External Corrosion Protection by Painting

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1 General

The reasons of painting items of equipment are many and varied. They include visual appearance, protection against corrosion, the provision of special surface properties such as good reflection of light as well as easy cleaning and resistance to chemical substances in the environment.

There is no single universal paint or other coating material. A particular paint must be chosen to suit the surface to which it is to be applied and its environment.

Paints may be of varying consistency ranging from liquid to paste-like. They may also be physically and/or chemically drying substances or blends which can be applied by brushing, spraying or other method.

An important constituent of a paint is the medium binding the particles of paint pigment together and to the surface. The pigment is responsible for the colour. The range of colours available will be found on the RAL shade card which is related to the colour register RAL 840 HR.

When applying paint, care must be taken to ensure that the whole structure receives good, uniform protection against corrosion suitable for the purpose. In the case of structures where the susceptibility to corrosion varies, extra corrosion protection must be provided in the more heavily stressed areas, e.g. by employing hot-galvanized components or using stainless materials.

2 Anti-corrosion design

Corrosion damage to metal parts can be prevented or reduced by various methods of design and construction. The design should be such that there is good accessibility to all parts of the structure so that corrosion protection can be applied, checked and kept in good order. If there are special reasons why this is impossible, the cleaning and painting of places which will no longer be accessible after assembly must be carried out beforehand.

Narrow gaps, voids and blind holes in which dirt can accumulate should be avoided.

Voids and the underside of metal plates on which condensation can form should be adequately ventilated.

When units are installed outdoors, with the attendant greater danger of corrosion, all weld seams should be continuous and there should be no sections open at the top.

Sharp cut edges and burrs should be avoided because the surface tension of liquid paints causes them to pull back from sharp edges and corners.

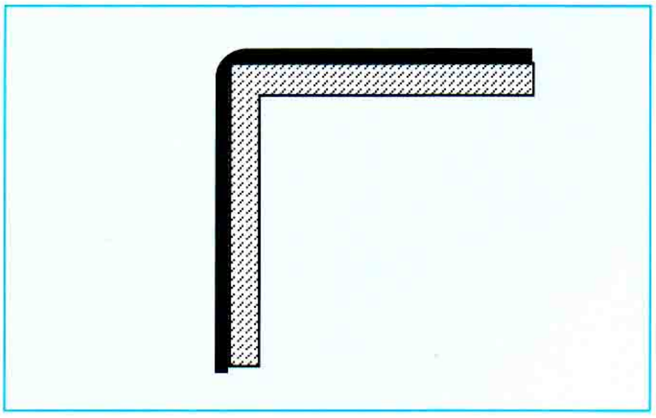


Fig. 226

3 Surface preparation

The effectiveness and life of anti-corrosion paints on metal surfaces depends to a large extent on good preparation of the surface to which the paint will be applied.

3.1 Preparation of steel parts

Steel parts are prepared by particle blasting to a standard cleanliness rating of SA 2 1/2. The standard ratings are laid down in DIN 55 925, Part 4.

SA 2 1/2 means that sufficient scale, rust and old paint have been removed to ensure that any residue remaining on the surface will simply be visible as slight shadows due to the toning of pores.

3.2 Surface preparation of hydraulic power units before applying the second undercoat

The surfaces must be carefully and completely cleaned with a suitable cleaning agent to remove all dirt, dust, grease and other substances which would have an adverse effect on the paint.

The cleaning agents must be handled in accordance with the relevant safety instructions.

4 Selecting paints according to corroding media and environmental factors

Both single-component paints and two-component paints are available. Which system is chosen depends on the corroding media to which the surface requiring protection will be exposed.

Note, for example, that a seawater or brackish water environment will require a different painting system to a dry or warm and moist environment.

