO 8501-3) The quality grades are used to describe the mechanical pretreatment of blasted steel surfaces before painting. In this case the pretreatment include steel preparation, removal of grease, rust and prefabrication primer, to different degrees. The different grades (P1-P3) are specified both by words and pictures which show typical examples of the described quality grade.

**Quality system** The quality system includes the build-up of organisation, responsibility, working directions, processes and resources, which are all required in order to realize the quality management.

**Stripe coat** Supplementary coat applied to ensure uniform coverage of critical and difficult to coat areas such as edges, welds, etc. (EN ISO 12944-5)

**Relative humidity** The relative humidity is the amount of water held by the air as a percentage of the greatest amount it can hold at that temperature.

**Resin** The resin forms a coat which sticks to the substrate. Into this coat the pigments are bound. The resin characterizes the properties of the coat, such as the adhesion to the substrate, the internal strength (cohesion) and chemical properties.

**Round grit** (shot) Particles which mainly are round, their length is less than their breadth and they have no edges or sharp surface defects. (ISO 11124-1; ISO 11126-1)

**Rural environment** The atmosphere in countryside and small towns does not contain noticeable amounts of compounds which cause corrosion, e.g. sulphur dioxide or chlorides. (EN ISO 12944-2)

**Rust** A visible corrosion product (iron, steel) which mainly consists of iron oxides.

**Rust grades** In standard ISO 8501-1 the rust grades of unpainted, hot-rolled steel are described, together with photographic representations. There are four rust grades; A, B, C, and D. Rust grade A: Steel surface covered completely with adherent mill scale and with little or no rust. Rust grade B: Steel surface which has begun to rust and from which the mill scale has begun to flake. Rust grade C: Steel surface on which the mill scale has rusted away or from which it can be scraped, but with little pitting visible to the naked eye. Rust grade D: Steel surface on which the mill scale has rusted away and on which considerable pitting is visible to the naked eye.

The rust grades of painted surfaces are specified in standard ISO 4628, according to the included photos. These photos provide examples of painted steel surfaces which have rusted in different ways. The grades are marked Ri 0 - Ri 5 and they correspond with the percentage of rusty area, 0% - 40/50%. Rust preventing paint See: Anti-corrosive paint.

**Rust prevention** See: Corrosion prevention.

**Sand sweeping** See: Sweep blast cleaning.

**SaS** See: Sweep blast cleaning.

**Shade** A changing property of the colour depending on the oscillation of the light waves.

**Sharp grit** (grit) Particles which are mainly angular and have jagged surfaces and sharp edges, the shape being roughly oval. (ISO 11124-1; ISO 11126-1)

**Shop-primer** See: prefabrication primer.

**Sign of pretreatment** The sign of pretreatment consists of the chemical sign for the metal of the substrate, possible prefabrication primer (abbreviation) and the preparation grade.

**SKY** An association in Finland dealing with corrosion prevention.

**Solids by weight** The solids are specified in percentage of the weight of the paint. ISO 3251.

**Solids by volume** (volume solids) The solids are specified in percentage of the volume of the paint. The determination of volume solids is usually calculated according to ISO 3233.

**Solvent** A component in solvent-borne paints which shall dissolve the firm resins and polymers and reduce their viscosity.

**Solvent-free paints** Paints which do not contain solvents, e.g. powder coatings and solventfree epoxy and polyurethane coatings.

**Solventless paints** (High solids) Paints with a solids by volume of 70-98% are called solventless paints. E.g. epoxy and polyurethane paints can be solventless paints.

**Specific gravity** See: density.

**Specification** A document where the demands on the work or the service are described. The document should specify the methods and criteria to ensure that the demands have been fulfilled. (ISO 9000) It can also be a detailed working specification, including details of the working methods and materials to be used. By following this the work or the service can be carried out so that it fulfils the demands in the specification or in the agreement.

