THE ACTUAL APPROACH FOR ATMOSPHERIC CORROSIVITY CLASIFFICATION IN RESPECT TO PROTECTIVE COATING CHOICE

[1]Katerina KREISLOVA

[1]*SVUOM Ltd., Prague, Czech Republic, EU, kreislova@svuom.cz*

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Abstract

Atmospheric corrosion can seriously affect the performance of steel structures over long periods of time. Standards and codes represent the general guidelines and suggest general protection techniques to prevent structures from corrosion damage. The EN ISO 12944 criteria and guidelines help to select the right paint system for each project. The basis system of atmospheric corrosivity classification was specified by EN ISO 9223 and this system is implemented into other standards for protective coating choice (paint coating, metallic coating, duplex system, etc.). The corrosivity category is also important for accelerated testing of chosen protective systems – regime and duration of test. Due to changing and varying environmental situation in Europe the actual data is necessary to use. The specific microclimates are presented too.

Keywords: corrosivity category, classification system, paint system, accelerated tests

1. INTRODUCTION

All steel structures, facilities and installations exposed to the atmosphere, submerged under water or in soil, suffer because of corrosion. Consequently, they require protection from the harm caused by corrosion during their lifetime. Selecting the correct paint system for protection against corrosion requires a variety of factors to be taken into account that the most economical and best technical solution is achieved.

The corrosivity category is a technical characteristic which provides a basis for the selection of materials and protective measures in different environments. The basic standard for atmospheric corrosivity classification is EN ISO 9223 *Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation.* The classification system had been implemented in many other standards specifying various types of corrosion protection (hot dip coating, paint coating, thermally sprayed coatings, coil coated sheet, etc.).

2. CORROSIVITY CATEGORY CLASSIFICATION

The EN ISO 9223 establishes a classification system for the corrosivity of atmospheric environments. The first edition of standard had been published in 1992 and during decades it was worldwide spread and implemented in many other standards, technical specifications, guidelines, etc. The EN ISO 9223 revised edition published in 2012 obtains some changes:

- defines six corrosivity categories (C1 – very low, C2 – low, C3 – medium, C4 – high, C5 – very high, CX – extreme) for the atmospheric environments by the first-year corrosion rate of standard specimens. The CX category, which covers the most extreme environments – usually offshore environments, had been implemented after revision in 2012. The corrosivity categories are based on one-year corrosion mass loss or penetration of carbon steel, zinc, copper and aluminium coupons. The corrosivity category for each of this metal should not be the same level in the same locality because each of standard metal has different sensitivity to different environmental parameters.

- gives dose-response functions for normative estimation of the corrosivity category based on the calculated first-year corrosion loss of standard metals. Dose-response functions for four standard metals describe the corrosion attack after the first year of exposure in open air as a function of yearly average values for SO_2 dry deposition, chloride dry deposition, temperature and relative humidity. Functions are based on results of worldwide corrosion field exposures and cover climatic earth conditions and pollution situation.
- makes possible an informative estimation of the corrosivity category based on knowledge of the local environmental situation. A corrosivity category estimated using the informative procedure based on the comparison of the local environmental conditions with the description of typical atmospheric environments can lead to misinterpretations. This approach is to be used if experimental data are not available.

The new method for determination of one-year corrosion rate is used resistive sensors instead of standard metallic coupons [1, 2].

The different approach of determination/estimation can be applied depending on the type of climate, resp. conditions affected corrosivity at given locality – **Figure 1**. The climate factors – temperature and relative humidity create the conditions for atmospheric corrosion themselves and change from place-to-place, from country-to-country and from season-to-season. The general climate pattern for a region of a country is usually known as the macroclimate. However, significant variations can occur locally (e.g. as a function of height or distance from the sea), as a function of human activity (e.g. cities are usually slightly warmer and more humid than the countryside) and vary locally (e.g. depending on the arrangement of buildings). These smaller variations are known as the microclimate. The microclimate corrosivity is also specific in the case of specific type of pollution in given locality.

