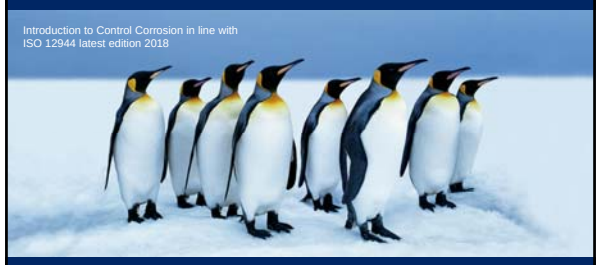
Introduction to Control Corrosion in line with
ISO 12944 latest edition 2018



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Agenda

ISO 12944 Corrosion Protection Of steel Structures

- Introduction to Jotun
- Cost Of Corrosion
- Corrosion mechanism
- Introduction to constituent parts of ISO 12944.
- Classification Of Environments
- Design Considerations
- Types Of Surface preparation
- Protective Paint Systems
- Laboratory Performance Test methods
- Execution and Supervision of projects
- Development of specifications
- ISO 12944–9: for offshore and related structures

JOTUN

A global paint solutions company, established in Norway in 1926.

JOTUN

39 factories
90 countries
USD 1.9bn in sales
9000 employees
950 advisors NACE / FROSIO qualified

Regional Laboratories

200 people working in R&D
R&D investment US34 million per year

Central Lab
Sandefjord, Norway

Regional Labs
Dubai, UAE
K.L, Malaysia
Pusan, South Korea
Zhangjiagang, China

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Introduction to Control Corrosion

in line with

ISO 12944

latest release 2018

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5 metric tons of steel is degenerated every second World Wide

That 40% of all produced steel is used to replace corroded steel

Corrosion affects precision equipments

...to infrastructures

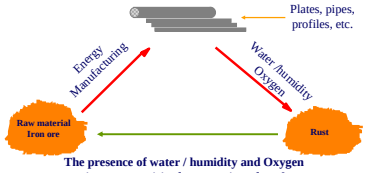
Pipelines destroyed by Corrosion

Definition of corrosion

Corrosion is a chemical reaction between
a metal
and
its surrounding environment
under the formation of corrosion products

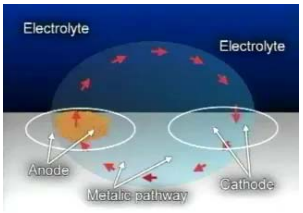
Production and degradation of steel

Reaction between the material and the surrounding environment takes place



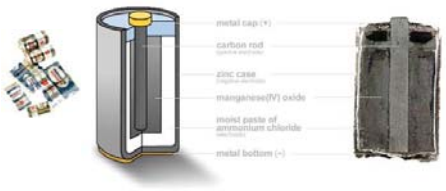
The presence of water / humidity and Oxygen is a pre-requisite for corrosion of steel

Corrosion Mechanism



Video

Galvanic cell - a battery



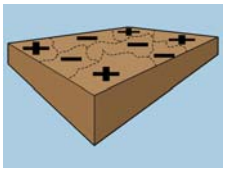
Corrosion

Single piece of metal showing the anodic and cathodic sites

Corrosion occurs at the anodic sites. If the steel was all cathodic corrosion would stop

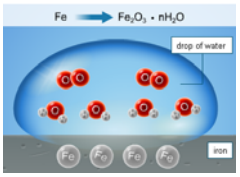
A piece of steel has thousands of anodic and cathodic sites

It is, however, unusual to find them uniform as various factors such as contaminants will cause different types of corrosion rates on a single piece of metal



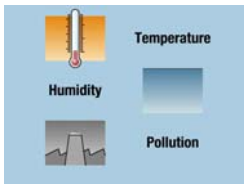
Pre requisites for Corrosion of Steel

- A **Cathode**:
  The noble metal / alloy (or part of metal)
- An **Anode:**
  The less noble metal / alloy
- An **electrical connection** between the two metals.
  Conducting electrical current (by electrons)
- An **electrolyte**:
  Conducting electrical current (by ions)

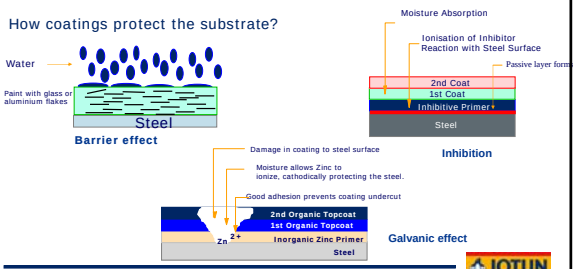


Parameters influencing the corrosion speed

- Humidity
- Temperature
- Concentration of salts
- Amount of air pollution, including acid rain, soot and dust particles



How coatings protect the substrate?



