Title: Risk and Integrity Management System for PETRONAS Gas Berhad’s Gas and Liquid Hydrocarbon Pipelines

Abstract

PETRONAS Gas Berhad (PGB), Malaysia currently operates one of Southeast Asia’s largest onshore pipeline systems comprising more than 2,500 km of large diameter high-pressure gas and liquid transmission, supply and lateral pipelines. Recognizing the value of a risk based approach to pipeline integrity management program, in 2002 PGB implemented a customized and fully integrated Risk and Integrity Management System (RIMS) which included software modules for:

- Data management;
- Semi-quantitative risk assessment;
- Risk control cost benefit analyses;
- Defect Assessment;
- Corrosion growth modeling; and
- Reporting.

As part of this project, a benchmarking study performed jointly with the contractor, PGB’s pipeline integrity programs were also compared with a broad group of international pipeline operators. This study compared the relative ranking position of PGB pre- and post-implementation of RIMS. It demonstrated that implementation of RIMS places PGB in a select group of first quartile international pipeline operators, with respect to the implementation of pipeline integrity management best practice. This paper describes the functionalities of RIMS system and how it has benefited PGB, which have been realized to date from its implementation.

1. Introduction

RIMS was first implemented in 2002 on 886km of pipelines, focusing on PGB’s PGU and liquid onshore transmission pipelines. Realising the benefits and importance of RIMS, the implementation has been extended to the entire 2400km which includes both onshore and offshore pipelines. The implementation has thus far resulted improvements in overall integrity management activities that minimizes risk of pipeline failure while optimizing maintenance cost. RIMS comprises of interactive modules that enable PGB to implement a data management system following the specifications of the Pipeline Open Database (POD) Model, perform semi-quantitative risk assessment for prioritization of integrity assessments, follow by post-assessment analysis and cost benefit analysis to optimize preventive and mitigation actions. Overall, RIMS can be used as a system to produce; monitor and update integrity management plans. These modules are developed in consistent with the requirements of API 1160 for liquid pipelines, and ANSI ASME B31G and B31.8S for gas pipelines. Details of each module is discussed.

2. Benchmarking Study

A benchmarking study has been conducted to compare the ranking position of PGB relatively to other international operators for both adopting and excluding RIMS. A series of questions were sent out to operators worldwide and a relative score is assigned to each of these questions. A detailed evaluation on PGB’s operating system, Operation Standards, Local Regulatory Requirements, and others, an overall rank value (ORV) is determined and compared with other pipeline operators. Based on the responses received, pipeline operators are grouped into 4
groups; above average, at average, below and well below average group. Without implementing RIMS, this will put PGB in the below average group; however when PGB has initiated the implementation of RIMS that put them within the above average group with the top ranked pipeline operators; mainly due to the fact that now, PGB has a tool that moves them into a full integrity management system.

3. Data Management Module

The core of the RIMS system is the database. It is developed using the industry standard data model, PODS that can directly integrate with other third party GIS and database systems as other information becomes available. Running on SQL Server, the database can be accessed by multi-user at different locations at the same time for optimal data manipulation and verifications using RIMS as the interface. Through the interface, PGB can add, modify, and update new pipeline data at any time, and at anywhere with the ease of having access to reliable network connection.

Modules built within RIMS interact with the database, which serve as storage/placeholders for pipeline data. RIMS pull all the relevant data together; integrate them in accordance to the specifications built within that will then be further used to perform assessment on each individual pipeline or the entire PGB’s system, as shown in Figure 1.

Data gathering is an ongoing effort. A “satisfactory” database is built over time and as pipeline data become available or changes, the database needs to be updated accordingly. In order to ensure the integrity of data is not jeopardized unintentionally, several levels of security have been implemented. The data will be editable by users with the required security clearance while other users of the RIMS system will have permissions to view data and perform assessments but with limitations on changing the pipeline data. This capability allows all level of PGB’s personnel to have access to the data as needed while monitoring and maintaining the integrity of data.

