Condition evaluation of pipelines by means of corrosion calculation – update

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Introduction

Due to limited effectiveness of measures for corrosion prevention, it is necessary to be in expectation of corrosion attacks regarding to buried steal pipelines, especially for older years of construction. This applies particularly to pipelines which have not been run with cathodic corrosion protection for a longer time.
For the recording of such possible corrosion attacks, ultrasonic sound or magnetic flux leakage inspection pigs are used preferentially. A process which allows the calculation of possible reductions of the wall thickness, due to external corrosion, has been developed. Thereby different influence factors, spatially and temporally discreet, are considered. This system is part of the productive operation of the Westnetz GmbH, so that several insights delivered by first evaluations, led to changes in the valuation methodology already.

Basics and functioning of the corrosion calculation

The mechanical stability of the pipeline is a necessary criteria in order to be able to evaluate technical integrity. Local reductions of the wall thickness, e.g. evoked by corrosion, can strongly influence this stability so that the pipeline cannot be run securely.
In case of gas pipelines, the relevant corrosion event is limited to the exterior wall of the pipeline. Internal corrosion is almost of no importance because of a dry medium.
The consistent application of active corrosion protection methods, connected with adequate encasement, can reduce strain by means of corrosion, to a technical negligible minimum. Times without sufficiently effective corrosion protection can lead to local corrosion attacks.

In order to get an objective overview on the state of the pipeline, it is necessary to evaluate such influences.
Relevant influence factors for the corrosion event are among other things, the composition of the ground, possible influences due to stray current or high voltages and special constructions such as casing pipes, culverts or trenchless laid pipeline sections. Connections between these influence factors and resulting corrosion processes have been defined in study [1]. Thereby, findings from regulations, literature and laboratory experiments have been taken into account just like practical experience. The corrosion calculation has already been introduced and clarified during the plenary session CEOCOR 2012 in Lucerne.

In the following, additional information which is partially a further development of the system and results from already gained operating experience, shall be given.

Involvement of the corrosion calculation in a Pipeline Integrity Management and thus in a maintenance process

The task of a corrosion calculation consequently consists in identifying relevant reductions of the wall thickness and evaluating their effects on the technical integrity of the pipeline. The necessity of a theoretical view of this reduction of the wall thickness is due to the fact that often used inspection procedures (pigging) cannot be used because of the structural composition of some pipelines. Nonexistent pig traps, too small radii in case of changes of direction, change of nominal diameter or too low pressures often do not allow an inline inspection.

For this reason the corrosion calculation is an integral part of the Westnetz' Pipeline Integrity Management (PIMS) for the technical valuation of the integrity of pipelines.

With the help of various documentation components, operational findings and measured values, it serves to determine possible residual wall thicknesses along the pipeline.

After this valuation it is possible to identify critical variables and thereby to initiate specific inspection operations or to introduce measures to ensure stability of the pipeline directly. Respectively the PIMS is integrated in the existing maintenance process.

