

Abstract

The application of zinc-rich primers on ferrous substrates is a very efficient method of anticorrosion protection. It is a known fact that to achieve a long life coating system you need a zinc primer as a first coat. Zinc offers threefold protection since it; seals the underlying metal from contact with its corrosive environment, provides galvanic protection and “repairs” minor damages in a coating forming a barrier to further electrochemical action. A short description of these properties will be presented in this paper. Compared to epoxy the silicates can be pigmented at extremely high levels of zinc dust giving zinc to zinc metal contact and, consequently, excellent cathodic protection properties like those obtained with galvanizing. There is a trend in new international standards that the demand for zinc content is the same for zinc epoxy and zinc silicate given weight by weight. If it is a wish to have the same zinc content level for inorganic and organic coatings the values should be given volume by volume. Calculation examples and figures will be presented.

The type of corrosion protection and the galvanic potential can easily be illustrated by electrical impedance testing. The potential of bare steel in seawater is approximately $-650 \text{ mV}_{\text{SCE}}$ (Saturated Calomel Electrode) and zinc has a potential of approximately $-1050 \text{ mV}_{\text{SCE}}$. As long as the potential is below -800 mV the primer still gives cathodic protection. Above this level the primer will only give you a barrier effect. For unexposed zinc primers the potential are usually between -900 mV and -1000 mV depending on type of binder, zinc content and film thickness.

Earlier the type of zinc primer normally specified has been zinc silicate and most typical zinc ethyl silicate. This is because within the parameters of zinc silicates the solvent-borne ethyl silicates have been found to be generally more tolerant than the water-borne alkali metal zinc silicates. The zinc silicates give the best corrosion protection (especially alone), adhesion to Sa 2½, chemical resistance, heat resistance, abrasion resistance, welding and cutting properties. The water-borne silicates can be made with zero VOC and is more environment friendly compared even to water-borne epoxy. Zinc silicate is a typical “new building” coating. The zinc epoxy is easier to apply in higher film thickness without mud cracking and can be applied with conventional airless spray while alkali silicates normally need special equipment. Top coating is also easier compared to silicate, which may give popping and adhesion failure because of high alkalinity on alkali silicate paint. The curing of the zinc epoxy is faster and is not depending on high humidity and the shelf life of a zinc epoxy is far longer than ethyl silicate. Zinc epoxy is also more surface tolerant and is a typical “maintenance” coating. Zinc epoxy was used in the shopprimer market for some years but the consumption has decreased a lot. The reason is high zinc content and poor weldability. The silicates are unbeatable on back burning, pore formation and welding fumes.

Keywords: - Zinc primers
 - Cathodic protection
 - Zinc dust

1. Introduction

1.1 General background

The application of zinc-rich primers on ferrous substrates is a very efficient method of anticorrosion protection. It is a common fact that to achieve a long life coating system you need a zinc primer as a first coat. Zinc primer offers threefold protection in that it:

1. Seals the underlying metal from contact with its corrosive environment, barrier effect. Figure 1.
2. Provides galvanic protection. Figure 2.
3. "Repairs" minor damages in the coating to form a barrier to further electrochemical action. Picture 1.

1.2. Zinc dust content

The anticorrosive and mechanical properties of zinc primers are highly dependent upon the level of zinc dust present. Compared to epoxy the silicates can be pigmented at extremely high levels of zinc dust giving zinc to zinc metal contact and, consequently, excellent cathodic protection properties like those obtained from galvanizing. The silicate will create a primary valency bonds with the substrate as well as the zinc particles while the epoxy will create a secondary valency bonds. The primary valency bonds are up to 6 times stronger than the secondary valency bonds. There is a trend in new International standards that the demand for zinc content is the same for zinc epoxy and zinc silicate given weight by weight. When standardizing the level of the zinc content in inorganic and organic coatings the values should be given volume by volume. It is clear from the tests in figure 3 that Zn-silicate will give much lower potential compared to Zn-epoxy even if the weight% of Zn-dust is higher. By comparing 86 weight% Zn-dust epoxy and silicate primers by volume instead, the zinc epoxy will have about 55 vol% Zn-dust while the zinc silicate will have 70 vol% Zn-dust.

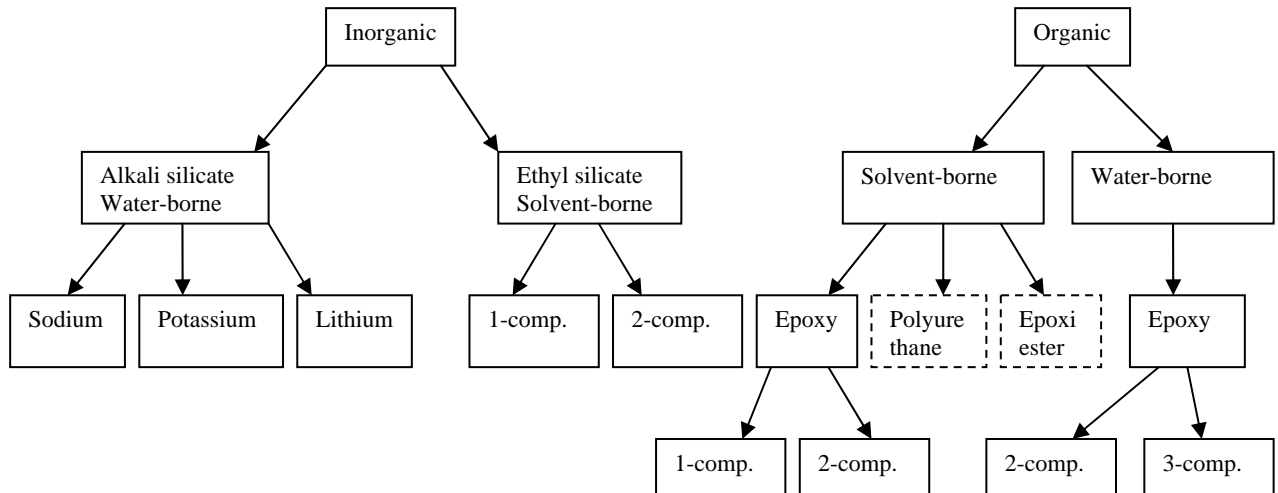
Another topic that is more and more highlighted is the composition of zinc dust. Some users of zinc primer specify metallic zinc content and other specify total zinc or zinc dust content. The general rules are:

1. Total zinc is the sum of all the zinc compounds in the formulation including: Zinc dust, zinc oxide, zinc phosphate etc.
2. The composition of the zinc dust is specified by ASTM D520 and ISO 3549.
3. Metallic zinc can be calculated from the zinc dust content. The zinc dust should contain minimum 94% metallic zinc according to ISO 3549.

The standards also specify the content of "impurities" allowed in the zinc dust. A new trend is the demand for "low lead" zinc according to ASTM D520 type II (max. 0.01%) or type III (max. 0.002%).

2. Inorganic or organic zinc primers

The zinc primers can be divided into different groups depending on the binder and solvent. The main groups used by the industry today are:



The typical properties of common zinc primers are compared in table 1.

2.1 The cathodic properties of a zinc primer

The type of corrosion protection and the galvanic potential can easily be illustrated by electrical impedance testing. The potential of bare steel in seawater is approximately -650 mV_{SCE} (Saturated Calomel Electrode) and zinc has a potential of approximately -1050 mV_{SCE}. As long as the potential is below -800 mV the primer still gives cathodic protection. Above this level the primer will only give you a barrier effect. For unexposed zinc primers the potential are usually between -900 mV and -1050 mV depending on type of binder, zinc content and film thickness. These properties are evaluated in figure 3. Three different formulations were tested on 4 test panels. 75 microns of zinc ethyl silicate with 86% zinc dust in dry film gave by far the lowest electrical potential. The other panels are covered with zinc epoxy and in the beginning the potential are the same independent of zinc content and film thickness. During the exposure it is obvious that higher zinc content gives lower potential and is more important than higher film thickness. The reason is that it is better conductivity when the zinc content is higher, see figure 3. After a while the conductivity is dropping when the Zn is sacrificing and creating Zn-salts instead. These salts will fill the “voids” in the film and the primer will have higher and higher potential until the protection is only by barrier effect. Higher film thickness will of course also contribute to better corrosion protection even if it is less important compared to the zinc content. The difference after outdoor exposure is clear in picture 2. A low zinc content epoxy primer applied in different film thickness is exposed at seaside. The area with only 15 µm is full of rust all over the area while the area with 35µm has started to rust only in the scribe. The area with 80 µm film thickness is still protecting the scribe and looks perfect.

The electrical impedance testing is a well known test for zinc primers. Most of the zinc primers will still have cathodic protection after 100 days and the primers with high zinc content applied in high film thickness will last for more than 300 days. Compared to real life testing of zinc primers this is not very long but still it is almost a year. By making a scratch with a standardized size in the film the time for testing can

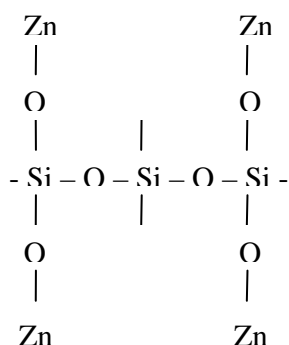
be reduced dramatically. See figure 4. After 4 days the potential has increased by 123 mV. In the “standardized” test with panels without scratch it takes more than 100 days to have the same increase in potential. By implementation of this test it is possible to test and screen a lot of formulations after relatively short time with exposure.

It is also possible to test other types of primers and multiple layers by electrical impedance. It is not only the benefit of the pure zinc primer that can be evaluated but also the barrier effect of the total system. As long as the potential is higher or lower compared to steel the corrosion has not started.

2.2. The curing mechanism

Even if the cured product based on ethyl silicate and alkali silicate is the same the initial products is very different. The ethyl silicate is an organic binder before curing while the alkali silicate is an inorganic binder. The ethyl silicate needs humidity to cure while the alkali silicate needs to get ride of the water before it cures. The speed of the curing of ethyl silicates compared to alkali silicates is faster and easier to achieve. The curing process of an alkali silicate is complex and is depending on the type of metal in the alkali silicate. The alkali silicates used are sodium, Na, potassium, K, and lithium, Li, or a mixture of some of them. See table 2 for properties regarding the different alkali silicates.

A short description of the curing is that the binder will react with metal, drop in pH or heat in the beginning with further reaction with the CO₂ in the air. These reactions will make acids that react with Zn-ions to form a zinc silicate polymer. Further developments are the introduction of colloidal silica and styrene acryl in combination with the alkali silicate. This is done to lower the pH of the paint which gives better application- and top coating properties. Unfortunately this will create other limitations. Ethyl silicates must be pre-hydrolyzed to achieve proper curing. The pre-hydrolyzed binder will react with water and Zn-ions to create zinc silicate polymer and ethanol. The ethanol will evaporate fast and contribute to the high VOC level. The finished matrix will only contain inorganic material:



The water-borne silicates can be made with 0 VOC and is much more environment friendly compared to even water-borne epoxy that needs co-solvents for film formation.