4. Semi-quantitative Risk Assessment/Cost Benefit Analysis Module

RIMS utilize a semi-quantitative approach for pipeline prioritization, express in terms of probability of failure, consequence of failure and overall criticality (risk). Quantified data includes pipeline attributes relating to design, and construction, operating pressure, damage/failure histories, inline inspection, close internal potential survey, and others while qualitative data tends to be more subjective in nature depending on the person making the judgment. Failure mode considered in the risk assessment includes:

- External corrosion
- Internal corrosion;
- Constructions threats;
- Fatigue;
- Stress Corrosion Cracking;
- Third Party Interference;
- Loss of Ground Support;
- Sabotage and Pilferage;
- Offpipe Equipment Failure; and
- Incorrect Operations threats

The general formulation of risk is defined as follows:

\[ \text{Total Risk} = \text{Probability of Failure} \times \text{Consequence of Failure} \]

The probability of a particular failure cause is determined from:

\[ \text{Probability of Failure} = \text{Susceptibility Factor} \times \text{Severity Factor} \]

The susceptibility factor is a measure of how susceptible (likely) the pipeline is to that failure cause and the severity factor gives an indication of how severe a failure would be, should one occur (how bad it can become).

The consequences considered included:

- Public Risk (principally safety),
- Environmental Effects,
- Customer impact,
- Financial impact, and
- Cost of Failure

The risk assessment methodology is customized specifically to meet the requirements and standards of PGB’s pipeline system. As part of the customizations, a score is assigned to each category of data based on statistical analysis, common industry practise and engineering judgment (Subject Matter Experts – SME’s).
Higher score indicate higher risk. The scores are combined to calculate the probability and consequence of failure ratings for each individual pipeline due to all the conceivable causes and overall to give an associated risk number. Using these scores, the relative influence of each of the failure causes are considered and the impact/consequences of these failures are measured. Built in RIMS is the capability to extract information from inline inspection results, CIPS and other assessment results and apply in the risk assessment calculations.

The risk results are shown in tabular as well as graphical format. Risk results can be exported to Microsoft Excel spreadsheet for further detail analysis as needed. However, the risk charting capabilities built within RIMS give PGB a good indication and enough information to plan and strategize the step forward. The histogram charts built within have the facility to “drill down” into the results to help rationalizing the factors that contributes to the risk and/or likelihood and/or the consequence scores. Another way of presenting the risk results is the risk matrix that allows PGB to review the risk status of the pipeline system on a high level basis. Example is as shown in Figure 2.

The risk results are used for assessment prioritizations to assess the threat identify by risk. The integrity assessment results are used as a validation method to ensure that the risk models mirror as close as possible the actual condition of the pipeline. Further customizations or fine-tuning of the models may require depending on the results. Repair and remediation actions follow integrity assessment. The specific actions depend on the nature and severity of the hazard and the operating environment, and may include one or several of the following:

- Pipe replacement;
- Re-coating;
- Repair sleeves;
- Enhancements to the cathodic protection system;
- Pressure reduction (usually a temporary measure);
- Addition or increase in efficiency of inhibitors;
- Increased signage and/or public awareness programs;
- Line lowering, provision of mechanical protection, or increase in depth of cover;
- Increased surveillance; and
- Terrain slope remediation (de-watering, provision of drainage berms, re-profiling etc.)

RIMS allow PGB to perform a cost benefit analysis/What-if scenarios to strategize and optimize the preventive and mitigative actions. The software gives the flexibility to perform the analysis at the segment or pipeline level. Integrating the cost data provided by PGB and the risk assessment methodology, the risk reduction per Ringgit spent is calculated to obtain the highest benefit per Ringgit ratio; as defined below.

\[
\text{Cost Ratio}_i = \frac{\text{Risk Reduction}}{\text{RM / Spent}}_i
\]

where i denotes the repair method mitigation action or prevention action of a specific threat.

