Corrosion of lightning protection system components placed in atmosphere (air) and in earth (soil)

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Abstract

The paper concerns corrosion problems of Lightning Protection System Components (LPSC). Test requirements of LPSC are specified in IEC standards related to LPS design (IEC 62305 series) and to LPSC tests (IEC 62561 series). The paper includes the analysis of several factors characterising the influence of LPSC corrosion partially placed in air and in soil and explores the complexity of this problem. In published IEC standards related to LPS and LPSC corrosivity categories in atmosphere and in soil connected with their locations are not evaluated and no corrosion tests procedures and passing criteria are specified. Some proposals and suggestions to introduce more requirements for corrosion tests to appropriate IEC standards are also discussed.

1 Introduction

The Lightning Protection System (LPS) is a complete system which shall reduce injury and physical damage due to lightning flashes to a structure and its contents. The requirements of LPS design and construction are thoroughly described in series of IEC 62305 standards. The test requirements for LPS components (LPSC) are given in series of IEC 62561 standards. These standards are systematically revised and updated by TC 81 IEC with the aim of ensuring their worldwide acceptance and application.

LPS consists of an external part which is intended to intercept the lightning flash with an air-termination system, to conduct the lightning current using a down-conductor system and to disperse the lightning current into earth using an earth-termination system.

All components of LPS are exposed to corrosion which is a specific problem due to its complexity and severity where LPSCs are partially placed in air (atmosphere) and in earth (soil). In particular, corrosion affects the metal components of the earth-termination system:

- an earth lead-in conductor which is defined in IEC 62561-2 [4] (but it is not defined in IEC 62305-3) as a conductor installed between a down-conductor or a test joint and an earth electrode intended to provide connection of the earth electrode with the test joint. It may be a rod or horizontal conductor and can be partially buried in soil (or partially embedded in concrete) and partially placed in air,
- earth electrode which is a conductive part in electric contact with local earth (soil), directly or through an intermediate conductive medium,
- clamps and joints which may be placed both in air and in soil.

Corrosion of metal will occur at a rate depending on the type of metal and the nature of its environment. Environmental factors such as moisture, dissolved salts (thus forming an electrolyte), degree of aeration, temperature and the extent of movement of electrolyte combine to make this condition a very complex one. In addition, local conditions, with different natural or industrial contaminants, can cause significant variations as observed in different parts of the world. In **Figure 1** the exemplary pictures of lead-in (earthing) conductors damaged by corrosion in different soil types and locations are shown.

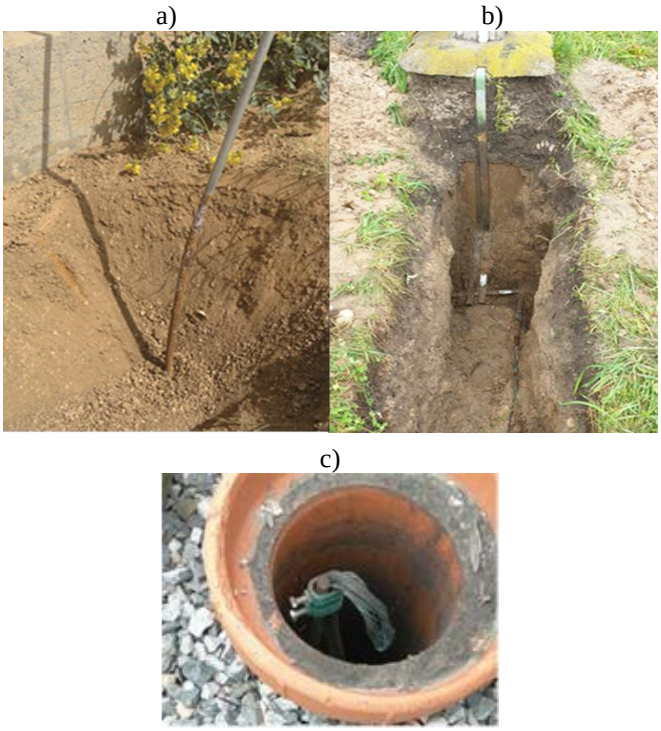


Figure1. Examples of corroded lead-in conductors (earthing conductors): a) round steel earth zinc galvanized conductor after 6-month service in Sudan [16], b) steel zinc galvanized tape conductor after 12-year service in Poland [from the authors' archive], c) junction of steel earth rod with copper stranded conductor in an inspection box [from the authors' archive].

