The Pipeline Integrity Management System of VNG Verbundnetz Gas AG

Referent: Dr. Volker Busack, Operation / Technology
1. Introduction VNG

- VNG in the European gas transmission grid -

- Gas transmission pipelines
- Existing
- LNG terminal
- Gas fields
- VNG delivery points

Map of the European gas transmission grid, with VNG delivery points highlighted.
1. Introduction VNG
- Technical infrastructure at VNG -

- Length of pipelines: 7,279 km
- Underground gas storages: 6 (at overall 5 sites)
- Total work gas capacity: 2.3 billion m³
- Compressor stations: 2 (+ 4 compressor units UGS)
- Total compression capacity: 77.8 MW (8 piston compressors 7 turbo compressors)
- Delivery stations / links: 8
- Metering and pressure regulating stations: 36
- Cathodic corrosion protection installations: 727

Supply area: 108,000 km²
2. Changes in pipeline status
- Pipeline quality curve -

Reserve in the bearing capacity of a high-pressure gas pipeline

Quality Q

- max Q
- min Q₁ (As defined by operator)
- min Q₂ (absolute)

Quality loss if maintained according to regulations
Standard on completion
Remaining useful life
Actual standard of a well-maintained pipeline
Rehabilitation
Minimum standard
Lack of quality on completion or maintenance

t [yrs.]
3. Aims, elements and methods of PIMS
- Aims and requirements -

Specific aims of PIMS at VNG - Verbundnetz Gas AG:

- Evaluation of results of inspection pigging by neuronal networks (FEM), incl. corrosion forecast with assessment program “COP” (Corrosion On Pipelines)
- Technical condition analysis of pipelines by probabilistic assessment criteria / parameters
- Evaluation of possible service life
- Identification of failures / weak spots with following prioritization of needed actions / measures
- Optimization and Processing of needed rehabilitation measures
- Data management and providing a pipeline information system
3. Aims, elements and methods of PIMS
- Pipeline failure probability, QRA and SRA -

- Pressure
- Traffic
- Soil
- Corrosion
- Defect statistics
- . . .
- . . .

<table>
<thead>
<tr>
<th>TCA Assessment of technical condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRA</td>
</tr>
<tr>
<td>Structural Reliability Analysis</td>
</tr>
<tr>
<td>Reliability analysis</td>
</tr>
<tr>
<td>Limit value balancing</td>
</tr>
<tr>
<td>Detection of system flaws</td>
</tr>
<tr>
<td>Rehabilitation control</td>
</tr>
<tr>
<td>Proof of integrity</td>
</tr>
</tbody>
</table>

Calculate failure probability Link Pf_i

QRA
Quantitative Risk Analysis

Calculate effect

Individual risk,
General risk

Population density

How failure occurred

Permission
3. Aims, elements and methods of PIMS
- Risk triangle -

Risk

not acceptable

10⁻³/a

very high: look for alternatives/major improvements

very high: major improvements reqd.

 Remarks

alarming

10⁻⁴/a

high: find improvements

acceptable to staff

10⁻⁵/a

low: find most economical solution

acceptable to general public

10⁻⁶/a

negligible: take normal precautions

10⁻⁷/a
3. Aims, elements and methods of PIMS
- PIMS elements at VNG -

PIMS elements at VNG

Technical Integrity

- Action
  - Time + Costs

- Proof of technical integrity
  - Operation / inspection

- Operation / inspection
  - TCA (incl. KaRo)

- Grid optimization / extension

- SCADA process data

- Expert systems

- GIS

- Raw data

Process Integrity

- Company strategies
  - Quality standard
  - Economic targets
  - Social aims

- Processes
  - Operation
  - Contingency planning
  - Training
  - Responsibilities
  - Group standards

- Quality assurance and performance review
  - Error assessment
  - Audits
  - Inspection standards (e.g. ISO 9000)
3. Aims, elements and methods of PIMS
- Modern and efficient methods of PIMS -

- Methods and techniques for pipeline assessment / inspection:
  - Pipeline Integrity Management System (PIMS)
    - Technical Condition Analysis (TCA)
      - specific expert systems
    - Intelligent / Inspection pigging
    - Program “KaRo” for corrosion assessment / forecasting
    - Program “FAD” for evaluation of old welding seams
    - Cathodic corrosion protection “CCP”
4. TCA and Inspection pigging
- Technical condition analysis TCA -

**Technical Condition Analysis** for high-pressure gas pipelines

<table>
<thead>
<tr>
<th>Non-piggable pipelines: 3,195 km</th>
<th>Piggable pipelines: 4,121 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCA</td>
<td>Inspection Pigs</td>
</tr>
<tr>
<td>- Assess linear section (pipeline data, ambient conditions, etc.) and specific features (valves, fittings, special structures, etc.) acc. to probabilistic criteria (failure probability)</td>
<td>- Assess wall thickness deterioration using Finite Element Method (FEM)</td>
</tr>
<tr>
<td>- Prioritize weak points</td>
<td>- For calculation use neural networks with KaRo (pipeline corrosion) program</td>
</tr>
<tr>
<td></td>
<td>- Estimate remaining service life by making corrosion forecast</td>
</tr>
</tbody>
</table>

