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Corrosion of metals and alloys — — Corrosivity of atmospheres — — Mapping areas of increased risk of corrosion

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documentsdocument should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.htmlwww.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Corrosion maps have become more frequent, and to ensure transparency and ease of comparison of corrosion maps, this work was initiated.

This document describes procedures for calculating corrosion maps based on arrays of environmental data organised in a grid and using a dose-response function. Corrosion maps based on dose-response functions can be very useful for illustrating geographical variations, trends in time and the relative importance of different underlying parameters (climate, pollution) and to communicate these results to those not working in the field of corrosion. The result for an individual grid cell of a corrosion map is, however, very uncertain. If a corrosivity assessment for a single location is needed, it is recommended to also consider direct measurements of corrosion according to ISO 9223.

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Corrosion of metals and alloys ~~–~~ — Corrosivity of atmospheres ~~–~~ — Mapping areas of increased risk of corrosion

1 Scope

This document gives guidelines for producing corrosion maps and maps related to increased risk of corrosion in outdoor open atmospheres, but not sheltered or semi-sheltered positions.

The maps are calculated based on environmental data using specific relationships, so-called dose-response functions. Other means of producing corrosion maps, for example using detailed measurements of corrosion and sub-sequent interpolation of measured corrosion values, are not within the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9223:2012, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation*

ISO 9224:2012, *Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories*

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3 Terms and definitions

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

ISO and IEC maintain ~~terminological~~terminology databases for use in standardization at the following addresses:

— ~~—~~ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— ~~—~~IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1
dose-response function
relationship derived from results of field tests for calculation of corrosion loss from average values of environmental parameters

Note 1 to entry: The term is commonly used for all functions, including those where it is not mathematically correct to denote the combination of time and pollution by the word “dose”.

4 Mapping of corrosion attack

4.1 Dose-response functions

For worldwide corrosivity mapping of carbon steel, zinc, copper and aluminium (C1-C5 and CX), dose-response functions given in ISO 9223 should be used. Other functions can also be used for comparison purposes.

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NOTE 1 The error associated with estimation of corrosivity categories using dose-response functions is always higher compared to direct measurements and couldcan lead to significant over or under estimation.

For mapping regions, countries or local areas other dose-response functions can be used.

NOTE 2 Several dose-response functions are available, and examples are given in Annex A and Annex B.Annex A and Annex B.

Dose-response functions should be derived from a statistical analysis of field exposure data collected according to the procedures given in ISO 8565.

The dose-response functions used shall be clearly indicted in the map or map legend. If dose-response functions are not derived from a statistical analysis of field exposure data, this shall be mentioned. This is also the case if dose-response functions based on field data are altered or if several functions based on different field exposure data are combined.

NOTE 3 It is permissible to simplify a dose-response function before its use by inserting a constant instead of an environmental parameter if it can be clearly motivated by an error analysis. This can, for example, be done with respect to temperature, if the mapped area is local with a small variation in temperature compared to other parameters.

4.2 Environmental data used as input to dose-response functions

Data used as input to dose-response functions shall be based on annual averages or longer time spans. The respective years(s) for the data shall be clearly indicted in the map or map legend.

NOTE 1 It is recommended to use the same time period for all data, but exceptions can be made. One example is if a map series is produced with the purpose of illustrating the effect of a changing pollution situation over time (trends), where it is appropriate to use the same climate data (for examplee.g. 30--year averages) for the meteorological data in all maps in this series.

NOTE 2 1 Data are generally available from national weather services, European agencies or other worldwide data sources. A list of some common sources for data is given in Annex C.Annex C.

Data used as input to dose-response functions shall normally not be outside the intervals for the parameters upon which the dose-response function was derived. An extrapolation outside the boundaries of the equation should be clearly marked in the map or map legend.

4.3 Transformation of the environmental data to a common grid system

To combine data by use of the dose-response function, all environmental data shall be transformed to the same grid system and resolution.

NOTE It is recommended to keep the data with highest degree of uncertainty untransformed and transform all remaining data accordingly.

4.4 Calculation and presentation of corrosion attack

The unit to be used for expressing uniform corrosion attack is µm. If the attack is localised but need to be expressed as an average the unit g m^{-2} shall be used.

NOTE The relationship between these two units for uniform corrosion attack (g m^{-2}/µm = g cm^{-3}) is equal to the density of the metal.

For carbon steel, zinc, copper and aluminium intervals corresponding to corrosivity categories C1-C5 and CX as defined in ISO 9223 shall be used. Intervals for low-alloyed steels, including weathering steels, shall follow those for carbon steel;, zinc alloys and zinc coatings shall follow those for zinc;, copper alloys those for copper;, and aluminium alloys those for aluminium.