It shall be emphasized that in IEC 62561 series of standards related to test requirements of LPSC no corrosion tests are specified. There are described so called environmental tests only, which consist of:

- Salt mist treatment in the chamber in accordance with IEC 60068-2-52 [5],
- Humid sulphurous atmosphere treatment in accordance with ISO 22479 [6].
- Ammonia atmosphere treatment in accordance with ISO 6957 [7].

These tests demonstrate the influence of aggressive environments on LPSC placed in air, which may appear in specific areas where artificial or natural air pollution is permanently or temporary present. The passing criteria are defined in [3,4] for materials (base and coated metal) accepted for design of LPSC resulted from visual inspection. I.e. white rust for steel galvanized zinc coating, patina (green oxidation), light red rust and other surface oxidations for copper or copper coated steel components are not considered as corrosive deterioration which is not related to any corrosion characteristic.

Unfortunately, no corrosive environment and corrosion risk for LPSC, totally or partially placed in earth (soil), are identified in IEC standards related to LPS and LPSC.

This problem is discussed in the paper and some suggestions for further study and implementation of corrosion tests of LPSC in standards related to LPS are presented.

2 Risk of corrosion of LPSC placed in air (atmosphere)

In ISO 9223 [8] standard corrosivity of the atmosphere in relation to one-year corrosion effect is categorized while the ISO 9224 standard [9] specifies guiding values of corrosion attack for metals and alloys exposed to natural outdoor atmospheres.

Six different categories are defined: C1 (very low corrosivity), C2 (low), C3 (medium), C4 (high), C5 (very high) and CX (extreme).

Corrosivity categories can be estimated in different ways:

• Based on corrosion rate (corrosion loss) measurement of standard specimens (usually recommended) or normative, based on exposure at test sites,

• Based on environmental information, normative based on dose-response functions including temperature, relative humidity sulphur dioxide level and chloride deposition.

• Based on environmental information and description of exposure conditions.

Environmental parameters can be classified into different types:

• Climatic parameters including temperature, precipitation amount, relative humidity, time of wetness, etc.

• Gaseous pollutants including SO_2, NO_X, O_3, etc.

• Particulate deposition including chloride deposition and other particles.

• Characteristics of precipitation influenced by long-range and local effects including pH, sulfate, nitrate, and chloride content, etc.

• Microbiological activity.

The environment in general is also frequently characterized as rural, urban, marine, and industrial. It is important to note that this description does not indicate the corrosivity category but only the type of the environment (and the types of pollutants that typically dominate in this environment). It is possible to find rural atmospheres having a high corrosivity category and urban sites having a low corrosivity category, even if the opposite is more frequent. A typical location for LPSC is open air, however, in some cases a part of them may be located under shelter, in a closed space, etc. It should be noted that exposure conditions are not easily extrapolated to different type of locations due to microclimatic factors.

Corrosion testing is an important part of corrosion work to estimate, assess, predict, and verify the performance and lifetimes of individual materials, systems, and components including LPSC. This is an essential input for selection of appropriate corrosion protection systems and to achieve reliable products.

Very useful information on corrosion assessment of LPSC placed in atmosphere (air) is provided in the first edition of Catalogue of Atmospheric Corrosion Field Exposure Sites in Europe published by the European Federation of Corrosion [10]. It includes estimated corrosion rates of different metals (steel, zinc, copper, aluminium) and defines environmental parameters including rainfall rate, relative humidity, time of wetness, SO_2 content, chloride deposition for 43 locations in Europe. These locations have been classified according to corrosivity categories given in ISO 9223 [8] as shown in **Figure 2** and **Table 1.**

Similar corrosion maps for the USA and other countries are available to be created using Whole Building Design Guide developed by the National Institute of Building Sciences (USA) [11]. Examples are shown in **Figure 3**.

While assessing corrosion performance of LPSC placed in air it is necessary to consider more detailed environmental factors and corrosivity categories in standards related to LPS [1,2], similarly as it is proposed for other metallic constructions and devices located in atmosphere (air) [7].



