Classification

Outdoor (ISO 9223-9226) and indoor (ISO 11844) classification

Context

- ISO TC 156 Corrosion of metals and alloys
  - WG 4 Atmospheric corrosion testing and classification of corrosivity of atmosphere
    - ISO 8565 General requirements for field tests
    - ISO 9223-9226 Corrosivity of atmospheres
    - ISO 11844 Classification of low corrosivity of indoor atmospheres
    - …
    - …

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ISO 9223-9226

Corrosion of metals and alloys — Corrosivity of atmospheres —

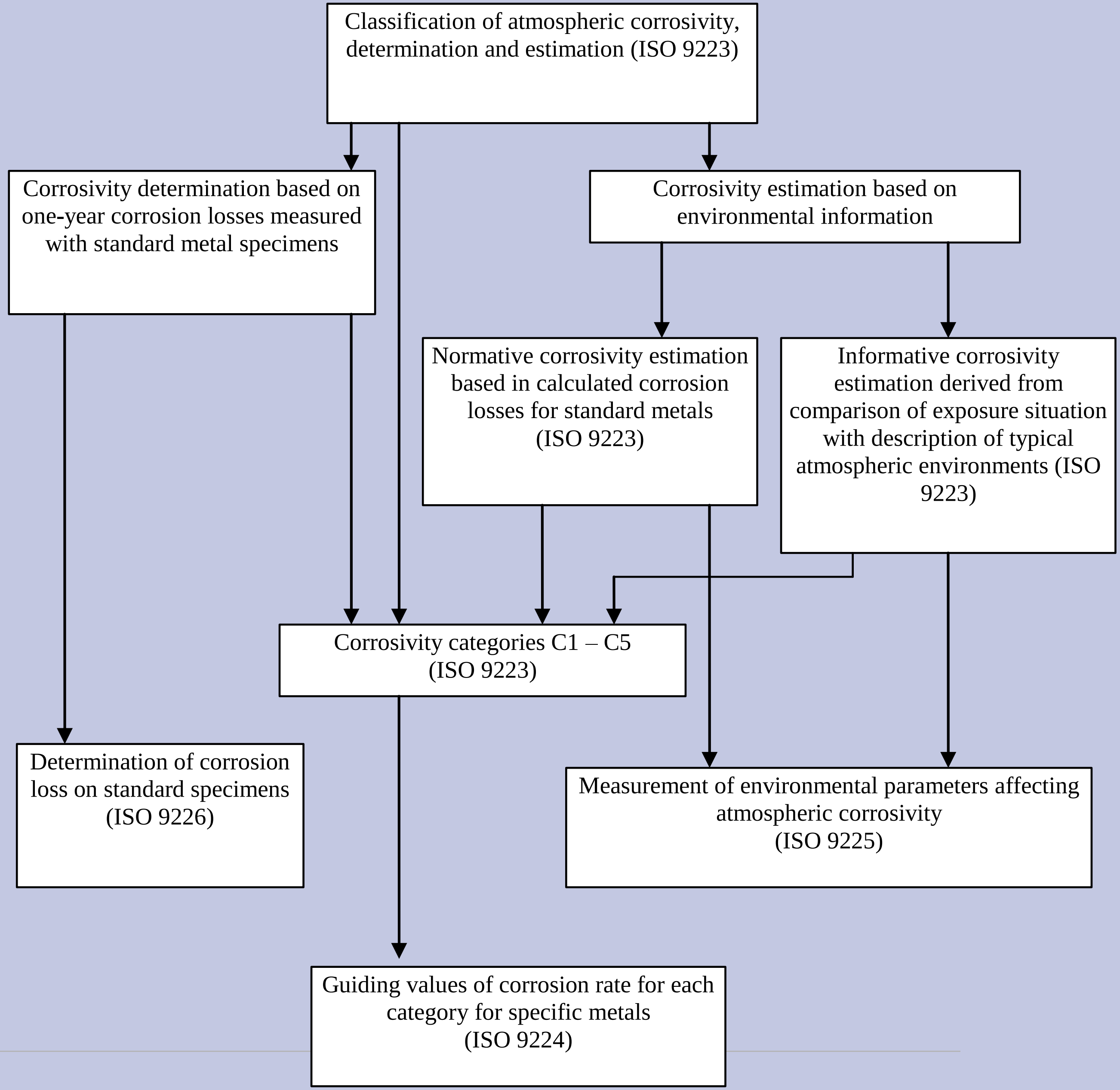
Classification, determination and estimation