Zinc epoxies are most used among organic zinc primers. The solvent-borne epoxies are normally 2-components. The water-borne epoxies used to be 3-components because a combination of zinc and water will react and create hydrogen gas. New technology has resulted in 2-component water-borne epoxies. Epoxy is normally cured with polyamides, amine adducts etc. Polyamides are used because of its reduced tendency to react with the zinc powder.

2.3. Mechanical resistance

The adhesion and cohesion strength of inorganic- and organic zinc primers are quite different. As mentioned earlier the silicates will react by forming primary valency bonding with the steel and give excellent adhesion if the pretreatment is good enough. Because of this reaction the silicate should only be applied on Sa 2½ (Or concrete which has a lot of metal ions accessible). On all other kind of surfaces like St 2 or old paint the silicate will have poor adhesion. The alkali silicate are very sensitive to impurities like oil and fat on the surface, since they do not contain any solvents for secondary cleaning of residual oils and contaminations. Because of the chemical reactions in the silicates the cohesion is also acceptable despite the extremely high pigment volume concentration (PVC). The adhesion of silicate primers are very good because of the primary valency bonding between the silicate and substrate. Zinc epoxy primers have properties similar to other epoxy primers, with good adhesion and mechanical strength because of the strong physical attraction in secondary valency bonds. It is possible to have good adhesion to most surfaces depending on the formulation. The adhesion and cohesion strength are strongly dependent of the ratio between PVC and CPVC (critical pigment volume concentration), see figure 5.

Where will the break come in a system with a zinc primer as a first coat? It is of course desirable to have a film that is impossible to break, but so far this is not possible. By using zinc primer with good adhesion properties there is minimum risk for under film corrosion. The paint system should have higher cohesion and adhesion strength compared to the cohesion strength of the zinc primer. This will make the cohesion in the zinc primer the weakest link so that if the paint system gets mechanical damages down to the steel it will have as much zinc as possible accessible to protect the "scribe". See figure 6.

The high PVC/CPVC ratio of the silicates gives also some limitations. First of all they have a big risk for mud cracking if they are applied to thick. The ethyl silicates have normally the highest PVC/CPVC ratio of the silicates and mud cracking will appear at lower film thickness compared to the alkali silicates. One of the reasons for the higher PVC/CPVC ratio of the ethyl silicates is the use of pigments and extenders in the paint formulation. Zinc pigments need very little binder to be "wetted" compared to normal extenders and the alkali silicates have normally higher zinc content than the ethyl silicates. But the most important issue with regard to mud cracking is the speed of curing. Ethyl silicates cure much faster than alkali silicates. Mud cracking appears when the silicate matrix cannot take the internal stresses that develop during the curing of the primer. At too high thicknesses, the upper layer of the inorganic zinc will cure faster than the layer underneath, causing excessive stresses which the inorganic silicate matrix cannot take.

Another benefit by using inorganic zinc silicates are that when applied it does not shrink. Together with the surface tension of the coating this property makes these kinds of primers very good in covering of edges, corners and bolts etc. The organic zinc primers are not as good because they will always have some shrinkage.

2.4 Chemical and heat resistance

When it comes to chemical resistance the silicate matrix is very inert and, with the exception of strong acid and alkalis, does not degrade in most industrial and marine environments. The film is inert to crude and refined oils, greases, solvents, chlorine,

CO₂ and industrial gases. In general it is resistant to most chemicals within the pH range 6-10 depending on the temperature. The corrosion resistance of zinc to the chemical is usually the primary consideration, but in some cases, the effect of zinc corrosion on a consumer product or chemical is of greater concern than the actual corrosion rate of zinc. One example is the formation of zinc salts that is not acceptable for cargoes like Jet-fuel. Zinc epoxy is normally not used for chemical protection because the epoxy used is not optimized for this purpose and the product will at the same time have limitations because of the zinc.

Inorganic zinc silicate will have high heat-resistance and is excellent against radiation including nuclear radiation. The heat resistance is limited by the zinc to maximum 400°C since the melting point of zinc is 419.5°C. Above this temperature it is a possibility of zinc to react with the oxygen in the air or with the silicate, rendering the zinc inert and leaving it as a simple barrier coating. The zinc epoxy primers are limited by the type of epoxy and will normally resist temperatures up to 120°C. Another limitation for zinc primers is in contact with hot water. The galvanic effect will start to decrease at 60°C and with further increase in temperature the potential difference will be zero or may actually be reversed at 70°C. This effect will only happen when the water is "soft" or distilled. When the "water" temperature is above 120°C there are normally not any problems regarding the reversed potential.

2.5 Top coating of zinc primers

All inorganic zinc silicates are formulated with PVC above CPVC. As mentioned earlier the film will be porous and let liquid and air come into the film. This will give problems with popping in the next coat and in the end create pinholes. This can be avoided by using a mist coat technique or by using a tie-coat. The zinc epoxy will normally not have this problem but since many of the formulations have PVC/CPVC ratio close to 1 it could happen.

The alkali silicates are binders with high pH. This high pH will give adhesion failures of the next coat if precautions are not taken. Usually products based on lithium silicate and with more than 90% zinc dust by weight can be top coated quite fast. By using slower curing alkali silicates and/or lower content of zinc the time to over coating will increase. The paint will be like fresh concrete and the pH will be reduced during the curing process. By applying water to the surface it is possible to reduce the pH. Ethyl silicates will not have the same problem and can easily be formulated down to 30% zinc dust by weight and still have good top coating properties.