Figure 2. Locations of corrosivity exposure sites in Europe published in [10].

Table 1. Overview of selected parameters and classification of exposure sites described in [10].

No.	Site name	Atmosphere	Corrosion rate [g/m² year]				Environmental parameters					
			Steel	Zinc	Copper	Aluminium	Temp. [°C]	Rainfall [mm/year]	Relative humidity [%]	Time of wetness [%]	SO_2 [µg/m³]	Chloride deposition [mg/m²·day]
1	AT, Linz	Urban, Industrial	106	11.4	8.2	0.3	12	735	70	41	7	3
2	CZ, Kasperske Hory	Rural	53	4.5	8.7	0.01	8	693	74		8	
3	CZ, Kopisty	Industrial	131	4.9	11.9	0.2	10	489	73		12	2
4	CZ, Kralupy	Urban	41	2.0	5.0	0.1	11	581	73	42	5	<1
5	CZ, Ostrava	Industrial	164	10.0			11	488	73		17	
6	CZ, Prague	Urban	56	3.1	3.1	0.1	11	473	70		5	3
7	DE, Berlin A103	Urban	159	4.9	14.0	1.1	11	460	73	35	2	94
8	DE, Berlin B1	Urban	38	4.3	15.9	0.2	10	725	79	46	2	12
9	DE, Berlin BAM	Urban	56	5.3	9.1	0.2	10	505	79	45	2	12
10	DE, Helgoland IFAM	Marine	2390				11	874	80			
11	DE, Helgoland Seawater	Marine	2376	60.0	62.5	1.9	9	718	75	52		
12	DE, Helgoland Südhafen	Marine	251	24.5	22.3	0.5	11	648	81	54		
13	DE, Helgoland Uplands	Marine		8.5			9	719	75	52		431
14	DE, Helgoland Seawater IFAM	Marine	2084	21.0	89.0	3.3	10	874	80			
15	DE, Helgoland-Westkaje	Marine	296	10.5	13.5	0.4	9	719	75	52		431
16	DE, Horstwalde	Rural	44	4.0	19.7	0.1	10	636	79	45		
17	DE, Leuchtturm alte Weser IFAM	Marine					11		82			
18	DE, Sylt Seawater IFAM	Marine			87.0		10	797	79			
19	ES, Barcelona	Rural, Urban	53	6.5			15	600	66	51	3	≤3
20	FR, Brest	Marine	750	11.0	20.0	0.6	13	1100	83	60	<1	1300
21	FR, Le Croisty	Rural	140	9.0	7.0	0.2	12	1000	84	67		<5
22	GR, Athens	Urban	77	6.4	5.0	0.1	20	448	58		9	
23	IT, Genoa	Marine, Urban	130	11.0	14.0	1.1	18	1254	64	9		57
24	IT, Milano	Urban			4.5		15	825	61		5	
25	IT, Monte Cimone	High UV					2		79		<1	
26	IT, Plateau Rosa	High UV										
27	IT, Trento	Urban					13	1306	27	30	3	
28	NO, Birkenes	Rural	58	8.1	7.6	0.4	6	1567	79		<1	7
29	NO, Oslo	Urban	19	5.8	3.5		7	716	73		2	
30	NO, Svanvik	Rural, Industrial	69	7.9	7.9	0.7	1	411	78		7	
31	NO, Tananger	Marine	600				9	1552			3	211
32	PL, Katowice	Urban	18	2.5	0.6	0.1	10	726	74		8	2
33	PT, Alfanzina	Marine	214	9.8	24.0	1.0	17	417	77	42	14	80
34	PT, Guincho	Marine			61.0		16	451	76	48		768
35	PT, Lisbon	Urban		9.5	8.3	0.7	16	723	71	38	32	9
36	PT, Lumiar	Urban	147	7.0	12.0	0.2	17		72	41	22	18
37	PT, Sines	Marine/Industrial	928	45.0	57.0	2.0	17		81	59	132	140
38	SE, Bohus-Malmön Kattesand	Marine	237	6.9	12.0	0.5	9	967	81	57	<1	75
39	SE, Bohus-Malmön Kvarnvik	Marine	751	11.0	26.0	2.3	9	967	81	57	<1	577
40	SE, Bohus-Malmön Kvarnvik 3	Marine	269	8.5	14.0	0.8	9	967	81	57	<1	125
41	SE, Gällivare	Rural	38	4.4	1.7	0.3	0		77	20		
42	SE, Kristineberg	Marine	378	5.3	18.9		10	1017	81	59		
43	SE, Ryda	Rural	28	2.9	3.9	0.1						

