Case Study on Black powder / Slurry Ingress in Gas pipeline

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MAHANAGAR GAS

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Mahanagar Gas Limited

- Mahanagar Gas Limited (MGL), established in the **year 1995**, is one of the leading Piped Natural Gas (PNG) & Compressed Natural Gas (CNG) Distribution company in India, currently operating in Mumbai & surrounding areas.

- Providing Safe & economical fuel to Domestic, Industries, Commercial & CNG Vehicles.

- MGL has laid down a network of around **600 kms** of High-pressure Steel pipelines.

Black Powder - Background

- Instances of presence of black powder / debris **encountered** in the pipeline network, especially steel, from time to time.
- Initial analysis of the dry debris was found to be a **Magnetite (Fe_3O_4)**
- Further, in Aug'19 due to operational upset on upstream supply side, **Black slurry with liquid ingress and High H_2S** observed at inlet of CGS Wadala.
- Concern was raised for possible effect on the pipeline integrity specially pertaining to the **Internal Health** of the pipeline.

What is Black Powder…..

- Black powder is general term used to describe a range of **corrosion related contaminants** found in pipelines.
- **Appears** in variety of forms - Black / Grey / Brown, wet tar like in appearance or dry / fine powder.
- Removal and management of black powder is typically reliant upon operational **pigging facility**.
- Short radius bends, telescopic type network and numerous tap-off points - **Difficult to pig**.

Challenges are to,

- Identify the locations on the pipeline network where black powder / slurry is **accumulated**.
- Identify the Severity at **hold up locations,** i.e. amount of Black Power / Slurry

Black Powder Management Approach

Phase 1	**Gap analysis** and initial assessment. Review of current operational practices, procedures and operational data.
Phase 2	Detailed Corrosion Threat Assessment (CTA), **Flow Modelling** and Development of Corrosion Management Plan (CMP).
Phase 3	Field verification - Excavation to **validate the flow model results** and corrosion rate observed during Corrosion Threat Assessment (CTA)

Following the principals of ICDA!!

Phase 1 - Pre assessment

- Historical and current operational data was reviewed
- Pipeline design parameters reviewed
- Construction related - Pipe book, Laying reports, Welding reports and Testing
- Corrosion control - Gas sample analysis reports (H_2O, H_2S, CO_2 & O_2)
- Operational data - Pressure, Temperature, Flow range etc.

Normal operation

Parameter	Max recorded
Pressure (Bar)	18.4
Temperature (Deg. C)	32.1
Moisture (PPM)	104
CO_2 (mol %)	2.01
H_2S (PPM)	11 (Occasionally)
Oxygen (PPM)	35

- Occasionally concentration of moisture, H2S & CO2 recorded on higher side.

Upset - Slurry period (Aug'19)

Parameter	Observed
Pressure (Bar)	Dropped up to 9
Temperature (Deg. C)	Dropped up to 20
Moisture (PPM)	1110 (fully saturated)
CO_2 (mol %)	3.02 (0.054 partial pr.)
H_2S (PPM)	86 (0.00021 partial pr.)
Oxygen (PPM)	Within limit

- CO2:H2S partial pressure ratio - 256:1
- Sour conditions if ratio is <500:1
- Gas quality during upset period - Fully saturated / free water.

Phase 1 - Recommendations

- Investigate if there is any threat of Sulphide Stress Corrosion cracking (due to high H2S).

  NDT / PAUT conducted on the above ground piping at CGS Wadala Terminal.

- Regular monitoring of O_2, H_2S and Moisture components in gas.

  Online Gas analyser installed at all CGS for real time monitoring of above constitutes.

NDT / PAUT @ Terminal Piping

- The Wadala CGS - Highest risk to internal cracking and corrosion due to an operational upset. Locations identified with high residual stresses. PAUT helps in,

  - Corrosion and wall thickness scanning.
  - Inspection of weld joints.
  - Inspection of Internal Cracking, if any.

- Result - **No internal cracking was found** at any of the test locations. No Immediate integrity Threats !