ISO 12944:CPD

Unique – Internationally recognized
Defines Corrosion Environments
Lifetime Expectancy
Recognised Worldwide

ISO 12944 concerns structures made of carbon steel of not less than 3 mm thickness, which are designed using an approved strength calculation.

Introduction to ISO 12944 (2017-2018)

International Organization for Standardization

Part 1 : **General** introduction
Part 2 : **Classification** of environments
Part 3 : **Design** consideration
Part 4 : Types of **surface** and surface preparation
Part 5 : (2018) Protective **paint systems**
Part 6 : Laboratory performance **test** methods
Part 7 : **Execution** and **supervision** of paint work
Part 8 : Development of **specifications**
Part 9 : Protective paint systems and laboratory performance test methods for **offshore** and related structures

ISO 12944 (1998) Part 2 Classification of Environments

Step No. 1

Atmospheric:

- **C1:** Very low
- **C2:** Low
- **C3:** Medium
- **C4:** High
- **C5:** Very high
- **CX:** Extreme corrosivity

New version 2017-2018

Immersion:

- **Im1:** Fresh Water
- **Im2:** Sea or Brackish Water
- **Im3:** Soil
- **Im4:** Sea or Brackish Water with CP

Meteorological Authority

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ISO 12944 – 2 Classification of environments

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m²	Thickness loss µm	Mass loss g/m²	Thickness loss µm		
C1 very low	≤ 10	≤ 1,3	≤ 0,7	≤ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e.g. depots, sports halls
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies

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ISO 12944 – 2 Classification of environments

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass	Thickness	Mass	Thickness		
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
CX extreme	> 1 500 to 5 500	> 200 to 700	> 60 to 180	> 8,4 to 25	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and subtropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere

NOTE The loss values used for the corrosivity categories are identical to those given in ISO 9223.

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ISO 12944 – 2 Classification of environments

Table 2 — 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)

NOTE For corrosivity category Im1 and Im3, cathodic protection can be used with a paint system tested accordingly

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Climatic conditions

Table A.1 — Calculated time of wetness and selected characteristics of various types of climate

Type of climate	Mean value of the annual extreme values			Calculated time of wetness at relative humidity > 80 % and temperature > 0 °C
	Low temperature °C	High temperature °C	Highest temperature with relative humidity > 95% °C	h/year
Extremely cold	−65	+32	+20	0 to 100
Cold	−50	+32	+28	150 to 2 500
Cold temperate	−33	+34	+23	2 500 to 4 200
Warm temperate	−20	+35	+25	
Warm dry	−20	+40	+27	10 to 1 600
Mild warm dry	−5	+40	+27	
Extremely warm dry	+3	+55	+29	
Warm damp	+9	+40	+31	4 200 to 6 000
Warm damp, constant	+18	+35	+33	

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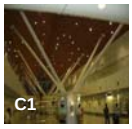

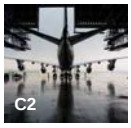

ISO 12944 – 2 Classification of environments

Exterior	Interior
Examples of typical environments in a temperate climate (informative only)	
—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.

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ISO 12944 – 2 Classification of environments

Exterior	Interior
Examples of typical environments in a temperate climate (informative only)	
Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.

