

**Corrosion Protection during
Production, Storage and Transport**

Ralf Möller, Dr. Martin Müller

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1. Introduction

The corrosion protection is significantly important in the production process because corrosion can lead to considerable economic damage due to waste. It can manifest itself through problems in subsequent treatment processes or through complaints of the customer (possibly only for visual reasons).

Many corrosion protection measures cannot be implemented during the production of a component because they either disrupt the process (e.g. during welding or hardening) or are worn away by the process (e.g. protective layers during removal processes). This requires special conditions of corrosion protection during production. Phosphating is one method that is used as an accessory in the process (e.g. in cold forming) and, at the same time, provides a good protection against corrosion.

Furthermore, very clean and that means active surfaces are often exposed during production, e.g. after degreasing or during and after removal processes. They require a special corrosion protection because neither passive layers nor impurities protect the surface from corrosion. In addition, aqueous auxiliary media (cooling lubricants etc.) are often used and they normally have a corrosion-promoting effect.

There are always two “partners“ in corrosion: the corroded material and the attacking corrosion medium. Generally, two types of corrosion protection are distinguished:

Active corrosion protection: the working pair is changed in such a way that the driving power of corrosion decreases.

Passive corrosion protection: a separating layer is created between material and corrosion medium.

Since the measures of **temporary corrosion protection** partly fit into both categories and it represents the most important barrier against corrosion during production, this category will be considered separately in a third section.

2. Active Corrosion Protection

2.1. Material Selection

The simplest, but often not practical way to avoid corrosion is an adequate material selection. It is usually confronted with economic and technical problems because resistant materials are too expensive, do not have the required mechanical properties or, in fact, cannot be processed in the desired way. Despite everything, this option should not be neglected because in a real economic efficiency calculation quite surprising results are possible. Adequate anti-corrosion agents that concurrently protect iron and non-ferrous metals (especially aluminium and copper) are very difficult to design because the requirements are partly contradictory. It is therefore desirable to keep this metal combination apart in the production process as long as possible.

2.2. Corrosion-Proof Design and Planning

Corrosion-proof design is a general requirement that should be considered at any time. In the production process, therefore, consider the following points:

- avoid crevices, joints, corners, edges, rough surfaces
- avoid contact elements (direct contact between different metals, even in connecting elements!)
- clean away turnings and metallic dust as soon as possible because they induce corrosion even under the protective layers
- clean aggressive media (acid fumes etc.) effectively by suction and neutralisation
- strictly separate iron and non-ferrous metals during fabrication
- dry and/or clean effectively and fast after processing with aqueous or corrosive media, especially in crevices, cavities and blind holes, and store as short as possible between individual processing steps

These requirements are desired for optimal corrosion protection but cannot always be complied with because of essential economic and technical reasons. They should, however, be strived for as much as possible.

2.3. Storage and Transport Conditions

The following conditions are required for storage and transport (especially sea transport):

- select appropriate packaging materials (air- and water-proof), and, where necessary, use VCI (=volatile corrosion inhibitor) papers or desiccant materials (silica gel)
- keep temperatures and humidities as constant and as low as possible
- avoid contact with aggressive media (condensation water, exhaust gases, sweat, salts,...)
- store cavities, grooves and notches pointed down, so that water drains off quickly and no corrosion pockets are formed
- ventilate sufficiently all components, especially if there is a danger of condensation water formation

2.4. Electrochemical Corrosion Protection

Here, the material is protected by application of current or by contact with a sacrificial anode. This method is generally used only in the case of direct contact with the ground or seawater, but can also be reasonably applied in aqueous processes.

2.5. Influence of the Corrosion Medium

It particularly includes:

- drying of air, compressed air, gases
- desalination of the used water, especially at high chloride content
- inhibition of aqueous processing media (cooling lubricants, cleaning agents, coolants) using inorganic or organic inhibitors; here it exists a variety of substances for addition by relevant specialist firms after thorough checking of the mentioned media
- inhibition of other processing media such as oils, lubricants etc. Amines and fatty acid derivatives are typically used here
- inhibition of acid pickles in order to suppress the undesired removal of bare metal and minimise the danger of hydrogen embrittlement. Please refer to the [Technical Letter No. 8](#) of SurTec Deutschland GmbH

3. Passive Corrosion Protection

Passive corrosion protection is the application of a separating layer on the working piece. In iron and steel, metallic coatings (such as zinc, nickel, zinc alloys), organic coatings (paints, varnishes) or non-metallic coatings (enamelling, cementing, burnishing, gas nitriding, Ionox) are normally used for this purpose. Essential for all methods is a very good pre-treatment of surfaces by degreasing and pickling/sandblasting in order to ensure a good adhesion of the layer. The application of a separating layer is usually performed as the last processing step to achieve a permanent corrosion protection for the working piece.

