DRAFT FOR DEVELOPMENT

DD ISO/TR 15235:2001

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

Confirmed
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National foreword

This Draft for Development reproduces verbatim ISO/TR 15235:2001.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because the source document is an ISO Technical Specification which is not an international standard. It should be applied on this provisional basis, so that information and experience of its practical application may be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion into an international standard. A review of this publication will be initiated 2 years after its publication by the international organization so that a decision can be taken on its status at the end of its three-year life. The commencement of the review period will be notified by an announcement in *Update Standards*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international standard. Comments should be sent in writing to the Secretary of BSI Technical Committee STI/21, Surface preparation of steel, at 389 Chiswick High Road, London W4 4AL, giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

This Draft for Development, having been prepared under the direction of the Sector Policy and Strategy Committee for Building and Civil Engineering, was published under the authority of the Standards Policy and Strategy Committee on 7 December 2001

Summary of pages

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TECHNICAL
REPORT

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15235

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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

Reference number
ISO/TR 15235:2001(E)

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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*.

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.

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.

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.

4 Sequential collection of data

4.1 Review of published papers on the effects of salt contamination

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

   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 µS/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 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 $\mu g\ cm^{-2}$, is calculated by converting conductivity readings obtained from Bresle patch sampling using the equation:

$$E_{\text{NaCl}} = S\ \lambda \tag{1}$$

where

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

λ 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 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^2 and 3 ml of water:

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

which gives the equation:

$$E_{\mathrm{NaCl}} = S \times 0{,}118 \tag{2}$$

The equivalent chloride, in µg cm^{-2}, is calculated by converting the conductivity readings using the equation:

$$E_{\mathrm{Cl}^-} = S \times \lambda \times \alpha \tag{3}$$

where

α is the molecular mass of the chloride ion (Cl$^-$) divided by the molecular mass of sodium chloride (NaCl), i.e. 0,605.

Hence

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

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.

Table A.1 — Data as from the references given in the bibliography

Number	Author	Title	Exposure				
1	Dekker, et al	“Combating Corrosion by Fighting a Hidden Enemy – Soluble salts – A theoretical and practical investigation on surface cleanliness of pre-treated steel”	**100 % humidity 40 °C**				
			Sodium chloride				
			Epoxy phenolic	Safe	Failure		
			1 coat	1 μg/cm^2	3 μg/cm^2		
			2 coats	3 μg/cm^2	[a]		
			3 coats	3 μg/cm^2	[a]		
			Epoxy	Safe	Failure		
			1 coat	[b]	1 μg/cm^2		
			2 coats	[b]	1 μg/cm^2		
			3 coats	[b]	1 μg/cm^2		
			[a] no failure at maximum level tested — 3 μg/cm^2 [b] failure at minimum level tested — 1 μg/cm^2				
2	Frondistou-Yannas, S	“Evaluation of rust-tolerant coatings for severe environments”	Immersion/freeze-thaw KTA envirotest UV light 60 C chloride 1½ immersion 1½ dry	Immersion KTA Envirotest Sulfate	Field exposure		
3	Frondistou-Yannas, S		Reference 2 and 3 generated below		Reference 2 generated below:		
	Combined results		Chloride	Sulfate	Field exposure		
		Red lead alkyd	< 10 μg/cm^2	100 μg/cm^2			
		Tar mastic	< 10 μg/cm^2	100 μg/cm^2			
		Epoxy urethane	< 10 μg/cm^2	100 μg/cm^2			
					Sheltered	Open marine	Open industrial
		Epoxy/mastic	< 10 μg/cm^2	100 μg/cm^2	< 10 μg/cm^2	< 10 μg/cm^2	> 10 μg/cm^2
		Moisture cured urethane			> 10 μg/cm^2	> 10 μg/cm^2	> 10 μg/cm^2
		Water-borne wax			> 10 μg/cm^2	> 10 μg/cm^2	> 10 μg/cm^2
		Rust, converter/alkyd			< 10 μg/cm^2	< 10 μg/cm^2	< 10 μg/cm^2
		Tannic acid/urethane			< 10 μg/cm^2	< 10 μg/cm^2	< 10 μg/cm^2
		Microcrystalline wax			< 10 μg/cm^2	< 10 μg/cm^2	> 10 μg/cm^2