When it comes to ethyl silicates and organic zinc epoxy the pH on the surface is not any topic but the products needs to be cured before they are top coated. Insufficient curing of the primer before top coating is the main cause of failure of coating systems based on ethyl silicates. If the primer is top coated before it is cured the film will not develop the necessary physical and corrosion protection properties. This can however easily be avoided by determining the degree of cure before top coating through tests for hardness and/or solvent sensibility of the primer. A solvent-borne zinc epoxy primer is more tolerant to be top coated but to develop the best mechanical properties and avoid solvent entrapment it is better to have it fully cured. The water-borne zinc epoxy can be top coated very early and almost as fast as the solvent-borne.

2.6 Cutting and welding

The high performance shopprimers used today are based on zinc ethyl silicate. These shopprimers are very good for the welding and cutting process because they do not contain any organic materials when cured. The silicates are unbeatable on back burning, pore formation and welding fumes as soon as it is cured. Uncured ethyl silicate has poor welding and cutting properties because it still contains some organic material. Any organic material will contribute to gas formation and then increased content of pores. The fastest shopprimers to weld in has also very low content of zinc. High content of zinc will give problems with zinc fever for the welders and pores in the welding seem. Picture 3 shows the pore formation when inorganic- and organic shopprimer is used. Zinc epoxy was used in the shopprimer market for some years but the consumption has decreased a lot. The reason is high zinc content and the organic vehicle that creates pores in the welding seems.

3. Discussion

Both inorganic and organic zinc primers have a lot of benefits but some properties are better for one type of primer. The different properties of alkali silicate, ethyl silicate, solvent-borne and water-borne epoxy zinc primers are compared in table 1. Because of these properties the area of use are different for the 2 type of primers and some typical are listed below.

Inorganic zinc silicate:

- Barge decks because of the extremely good abrasion resistance
- High strength bolted steel because of high friction (slip) coefficient
- Pipelines, power plants and power transmission lines
- Bridges, ships and tankers (interior and exterior surfaces including storage tanks
- Oil rigs and offshore drilling platforms
- Rocket launch gantries
- Water tanks
- Construction materials operating over 100°C like: chimneys, kilns, incinerators, furnaces, ductwork and piping
- Coal washeries
- Wharf facilities
- Mineral processing plants
- As shopprimer
- Inside the Statue of Liberty

Organic Zinc epoxy:

- "Bad" pre-treatment steel
- Maintenance project
- Touch-up of zinc silicate shopprimed steel
- High performance coatings with good flexibility
- Steel that is impossible or hard to blast to Sa 2½ because of cost or accessibility

The type of primer normally specified for new building has been zinc silicate and then typical zinc ethyl silicate. This is because within the parameters of zinc silicates the solvent-borne ethyl silicates have been found to be more generally tolerant than the water-borne alkali metal zinc silicates. The zinc silicates give the best corrosion

protection (especially alone), adhesion to Sa 2½, chemical resistance, heat resistance, abrasion resistance, welding and cutting properties. The corrosion protection properties of inorganic zinc primers and organic zinc primers are compared in figure 3. Even if the zinc epoxy primer with higher zinc content is compared to the zinc ethyl silicate the electrical potential of the zinc epoxy is higher.

While zinc silicate is a typical “new building” coating the zinc epoxy is more a maintenance primer. The epoxy is easier to apply in higher film thickness without cracking and can be applied with conventional airless spray while alkali silicates normally need special equipment. Top coating is also easier compared to a silicate which may create popping and also adhesion failure because of high alkalinity on alkali silicate paint. Shelf life of a zinc epoxy is far better than ethyl silicate. Zinc epoxy is also more surfaces tolerant.

The development of zinc silicate shopprimers made a revolution for the welders and cutters in the steel business. After years with slow welding with a lot of pores in the welding seam and slow cutting with large damages of the shopprimer, it is now possible to do this with minimal problems. A total inorganic film with a low content of zinc will give very good properties. The difference in welding properties is obvious in picture 3. The next generation of shopprimers will be inorganic- and organic water-borne products. Today these kinds of products still have some challenges that need to be solved.

4. Conclusion

It is no doubt that zinc-rich primers a very efficient method of anticorrosion protection. Zinc offers threefold protection since it; seals the underlying metal from contact with its corrosive environment, provides galvanic protection and “repairs” minor damages in a coating forming a barrier to further electrochemical action. In Picture 1 is the formation of zinc salts and how the zinc protects the scribe on a test panel during exposure obvious.

Compared to epoxy the silicates can be pigmented at extremely high levels of zinc dust giving zinc to zinc metal contact and, consequently, excellent cathodic protection properties like those obtained with galvanizing. There is a trend in new international standards that the demand for zinc content is the same for zinc epoxy and zinc silicate given weight by weight. If it is a wish to have the same zinc content level for inorganic and organic coatings the values should be given volume by volume.

The type of corrosion protection and the galvanic potential can easily be illustrated by electrical impedance testing. The potential of bare steel in seawater is approximately -650 mV_{SCE} (Saturated Calomel Electrode) and zinc has a potential of approximately -1050 mV_{SCE}. As long as the potential is below -800 mV the primer still gives cathodic protection. Above this level the primer will only give you a barrier effect. For unexposed zinc primers the potential are usually between -900 mV and -1000 mV depending on type of binder, zinc content and film thickness.

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protection (especially alone), adhesion to Sa 2½, chemical resistance, heat resistance, abrasion resistance, welding and cutting properties. The water-borne silicates can be made with zero VOC and is more environment friendly compared even to water-borne epoxy.

