ABC
COMPANY
LOGO

FAILURE REPORT

CALGARY GGS-STATION 3

01-23-45-6W1 License #XYZ123

Gas Line

Report by

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Cormetrics LTD
A Division of Ammonite Corrosion Engineering Inc.

Job # 13-123
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LINE DATA

COMPANY		**ABC Company**
FIELD		**Calgary GGS-Station 3**
01-23-45-6W2 Pipeline	**To**	**01-23-45-6W1 Pipeline**
License Number		XYZ123
Failure Date		11/07/2013
Internal Diameter	mm	265.9
Line Length	km	1.3
Service Years	Years	62.0
Corrosion Rate (to failure)	mpy	2.3
Gas	E^3m^3/d	3.0
Chloride	mg/l	1530
Pressure	kPa	275
Temperature	^oC	18
Gas - CO_2	Mole %	0.27
Gas - H_2S	Mole %	0.0012
FLOW CONDITIONS		
Vsl	m/s	0.000
Vsg	m/s	0.2
Uphill Flow Regime		**Slug**
Downhill / Horizontal Flow Regime		**Stratified**
Flow Regime (Reynolds)		**LAMINAR**
Line Volume	m^3	73.3
Net Holdup Volume	m^3	0.05
Mean Fluid Retention Time	Hr/km	86.33
Va / Ve		0.00
CO_2 Corrosion Rate	mpy	**1.1**
Stability Index (Oddo Thomson)		0.5
pH (Thomson)		8.29
Aqueous CO_2	mg/l	12
Aqueous H_2S	mg/l	0

1 Introduction

A sample of failed 10” (273.1 mm) pipe was received from ABC Company GGS Station 3 field at location 01-23-45-6W1. This line is licensed under #XYZ123. Cormetrics Limited was retained to investigate the cause of the failure and document the sample condition.

2 System Description

This gas system is approximately 62 years of age. The license has experienced 8 failures, three of which were on this line. Line length is 1.32km, transporting 3 e^3m^3/day gas. No water or hydrocarbons volumes are reported. The gas phase is expected to contain 0.27% carbon dioxide and 12 ppm of hydrogen sulphide. Pipeline material is API 5L Grade A, 273 mm diameter with a 3.6 mm wall thickness.

The line operates at 15-20˚C and 275kPa with a MOP of 410kPa. Pipe internal is bare steel with external tape wrap and cathodic protection. Lines are equipped with drip pots and are non-piggable. Corrosion mitigation is achieved with upstream treatment using INHIBI-PRO inhibition sticks, placed at varied locations. There is injection of methanol for hydrate control.

The failure occurred in a low spot at a pipeline elevation incline upstream of the header. The line has low gas flowrates and little produced fluids. Calculated gas velocities are 0.2m/s putting the line in a laminar flow condition and requiring fluids to be displaced up inclines as a slug. The mean fluid retention time is 86hrs/km which is indicative of low produced fluid volumes.

Based on a service interval of 62 years the failure corrosion rate is equivalent to 2.3mpy. Calculated DeWaard Milliams corrosion rate was 1.1 based on carbon dioxide level and system operating pressures.

3 Water Analysis

The water analysis from the treater at 01-23-45-6W4 was used as a representative sample for water that would be found in the line. The brine has a very low TDS (5091 mg/L) and chloride level (1530 mg/L). It had a neutral pH at the time of sampling and a large buffering capacity due to the high bicarbonate level (1910 mg/L). The water is not predicted to be overly corrosive due to the neutral pH and low CO_2 concentration. The water chemistry demonstrates a slight barium sulphate scaling tendency based on the low available sulphate. There is also a weak tendency for calcium carbonate due to the elevated system pH. Analysis indicates the majority of water would be water of condensation based on its composition.

4 Sample Description

The sample of 10 inch (273.1 mm) pipe received was 76cm long. Flow direction was indicated on the sample with field markings on the sample labeled as

'SOUTH' and 'NORTH' (see figures 1-2). Flow being expected from the south to the north end.