ISO 12944 – 2 Classification of environments

Exterior	Interior
Examples of typical environments in a temperate climate (informative only)	
Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

Cover by ISO 12944-9

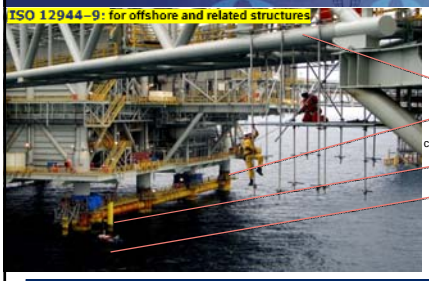
ISO 12944 – 2 Classification of environments

Immersion exposure

Table 2
Categories of water and soil

Table 2 — Categories for water and soil

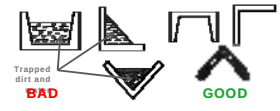
Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
Im2	Sea or brackish water	Immersed structures without cathodic protection (e.g. harbour areas with structures like sluice gates, locks or jetties)
Im3	Soil	Buried tanks, steel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

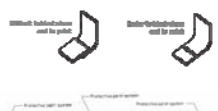


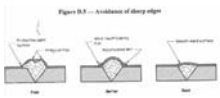
- CX
- Splash Zone
  combination of category CX & Im4
- Tidal Zone
- Im4

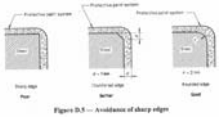
Environments examples:

ISO 12944-3 design consideration









ISO 12944-4 surface preparation

Pre-surface condition

•Visual inspection should be conducted on all steel items prior to surface preparation

•This will determine the level of pre-preparation requirements such as grinding, filling etc.

ISO 12944-4 surface preparation

- **It is very important for the life of a coating system**
- **Substrate must be free from oil, grease, salt, soil and any foreign material prior to surface preparation**
- **Minimum Sa2 ½ for all systems**

Needle hammer

Bristle blaster

Grinded 3M disk

Blasting standard ISO 8501-1 Pictorial standard

Dry Blast Standards

Application of paint by combination of tools

- Some areas are difficult to reach with a spray gun
- Start with the paint brush
- Then, use the back roller
- Finally, apply the remaining areas with the spray gun

ISO 12944-5: 2007 protective paint systems

7.4 Durability

The durability of a protective paint system depends on several parameters, such as:

— the type of paint system
— the design of the structure;
— the condition of the substrate before preparation;
— the surface preparation grade;
— the quality of the surface preparation work;
— the condition of any joints, edges and welds before preparation;
— the standard of the application work;
— the conditions during application;
— the exposure conditions after application.

ISO 12944-5: 2018 protective paint systems

Step No. 2

Durability: Coating system life expectancy to the first major maintenance
low (L) up to 7 years
medium (M) 7 years to 15 years
high (H) 15 years to 25 years
very high (VH) more than 25 years

The durability range is **not a "guarantee time".** Durability is a technical consideration that can help the owner set up a **maintenance program**.

A guarantee time is the subject of clauses in the contract and is not within the scope of this part of ISO 12944. There are no rules that link the two periods of time.

Rust grade evaluation

According to ISO 12944-5 first major maintenance would normally need to be carried out for reasons of corrosion protection once coating have reached Ri3 (1% rust intensity).

ISO 12944–5: 2018 protective paint systems

8.4 Guidelines for selecting the appropriate paint system

Step No. 3

— Determine the **corrosivity category** of the environment (macroclimate) where the structure will be located, as described in ISO 12944-2.

— Establish whether special conditions (**microclimate**) exist which can result in a higher corrosivity category (see ISO 12944-2).

— Search in Annexes B to E for the **relevant table**. Annex B establishes a set of minimum requirements for protective systems in the various **corrosivity** and **immersion** categories and **durability**.
Tables C.1 to C.6, D.1 and Table E.1 give proposals for different generic types of paint system for corrosivity categories C2 to C5 and Im1 to Im3.

— Identify in the table paint systems with the required **durability**.

— Consult **the paint manufacturer** in order to confirm the choice and to determine what **commercially available** paint system(s) correspond to the paint system selected.