The zinc epoxy is easier to apply in higher film thickness without mud cracking and can be applied with conventional airless spray while alkali silicates normally need special equipment. Top coating is also easier compared to silicate, which may give popping and adhesion failure because of high alkalinity on alkali silicate paint. The curing of the zinc epoxy is faster and is not depending on high humidity and the shelf life of a zinc epoxy is far longer than ethyl silicate. Zinc epoxy is also more surface tolerant and is a typical “maintenance” coating.

Zinc epoxy was used in the shopprimer market for some years but the consumption has decreased a lot. The reason is high zinc content and poor weldability. The silicates are unbeatable on back burning, pore formation and welding fumes.

Inorganic zinc should be used where high performance is necessary. In less severe environments, organic zincs may be used to provide good protection with better physical properties.

References

1. Charles G. Munger, "Zinc silicate Coatings" – 40 years experience, *Journal of Protective Coatings & Linings*, p.34 – 44, March 1985.
2. Clive H. Hare, "Protective Coatings – Fundamentals of chemistry and composition, SSPC 94-17
3. Clive H. Hare, Matthew Steele and Steven P. Collins, "Zinc loadings, cathodic protection, and post-cathodic protective mechanisms in organic zinc-rich metal primers" *JPCL* September 2001 p.54 – 72
4. Mike Mitchell and Mark Summers, "How to select zinc silicate primers", *PCE* July 2001 p.12 – 15.
5. B. del Amo and C.A Giudice, "Influence of some variables of zinc-rich paints based on ethyl silicate and epoxy binders, *American Paint & Coatings Journal* September 23, 1991 p. 36 – 43.
6. D. Pereira, J. D. Scantlebury, M. G. S. Ferreira and M. E. Almeida, "The application of electrochemical measurements to the study and behavior of zinc-rich coatings", *Corrosion Science*, vol. 30, No. 11, pp. 1135-1147, 1990.
7. Ray Mudd, "organic zinc-rich coatings" *Journal of Protective Coatings & Linings* October 1995, p. 51 – 63.

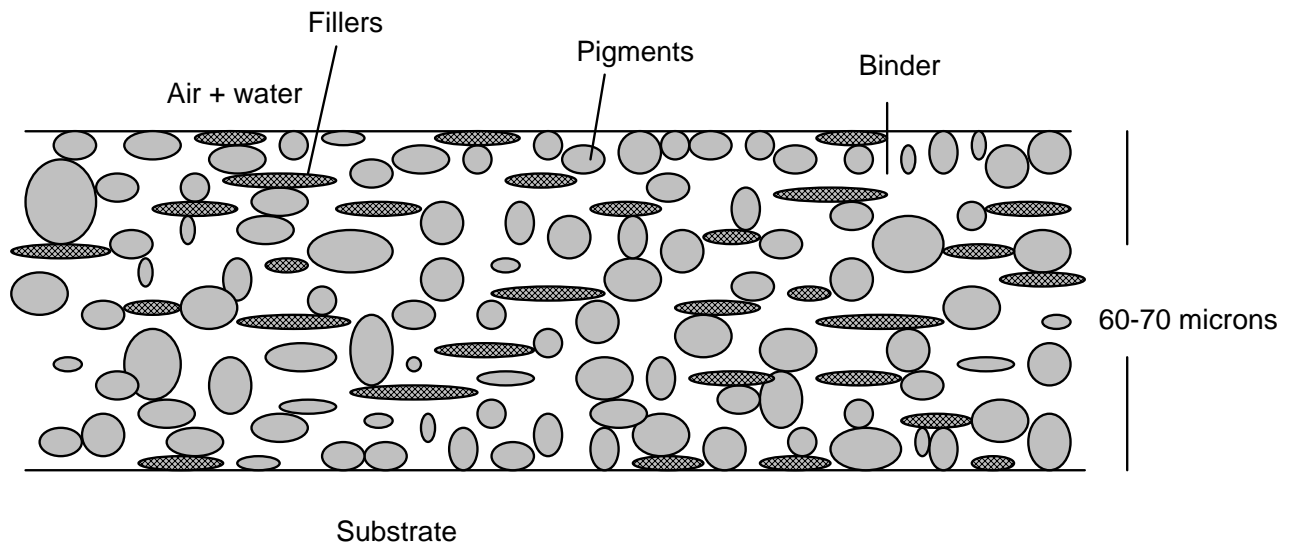


Figure 1. Sealing the underlying metal from contact with its corrosive environment, the barrier effect stops oxygen and water from penetrating down to the steel to create corrosion.

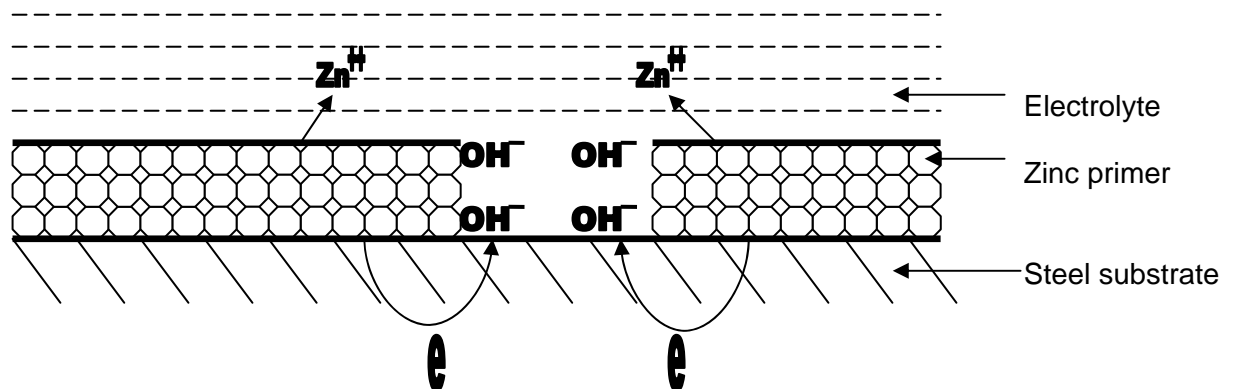


Figure 2. The presence of strongly electronegative zinc-pigmented coating short-circuits all local cell activity on steel. The steel becomes totally cathodic to the zinc anode. The zinc corrodes, but the steel will not corrode even at bare spots. It is mandatory that the zinc coating be in electrical contact with the steel surface; therefore, the steel must be stripped of all contamination.