4	Weldon, Bochan and Schleiden	"The Effect of Oil, Grease and Salts on Coating Performance — A Laboratory Evaluation"	**Condensing humidity**					
			Chloride	Safe	Failure	**Sulfate**	Safe	Failure
			Epoxy polyamide	5 µg/cm^2	10 µg/cm^2	Epoxy polyamide	20 µg/cm^2	50 µg/cm^2
			3-coat vinyl	5 µg/cm^2	10 µg/cm^2	3-coat vinyl	> 100 µg/cm^2	*
						* No failure in range tested (100 µg/cm^2 max)		
5	Morcillo, Feliu, Galvan and Bastidas	"Some observations on painting contaminated rusty steel"	**Outdoor (marine and industrial)**					
			Chloride			**Ferrous sulfate**		
				Safe	Failure		Safe	Failure
		oil alkyd		10 µg/cm^2	50 µg/cm^2		> 250 µg/cm^2	[b]
		alkyd		10 µg/cm^2	50 µg/cm^2		50 µg/cm^2	100 µg/cm^2
		chlorinated rubber		2 µg/cm^2	10 µg/cm^2			
		vinyl		10 µg/cm^2	50 µg/cm^2			
		polyurethane		10 µg/cm^2	50 µg/cm^2			
		epoxy/polyurethane		10 µg/cm^2	50 µg/cm^2			
		zinc silicate		> 50 µg/cm^2	[a]			
		zinc silicate/chlorinated rubber		> 50 µg/cm^2	[a]			
		zinc silicate/vinyl		> 50 µg/cm^2	[a]			
		chlorinated rubber/acrylic					50 µg/cm^2	100 µg/cm^2
		vinyl/alkyd					50 µg/cm^2	100 µg/cm^2
			[a] No failure at maximum level tested — 90 µg/cm^2			[b] No failure at maximum level tested — 250 µg/cm^2		

<table>
<tr><td rowspan="11">6</td><td rowspan="11">West</td><td rowspan="11">British Ship Research Association report “Salt contamination of steel surface before coating” sponsored by General Council of British Shipping, 1982

