Quality control in the passive corrosion protection – the coating inspector

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Abstract

A highly sophisticated and well coordinated active and passive corrosion protection is mandatory for a long-lasting integrity and an error-free operation of a new pipeline.
Furthermore, importance from an economic point of view it is of essential importance for the achievement of the target lifetime.
The passive corrosion protection includes all activities shielding the steel from corrosive media. This can be realized for instance either by a suited plating or coating or by constructional features. With respect of the construction of buried pipelines there is a detailed technical regulation for all relevant applications.
Beside the choice of the correct material and its quality a high-grade workmanship is of crucial significance, especially in the course of field joint coatings. After successful implementation of the tools of error prevention like product training or optimal material usage, according to the Poka Yoke principle, coming from the automotive industry, only the possibility of inspection of sources of error remains. Applied to the pipeline construction this means quality control of the used components and materials as well of the coating works in the field.
For this reason coating inspectors have been established for the first time in 2012 within the framework of the pipeline project Loop Sannerz-Rimpar of the Open Grid Europe GmbH, in order to execute the mentioned tasks of inspection of sources of errors / quality control.

1 Introduction

1.1 Passive corrosion protection

The world corrosion organization estimates the costs caused by corrosion at about 3.300 billion US$ per year [1]. In most of the industrialized countries the costs caused by corrosion are around 3 % of the gross doestic product gdp und come up to 5 % in some cases. Furthermore, if one takes into account, that by the use of available technology cost savings of annual 990 billion US$ could be reached, it is obvious that the coating of a buried steel pipeline is a substantial condition for a technical reliable and an economical corrosion protection.

From a technological but also from an economical point of view usually a combination of active and passive corrosion protection is implemented. Theoretically a sufficient corrosion protection could be achieved solely by the use of cathodic protection, but for financial and technical reasons this is not an option. The use of a coating allows a low current demand paralleled by an optimal distribution of the protective current. There is a quantity of requirements the coating has to fulfill, arising from the mentioned properties that it is necessary for a functional corrosion protection (see Table 1). A principle distinction can be made concerning the feature of the corrosion protection and third-party interference affecting the integrity.

	influencing parameter	**requirement**
corrosion protection effect	Water	low water vapor permeability
	Oxygen	low oxygen permeability
	Electrolyte	impermeable for ions
	stray current	high electric resistivity
third-party influences affecting the integrity	loading / transport / storage / handling and installation: • hit • point load • shear forces • sun light • compaction of the bedding/the soil	impact resistance indentation resistance peel strength shear strength UV-resistance
	Operation • movement in the soil • high operation temperature • aggressive soil • bacteria in the soil	adhesion and shear strength persistent versus thermal and oxidative aging chemical persistence microbiological persistence

Table 1: Coating requirements

Coatings are classified into mill coatings, that are applied in the plant, and field joint coatings or field-applied coatings, that are applied on-site. The distinction is not only reasoned by the place of the application but also the different technical capabilities as well as different environmental conditions during the application. This causes various compositions of the coatings and leads in general to a less resistant field joint coating or field applied coating with respect of mechanical and thermal influences.

1.2 Mill coating

Depending on the thermal and mechanical requirements as well as the geometry of the components, nowadays the following mill coatings are used nearly exclusively in Germany:

- 3 layer polyethylene (mainly HD-PE) according to DIN EN ISO 21809-1 or DIN 30670
- 3 layer polypropylen according to DIN EN ISO 21809-1 or DIN 30678
- Polyurethane according to DIN EN 10290 (pipes, pipe fittings and valves) and
- DIN 30677-2 respectively

In some cases, e.g. trenchless pipe laying, an additional mechanical protection made of fiber cement or glass fiber reinforced plastic grp could be mandatory.
The three mill coating systems are accompanied by an increased number of field joint coating (fjc) or field-applied systems. This can be explained by the fact, that there must be compatible field-applied systems for all mill coatings being used during the last 100 years. For example, bituminous systems have been used till the mid of the seventies as standard. Therefore, an estimated 50 % of the German pipelines are coated with bitumen.

1.3 Field joint coatings fjc and field applied coatings respectively

The classification oft he field-applied coatings is usually based upon the application process and results in cold-applied and hot-applied systems as well as spray applied or painted systems, e.g. polyurethane or epoxy resin (see Figure 1).