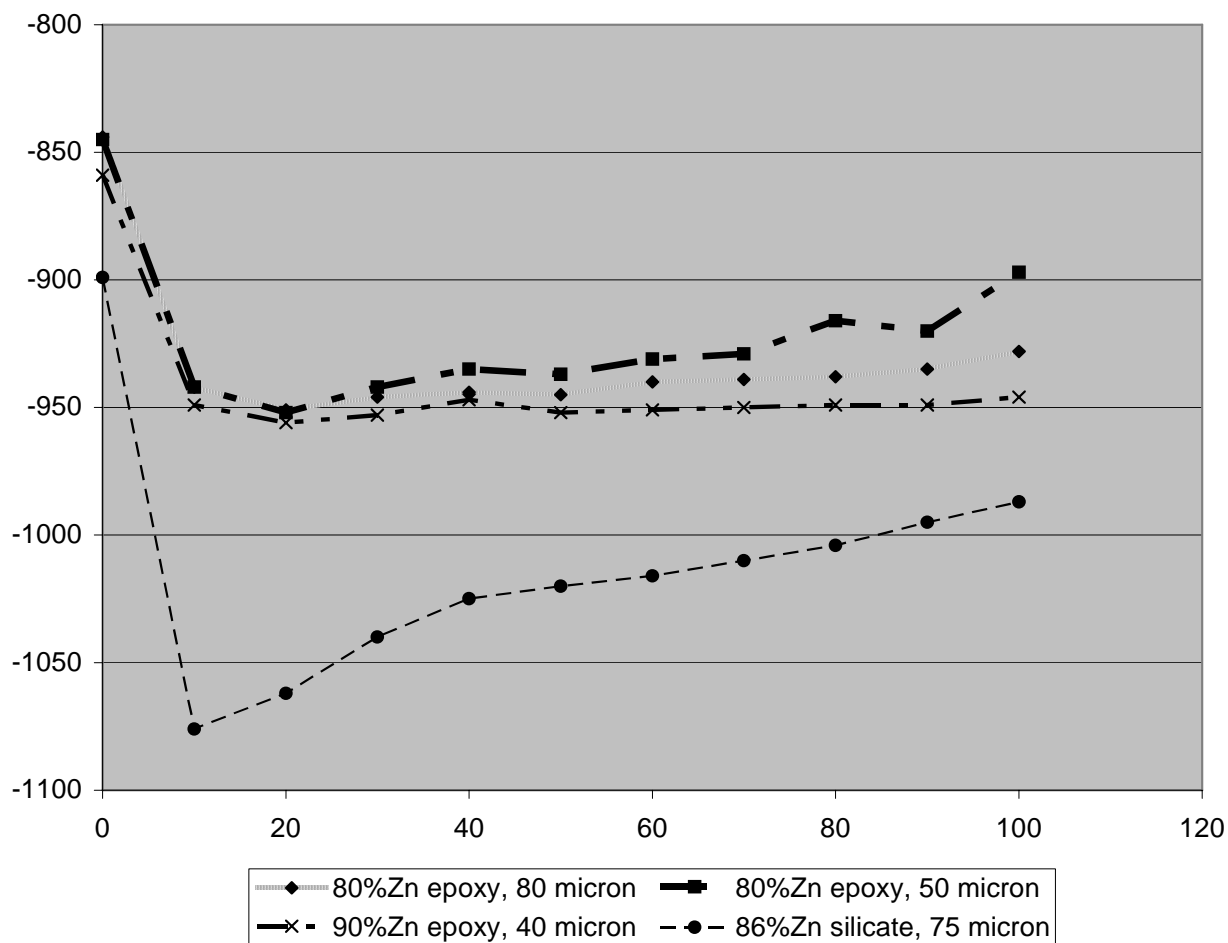


Figure 3. Development of the electrical potential in mV up to 100 days for zinc primers with different zinc content, film thickness and binders