Present and revised version

- Existing standards 9223-9226 are the most important standards in atmospheric corrosion
- At present revised versions are prepared but it will take 1-2 years before they are issued.
- Present presentation focus on the new standards under development but the classification system is similar. Differences will be pointed out

Scope

- To establish a classification system
- Specifies the key factors in the atmospheric corrosion of metals and alloys
- Does not characterize the corrosivity of specific service atmospheres, e.g. atmospheres in chemical or metallurgical industries
- The classified corrosivity categories and introduced pollution levels can be directly used for technical and economical analyses of corrosion damage and for a rational choice of corrosion protection measures


Classification of atmospheric corrosivity, determination and estimation (ISO 9223)
Corrosivity determination based on one-year corrosion losses measured with standard metal specimens
Corrosivity estimation based on environmental information
Normative corrosivity estimation based in calculated corrosion losses for standard metals (ISO 9223)
Informative corrosivity estimation derived from comparison of exposure situation with description of typical atmospheric environments (ISO 9223)
Corrosivity categories C1 – C5 (ISO 9223)
Determination of corrosion loss on standard specimens (ISO 9226)
Measurement of environmental parameters affecting atmospheric corrosivity (ISO 9225)
Guiding values of corrosion rate for each category for specific metals (ISO 9224)

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Categories of corrosivity of the atmosphere (CX new)

Category	Corrosivity
C 1	Very low
C 2	Low
C 3	Medium
C 4	High
C5	Very high
CX	Extreme

Corrosivity category	Corrosion rates (r_{corr}) of metals				
	Units	**Carbon steel**	**Zinc**	**Copper**	**Aluminium**
C1	g(m^2.a)	$r_{corr} \leq 10$	$r_{corr} \leq 0,7$	$r_{corr} \leq 0,9$	negligible
	µm/a	$r_{corr} \leq 1,3$	$r_{corr} \leq 0,1$	$r_{corr} \leq 0,1$	-
C2	g(m^2.a)	$10 < r_{corr} \leq 200$	$0,7 < r_{corr} \leq 5$	$0,9 < r_{corr} \leq 5$	$r_{corr} \leq 0,6$
	µm/a	$1,3 < r_{corr} \leq 25$	$0,1 < r_{corr} \leq 0,7$	$0,1 < r_{corr} \leq 0,6$	-
C3	g(m^2.a)	$200 < r_{corr} \leq 400$	$5 < r_{corr} \leq 15$	$5 < r_{corr} \leq 12$	$0,6 < r_{corr} \leq 2$
	µm/a	$25 < r_{corr} \leq 50$	$0,7 < r_{corr} \leq 2,1$	$0,6 < r_{corr} \leq 1,3$	-
C4	g(m^2.a)	$400 < r_{corr} \leq 650$	$15 < r_{corr} \leq 30$	$12 < r_{corr} \leq 25$	$2 < r_{corr} \leq 5$
	µm/a	$50 < r_{corr} \leq 80$	$2,1 < r_{corr} \leq 4,2$	$1,3 < r_{corr} \leq 2,8$	-
C5	g(m^2.a)	$650 < r_{corr} \leq 1500$	$30 < r_{corr} \leq 60$	$25 < r_{corr} \leq 50$	$5 < r_{corr} \leq 10$
	µm/a	$80 < r_{corr} \leq 200$	$4,2 < r_{corr} \leq 8,4$	$2,8 < r_{corr} \leq 5,6$	-
CX	g(m^2.a)	$1500 < r_{corr} \leq 5500$	$60 < r_{corr} \leq 180$	$50 < r_{corr} \leq 90$	$r_{corr} >10$
	µm/a	$200 < r_{corr} \leq 700$	$8,4 < r_{corr} \leq 25$	$5,6 < r_{corr} \leq 10$	-

NOTES

1. The classification criterion is based on the methods of determination of corrosion rates of standard specimens for the evaluation of corrosivity (see ISO 9226)
2. The corrosion rates expressed in grams per square metre year [g/(m^{2}a)] have been recalculated in micrometres per year (µm/a) and rounded.
3. The materials are characterized in ISO 9226.
4. Aluminium experiences localized corrosion but the corrosion rates shown in the Table 2 were calculated as uniform corrosion. Maximum pit depth is a better indicator of potential damage, but this characteristic cannot be evaluated after the first year of exposure excepting the effects in corrosivity category CX.
5. Corrosion rates exceeding the upper limits in category C5 are considered as extreme. Corrosivity category CX refers to marine and marine/industrial environments.