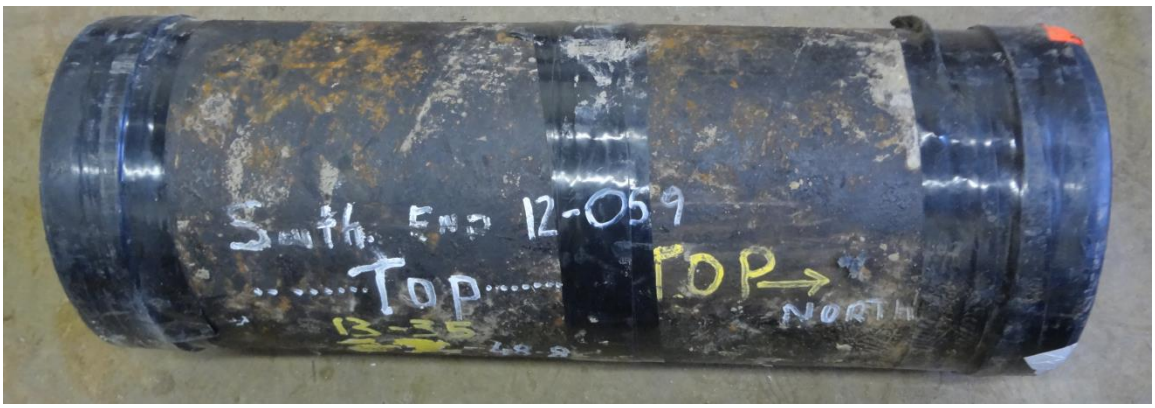

Figure 1: Sample as Received

Based on the indicated orientation the failure had occurred at the 6 o'clock position 41.5cm from inlet. The failure was encompassed with black electrical tape.

Figure 2: The failure after the black tape was removed

The internal surfaces were laden with a thick, dark grey slimy sludge. The substance was wet, had a foul odour and was somewhat runny. Due to the odour and abundance of deposition, a Hydrogenase test was conducted to assess if bacteriological matter was present. The test proved negative for active bacteria.

Figure 3: Heavy Deposition of Solids

Pictures were taken of the sample as received and after a 20 cm segment had been removed for analysis at the failure location. The sample was split at 3 and 9 o'clock to perform a detailed assessment of the internal defects.

