# MANAGING INTEGRITY OF HIGH PRESSURE GAS PIPELINE: ROOT CAUSE ANALYSIS AND HYDROGEN INDUCED CRACK (HIC) DIRECT ASSESSMENT OF WELDMENT CRACK ON 30" GAS PIPELINE

Mohd Nazmi bin Mohd Ali Napiah - Principal (Pipeline Integrity) - Group Technical Solutions (GTS) PETRONAS, Malaysia
Zaabah bin Abdullah - Specialist Engineer (Pipeline Integrity) - PETRONAS Gas Berhad, Malaysia
Shaidi bin Ahmad - Staff Engineer (Pipeline Integrity) - PETRONAS Gas Berhad, Malaysia
Mohd Nazri bin Ahmad - Staff Engineer (Pipeline Integrity) - PETRONAS Gas Berhad, Malaysia
Mohd Hanif bin Ahmad Fuad - Sr. Engineer (Pipeline Operation & Maintenance) - PETRONAS Gas Berhad, Malaysia

**Abstract:**

## 1.0 Background

PETRONAS Gas Berhad (PGB), a subsidiary of Malaysia's national oil and gas corporation, PETROLIAM Nasional Berhad (PETRONAS), processes, transports and supplies natural gas and utilities to petrochemical plants. PGB through its operating division, Transmission Operations Division (TOD) currently operates and maintains the nation's 2,554 km of high pressure on-shore gas pipelines ranging from NPS 2 up to NPS 48. TOD has been operating the pipelines for more than twenty-six (26) years and has kept good track record with regard to pipeline safety.

One of PGB-TOD's pipelines is the 30" PGU II Sector 3 pipeline which carries high pressure i.e. 45-60 barg sales gas to PETRONAS' customers in southern part of Peninsular Malaysia i.e. power plants and general industries; and as well as point of sales gas export to Malaysia's neighbour country i.e. the Republic of Singapore. The pipeline was designed per ASME B31.8 code, constructed in 1989, commissioned in 1991 and it is coated with FBE coating as primary corrosion control and equipped with ICCP system as secondary corrosion control measure. The pipeline traverses relatively flat land with some part of the R.O.W consists of undulating terrain, the land adjacent to the R.O.W is cultivated with palm oil estates.

In February 2009, the pipeline experienced leak at KP 69.2 and due to fast respond from PGB-TOD's emergency repair crew, it was temporarily repaired using PLIDCO leak clamp without shutting down the pipeline. It appeared that the leak was at the circumferential weld and crack was also evident. Following the temporary repair, in June 2009, PGB-TOD conducted permanent repair by replacing the damaged portion with a pipe spool via hot-tapping and line stopping method.

## 2.0 Root Cause Analysis and Investigation

As prudent pipeline operator, PGB-TOD conducted pipeline leak investigation utilising 5-Why root cause analysis (RCA) methodology in order to find the root cause/s of the leak/failure and eliminate similar occurrence in the future. In RCA investigation and in other to produce a credible outcome, the problem statement is the KEY aspect; the RCA team come up with

several problem statements and finally the management consented on the following problem statement:-

"*Why pipe adjacent to welding joint (HAZ) at KP 69.2, PGU II, Sector 3 pipeline cracked and lead to leak; and resulted in estimated opportunity loss of RM 4 mill. (USD 1.3 mill.)?*"

Based on the problem statement, the RCA team built its RCA tree and established several hypotheses that needed to be proved and/or disprove. In general, the RCA team looked into the design of the pipeline material, the manufacturing of the line pipes, the construction practices in particular welding of the pipes, the operation and maintenance practices in particular overpressure, third party intrusion and stress corrosion cracking (SCC). As part of the investigation, the failed pipe spool was sent for destructive testing in order to gain specific information/data on the crack initiation, the material specifications of the weldment and the pipe, and the hardness level of the pipe, HAZ and the weldment.

At the end of the RCA investigation and based on all evidences, the team concluded that the crack was due to hydrogen induced cracking (HIC) that originated from construction and improper pipe jointing; and the latent cause of the crack could have been from human error i.e. welders and welding inspector were not following the written and approved procedure during the construction of the pipeline. With that, the team put forward several recommendations to the management i.e.:-

i. Weld cracking normally appears 24 to 48 hours after welding completed, therefore:-
   - requirement of performing NDT for field joint welding i.e. after 48 hours needs to be clearly stated in construction procedure,
   - requirement of using low hydrogen electrode needs to be clearly stated in construction procedure, and
   - requirement of having at least two inspectors for field welding inspection and verification to be strongly considered especially for tie-in and golden weld.

ii. To conduct continuous engagement sessions with project team, site supervisors and QA/QC inspectors to brief on past pipeline incidents and lessons learnt.

iii. To conduct direct assessment on PGU II Sector 3 pipeline's circumferential weldments based on conditions similar (i.e. welder/s, welding inspector, type of pipeline welding (tie-ins), located downhill/slope etc.) to the cracked weldment.