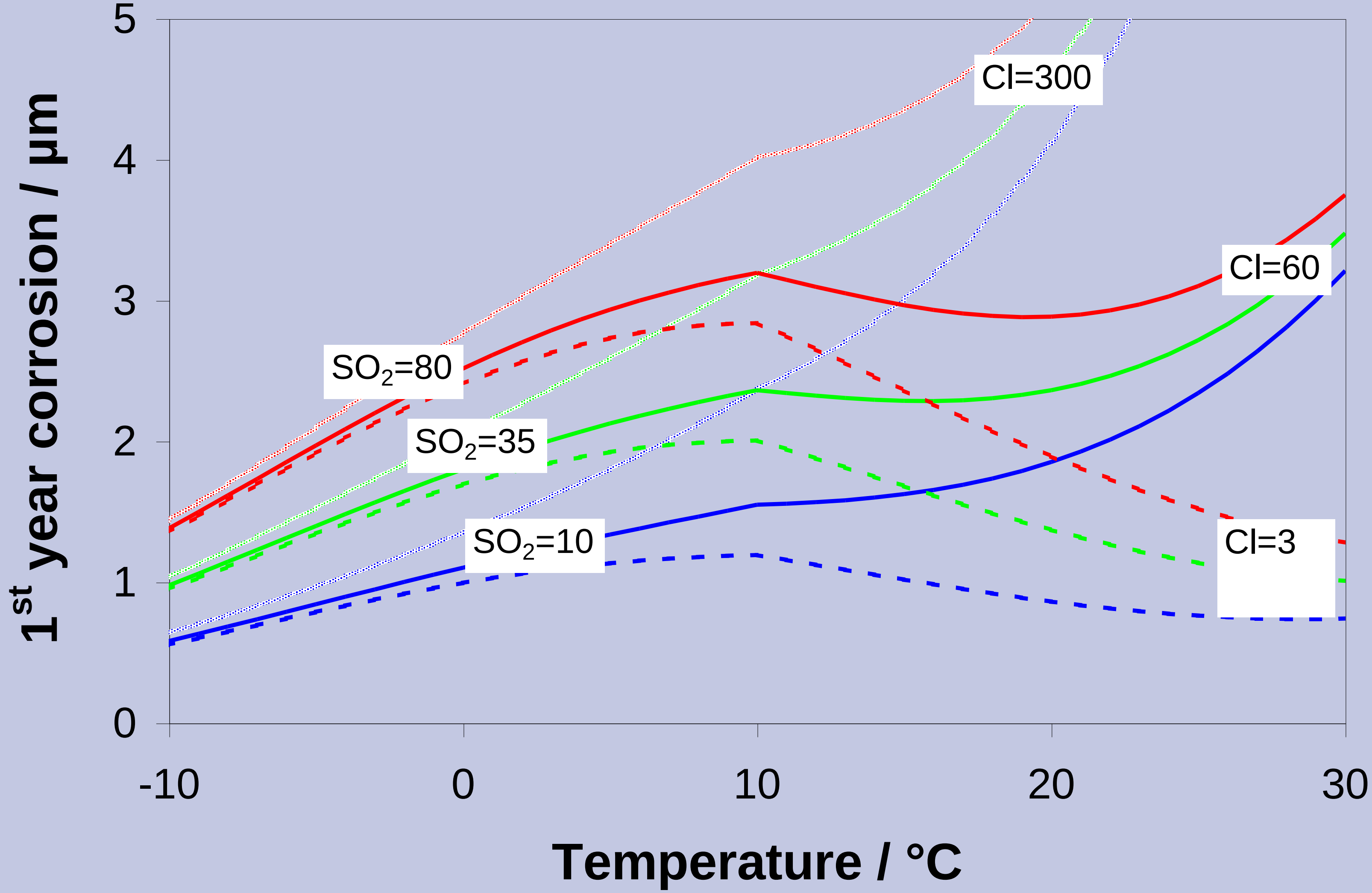
Corrosivity estimation based on calculated one year corrosion losses