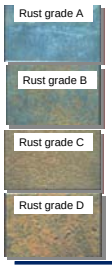
ISO 12944–5: 2018 protective paint systems

Annex A (normative)

Table A.1 — Abbreviated terms and descriptions

Abbreviations to different generic types and corrosivity categories

	Abbreviated term	Description			
Type of primer	Zn (R)	Zinc rich primer, see 7.1.2 for further details. The usual nominal dry film thickness varies from 40 µm up to 80 µm.			
	Misc.	All other categories of primers			
Binder base for primers and subsequent coats		Main binder	Type	Water-borne possible	Additional remarks
	AK	Alkyd	single pack	X	
	AY	Acrylic	single pack	X	Usually water-borne
	EP	Epoxy	two pack	X	Four UV-resistance
	PUR	Polyurethane	single or two pack	X	Only aliphatic types for topcoats
	ESI	Ethyl silicate	single or two pack		It is recommended to use a tie coat compatible with the next subsequent coat
	C2 to C5	Corrosivity categories, see ISO 12944-2.			
	Im1 to Im3	Immersion categories, see ISO 12944-2.			
	NDFT	Nominal dry film thickness. See 7.3 for further details.			
	MNOC	Minimum number of coats. Depending on the coating material, the application method and the design of the parts, it may be necessary to apply a higher number of coats.			



Minimum requirements for protective systems

Table B.1 — Surface preparation

Substrate	Minimum preparation grade (if not otherwise specified)	First layer of protective system
Carbon steel rust grades A, B, C or D* according to ISO 8501-1	Sa 2 1/2 according to ISO 8501-1 medium (G) according to ISO 8503-1	Zn (R) primer
	Sa 2 1/2 according to ISO 8501-1 additional information should be given in the technical data sheets	Miscellaneous primer
	According to ISO 2063	Thermal-sprayed metallic coating and sealer (according to ISO 2063)

* For rust grade D special care is needed to ensure proper surface preparation.

NOTE Other criteria are also important, such as **presence of water soluble salts, dust, oil, grease, etc**.
The NDFT as stated in Tables B.2 to B.5 for guidance in specific circumstances might not be appropriate to the end use. **Increased DFT might be necessary**.

Special consideration

For hot dip galvanized steel sweep blasting is minimum

ISO 12944–5: 2018 protective paint systems

Table B.2 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on abrasive blasted steel substrates

MNOC (minimum number of coats and minimum NDFT (Nominal Dry Film Thickness) are increased with the corrosivity and expected durability for abrasive blasted steel

Durability		Low (l)		Medium (m)		High (h)		Very high (vh)	
Type of primer		Zn (R)	Misc.	Zn (R)	Misc.	Zn (R)	Misc.	Zn (R)	Misc.
Binder base of primer		ESI, EP, PUR	EP, PUR, ESI	ESI, EP, PUR	EP, PUR, ESI	ESI, EP, PUR	EP, PUR, ESI	ESI, EP, PUR	EP, PUR, ESI
Binder base of subsequent coats		EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	AK, AY	EP, PUR, AY
C2	MNOC	*		—	—	1	1	1	1
	NDFT			—	—	160	120	160	200
C3	MNOC	—	—	1	1	1	2	2	2
	NDFT	—	—	160	120	160	160	200	240
C4	MNOC	1	1	2	2	2	2	3	3
	NDFT	60	120	160	160	200	200	240	240
C5	MNOC	2	2	2	2	3	3	3	—
	NDFT	160	160	200	240	240	320	320	—

AK & AY Are not Recommended For C4 vh & C5

NOTE 1 The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.
NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].
* If a coating is desired, use a system from a higher corrosivity category or durability, e.g. C2 high or C3 medium.

ISO 12944–5: 2018 protective paint systems

Table B.3 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on hot dip galvanized steel according to ISO 1461

MNOC (minimum number of coats and minimum NDFT (Nominal Dry Film Thickness) are increased with the corrosivity and expected durability for *hot dip galvanized steel*

Durability		Low (l)		Medium (m)		High (h)		Very high (vh)	
Binder base of primer		EP, PUR	AY	EP, PUR	AY	EP, PUR	AY	EP, PUR	AY
Binder base of subsequent coats		EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY
C2	MNOC	*		*		1	1	1	2
	NDFT					80	80	120	160
C3	MNOC		*			1	1	2	2
	NDFT					80	80	160	200
C4	MNOC	1	1	1	2	2	2	3	
	NDFT	80	80	120	160	160	200	200	
C5	MNOC	1	2	2	3	3		3	
	NDFT	120	160	160	200	200		240	

AK &AY are not Recommended For C4 vh C5 h & vh

NOTE 1 The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.
NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].
NOTE 3 The durability is in this case related to the paint system adhesion to the hot dip galvanized surface. In case of damaged paint system, the remaining hot dip galvanized layer delivers further protection to the steel.
* If coating is desired, use a system from higher corrosivity categories or durability: e.g. C2 high or C3 medium.