Identify immediate steps, derive multi-stage plan for weak point rehabilitation
### Priority: must (1)
1. Year of construction
2. Culvert
3. Diameter
4. Casing pipe
5. Design pressure
6. Settling pressures
7. Coverage
8. Wall thickness

### Priority: must (2)
1. As-built quality, ZfP-test
2. Operating pressure
3. Empirical values at pipeline, damage statistics
4. Above ground pipeline
5. Slope
6. Medium
7. Proximity seam of a secure connection
8. Insufficient distance from structure
9. Type of seam
10. Seam fracture on this pipeline
11. Hollow
12. Mining pressures
13. Temperature
14. Type of connection
15. Traffic route (rail, road)
16. Material

### Priority: should
1. Pipeline construction details (Bends etc.)
2. Cathodic Corrosion Protection
3. Pigging data
4. Damages
5. Repairs

### Priority: can
1. Coating
2. Groundwater
3. Ground utilization
4. Dynamic stresses
5. Soil aggressiveness
6. Electrical external voltage

### Priority: Information
1. Manufacturer
2. Documentation
...
5. Content and results of TCA
- Example for pipeline assessment (I) -

Exemplary result of pipeline characteristics

<table>
<thead>
<tr>
<th>No.</th>
<th>Cause</th>
<th>Cover [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crossing with traffic route, no casing pipe</td>
<td>0.80</td>
</tr>
<tr>
<td>2</td>
<td>Crossing with traffic route, no casing pipe</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>Crossing with traffic route, no casing pipe</td>
<td>1.01</td>
</tr>
<tr>
<td>4</td>
<td>Insufficient cover</td>
<td>0.54</td>
</tr>
<tr>
<td>5</td>
<td>Structure erected over pipe</td>
<td>0.64</td>
</tr>
<tr>
<td>6</td>
<td>Crossing with traffic route, casing pipe</td>
<td>0.63</td>
</tr>
<tr>
<td>7</td>
<td>Insufficient cover</td>
<td>0.69</td>
</tr>
<tr>
<td>8</td>
<td>Insufficient cover</td>
<td>0.68</td>
</tr>
<tr>
<td>9</td>
<td>Insufficient cover</td>
<td>0.45</td>
</tr>
<tr>
<td>10</td>
<td>Insufficient cover</td>
<td>0.64</td>
</tr>
<tr>
<td>11</td>
<td>Insufficient distance from parallel traffic route</td>
<td>0.70</td>
</tr>
<tr>
<td>12</td>
<td>Crossing with traffic route, no casing pipe</td>
<td>0.81</td>
</tr>
<tr>
<td>13</td>
<td>Crossing with traffic route, casing pipe</td>
<td>0.58</td>
</tr>
<tr>
<td>14</td>
<td>Structure erected over pipe</td>
<td>0.83</td>
</tr>
<tr>
<td>15</td>
<td>Insufficient distance from parallel traffic route</td>
<td>0.80</td>
</tr>
<tr>
<td>16</td>
<td>Crossing with traffic route, casing pipe</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Explanation of the marked locations
HP gas pipeline, PN 25, DN 400
Year of construction 1969
Overall length 73.27
Exemplary result for design pressure PN 25 bar

Metre of pipeline
KaRo - program for corrosion assessment

**Evaluate large data quantities from inspection pigging:**

- Assess / classify defective places
- Derive immediate steps (e.g. safeguarding program, pressure reduction)

**Assess local defects (digging):**

- Determine defect parameters (wall thickness reductions) on site (length, width, depth)
- Recalculate operating pressure, identify repair method
6. Selected methods and tools
- Corrosion forecast -

**Corrosion forecast**

**Aims:**

- Determine remaining operation life for wall thickness deterioration
- Optimize repair time / method (avoiding supply interruption, e.g. by field coating, clock spring, collars, etc.)
- Plan repeat inspection pigs

**Applications:**

- Wall thickness deterioration requiring no immediate repair and for which the effectiveness of cathodic protection has not been proven
6. Selected methods and tools
- FE Modelling of corrosion areas -

Surface scan

FE result
7. Process steps of PIMS

- Dynamic segmentation
- Technical condition analysis TCA
- External assessment algorithms (i.e. risk)
- Visualization
- Data management for pipeline condition
- KARO / KAROSAN
- Expert data
- Pigging data
- CCP data
- GIS data
- KARO / KAROSAN

- Result analysis
- Proof documentation
- Measure planning
- Measure proceeding
- Rehabilitation and cost planning
- Documentation feedback
8. Conclusions

• Using the TCA method since 1998 within the scope of PIMS

• up to now approx. 3,000 km of high-pressure pipelines assessed in detail and rehabilitation measures classified into priority stages 1 - 3 (defined levels)

• Results of rehabilitation processing in reference to realistic conditions optimally suitable for verifying

• **Advantages:** - Planning reliability / safety
  - cost lowering / optimization
  - proof of reliability and technical integrity