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Enlargement of the Process Window during the Application of Passive Corrosion Protection Systems with a Newly Developed Adhesive

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Enlargement of the Process Window during the Application of Passive Corrosion Protection Systems with a Newly Developed Adhesive

Corrosion can lead to unforeseen consequences. The consistent use of corrosion protection measures can reduce the risk considerably. Not only the development of further steps to improve corrosion protection, but also doing justice to the conditions on job sites and low installation sensitivity are of the utmost importance. A corrosion protection system in a pipe network must be seen from various user aspects. The compatibility of the different systems with each other and recognising the weakest link in the chain are prerequisites for a long-term and long lasting corrosion protection network system.

Passive corrosion protection systems are approved according to DIN 30672. Additionally an installer test is required by the DVGW in accordance with worksheet GW 15, but the DIN cannot cover the application sensitivity of a passive corrosion protection system and show test results which will take into account the critical points of an application under field conditions.

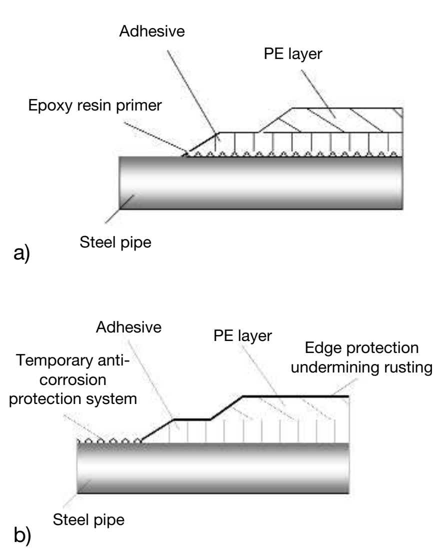

Fig. 1: a) Three-layer factory coating, b) Two-layer factory coating

Passive Corrosion Protection

Apart from cathodic corrosion protection, the other method used is the application of a passive corrosion protection system. "Passive" means in this context that the corrosion protection system does not interfere with the electrochemical corrosion process. It is wrapped around the object and shields it from the corrosive environment [1].

Passive corrosion protection systems and split onto factory applied and field applied coatings.

Factory applied coatings

Factory coatings are applied by the pipe or pipe fitting manufacturers. These are two-layer or three-layer coatings (**Figure 1**). Picture 1a shows a three-layer coating. Before applying the PE a layer of epoxy resin is applied. A two-layer coating is applied without epoxy. Both systems include an adhesive, which is necessary to achieve a bond to the PE layer.

Field applied coatings

Field applied coatings are those materials which are applied on site. The requirements for field applied coatings were determined in the DIN 30672, part 1, which was issued in 1972.

As factory applied coatings improve, the requirements for field applied coatings increase. The DIN standard was revised and issued again in September 1991.

However, DIN 30672 refers only to thermoplastic tapes, bitumen and shrink products and does not include duro-plastic reaction material. The require-ments for these can be seen in DIN 30672, part 2.

Requirements for field applied coatings are laid down in the DIN 30672. It is divided up into load and temperature classification from which the following matrix is derived.

A-B-C are the load classification for mechanical properties of field applied coatings; C being the highest class. The classification shown in the illustration above is derived from the two operating temperatures.

DVGW worksheet GW 15

Apart from DIN 30672 there is the DVGW (German Association for the Gas and Water Sector) set of rules for certifying installers, which is of great importance in Germany.

"The coating of pipelines with high quality organic coating materials in the factory must be complemented by expert knowledge of the installers when applying the field applied coatings on site. There are high quality field applied coatings available which are stand-ardised in DIN 30672. The application of these coatings requires competence in installing as well as sound knowledge concerning the materials themselves. (2)"

The DVGW members of the expert committee "outer corrosion protection" are responsible for field applied coatings and were instrumental in creating the DIN 30672.

The DVGW worksheet sets out training and examination plans for the installation of field applied coatings on pipes, fittings and couplings. This consists of a practical training programme with an integrated examination of the installers. At the end of the training programme there is a test to determine how much knowledge they have acquired during the training period. This is established by supplying answers to written questions. The duration of training and examination is 16 hours. Should the installer pass the test, he is given an "installer's certi-ficate", which is valid for three years and is required by practically all utilities for field applied coatings on job sites in Germany.

Field Applied Coating Systems

Field applied coating systems are divided up into cold and warm applied systems.