Figure 4: External walls after splitting

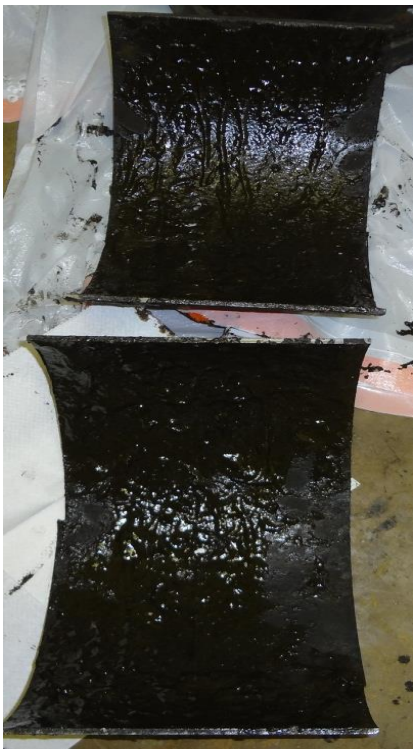

Figure 5: Internal walls after splitting

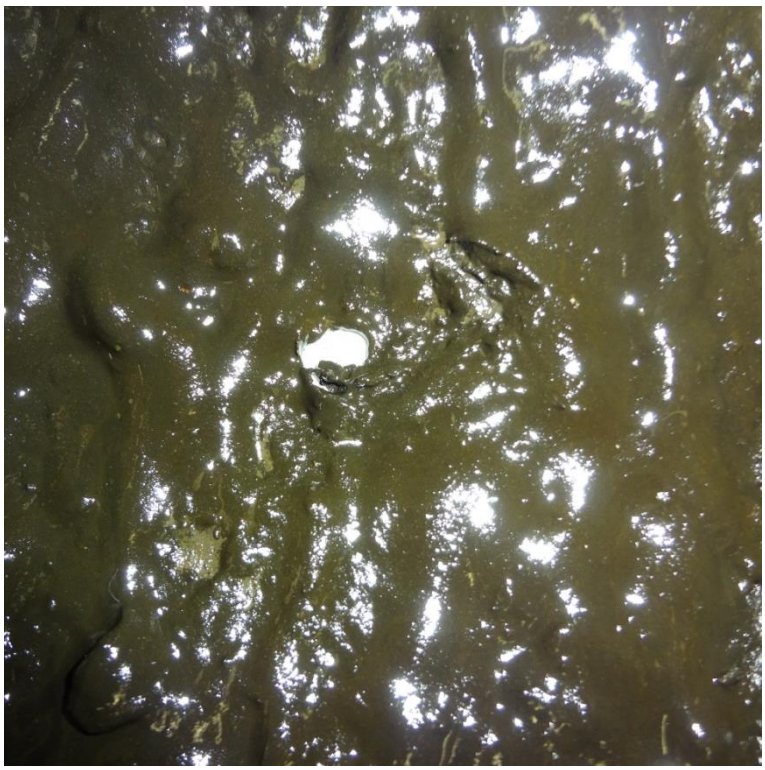

Figure 6: Internal failure prior to cleaning with heavy deposition

A deposit sample was collected from the pit for X-Ray Diffraction analysis. A sulphide spot test was performed prior to cleaning and indicated a positive result.

Figure 7: Positive result of Sulphide test

5 Sample Examination

The sample was first cleaned with Varsol to remove all hydrocarbon residuals and then cleaned with inhibited hydrochloric acid to remove corrosion products. When immersed in the acid bath the scale exhibited only a slight effervescence. The scale was relatively easy to remove, requiring only light scrubbing and soaking. A slight sour odour was noted during the acid cleaning.

The following series of photographs illustrate the defect morphology with the most severe corrosion being in 6:00 o'clock location.