Corroding media and environmental factors	Painting system Single-component system Alkyd resin top coat	Two-component system Polyurethane top coat
Dry temperate climate (DIN 50019)	●	
Warm humid climate (DIN 50019)	●	
Marine climate (DIN 50019)	●	
Fresh water	●	
Seawater or brackish water		●
Mineral oil (DIN 51524)	●	
Oil-in-water emulsion HFA (DIN 24320)		●
Water-in-oil emulsion HFB (VDMA 24317)		●
Aqueous polymer solutions HFC (VDMA 24317)		●
Phosphate ester HFD-R (VDMA 24317)		●
● resistant to		

Table 65

5 Single-component paint systems

In order to obtain the required properties of protection, more than one coat of paint must be applied to a surface, i.e. undercoat and top coat. Remember, of course, that the sequence of application - undercoat first, top coat second - cannot be reversed. And no more undercoat may be applied to parts which have already received their top coat.

Top coat Hydraulic power units	Alkyd resin paint (any desired RAL colour)
2nd undercoat Hydraulic power units	Epoxy undercoat RAL 7031 or RAL 6011
1st undercoat Hydraulic power units	Epoxy undercoat RAL 7031
1st undercoat Steelwork	Zinc-rich primer RAL 7000
Surface	Steel to normal grade of cleanliness SA 2 1/2

Table 66: *Painting procedures*

5.1 Paints

5.1.1 Zinc-rich primer

Zinc-rich primer is a high-quality single-component polyurethane based paint containing approximately 84% zinc in solid form. It is sprayed on to surfaces which have been previously sand or shot blasted (the necessary surface roughness for zinc-rich primer is 50 µm).

Where bruises, cracks or voids are present, zinc-rich primer clearly provides protection for a small, although limited, exposed surrounding area. It initiates a cathodic process which produces large quantities of a product of zinc corrosion which eventually covers the damaged area. In fact, the protection is due less to the cathodic process, which is only present initially, but more to the products of corrosion produced by the cathodic process preventing the zinc going into solution and thereby increasing the durability.

Zinc-rich primer has good adhesion, high abrasion resistance and good impact resistance. Subsequent welding is possible, although the welded area must be repainted after careful cleaning. Subsequent undercoats and top coats do not have to be applied immediately.

5.1.2 Epoxy undercoat

Epoxy undercoat comprises a medium containing a single-component epoxy resin ester with 54% solids.

The advantages of epoxy undercoating are:

- optimum corrosion resistance
- good resistance to chemicals, water and solvents
- good elasticity at high temperatures
- good adhesion.

5.1.3 Alkyd resin paint (top coat)

Alkyd resin paint comprises a medium of alkyd resin containing 56% solids. Its key features are good surface properties such as hardness, shine and scratch resistance.

Note:
The commonly used term "synthetic resin paint" does not describe the quality of a paint sufficiently well because there are a wide variety of different compositions and properties for such paints.

5.2 General features of single-component paints

Description		1st undercoat Steelwork	2nd undercoat Complete power unit with pipe work	Top coat Complete power unit (any desired RAL colour)
Product designation		Zinc-rich primer RAL 7000	Epoxy under coating RAL 7031 or RAL 6011	Alkyd resin paint RAL 6011
Chemical characteristics		Single-component polyurethane Zinc-rich primer	Epoxy resin ester (free from zinc chromate, lead and asbestos)	Alkyd resin base (lead-free)
Drying		Chemical under influence of air humidity	Air-drying	Air-drying
Paint	Solids % Specific gravity in kg/dm³	84 2,8	54 1,2	56 1,2
	Flashpoint in °C Danger class [1] Warning sign [1]	30 AII	25 AII ✗ Xn	24 AII
Viscosity as-supplied mm²/s Working viscosity mm²/s		60 to 70 17 to 18	100 25	130 40
Thinning required % Pot life in h at 20 °C		10 6 to 8	15 —	15 —
Thinners Flashpoint in °C Danger class [1] Warning sign [1]		Special thinners 43 AII	Special thinners 24 AII ✗ Xn	 24 AII ✗ Xn
Application		Brush or spray	Brush or spray	Brush or spray
Method		Spray gun, Airless	Spray gun, Airless, Esta	Spray gun, Airless
Theoretical consumption for 30 µm dry film in g/m² Coating thickness per application in µm Max. coat thickness in µm Spreading capacity in m²/kg with approx. 30% wastage allowance (coating thickness 40 µm)		200 bis 250 40 70 3	120 30 60 4	120 30 60 4
Dust-dry at 20 °C in h Transport-dry at 20 °C in h Re-coatable at 20 °C in h		 0,25 8	0,5 1 8	4 16 6
Storage stability in months in original container at 5 to 40 °C		6	6	6
Max. temperature resistance of painting system in °C		-40 to 150	-40 to 150	-40 to 150
Surface preparation for painting		Sand-blasting SA 2,5 or free from rust, dust and grease Surface roughness ≥ 50 µm	Free from rust, dust and grease	Free from rust, dust and grease