ISO 12944–5: 2018 protective paint systems

MNOC (minimum number of coats and minimum NDFT (Nominal Dry Film Thickness) are increased with the corrosivity and expected durability for *Thermal Sprayed Metallic Coatings*

Table B.4 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on thermal-sprayed metallic coating

Durability		High (h)	Very high (vh)
Binder base of subsequent coats		EP, PUR	EP, PUR
C3	MNOC	1	2
	NDFT	120	160
C4	MNOC	2	2
	NDFT	160	200
C5	MNOC	2	2
	NDFT	200	240

NOTE 1 For abbreviations see Table A.1.

NOTE 2 Special care should be taken when overcoating thermal-sprayed aluminium in a chloride environment as premature failure have been documented. See also Reference[68].

ISO 12944–5: 2018 protective paint systems

MNOC (minimum number of coats and minimum NDFT (Nominal Dry Film Thickness) are increased with the corrosivity and expected durability for *Immersed steel*

Table B.5 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint systems for carbon steel for three immersion categories of two different durabilities on abrasive blasted steel substrates

Durability	High (h)			Very high (vh)		
Type of primer	Zn (R)	Misc.	—	Zn (R)	Misc.	—
Binder base of primer	ESI, EP, PUR	EP, PUR	—	ESI, EP, PUR	EP, PUR	—
Binder base of subsequent coats	EP, PUR	EP, PUR	EP, PUR	EP, PUR	EP, PUR	EP, PUR
MNOC	2	2	1	2	2	1
NDFT	360	380	400	500	540	600

Minimum requirements for lower durabilities shall be agreed upon between the interested parties.

NOTE For abbreviations see Table A.1.

ISO 12944–5: 2018 protective paint systems

C1

Table C.1 — Paint systems for carbon steel for corrosivity category C1

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
For C1 any system used for a higher corrosivity category, preferably for C2, may be used.											

If unprotected steelwork destined for corrosivity category C1 is initially transported, stored temporarily or assembled in an exposed situation (for example, a C4/C5 coastal environment), corrosion will commence due to air-borne contaminants/salts and will continue even when the steelwork is moved to its final category C1 location. To avoid this problem, the steelwork should either be protected during site storage or given a suitable primer coat. The dry film thickness should be appropriate for the expected storage time and the severity of the storage environment.

ISO 12944–5: 2018 protective paint systems

C2

Table C.2 — Paint systems for carbon steel for corrosivity category C2

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C2.01	AK, AY	Misc.	1	60 to 80	AK, AY	1-2	80				
C2.02	AK, AY	Misc.	1	60 to 100	AK, AY	1-2	100				
C2.03	AK, AY	Misc.	1	60 to 160	AK, AY	1-2	160				
C2.04	AK, AY	Misc.	1	60 to 80	AK, AY	2-3	200				
C2.05	EP, PUR, ESI	Misc.	1	60 to 120	EP, PUR, AY	1-2	120				
C2.06	EP, PUR, ESI	Misc.	1	80 to 100	EP, PUR, AY	2	180				
C2.07	EP, PUR, ESI	Zn (R)	1	60	—	1	60				
C2.08	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160				

NOTE 1 For abbreviations see Table A.1.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

- Durability increased with NDFT
- EP, PUR, ESI can save NDFT for similar durability compared to AK, AY
- Zinc primers gives higher durability at relatively lower NDFT

ISO 12944–5: 2018 protective paint systems

C3

Table C.3 — Paint systems for carbon steel for corrosivity category C3

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C3.01	AK, AY	Misc.	1	80 to 100	AK, AY	1-2	100				
C3.02	AK, AY	Misc.	1	60 to 160	AK, AY	1-2	160				
C3.03	AK, AY	Misc.	1	60 to 80	AK, AY	2-3	200				
C3.04	AK, AY	Misc.	1	60 to 80	AK, AY	2-4	260				
C3.05	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1-2	120				
C3.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180				
C3.07	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2-3	240				
C3.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60				
C3.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160				
C3.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2-3	200				

NOTE 1 For abbreviations see Table A.1.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