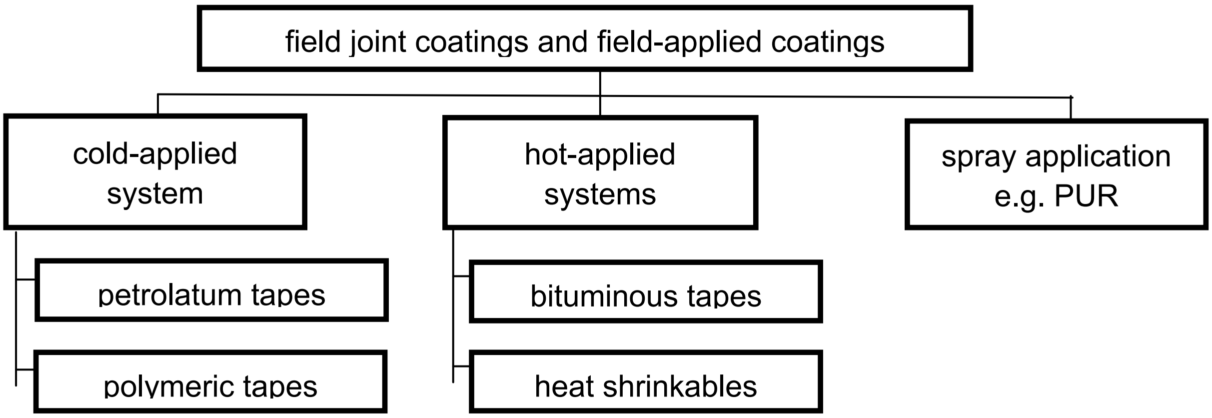

Figure 1: Classification of field joint coatings fjc and field applied coatings respectively

In the case of the cold applied and hot applied materials the requirements are described in the DIN 30672 and DIN EN 12068. The normative PUR requirements for field joints or field-applied coatings do not differ from those for mill coatings, i.e. DIN EN 10290 (pipes, pipe fittings and valves) and DIN 30677-2 respectively (fittings).

In the past field-applied coatings were considered to be the “weak points” of the whole corrosion protection system. In the case of the cold-applied polymeric tapes, that has been used by the Ruhrgas AG as fjc for more than 30 years successfully, this point of view was disproved impressively [2]. The detailed analysis of the internal inspection results of ca. 2.000 km pipeline displayed no indications of a higher corrosion probability when using cold applied polymeric tapes as fjc compared to the mill coating.

1.4 Quality Control – historical development

Although a quality philosophy was linked to production of goods in the middle age the situation drastically changed with the beginning of the industrialization. From now on a lack of well qualified workers limited the productivity. In the context of industrial processes a separation of production and control of the products was established. Later on the consciousness became accepted, to generate quality, not to control it. In this age such famous names as Bosch, Krupp, Daimler, Siemens or Ford set the benchmarks. After World War II the Japanese industry developed an enhanced way together with the famous US Deming and Juran such that quality became an essential task of the management. One highlight of this development is the undoubted impressive way of Toyota, see The Toyota way [3], to

the world´s largest car manufacturer. Incited by this also in Europe the realization enters that quality starts in the marketing, draft as well as the construction phase.
Today, it is generally accepted, that a consequent quality strategy is a determining factor of the success of a company [4]. Or in other words, a wrong planning, an inefficient control and communication, a lack motivation and responsibility as well as nonobservance of the requirements lead to a flop.

2 Aspects of quality control of coatings in pipeline construction

2.1 Historical background

Coating systems of buried steel pipelines are at risk to damage from time of fabrication to transport, site-storage, pipe laying, backfilling and during operation of the pipeline. This implies transport- and distribution pipelines as well as compressor-, pumping- and metering stations.
These coating deficiencies are of different character and may occur during different phases of the application process.
The key failures are:

- Improper mixture of two component systems (epoxy, polyurethane)
- Incorrect manually operated surface cleaning basically in the field
- Deviation of coating material use from specification
- Inaccurate application (minor thickness, wrong system setup)
- Irregular application parameters (temperature, humidity, dust, dirt)
- Damage during transport and pipe handling

For several years, it has been observed that anomalies in coating systems affect the long life quality expectance for a pipeline system and may lead in the worst case to pipeline integrity-relevant impacts. As part of the pipeline operation and maintenance work, coating defects are generally detected using over the line techniques (e.g. close holiday detection). Investments for excavation and repair of previously detected coating defects are cost-effective and measures to reduce these costs have been discussed widely.

Health, safety, environmental protection and quality are for Open Grid Europe GmbH, the former Ruhrgas AG, of significant importance and pari passu part of corporate policy and corporate objectives. In recent years, and also continuously extensive efforts have been made the subject of health, safety, environmental protection and quality of Open Grid Europe GmbH to improve steadily. Open Grid Europe GmbH has a fully integrated management system in the area of health, safety, environmental protection, quality and technical safety. There is also a special focus placed on new pipeline projects.