In the case of **phosphating**, an iron, zinc or manganese phosphate layer is applied on the working piece by the spraying or dipping method. The corrosion protection increases in the below order but should usually be strengthened further by after-treatment (containing Cr(VI) or with oil). The phosphating serves in the production process primarily for improvement of material properties in various methods (e.g. cold forming) or as adhesive ground, and only to a lesser extent for corrosion protection.

The direct **passivation and chromating** of stainless steel or brass using chromic acid or other oxidising solutions is also one of the methods of passive corrosion protection but is used rarely. An exception here is the passivation of aluminium and galvanically isolated layers, especially of zinc and cadmium. They were protected by chromium(VI) containing passivations while more recent methods work without chromium(VI) and use the non-toxic chromium(III) instead. Further information about these methods is available on <http://Chromiting.SurTec.com/>.

4. Temporary Corrosion Protection

The temporary corrosion protection is usually a passive protection against corrosion but it can also be considered as an active corrosion protection, e.g. in degreasing baths and rinses or when using VCI paper.

The purpose of temporary corrosion protection is to ensure a protection effect during the production process, storage and transport of workpieces. Two years is a maximum period that is generally not exceeded. At the same time, the layers should be as easily removable as possible in order not to disrupt subsequent processes. The durability of the protection is strongly dependent on the surrounding conditions but increases in the order of the below listed anti-corrosion agents. By contrast, the removal becomes more difficult.

4.1. Aqueous Temporary Corrosion Protection

It generally concerns adducts of fatty acids and amines that form on the metallic surface of a thick film. These substances are added to the last rinse after cleaning and pickling baths or to aqueous processing media such as coolants. The films should generally not be washed off and only very rarely interfere with subsequent processes (e.g. water-repellent films for after varnish). At temperatures above 200 °C the films evaporate and thus do not interfere with the heat treatment. However, the drying temperatures should also not exceed this value.

Depending on the choice of substances, volatility (effect in the vapour phase) and water-repellent effect can be adjusted. The latter leads to a water-repellent layer that facilitates drying and, contrary to other films, can be washed off by condensation water only very slowly. However, hydrophobic films can only be removed alkalinely.

If only iron and steel are processed, the agents are adjusted to be weakly alkaline in order to utilise the corrosion-inhibiting effect of alkalinity. If non-ferrous metals also come in contact with the media (even as a component part of the installation), the agents must be adjusted to neutrality.

Temporary anti-corrosion agents allow achieving corrosion protection times from 2 weeks to 6 months (depending on the material and storage conditions such as humidity, temperature, stability of surrounding conditions).

Such corrosion protection times can be achieved without problems if the following process parameters are met:

- the products should be preferably put and processed in deionised water with a quality of chloride < 10 ppm and sulfate < 20 ppm. (Chlorides and sulfates are known to be corrosion activators on steel/cast iron and aluminium)
- after cleaning the processed product must be quickly dried by blowing off and using own heat of the parts. For parts with holes and undercuts a vacuum drying is advisable
- the ambient air must be dry
- the processed parts that are sent directly to assembly must be dry and be kept in dry environment
- regular concentration checks of the cleaning and preservation solutions as well as tests for contamination by chloride and sulfate are indispensable
- falling concentration of the preservation components and too high content of chloride and sulfate can significantly reduce the corrosion protection times

4.2. Oleaginous Corrosion Protection

A) Anti-corrosion emulsions

These are aqueous emulsions of mineral oils and waxes with added biocides and corrosion inhibitors. They prevent that the aqueous phase leads to metal corrosion before it evaporates. Depending on the composition of emulsions, it is possible to reach the corrosion protection values of anti-corrosion waxes. The advantage consists in the solvent-free application, which is desirable in terms of work and fire safety and environment protection.

B) Anti-corrosion oils

Anti-corrosion oils are mineral oil raffinates of various viscosity. The thickness of the oil film and therefore the protection effect depends directly on the viscosity of the products. In special case metal soaps are added to the oils to increase the viscosity and thereby the protection effect. In order to achieve the necessary protection effect, in most cases the oils are inhibited by oil-soluble amines in concentration below 1 %. They are applied as a fluid either in undiluted form or diluted with benzines.

