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## **Preparation of steel substrates before application of paints and related products — Collected information on the effect of levels of water-soluble salt contamination**

*Préparation des subjectiles d'acier avant application de peintures et de  
produits assimilés — Conseils sur les teneurs en contamination des sels  
solubles dans l'eau*  
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## Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this Technical Report may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 15235 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 12, *Preparation of steel substrates before application of paints and related products*.

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## Introduction

The performance of paints and related products applied to steel can be significantly affected by the presence of water-soluble salt contaminants on a steel surface.

Sources of salt contamination are numerous. In the painting industry, the blasting abrasive itself, the paint ingredients (particularly pigments), and the rinse water that may be used in wet cleaning methods can all be sources of salt contamination. In addition, salts settle from the atmosphere during fogs, dews, inversions, and rain, and they may also be deposited from chemical splashes or air pollutants. De-icing salts, which are used on highways and bridges in cold climates, may remain on the steel surfaces. Furthermore, some steel surfaces, during service, come into direct contact with salts, e.g. ships carrying salt water ballast in steel tanks or vessels with salt-containing cargoes.

Unless salts are removed from a steel surface prior to painting, problems may occur that lead to poor paint performance. Salts on the steel surface can absorb moisture from the air, cause osmotic blistering of the paint system, and accelerate the rate of corrosion.

Removal of salts is often difficult, and the salts accelerate pitting corrosion. The salt contaminant can remain in the bottom of pits, often beneath the corrosion product. In order to adequately remove salts from the surface, it is often necessary not only to remove the corrosion product, but also to flush the salt from within the corrosion pits.

The performance of a paint system applied over a salt-contaminated surface depends on the service environment, the type and design of the paint system, the thickness of the paint, and the nature and amount of salt contaminants.

International Standards ISO 8501 and ISO 8502 have been prepared to provide methods of assessing visually or by chemical analysis the presence and surface concentration of contaminants, and ISO 8504 provides guidance on methods for cleaning steel surfaces. These International Standards, however, do not contain guidance on the levels of salt contamination that can be tolerated by paint systems.

This document provides information on the levels of water-soluble chloride and sulfate salt contamination that will minimize the risk of coating failure. The information in this document is based on an evaluation of published data from technical literature, as well as unpublished data from coating-system manufacturers and users.

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# Preparation of steel substrates before application of paints and related products — Collected information on the effect of levels of water-soluble salt contamination

## 1 Scope

This Technical Report provides information on the effect of water-soluble chloride and sulfate contamination levels on steel surfaces, before the application of paint or related products to surfaces prepared in accordance with standard mechanical or blast-cleaning surface preparation methods.

NOTE The tolerance for water-soluble salt contamination may be different for different paint types.

This information may be used when evaluating the adequacy of surface preparation prior to painting.

This document is concerned only with measured levels of salt contamination based upon either laboratory or field testing. The levels of soluble chloride and sulfate discussed in this document are to be compared using soluble surface densities of the species as determined after extraction in accordance with ISO 8502-6 (the Bresle method), or other methods giving equivalent results. Total soluble-salt contamination may be determined by conductometric testing, but such testing will not determine the nature and concentration of the specific salts present, e.g. whether chloride or sulfate is present, or its concentration.

This document does not define specific levels of cleanliness or methods of salt removal.

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## 2 Conclusions

From the information in this Technical Report, it is apparent that there is a great variation in the depth of knowledge related to contamination levels of water-soluble salts (chlorides and sulfates) and their subsequent effect on the performance of paints and related products in various environments.

Most knowledge relates to coatings subjected to immersed conditions, which are judged to be the most severe and therefore, in practice, the most costly should failure occur. The data obtained from paint manufacturers has tended to concentrate on this area and therefore provides the best guidance values for the levels of water-soluble salts with respect to coatings used for protection in immersed conditions.

In other, less demanding, environments, often protected by less sophisticated coatings than those used for immersed conditions, information on water-soluble salt levels and their effect on these coatings is scarce. It is acknowledged that, in these areas, further experimental work is required to produce data, but this is likely to take a significant period of time.

It is in this context that ISO/TC35/SC12 has concluded that the information available does not provide the necessary confidence to provide guidance values that can be issued as an ISO standard.

The publication of ISO standards for methods of determining the water-soluble salt levels on steel surfaces, together with the recommended test procedure given in annexes E and F should provide further data that can be assessed for incorporation into a future ISO standard.

### 3 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply.

#### 3.1

##### **contaminants**

water-soluble salts present on the steel surface immediately prior to painting

NOTE Only water-soluble chloride and sulfate ions are considered in this document.