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Corrosion attack shall be presented in maps with different colours ranging from lighter, corresponding to low values of corrosion attack, to darker, corresponding to high values of corrosion attack.

~~NOTE~~ It is recommended to use a scale which gives a logical representation of corrosion attack (lighter – low; darker – high) when a colour map is printed in black and white.

5 Mapping of lifetime

If the time development is given in the dose-response function, this expression shall be used. Otherwise, the time expression given in ISO 9224 shall be used.

The corrosion attack, D, is given as a function of time according to ISO 9224:

$$D = r_{corr}\, t^{b} \quad (1)$$

where

r_{corr} is the corrosion rate experienced in the first year, which can be mapped and expressed according to the procedures in ~~Clause 4;~~Clause 4;

t is the exposure time, expressed in years and t < 20 years;

b is the metal-environment-specific time exponent, usually less than 1.

The use of ~~Formula (1)~~Formula (1) beyond 20 years is probably justified in most cases, especially if the exposure is not much greater than 20 years. However, ISO 9224 also introduces an alternative linear approach of estimating the corrosion rates at longer exposure times (> 20 years). The lifetime, t_l, can be calculated as given in ~~Formula (2),~~Formula (2), by assuming a specified limiting corrosion attack at which the material/component shall be replaced or maintained, D_l.

$$t_l = (D_l / r_{corr})^{1/b} \quad (2)$$

When selecting D_l, the particular application ~~must~~shall be taken into account.

NOTE An example of a typical lifetime calculation is given in ~~Annex D.~~Annex D.

6 Mapping of corrosion cost

The corrosion cost can be calculated according to ~~Formula (3):~~Formula (3):

$$C = c \cdot S / t_l \quad (3)$$

where

C is the corrosion cost per year;

c is the replacement or maintenance cost per surface area;

S is the total surface area of the material;

t_l is the lifetime, which can be mapped and expressed according to the procedures in ~~Clause 5~~Clause 5.

NOTE 1 The replacement or maintenance cost per surface area, c, is not a constant and can vary substantially between countries.

NOTE 2 The total surface area of the material, S, or the so called "stock of materials at risk" is a geographically dependent parameter that can be very difficult to estimate.

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Dose-response functions are particularly suitable for mapping costs related to different scenarios with respect to climate (climate change) or pollution (air quality policy). For such purposes, it is necessary to estimate the difference in cost between two alternative scenarios. It ~~could~~can, for example, express the cost savings associated with air quality policy from a difference between the current situation and a future scenario. The cost difference, Δ*C*, can then be calculated as given by ~~Formula (4):~~Formula (4):

$$\Delta C = c \cdot S\,(t_{l,1}^{-1} - t_{l,2}^{-1}) \qquad (4)$$

where

$t_{l,1}$ is the lifetime (scenario 1);

$t_{l,2}$ is the lifetime (scenario 2~~)~~).

7 Mapping errors

Corrosion attack in a certain location can be determined by one-year exposure tests in accordance with ISO 9223. The level of uncertainty for this determination is given in ISO 9223:2012, Annex A and is in the range between ±2 % to ±5 %, depending on the metal. The uncertainty associated with the estimation of corrosion attack from dose-response functions is much higher and depends on errors in the used environmental data, uncertainty in the dose-response function and error from the chosen geographical scale. For mapping of lifetime, there is an additional extrapolation error while for mapping of corrosion cost, there ~~is~~are all these errors and in addition errors associated with the estimation of costs for replacement or maintenance.

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NOTE The natural variation in the environment from year to year resulting in a corresponding variation in corrosivity from year to year can be substantial but is not part of this error analysis. This natural variability will affect both the determination of the corrosion attack by one-year exposure tests as well as the estimation of corrosion attack with dose-response functions.

Environmental data used as input to the dose-response functions are either from models based on physical and chemical transport equations or from interpolation of measurements from weather station data. The errors can be substantial but vary significantly depending on the data source and it is not possible to give a general magnitude of the error. It is recommended to make an estimation of the errors for all the input environmental mapping data.

Dose-response functions are statistical relationships and the statistical error when using a dose-response function, even with perfect input data, is about ±50 %, depending on the ~~equation~~formula (see ISO 9223:2012, Annex A).

Maps are produced at a certain scale represented by the grid size, which is determined by the geographical resolution of the input data. Geographical variations in corrosivity can, however, be substantial. Special care should be taken when interpreting maps where ~~there is expected to be~~ a strong gradient in one or more of the input parameters is expected, for example, variation in SO_2 within an urban area or variation in chloride deposition in coastal areas.

Errors associated with extrapolation in time can be substantial, especially for longer lifetimes. ISO 9224 give uncertainties for the coefficient *b* in ~~Formula (1),~~Formula (1), which can be used to estimate uncertainties for estimated lifetimes.

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