PIMS – THE PIPELINE INTEGRITY MANAGEMENT SYSTEM OF VNG - VERBUNDENETZ GAS AG

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ABSTRACT

To ensure integrity and a high level of availability of its high-pressure gas pipelines, VNG uses PIMS which fully meets current requirements as contained in well-known regulations and specifications. PIMS is designed to guarantee the safety of staff and the general public, to protect the environment, and to ensure the reliability of pipeline operation while making allowance for technical and economic requirements. For VNG it provides a wealth of technical information and can interact with other systems or components thereof in giving the desired proof of technical integrity and, thus, the reliability of high-pressure gas lines.

Data were analyzed and assessed in probabilistic terms using standard criteria. This means that defective spots and flaws are precisely evaluated and located. For this purpose, all process-related data is stored and administered in a PIMS database. The results of this pipeline information system are used to assess the probability of failure and possible service life. At the same time, any defective spots and flaws which have been detected are classified into a stepped program and necessary measures are derived for monitoring. The rehabilitation projects which have thus been prioritized will be further optimized in technological terms and then implemented.
1 BACKGROUND

Gas utilities are legally required to maintain their technical systems in a proper condition and to meet all relevant safety requirements in order to guarantee maximum security of supplies at all times. This is meant to ensure the “integrity” of systems. VNG uses PIMS (its proprietary Pipeline Integrity Management System) which fully meets the requirements listed in established regulations and specifications such as TS 15173 and 15174 of CEN, and ANSI B31.8S.

2 QUALITY OF HIGH-PRESSURE PIPELINES

There can be no doubt that the quality standard of a pipeline is best at the time of completion. This is due to a variety of regulations, most of which are followed meticulously worldwide. It is also due to the pressure test which, in steel pipelines, normally comes close to the yield stress of the material and thus provides the most informative load test conceivable for a load-carrying structure.

Now as before, high-pressure pipelines are designed to give exactly the admissible stress when nominal pressure is applied. This approach is not only economic but also safe as any other loads from coverage, traffic, etc. can generally be neglected compared with the internal pressure load. It is, then, obvious that a pipeline has little capacity for accommodating extra stress resulting, for example, from corrosion or scores and notches caused by third parties. These may reduce load capacity in specific sites, or over larger areas as shown qualitatively in Figure 1.

The green line, a "quality curve for a well-maintained pipeline", shows the inevitable deterioration in daily use. Operating engineers, on the other hand, know from experience that there is no immediate need for rehabilitation or upgrading work every time the quality of a pipeline suffers. Each load-carrying structure has a "utilization reserve" that allows for, and compensates these effects within certain limits.

The crucial question is how to determine and define this utilization reserve in terms that are technically correct and at the same time litigable. If a pipeline fails which has previously been defective, the authorities and regulatory bodies will automatically assume that failure was caused by these earlier defects, putting the pipeline operator who is responsible into an uneasy position. The assumption can only be refuted if the operator proves that the quality of his grid was above a generally accepted limit.

Similarly, a reliable limiting criterion is needed for pipelines, or parts thereof, whose quality curve over time is shown as a red line in Figure 1, to make an economically and legally justified decision on what parts to upgrade when. Existing European regulations are not helpful in this context and largely deterministic in that they hinge on the maximum quality standard typical of a just completed pipeline as shown in Figure 1.

No definite assessment procedures exist for high-pressure pipelines with restricted load-carrying capacity and stability. One such procedure is to look into the system’s failure probability and balance it against a limit value, as described later on.

For the time being, suffice it to say that with the above approach pipeline quality may be assessed in its entirety only as part of a Pipeline Integrity Management System that makes allowance for all factors involved.
3 AIMS

PIMS aims to guarantee the safety of staff and the general public, to protect the environment, and to ensure the reliability of pipeline operation while making allowance for technical and economic requirements. Designed by VNG, it provides ample technical information and assessment tools and can interact with other systems, or components thereof (such as GIS, the Geographic Information System, and specific assessment and supervision functions) to give the desired proof of technical integrity and, thus, the reliability of high-pressure gas lines.

It should be pointed out that PIMS has been fully accepted and certified by the authorities supervising high-pressure gas pipelines, even though practically no normative rules exist as yet in this field.

4 METHODS

Pipeline integrity can only be achieved if, firstly (as shown in Figure 2), the technical integrity of the system is guaranteed by equipment which is as stable and reliable as specified in regulations and, secondly, process integrity is such as to ensure operation in keeping with applicable quality criteria.

Process integrity calls for corporate and operating procedures to be planned and effectively monitored according to regulations, from defining quality grades, day-to-day working and maintenance to the training of staff. It is, then, essential to PIMS to define these procedures and integrate them into the workflow. Quality assurance in terms of this system can only work if a company dovetails all of its QA processes, along with staff training, the allocation of responsibilities, data management and documentation, etc.
**Figure 2: PIMS elements at VNG**

**Figure 3: Failure probability (Pfᵢ), Quantitative Risk Analysis (QRA) and Structural Reliability Analysis (SRA)**
Technical integrity, the key element of PIMS, can be convincingly demonstrated only if all major factors acting on the system are assessed in standard terms for every point along the line. The criterion used in this connection by VNG is failure probability. As seen in Figure 3, individual probabilities are determined for all influencing factors and every point along the line and then summarized to give a total failure probability. Where this is below the limit for system failure, technical integrity prevails (structural reliability analysis SRA).