- Durability increased with NDFT
- EP, PUR, ESI can save NDFT for similar durability compared to AK, AY
- Zinc primers gives higher durability at relatively lower NDFT

ISO 12944–5: 2018 protective paint systems

C4

Table C.4 — Paint systems for carbon steel for corrosivity category C4

System No.	Priming coat				Subsequent coat(s)	Paint system		Durability			
	Binder type	Type of primer	No. of coats	NDFT in µm	Binder type	Total no. of coats	NDFT in µm	l	m	h	vh
C4.01	AK, AY	Misc.	1	60 to 160	AK, AY	1-2	160				
C4.02	AK, AY	Misc.	1	60 to 80	AK, AY	2-3	200				
C4.03	AK, AY	Misc.	1	60 to 80	AK, AY	2-4	260				
C4.04	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1-2	120				
C4.05	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180				
C4.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2-3	240				
C4.07	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2-4	300				
C4.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60				
C4.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160				
C4.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2-3	200				
C4.11	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2-4	260				

NOTE 1 For abbreviations see Table A.1.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

- Durability increased with NDFT
- EP, PUR, ESI can save NDFT for similar durability compared to AK, AY
- AK, AY can NOT give very high durability
- Zinc primers gives higher durability at relatively lower NDFT

ISO 12944–5: 2018 protective paint systems

C5

Table C.5 — Paint systems for carbon steel for corrosivity category C5

System No.	Priming coat: Binder type	Priming coat: Type of primer	Priming coat: No. of coats	Priming coat: NDFT in µm	Subsequent coat(s): Binder type	Paint system: Total no. of coats	Paint system: NDFT in µm	Durability: l	Durability: m	Durability: h	Durability: vh
C5.01	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180				
C5.02	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2-3	240				
C5.03	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2-4	300				
C5.04	EP, PUR, ESI	Misc.	1	80 to 200	EP, PUR, AY	3-4	360				
C5.05	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160				
C5.06	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2-3	200				
C5.07	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3-4	260				
C5.08	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3-4	320				

NOTE 1 For abbreviations see Table A.1.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer (fluoroethylene/vinyl ether co-polymer (FEVE)).

- Durability increased with NDFT
- AK, AY are not recommended for C5
- Zinc primers gives higher durability at relatively lower NDFT

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ISO 12944–5: 2018 protective paint systems

C6

Table C.6 — Paint systems for carbon steel for immersion categories Im1, Im2 and Im3

System No.	Priming coat: Binder type	Priming coat: Type of primer	Priming coat: No. of coats	Priming coat: NDFT in µm	Subsequent coat(s): Binder type	Paint system: Total no. of coats	Paint system: NDFT in µm	Durability: l	Durability: m	Durability: h	Durability: vh
I.01	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR	2-4	360				
I.02	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR	2-5	500				
I.03	EP, PUR, ESI	Misc.	1	80	EP, PUR	2-4	380				
I.04	EP, PUR, ESI	Misc.	1	80	EP, PUR	2-4	540				
I.05			—	—	EP, PUR	1-3	400				
I.06			—	—	EP, PUR	1-3	600				

NOTE 1 Water-borne products are not yet suitable for immersion.

NOTE 2 Depending on mechanical and abrasive loads, it can be necessary to increase the NDFT of the systems to ensure the durability. For abrasive loads, NDFT of up to 1 000 µm are recommended, and for extreme abrasive loads even up to 2 000 µm.

NOTE 3 The immersion categories deal with external exposure only. Confined spaces and tank internals are outside the scope of this document (see ISO 12944-2).

NOTE 4 For abbreviations see Table A.1.

NOTE 5 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer (fluoroethylene/vinyl ether co-polymer (FEVE)).