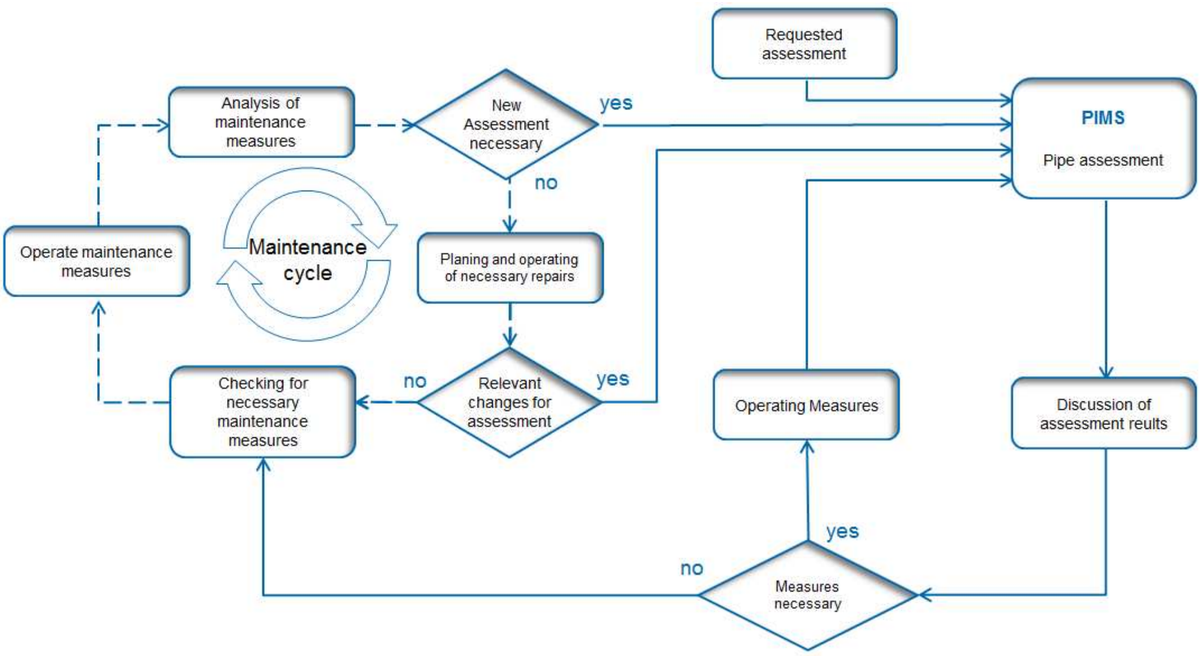

Figure 2: Involvement of the PIMS in a maintenance process

Figure 2 shows the overview of the maintenance process, which comprises the Pipeline Integrity Management as an integral part.

A valuation can be initiated due to an individual requirement, measures carried out or in cyclical repetitions. If measures that have an effect on the technical condition of the pipeline, have been carried out, it can become necessary to consider new knowledge in a valuation. These measures can be repairs, as well as specific inspections for the exploration of factors on the impact of measurements.
Repeated evaluations can occur in periodic cycles or can be made conditional on expected changes of relevant influence factors. In any case, the periods will typically be > 5 years.

Soil maps of the geological service for determining corrosion risk

Until now the specific soil resistance of the surrounding ground has been used for the determination of the corrosion risk of a pipe due to the condition of the soil.
Alternative specification options shall be discussed here. Until now it was necessary to record the specific soil resistances metrologically on site. With the soil maps necessary information can possibly be derived from these maps provided by the geological services for instance.
Here the detour via the specific ground resistance is not needed. The corrosion risk shall rather be derived from soil composition and moisture content.
Such soil maps are produced from the analysis of an abundance of drills which provide information about the composition of the particular ground. Thereby the compositions of the soil are basically identifiable until a depth of 5 m. For the described purposes it is sufficient to determine the condition of the soil in an average depth of approx. 1.5 – 2 m.