Colour code (for explanation, see ISO 9223)

C1	C1	C1	C1
C2	C2	C2	C2
C3	C3	C3	C3
C4	C4	C4	C4
C5	C5	C5	C5
CX	CX	CX	CX

	P_0	S_0
τ_3	P_1	S_1
τ_4	P_2	S_2
τ_5	P_3	S_3

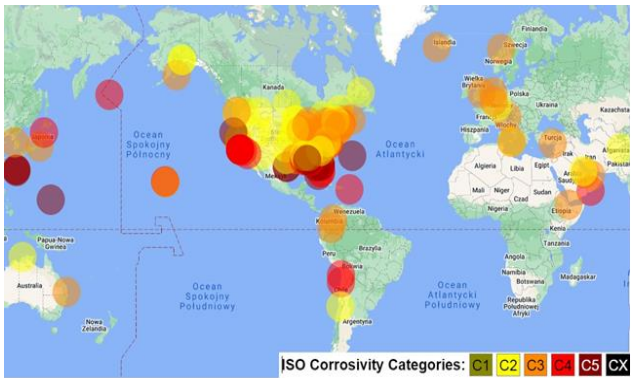


Figure 3. Map of locations with different ISO corrosivity categories [9] created using Whole Building Design Guide Toolbox [11].

3 Risk of corrosion of LPSC placed in earth (soil)

The general description of metallic materials corrosion likelihood in soil is given in EN 12501-1[12]. The diagram of risk assessment of metal components in soil is shown in **Figure 4.** Classes of soil corrosion hazard according to [12] are shown in **Table 2** [12], risk level of corrosion is described in **Table 3**, while commonly used soil corrosion aggressiveness factors are assessed in **Table 4** [8,9,12,13,16].

Major factors influencing soil corrosion intensity of metal LPSC are:

- Environmental factors related to electrical interaction between soil and external electrodes caused by e.g. stray currents, cathodic protection or power frequency currents
- Categories of local soil, backfill soil and/or enhancement (if used) and their corrosion aggressiveness.
- Types of metal materials which LPSC is made of.

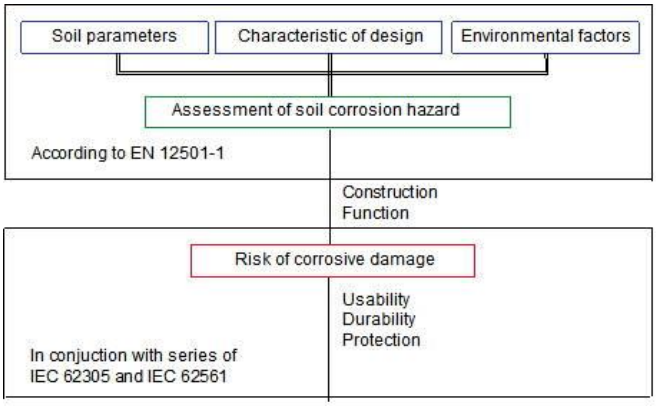


Figure 4. Diagram for assessment of corrosion risk in soil [8].

Table 2. Classes of soil corrosion hazard [12]

Classes of corrosion hazard	**Classification of soil corrosion risk**
Low	A low risk of corrosion loss being higher than the threshold value or occurrence of specific corrosive effect.
Medium	A high risk of corrosion loss being between upper and lower threshold value.
High	A high risk of corrosion loss binge higher than the threshold value of occurrence of a specific corrosive effect.
Specific corrosive effect depends on corrosion type such as: pitting corrosion, crevice corrosion, bimetallic corrosion, fatigue corrosion or stress corrosion cracking. If one of this corrosion types occurs corrosion hazard is HIGH	

Table 3. Risk of corrosion related to durability of LPSCs [12]

Risk of corrosion	**Durability requirements**	**Notes**
Low	Fulfilled	Sufficient corrosion resistance. No additional anticorrosion protection required.
Medium	Not always fulfilled	Corrosion resistance not always sufficient. Recommended monitoring and decision if additional anticorrosion measures are required
High	Not fulfilled	Not sufficient corrosion resistance. Additional anticorrosion protection required.

