SURFACE PROTECTION

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SURFACE PROTECTION

5.1 Corrosion

About 4% of the gross national product of a western industrial nation is destroyed by corrosion.

About 25% of this could be avoided by applying existing knowledge.

Corrosion is the reaction of a metallic material with its environment that causes a measurable change to the material and may lead to an impairment of the function of a component or of a complete system. This reaction is usually of an electrochemical nature, but in some cases it may also be of a chemical or metal-physical nature.

We can also observe corrosion in our daily lives:

- Rust on vehicles, railings and fences
- Creeping destruction of road structures, bridges, buildings
- Leaks in water pipelines and heating pipes made of steel

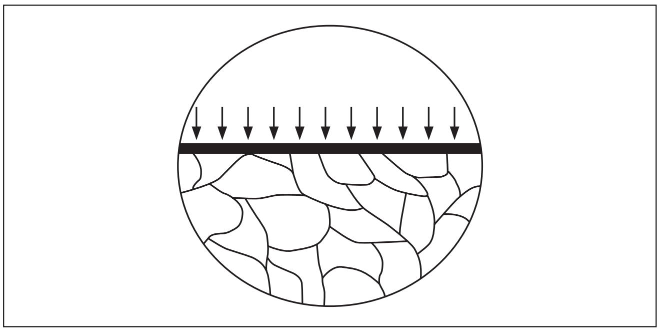
Corrosion is unavoidable – but the damage caused by corrosion can be avoided through the correct planning of suitable corrosion protection measures.

The corrosion system of a screw assembly should, under operating conditions, be at least as corrosion-resistant as the parts that are to be connected.

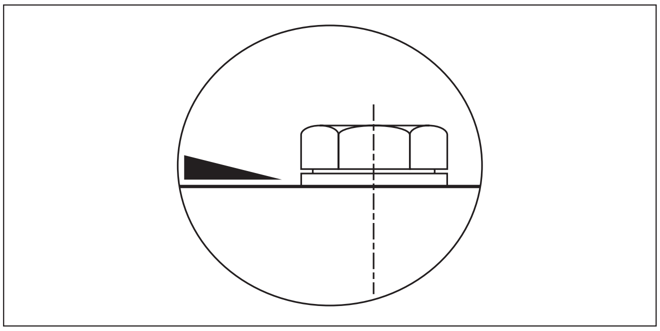
The design engineer's job is to decide on the necessary corrosion protection measures. Here, the wear reserve of a corrosion protection system and the ambient conditions have to be taken into account.

The ways in which corrosion manifests itself can vary greatly. (See DIN 50900 for corrosion types).

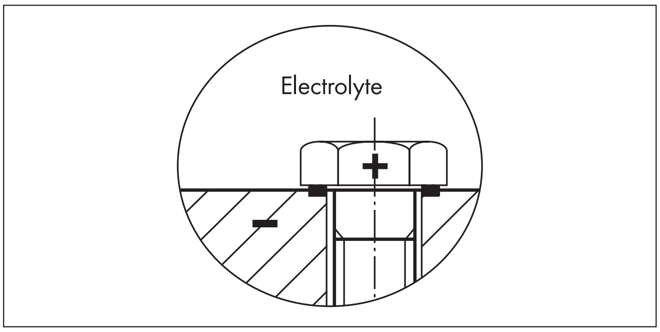
5.2 Corrosion types



Surface corrosion e.g. rust



Crevice corrosion



Contact corrosion

Corrosion rates, reference values in µm per year

Medium	Zincnon-chromated	Brass Ms 63	Copper CuNi 1.5 Si	Unalloyed steel unprotected
Country air	1–3	≤ 4	≤ 2	≤ 80
Urban air	≤ 6	≤ 4	≤ 2	≤ 270
Industrial air	6–20	≤ 8	≤ 4	≤ 170
Sea air	2–15	≤ 6	≤ 3	≤ 170