The definition of warm applied is that the

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energy is administered to the coating, usually by means of a liquid gas torch. When bitumen tapes are used, the torch is required to melt the bitumen onto the surface of the tape. In its plasticised state the tape a kind of adhesion to the pipe surface occurs.

Shrink materials consist of crosslinked irradiated polyethylene, with a frozen state of stress, coated with adhesive. When heat is applied, the polyethylene becomes soft. Due to the resulting inner stress the PE begins to shrink and tightly covers the pipe over which it has been placed [3].

In the main, no primer is required, since the material is integrally equipped with a substance which not only protects but also adheres. The shrinkable backing provides the mechanical protection and distributes force evenly around the pipe. Due to the superior penetration resistance and high shrink force, the backing should be of high density PE.

Cold applied systems require no heat to be administered. Only pipe surface preparation, i.e. drying and preheating, needs to be accomplished by using a liquid gas torch.

Petrolatum tapes (vaseline tapes) consist of backing material soaked with permanent elastic Petrolatum (a saturated mix of carbohydrates) and covered on one side with PE tape.

Synthetic (plastic) tapes consist of a butyl rubber substance which, according to its type, can be covered with PE tape. The butyl rubber is actually responsible for the corrosion protection and is applied to the previously applied and already dried primer (in each case according to the manufacturers instructions, wrapped with 50 % overlap). For additional mechanical protection the first butyl rubber layer is covered with a second layer of PE tape.

Corrosion Protection by Specific Use of Adhesives

The by-product, corrosion protection, as it were, achieved from bonding joints results from the fact that the adhesives and polymers are not conductive materials. Layered between two metal joint pieces, the adhesive prevents the galvanic elements forming and as a firmly fixed layer, the adhesive prevents the access of corrosive mediums.

Adhesives allow effective passive corrosion protection only when sufficient long-term adhesion can be achieved. Only under these circumstances can the adhesives prevent contact of corrosive mediums with the (steel) surface. Bonding is due to chemical and physical interaction between the molecules of the adhesive and the substrate (main and secondary valence bond). The legitimacy of the bonding of substances to surfaces is the object of current research and has not been sufficiently clarified yet. However, tests explaining the bonding mechanism of adhesives to metal surfaces establish complex bonding between epoxy resin adhesives and steel [4].

This bonding mechanism is based on cyclical connections (chelates) which have proved to be extremely moisture resistant. Technically, this discovery will be used in the passive corrosion protection field by using epoxy based primers and epoxy resin adhesives, applied in adequately thick layers [5].

Passive corrosion protection requires no strength related properties from adhesives. This situation allows PSI (pressure sensitive adhesive) to be used in field applied coatings. PSI represents a special adhesive group. They don't harden or set. They can be seen as permanently tacky, highly viscous liquids and are widely used in trade and industry. Their usage ranges from paintwork, over insulating tapes through to demanding applications in aeroplanes.

The common denominator of all Pressure Sensitive Adhesives (PSA) is its pressure sensitivity. The achievable strength of a joint (i.e. the amount of adhesion force with sufficient cohesion) depends on the pantograph pressure.

By using a specific consistency, tackiness, adhesion performance and cohesion can be widely altered. According to formula and construction adhesives possess more or less temperature-dependent flow behaviour. This is determined by the amount of resin and the polymer construction. In order to be able to use them for field applied coatings the following criteria must be met:

- good tackiness
- good flow behaviour, even at low temperatures (optimal surface wetting)
- sufficient stability for the required temperature.

In order to be able to achieve good adhesion, the adhesive, no matter which type, must wet the surface of the solid. In this case, wetting means close approximation of the liquid to the surface on an atomic scale. The molecules of the adhesive must be in approximation to the surface within bonding range, which at main and secondary valence bond reache a value of 0.1 to 0.5 nanometers. If other substances are on the surface, no adhesion can be achieved to the actual material but only to unknown layers. This proves that any layers that impede the wetting of the surface, e.g. grease, dust or oxides, must be removed if optimal adhesion for long-term corrosion protection is to be achieved.

Application and Pipe Preparation of Field Coatings

Current (DIN Approved) field coatings provide very good protection against corrosion if they are applied according to the official installation instructions. However, it often occurs that, particularly in the case of field coatings, this is not the case. For example the mandatory overlap is not adhered to, the primer is forgotten when installing cold applied tape or then again a primer is applied under 2-layer heat shrink material. With all these possible malfunction can be foreseen. The DVGW GW 15 installer certificate is only one of the additional measures for proper field installations.