- Dose response functions for calculation of the year corrosion loss of structural metals
  - Carbon steel
  - Zinc
  - Copper
  - Aluminium
- This method is new and not employed in the present existing ISO standards

Parameters used in dose-response functions

Symbol	Description	Interval	Unit
T	Temperature	-17.1 – 28.7	°C
RH	Relative humidity	34 - 93	%
SO_2	SO_2 deposition	0.7 – 150.4	mg m^{-2} day^{-1}
Cl	Cl^- deposition	0.4 – 760.5	mg m^{-2} day^{-1}

Calculated zinc corrosion



Informative Annexes (new)

- Annex A: Atmospheric corrosivity derivation and estimation. Sources of uncertainties
- Annex B: Characterization of the atmosphere in relation to its corrosivity
- Annex C: Description of typical atmospheric environments related to the estimation of corrosivity categories

Table C.1. Description of typical atmospheric environments related to the estimation of corrosivity categories

Corrosivity category (C)	Corrosivity	Typical environments (examples)	
		Indoor	Outdoor
C1	Very low	Heated spaces with low relative humidity and insignificant pollution e.g. offices, schools, museums	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, central Antarctica
C2	Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls	Temperate zone, atmospheric environment with low pollution (SO_2 < 5 µg/m^3), e.g.: rural areas, small towns Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas
C3	Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution (SO_2: 5 µg/m^3 to 30 µg/m^3) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides Subtropical and tropical zone, atmosphere with low pollution
C4	High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution (SO_2: 30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas, without spray of salt water, strong effect of de-icing salts Subtropical and tropical zone, atmosphere with medium pollution
C5-CX	Very high - extreme	Spaces with almost permanent condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in humid tropical zones	Temperate zone, atmospheric environment with very high pollution (SO_2: 90 µg/m^3 to 250 µg/m^3) and/or strong effect of chlorides, e.g. industrial areas, coastal and off shore areas, with salt spray Subtropical and tropical zone, atmosphere with high pollution and/or strong effect of chlorides

NOTE 1 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea-salt, such as wind direction, wind velocity, local topography, wind sheltering islands outside the coast, distance of the site from the sea, etc.

NOTE 2 Extreme effect by chlorides, which is typical of marine splash or very heavy salt spray, as well as areas close to the coast in hot humid climates, are beyond the scope of this International Standard

NOTE 3 Sheltered surfaces in marine atmospheric environment where chlorides are deposited can experience a higher corrosivity category due to the presence of hygroscopic salts

NOTE 4 In environments with expected CX category is recommended to determine the corrosivity from one-year corrosion losses.

NOTE 5 The concentration of sulphur dioxide (SO_2) should be determined during at least 1 year and is expressed as the annual average.)

NIOTE 6 Detailed description of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1. Indoor corrosivity categories IC1 to IC5 are distinqui ted

ISO 9223 Guiding values for the corrosivity categories

- The corrosion rate of metals and alloys exposed to natural outdoor atmospheres is not constant with exposure time. For most metals and alloys it decreases with exposure time because of the accumulation of corrosion products on the surface of the metal exposed. The progress of attack on engineering metals and alloys is usually observed to be linear when the total damage is plotted against exposure time on logarithmic coordinates. This relationship indicates that the total damage expressed either as penetration depth or mass loss per unit area, “D”, may be expressed as:

$$D = At^{b}$$

- Where “t” is the exposure time in years, “A” is the damage experienced in the first year, and “b” is the metal-environment specific time exponent, usually less than one; the slope of the log D versus log t plot.

Time exponent values (b values)

Metal	B1	B2
Carbon steel	0.523	0.575
Zinc	0.813	0.873
Copper	0.667	0.726
Aluminum	0.728	0.807

- The B1 values were taken as the average time exponents from regression analyses of flat panel long-term results
- The B2 values include two standard deviation additions and may be used where an upper limit of corrosion damage is desired