Tab. 1

5.3 Frequently used types of coatings for fasteners

5.3.1 Non-metallic coatings

Designation	Procedure	Application	Corrosion resistance
Rubbing with oil	Workpieces are immersed in oil	Bright steel parts Suitable for short-term corrosion protection e.g. during transport	Undefined
Burnishing	Workpieces are immersed in acid or alkaline solutions. Oxide layers with a (brown) black colour are created through reaction No layer development Purpose: formation of a weak protective layer on the surface No hydrogen embrittlement	Parts of weapons Gauges and measuring technology	Salt spray test approx. 0.5 h Corrosion protection oil can increase resistance
Phosphatising	Steel component in metal phosphate bath or chamber with metal phosphate solution 5–15 µm layer connected with the material Iron/manganese/nickel/zinc phosphate	Cold forming of steel Combination with corrosion protection media Reduction of wear on manganese phosphatising Primer for coat of lacquer (prevents rust creep)	Salt spray test: approx. 3 h Corrosion protection oil can increase resistance

Tab. 2

5.3.2 Metallic coatings

Designation	Procedure	Application	Corrosion resistance
Electro-galvanised	Metal deposition in the galvanic bath After treatment through passivation Optionally with sealing	In areas with low to average corrosion exposure, e.g. general mechanical engineering, electrical engineering – system-dependent thermal loadability 80 °C–120 °C	Corrosion resistance to 120 h against backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and dependent on the system)
Galvanic zinc alloy layer (zinc-iron) (zinc-nickel)	Metal deposition in the galvanic bath After treatment through passivation Optionally with sealing	In areas with extreme corrosion exposure – e.g. components in the engine compartment – or on brakes, where normal electro-plating is unable to cope not only because of the great heat but also because of the effect of salt in winter	Greatest cathodic corrosion protection – even with layer thicknesses from 5 µm (important for fits) No voluminous corrosion products with zinc-nickel) Corrosion resistance to 720 h to backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and system-dependent)
Electro-nickel plated	Metal deposition in the galvanic bath Optionally with impregnation	In areas with very low corrosion exposure, e.g. decorative applications in interiors Component of a multilayer system e.g. copper-nickel-chromium	Because of its electrochemical properties with regard to steel nickel cannot take over the function of a reactive anode.

Designation	Procedure	Application	Corrosion resistance
Electro-chrome plated	Metal deposition in the galvanic bath Usually as a coating on a nickel-plated surface Thickness of the chromium layer usually between 0.2 μm and 0.5 μm	In areas with very low corrosion exposure, e.g. decorative applications in interiors Component of a multilayer system e.g. copper-nickel-chromium	Because of its electrochemical properties with regard to steel chromium cannot take over the function of a reactive anode.
Mechanically galvanised	Metal powder is hammered onto the components, glass beads are used as "impact material". Coating is carried out by means of a chemical medium, electricity is not used. Coating is carried out at room temperature.	Retaining washers, high-strength spring-mounted components (no risk of hydrogen induction during the coating process)	Corrosion resistance to 144 h against backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and system-dependent)
Hot-dip galvanising	Immersion in molten metal bath Min. layer thicknesses approx. 40 μm Process temperature approx. 450 °C Greater corrosion protection Not suitable for small screws Cathodic corrosion protection	Fasteners for steel construction. For example, HV kits. Applicable for fasteners ≥ M12	Corrosion resistance between 5 and 25 years depending on the environmental conditions