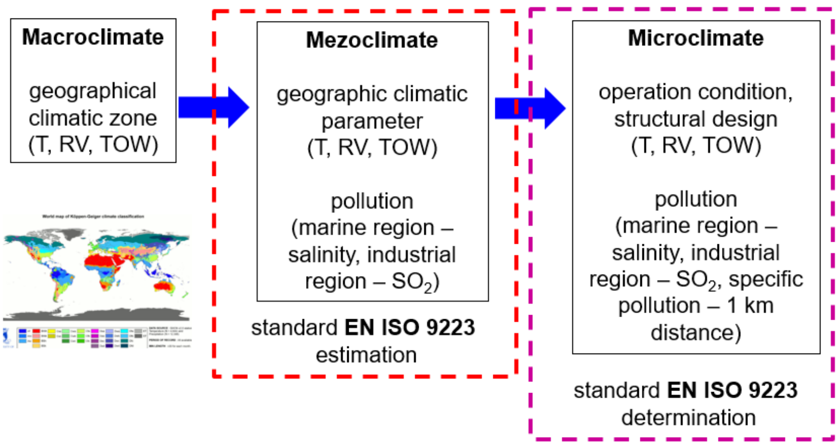

Figure 1 Type of climates

The EN ISO 9223 does not take into consideration the design and mode of operation of the product, which can influence its corrosion resistance, since these effects are highly specific and cannot be generalized. In such case of specific microclimate, the direct determination of corrosivity category is necessary to used.

Very important is also the trend in decreasing the corrosivity categories in the majority of countries in Europe, USA, Canada, etc. This decreasing is mainly caused due to reduction of industrial pollution of SO_2 from large sources. This trend is illustrated on **Figure 2** – in Europe the long-term exposure program is performed since 1986 and exposure the standard metals in yearly periods together with measuring the basic environmental parameters [3]. The measured increasing of yearly average temperature is not so significant to affect the corrosivity, but SO_2 changes are very significant. The same decreasing trend is evident for long-term exposure of standard metals.

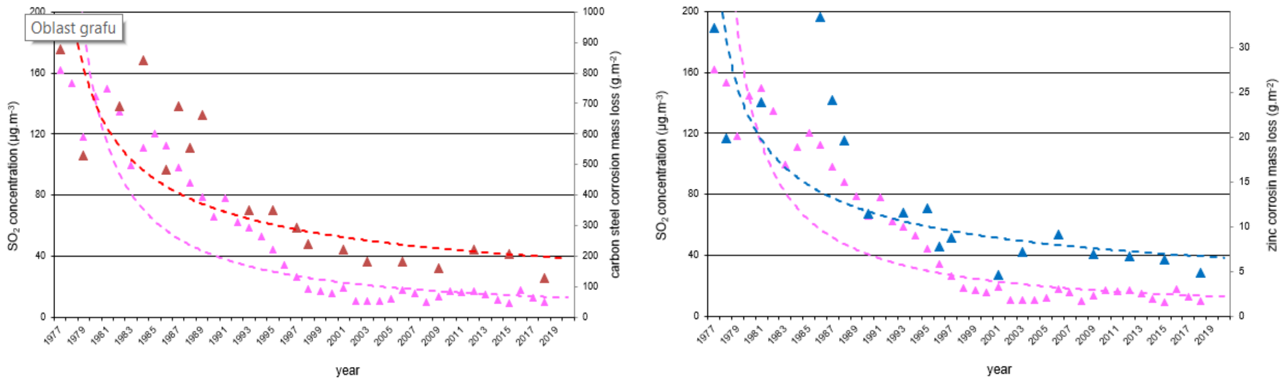

Figure 2 Trends of yearly SO_2 pollution concentration and yearly mass loss of carbon steel and zinc at the industrial test site Kopisty at Northern Bohemia

3. CLASSIFICATION OF ENVIRONMETAL CORROSIVITY ACCORDING TO EN ISO 12944-2

The EN ISO 12944 *Paint and varnishes – Corrosion protection of steel structures by protective paint systems* was developed in the 1990s and the first edition was published in 1998. The standard series EN ISO 12944 (parts 1 – 9) had been revises in 2017-18 and it is intended to assist engineers and corrosion experts in adopting best practice in corrosion protection of structural steel at new and renovated construction. There are many changes in this revision of EN ISO 12944, some of which have a practical impact on how to protect steel against corrosion by using paint. A few of the most important changes are highlighted below – **Figure 3**:

New corrosivity category CX	New durability category – very high VH	New part 9 – ISO 12994-9 for offshore construction	Update of DFT values which have become normative

Figure 3 The most important changes into revised version

The EN ISO 12944 becomes a truly global benchmark in corrosion control, too. Selecting paint systems specifications that comply with EN ISO 12944 provides clients with:

- confidence that the corrosion protection specified will be fit for purpose,
- an objective approach to coating selection – a universally accepted standard,
- a meaningful coating design life,
- a simplified matrix of coating systems to select from.

