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The Oldest Geothermal Production Pipeline in Indonesia

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INTRODUCTION

The Kamojang Geothermal Field is the oldest geothermal field in Indonesia, where Pertamina began exploration activities in 1974. Five Geothermal Power Plant (GPP) units have been operating commercially since 1983, with steam supplied through production pipelines owned by Pertamina Geothermal Energy (PGE) Area Kamojang. For more than 40 years, PL-401 which is the oldest production pipeline system has operated without experiencing any significant damage — an outstanding achievement for a geothermal facility that operates under high temperature, high pressure, and highly corrosive conditions. However, several important factors have emerged, necessitating a more comprehensive evaluation of the pipeline's feasibility. These factors include ensuring compliance with applicable standards and regulations, as well as addressing the fact that the operational age has exceeded the original design life, thus requiring verification to confirm whether the pipeline remains safe and reliable for continued operation.

Based on these concerns, a Risk-Based Inspection (RBI) study was conducted with several objectives, including:

. Assessing the structural integrity of the production pipeline after more than 40 years of operation.

. Determining the inspection interval based on wall thickness measurements obtained through Ultrasonic Thickness (UT) testing.

. Estimating the remaining life of pipeline to determine Probability of Failure

METHODS

The condition assessment of the Kamojang production pipeline was carried out using a Risk-Based Inspection (RBI) approach, which focuses on identifying, evaluating, and controlling potential failure risks based on the pipeline's actual condition and possible consequences. The study method includes data collection, UT thickness measurement, Remaining Life Assessment analysis, and Risk-Based Inspection analysis. Based on the analysis results, the risk category for each pipeline segment (low, medium, or high) was determined, along with the inspection priority and interval for the next inspection according to the identified risk level. PoF is determined based on the Remaining Life (RL) of each pipeline segment. The shorter the remaining life, the higher the probability of failure.