Phase 2 - Corrosion Threat Assessment (CTA)

Sr.	Scenario	Description
1	Worst Case	All operational parameters are at the **peak conditions** that would allow for corrosion to occur at its highest rate.
2	Typical Operational Case	Operational parameters are at conditions most likely to be experienced during normal operation.
3a	Typical Operational Case (Upper limit)	Operational parameters are at conditions most likely to be experienced during normal operation, **plus 1 standard deviation**.
3b	Typical Operational Case (Lower limit)	Operational parameters are at conditions most likely to be experienced during normal operation, **minus 1 standard deviation**.
4	Black Slurry upset	Operational parameters are at the **worst-case conditions**, most recorded during the upset period where corrosion would be at its highest rate.

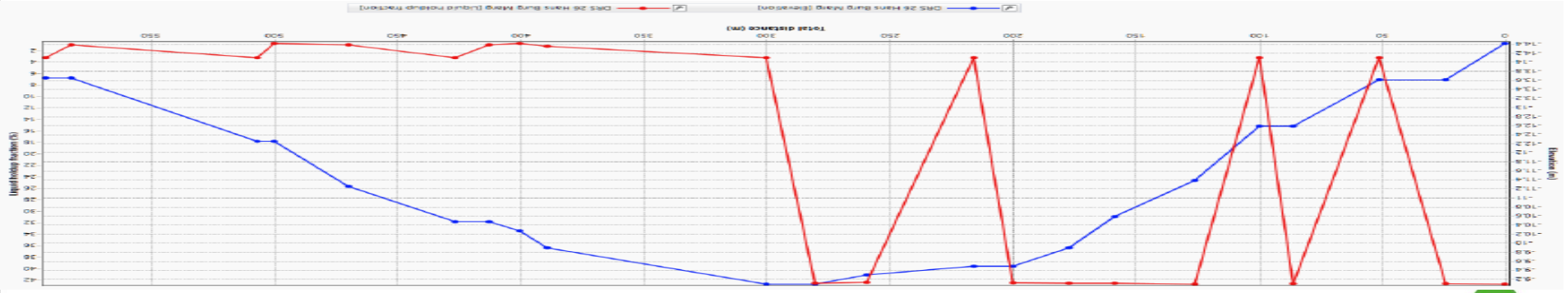
For further analysis, scenario 3a was considered as most appropriate.

Predicted Corrosion Rate

Scenarios		Corrosion Rate (mm / year)	Corrosion Rate Category
1	Worst Case	1.49	Very High
2	Typical Operational Case	0.06	Moderate
3a	Typical Operational Case (Upper limit)	0.09	Moderate
3b	Typical Operational Case (Lower limit)	0.02	Low
4	Black Slurry upset	2.93	Very High

Flow Modelling

- Use of latest **modeling software** - Schlumberger's PIPESIM, Steady State Hydraulic Simulator & OLGAS Phase HD pipeline correlation.
- **Elevation profile** made available in GIS for high pressure steel pipeline network .
- **Comparing** flow modeling results viz a viz actual field conditions (pressure measurement @ outlets).
- Overall **accuracy** of modeling result is about **94%.**



Phase 2 - Corrosion Management Plan (CMP)

Internal corrosion factors	Corrosion control matrix						
	Activity	Frequency	Threshold	Remedial action	Monitoring		
					Green	Amber	Red
CO2 / H2S Corrosion	Monitor moisture and corresponding dew point in gas vs. operational conditions (temperature & Pressure)	Online	The gas shall be free of water Water vapor < 112 ppm	Identify source of upset. Monitor situation, alert relevant superior	Dew point vs. operation ΔT - ≥ 10 °C and Water vapor in gas <112 ppm	Dew point vs. operation ΔT 0° - 10 °C Water vapor in gas <112 ppm	Dew point vs. operational ΔT - <10 °C Water vapor in gas <112 ppm
Sour cracking							
Oxygen Corrosion							
Erosion							
MIC							
Other							