To select a compliant system, follow few steps:

- to select the most appropriate corrosivity category classification,
- to choose the required durability of the coating system,

The part 2 of EN ISO 12944 standard gives the corrosion classifications for atmospheric conditions, soil and water. This standard is a very general evaluation based on the atmospheric corrosion classification for carbon steel and zinc identic to ISO 9223. It does not reflect specific chemical, mechanical or temperature exposure. The standard says that mass or thickness losses obtained for steel and zinc specimens can sometimes give different categories. In such cases, the higher corrosivity category shall be taken. This recommendation is wrong because carbon steel and zinc have different sensitivity to environmental parameters and if the paint system failed the corrosion attack occurred according to type of substrate metal. There are many cases when the not respecting propriate corrosivity category according to substrate metal led to failure of painting systems.

In the first edition of standard (1998) the category C5 was divided into two subcategories C5I and C5M – **Table 1**. The corrosion mass loss of all four metals was the same as for category C5 and only reason for this dividing was for accelerated laboratory testing the paint system applying for such different high corrosive environments. Due to changes in SO_2 pollution level – see above – the C5 corrosivity category can be found only in marine environments.

Table 1 EN ISO 12944-2:1998 Corrosivity category C5

Corrosivity category		Corrosion risk	Typical steelwork location	Pollution level
C5	C5I	Very high	Industrial areas with high humidity and aggressive atmospheres	90 to 250 µg SO_2 .m^{-3}
	C5M		Coastal and offshore areas with high salinity	300 to 1 500 mg Cl^-.m^{-2}.d^{-1}

Special care shall be taken when considering structures that are partly immersed in water or partly buried in soil – **Table 2**. The category Im4 is newly added into revised edition. Corrosion under such conditions is often restricted to a small part of the structure where the corrosion rate can be high. For these categories there are not such values/limits for corrosion mass loss as for atmospheric environments.

Table 2 EN ISO 12944-2:2017 Corrosivity categories for water and soil

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
Im2	Sea or brackish water	Immersed structures without cathodic protection (e.g. harbour areas with structures like sluice gates, locks or jetties)
Im3	Soil	Buried tanks, steel piles, steel pipes
Im4	Sea or brackish water	Immersed structures with cathodic protection (e.g. offshore structures)

The different types of water make predicting corrosion rates rather difficult. Many parameters, including pH level, oxygen content, water temperature, agitation, the presence of inhibitors, and tide conditions affect corrosion of metals in the water environment. In the 1980's a year's exposure of carbon steel (80 – 95 µm.a^{-1}) and zinc (20 – 25 µm.a^{-1}) was performed in Czech rivers. **Figure 4** illustrate corrosion damage of paint system after 3 years of service applied on inside surface of sewage tanks chosen for Im1 category instead of Im2 category – the main reason of damage was low thickness of paint system (ca 150 µm). According to required service life of painting system protection the DFT is ca 350 µm or ca 500 µm.

Figure 3 The paint failure after 3 years of service

The nature of the environment and the corrosion contributing conditions will have an effect on:

- the type of paint used for protection,
- the total thickness of a paint system,
- the surface preparation required,
- minimum and maximum recoating intervals.

All these recommendations are given in EN ISO 12944 Part 5 *Protective paint systems.*

4. PAINTING SYSTEM TESTING

Testing coating systems in accordance with EN ISO 12944 standard specifications can provide the end user with reasonable assurance that the materials they are considering have been subjected to the same test parameters, and based on the results are considered satisfactory for use by meeting the minimum performance requirements. However, accelerated weathering laboratory testing results should be analysed with caution as there is no direct correlation of hours exposed versus service life expectancy, but meeting these minimum specification requirements can provide the user with some insight to the overall durability of the coating system under consideration. The standard EN ISO 12944 not only takes into account the laboratory testing (salt spray test, ageing, chemical resistance etc.) but also considers the vast industrial knowledge gained on these coating systems through years of practical experience in the specific corrosivity category environments. The practical experience is reflected in EN ISO 12944-5, since the suggested systems are based on this extensive industrial experience.