**Spreading rate** See: coverage.

**Storage time** The time the paint preserves its properties and usefulness. This assumes that the paint is stored in the original package in normal warehouse conditions, at a temperature between +3°C and +30°C. (EN ISO 12944-5)

**Stoving enamel** Stoving enamel is a paint where drying and coat forming begins at temperatures above 80°C. The necessary temperatures are generally 120°C-180°C depending on type of paint.

**Substrate** The surface on which the coating is or has been applied. (EN 971-1)

**Supervision** (control, inspection) The measuring, inspection, testing, estimation of one or several properties of the work or service and to compare how well these fulfil the demands in the specification and other corresponding actions.

**Supervisor** A person who is responsible for ensuring that the actions are compatible with the demands in one or several documents concerning the project. (EN ISO 12944-8)

**Surface treatment** A general term for alteration of the surface, e.g. pretreatments and painting. The term is also used in a limited sense excluding metallic coatings.

**Surface pretreatment** Any method which is used to prepare the surface before coating.

**Surrounding atmosphere** A mixture of gases and generally also aerosols and particles which is the environment for a certain object. (EN ISO 12944-2)

**Surveyor** See: supervisor.

**Sweep blast cleaning** In Finland the marking of the method is SaS (SFS 5873). A light blasting of the surface in order to clean or roughen organic or metallic coatings without significant damage to them. (EN ISO 12944-8)

**Thinner** Thinner is an evaporating liquid, solvent or water, which is added to the paint in order to reduce the viscosity. The thinner is often the same as the solvent in the paint.

**Tinting system** An economic, accurate and fast method to produce coloured paints. It is suitable for most types of paints. The tinting system generally includes tinting pastes, base paints, tinting formulas, a tinting machine and a mixer (shaker).

**Topcoat** See: Finishing paint.

**Treatment system** The treatment system means the treatment which concern a certain object, including pretreatment and painting work with material included. The term is usually used for painting of buildings.

**TVT** Abbreviation used by Tikkurila Oyj to describe some colour codes.

**Two-component paint** A paint to which another component is added in order to start the curing process. The components react with each other and form the coat. Two component paints can be solvent or water-borne or solvent-free. E.g. epoxy, polyurethane and oxirane ester paints are two component paints.

**Type of paint** The paints can be divided in different groups depending on the way they dry or their resin. E.g. alkyd, epoxy and polyurethane paints.

**Type of surrounding atmosphere** A classification of the atmosphere based on the quantity and type of corrosive agents present. The compounds of most importance are gases (particularly sulphur oxide) and salts (mainly chlorides and sulphates). (EN ISO 12944-2)

**Urban environment** Contaminated atmosphere in crowded regions with little industries. The amount of sulphur oxide and/or chloride is moderate. (EN ISO 12944-2)

**VOC** Volatile organic compounds (i.e. solvent).

**Volume solids** see: Solids by volume.

**Water-borne paints** In water-borne anticorrosive paints the polymer is dispersed, emulsified or dissolved in water. Typical resins are alkyd, polyester, acrylic, polyurethane and epoxy resins and modifications of them.

**Wet time** The period during which the metal surface is covered by electrolyte which can cause corrosion. The wet time can be calculated as that period when the relative humidity exceeds 80% and the temperature exceeds 0°C. (EN ISO 12944-2)

**White rust** Zinc corrosion products on galvanized or zinc-primer surfaces, the colour varies from white to dark grey. (EN ISO 12944-4)

**Viscosity** Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. The greater the viscosity the worse the consistency of the paint. Consistency of the liquid is measured with a flow cup. The measured viscosity is generally expressed in seconds of flow time.

**Working manual** (see also specification) A specification which describes the working process, the paint system, inspection and estimation specifications. (EN ISO 12944-8) **Writer of specification** The person who is responsible for the specification.

**Zinc-rich paint** (zinc dust paint) A zinc-rich paint should contain at least 80% zinc by weight of the solids of the paint (ISO 12944-5). Zinc-rich paints can be one or two component and be based on resins including epoxies, ethyl silicates and physically drying resins.

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