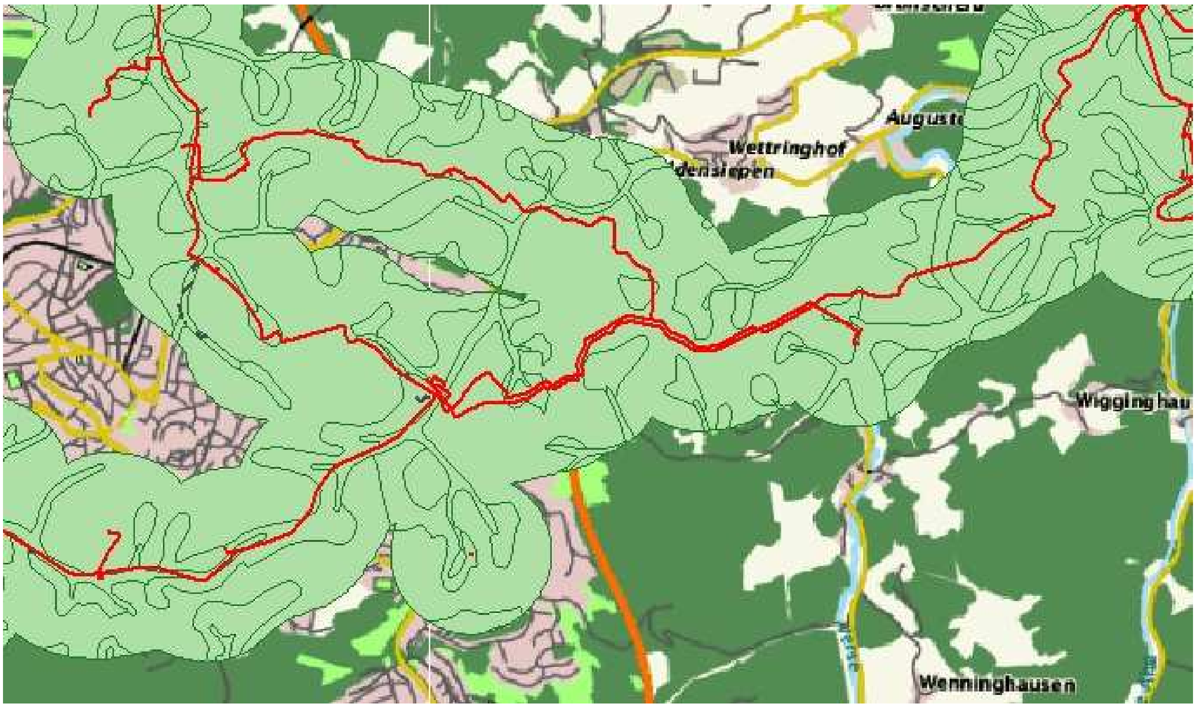

Figure 3: Soil map of the Geological Service (© GD NRW, Openstreetmap)

Figure 3 shows the combination of the pipe courses and the soil maps how they are used in a geographical information system (GIS).

The soil maps contain information to various criteria. These include, among other things:

- Sand content, solid rock content and other components
- groundwater and tailwater
- electrolyte conductivity

Following assumptions are intended to evaluate the composition of the soil [2]:

- The ventilation of the soil reduces the corrosion probability strongly:
  The air capacity (respectively sand content) serves as a measure of ventilation

- High and particularly varying water contents increase the probability of corrosion strongly:
  groundwater and tailwater describe the corrosion-promoting effect of the soil moisture

- Acidic soil solutions increase he probability of corrosion strongly:
  The existence of organic material (humus, peats) justifies the assumption of mostly (strongly) acidic soil conditions

- High ion concentration in soil solutions increase the probability of corrosion strongly:
  cation exchange capacity (potential clay contents) make a high ion concentration very likely

Through the sand content and the influences of groundwater and tailwater a corrosion risk can be derived.
Table 1 shows a possible determination of corrosion risk for different conditions of the soil.

Table 1: Determination of corrosion risk by means of sand content and moisture [2]

sand content	anhydrous	damp	wet
$> 75\ \%$	very low	low	medium
$> 25\ \%$	low	medium	high
$< 25\ \%$	medium	high	high

By means of these corrosion risks, possible corrosion rates from [1] can be determined.
To what extent a correlation between the corrosion risk and specific soil resistances (respectively the soil class (see [2])) exist, shall be investigated in the future. Table 2 shows a possible classification.

Table 2: Determination of corrosion risk by means of sand content and moisture [2]

Corrosion risk	soil class	specific soil resistance
very low	1a	$> 500\ \Omega m$
low	1b	$> 150\ \Omega m$
medium	2	$> 30\ \Omega m$
high	3	$< 30\ \Omega m$

Consideration of casing pipes and other types of installation in the calculation of corrosion

For pipelines it is generally assumed that they have been installed in the ground due to an open construction. For the open laying the corrosion calculation applies as described in [1].
However there are two exceptions which should be considered.
These are on the one hand casing pipes and on the other hand trenchless laying of pipelines.