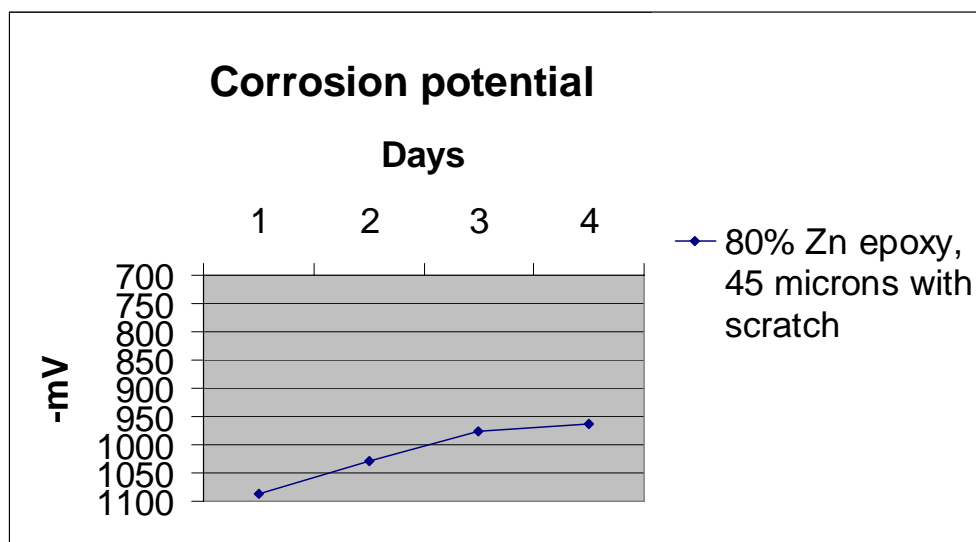


Figure 4. Testing of electrical potential on a panel with scratch

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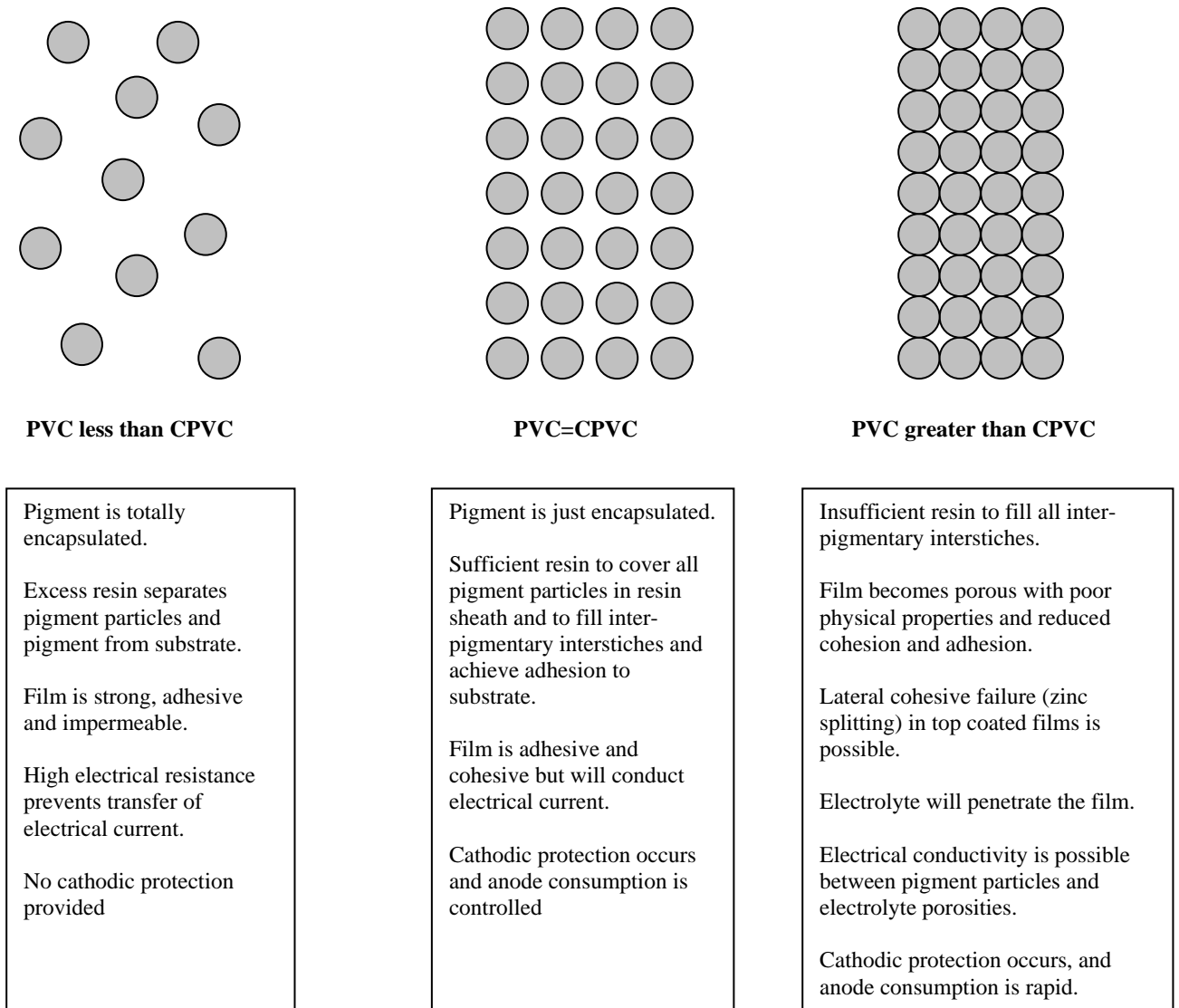


Figure 5. Effect of PVC/CPVC ratio on electrical properties of organic zinc rich primers