#### 3.2

##### **service environment**

conditions to which the coating system is exposed in service

NOTE This report covers six types of service environment, defined by the atmospheric-corrosivity categories given in ISO 12944-2:

- a) **IM-1**: fresh- water immersion;
- b) **IM-2**: sea or brackish-water immersion;
- c) **C3 medium**: industrial atmospheric exposure;
- d) **C4 high**: industrial atmospheric exposure;
- e) **C5-I very high (industrial)**: high-humidity/aggressive industrial atmospheric exposure;
- f) **C5-M very high (marine)**: high-salinity marine exposure.

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### 4 Sequential collection of data

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#### 4.1 Review of published papers on the effects of salt contamination

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##### 4.1.1 Sources

A comprehensive review of the technical literature was conducted using journals and electronic databases that examined published literature. A total of 168 relevant articles were reviewed.

NOTE A list of these articles is available from the Netherlands Standards Institute (NEN), which holds the Secretariat of ISO/TC35, *Paints and varnishes*.

##### 4.1.2 Criteria for evaluation

From such a large database, the following criteria were established to provide a basis for evaluation:

- a) The paper/report contained information about original work and was not simply a report of others' efforts;
- b) The paper/report correlated coating performance with salt contamination levels on steel surfaces.

A list of the papers and reports which met these criteria and provided useful information is given in the bibliography, and a summary of the findings is given in annex A.

NOTE The above references given in the bibliography were obtained as a result of an extensive computer literature search done in 1995. The computer results were examined to determine whether the literature reported original testing, or was a compilation of work done by others. Only that literature reporting original test results is given.

It is likely there is original published work since 1995 that will be suitable for future inclusion in the tables. Researchers are encouraged to conduct testing as described in annexes E and F, and to submit results to the Secretariat of ISO/TC 35/SC 12.



### 4.1.3 Parameters relating to the rate of paint system failure

Some parameters relating to the rate of failure of the paint system were:

- a) The type of exposure/service environment.
- b) The type of contaminant (chloride, sulfate, etc.).
- c) The type of paint system (and formulation within generic types), thickness and number of coats.
- d) The application method (brush, roller, spray, etc.), particularly for the primer coat.
- e) The contamination level. The extraction of soluble contaminants from a steel surface depends upon the extraction conditions, e.g. extraction liquid, temperature and extraction time. Comparable results may be obtained by extraction in accordance with ISO 8502-6 (the Bresle method), or methods giving equivalent results. Analysis of chloride and sulfate may be made by methods described in ISO 8502-9 and ISO 8502-10.
- f) The type of failure (blisters, rust, etc.).

### 4.1.4 Use of contamination levels

The data are presented in tabular form using the reference sources given in annex A. The information is generally presented as a safe/failure figure for chloride or sulfate. Also included when given are the following:

- a) Coating system
  - 1) Single systems, defined as consisting of one or more coats of paint based on the same binder (or general chemical composition), e.g. epoxy primer, epoxy topcoat.
  - 2) Mixed systems, defined as consisting of coats of paint in which the binder (or general chemical composition) differs with each successive coat, e.g. inorganic-zinc-rich primer, epoxy topcoat.
- b) Dry film thickness range
 

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The total dry film thickness of the coating system (as defined in ISO 12944-2), as tested or evaluated.
- c) Number of coats
 

The number of coats of the system.
- d) Risk of failure
  - 1) Low risk of failure
 

If chlorides or sulfates contaminate a surface in quantities equal to or less than the amounts expressed in this column, then the risk of coating failure is considered low.
  - 2) High risk of failure
 

If chlorides or sulfates contaminate a surface in quantities equal to or greater than the amounts expressed in this column, then the risk of coating failure is considered high.
  - 3) Intermediate risk of failure
 

For contamination levels between the “low” and “high” ranges, failure may or may not occur, depending upon the service environment, the coating formulation and other variables.

## 4.2 Review of data from industry surveys on the effects of salt contamination

Industrial sources, including paint manufacturers, were approached to obtain further data on the levels of water-soluble salt contamination that they would permit prior to coating. The test methods employed and the systems tested were also requested. One supplier replied and the details are given in annex B.

Due to the poor initial response from industry, a further direct request from ISO/TC 35/SC 12 was made directly to paint manufacturers, with better results.

A good response was received from paint manufacturers in this exercise, including the latest information and the test methods used. The paint manufacturers did not distinguish between the different types of coating system but related the levels of contamination to the service environment. This information is provided in annex C.

Data was received from Japan regarding the permitted levels of chloride (as NaCl) relating to steel structures, steel bridges and industrial plants. This information is given in annex D.