Installation in casing pipes

Casing pipes influence a valuation of the pipeline in so far as it is not possible to be indicative of the effectiveness of cathodic corrosion protection within a casing pipe offhand. Then the proof has to be raised by means of adequate valuation systems. For this purpose the AfK-recommendation No.1 [3] which deals with cathodic corrosion protection within casing pipes is recommended.

By means of such a valuation, the proof whether the corrosion protection for the section of the pipe within a casing pipe is effective, can be raised.

Two cases are here differentiated:

- valuation is not carried out or critical casing pipe:
  It is assumed that the section of the pipe within a casing pipe is and was not protected sufficiently, so that the corrosion calculation (since construction year) assumes a non-effective corrosion protection.

- Valuation proves the effectiveness of the corrosion protection:
  It is assumed that the pipe section has received effective corrosion protection until today. The corrosion rate is in the range of the technical negligible value of $< 10\mu m$ p.a..

Trenchless installation types

Trenchless installation types (such as Horizontal Directional Drilling (HDD) and Microtuneling) have the characteristic that the drill hole is usually filled with a low-resistance detergent which stays within the drill hole during the insertion of the pipe.

During the corrosion calculation, this low-resistance range of the pipe would then be calculated as a range with strongly increased risk of corrosion (see [1]). But this is due to usual pH-values of the drilling muds not probable.

Current investigations have shown that contrary to behavior of so called liquid soils these drilling muds keep their characteristics in the long run. An alignment of relevant characteristics with the surrounding soil could not be noticed.
Correspondingly low corrosion rates can be assumed for the corrosion calculation.

Assumed values for the corrosion calculation

Basis for the corrosion calculation is complete data. Missing data makes the implementation of the corrosion calculation difficult or prevents it completely. Therefore qualified assumptions have to be made in order to fill data gaps. As a matter of priority, it is difficult to find out any data of the cathodic corrosion protection because frequently older documents are not available anymore. In the following, the proceeding for the corrosion calculation with some data that is not available or insufficiently available, shall be explained.

Start date corrosion calculation

If it is assumed that corrosion can only occur if the casing is damaged, it makes sense to use examination methods which almost preclude a defect on the casing. Thereby corrosion under removed coating shall be neglected for the time being.
If such investigations have been carried out and it has been proved that no coating defects are existent for the corrosion calculation it can be assumed that before the investigation no (or only technical negligible) corrosion has occurred. However for times after these investigations, in the worst-case scenario, the assumption applies that corrosion can occur every time if cathodic corrosion protection is not available or limited effective.

Following investigations or measures are here relevant.

- Repaired coating:
  In case of an executed repair of the coating it is assumed that relevant reductions of the wall have been documented or eliminated. The quality of the this repaired coating is as a general assumption at least equal or better than the casing at the time of the construction of the pipe (age, quality of the execution, further development of the material, etc.). Because of that, the start date for the corrosion calculation will be equalized with the time of the repair.

- Intensive measurement:
  If there are no defects in the coating which has been proven through an intensive measurement the date of the intensive measurement is the start date of the corrosion calculation. As general assumption coating defects are not supposed to exist if the a potential gradient not greater than 1.1 mV. This will be assumed because of the measurement uncertainty.

- Pigging:
  In the case of intelligent pigging as a general rule the condition of the pipeline casing will not be proven. But the thicknesses of the wall will be measured. If there cannot be noticed any relevant reductions of the wall thickness, the start date will be set on the date of pigging.

Effectiveness of the cathodic corrosion protection

If it is assumed that an effective cathodic corrosion protection reduces the expected corrosion to a technical negligible extent the effectiveness of the cathodic corrosion protection is an important date for the corrosion calculation. However there are hardly recordings of the effectiveness, especially of times before 1980. In this section an approach for assumed values shall be explain. Furthermore it should be taken into account that at different points of time the standard protective effects of the cathodic corrosion protection from today's point of view also contains different quality standards.