ISO 11844

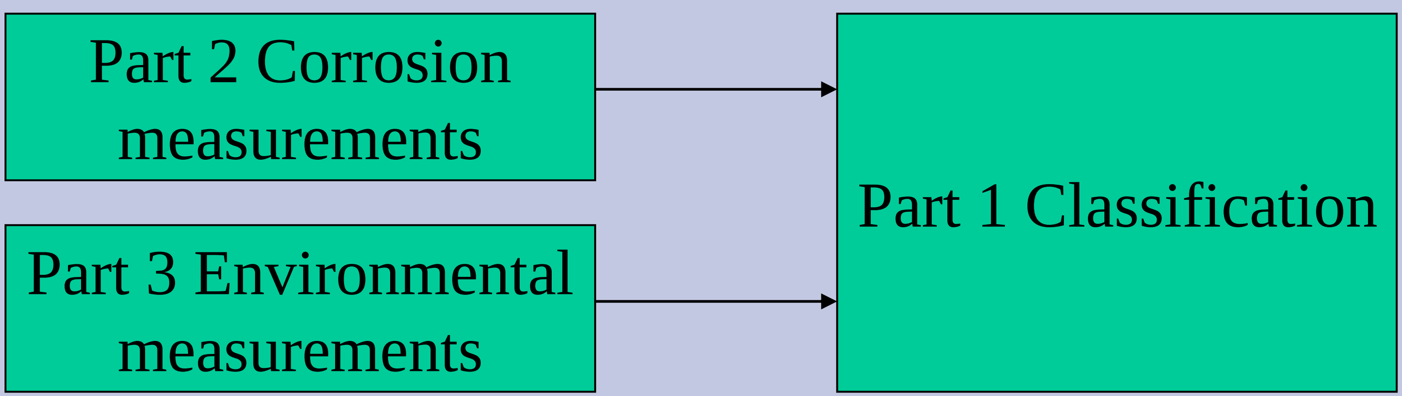
Classification of low corrosivity of indoor atmospheres

Materials

- Normative
  - Silver
  - Copper
  - Zinc
  - Carbon steel
- Informative (several other metals)

Structure

- ISO 11844 Classification of low corrosivity of indoor atmospheres
  - Part 1: Determination and estimation of indoor corrosivity
  - Part 2: Determination of corrosion attack in indoor atmospheres
  - Part 3: Measurement of environmental parameters affecting indoor corrosivity



Part 3: Environmental measurements

- Climate
  - Temperature
  - Relative humidity
- Airborne gas contaminants
  - Continuous gas concentration measuring instruments
  - Average gas concentration with active sampler and air pump
  - Average gas concentration with passive sampler
  - Average gas deposition equipment
- Airborne particle contaminants
  - Concentration measurements
  - Deposition measurements