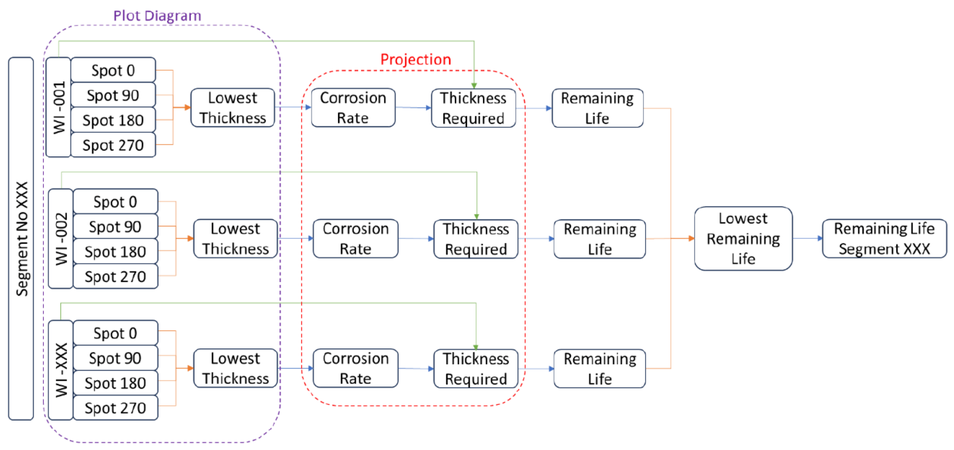


Figure 1. The stages of the Remaining Life Methodology

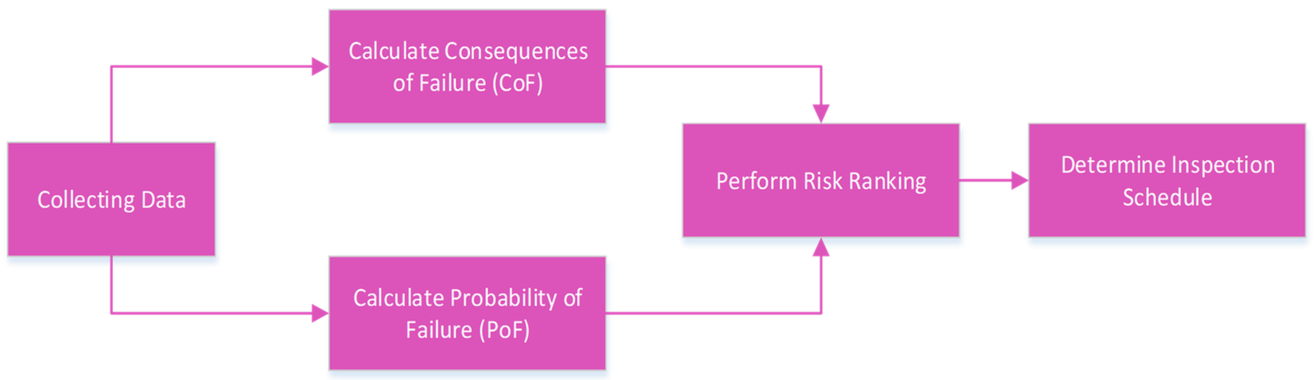


Figure 2. The stages of the Risk-Based Inspection (RBI) methodology

RESULTS

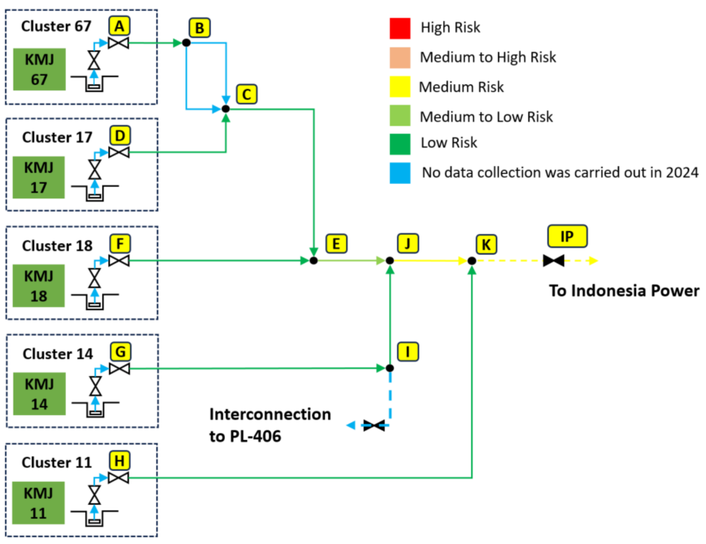


Figure 3. Simplified Segmentation of PL-401 Pipeline by Risk Based

Segment	Representative WI	RBI Inspection Schedule (Years)	SKPP Inspection Schedule (Years)	Recommendation Inspection Schedule (Years)
A - B	401-67-WI-002	10	3	3
D - C	401-17-WI-005	10	3	3
F - E	401-18-WI-004	10	3	3
G - I	401-14-WI-006	10	3	3
H - K	401-11-WI-004	10	3	3
C - E	401-PL-WI-002A	10	3	3
E - J	401-PL-WI-006	8	3	3
I - J	401-14-WI-007	10	3	3
J - K - IP	401-PL-WI-010	8	3	3
J - K - IP	401-PL-WI-011	8	3	3

Figure 4. Recommended Inspection Intervals for Pipeline Segments

The Regulation of the **Director General of New and Renewable Energy and Energy Conservation** No. 387K/30/DJE/2012 concerning the Certification of Equipment Usage Feasibility (SKPP) requires that an inspection be carried out every three years on pressure equipment.

DISCUSSION

The Risk-Based Inspection (RBI) assessment of the PL-401 confirmed that the system remains structurally safe despite over four decades of continuous operation. Most segments were classified within the low to medium risk category, indicating safe and reliable performance. This outcome reflects the effectiveness of robust design, proper material selection, and consistent maintenance management implemented by PGE. The exceptional longevity of the pipeline is primarily influenced by the stable thermochemical conditions of the geothermal steam. In geothermal systems, corrosion and material degradation are strongly affected by thermodynamic parameters such as temperature, pressure, phase condition, pH, and fluid composition (Penot et al., 2023).

At Kamojang, the steam pH remains above 4, representing a relatively near-neutral environment that minimizes acid-induced corrosion. pH values below this level are typically associated with increased metal loss due to higher hydrogen-ion activity (Aristia et al., 2019). At Kamojang also, the geothermal steam has an exceptionally low TDS value, consistent with the characteristics of a dry-steam reservoir. This value is far below even the 'low-salinity' geothermal category (< 1,000 ppm), explaining the minimal scaling and corrosion observed in the PL-401 pipeline over four decades of operation. Besides chemical stability, operational steadiness also contributes to maintaining pipeline integrity. Real-time operational data show that the actual steam velocity in PL-401 segments remains well below the erosion velocity, effectively reducing the risk of erosion, thermal or mechanical fatigue that could accelerate material degradation. This indicates that both design and operation parameters are well-optimized for long-term reliability.

However, several correction and uncertainty factors should be considered when interpreting the RBI results. Potential instrumental errors may arise during ultrasonic thickness (UT) measurements due to calibration deviations or uneven pipe surfaces. Environmental fluctuations, such as minor variations in steam composition or condensate carryover, may locally influence corrosion rates. Human factors, including data handling and procedural inconsistencies, can also affect the reliability of the assessment. To minimize these uncertainties, continuous data validation, instrument calibration, and training of inspection personnel are recommended. Integrating chemical monitoring (pH, TDS, and H_2S concentration) within the RBI framework will improve the accuracy of corrosion prediction models and enable more effective inspection scheduling.

CONCLUSION

The Risk-Based Inspection (RBI) assessment of the PL-401 production pipeline confirms that the system remains structurally safe and operationally reliable after more than 40 years of service.

The favorable steam chemistry—characterized by a stable pH above 4 and moderate TDS—combined with robust material selection and steady operational parameters, has effectively minimized corrosion and fatigue-related degradation.

The RBI approach has proven to be an efficient and data-driven method for evaluating pipeline integrity, prioritizing inspections, and optimizing maintenance intervals. Incorporating continuous chemical monitoring and periodic reassessment will further enhance accuracy and reliability in future evaluations. The Kamojang case stands as a benchmark for geothermal pipeline integrity management, demonstrating how RBI can extend the safe and sustainable operating life of geothermal assets.

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