In EN ISO 12944 Part 6 *Laboratory performance test methods* there is information about relationship between artificial ageing and natural exposure. The main changes compared to the previous edition are as follows:

- additional performance tests,
  The new testing for very high durability (25+years) in the corrosive categories C2, C3 and C4 is introduced. In addition, in category C5 (high and very high corrosivity) the updated standard introduced cyclic testing for high and very high durability. The aim of cyclic testing is to better replicate in-field conditions, and industry has found that this method of testing is more representative of what happens out of the lab, in the real world.
  One of the major changes in the revision is the addition of cyclic testing for systems operating in environments of C4 very high and above. A cyclic ageing test (Annex B) is introduced for C5 VH/ H and C4 VH – **Figure 4**. In case of C5 H and C4 VH the test regime including salt spray and condensation test can still be used as alternative to cyclic ageing test.
- requirements for test panels have been revised - **Figures A.1** and **A.2** (example of scribe line) have been added,
- paint systems description has been revised and requirements for maximum film thickness added,
- paint system assessment has been revised including a new Table 3 *Assessment before artificial ageing* and a new **Table 4** *Assessment after artificial ageing for the specified time* according EN ISO 4628 parameters.

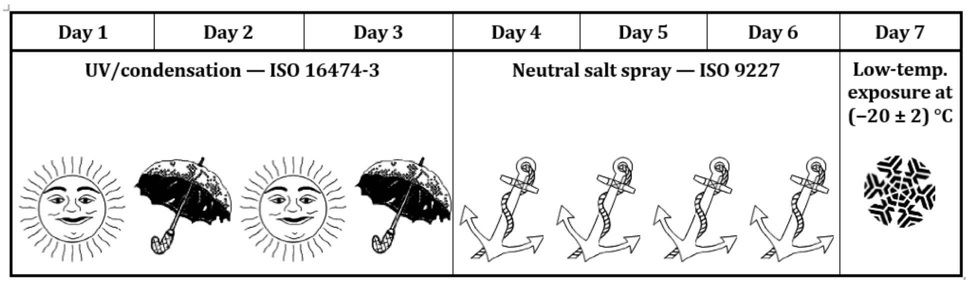

Figure 4 Cyclic ageing test

The EN ISO 12944 Part 9 *Protective paint systems and laboratory performance test methods for offshore and related structures* replaces ISO 20340:2009 *Offshore and related structures* and deals with the atmospheric corrosivity category CX (offshore) for operating temperature and the immersion category Im4 as defined in EN ISO 12944-2. It requires specific attention in order to be able to withstand the severe corrosion stresses to which they are exposed during their service life and to minimize the risk of failures that would impact safety, operating costs or capital cost. Specific requirement for paint system applying for offshore CX and immersion Im4 environments is quality control of paints including "fingerprint" – FTIR spectrum of paint. The aim of a fingerprint check is to confirm the consistency of the paints supplied with reference to qualified paints. After qualification of a paint system, this fingerprint may be used, if necessary, to verify that the paints supplied are identical to those subjected to qualification testing.

Optional tests may also be carried out, such as chemical resistance, impact resistance, abrasion resistance and thick film cracking resistance. The actual optional tests to be carried out shall be agreed between the interested parties.

5. CONCLUSION

The revised edition of EN ISO 12944 series had been implemented in the majority of aspects of paint industry, from research and development through to technical services and marketing communication.

The local intensity of atmospheric corrosion within a country or region can be experimentally mapped by exposing regularly spaced metal samples outdoors for a given length of time then determining the mass loss due to corrosion at that location [4, 5]. For many specific operation environments/conditions detailed corrosivity information is often scarce and/or unreliable, which prevents or limits the application of many Risk Based Inspection (RBI) databases / software systems, which are "data hungry". In order to overcome this limitation, and to allow corrosion risk assessment of both existing and aging facilities, an alternative in-house expert database has been created. SVUOM creates such databases from its accredited laboratory testing and field evaluation of paint systems applied on various steel structures.

For other type of coatings (inorganic, conversion, electrodeposit coatings) there is not such precise system of classification elaborated – EN ISO 27830 *Metallic and other inorganic coatings — Guidelines for specifying metallic and inorganic coatings* specifies the technical requirements (thickness) of metallic and other inorganic coatings in respect to service conditions and required service life.

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