C) Anti-corrosion greases

These are vaselines that can also be mixed with inhibitors to increase the protection effect, mostly with long-chain fatty acid esters. Unlike oils, anti-corrosion greases can be applied in a larger thickness and generally layer thicknesses of about 500 µm are desirable. To ensure this layer thickness at higher temperatures as well, the fats are selected according to their drop point and then partially thickened by adding metal soaps. For applications at higher temperatures, drop points of about 80 °C are required.

D) Anti-corrosion waxes

Anti-corrosion wax fluids are complex, liquid, colloid-disperse systems of wax or waxy substances, solvent naphtha and corrosion-inhibiting additives (e.g. alkaline stearates and silicone oils). They produce plastic hard layers that are rub-proof, unlike oils and fats. Hard paraffins, slack wax vaselines or various natural waxes, such as bees was or lanolin, serve as layer-forming agents. Bitumens or synthetic resins are sometimes added to improve the properties.

4.3. Vapour Phase Inhibitors VCI (Volatile Corrosion Inhibitors)

The VCIs offer a cost-effective way of protection against corrosion during long-term storage and transportation. They consist of highly volatile powders or liquids that are used in the form of tablets, small packets or as impregnated sponges, papers, foils.

Their effect is essentially based on corrosion inhibition on the metal surface. First they evaporate until the saturation vapour pressure is reached and condense on the metal surface. When the VCI is consumed, the effect ends. Therefore the manufacturer's instructions about the used quantities should be precisely followed. This, however, means that VCIs can only be used in hermetically closed spaces, boxes etc.

The first technically used VCI was DICHAN (dicyclohexylammonium nitrite). It was introduced to the market by Shell already shortly after the Second World War and still is today the most common ingredient. However, a variety of other agents became known in the meantime. Less volatile substances are also partly used, they are transported onto the metal surface by a carrier. A combination of various agents allows producing mixtures that, on one hand, provides an immediate protection through highly volatile substances and, on the other hand, also ensures a long-term protection through less volatile compounds.

4.4. SurTec Products for Temporary Corrosion Protection

	INGREDIENTS					SUITABLE FOR					FILM		CLEANING	
	Mineral oil	Tensides	Borates	Phosphates	Solvents	Iron & steel	Non-ferrous metals	Aluminium	Subsequent heat treatment	Subsequent painting ^a	Washable with water	hydrophobic	sprayable ^b	Suitable for US ^b
SurTec 001	-	+	-	-	-	+	+	+	+	+	+	-	from 30 °C	-
SurTec 005	-	+	+	+	-	+	o	o	-	+	+	-	from 30 °C	-
SurTec 006	-	+	-	+	-	+	-	-	-	+	+	-	from 30 °C	-
SurTec 010 ^c	-	+	-	-	-	+	+	+	+	+	+	-	from 30 °C	-
SurTec 011	-	+	-	-	-	+	+	o	+	+	+	-	from 30 °C	-
SurTec 042	-	+	-	-	-	+	o	-	+	+	+	-	from 40 °C	+
SurTec 101	-	+	-	-	-	+	+	+	+	+	+	-	from 40 °C	+
SurTec 104	-	+	-	-	-	+	+	+	+	o	-	+	-	+
SurTec 107	-	-	+	+	-	+	+	+	-	+	+	-	o	o
SurTec 108	-	-	-	+	-	+	o	-	-	+	+	-	o	o
SurTec 418	-	-	-	-	-	+	+	-	+	+	-	-	-	-
SurTec 531	-	-	-	-	-	+	-	-	+	+	+	-	o	o
SurTec 533	-	-	-	-	-	+	o	-	+	+	+	-	o	o
SurTec 534	-	-	-	-	-	+	+	+	+	+	+	-	o	o
SurTec 560	-	-	-	-	-	-	+	-	-	+	-	-	-	-
SurTec 590	+	-	-	-	-	+	+	+	-	-	-	+	-	-
SurTec 994	+	-	-	-	+	+	+	+	-	-	-	+	-	-

a: The paintability should be thoroughly tested. SurTec 104 is not suitable for subsequent aqueous painting