Table 67: *Single-component paints*

[1] *Description of danger class and identification see Section 11*

6 Two-component paint systems

The advantages of two-component paints are their exceptional toughness, abrasion resistance, adhesion and resistance to chemical attack. More than one coat of paint must be applied to a surface, i.e. undercoat and top coat, in order to obtain the required properties of protection.

Remember, of course, that the sequence of application - undercoat first, top coat second - cannot be reversed. And no more undercoat may be applied to parts which have already received their top coat.

Top coating Hydraulic power units	Two-component polyurethane paint (any desired RAL colour)
2nd undercoat Hydraulic power units	Two-component epoxy undercoat RAL 7032
1st undercoat Hydraulic power units	Epoxy undercoat RAL 7031
1st undercoat Steelwork	Zinc-rich primer RAL 7000
Surface	Steel to normal grade of cleanliness SA 2 1/2

Table 68: *Painting procedures*

6.1 Paints

6.1.1 Two-component epoxy undercoat

Two-component epoxy undercoat is an epoxy resin paint with a total solids content of 67%.

The advantages of two-component epoxy undercoat are:

- universal application on almost any surface (including hot-galvanized parts)
- good filling power, good running qualities
- toughness, scratch resistance, excellent resistance to bubbling
- resistant to solvents
- exceptionally resistant to chemical attack.

6.1.2 Polyurethane paint

Polyurethane paint is of the reaction type on a polyurethane base with a solids content of 67%.

The drying process comprises a combination of solvent evaporation and chemical reaction.

Careful mixing before use will ensure the following properties:

- resistance to chemicals, water and solvents
- fire-resistance
- excellent hardness, abrasion resistance, filling and shine
- resistance to fire-resistant hydraulic fluids

Note:

Surfaces which have received a top coat of two-component paint can be painted again with two-component top coat within 14 days. After this time it will be necessary to roughen the surface first with a fine glasspaper.

Note:
The term "DD paint" stands for Desmodur and Desmophen (trade-marks of Bayer AG). The reaction between these two single components produces a polyurethane film.

6.2 General features of two-component paints

Description	**1st undercoat** Steelwork	**2nd undercoat** Complete power unit with pipework	**Top coat** Complete power unit (any desired RAL colour)
Product designation	Zinc-rich primer RAL 7000	2 part Epoxy resin under coat RAL 7032	Polyurethane paint RAL 6011
Chemical characteristics	Single-component polyurethane Zinc-rich primer	2 part epoxy resin with Polyamid hardener (free from zinc chromate, lead and asbestos)	2- part Polyurethane (lead-free)
Drying	Chemical under influence of air humidity	Chemical reaction	Chemical reaction
Paint — Solids % Specific gravity in kg/dm³	 84 2,8	Undercoat / Hardener 60 / 7 1,67 / 0,97	Top coat / Hardener 67 / 67 1,3 / 1,1
Paint — Flashpoint in °C Danger class [1)] Warning sign [1)]	30 All	25 / 25 All / All – / ✖ Xn	25 / 30 All / All
Viscosity as-supplied mm²/s Working viscosity mm²/s	60 to 70 17 to 18	100 to 110 25	40 to 80 20 to 25
Thinning required % Pot life in h at 20°C	10 6 to 8	5 to 10 12	aprox. 10 8
Mixing ratio, base/hardener		87,5 : 12,5	100 : 40
Thinners Flashpoint in °C Danger class [1)] Warning sign [1)]	Special thinners 43 All	Special thinners 25 All ✖ Xn	 24 All
Application	Brush or spray	Brush or spray	Brush or spray
Method	Spray gun, Airless	Spray gun, Airless, Esta	Spray gun, Airless, Esta
Theoretical consumption for 30 µm dry film in g/m² Coating thickness per application in µm Max. coat thickness in µm Spreading capacity in m²/kg with aprox. 30 % wastage allowance (coating thickness 40 µm)	200 to 250 40 70 3	120 40 80 4	150 35 to 40 50 4
Dust-dry at 20 °C in min Transport-dry at 20 °C in h Re-coatable at 20 °C in h	 0,25 8	10 2 16	20 6 to 8 6
Storage stability in months in original container at 5 to 40 °C	6	6	6
Max. temperature resistance of painting system in °C	-40 to 150	-40 to 150	-40 to 150
Surface preparation for painting	Sand-blasting SA 2,5 or free from rust, dust and grease Surface roughness ≥ 50 µm	Free from rust, dust and grease	Free from rust, dust and grease