Footnotes
[a] micrograms per square centimetre
[b] deionized water
[c] seawater
[d] 28 cycles of: 5 days accelerated weathering (carbon arc and water spray, BS 3900), 2 days salt fog (BS 3900)
[e] no failure at maximum level tested — 250 g/cm²</td><th colspan="7">Sea water immersion</th></tr>
<tr><th rowspan="2">Coating system</th><th rowspan="2">DFT</th><th rowspan="2">Exposure</th><th colspan="2">Effect of chloride [a]</th><th colspan="2">Effect of sulfate [a]</th></tr>
<tr><td>Safe</td><td>Failure</td><td>Safe</td><td>Failure</td></tr>
<tr><td>Chlorinated rubber</td><td>4 mils</td><td>500 h immersion [b]</td><td>0,6</td><td>155</td><td>10</td><td>159</td></tr>
<tr><td>Chlorinated rubber</td><td>4 mils</td><td>500 h immersion [c]</td><td>10</td><td>155</td><td>159</td><td>[e]</td></tr>
<tr><td>Coal tar expoxy</td><td>10 mils</td><td>500 h immersion [b]</td><td>50</td><td>[e]</td><td>90</td><td>[e]</td></tr>
<tr><td>Chlorinated rubber</td><td>5 mils</td><td>500 h immersion [b]</td><td>7</td><td>50</td><td>30</td><td>50</td></tr>
<tr><td>Chlorinated rubber</td><td>10 mils</td><td>500 h immersion [b]</td><td>50</td><td>250</td><td>90</td><td>250</td></tr>
<tr><td>Aluminium bitumen</td><td>10 mils</td><td>500 h immersion [b]</td><td>50</td><td>[e]</td><td>90</td><td>[e]</td></tr>
<tr><td>Chlorinated rubber</td><td>6 mils</td><td>500 h immersion [d]</td><td>50</td><td>[e]</td><td>90</td><td>[e]</td></tr>
<tr><td>Alkyd</td><td>6 mils</td><td>500 h immersion [d]</td><td>50</td><td>[e]</td><td>90</td><td>[e]</td></tr>
<tr><td rowspan="7">7</td><td rowspan="7">West</td><td rowspan="7">“The relationship between coating thickness and salt contamination on blistering of coatings" UK Corrosion 85, Harrogate</td><th colspan="7">Salt contamination $\mu g/cm^2$, sodium chloride and ferrous sulfate [a]</th></tr>
<tr><th colspan="2">Thickness</th><th colspan="3">Safe</th><th colspan="2">Failure</th></tr>
<tr><td colspan="2">99 microns</td><td colspan="3">10</td><td colspan="2">25</td></tr>
<tr><td colspan="2">149 microns</td><td colspan="3">10</td><td colspan="2">25</td></tr>
<tr><td colspan="2">209 microns</td><td colspan="3">25</td><td colspan="2">50</td></tr>
<tr><td colspan="2">251 microns</td><td colspan="3">25</td><td colspan="2">50</td></tr>
<tr><td colspan="7">[a] In the text of the report, West states: “Sodium chloride is more severe in its effect on blistering than ferrous sulfate”, but specific information is not included.</td></tr>
</table>

8	Midwest Research Institute Cecil Chaplow	Fusion bonded Epoxy	**Contaminate ion threshold values for FBE coatings**				
			Hot water immersion 48 h — 1,5 VOC 65 °C				
			Cathodic disbondment				
				Chloride	Ferrous	Nitrate	Sulfate
				3 µg/cm^2	5 µg/cm^2	3 µg/cm^2	3 µg/cm^2
			Hot water immersion				
			Adhesion after 1 hour	5	24	9	7
			Adhesion after 24 hours	7	18	6	6
			Tensile bond strength	5	16	4	6
			Blister size	5	47	24	9
			Blister density	6	30	27	6
			NOTE The report states: “At mixed ion (Cl^-, NO_3^- and SO_4^{2-}) contamination levels ranging from 12,5 µg to 100 µg of each ion per square centimetre, osmotic blistering of all the test coatings was observed.”				
Synthetic seawater						**Immersion (90°F/50 psi)**	
9	NSRP 0329	“The Effect of Substrate Contaminates on the Life of Epoxy Coatings Submerged in Seawater”		**Chloride**		**Sulfate**	
				Safe	Failure	Safe	Failure
		Tank lining epoxy		20 µg/cm^2	40 µg/cm^2	40 µg/cm^2	125 µg/cm^2
		Clear epoxy (polyamide)		5 µg/cm^2	16 µg/cm^2	40 µg/cm^2	125 µg/cm^2
		Coal tar epoxy		5 µg/cm^2	16 µg/cm^2	40 µg/cm^2	125 µg/cm^2
		Military epoxy (C22241)		10 µg/cm^2	20 µg/cm^2	250 µg/cm^2	[a]
						[a] No failure at maximum level tested.	