The general scheme of interaction between several factors influencing the soil aggressiveness and corrosion rate of metal materials embedded in soil is shown in **Figure 5**.

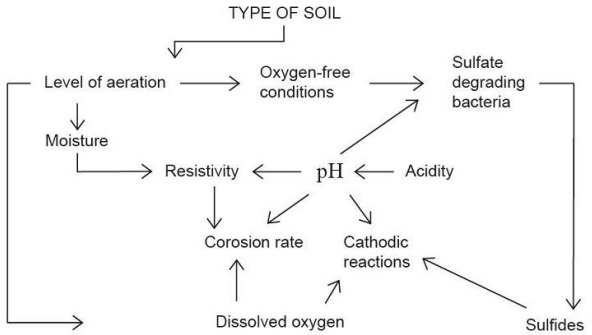


Figure 5. General scheme of several factors interaction influencing soil corrosion aggressiveness.

All the factors mentioned in **Table 3** are decisive for the soil corrosion aggressiveness level but in case of on medium or high aggressiveness just one of them may be decisive.

Table 4. Soil corrosion aggressiveness factors

Factor	Class of corrosion aggressiveness		
	Low	Medium	High
Resistivity [Ω·m]	> 100	30 ÷ 100	> 30
pH	7	6	< 5 or >8
Indicator of sulfate degrading bacteria (H_2S)	No	No	Present
Content of sulfates [mg/kg]	> 200	200 ÷ 1000	> 1000
Content of chlorides [mg/kg]	> 100	100 ÷ 200	> 200
Groundwater level	-	-	Up to the structure
Stray currents			Present

It is evident that soil corrosion of metal products represents very complex problem and cannot be neglected in the requirements for tests of LPSC.

4 Corrosion effects on LPSC in different atmospheric and soil environments

The components of LPSC totally or partially embedded in soil (ground) for a long term play important role in proper functioning of LPS and in ensuring the safe operation of the power system (earthing systems of both installations are usually interconnected).
Several investigators have performed experiments focused on the corrosion rate of different metals in atmosphere (air) and of interactions of metals recommended and used for LPSC design with soil. On the other hand, there are only a few publications available related to corrosion of the specific LPSC which are partially placed in air and in soil.
The earth termination components (earth electrodes, earth lead-in conductors and clamps) recommended in [1-4] are made of copper coated steel, galvanized steel, solid copper, stainless steel and plain bare steel if placed in concrete. During the service they are exposed to the corrosion, which reduces the performance of LPS.
Some published observations on corrosive effects of metal used for construction of LPSC, selected by authors, are discussed below.

4.1 Naval Civil Engineering Laboratory (NCEL) report

The report [13] describes results of corrosion effects after 1-, 3- and 7 year exposure of earth rods made of different metals in two different sites; – NCEL test site (less aggressive soil) and – Point Mugu site (very aggressive soil). Each rod was a single piece with dimensions: 8 feet in length and 5/8 inch in diameter. Three inches of the rod were to extend above the ground (in air) to permit coupling to other rods and making electrical measurements periodically. The summary of 7-year corrosion effects of single earth rods made of metals recommended for LPSC according to [13] is presented in **Table 5**. Exemplary pictures of corroded earth rods are shown in **Figure 6.**

Table 5. Selected results and comments related to NCEL investigations [14]

Type of rod	Percent weight loss after 7 years	Comments
Mild bare steel	7,61	Non-uniform rusting and pitting. Some of the pits were quite broad. The rust scale adhered very tightly.
Zinc galvanized steel	2,2	Most of the galvanizing had been lost. Rusting of steel was greatest near the surface of the ground. Pitting was worst near the tip.
Copper coated (clad) steel	0,93	The copper cladding was free of corrosion, but the steel core had corroded at the tip to a point 2 inches inside the cladding.
Stainless steel type 302	0,53	Very little corrosion except for localized deep pitting near the tip and near the surface of the ground.