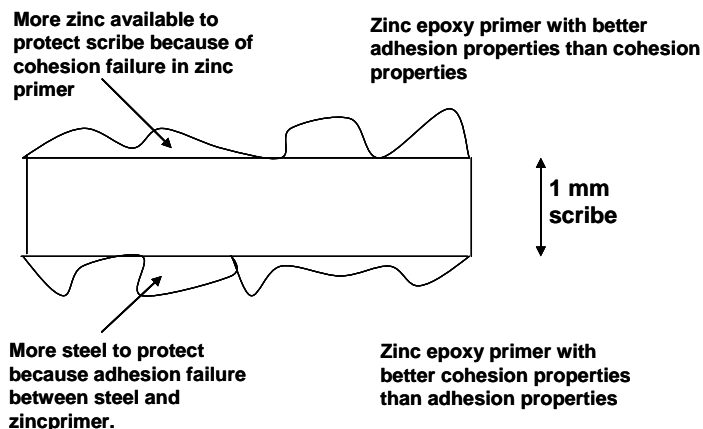
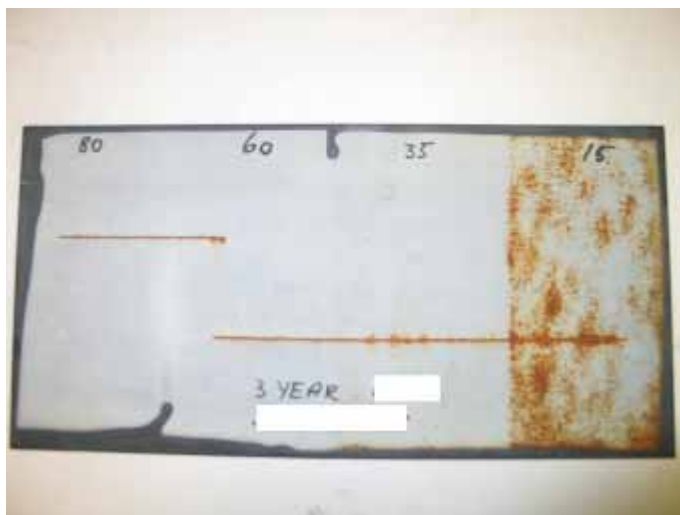


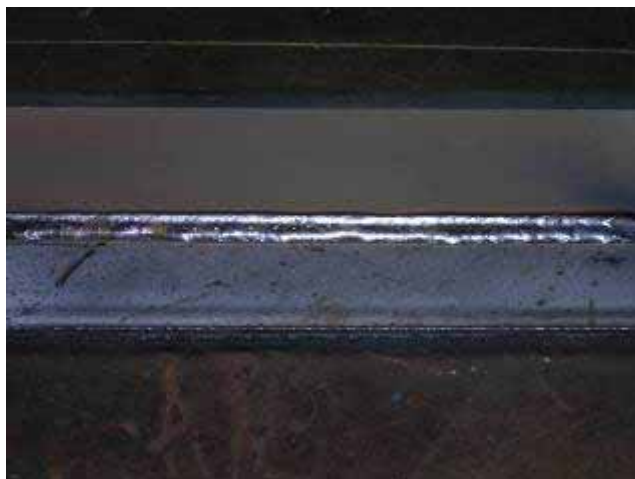
Figure 6. Schematic illustration of a scribe in a steel panel. Mechanical damages down to the steel will be created differently depending on the "weakest link" in the paint system. The upper part of the scribe is protected with a zinc primer with better adhesion than cohesion properties. The lower part has better cohesion than adhesion properties.



Picture 1. Ethyl silicate exposed for high humidity and salt spray for 10000 hours. The scribes are soon "repaired" and closed by zinc salt.



Picture 2. Testing of a low zinc dust content epoxy primer applied in 80 µm, 60µm, 35 µm and 15 µm and exposed at seaside.



Picture 3. Seem after welding in inorganic shopprimer to the left and organic shopprimer to the right. The organic material forms gasses that create pores in the welding seem.

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Table 1. Typical properties of common zinc primers

Property	Alkali silicate	Ethyl silicate	Solvent epoxy	Water epoxy
Corrosion protection	Excellent	Excellent	Very good	Very good
Top coating	Fair	good	Very good	Very good
Adhesion	Very good	Very good	Good	good
Cohesion	Fair	Fair	Good	Good
Surface tolerant	Fair	Good	Very good	Good
Mud cracking	Good	Not so good	Very good	Very good
Welding	Excellent	Excellent	Fair	Bad
Cutting	Excellent	Excellent	Fair	Bad
Abrasion	Excellent	Excellent	Very good	Very good
Flexibility	Limited	Limited	Good	Fair
Shelf life, months	9	6	12	12
Curing	5 Days	12 hours	7 Days	7 Days
Pot life, hours	5	8-12	24-48	6
Flash point	>100°C	<23°C	25-35°C	>100°C
Over-coating interval 23°C/10°C:	2h / 8h	12 h / 24h	1.5h / 2h	2h / 3h
Chemical resistance	Excellent within pH 6-10	Excellent within pH 6-10	Not used	Not used
Heat resistance	400°C	400°C	120°C	120°C
VOC g/l	0	470	420	140
Vol% solid	75	60	60	55
Tolerance of high humidity	Very good	Excellent	Fair	Very good
Water resistance	Very good	Very good	Excellent	Very good
Solvent resistance	Excellent	Excellent	Very good	Very good
User-friendly	Fair. Need special equipment and water must be removed for drying	Good. Needs humidity to cure.	Very good	Good. Water must be removed for drying.

Table 2. The effect of ratio of silica to alkali metal oxide on coating characteristics:

Ratio of silica to alkali metal oxide	Effect on coating characteristics
Higher	Higher the viscosity of the solution Higher the drying speed of the film Higher the curing speed of the film Higher the susceptibility to low temperature Higher the chemical resistance of coating films
Lower	Higher the specific gravity of the solution Higher the solubility in water Higher the pH value of the solution Lower water resistance Higher the adhesion and binding power

Silicate	Chemical composition	Ratio of silica to alkali metal oxide
Sodium silicate	SiO ² :Na ² O	2.4:1 to 4.5:1
Potassium silicate	SiO ² :K ² O	2:1 to 5.3:1
Lithium silicate	SiO ² :Li ² O	2:1 to 8.5:1

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