Figure 8: External walls after acid cleaning

Figure 9: External failure close-up after acid cleaning

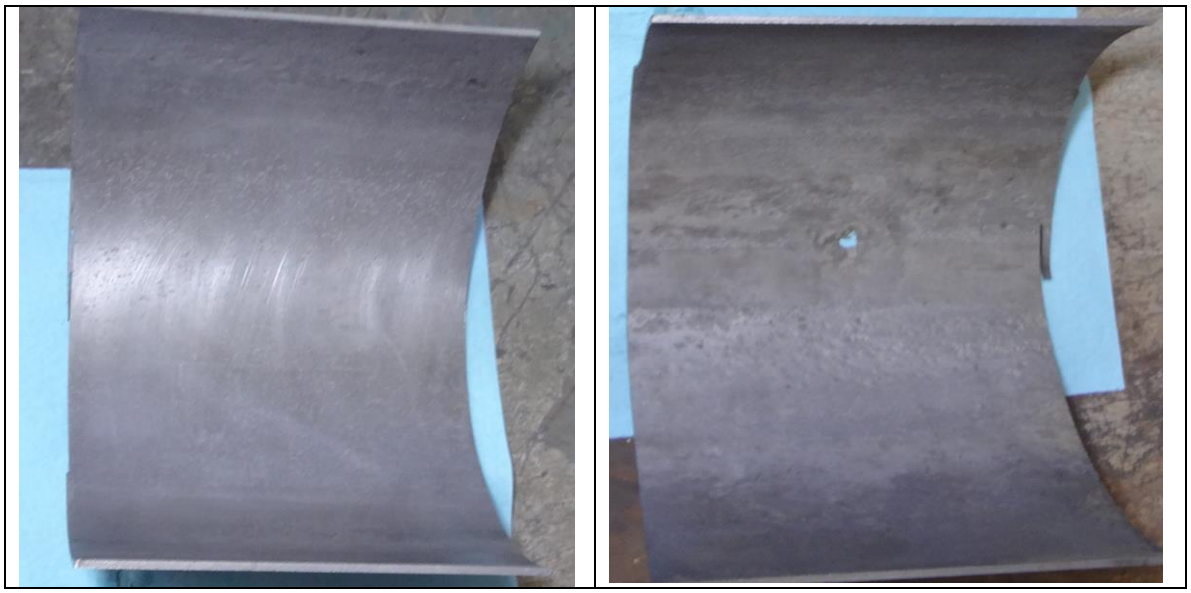

Figure 10: Internal walls after acid cleaning

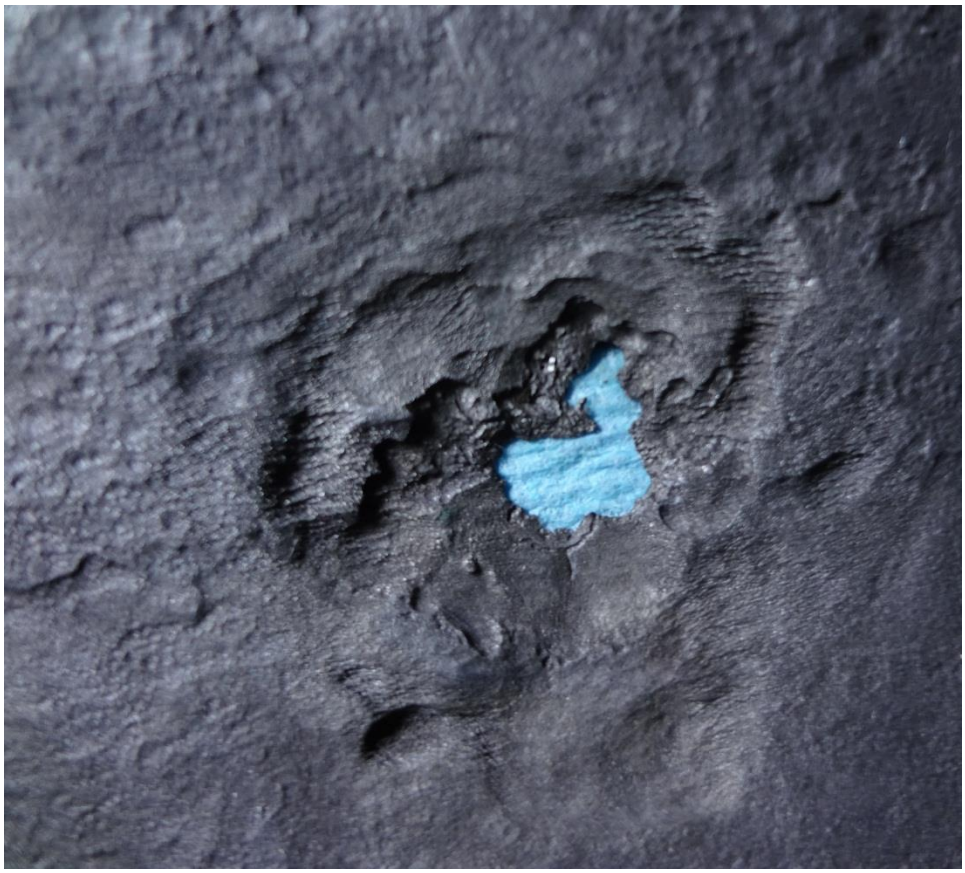

Figure 11: Internal failure close-up after acid cleaning

ERW was at the 9:30 o'clock position. The failure pit measured 34mm in length, 41mm in width and was through wall.