10	SSPC91-07	“The Effect of Surface Contaminates on Coating Life” a) These levels are preliminary levels, based on accelerated laboratory testing and limited exterior exposure testing. Additional information and revisions of these levels will be available in future from SSPC and FHWA. b) Levels given in µg/cm^2 based on chloride. If sulfates are determined to be the major contamination species, these levels should be multiplied by 2. c) Aggressive atmospheric: moderate to high industrial fallout (acid rain), intermittent exposure to deicing salts, no accumulation. d) Immersion-like: heavy deicing salt usage, frequent splash, high time of wetness, ponding (e.g. top flange near leaking joints), intermittent immersion.	**Coating system**				**Comments**
			Environmental zone 2A	**DFT (mils)**	**Safe**	**Failure**	
			1 Ethyl silicate zinc/epoxy or epoxy/urethane	6 to 8	< 50	> 50	Based on pressure immersion on testing, which is a more aggressive exposure
			2 Epoxy zinc/epoxy or epoxy/urethane	6 to 8	< 30	> 30	Based on cyclic salt spray for 5 000 hours
			3 High solids, high-build epoxy (mastic)/epoxy or urethane	6 to 9	< 30	> 30	Based on cyclic salt spray for 5 000 hours
			4 Alkali silicate zinc/waterborne acrylic	5 to 7	< 16	> 16	Based on cyclic salt spray for 5 000 hours
			5 Acrylic waterborne (3 coats)	6 to 9	< 8	> 8	Based on cyclic salt spray for 5 000 hours
			Environmental zone 2B				
			1 Ethyl silicate zinc/epoxy or epoxy/urethane	6 to 8	< 50	> 50	Based on pressure immersion testing for 2 000 hours. No degradation observed at 50 µg/cm^2 which was highest level tested.
			2 Epoxy polyamide (2 coats)/ urethane (optional)	6 to 8	< 10	16	Immersion-grade epoxy (e.g. MIL-P-24441). Based on pressure immersion for 1 000 to 2 000 hours.

Steel weathering limits from laboratory testing					
10 (contd)	SSPC91-07	“The Effect of Surface Contaminates on Coating Life”	**Paint system**	Safe* chloride level (µg/cm^2)	Failure chloride level (µg/cm^2)
			Immersion study		
			2 Ethyl silicate inorganic-zinc, vinyl topcoat	[a] (50)	[a] (50)
			3 Organic-zinc epoxy topcoat	7	50
			4 Epoxy mastic, 2 coats	7	50
			5 Moisture-cured urethane	[a] (50)	[a] (50)
			6 Zinc-rich urethane	7	50
			Salt fog exposure		
			1 Oil/alkyd TT-P-615	[b] (7)	[b] (7)
			2 Ethyl silicate inorganic-zinc, vinyl topcoat	[b] (7)	[b] (7)
			3 Organic-zinc epoxy topcoat	7	$\geqslant$ 30
			4 Epoxy mastic, 2 coats	7	50
			5 Moisture-cured urethane	[a] (50)	[a] (50)
			6 Zinc-rich urethane	[b]	$\geqslant$ 7
			7 Petroleum wax coating	[b]	$\geqslant$ 30
			8 Thermal-spray zinc	[a] (50)	[a] (50)
			Ultraviolet condensation/freeze-thaw exposure		
			1 Oil/alkyd TT-P-615	60-100	400
			4 Epoxy mastic, two coats	130	400
			5 Moisture-cured urethane	$\leqslant$ 50	[a]
			6 Zinc-rich urethane	50	400
			7 Petroleum wax coating	[b]	50

			Outdoor exposure		
			1 Oil/alkyd (2)/alkyd	5,7	b (7)
			2 Ethyl silicate zinc/high build	6-9	7
			3 Epoxy zinc/epoxy/urethane	8-12	7
			4 Epoxy mastic (2 coats) urethane	12-15	7
			5 Zinc-rich urethane/epoxy urethane	7-9	7
			6 Water-borne alkali silicate	8-11	b (7)
			7 Thermal-spray zinc	4-6	a (50)
			* Safe indicates no failure noted below this level in this test a Indicates no failure noted at highest level tested, given in parentheses b Indicates failure occurred at lowest level tested, given in parentheses		

Annex B
(informative)

Data from a paint manufacturer
(see 4.2)

These test data were not necessarily collated at one and the same time but over a period of years. The company has been using a test to determine coating performance over “salt contaminated” surfaces for over 4 years. However, in each test a control was used of known and recognised performance which allows the correlation of systems or schemes tested at different times. The “low risk of failure” figures are relatively well defined. The company has used internal information and knowledge of products in some cases to predict the “high risk of failure” figures.