Pipe Preparation as an example of a joint coating

Preparation of the coating area

In the DVGW GW 15 Worksheet the pipe preparation is summarised as follows:

- The complete area has to be cleaned (no dust or other particles), dry (preheating over the dew point) and free of other materials such as oil, grease etc. The factory coating has to be bevelled to an angle of 30°.
- The joint area is generally 400 mm. The pipe preparation as described below is standardised in Germany for all field applied coating materials such as cold tapes, bitumen tapes, petrolatum and shrink products. For GRP, EP and PUR systems the manufacturers' installation instrucions must be followed.

Preparation of the steel surface

The steel surface must be free of dust and other foreign materials. The temporary coating at the pipe ends has to be removed. For the cut back of new 3LPE pipes it is accepted that the steel surface is prepared according to SA 21/2 and DIN 55928 Part 4. In this cases it is sufficient to clean it with a steel brush or sandpaper to get the required peel and shear values. For EP, PUR and GFK it is neccesary to blast the coating area (SA 21/2).

In cases of bend coatings or other factory coating free parts it is important to realize if remaining mill scale (tinder) on the surface. If so the are have to sandblast.

For pipes with 3 Layer PE Coating and PP coatings the adhesives and the EP can be included in the field coating.

The adhesive and the remaining EP of

Fig. 2: Overall view

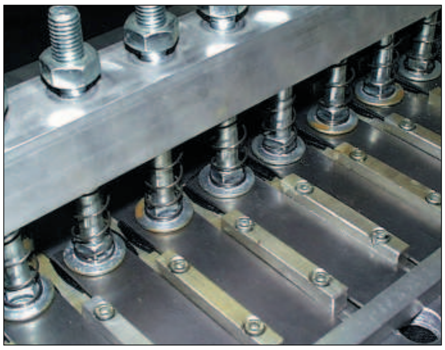

Fig. 3: Spring-loaded thrust ram

the factory coating have to abraded and cleaned with a PE Cleaner.

Preparation of the PE

As a general rule the ends of the factory coatings are bevelled. In accordance with the type of field coating being used, it must be assured that the installation can be carried out without voids. If this cannot be guaranteed, e.g. if the ends are straight or if the factory applied coating is damaged, the ends will have to be prepared manually with a scraper.

The preparation of the PE surface is important for the bonding quality of the field coating. The remaining oxide on the PE/PP surface has to removed by cleaning and abrading (steel brush or sand paper). The preparation overlap least 100 mm onto the factory applied coating.

For EP, PUR and GRP factory coatings the installation instructions of the manufacturers must be followed.

Primer

Except for Petrolatum Tapes and some 2-layer heat shrink products, a primer is required for all corrosion protection tapes. Only the use of a primer which is compatible with the system is allowed. Before applying the coating the primer has to be dry. The use of a torch to accelerate the drying process is not allowed. If the primer is exposed to weather conditions for more than 24 hours it must be applied again.

Special attention must be paid to the fact that the most errors occur because of this. The pipe is only partly or not dried at all; dirt or other particles remain on the surface or it has not been abraded. In this case, we can no longer speak of sufficient corrosion protection from the system.

Testing of various application conditions

As previously explained, the surfaces should be put into a defined state before applying a field coating. Use of the subjunctive means that under field conditions this is very difficult to accomplish. Additionally, the individual performance of the installer is a further parameter for the quality of field coatings (especially for wraparounds) and, not to be disregarded, the pressure of rising costs leaving very little scope for painstaking installations.

With this in view, it is obvious that the question of the effects of inferior applications arise: what, for instance, happens to surfaces which are not sandblasted?

For this reason a pressure sensitive adhesive was developed, within the framework of continuous product improvement, to discover how substandard surface preparation would affect adhesion.

How would the product behave under realistic field conditions? Peel and shear tests were carried out. 100 mm test pipe parts for the testing following the methods of DIN 30 672 were prepared (**Table 1**).

The recommendation (the basis of all DIN testings) is

- ▷ Preheating up to 60 °C
- ▷ Surface abrasion according to SA 21/2

thus creating optimal circumstances for field coatings.