In the first years of application of cathodic corrosion protection the protective effect was regarded as given if an on-potential of U_{CSE} ≤ -850 mV was identified as sufficiently. Later on, the same criteria was applied to off-potentials. Because possibly there can be critical values at possible coating defects between two measuring points a limiting value of U_{CSE} ≤ -950 mV was introduced in later times. Only with the new edition of the DVGW work sheet GW10 in 2000, the proof of the protective effect of cathodic corrosion protection at all existing coating defects was unmistakable required.

Depending on the used valuation or valuation basis, the identified corrosion rate without cathodic corrosion protection will be reduced completely (factor 0) or partially (factor < 1). If KKS is ineffective, it will be calculated with the unabated corrosion rate.

Against this background, the effectiveness is defined as follows [4]:

- Effective in accordance with GW 10 (2000) (factor 0)
- Effective in accordance with criteria U_{CSE} ≤ -950 mV (factor 0.3)
- Effective in accordance with criteria U_{CSE} ≤ -850 mV (factor 0.5)
- Probably effective in accordance with criteria U_{CSE} ≤ -850 mV (factor 0.8)
- Questionable or non-effective cathodic corrosion protection (factor 1)

This division of effectiveness will thereby only be put into account if there are measured values at regular minimum intervals. Besides regular local surveillance, further data from remote surveillance, function control or intensive measurement are used. If the distance between the established measuring values is greater than 3 years, none of the present attributes can be accepted with certainty for this time interval.

If the respective measuring values are suggestive of an non-effective cathodic corrosion protection, the attribute "Probably effective in accordance with criteria U_{CSE} ≤ -850 mV" applies for a maximum time period of 10 years.

For greater time periods the cathodic corrosion protection is recognized as questionable or non-effective in any case.

Absences of the cathodic corrosion protection are only taken into account from a time period > 0.5 years (see [4]).

Unkown influenceable objects – influence of static potential gradients

Static potential gradients are caused by constant stray current sources. These can be unknown influeneceable or influencing objects such as reinforced concrete structures or foreign cathodic corrosion protection devices. Thereby they can influence the regarded pipe inadmissibly. As part of the corrosion calculation some of these objects should be considered generally [4].

Following objectives can be relevant in a worst-case scenario:

- Reinforced concrete foundation
- Building with earth electrode (circumferential earth electrode), also bigger constructions, for instance bridges with earth electrode
- cathodic corrosion protection or local cathodic corrosion protection

Following objects are classified as not relevant:

- canals (generally not completely electrical connected)
- cabels (generally no relevant elemental current)
- Pipes (for example water pipes (material unknown/known and not cathodic protected → no relevant elemental current)
- Other objects near the pipe

Known objects are considered locally depending on the distance (< 5 m) with an static voltage pattern of U_{static} = 0.3 V [1].

When considering relevant cathodic protected objects near the pipe no general value for a potential gradient can be assumed because they can have a much higher value than 0.3 V. For this reason, a valuation of the matter by the responsible person is necessarily needed.

As a first assumption cathodic protected objects are assumed as not relevant regarding the influence if one of the following conditions are met:

- Parallel course/crossing of cathodic protected objects in the same protection system as the considered pipe,
- cathodic protected objects with a distance higher than 15 m

Conclusion

The corrosion calculation is an approach for determining possible corrosion defects in a supply network which is not piggable. A lot of flexibility within the valuation of individual cases can be attained. This requires the determination and documentation of corresponding degrees of freedom as assumed values.

The valuation system was included in the German policy and is mentioned in the technical leaflet GW18 of the DVGW as an approach for the state evaluation of cathodic protected pipelines of the gas and water supply [5]. A continuous improvement process shall secure that the evaluation logic with the corresponding algorithms reflects the current state of knowledge and investigation.

References:

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