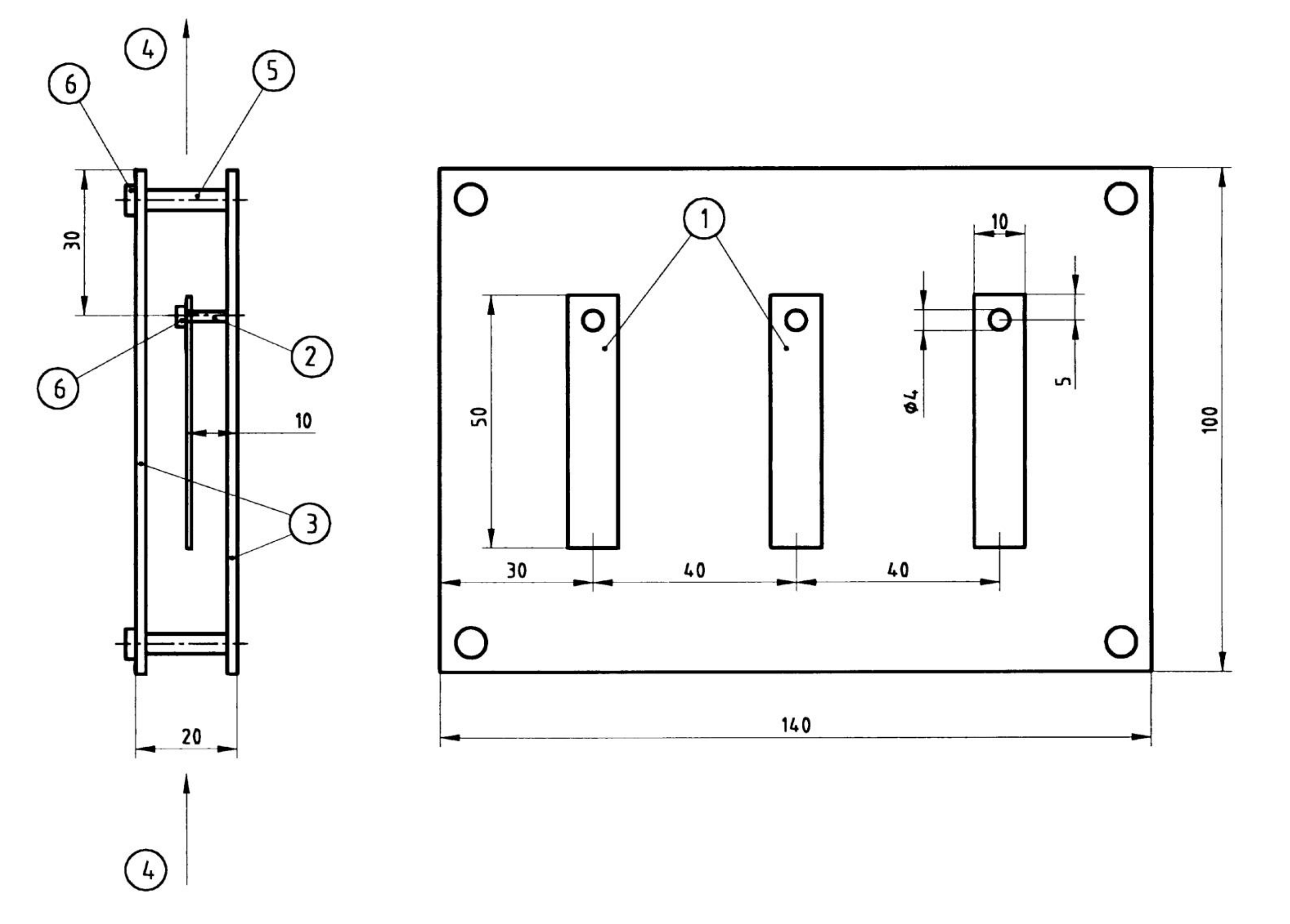
Part 3, Annex A (informative)

- Reagents used for both passive and active samplers
  - Sulphur dioxide (SO_2)
  - Nitrogen dioxide (NO_2)
  - Dihydrogen sulphide (H_2S)
  - Ammonia (NH_3)
  - Ozone (O_3)
  - Formic acid (HCOOH)
  - Acetic acid (CH_3COOH)