Tab. 3

5.3.3 Other coatings

Procedure	Explanations	Maximum application temperature
Veralising	Special hard nickel-plating.	
Brass coating	Brass coatings are used mainly for decorative purposes. Apart from this, steel parts are coated with brass to improve the adherence of rubber on steel.	
Copperplating	If necessary, as an intermediate layer before nickel-plating, chrome-plating and silver-plating. As a cover layer for decorative purposes.	
Silver-plating	Silver coatings are used for decorative and technical purposes.	
Tinning	Tinning is used mainly to achieve or improve soldering capability (soft solder). Serves at the same time as corrosion protection. Thermal after-treatment not possible.	
Anodising	A protective layer is generated in aluminium through anodic oxidation that works as corrosion protection and prevents staining. Nearly all colour shades can be achieved for decorative purposes.	
Ruspert	High-grade zinc-aluminium flake coating, can be produced in extremely different colours. Depending on the layer thickness 500 h or 1000 h in fog test (DIN 50021).	
Burnishing (blackening)	Chemical procedure. Bath temperature approx. 140 °C with subsequent oiling. For decorative purposes. Only slight corrosion protection.	
Blackening (stainless)	Chemical procedure. The corrosion resistance of A1–A5 can be impaired by this. For decorative purposes. Not suitable for external application.	70 °C
Polyseal	Following a conventional immersion procedure a zinc-phosphate layer is applied at first. An organic protective layer is then applied that is precipitation-hardened at approx. 200 °C. Following this, a rust-protection oil is applied as well. This protective coating can be carried out in different colours (layer thickness approx. 12 μm).	
Impregnating	With nickel-plated parts above all, the micropores can be sealed with wax through after-treatment in dewatering fluid with added wax. Significant improvement of corrosion resistance. The wax film is dry, invisible.	

Tab. 4

5.4 Standardisation of galvanic corrosion protection systems

5.4.1 Designation system in accordance with DIN EN ISO 4042

The most common system for the abbreviated designation of galvanic surfaces on fasteners is the standard DIN EN ISO 4042. In the first place, this standard stipulates the dimensional requirements for fasteners made of steel and copper alloys that are to be given a galvanic coating. It stipulates layer thicknesses and provides recommendations for reducing the risk of hydrogen embrittlement in high-strength or very hard fasteners, or with surface-hardened fasteners.

DIN EN ISO 4042 does not differentiate between surface coatings containing chromium (VI) and those without chromium (VI).

Designation example

A surface designation must always consist of the code letter table A + code number table B + code letter table C

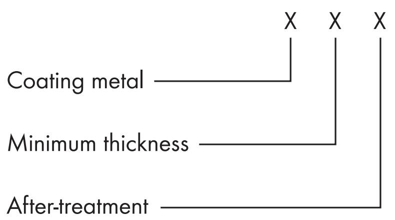


Table A Coating metal/alloy

Coating metal/alloy		Code letter
Abbreviation	**Element**	
Zn	Zinc	A
Cd	Cadmium	B
Cu	Copper	C
CuZn	Copper-zinc	D
Ni b	Nickel	E
Ni b Cr r	Nickel-chromium	F
CuNi b	Copper-nickel	G
CuNi b Cr r	Copper-nickel-chromium	H
Sn	Tin	J
CuSn	Copper-tin	K
Ag	Silver	L
CuAg	Copper-silver	N
ZnNi	Zinc-nickel	P
ZnCo	Zinc-cobalt	O
ZnFe	Zinc-iron	R

Tab. 5: Extract from ISO 4042

Table B layer thickness

Layer thickness in μm		Code no
One coating metal	**Two coating metals**	
No layer thickness prescribed	–	0
3	–	1
5	2+3	2
8	3+5	3
10	4+6	9
12	4+8	4
15	5+10	5
20	8+12	6
25	10+15	7
30	12+18	8

Tab. 6: Extract from ISO 4042

Table C Passivation/chromating

Gloss level	Passivation through chromating	Code letter
Matte	No colour	A
	Bluish to bluish iridescent	B
	Yellowish shimmering to yellow-brown iridescent	C
	Olive green to olive brown	D
Bright	No colour	E
	Bluish to bluish iridescent	F
	Yellowish shimmering to yellow-brown iridescent	G
	Olive green to olive brown	H
Glossy	No colour	J
	Bluish to bluish iridescent	K
	Yellowish shimmering to yellow-brown iridescent	L
	Olive green to olive brown	M

Gloss level	Passivation through chromating	Code letter
High gloss	No colour	N
Any	As B, C or D	P
Matte	Brown-Black to black	R
Bright	Brown-Black to black	S
Glossy	Brown-Black to black	T
All gloss levels	Without chromating	U