In order to implement a further improvement in the quality assurance of the passive corrosion protection on new pipeline projects, a monitoring concept for pipeline projects has been developed within Open Grid Europe, comprising the steps of material manufacturing, delivery and installation. The example of the implementation of the new pipeline Loop Sannerz-Rimpar (LSR) and the advanced quality assurance of the passive corrosion protection by coating inspectors are presented in the following.

2.2 Conception – coating inspector and quality benchmark

The two key aspects of the conception are firstly quality benchmark/thresholds that are to be fulfilled and secondly exclusively trained personnel – coating inspectors CI's-, experts that control, test and document all coating quality relevant parameters.

Referring to the 1st conception part, the coating quality is checked by several test methods during pipeline construction. A widely used and technically easy applicable testing of coating quality is the high-voltage test "holiday test", which is carried out before the pipeline stretches are lifted into the trench.
After backfilling is completed and sufficient ground contact has been achieved, current drainage tests were executed sectionwise, the current demand was recorded and the average coating resistance r_{co} in [Ωxm²] was calculated. A threshold value[1] of 10^8 Ωxm² has to be fulfilled to demonstrate a coating defect free pipeline section [5][6][7]. These drainage tests were carried out on all water pressure test sections and additionally on trenchless laid pipeline parts. For those sections the criterion could not be met, defects were searched using the close holiday detection technique.

The 2nd part of quality method is the elaboration of coating inspectors that focus their supervision activities exclusively on the coating quality.

Raising the question how these personnel is selected, it was considered that they could be either contracted as external consultants especially for the pipeline construction or are 'trained on the job' for the specific work by Open Grid Europe itself. Open Grid Europe decided to educate for this specific field the CI's 'in-house' because a subcontracted expert from the pipelaying contractor was not found to be independent enough in his ability of judgments.

The in-house training of the CI's has been executed by the Competence Center of Corrosion Protection at Open Grid Europe, comprising classroom- and practical exercises and was started such early, that factory coating expediting could be implemented.
Detailed checklists for the coating quality tests have been developed and test equipment has been supplied (e.g. holiday tester, thickness- and hardness gauges).

The main working tasks that have been in the responsibility of CI's were the following:

- Planning and executing preproduction and expediting activities of any coated or painted pipes, pipe fittings and valves in factory

[1] A criterion of $r_{co} \geq 10^8$ Ωxm² was added to the DVGW worksheets No. 12, 20 and 28 to verify a defect free pipeline coating system.

- Planning, executing, supervising and documenting the personnel prequalification of contracted field applied coating companies prior to start of pipeline construction.
- Checking quality, ability and specification conformity of all field coatings / paintings and accordance with purchase documents
- Performing any quality income inspection on pipes, pipe fittings and valves that came from factory and are stored on site
- Random testing and documenting of factory- and field coatings / paintings of pipes, pipe fittings and valves (on site and factory)
- Planning, executing, supervising and documenting the coatings/paintings quality on pipes, pipe fittings and valves in the field. This also implies carrying out destructive and non- destructive testing on a random basis. Quality checks and testing cover all pipe parts but especially trenchless laid sections like thrust- or auger bored, micro-tunneling, horizontal direct drilling or pipes that are laid inside metallic casings
- Checking and approving the documentation prepared by coating / painting contractors
- Checking and approving the documentation of any current drainage tests carried out on pipeline sections
- Claiming any occurring deficiency, flaws and defects towards the involved contractor

3 Example from practice – coating inspector on LOOP Sannerz-Rimpar

3.1 Pipeline project - LOOP Sannerz-Rimpar (LSR)

In transmission pipeline from Sannerz in Hessen to Rimpar in Bavaria was built in 2012. The construction of this order to provide additional transport capacity or the expansion of existing capacity, the natural gas line is based on the Open Season process 2008/2009 carried out by Open Grid Europe in which by querying market participants in the future transport requirements have been identified.

The route has been widely published as so-called "Loop" parallel to an existing natural gas transmission pipeline of Open Grid Europe. The natural gas transmission LSR has a transport capacity of around 1.5 million cubic meters of natural gas per hour. It is about 67 kilometers long, running from Sannerz about 10 km in Hessen and 57 km in Bavaria to Rimpar (see figure 2). For this purpose, a total of over 3800 pipes, each with a 40'' diameter (DN 1000), about 18 m in length and about 7.5 t weight was moved. The total weight of the tubes is about 28000 tons. The pipeline is designed for an operating pressure of up to 100 bar and protected against corrosion by polyethylene (PE) coating (see figure 3).