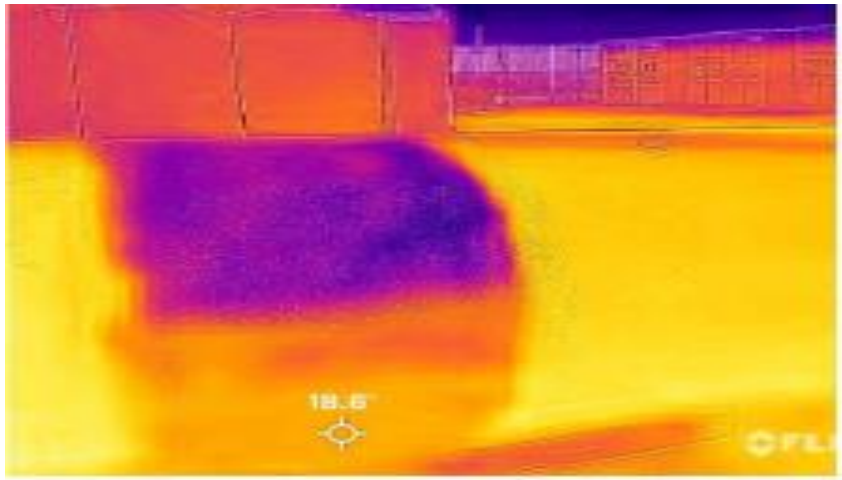
Phase 2 - Summary

- Modelling predicts corrosion rate maximum **0.09 mm per year**.
- The above corrosion rate is considered **moderate** and would be the source of black powder generation in the pipeline. Overall threat of CGS Wadala network is moderate.
- The slurry ingress incident was for short duration, and it was singular event in last 25 years.
- The effect of black slurry upset is not considered to have significant impact on MGL network (Although, corrosion rate was estimated as 2.93 mm / year)
- Similar upsets if repeated frequently, would have more significant effect on gas pipeline network.

Phase 3 - Direct Examination

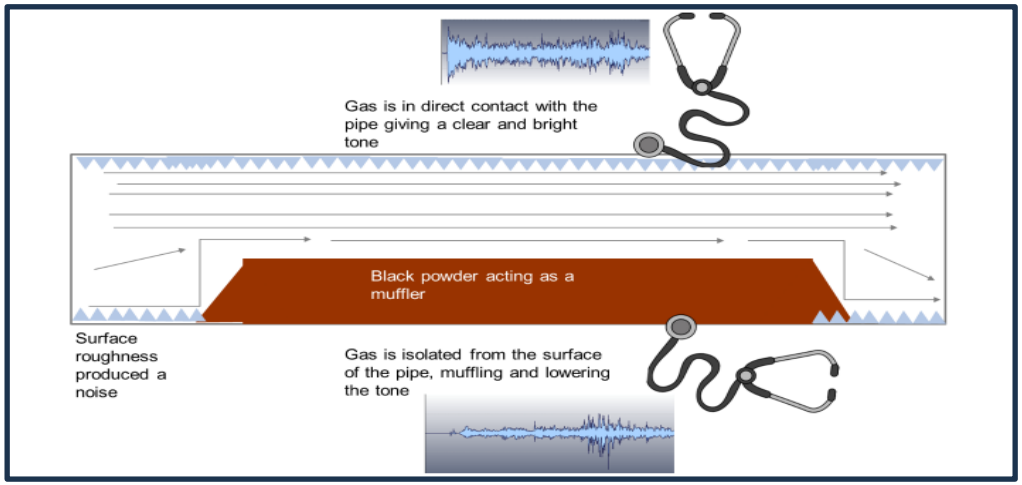
- Few of hold up locations selected for **Direct Examination (DE).**
- Non-intrusive techniques viz**. Thermography & Acoustic Testing** selected for DE.
- Proof of Concept - Both these techniques were **tried and tested in lab**, simulating field conditions.
- Flow modeling results viz a viz field validation - **87%**
- Actual corrosion rate, 0.02 mm / year against predicted modelling corrosion rate of 0.09 mm / year

Thermography



The principal of detection relies upon Joule Thomson Cooling effects and the thermal conductivity / absorption of the solid vs gas.

Acoustic testing



Where debris exists (also known as a static bed), this isolates the inner pipe surface from the flowing gas, muffling the noise and lowering the audio frequency.

Phase 3 - Findings

- **No immediate actions** are required with regards to the internal integrity or presence of black powder.
- Operational monitoring should continue to be conducted with full **implementation of the Corrosion Management Plan (CMP).**
- **KPI monitoring** to identify the possible occurrence of a future operational upset.
- For further design and corrosion monitoring plan, **Scenario 3b (corrosion rate 0.02 mm / year)** is most appropriate.

Conclusion

- The overall effect of Black powder / slurry on pipeline network is NOT significant.
- Black powder generation was mainly due to uniform corrosion rate, further exaggerated by slurry event.
- The generation of Black powder under normal conditions is **NOT** expected to be a significant.

Thank You...

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