The different tested metals vary greatly in percent losses rather than actual weight losses which were measured. The losses per year, however, decreased with time as the buildup of passive films of corrosion product tended to mitigate further corrosion.



Figure 6. Pictures of excavated earth rods after 8-year exposure of copper coated steel rod (a) and after 3-year exposure of zinc galvanized steel rod from sandy clay loam soil, pH = 6,1 ÷ 6,5 [13].

4.2 Examples of corrosion effect of LPSC exposed in different environments

The examples of different corrosion effects on LPSC placed in air and in soil, selected from published publications and the authors' archive are shown in **Figures 7 ÷ 9**. In **Figure 7 there** are shown 14].

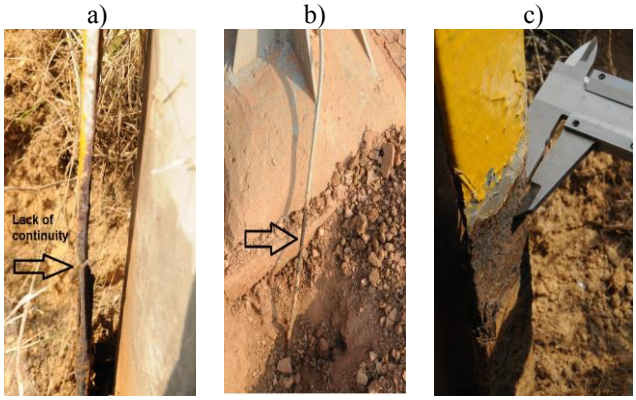


Figure 7. Examples of LPSC corrosion exposure in red soil in China [from the authors' archive]: a) zinc galvanized steel tape earthing conductor, b) zinc galvanized steel solid round earthing conductor.

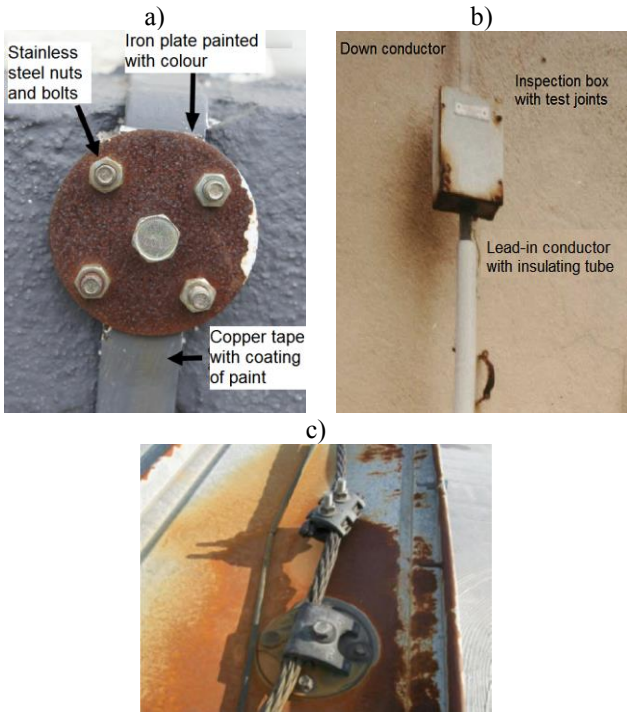


Figure 8. Corroded LPSCs: a) multi-metal contact point (copper, iron and stainless steel) with paint coating layers [15], b) copper-galvanized steel inspection box (painted) in contact with galvanized steel lead-in (earthing) conductor and painted galvanized steel down conductor [15], c) copper horizontal air-termination and bronze clamps in contact with zinc galvanized steel [16].

The measured cross-section dimensions of earthing conductor shown in **Figure 7** were reduced as follow [14]:

- **7a** - lack of continuity,
- **7b** - thickness of tape conductor reduced from 4 mm to 1,5 mm,
- **7c** - diameter of round conductor reduced from 12 mm to 9 mm.

Other typical corrosion effects of LPSC are shown in **Figure 8.** A more detail description of corrosion effects presented in this figure is available in [15].