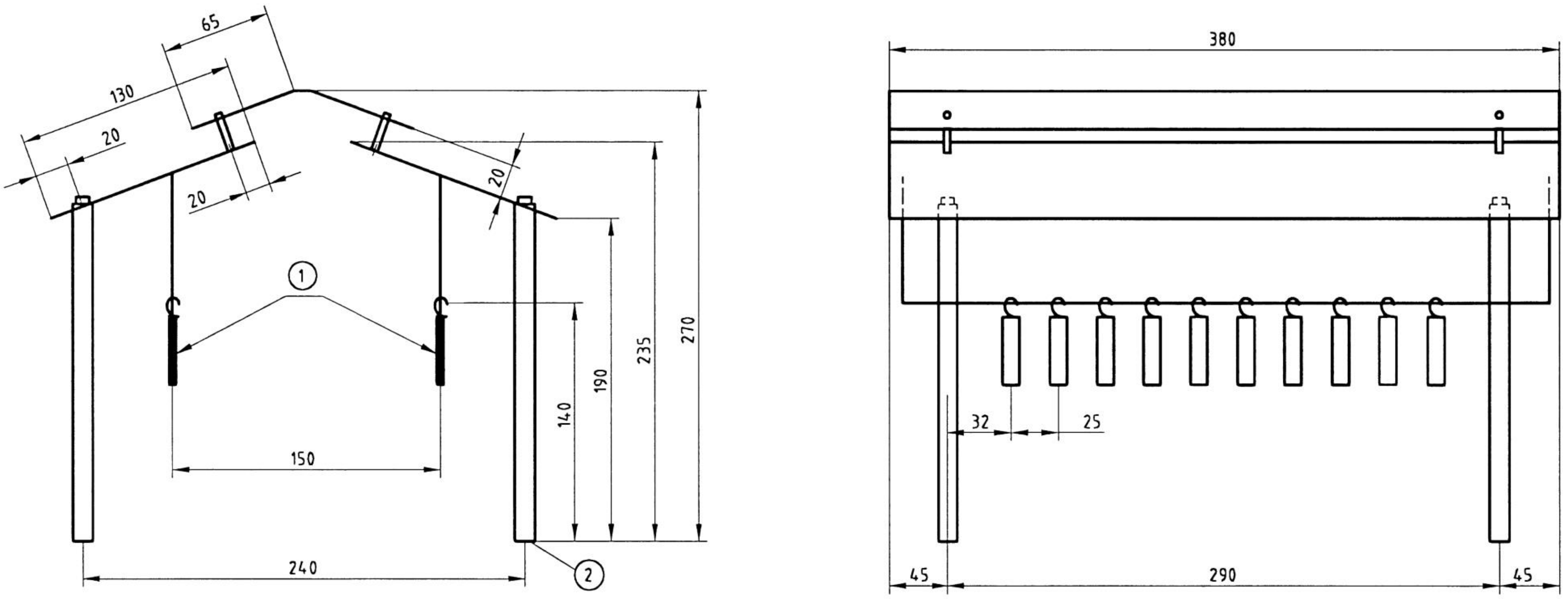
Part 2: Corrosion measurements

- Materials and sample preparation
- Exposure of specimens
- Evaluation of corrosion attack
  - Mass increase and mass loss (Annex A, normative)
  - Electrolytic cathodic reduction (Annex B, normative)
  - Resistance measurements (Annex C, informative)

Part 2, unsheltered exposure



Part 2, sheltered exposure



Annex A: Determination of corrosion rate by mass change measurements

- Determination of mass increase (MI)

  MI = Mass after exposure – Mass before exposure
- Determination of mass loss (ML)

  ML = Mass before exposure – Mass after pickling

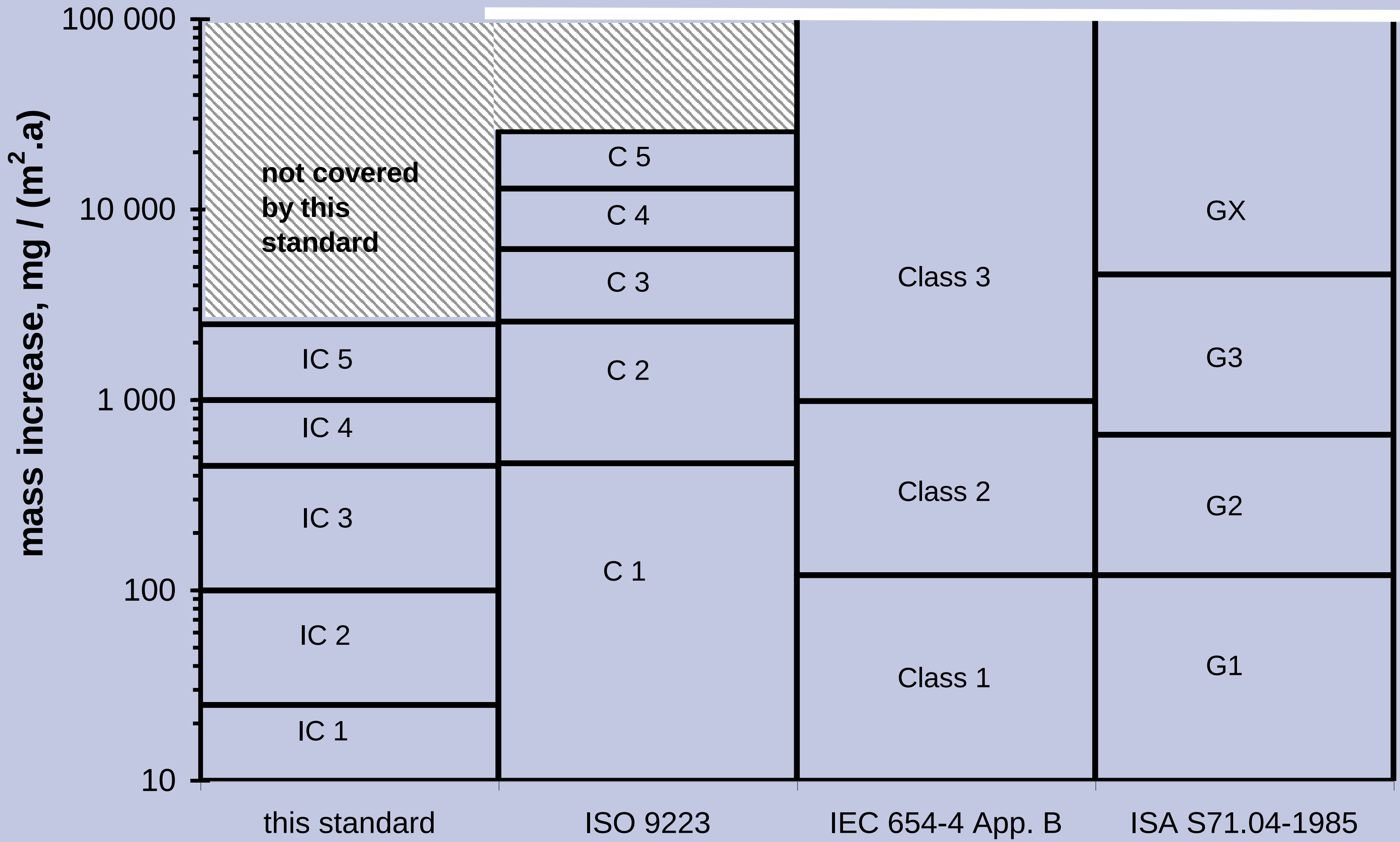
Recommended pickling solutions included in standard