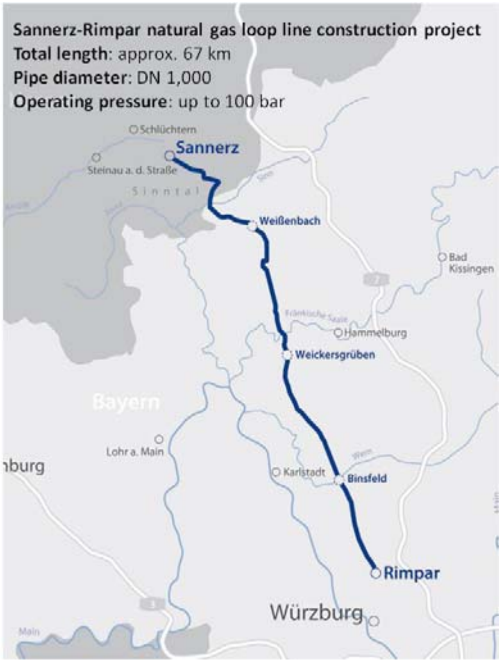

Figure 2: Line course LSR pipeline

Figure 3: Working Strip and welded pipeline section

The 67 km long LOOP pipeline system Sannerz-Rimpar was divided into 2 lots. Coating works for each lot were supervised by a CI (see figure 4 and 5). All CI's verifications and supervision activities have been accompanied by the Competence Center Corrosion Protection and by the main pipeline supervisor.

Figure 4: Destructive testing –peel resistance on cold applied PE/butyl rubber fjc

Figure 5: Coating damage during transport at valve support

3.2 Results and conclusion

All observation and quality control activities have been reported. A total number of 122 reports have been written (see table 2). 66% have shown positive results with no claimable outcome.

Number of Inspection Reports	122	100%
No observation	80	66%
Mechanical damage	19	16%
Poor painting / coating application	17	14%
Transport damage	6	5%

Table 2: Number of reports and percentile distribution of findings

The coating quality statistic on 42 inspected faults/defects can be summarized as follows:

- 16% of observed discrepancies were due to mechanical damage whereas 42% of these defects are caused during grid welding due to inaccurate deposition of welding equipment on the adjacent factory coating of the pipe ends
- 14% were poor or non-specification conform paintings / coatings. 94% belong to faults and non-conform mixing ratios of polyurethane coating of pipe fittings and valves
- 5% refer to damage caused during transport and 90% have been detected on transported valves and pipe fittings

A very good impression of the general effectiveness of quality control established by the CI's work could be derived when the drainage tests carried out on pressure tested pipeline sections (DPA) of Loop Sannerz-Rimpar compared to another pipeline system. Both pipelines have the same diameter but the second pipeline was not supervised by CI's.

LSR with CI supervision	r_{co} [Ωxm²]	**Pipeline without CI supervision**	r_{co} [Ωxm²]
DPA 1	1,8 $x10^8$	DPA 1	5 $x10^8$
DPA 2	2,3 $x10^8$	DPA 2	0,2 $x10^8$
DPA 3	3,1 $x10^8$	DPA 3,4,5,6,7	0,8 $x10^8$
DPA 4	1,6 $x10^8$	DPA 8	0,2 $x10^8$
DPA 5	1,6 $x10^8$	DPA 9	0,06 $x10^8$
DPA 8-1	2,2 $x10^8$	DPA 10	0,2 $x10^8$
		DPA 11	0,2 $x10^8$

Table 3: Summary of drainage tests carried out on pressure test pipelines sections

Table 3 summarizes the results of drainage tests performed on both pipelines which allow a quality related assessment of the CI work effectiveness. Drainage tests on the supervised pipeline LSR all fulfilled the criterion for r_{co}. No further coating quality measures were necessary.

For the pipeline that has not been supervised the result is completely different. With the exception of one test section, the threshold criterion of the drainage test readings was not met. All pressure test sections (excluding DPA 1) with a length of 60 km had to be checked for defects using laborious close holiday detection.

From this outcome, it can be concluded, that the CI work has a general significant effect on increasing the coating quality for the pipeline supervised. Open Grid Europe has decided in this way to supervise all larger pipeline projects by CI's. Additionally in 2014 it is scheduled to train CI's especially for quality control activities of coatings / paintings in buried / aboveground structures of compressor stations.

Literature

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