Tab. 7: Extract from ISO 4042

5.4.2 Reference values for corrosion resistances in the salt spray test DIN 50021 SS (ISO 9227)

Procedure group	Chromating designation	Inherent colour of the chromate layer	Designation in accordance with ISO 4042	Nominal layer thickness	White rust h	Red rust h
Passivation colourless	A	Transparent	A1A, A1E, A1J	3	2	12
			A2A, A2E, A2J	5	6	24
			A3A, A3E, A3J	8	6	48
Passivation blue	B	Blue iridescent	A1B, A1F, A1K	3	6	12
			A2B, A2F, A2K	5	12	36
			A3B, A3F, A3K	8	24	72
Chromating yellow	C	Yellow iridescent	A1C, A1G, A1L	3	24	24
			A2C, A2G, A2L	5	48	72
			A3C, A3G, A3L	8	72	120
Chromating olive	D	Olive green	A1D, A1H, A1M	3	24	24
			A2D, A2H, A2M	5	72	96
			A3D, A3H, A3M	8	96	144
Chromating black	BK	Sooty to black	A1R, A1S, A1T	3	12	36
			A2R, A2S, A2T	5	12	72
				8	24	96

Tab. 8

5.4.3 Designation system in accordance with DIN 50979

This standard applies to electroplated and Cr(VI)-free passivated zinc and zinc alloy coatings on ferrous materi-als. The zinc alloy coatings contain nickel or iron (zinc/nickel, zinc/iron) as the alloy components.

The main purpose of the coatings or coating systems is the corrosion protection of components made of ferrous materials.

This standard defines the designations for the coating systems that are shown below and stipulates minimum corrosion resistances in the described test procedures as well as the minimum layer thicknesses required for this.

5.4.4 Designation of the galvanic coatings

The galvanic coatings consist of zinc or zinc alloys

Abbreviation	Definition
Zn	Zinc coating without added alloy partner
ZnFe	Zinc alloy coating with a mass share of 0.3% to 1.0% iron
ZnNi	Zinc alloy coating with a mass share of 12% to 16% nickel

Tab. 9: Extract from DIN 50979

5.4.5 Passivation

Passivating means making conversion layers by treating with suitable Cr(VI) free solutions in order to improve the corrosion resistance of the coatings. Colouring is possible.

Passivation or procedure group	Abbreviation	Appearance of the surface	Notes
Transparent passivated	An	Colourless to coloured, iridescent	Frequently referred to as thin layer passivation
Iridescent passivated	Cn	Coloured iridescent	Frequently referred to as thick layer passivation
Black passivated	Fn	Black	

Tab. 10: Extract from DIN 50979

5.4.6 Sealings

Sealings increase corrosion resistance and usually have a layer thickness up to 2 µm. Sealings consist of Cr(VI)-free organic and/or inorganic compounds.

Products that can be removed with cold cleaners, e.g. on an oil, grease, wax basis, are not considered as sealings in the context of this standard. The influence of sealings on the functional properties of the component, such as, for example, transition resistance, weldability, compatibility with fuels, glued joints, is to be assessed on the basis of the component. In case of the special requirements for the surface functionality the use of the sealing and the type of sealant have to be agreed, because the band width of the possible surface modifications through sealings is large.

In most cases the sealings also eliminate the interference colours (iridescences) formed by passivating.