Table 69: *Two-component paints*

[1)] *Description of danger class and identification see Section 11*

7 Applying paint

The manufacturer's instructions must be followed closely when applying paint.

In the case of steel parts where there are surfaces which will no longer be accessible after they have been joined by welding or bolting, the affected areas must be treated with zinc-rich primer first *(see Section 5.1.1)*.

The minimum coat thicknesses listed in *Tables 68 and 69* must be adhered to when applying the paints. However, the total thickness should not exceed 120 µm. Excessive thickness can cause surface tension which will have an adverse affect on the corrosion protection.

The following items must be left free of paint:

- nameplates and instruction plates
- plastics
- oil level sights and gauges
- piston rods and hoses.

All relevant regulations must be adhered to when using and applying paints.

8 Methods of painting

The application of paint by spray produces an excellent surface finish when the proper methods are used. However, there are many different methods of spraying, each having its own special properties.

8.1 Air spraying

Air spraying is excellent for large, flat surfaces. However, due to the high spray loss, it is less suitable for parts with a small specific surface area.

Paint wastage when spraying small suspended items is usually very high.

It is also difficult to spray inside voids and channels by this method *(Fig. 227)*. The large amount of compressed air in the paint spray causes an air cushion to form which makes the deposition of the paint difficult or impossible. There are, nevertheless, special nozzles and extensions which make it possible to paint inside voids by this method.

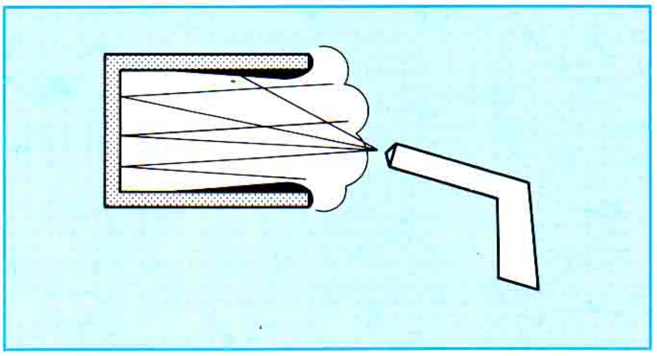


Fig. 227: *Air spraying inside voids causes a pressure build-up which, in extreme cases, can completely stop the paint being deposited*

8.2 Airless spraying

Airless spraying avoids some of the difficulties of air spraying. In this case the paint is expelled under high pressure and does not need compressed air to carry it. Its principal advantages are a high throughput (making it suitable for painting large surface areas) and practically no pressure build-up when painting inside voids and channels. Generally speaking, the paint is not atomized so finely as with the air spraying method, which makes control easier.

8.2.1 Hot airless spraying

The advantages of hot airless spraying are that it permits the use of high-viscosity, low-solvent paints. The paint is heated to about 55 to 70°C either directly in the can or in a heat exchanger. The elevated temperature reduces the viscosity of the paint.

The advantages of hot airless spraying are:

- economy due to the saving of thinners (cold spraying needs about 5 to 15% by weight of thinners
- faster drying
- thicker application if necessary
- less pollution.

