# Case Study on Black powder / Slurry Ingress in Gas pipeline

28<sup>th</sup> June 2024



www.mahanagargas.com

#### 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**

- MAHANAGAR
- 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<sub>3</sub>O<sub>4</sub>)
- Further, in Aug'19 due to operational upset on upstream supply side, Black slurry with liquid ingress
   and High H<sub>2</sub>S 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 tapoff 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**





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<sub>2</sub>O, H<sub>2</sub>S, CO<sub>2</sub> & O<sub>2</sub>)
- Operational data Pressure, Temperature, Flow range etc.

Parameter	Max recorded			
Pressure (Bar)	18.4			
Temperature (Deg. C)	32.1			
Moisture (PPM)	104			
CO <sub>2</sub> (mol %)	2.01			
H <sub>2</sub> S (PPM)	11 (Occasionally)			
Oxygen (PPM)	35			

Normal operation

 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 <sub>2</sub> (mol %)	3.02 (0.054 partial pr.)
H <sub>2</sub> S (PPM)	86 (0.00021 partial pr.)
Oxygen (PPM)	Within limit

- CO2:H2S partial pressure ratio 256:1
- Sour conditions if ratio is <500:1</li>
- 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,
- o Corrosion and wall thickness scanning.
- o Inspection of weld joints.
- o Inspection of Internal Cracking, if any.
- Result **No internal cracking was found** at any of the test locations. No Immediate integrity Threats !







Sr.	Scenario	Description
1	Worst Case	All operational parameters are at the <b>peak conditions</b> 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.
За	Typical Operational Case (Upper limit)	Operational parameters are at conditions most likely to be experienced during normal operation, <b>plus 1 standard deviation</b> .
3b	Typical Operational Case (Lower limit)	Operational parameters are at conditions most likely to be experienced during normal operation, <b>minus 1 standard deviation</b> .
4	Black Slurry upset	Operational parameters are at the <b>worst-case conditions</b> , 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**



- 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			MAHANAGAR		
	Activity	Frequency	Threshold	Remedial action		Monitorin	g GAS
Security Reads and a security and a	Tagaalaithtee tagaa		ternetrative Ternetrative Specification and annual of	Name	Green	Amber	Red
CO2 / H2S Corrosion	nitor sture and responding v point in vs. erational ditions		The gas shall be free of water Water vapor < 112 ppm	Identify source of upset. Monitor situation, alert relevant superior	Dew point vs. operation ∆T - ≥ 10 °C and Water vapor in gas <112 ppm	Dew point vs. operation ∆T 0° - 10 °C Water vapor in gas <112 ppm	Dew point vs. operational ∆T - <10 °C Water vapor in gas <112 ppm
(ten Pre:	nperature & ssure)	non na minimum research i minimum research i non na na minimum na minimum	g wataning at any at an	Ngright distance invariantial of grind regions and the second sec	Andream and an and a second of the second and a second an	Control         Control <t< td=""><td></td></t<>	
• Sour cracking	Auroperindust Teach I in Automation Teach I in Automation	nonan Arago Sector particular construction aragonal	Name dellas, antidast specificad Reserve dellas, antidast specificad della contra contractori della co	Agelys Generalized former Agelys Agelys Agelys	Por anting space support of the state support support of the state support suppo	Maniferrature galacentegi yé Kanon Maniferrature ga	energien – stary annexe or ye opract option days n parpenties and a particular days of particular days generic sectors
Oxygen Corrosion	na regenerational de la construir de la constr		Name dang atroduct period at dang atroduct period at dang atroduct period at dang atroduct at an area. Party period period at Neurope Period at an area.	unuk ilongenelek promo	in and the second secon	Ramp parents and gas to the second se	an a
Erosion descent and the second	Sector Places & Artiste Acceptions	manifest data a second	Lapon fina nganjagarina valan adamatika ali nganita a pajarini		na Manayapantana yana di Santa yana ayaa di Santa yana ayaa da sa	Manang PE (A Banang	para di sua da su
• MIC was been and and a second secon	anno agostores "Neu arrapitas" de prima desarra	transferrar to a constant of the second seco	tanto genera anti-ant anti-trag	the second test second	anna ann an a	<ul> <li>Scatter managements</li> <li>Scatter spectra</li> <li>Scatter spectra</li> </ul>	na salajan partang
Produktion and a set of a second set of the seco				Were specific a specific at the specific at			
Other water and the second sec	anarageneter opanisten Agentangen	ona variationaria pressonaria any ara	nan an Aris an Aris an Aris an	under spennenser versen seiner spennenser versen einer stellen seiner versen seiner stellen seiner versen seiner seine	andoroport Mite Manual QL difference difference	analogia ang katalang da ang ang Katalang pang katalang	ha provinsion
	decays word must be dealers. Bits follows	non na maga na ana anarara miga na ana anarara	Natio data protosta protosta data atra contrato data a suborgan suborgan	аралыктару болоот браз авге лагр, Трантон	n Bany generation of Salty generation of the Systems against	umo ang man	g tau
ana	array was and to be an an array	natus segmen sengeripes	Anna Anna Airthean anna Anna Anna Anna Anna Anna Anna A	openseringin hersen openseringin hersen openseringin hersen	n	integr Gi Lanor menangka menangka Lanor ne na na na na na na	per man para tanàna ferrena jaon ao ke a gana tao ara dia dari amin'ny dia

T

11/15

#### 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. 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.

Black powder acting as a muffler Surface roughness produced a noise Cas is isolated from the surface of the pipe, muffling and lowering the tone Where debris exists (also known as a static bed), this isolates the

Acoustic testing

Nahammana Andrewalka Alla waaningana amin'ny salana ka

Gas is in direct contact with the pipe giving a clear and bright



13/15



#### Phase 3 - Findings

- MAHANAGAR GAS
- 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**



5/1

- 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...



MGL House, G-33 Block, Bandra Kurla Complex, Bandra (E), Mumbai - 400051 | T +91 22 6678 5000 | F +91 22 654 0093/ 1046