NOTE 1 Much of the data provided in the tables is based upon artificially contaminated surfaces. It should be borne in mind that laboratory tests using artificially contaminated surfaces may show limited correlation with in-service environments.

NOTE 2 The surface density of the soluble surface contaminants measured are expressed as mass per unit area. Generally, the surface density is referred to the apparent area, i.e. micrograms/square centimetre. However, the increase in area caused by surface roughness is often not taken into account. Different blast-cleaning profile grades are defined in ISO 8503-1. For steel, blast-cleaned with grit abrasives, the surface roughness of the profile grades "fine", "medium" and "coarse" is considered to cause an increase in the surface area of about 35 %, 70 % and 110 % respectively over a smooth, flat surface. For steel blast-cleaned with shot abrasives, the corresponding surface area increases are smaller.

NOTE 3 In the literature survey (see annex A), the measurement of salt contamination was made on a mass per unit area basis and these measurements did not consider the increase in surface area caused by surface profile or roughness.

NOTE 4 Total soluble-salt contamination may be determined by conductometric testing, whereby the electrical conductivity of water is increased by the dissolution of soluble salts from a surface. The extent of the increase in conductivity quantitatively reflects the amount of soluble salt on the surface. However, conductometric testing does not determine the nature and quantity of specific salts, e.g. chlorides, sulfates, etc., or their concentrations. Sometimes conductometric test results, usually expressed in microsiemens, or  $\mu\text{S}/\text{unit area}$ , are expressed as equivalent chloride, or equivalent sodium chloride (NaCl). This assumes that all the soluble salts resulting in the conductivity increase are  $\text{Cl}^-$  or NaCl, respectively. As the chloride ion is considered the most corrosive ion species in most cases, this is considered by many as an appropriately conservative expression.

The formulae for expressing conductivity as equivalent chloride and equivalent NaCl are given below.

The NaCl equivalent, in  $\mu\text{g}\cdot\text{cm}^{-2}$ , is calculated by converting conductivity readings obtained from Bresle patch sampling using the equation:

$$E_{\text{NaCl}} = S \cdot \lambda \quad (1)$$

where

$S$  is the conductivity reading, in microsiemens per centimetre ( $\mu\text{S}\cdot\text{cm}^{-1}$ );

$\lambda$  is a constant which depends on the area sampled, calculated from the equation

$$\lambda = \frac{V}{2\,028\,A} \times 10^3$$

where

$V$  is the volume, in ml;

$A$  is the area sampled, in  $\text{cm}^2$ ;

2 028 is the conductivity measured for 1 g of sodium chloride in 1 litre of distilled water (this constant is valid for dilute solutions of sodium chloride).

For a Bresle patch of area 12,5 cm<sup>2</sup> and 3 ml of water:

$$\lambda = \frac{3}{2\,028 \times 12,5} \times 10^3 = 0,118$$

which gives the equation:

$$E_{\text{NaCl}} = S \times 0,118 \quad (2)$$

The equivalent chloride, in µg·cm<sup>-2</sup>, is calculated by converting the conductivity readings using the equation:

$$E_{\text{Cl}^-} = S \times \lambda \times \alpha \quad (3)$$

where

$\alpha$  is the molecular mass of the chloride ion (Cl<sup>-</sup>) divided by the molecular mass of sodium chloride (NaCl), i.e. 0,605.

Hence

$$E_{\text{Cl}^-} = S \times 0,071$$

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## 5 Protocol for assessing surface contamination

It is important when evaluating the amount of salt contamination on a surface to assess its quantity in a consistent manner to enable comparisons to be made with other evaluators, and to obtain meaningful results. Annex E provides an outline of the information that is necessary in order to develop a consistent contamination-sampling protocol.

## 6 Recommended test protocol to investigate the influence of salt contamination on coating service life

When conducting laboratory or field testing to evaluate the effects of soluble-salt contamination on coating system performance, the use of a standardized test protocol will ensure comparability of results and enable users to determine the suitability of the testing for their own use. Annex F provides information on a recommended test procedure to be used for determining the influence of salt contamination beneath a coating system.

## 7 Other standards of interest

When conducting surface preparation prior to painting, or assessing the type and quantity of contaminants on a surface to be painted, there are standards that may be useful. The bibliography lists ISO standards that may be of interest when preparing a steel surface prior to the application of paints or related products.

## **Annex A** (informative)

### **Summary of data from bibliographic references**

Table A.1 gives the data as sourced with the reference numbers corresponding to the references given in the bibliography.

The reader is referred to the original articles for detailed information.

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