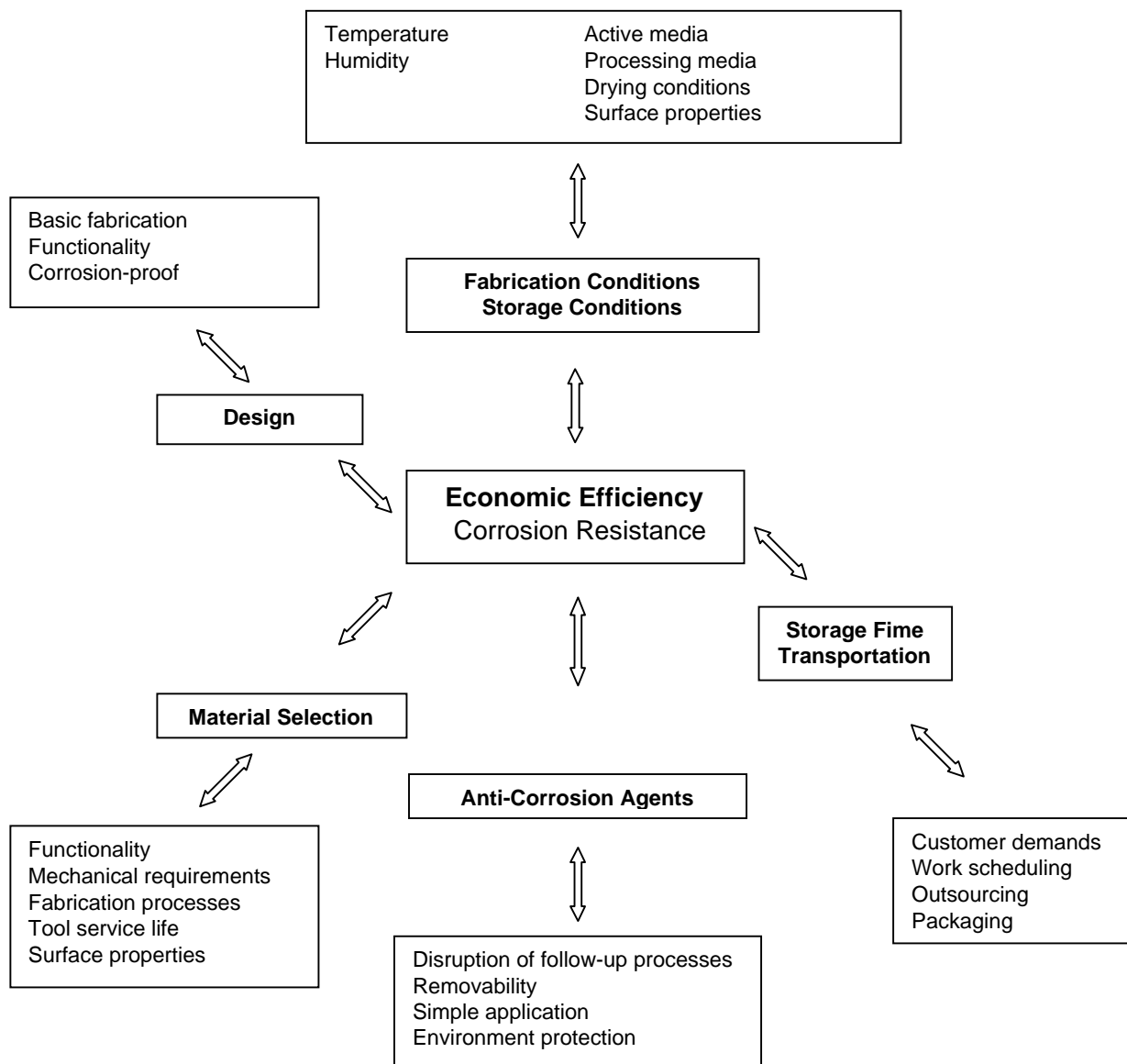
b: o means “in combination with appropriate tensides/cleaning boosters

c: contains biocides

5. Summary

The corrosion resistance of working pieces depends on many factors and generally correlates directly to the arising costs. It is therefore necessary to conduct economic efficiency analyses regularly (especially when a parameter is changed) and to optimise all influencing factors involved. The most important influencing factors are shown in the diagram below. Of particular importance are the following points:

- surface properties (prevention of rough surfaces, drying of salts, fast cleaning)
- shortest possible storage times and transport routes under optimal conditions
- best corrosion-resistant materials
- avoiding aggressive active media (condensation water, acid fumes, exhaust gases, turnings, dust,...)



6. Literature

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