The tests were carried out around the company's group laboratories by a standard test method.

The method ensures that correct levels of contamination were deposited on the test panels and control determinations were made of the contaminated levels via Bresle patch testing and also from “clean” panels.

The panels were then coated with the appropriate test coatings and/or schemes for their resistance to osmotic blistering either under permanent immersion or under wet/dry cycling.

Since the commencement of such detailed work on contamination levels, the company has not carried out any specific testing to attempt to correlate laboratory data against actual practical vessel outturns.

Table B.1 — Guidance levels of water-soluble salt contamination — Salt water immersion — Single systems

Paint system	**Dry film thickness** µm	**No. of coats**	**Risk of failure**		**Type of failure**
			Low	**High**	
			µg/cm^2 chlorides		
Chlorinated rubber	> 225	3	5	10	blistering
Epoxy	> 200	2	< 10	> 25	blistering
Coal-tar epoxy	> 200	2	< 10	> 25	blistering
Vinyl tar	> 220	2/3	< 10	> 25	blistering
Epoxy polyamide	> 200	2	< 10	> 25	blistering
Aluminium bitumen	200	2	< 10	> 50	blistering
Tank lining epoxy	250	2/3	< 5	> 15	blistering
Tar mastic	350	1/2	< 10	> 25	blistering
Epoxy mastic	200	2	< 10	> 25	blistering

Table B.2 — Guidance levels of water-soluble-salt contamination — Atmospheric exposure, industrial — Single systems

Paint system	Dry film thickness µm	No. of coats	Risk of failure		Type of failure
			Low	High	
			µg/cm^2 chlorides		
Chlorinated rubber	> 150	2/3	< 25	> 50	blistering
Epoxy	> 150	1/2	< 25	> 50	blistering
Alkyd	> 180	2/3	< 15	> 25	blistering
Epoxy polyamide	> 150	1/2	< 25	> 50	blistering
Oil alkyd	> 180	2/3	< 15	> 25	blistering
Urethane	150-200	2/3	< 10	> 25	blistering
Zinc silicate	> 75	1	< 10	> 25	blistering

Table B.3 — Guidance levels of water-soluble salt contamination — Atmospheric exposure, marine — Single systems

Paint system	Dry film thickness µm	No. of coats	Risk of failure		Type of failure
			Low	High	
			µg/cm^2 chlorides		
Chlorinated rubber	> 150	2/3	< 25	> 50	blistering
Epoxy	> 150	1/2	< 25	> 50	blistering
Alkyd	> 180	2/3	< 15	> 25	blistering
Epoxy polyamide	> 150	1/2	< 25	> 50	blistering

Table B.4 — Guidance levels of water-soluble salt contamination — Atmospheric exposure, marine — Mixed generic systems

Paint system	Dry film thickness µm	No. of coats	Risk of failure		Type of failure
			Low	High	
			µg/cm^2 chlorides		
Epoxy/polyurethane	> 150	1/2	< 25	> 50	blistering
Zinc silicate/chlorinated rubber	> 225	3	< 5	> 15	blistering

Annex C
(informative)

Coating-system manufacturers' recommendations regarding toleration of salt contamination on a steel surface before application of paints or related products
(see 4.2)

Recommendations from coating-system manufacturers regarding toleration of salt contamination on a steel surface before application of paints or related products are sumarized in Tables C.1 and C.2.