These conditions are rarely achieved in the field and the state of pipe preparation

Fig. 4: DN 100 test body following peeling test

in the test series 4 to 24 deteriorates as far down as:

- ▷ no preheating
- ▷ no rust removal or other manual preparation (abrading)

a state of affairs that should never be seen in practice.

To keep to the required DIN pressure for the sheer test a special device was used, which produced a force of 5 N (with springs) to the area of adhesion. **Figure 2** and **3** show the construction of this device. **Figure 4** shows the test samples after peel tests.

In order to be able to differentiate, additional tests were carried out on PE coated pipes. The results of these tests

- ▷ peel tests on metal and PE as well as
- ▷ shear tests on metal sheets

can be seen in **Figure 5**.

The results of the peel and shear strength correspond with each other, thereby giving practical evidence of the quality of the application under adverse conditions. These two related quantities were necessary to be able to give a definite and relevant statement.

All results are above the DIN 30672 required values. Not only does the tensile strength exceed the minimum norm expectancy of 5 N/cm^2, but the peel results also surpass the 15 N/cm^2 with every measured value.

Surprisingly, no trend can be established. The surface preparation of the test

Table 1: Surface preparation of test specimen and bodies DN 100

Nr.	*Surface preparation*	*Preheat temperature*	*Note*
1-3	SA 2 ½	60°C	Reference according to DIN 30672
4-6	SA 2 ½	None	
7-9	Sand paper K 40	60°C	
10-12	Sand paper K 40	None	
13-15	Steel Brush	60°C	
16-18	Steel Brush	None	
19-21	None	60°C	
22-24	none	None	Peel test on steel with slightly corroded surface, without loose particles

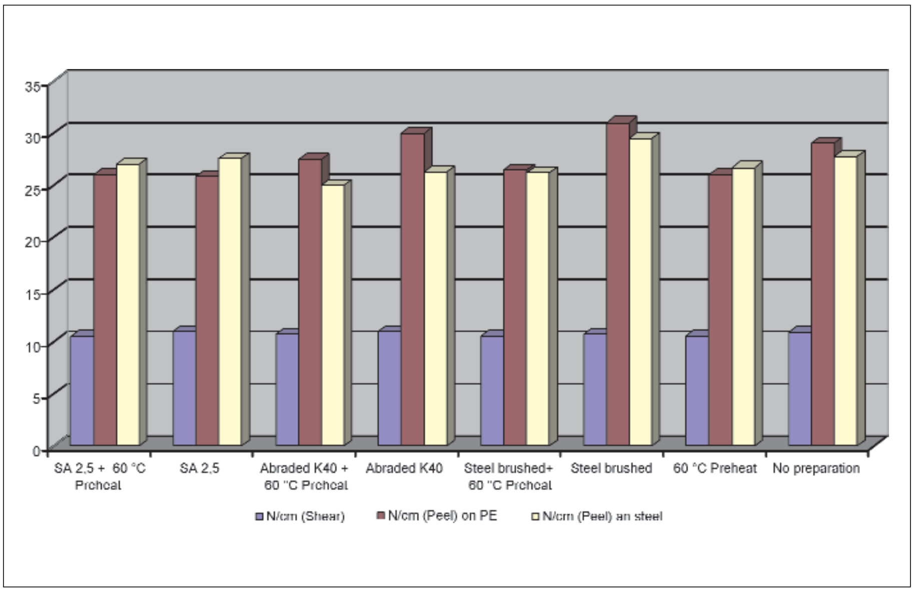

Fig. 5: Results of teh peeling and shearing test series

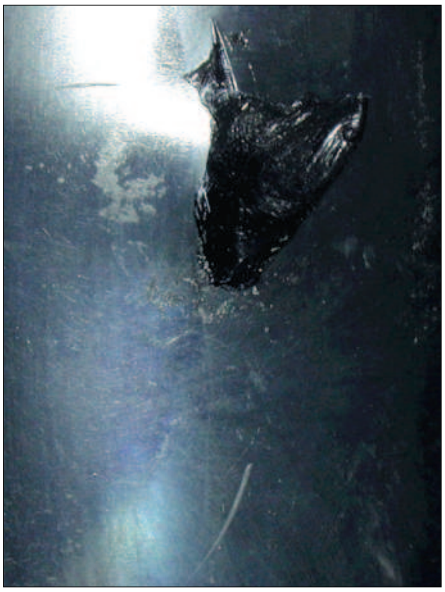

Fig. 7: Self-healing effect in case of damage to the HDPE base material

objects had no measurable influence on the end results.