8.3 Electrostatic spraying

The generation of an electric field between the spray gun and the item being painted causes the particles of paint to be attracted to the item so that the overspray loss is greatly reduced.

Naturally, electrostatic spraying is primarily intended for items which are good conductors of electricity, i.e. metal parts.

In terms of paint yield, the pure electrostatic method achieves the highest efficiency, particularly for items which have large gaps, e.g. hydraulic power units with their pipework.

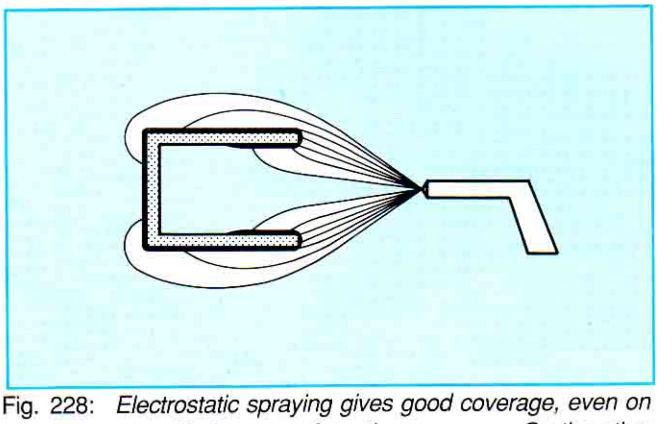


Fig. 228: *Electrostatic spraying gives good coverage, even on areas facing away from the spray gun. On the other hand, the Faraday cage effect makes painting the inside of voids difficult because the lines of force cannot penetrate inside the hollow section*

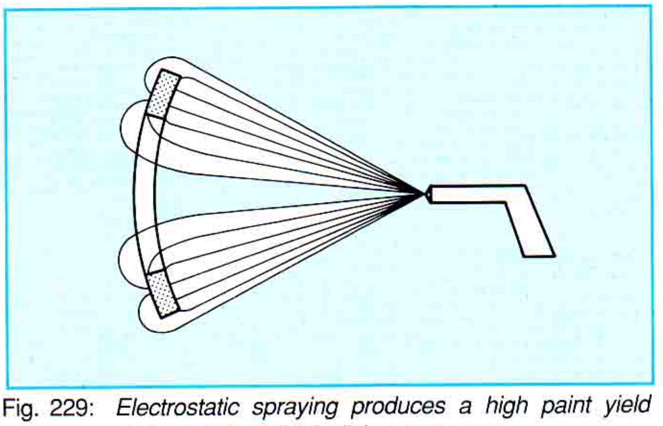


Fig. 229: *Electrostatic spraying produces a high paint yield and correspondingly little overspray*

9 Paintwork for hydraulic power units and equipment for hydraulic engineering

Customers in the hydraulic engineering field usually require corrosion protection for hydraulic power units and equipment to be in accordance with DIN 55 928, Part 5. DIN 55 928, Part 5 - Table 6 lists all the usual and well tried protection systems with different protection parameters. The different stresses due to atmospheric, chemical and mechanical effects are also listed.

Coat thicknesses are recommended to DIN 55 928, Part 5. Structural viscosity adjustments make it possible to apply paints thickly.

The customer specifies the corrosion protection according to the corrosion stresses involved.

a Light corrosion attack, e.g. installation in enclosed spaces, use protection parameters 6.11.1 to 6.11.5.

b Medium corrosion attack, e.g. installation outdoors, use protection parameters 6.30.1 to 6.30.3.

c Heavy corrosion attack, e.g. cylinders outdoors, use protection parameter 6.31.1.