Table C.1 — Manufacturer A

Manufacturer	**Service environment**	**Highest salt level tolerated**						**Comments**
		Conductivity		**equiv. Cl$^-$**		**equiv. NaCl**		
		mS/m	µS/cm	µg/cm^2	mg/m^2	µg/cm^2	mg/m^2	
A	Fresh water immersion	5,3	53	6,9	69	11,1	111	1) Bresle extraction (12,5 cm^2) with 5 ml distilled water. 2) They use conductometric testing only for total salt and convert to equivalent chloride, NaCl. Therefore sulfate and other salts are included in the conductometric measurement.
	Salt water immersion	5,3	53	6,9	69	11,1	111	
	Chemical immersion	5,3	53	6,9	69	11,1	111	
	Atmospheric exposure:							
	Marine	15,0	150	19,5	195	31,5	315	
	Industrial	15,0	150	19,5	195	31,5	315	

Table C.2 — Manufacturers B to L

Manufacturer	Service environment	µg/cm^2 chloride	Sulfate	Comments
B	Fresh water immersion	5	—	1) Use Bresle conductometric extraction for total salt expressed as chloride. 2) If extraction in range 5-10 µg/cm^2, then measure for chloride only.
	Salt water immersion	10	—	
	Chemical immersion	5	—	
	Atmospheric exposure:			
	Marine	—	—	
	Industrial	—	—	
C	Fresh water immersion	6	—	Use Bresle conductometric extraction for total salt calculated as chloride equivalent.
	Salt water immersion	8	—	
	Chemical immersion	6	—	
	Atmospheric exposure:			
	Marine	—	—	
	Industrial	—	—	
D	All immersions	10	—	1) Use Bresle extraction but drop titration for chloride. 2) Test only for chloride.
	Atmospheric exposure:			
	Marine	—	—	
	Industrial	—	—	
E	Fresh water immersion	1	—	Use Bresle conductometric extraction for total salt calculated as chloride.
	Salt water immersion	5	—	
	Chemical immersion	1	—	
	Atmospheric exposure:			
	Marine	—	—	
	Industrial	—	—	
F	Fresh water immersion	3	—	1) Same requirement as US Navy. 2) Test method unknown.
	Salt water immersion	3	—	
	Chemical immersion	3	—	
	Atmospheric exposure:			
	Marine	—	—	
	Industrial	—	—	
G	Fresh water immersion	5	—	Use Bresle extraction for total salt, expressing results as chloride.
	Salt water immersion	10	—	
	Chemical immersion	5	—	
	Atmospheric exposure:			
	Marine	25	—	
	Industrial	25	—	

Manufacturer	Service environment	µg/cm^2 chloride	Sulfate	Comments
H	Fresh water immersion	5	50	1) Levels based on “DIN Working Paper 28”. 2) In practice, can accept “higher chloride levels” for seawater immersion.
	Salt water immersion	5	50	
	Chemical immersion	5	50	
	Atmospheric exposure:			
	Marine	5	50	
	Industrial	5	50	
I	Fresh water immersion	5	50	Levels based on “DIN Working Paper 28”.
	Salt water immersion	5	50	
	Chemical immersion	5	50	
	Atmospheric exposure:			
	Marine	5	50	
	Industrial	5	50	
J	Fresh water immersion	3	—	1) Use Bresle extraction for total salt, expressing results as chloride. 2) Sulfate levels “not available yet”.
	Salt water immersion	3	—	
	Chemical immersion	3	—	
	Atmospheric exposure:			
	Marine	5	—	
	Industrial	10	—	
K	Fresh water immersion	7	—	1) Test method unknown. 2) Data for ambient temperature and “aggressive” cargo.
	Salt water immersion	7	—	
	Chemical immersion	2 to 5	—	
	Atmospheric exposure:			
	Marine	7	—	
	Industrial	7	—	
L	Atmospheric exposure:			Total salt level.
	Marine	7	—	
	Industrial	10	—	

NOTE 1 "—" indicates "Not reported" or "Not applicable" (see comments section).

NOTE 2 1 µg/cm^2 = 10 mg/m^2.

The information presented above from coating-system manufacturers was obtained as a result of discussions with committee members, or as a result of a survey questionnaire sent to approximately 30 coating-system manufacturers, the majority of whom manufactured coating systems for ships and for the marine industry. Their responses were presented literally or were interpolated into the standard reporting format of the questionnaire.

The identity of the coating-system manufacturers has been coded, although most of the information presented herein is publicly available.