Summary – Conclusions for future practice

The test, which went beyond the normative spectrum achieved satisfactory results. Further development of the adhesives proved to be extremely relevant in practice. Even under adverse conditions (particularly for adhesive bonds) a bond was achieved which, from a corrosion protection point of view, was higher than the required standard values. The targets set for the adhesive were reached:

- ▷ visco-elasticity
- ▷ tackiness at low temperature.

These properties must be assessed in connection with the heat shrinkable backing, since the adhesive alone does not constitute sufficient corrosion protection. The formulation of the adhesive produces a soft, tacky substance, which due to its physical properties is unable to achieve the mechanical requirements. With adapted rheology and modified ratio of backbone polymer to epoxy resin and leaving aside cohesion, which, in any case, is not required for corrosion protection, it was possible to optimise the adhesive properties. Sealed in under the backing material and put under permanent strain by the shrink force, the pressure sensitive adhesive is exposed to ideal conditions.

The backing material of a corrosion protection application must, in the first instance, be able to withstand intense indentation pressure. This is guaranteed by high density polyethylene with a sufficient layer thickness (> 1 mm).

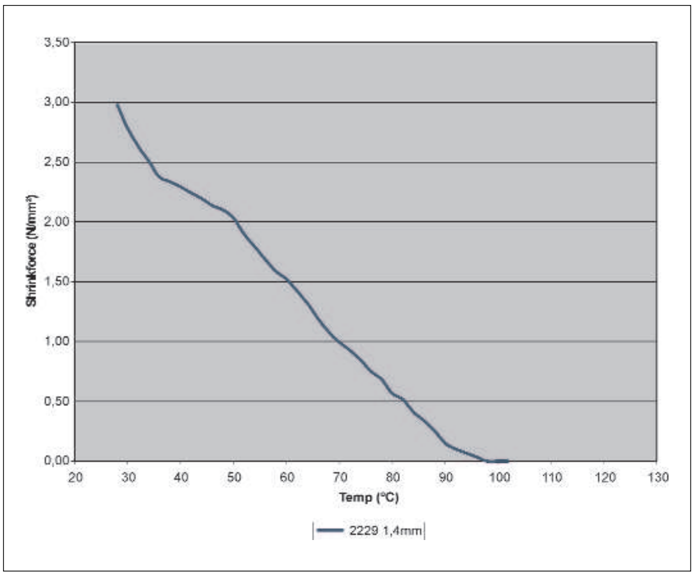

Fig. 6: Plot of temerature-dependet shrinkage force for a range of HDPE base materials

The high density polyethylene backing material used in this corrosion protection system achieved the shrink force represented in **Figure 6**.

After cooling the crystalline zones of the crosslinked backing material reform, increasing the shrink force of the crosslinked backing material from approx. 2,5 N/mm^2 to approx. 3 N/mm^2 at 30 °C (approx. 135 kg for a standard sleeve width of 450 mm).

Out of this combination of "soft" adhesive and high shrink force a positive, safety relevant "self-healing effect" results (**Figure 7**).

Under pressure from the backing material and due to the viscous behaviour of the adhesive, the fault seals itself in.

From the application conditions as repeatedly mentioned above and the field surroundings the following points must be taken into consideration:

- ▷ preparation in accordance with field conditions
- ▷ high rate of error (emphasis on time and cost)
- ▷ basic and insensitive preparation.

These criteria can hardly be taken into consideration by the norm, which must - for technical reasons - rely on the result of tests such as peel and shear strength.

Generally speaking the following points must be considered for a secure and easy installation of corrosion protection systems in the field:

- ▷ The less single components per application to be used the easier the installation will be in the field.
- ▷ The less manual tasks to be carried out, the less mistakes will be made.
- ▷ The less different systems are used, the less bewildering for the installer (no confusion as to which component should be used for which system)
- ▷ The more installer friendly the system is, the better the corrosion protection.

The tested corrosion protection system from the combination high density polyethylene backing material with the adhesive is incredibly installer friendly, which enables it to offer corrosion protection under the most adverse conditions. It is quick and easy to install and can be applied in one pass.

This corrosion protection system not only meets all the current technical requirements, but also improves the work flow on site.

However, even the most optimised system cannot replace the elementary preparation of the pipe before installation. Remaining particles of dust, rust or wet film will lead to functional failure of a field coating system.

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