The system can also generate a quantitative risk analysis (QRA), if failure scenarios and the population density are known. This approach can help in the planning of upgrading measures for those parts of the grid where limit values have been reached or exceeded.

In the course of technical condition analysis (TCA), 45 source data (pipeline/monitoring/risk parameters such as coating, inspection intervals or cathodic protection data) and a number of singular items (points along the line such as valve sets, crossings, geographic features or insufficient cover) are currently recorded. Specific expert systems help assess the impact of other important factors (e.g. soil mechanics/corrosiveness or the effect of cathodic protection) on the technical condition of a pipeline.

As has been said, the use of failure probabilities is little reflected in technical standards. There is, however, a wealth of literature on the subject, along with first normative rules which are of gratifying clarity.

The Dutch "Purplebook", for example, lists limit values for risks. As is known, these result from failure probability multiplied by the effects caused. ISO 16708, which is still a draft, also gives limit values for failure probability. An overview of the dimensions involved is shown in the risk triangle, Figure 4. Limit values derived for the failure probability of a system (SRA) are in the order of $10^{-6}$, those for quantitative risk analysis (QRA) between $10^{-7}$ and $10^{-8}$. By comparison, for a road user in Western Europe the risk of being involved in a serious accident is $10^{-4}$. All limit values of this kind relate to a unit of system and a unit of time. Limit values for high-pressure gas pipelines apply per kilometre and per year.

![Figure 4: Risk triangle](image)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>not acceptable</td>
<td>too high: major improvements reqd.</td>
</tr>
<tr>
<td>alarming</td>
<td>very high: look for alternatives/major improvements</td>
</tr>
<tr>
<td>acceptable to staff</td>
<td>high: find improvements</td>
</tr>
<tr>
<td>acceptable to general public</td>
<td>low: find most economical solution</td>
</tr>
<tr>
<td></td>
<td>negligible: take normal precautions</td>
</tr>
</tbody>
</table>
Figure 5 gives results from analyzing the technical condition of a 5 km long pipeline section the failure probability of which is in the order of $10^{-15}$ in places where little or no extra loads are applied. This is a common average for normal high-pressure lines. The peaks which exceed this order of magnitude, some of them significantly, may derive from specific features such as considerable corrosion, high extra loads (from traffic routes/embankments), river crossings, etc.

The system instantly detects such deviations, and the operator of a line will then no longer be dealing with each and every feature but only with effects indicating a failure probability that is near, or above, the limit. Before taking any action it is, of course, advisable to check data quality for the points in question, as individual parameters could have been entered in a conservative manner. Only if the results have been confirmed should a schedule of quantities be drawn up for the line.

![Graph](image)

**Figure 5**: Results of analyzing technical condition

Up to this point, analyzing the technical condition of a pipeline is largely an automatic procedure which includes generating schedules of quantities for rehabilitation or monitoring. The next step would be to bring in experienced technicians and engineers who may be aware of future plans for the company's own grid, or construction projects of third parties.

Against this overall background, a set of measures can be drawn up and prioritized, i.e. chronologically arranged, using failure probability calculations. After completing work, the condition of the pipeline and its new data should be assessed once more to ensure that the limit value for failure probability is again below the ceiling and the overall quality of the line is in the required range.

A key element of TCA is corrosion assessment. Lines where pigging is possible are diagnosed in this way, any wall thickness reductions found are assessed with the help of FEM calculations. These are very accurate and can thus be an integral part of technical assessments. The method requires so much computing time, however, that evaluating pig runs which may find several thousand flaws in a section of line becomes uneconomical. VNG has therefore developed neural networks for rapid and efficient assessment. These were "coached" using large quantities of data from the assessment of individual corrosion spots.
Figure 6: Process for proof of integrity
The KaRo program developed in the same context can calculate and classify both separately entered flaws and entire lists of features produced by pig runs. It incorporates corrosion forecast models permitting direct conclusions as to how long the line will carry loads safely, and will set deadlines for a new check on corrosion progress or upgrading measures.

KaRo derives immediate steps to be taken (such as inspections, pressure reduction, repair times/methods) and estimates the remaining useful life. Corrosion models have been developed for pipelines that can not be pigged, and defects found will be prioritized for optimal upgrading.

FAD is an assessment program which calculates defects in girth welds of old lines and assesses old field welds in terms of fracture mechanics.

By definition, a pipeline is in a state of technical integrity if immediate steps found necessary after assessing its condition have been taken and the remaining flaws detected have been prioritized and listed in an upgrading program. This is shown in Figure 6.

5 RESULTS

Data recorded in the course of TCA is analyzed and assessed in probabilistic terms using standard criteria. This means that defective spots and flaws are precisely assessed and located. In addition, all process-related data is stored and administered in a PIMS database.

The results of this pipeline information system serve to assess the probability of failure and possible service life. At the same time, any defective spots and flaws detected are classified into a stepped program and necessary measures derived for monitoring. The rehabilitation projects thus prioritized will be further optimized in technological terms and then implemented.

6 SUMMARY / CONCLUSIONS

Using the PIMS method, approx. 3,000 km of high-pressure gas pipelines have been assessed since 1998 and rehabilitation measures classified into priority stages. Apart from safety aspects, i.e. the reliability of a line and its technical integrity, the method has proven ideal for enhancing planning reliability and lowering/optimizing costs.