It is assumed that the data is applicable to all types of coating system.

Coating-system manufacturers are encouraged to submit data, update data or conduct testing as described in annexes E and F and submit results to the Secretariat of ISO/TC 35/SC 12.

Annex D
(informative)

Data supplied by Japan
(see 4.2)

Practical Japanese allowable levels of water-soluble salt contamination before application of paints and related products for steel structures, bridges and chemical and industrial plant are given in Table D.1.

Table D.1 — Japanese levels of water-soluble salt contamination before application of paints and related products for bridges, chemical and industrial plant and other steel structures

Paint system	Surface preparation		Dry film thickness µm	Contamination level tolerated		Measurement method (ISO 8502-5)	Structure	Reference
	Grade	Roughness		Sodium chloride $\mu g/cm^2$	Sulfates			
Etching primer	Sa 2½	70-80 *Rz*	20	100	—	Ion tube	Steel bridge	Factory
Oil alkyd	Sa 2	40-75 *Rz*	50	50	—	Ion tube	Steel structure	Field
Red lead alkyd	Sa 2½	70-80 *Rz*	30	50	—	Ion tube	Steel structure	Field
Phenol phthalic	—	—	20-30	50	—	Ion tube	Steel structure	Field
Vinyl resin	Sa 2½	70-80 *Rz*	20-50	50	—	Ion tube	Shipbuilding	Yard
Chlorinated rubber	Sa 2	50-70 *Rz*	35	100	—	Ion tube	Tank, bridge, shipbuilding	Yard, field
Epoxy resin			60	100	—	Ion tube	Steel bridge	Factory
Epoxy mastic	St 3		300	100	—	Ion tube		Field
Coal tar epoxy	St 3	70 *Rz*	75	100	—	Ion tube	Tank, bridge, shipbuilding	Yard, field
Inorganic zinc	Sa 2½	70-80 *Rz*	75	100	—	Ion tube	Steel bridge	Factory
Organic-zinc epoxy	Sa 2	70-80 *Rz*	75	100	—	Ion tube	Steel bridge	Factory
Epoxy/polyurethane	—	70-80 *Rz*	60/30	100	—	Ion tube	Tank, bridge	Yard
Silicate-alkyd	—	—	25	50	—	Ion tube	Steel structure	Field
Acrylic silicone	—	—	30	100	—	Ion tube	Steel structure	Field

Annex E
(informative)

Assessment of soluble chloride and/or sulfate contamination on a steel surface — Surface inspection protocol

The protocol should include information on:

a) Steel condition

  Rust grade (ISO 8501-1)

  Surface preparation: method, abrasive used, preparation grade (ISO 8501-1)

  Surface roughness (ISO 8503-1)

b) Extraction of soluble surface contaminants

  Surface area extracted for sample, extraction method (ISO 8502-6)

  Extraction liquid

  Volume of extraction liquid

  Temperature

  Extraction time

c) Analysis of extract

  Method used for chloride analysis

  Surface density of chloride measured

  Method used for sulfate analysis

  Surface density of sulfate measured

Annex F
(informative)

Recommended test procedure when investigating the influence of soluble chloride and/or sulfate contamination on coating service life

In order to obtain comparable results, the following should be determined and recorded:

a) Characterization of the steel tested: rust grade (ISO 8501-1), preparation method, preparation grade (ISO 8501-1), surface roughness (ISO 8503-1), and the number of replicate specimens (at least three of each variant).

b) Contamination of the steel surface: method used for the application of contaminants.

c) Measurements of the surface density of soluble chloride and/or sulfate contamination on the steel, extraction method (e.g. ISO 8502-6 or other method giving equivalent results), extraction liquid, temperature, extraction time, and method of analysis used (e.g. ISO 8502-9, ISO 8502-10 or ISO 8502-11 or other techniques as appropriate).

d) Application of paint system: method, type of paint, dry film thickness and number of coats.

e) Testing of the resistance of the coating to deterioration, preferably by laboratory or field exposure testing in environments specified in ISO 12944-2, e.g.:

fresh-water immersion, IM-1;

sea water immersion, IM-2;

exposure in urban/industrial atmosphere, C3;

exposure in marine atmosphere, C5-M.

f) Inspection of coating deterioration after exposure (e.g. ISO 4628).

g) Evaluation of the relation between soluble chloride and/or sulfate contamination on the steel surface and the coating deterioration during exposure.

h) Test report including information on test performance and results.