Example of protection system designation to DIN 55 928, Part 5, Table 6, protection parameter 6.30.2 "Corrosion protection DIN 55 928 - T 05 - 6.30.2"

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		Type of painting							Applicable for														
		Undercoat [1] UC		Top coat [1] TC					Outdoor steelwork (conditions to DIN 55 928, Part 1)									Indoors e.g. workshops					
																		accessible			inaccessible		
																		Areas of components subject to similar internal stress					
Protection parameter	Binding element	No.	Total req. coat thickness µm	No.	Total req. coat thickness µm	Total system [1] UC + TC Total req. coat thickness µm	Surface preparation to DIN 55 928 Part 4 [2]	Usual medium for production painting Parameter	Agricultural atmosphere L	Town atmosphere S	Industrial atmosphere I	Marine atmosphere M	Chemical attack Ch	Road salt	Road sand and gravel	Mech. stress	Mech. stress, flying gravel	LS	I	Ch	LS	Ch	Remarks
6-10.1	Oil, oil blends	1	40	1	40	80			—	—	—	—	—	—	—	—	—	x	—	—	0	—	
6-10.2		1	40	2	80	120			x	0	—	—	—	—	—	—	—	x	—	—	x	—	
6-10.3		2	80	2	80	160	Sa 2 1/2		x	x	0	—	—	—	—	—	—	•	—	—	•	—	
6-10.4		2	80	3	120	200			•	x	x	—	—	—	—	—	—		—	—		—	
6-11.1	Alkyd resin;	1	40	1	40	80	Fl [3]		—	—	—	—	—	—	—	—	—	x	—	—	0	—	
6-11.2	Alkyd resin blends;	1	40	2	80	120		11	x	0	—	—	—	—	—	—	—	x	—	—	x	—	Phthalic resin is an alkyd resin
6-11.3	epoxy resin ester	2	80	2	80	160	Sa 2 [4]	24	x	x	0	—	—	—	—	—	—	•	—	—	•	—	
6.11.4		2	80	3	120	200		30	•	x	x	x [6]	—	x [6]	—	—	—			—		—	
6.11.5		2 [5]	160	1	80	240			•	x	x	x	—	x [6]	—	—	—			—		—	DICK
6-12.1	Bitumen-oil blend	1	40	3	210	250	Fl [6]; Sa 2 [6]		—	•	x	x	0	x	0	—	—		x	0		0	Bitumen-oil blends only for TC, UC with anti-corrosion pigment, medium: oil, alkyd resin or blends
6-20.1	Chlorinated rubber,	2	70	2	70	140	Sa 2 1/2	24 30 52 53	x	0	0	—	—	—	—	—	—	x	x	—	x	—	
6-20.2	vinyl chloride,	1	80	1	80	160			x	0	0	—	—	—	—	—	—	x	x	—	x	—	DICK
6-20.3	copolymer	2 [5]	160	1	80	240	Sa 2 1/2, Fl [7]		•	x	x	x	x	x	—	—	—			x		x	DICK
6-21.1	Chlorinated rubber blend,	2	70	2	70	140	Sa 2 1/2	11 24 30	x	0	0	—	—	—	—	—	—	x	x	—	x	—	
6-21.2	vinyl chloride copolymer blend	1	80	1	80	160			x	0	0	—	—	—	—	—	—	x	x	—	x	—	DICK
6.21.3		2 [5]	160	1	80	240	Sa 2 1/2; Fl [7]		•	x	x	x	x [8]	x [8]	—	—	—			x [8]		x [9]	DICK
6-30.1	Epoxy resin; polyurethane	2	100	2	100	200		30		x	x	0	—	—	—	—	—		x	0	x	0	
6-30.2		1	80	2	160	240				•	x	x	x	x	0	—	—			x		x	DICK
6-30.3		1	80	3	240	320					•	x	x	x	x	0	—			x		x	DICK
6-30.4	Epoxy resin, abrasion-res.	2		1		2000 [10]	Sa 2 1/2 [9]						x	x	x	x	—						Painting method in 3 coats of 300 µm each, sprinkled with quartz sands between coats
6-30.5	Epoxid resin, abrasion-res.	2	600	1	4000	4600 [10]										•	x						UC with quartz sand brushed, TC applied by spatula
6-31.1	Tar epoxy resin, tar pitch epoxy resin, tar/tar pitch polyurethane			3	360	360	Sa 2 1/2	30			•	x	x	x	x	0	—			x		x	DICK
6-31.2	Epoxy resin, polyurethane / Tar/tar pitch epoxy resin, tar/tar pitch polyurethane	1	60	2	240	300	Sa 2 1/2 [9]	30	—	—	•	x	x	x	x	0	—					x	UC with zinc / DICK
6-40.1	Bitumen, filled	1	40	3	240	280	Fl [6]	11 24 30	x	x	x	x	0	0	—	—	—	x	x	0	x	0	Only for TC, UC with anti-corrosion pigment, medium: alkyd resin or blends
6-41.1	Coal tar pitch, filled	1	40	3	240	280	Sa 2 [6]		•	•	x	x	x	x	—	—	—	•	x	x	•	x	
6-50.1	Silicone resin	1	30	2	50	80	Sa 3					—	—	—	—	—	—			—		—	For high temperatures (400°C), UC with zinc and TC with aluminium pigment and/or mica
6-52.1	Zinc alkali silicate	1	80		[11]	80			x	x	0	x	—	x	x		—	x	0	—	x	—	Without TC,
6-53.1	Zinc ethyl silicate	1	80		[12]	80			x	x	0	x	—	x	x		—	x	0	—	x	—	for high temperatures (400°C)