Part 1 Classification

Indoor corrosivity category	
IC 1	Very low indoor corrosivity
IC 2	Low indoor corrosivity
IC 3	Medium indoor corrosivity
IC 4	High indoor corrosivity
IC 5	Very high indoor corrosivity

Mass increase (MI) and mass loss (ML) intervals given for silver, copper, zinc and carbon steel

Annex A: Relation between ISO, IEC and ISA classification systems



Annex B: Outdoor/indoor concentration of some of the most important pollutants in different types of environments

- SO_2
- NO_2
- O_3
- H_2S
- Cl_2
- Cl^-
- NH_3
- Organic components (acids, aldehydes)
- Particles (dust deposits)
- Soot

Annex C: General characterization of metal corrosion in indoor atmospheres

- Steel
- Zinc
- Copper
- Silver
- Nickel
- Lead
- Tin
- Aluminium
- Gold
- Stainless steel

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Annex D: Guideline for estimation of indoor corrosivity

General description, temperature, relative humidity, pollution and estimation:

Corrosivity category (IC)	Corrosivity	Typical environments
IC 1	very low indoor	Heated spaces with controlled stable relative humidity (< 40 %) without risk of condensation, low levels of pollutants, no specific pollutants, e.g. computer rooms, museums with controlled environment Unheated spaces with dehumidification, low levels of indoor pollution, no specific pollutants e.g. military stores for equipment
IC 2	low indoor	Heated spaces with low relative humidity (< 50 %) with certain fluctuation of relative humidity without risk of condensation, low levels of pollution, without specific pollutants e.g. museums, control rooms Unheated spaces with only temperature and humidity changes, with no risk of condensation, low levels of pollution without specific pollutants, e.g. storage rooms with low frequency of temperature changes
IC 3	medium indoor	Heated spaces with risk of fluctuation of temperature and humidity, medium levels of pollution, certain risk for specific pollutants, e.g. switch boards in power industry Unheated spaces with elevated relative humidity (> 50 % - 70 %) with periodic fluctuation of relative humidity, without risk of condensation, elevated levels of pollution, low risk of specific pollutants, e.g. churches in non-polluted areas, outdoor telecommunication boxes in rural areas
IC 4	high indoor	Heated spaces with fluctuation of humidity and temperature, elevated levels of pollution including specific pollutants, e.g. electrical service rooms in industrial plants Unheated spaces with high relative humidity (> 70 %) with some risk of condensation, medium levels of pollution, possible effect of specific pollutants, e.g. churches in polluted areas, outdoor boxes for telecommunication in polluted areas
IC 5	very high indoor	Heated spaces with limited influence of relative humidity, higher levels of pollution including specific pollutants like H_2S, e.g. electrical service rooms, cross connection rooms in industries without efficient pollution control Unheated spaces with high relative humidity and risk for condensation, medium and higher levels of pollution, e.g. storage rooms in basements in polluted areas