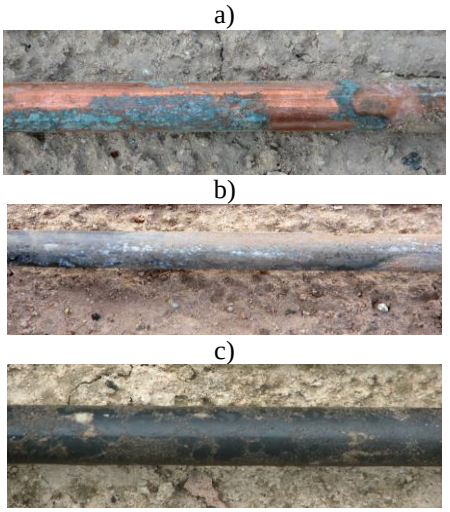


Figure 9. The exemplary pictures of rod fragments directly after removal from the soil, after 6-year exposure: (a) – copper coating, (b) zinc galvanized coating, (c) – zinc electrodeposited coating [16].

In **Figure 9** there are presented corrosion effects of the exemplary steel earth rods with different protective coating materials. They include: (a) copper coated steel, (b) zinc galvanized steel and (c) electrodeposited zinc steel. These rods were embedded in two different sites in Poland for 6 years with the aim to compare the influence of environmental conditions on different materials placed in the same soil type [16].

The thickness of zinc coatings was much lower than the initial one, except the copper coating. In the fragmentary parts of zinc galvanized rods the coating was completely damaged by corrosion.

4.3 Comments and proposals on corrosion requirements for LPSC placed in air and soil

In the recently published or being under consideration new editions of IEC series of lightning protection standards there are several mentions and recommendations related to corrosion resistance properties of LPSC.

In part 3 of IEC 62305 [2] one can find general statements expressing the necessity of taking into consideration corrosion problems when designing and constructing LPS. The LPS materials and conditions of use (related to corrosion issues) are given in Table 5 of IEC 62305-3 [2], while general recommendations related to protection against corrosion of individual components of LPS are described in the informative Annex D.

Some exemplary requirements of [2] are cited below:

- "Material and its dimensions shall be chosen considering the effects of corrosion either of the structure to be protected or of the LPS and shall comply with the requirements and tests according to the IEC 62561 series" (clause 5.6),
- "An LPS tends to lose its effectiveness over the years because of *corrosion*…" (clause 7.3),
- "During the periodic inspection, it is particularly important to check… deterioration and *corrosion* of air-termination elements, conductors and connections" (clause 7.4),
- "Mechanical and electrical characteristics, as well as *corrosion resistance properties*, shall meet the requirements of IEC 62561-2" (table 7 and table 8).

In part 3 of IEC 62305 [2] "know how" of design and installation of LPS is described while in series of IEC 62561 (parts 1-8) there are test requirements of LPSC.

In the authors' opinion, corrosion requirements in IEC 62305 standards shall be described in a more detailed way, and taking into account recommendations related to:

- Corrosion aggressiveness of the location of a structure protected against lightning based on corrosion maps defined by e.g. using methodology and results published in [10, 11],
- Categorisation of corrosivity of the atmosphere of a structure to be protected based on ISO 9223 [8] standard,
- Description of likelihood or risk of corrosion of metallic materials placed in soil according to EN 12501-1[12].

Based on the above assessments it is suggested that IEC 62305-3 [2] should introduce recommendations of application of materials for LPSC in locations categorised by severity of corrosion as well as adequate additional protective measures.

The general statements on corrosion issues which are described in Table 6 of IEC 62305-3 related to LPS materials [2] shall be accompanied by more specific requirements in line with the requirements given in ISO 9223, ISO 9224 and EN 12501 [8,9,12].

More detailed considerations on minimization of corrosion effects described in Annex D of [2] should be introduced in [2].

An exemplary proposal related to D.5.6.2.2 Annex D is the following:

- Lead-in conductors placed in atmosphere (air) classified according to corrosivity as C4 (high), C5 (very high) and CX (extreme) should be protected against corrosion for the total length from soil at the entry point, to the test joint. In [2] there is only a recommendation to protect at least length of 0,3 m in soil by means of anti-corrosion wrapping or sleeving.

The materials used for the joints between conductors in soil should have identical corrosion resistance as the conductors and shall be protected against corrosion.