DICK Thick coat system
x Recommended
• For exceptionally long protection only
0 With comparatively low stress
— Not recommended
No code Indeterminate

1) Systems with the same system for UC and TC are generally used. However, compatible combinations of UC and TC with different media can be used, also combinations of thin-coat and thick-coat systems. The governing factor is the total coat thickness allowed. The number of coats indicated can be applied most uniformly by the airless spraying method. If this is not available the number of coats should be increased.

2) The information in Column 8 gives cleanliness standards for specific painting systems. They are not intended as a basis for comparing cleanliness standards.

3) If the object is suitable for flame cleaning and the work is performed by trained staff; but not for UC with zinc.

4) Only with red lead in the UC; for overhaul work also St 3 and, indoors, St 2.

5) 1 UC + 2 TC is also possible

6) For stresses M, road salt and Ch: Sa 2 1/2 or Fl with additional flame phosphating

7) Fl only with additional flame phosphating

8) With alkaline stress TC with highly saponifying softener

9) In special cases Sa 3; see DIN 55 928, Part 4, January 1977 edition, Section 4.1

10) With quartz sand

11) Soaping-resistant TC possible

12) Also usual with TC

Table 70: *Examples of proven corrosion protection systems for steel structures (except thin-walled, load-bearing components, hydraulic engineering, marine engineering)*

10 Special customized painting

The considerable expense of purchase, storage, application and disposal of special paints must be taken into account when considering special customized painting.

There are a number of points to watch:

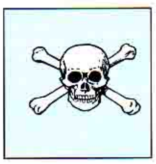
- paints must be free from carcinogenic substances such as chromate and cadmium
- paints classified as poisonous, e.g. containing lead, must not be used
- paints, thinners and hardeners of danger class A1 (e.g. nitro-cellulose paints) must not be used.

11 Danger classes and warning signs

Dangerous substances must be marked in accordance with the appropriate regulations.

In the case of West Germany, typical warning signs are as follows:

poisonous



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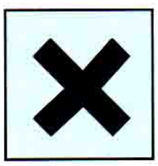
Slightly poisonous (injurious to health)



Xn

German danger classes are as follows:

Danger class A I: Liquids with a flashpoint below 21°C

Danger class A II: Liquids with a flashpoint between 21° and 55°C

Danger class A III: Liquids with a flashpoint between 55° and 100°C

12 The principal relevant standards

DIN 55 928

Corrosion protection for steel structures by painting and coating

Part 1: General

Part 2: Anti-corrosion design

Part 4: Surface preparation and testing

Part 5: Paints and protection systems

DIN 55 945

Paints, lacquers and similar coating materials
Terms

13 References

Jurgen Fichtner — Die bessere Lackierung kommt vom Reissbrett, Ingenieur Digest, March 1977

Karl-Albert van Oeteren — Zinkstaubanstrichstoffe und ihre Anwendung, Maschinenmarkt, Wurzburg 1970, No. 30