- Durability increased with NDFT
- AK, AY are not recommended for Im
- Only h & vh are listed due to difficult inspection/repair of Im environment

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ISO 12944–5: 2018 protective paint systems

D1

Table D.1 — Paint systems on hot dip galvanized steel for corrosivity categories C2 to C5

System No.	Corrosivity category	Priming coat: Binder type	Priming coat: No. of coats	Priming coat: NDFT in µm	Subsequent coat(s): Binder type	Paint system: No. of coats	Paint system: NDFT in µm	Durability[a]: l	Durability[a]: m	Durability[a]: h	Durability[a]: vh
D2.01	C2	EP, PUR, AY	1	80		1	80				
D2.02		AY	1	80	AY	2	160				
D2.03		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120				
D3.01	C3	EP, PUR, AY	1	80		1	80				
D3.02		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120				
D3.03		AY	1	80	AY	2	160				
D3.04		EP, PUR	1	80	EP, PUR, AY	2	160				
D3.05		AY	1	80	AY	2 to 3	200				
D4.01	C4	EP, PUR, AY	1	80		1	80				
D4.02		EP, PUR	1	80 to 120	EP, PUR, AY	1 to 2	120				
D4.03		AY	1	80	AY	2	160				
D4.04		EP, PUR	1	80	EP, PUR, AY	2	160				
D4.05		AY	1	80	AY	2 to 3	200				
D4.06		EP, PUR	1	80	EP, PUR, AY	2 to 3	200				
D5.01	C5	EP, PUR	1	80 to 120	EP, PUR, AY	[illegible]	120				
D5.02		AY	1	80	AY	2	160				
D5.03		EP, PUR	1	80	EP, PUR, AY	2	160				
D5.04		AY	1	80	AY	2 to 3	200				
D5.05		EP, PUR	1	80	EP, PUR, AY	[illegible]	[illegible]				
D5.06		EP, PUR	1	80	EP, PUR, AY	2 to 3	240				

NOTE 1 For abbreviations see Table A.1.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer (fluoroethylene/vinyl ether co-polymer (FEVE)).

a The durability is in this case related to the paint system adhesion to the hot dip galvanized surface. In case of a damaged paint system, the remaining hot dip galvanized layer delivers further protection to the steel.

- Durability increased with NDFT
- EP, PUR, can save NDFT for similar durability compared to AK, AY
- No special pigments i.e. Zn or others in the primer since **galvanizing** gives cathodic protection to the steel

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ISO 12944–5: 2018 protective paint systems

E1

Table E.1 — Paint systems on thermal-sprayed metallic coatings for corrosivity categories C4 and C5

System No.	Corrosivity category	Sealer coat: Binder type	Sealer coat: No. of coats	Sealer coat: NDFT in µm	Subsequent coat(s): Binder type	Paint system: No. of coats	Paint system: NDFT in µm	Durability: h	Durability: vh
TSM 4.01	C4	EP, PUR	1	NA	EP, PUR	2	160		
TSM 4.02		EP, PUR	1	NA	EP, PUR	2	200		
TSM 5.01	C5	EP, PUR	1	NA	EP, PUR	2	200		
TSM 5.02		EP, PUR	1	NA	EP, PUR	2	240		

NA = Not applicable

NOTE 1 For abbreviations see Table A.1.

NOTE 2 The sealer shall fill the metal pores. It shall be applied until absorption is complete. There should not be measurable overlay of sealer on the metallic coating after application.

NOTE 3 Systems in corrosivity category C2 and C3 are only considered relevant where special stresses are present in the form of high mechanical or thermal impact. Use DFT as for the relevant system for carbon steel.

NOTE 4 Special care should be taken when overcoating thermal-sprayed aluminium in a chloride environment as premature failures have been documented. See also Reference[4].

NOTE 5 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer (fluoroethylene/vinyl ether co-polymer (FEVE)).

- Durability increased with NDFT
- **Metalizing** gives excellent corrosion protection alone, by duplex system expected durability is h or vh
- 2 coats since a sealer is required for porous **metalizing**

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ISO 12944–5: 2018 protective paint systems

F2

Table F.2 — Suitability of pre-fabrication primers, used with a related paint system, in various exposure conditions

Pre-fabrication primer: Binder type	Pre-fabrication primer: Anticorrosive pigment	C2	C3	C4	C5	Immersion: without cathodic protection	Immersion: with cathodic protection
AK	Miscellaneous	√	√	√	NS	NS	NS
EP	Miscellaneous	√	√	√	√	√	√
EP	Zinc dust	√	√	√	√	√	√
ESI	Zinc dust	√	√	√	√	√	√
AY (water-borne)	Miscellaneous	√	√	√	NS	NS	NS

NOTE 1 For abbreviations see Table A.1.