It might be confusing that series of IEC 62561 do not describe corrosion tests and pass criteria for individual LPSC. There are only so called "environmental tests" related to three aggressive media - salt mist, ammonia and humid sulphurous atmospheres. The last two characterise the atmospheres (polluted air) which may appear in specific industrial locations or in the vicinity of a see or an ocean. However, the pass criteria for environmental tests are not based on typical corrosion test procedures and corrosion characteristics such a corrosion rate, loss of weight, cross section reduction or degradations as mechanical or electrical properties of LPSC and their connections.

Even a partial reduction in the cross-section of the earth-termination conductor limits the ability to discharge lightning and short-circuit currents and cannot be detected based on typical grounding resistance measurements.

5 Conclusions

The actual IEC standards related to design of LPS (series IEC 62305) and to tests of LPSCs (series IEC 62561) do not cover specific corrosion problems or relevant corrosion test requirements.

More detailed recommendations for selection, application and corrosion test procedures of metal materials used for LPSCs taking into account risk of corrosion shall be implemented in future editions of relevant IEC standards.

It is suggested to reconsider, in a new edition of IEC 62561-1 and -2, the implementation of corrosion test procedures and requirements (to be elaborated by a proper IEC TC 81 Maintenance Team or Working Group) for earth-termination components placed totally or partially in air and in soil.

It may be done on the basis of corrosion test proposals discussed within WG2 TC 81X CLC in 2012 (when the first version of EN 51064-2 standard was discussed).

6 Literature

[1] IEC 62305-1: Protection against lightning - Part 1: General principles.

[2] IEC 62305-3: Protection against lightning - Part 3: Part 3: Physical damage to structures and life hazard.

[3] IEC 62561-1: Lightning protection system components (LPSC) - Part 1: Requirements for connection components.

[4] IEC 62561-2: Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes.

[5] IEC 60068-2-52: Environmental testing - Part 2-52: Tests - Test Kb: Salt mist, cyclic (sodium, chloride solution).

[6] ISO 22479: Corrosion of metals and alloys – Sulphur dioxide test in a humid atmosphere (fixed gas method).

[7] ISO 6957: Copper alloys - Ammonia test for stress corrosion resistance.

[8] ISO 9223: Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation.

[9] ISO 9224: Corrosion of metals and alloys - Corrosivity of atmospheres - Guiding values for the corrosivity categories.

[10] European Federation of Corrosion: Exposure Site Catalogue - Catalogue of Atmospheric Corrosion

Field Exposure Sites in Europe, 2021 - https://efcweb.org/WP25.html

[11] https://www.wbdg.org/additional-resources/tools/ corrosion-toolbox/maps

[12] EN 12501-1: Protection of metallic materials against corrosion - Corrosion likelihood in soil - Part1: General

[13] Naval Civil Engineering Laboratory, Technical Report R660, February 1970: Field testing of electrical grounding rods

[14] R. Marciniak, M. Loboda: Influence of climatic conditions on corrosion of earth electrodes for lightning protection, 30th International Conference on Lightning Protection, Cagliary 2010, Sept.13-30, paper 1326

[15] A. Ghavamian, M.R. Maghani, S. Dehghan, C. Gomes: Concerns of corrosive effects with respect to lightning protection systems, Engineering Failure Analysis, Journal homepage: www.elsevier.com

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He is an expert in IEC TC 81 MT 14 (lightning protection components) and MT 21 (lightning protection of structures) as well in CLC/TC 99X/WG 01- Earthing aspects in power installations exceeding 1 kV A.C. (1,5 kV D.C).

Currently he is CEO at the CBM Technology, manufacturer of copper coated materials for earthing and lightning protection systems.



Marek Loboda, studied electrical Engineering at Warsaw Technical University (WUT), where he earned PhD in High Voltage Engineering in 1980. He was researcher and academic teacher in the field of High Voltage Engineering, Lightning Protection, Electromagnetic Compatibility, Grounding Systems and Live Working for over 40 years. He published app. 150 scientific papers related to those subjects.

He is the expert in IEC TC 81 (Lightning Protection) and CLC TC 78 (Live Working).

He is the member (currently Honorary Member) of ICLP Scientific Committee since 2006 and member of Live Working Association (LWA) since 2017.