Given that integrity management plan is a continuous process, PGB has implemented within RIMS the facility to track changes via the Risk Tracking tool. This tool allows PGB to perform evaluations to track the reduction in the risk score for a specific interval by feeding additional information into the system when information becomes available and/or when mitigation/prevention actions have been taken. Comparisons can be made between risk charts to show the risk reduction due to specific actions taken; as shown in Figure 3.

5. Defect Assessment Module

Upon performing the integrity assessment; by means of inline inspection, direct assessment, hydrostatic testing and/or other assessment methods, these newly available information can be feedback into RIMS via the Inspection Import Data Module within the Defect Assessment Module. Assessment can be carried out on the results found using the B31G or Modified B31G method for metal loss defects. Standard industry acceptance criteria is used to identify locations where existing dents may threaten the integrity of the pipeline. Criteria define in BS7910 Level 1 is used to assess crack in RIMS.
PGB can then use the assessment results to determine the locations where repairs are required and further plan for mitigative/preventive actions as an on-going integrity management plans. Where repairs are required, RIMS has the facility to generate excavation sheet serves as a handy reference material during the repair job. Upon completing the necessary repair according to the industry acceptable methods, RIMS allow PGB to feed field information back into the system, indicate that the defect has been remediated and assessed and should not be threatening the integrity of the pipeline.

6. Corrosion Growth Module

As part of its integrity assessment planning, PGB has performed inline inspections in the past to determine areas where corrosion may occur and the severity of these defects can be assessed. Further the Defect Assessment module, PGB has implemented the Corrosion Growth Module that gives them the ability to calculate the corrosion growth rate for external and internal corrosion using the following theoretical models:
- Full life rate – external/internal defects
- Half life rate – internal defects
- De Waard and Milliams rates

Knowing the need and benefits of threat validation, it is part of PGB’s integrity program to perform field excavations to validate the inline inspection results. In any event that “huge” discrepancy is found and a higher/lower corrosion rate is determined, RIMS provides PGB the capability to apply these corrosion rate to perform corrosion growth on all other corrosion defects detected by the inline inspection. By this means, the re-inspection interval can be maximized. Additionally, the ability to determine and predict the remaining strength of corrosion defects allow PGB to establish corrosion management program that allows them to better define and plan future rehabilitation and operation regimes.

7. Reporting Module

The Reporting Module has been customized for PGB to enable them to produce Excavation Sheets and Management reports based on corporate requirements. The aim of these reports is to minimize the amount of time spent on documentations while ensuring that operations and maintenance programs are communicated effectively at any given management level.

The “Query” function built within RIMS allows PGB to extract information pertaining to a pipeline at an ease of a touch. Query/filtering of the database can be carried out when there is a need to evaluate a subset of data pertaining to specific pipelines. Overall, this allows PGB to gather and integrate different data together with minimum time required.

8. Conclusion

PGB has developed and implemented RIMS on over 2,500 km of pipelines that serves as a data management tool that has the capability to perform integrity assessment; risk assessment, defect assessment and corrosion growth study. The cost-benefit analysis can be performed to maximize the dollar spent on repair, mitigation and prevention activities while not compromising the integrity of the pipeline. With the implementation of this system, PGB has placed itself in the same group among other international pipeline operators.
9. References

1. Risk Integrity Management System (RIMS).
2. Risk Integrity Management System (RIMS) Risk Assessment Methodology.
4. Duraid Alkazraji, “Phase 1 Benchmarking Study of the 2400km PGB Transmission and Lateral Pipeline”.
Figure 1 Interaction Between Modules Built in RIMS

<table>
<thead>
<tr>
<th>Increasing Probability of Failure</th>
<th>Increasing Consequences of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>Minor 1</td>
</tr>
<tr>
<td>Occasional</td>
<td>Minor 1</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Minor 2</td>
</tr>
<tr>
<td>Improbable</td>
<td>Minor</td>
</tr>
</tbody>
</table>

Figure 2 Risk Matrix Implemented in RIMS
Figure 3 Risk Tracking Tool