Bibliography

References meeting the criteria given in subclause 4.1.2

[1] T.T. DEKKER, T.R. BOK and J. VERBORGT, "*Combating Corrosion by Fighting a Hidden Enemy, Soluble Salts*", 12th International Conference on Organic Coatings Science and Technology, Athens, Greece, 1989, pp. 164-170

[2] S. FRONDISTOU-YANNAS, "*Evaluation of Rust-tolerant Coatings for Severe Environments*". Journal of Protective Coatings and Linings 2, 8 (1986): pp. 26-35

[3] S. FRONDISTOU-YANNAS, R.D. DEANIN, K.B. TATOR, W.C. JOHNSON, "*Coatings for Non-Abrasive Cleaned Highway Steel*", Report No. FHWA/RD-86/053 Federal Highway Administration, Washington DC, December 1985. SSPC Report 86-07

[4] D. WELDON, A. BOCHAN and M. SCHLEIDEN "*The Effects of Oil, Grease and Salts on Coating Performance*", Journal of Protective Coatings & Linings 3, 8 (1987): pp. 46-58

[5] M. MORCILLO, "*Some Observations on Painting of Contaminated Rusty Steel*", Journal of Protective Coatings & Linings 3, 9 (1987): pp. 38-43

[6] British Ship Research Association Report, "*Salt Contamination of Steel Surfaces Before Coating*", Sponsored by General Council of British Shipping, ca. 1982

[7] J. WEST, "*The Relationship Between Coating Thickness and Salt Contamination on Blistering of Coatings*", Presented at UK Corrosion/85, Harrogate, 4-6 November 1985

[8] American Gas Association, Report "*Fusion-Bonded Epoxy Pipe Coatings*", Midwest Research Institute, 1992

[9] National Shipbuilding Research Program, Report Number NSRP 0329, GCS Corrosion Services, "*The Effect of Substrate Contaminants on the Life of Epoxy Coatings Submerged in Seawater*", March 1991

[10] SSPC Report 91-07, "*Effect of Surface Contaminants on Coating Life*." Pittsburgh, PA: Steel Structures Painting Council, 1991

International Standards of interest

Referenced standards:

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

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

ISO 8502-10, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 10: Field method for the titrimetric determination of water-soluble chloride*

ISO 8502-11, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 11: Field method for the turbidimetric determination of water-soluble sulfate* (in preparation)

ISO 8503-1, *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*

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

DIN Working Paper 28, *Testing of prepared steel and paint coating surfaces for contaminants that cannot be detected visually*

Other standards:

ISO 4628:Parts 1 to 6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of intensity, quantity and size of common types of defect*

ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO/TR 8502-1:1991, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 1: Field test for soluble iron corrosion products*

ISO 8502-2:1992, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 2: Laboratory determination of chloride on cleaned surfaces*

ISO 8502-3:1992, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

ISO 8502-4:1993, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 4: Guidance on the estimation of the probability of condensation prior to paint application*

ISO 8502-5:1998, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 5: Measurement of chloride on steel surfaces prepared for painting (ion detection tube method)*

ISO 11127-6:1993, *Preparation of steel substrates before application of paints and related products — Test methods for non-metallic blast-cleaning abrasives — Part 6: Determination of water-soluble contaminants by conductivity measurement*

ISO 11127-7:1993, *Preparation of steel substrates before application of paints and related products — Test methods for non-metallic blast-cleaning abrasives — Part 7: Determination of water-soluble chlorides*

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