6 X-ray Diffraction Analysis

A sample of the pit scale from the failure was removed for analysis with X-ray diffraction. The reflections obtained from the diffraction pattern were matched to the standard patterns for siderite (iron carbonate), goethite (iron oxide hydroxide), cohenite (iron carbide), paraffin (wax) and mackinawite (iron sulphide). The abundance of each crystalline phase was estimated from the peak intensities and is shown in Table 1.

Compound	Chemical Formula	Abundance
Siderite	$FeCO_3$	50-60%
Goethite	FeO(OH)	15-25%
Cohenite	Fe_3C	5-15%
Paraffin	$(CH_2)_X$	5-15%
Mackinawite	FeS	2-8%

Table 1: Composition of pit wall scale

Siderite is a product of CO_2 corrosion. Goethite can be a reaction product from exposure of iron sulphides to air and is more likely to form in systems with low chloride levels. Cohenite is a remnant of the carbide in the steel. Mackinawite is a product of H_2S corrosion or the reaction product of dissolved iron precipitation in a sour system. The presence of paraffin indicates there are some liquid hydrocarbons present in the production.

7 Corrosion Mechanism

Corrosion activity was most severe to the bottom of the line. The top quadrant had frequent isolated etching attack with corrosion becoming more pronounced at the 2 and 10 o'clock positions. From 5 to 7 o'clock there was a continuous area of general corrosion including the through wall pitting attack in the 6 o'clock position.

The primary corrosion mechanism was an under deposit type of attack, CO_2 was the driving mechanism for corrosion. The majority of the corrosion by-product was siderite from CO_2 corrosion. The produced brine is high in bicarbonate which may reduce the rate of corrosion. Goethite in the corrosion product is most likely oxidized iron sulphides. Spot tests on the wall of the sample indicated a positive for sulphide deposits and this was confirmed in the XRD analysis.

8 Conclusions

8.1 Corrosion mechanism is under deposit attack driven by carbon dioxide.

8.2 There was a large amount of easily removed deposition in the line.

8.3 Flow characteristics within the line are extremely low allowing water and solids to build up in the line and there is no means for their removal besides the installed drip pots.

9 Recommendations

9.1 Consider a line clean out to remove loosely adherent deposits or installation of pigging facilities to accomplish the same goal.

APPENDIX I
WATER ANALYSIS

COMPANY:		**ABC Company**
FIELD:		**Calgary GGS-Station 3**
SAMPLE DATE:		**July 6, 2012**
CHEMICAL COMPONENT		
CHLORIDE (Cl)	(mg/l)	1530
SULFATE (SO4)	(mg/l)	3.7
CARBONATE (CO_3)	(mg/l)	0
BICARBONATE (HCO_3)	(mg/l)	1910
CALCIUM (Ca)	(mg/l)	8.16
MAGNESIUM (Mg)	(mg/l)	1.89
IRON (Fe)	(mg/l)	4.94
MANGANESE (Mn)	(mg/l)	0.09
BARIUM (Ba)	(mg/l)	5.07
STRONTIUM (Sr)	(mg/l)	1
POTASSIUM (K)	(mg/l)	6
SODIUM (Na)	(mg/l)	1620
DISSOLVED SOLIDS (TDS)	(mg/l)	5091
SPECIFIC GRAVITY		1.0033
TEMPERATURE	(^oC)	18
STABILITY INDEX (TOMSON-ODDO)		0.54
PRESSURE	(kPa)	275
pH CALCULATED (TOMSON)		8.29
SURFACE pH		7.00
SCALING TENDENCIES		
gm/M3 CACO3 (TOMSON-ODDO)		14.1
gm/M3 BASO4 (TOMSON)		2.0
gm/M3 CASO4 (TOMSON)		-3944
gm/M3 SRSO4 (TOMSON)		-237.2
Anion /cation ratio		**-2.1%**