Abbreviation	Description
T0	Without sealing
T2	With sealing

Tab. 11: Extract from DIN 50979

5.4.7 Minimum layer thicknesses and test duration

Type of surface protective layer	Execution type	Procedure type	Without coating corrosion	Minimum test duration in h Without base material corrosion (in dependence on the Zn or Zn alloy layer thickness)		
				5 µm	8 µm	12 µm
Galv. zinc coating, transparent passivated	Zn//An//T0	Drum	8	48	72	96
		Frame	16	72	96	120
Galv. zinc coating, iridescent passivated	Zn//Cn//T0	Drum	72	144	216	288
		Frame	120	192	264	336
Galv. zinc coating, iridescent passivated and sealed	Zn//Cn//T2	Drum	120	192	264	360
		Frame	168	264	360	480
Galv. zinc iron alloy coating, iridescent passivated	ZnFe//Cn//T0	Drum	96	168	240	312
		Frame	168	240	312	384
Galv. zinc iron alloy coating, iridescent passivated and sealed	ZnFe//Cn//T2	Drum	144	216	288	384
		Frame	216	312	408	528
Galv. zinc nickel alloy coating, iridescent passivated	ZnNi//Cn//T0	Drum	120	480	720	720
		Frame	192	600	720	720
Galv. zinc nickel alloy coating, iridescent passivated and sealed	ZnNi//Cn//T2	Drum	168	600	720	720
		Frame	360	720	720	720
Galv. zinc iron alloy coating, black passivated and sealed	ZnFe//Fn//T2	Drum	120	192	264	360
		Frame	168	264	360	480
Galv. zinc nickel alloy coating, black passivated and sealed	ZnNi//Fn//T2	Drum	168	480	720	720
		Frame	240	600	720	720
Galv. zinc nickel alloy coating, black passivated	ZnNi//Fn//T0	Drum	48	480	720	720
		Frame	72	600	720	720

Tab. 12: Extract from DIN 50979

Designation examples:
Zinc/nickel alloy coating on a component made of steel (Fe), a thinnest local layer thickness of 8 µm (8) and iridescent passivated (Cn), without sealing (T0) Fe//ZnNi8//Cn//T0

Zinc/iron alloy coating on a component made of steel (Fe), a thinnest local layer thickness of 5 µm (5) and black passivated (Fn), with sealing (T2) Fe//ZnFe5//Fn//T2

5.5 Standardisation of non-electrolytically applied corrosion protection systems

5.5.1 Zinc flake systems

The parts that are to be coated are placed in a centrifuge basket and immersed in the coating medium. Part of the coating substance is thrown off through centrifugation. In this way a largely even layer is created. The coating is then burnt in a continuous furnace at 150 °C–300 °C (depends on the system). To obtain an even and covering layer it is necessary that the parts to be coated pass through two coating passes. Larger parts can also be coated by spraying the coating medium on.

This procedure is unsuitable for threaded parts ≤M6 and for fasteners with small internal drives or fine contours. Here, threads that are not true to gauge size and unusable internal drives must be reckoned with.

Zinc flake systems are suitable for coating high-strength components. If suitable cleaning procedures are used hydrogen inducement in the coating process is ruled out.

5.5.2 Standardisation of non-electrolytically applied corrosion protection systems

Designations in accordance with DIN EN ISO 10683

- **flZn-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, e.g. Geomet 500A, Geomet 321A, Dacromet 500A, Dacromet 320A, Delta Tone/Seal
- **flZnL-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with integrated lubricant, e.g. Geomet 500A, Dacromet 500A
- **flZn-480h-L** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with subsequently applied lubricant, e.g. Geomet 321A+VL, Dacromet 320A+VL
- **flZnnc-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, without chromate, e.g. Geomet 321A, Geomet 500A, Delta Protect, Delta Tone/Seal
- **flZnyc-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with chromate, e.g. Dacromet 500A, Dacromet 320A

5.6 Standardisation of the hot-dip galvanising of screws in accordance with DIN EN ISO 10684

5.6.1 Procedure and area of application

Hot dip galvanising is a procedure in which the fasteners are immersed in a molten bath after suitable pre-treatment. Excessive zinc is then thrown off in a centrifuge in order to set the zinc layer thickness required for corrosion protection. Following this, the fasteners are usually cooled down in a water bath.

Hot dip galvanising is permissible to strength class 10.9. DIN EN ISO 10684 provides information for pre-treatment and galvanising processes that minimise the risk of brittle fractures. Further specifications, which are described in the technical guidelines of the Gemeinschaftsausschusses Verzinken e.V. (GAV) and of the Deutscher Schraubenverband e.V. (DSV), are required, in particular with screws in strength class 10.9. Only normal temperature galvanising should be applied above the thread size M24.