NOTE 2 Paint formulations vary. Checking compatibility with the paint manufacturer is recommended.

√ = Suitable

NS = Not suitable

Pre-fabrication primers are applied as thin films to freshly blast-cleaned steel to provide temporary corrosion protection during the period of fabrication, transportation, erection and storage of the steel structure. The pre-fabrication primer is then overcoated with a final paint system which normally includes a further priming coat.

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ISO 12944-6 laboratory testing

Table 1 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating

Corrosivity category as defined in ISO 12944-2	Durability ranges according to ISO 12944-1	Test regime 1: ISO 2812-2 (water immersion) h	Test regime 1: ISO 6270-1 (water condensation) h	Test regime 1: ISO 9227 (neutral salt spray) h	Test regime 2: Annex B (cyclic ageing test) h
C2	low	—	48	—	—
	medium	—	48	—	—
	high	—	120	—	—
	very high	—	240	480	—
C3	low	—	48	120	—
	medium	—	120	240	—
	high	—	240	480	—
	very high	—	480	720	—
C4	low	—	120	240	—
	medium	—	240	480	—
	high	—	480	720	—
	very high	—	720	1 440	1 680
C5	low	—	240	480	—
	medium	—	480	720	—
	high	—	720	1 440	1 680
	very high	—	—	—	2 688

- For C4 vh and C5 h its an option to use Test regime 1 or 2
- For C5 vh; use only test regime 2

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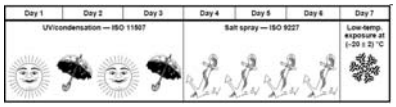
Ageing resistance ISO ~~20340~~ 12944-9



ISO 20340 withdrawn and becomes ISO 12944 part 9

- 72h UV and Condensation
  - 4h exposure to UV at 60° C (UVA 340)
  - 4h exposure to condensation at 50° C
- 72h Salt Spray
- 24h exposure to low temperature -20°C
- 25 cycles, 4200h

ISO 12944-6 laboratory testing

Table 2 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating

Corrosivity category as defined in ISO 12944-2	Durability category according to ISO 12944-1	ISO 2812-2 (water immersion) h	ISO 6270-1a (water condensation) h	ISO 9227a (neutral salt spray) h
Im1	high	3 000	1 440	—
	very high	6 000	2 160	—
Im2	high	3 000	—	1 440
	very high	6 000	—	2 160
Im3	high	3 000	—	1 440
	very high	6 000	—	2 160

a Only relevant if systems are partially or temporarily immersed/buried.

An interruption of greater than 72 h is not permitted, and the total duration of interruptions shall not exceed 10 % of the total test time. The total duration of test interruptions shall not be considered part of the elapsed test time.

Systems tested according to C5 vh are also suitable for lower corrosivity categories and durabilities.

Part 7 : **Execution** and **supervision** of paint work

- This part looks at the execution of the painting project and includes.

- Supply and storage of coatings.
- Site & weather conditions.
- Method of application Brush, Roller, Spray.
- Inspection and control during painting

ISO 12944-8:2007 development of specifications for new work and maintenance

How to develop a specification for new work.
All relevant parameters shall be taken into consideration, for example:

- required durability;
- environmental conditions and special stresses;
- surface preparation;
- different generic types of paint;
- number and types of coats [priming coat(s), intermediate coat(s) and top coat(s)];
- methods of application and application requirements;
- place of application (shop or site);
- scaffolding requirements;
- requirements regarding (future) maintenance (if any);
- health and safety requirements;
- environmental protection requirements.

ISO 12944–9: for offshore and related structures

(replaces ISO 20340)

Type of environment:

The structure may be divided into different zones based on the type of environment each zone is exposed to:

—one zone corresponds to the area exposed to atmospheric category **CX (offshore);**

— another zone corresponds to the area that is permanently immersed in sea water, i.e. category **Im4**;

— two further zones correspond to the tidal and splash zones which are a **combination of category CX (offshore) and Im4:**

— the **tidal zone** is the area in which the water level changes because of natural or artificial effects, thus giving rise to increased corrosion due to the combined effect of cyclic exposure to water and the atmosphere;

— the **splash zone** is the area wetted by wave and spray action which can give rise to exceptionally high corrosion stresses, especially with sea water.