## 3.0 HIC Direct Assessment on Weldment

Since there is no technical papers or code or recommended practice on HIC direct assessment, PGB-TOD devised a HIC Direct Assessment method that comprises of the following steps:-

### i. Pre-assessment

a. Established a set of prescriptive criteria to enable team to focus on the issue at hand rather than being too general.
b. The criteria are:-
   i. Weldment welded by same welder/s during construction.
   ii. Weldment that is tie-in and/or golden weld during construction.
   iii. Weldment that has gone through repair i.e. cut-out during construction.
   iv. Pipeline portion that is located at downhill and/or uphill area.
c. Cross referencing with the following records/reports:-

i. Route & Profile as-built drawings.
ii. Tie-in and cut-out reports.
iii. Pipeline welding book.
iv. NDT records during construction i.e. radiographic testing.

d. Utilising PGB-TOD's GIS to identify the locations.
e. Prioritising the weldments for the next step of direct assessment based on pipeline location i.e. in High Consequence Areas (HCAs) as defined in PETRONAS Technical Standard (PTS) 30.40.60.13 – Managing System Integrity of Gas Pipelines (Amendments/Supplements to ASME B31.8S-2004).

**ii. Direct examination**

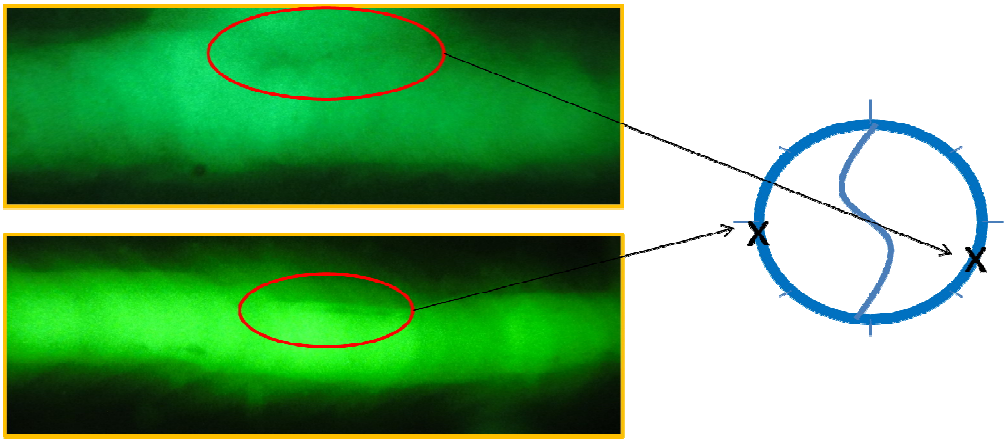
a. Based on the prioritised list, excavations were carried out based on company's procedures, work instructions and HSE requirements.
b. The original field joint coating i.e. heat shrink sleeve was removed and the weldment was cleaned and prepared for NDT.
c. Three NDT methods were employed i.e. radiographic test (RT), ultrasonic test flaw detection (UTFD) and magnetic particle inspection (MPI). Results from NDT were assessed and evaluated based on acceptance criteria from ASME B31.8-2010 Gas Transmission and Distribution Piping System and API 1104-2005 Welding of Pipelines and Related Facilities.
d. If found crack, temporary repair was performed i.e. installation of leak clamp and/or installation of overlapped composite sleeve.

**iii. Post-assessment**

a. Results from the NDT were assessed and evaluated based on acceptance criteria from ASME B31.8-2010 Gas Transmission and Distribution Piping System and API 1104-2005 Welding of Pipelines and Related Facilities.
b. For crack that was unacceptable to the above codes, advance assessment was conducted utilising API 579-1/ASME FFS-1 2007 Fitness-For-Service Part 9- Assessment of Crack-Like Flaws - Level 3 and remaining life assessments. Following the assessments, re-inspection period was determined.
c. If requires permanent repair, it will be conducted per PTS 31.40.60.12 Pipeline Repairs.
d. A comprehensive report will be prepared for future reference.