Corrosion resistances in accordance with DIN 50021 SS (ISO 9227) in dependence on the layer thickness

	Minimum values for the local layer thickness (if specified by buyer)	
Test duration in hours (salt spray test)	**Coating with chromate (flZnyc) µm**	**Coating without chromate (flZnnc) µm**
240	4	6
480	5	8
720	8	10
960	9	12
If the layer weight per unit of area in g/m² is specified by the buyer, it can be converted as follows into the layer thickness: • Coating with chromate: 4.5 g/m² corresponds to a thickness of 1 µm • Coating without chromate: 3.8 g/m² corresponds to a thickness of 1 µm		
The buyer may specify whether he wants to have a coating with chromate (flZnyc) or without chromate (flZnnc); in other cases the abbreviation flZn applies.		

Tab. 13: Extract from DIN EN ISO 10683

With female thread parts such as nuts, the thread is not cut until after galvanising.

The load bearing capacity of the paired threads can be reduced with thread sizes less than M12, because the zinc coating, with its thickness of at least 50 µm on average, leads to a reduction of thread overlapping.

5.6.2 Thread tolerances and designation system

Two different ways of proceeding have proved their worth for creating sufficient space for the quite thick coating when screws and nuts are paired. Starting from the zero line of the thread tolerance system, the space for the coating is placed either in the screw or in the nut thread. These methods may not be mixed. It is therefore very advisable to obtain hot-dip galvanised fasteners in a set. In the building industry this is in fact prescribed in standards.

Mixing the procedures 1 and 2 shown in table 15 leads either to a reduction of the connection's load bearing capability or to assembly problems .

5.7 Restriction on the use of hazardous substances

5.7.1 RoHS

Electrical and electronic equipment brought onto the market from 1 July 2006 may not contain any lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl (PBB) or polybrominated diphenyl ethers (PBDE).

Exceptions (among others)

- Lead as alloy element in steel up to 0.35% by weight
- Lead as alloy element in aluminium up to 0.4% by weight
- Lead as alloy element in copper alloys up to 4.0% by weight

Up to 0.1% by weight of the above-mentioned substances (cadmium 0.01% by weight) per homogeneous material is permissible.

	Nut thread tolerance	**Screw thread tolerance before galvanising**
Procedure 1	6AZ/6AX	6g/6h
Special marking	„Z" or „X"	None
Procedure 2	6H/6G	6az
Special marking	None	„U"

Tab. 14: Tolerance systems on pairing hot-dip galvanised screws and nuts

The special marking is to be applied after the strength class marking. In the order designation, the hot-dip galvanising is expressed by the notation "tZn".

Example:
Hexagon head screw ISO 4014 M12x80 - 8.8U – tZn

This concerns:
- Large and small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electric and electronic tools, with the exception of large-scale stationary industrial tools
- Toys
- Sports and leisure equipment
- Medical devices
- Monitoring and control instruments
- Automatic dispensers

5.7.2 ELV
End-of life vehicles directive
(up to 3.5 t gross vehicle weight)
Materials and components for vehicles brought onto the market from 1 July 2007 may not contain any lead, mercury, cadmium or hexavalent chromium.

Exceptions include
- Lead as alloy element in steel up to 0.35% by weight
- Hexavalent chromium in corrosion protection layers (to 01 July 2007)
- Lead as alloy element in copper alloys up to 4.0% by weight

Up to 0.1% by weight of the above-mentioned substances (cadmium 0.01% by weight) per homogeneous material is permissible, insofar as they are not added intentionally.

This concerns:
All vehicles with a gross vehicle weight not exceeding 3.5 t

5.8 Hydrogen embrittlement
With galvanically coated steel components with tensile strengths Rm ≥1000 Mpa or hardness ≥320 HV that are subject to tensile stress there is a risk of a hydrogen-induced brittle fracture.

Tempering the components immediately after the coating process contributes to minimising the risk. However, a complete elimination of the risk of brittle fractures cannot be guaranteed under the current state of the art. If the risk of a hydrogen-induced brittle fracture has to be reduced, alternative coating systems should be preferred.

Corrosion protection and coating systems should be selected for safety components that exclude the possibility of hydrogen inducement during coating through the procedure, e.g. mechanical galvanising and zinc flake coatings.

Users of fasteners are familiar with the respective purposes and the resulting requirements and must select the most suitable surface system themselves.