## 4.0 Summary of Findings from HIC Direct Assessment

| Location | Findings | Remarks |
|---|---|---|
| Tenang | Cracks at 2 locations | 1) 840 mm from 12 o'clock (L: 25 mm, D: 4-6 mm)<br>2) 1600 mm from 12 o'clock (L: 15 mm, D: 4-6 mm) |

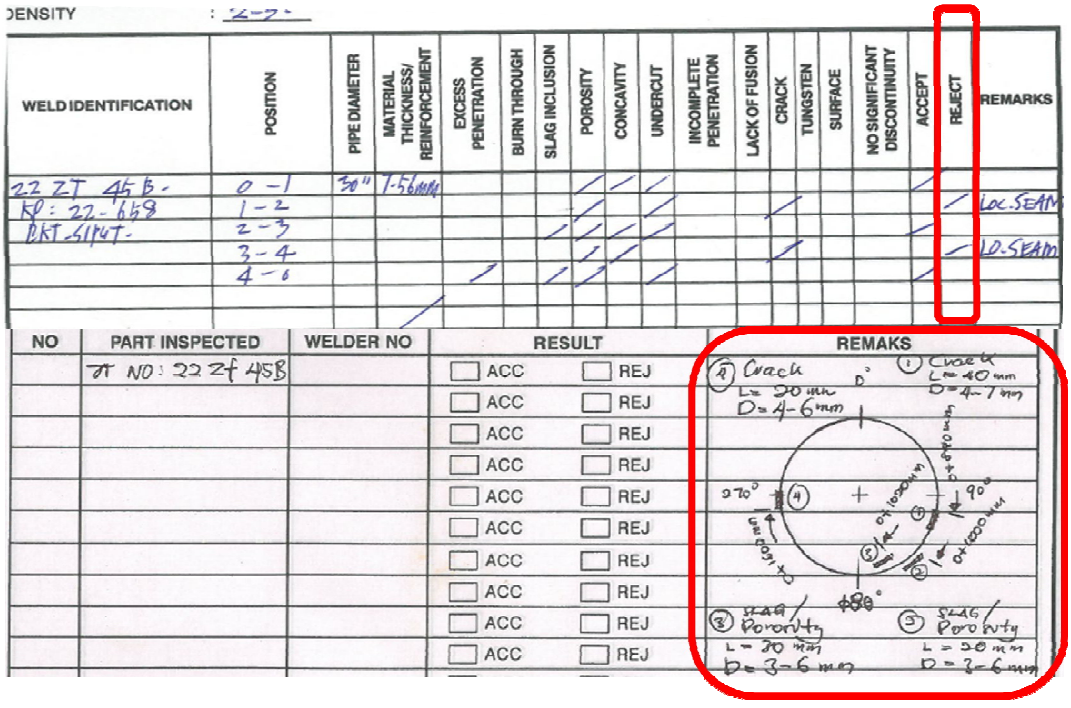



Cracks RT Film  Position of cracks

**Figure 1 – RT films showing crack-like flaws at two locations**

RT report

UT report




10

**Figure 2 – RT and UT reports**

| No | Weld No | Location | Finding |
|---|---|---|---|
| 1 | 22zt45B | Bukit Siput | Confirmed cracks at 2 locations |
| 2 | 39zt16 | | Acceptable |
| 3 | 39zt19 | Tenang | Confirmed cracks at 2 locations |

| | | | |
|---|---|---|---|
| 4 | 43zt41A | | Acceptable |
| 5 | 48zt64 | | Acceptable |
| 6 | 62zt17A | | Acceptable |
| 7 | 65z38c/o | | Acceptable |
| 8 | 99zt22Ac/o | | Acceptable |
| 9 | 151zt68 | Sedenak | Confirmed cracks at 2 locations |

**Table 1 – Prioritised list of weldments**

In conclusion, PGB-TOD has devised an integrated approach in managing integrity of the 30" high pressure gas pipeline by combining RCA and HIC Direct Assessment; the HIC Direct Assessment method was also devised for the purpose of the pipeline and can be utilized for other pipelines that could have similar situation. The approach is proven to be effective in sustaining the reliability and integrity of the pipeline at 99.99% rate which is well above industry standard.

The paper will detail out the RCA steps, trees, hyphotheses and findings; as well as detail out the HIC Direct Assessment at each step i.e. pre-assessment, direct examination and post-assessment.