Petroleum & Coal
ISSN 1337-7027
Available online at www.vurup.sk/petroleum-coal
Petroleum & Coal 54 (1) 1-8, 2012

AN INNOVATIVE APPROACH TO MANAGING THE INTEGRITY OF OIL AND GAS PIPELINES: PIPELINE INTEGRITY MANAGEMENT SYSTEM

M. A. Usman[1]* and S. E. Ngene[2]

[1] *Department of Chemical Engineering, University of Lagos, Akoka, Lagos, Nigeria*
[2] *Department of Petroleum Resources, Lagos, Nigeria, *corresponding author: mawwal04@yahoo.com; musman@unilag.edu.ng*

Received August 17, 2011, Accepted January 5, 2011

Abstract

In the oil and gas industry, management of the integrity of pipeline has grown to become a serious business because of the overall consequence of pipeline failure: economic, social, environmental, and possibly legal. This research is an attempt to check pipeline failures by carefully following a suite of activities. This suite of activities, also called Pipeline Integrity Management System (PIMS), is generated for an operational pipeline and populated with data gathered on the pipeline system. An analysis of the data collected on the pipeline over a period of five years indicates improved monitoring, reliability, availability, and compliance to regulatory guidelines in the operation of the pipeline systems.

Key Words: Pipeline; Failure; Integrity; Management; System.

1. Introduction

In the past, management techniques for pipelines were minimal. In general, pipelines were typically not maintained regarding their structural integrity until a failure occurred, at which time either the failed section, or the entire pipeline would be replaced. These pipelines may have been inspected at planned outages, at which time obvious problems were typically repaired. Systematic methods of managing pipe, pipelines, or pipe systems were not used to anticipate failures and attempt to conduct preventive maintenance or replace the pipe before failure occurs [1]. The approach of fixing the pipeline when it fails may not be acceptable in cases where burst of pipe may lead to huge damage to property or injury to people, or where loss of the fluid would have deleterious environmental consequences. The upward and continuous surge in the cost of energy will also compel the operator to make appropriate plans to avoid production down time due to pipeline failures. A pipeline integrity management program is needed for these pipeline systems to increase their reliability and availability, and to effectively manage and minimize maintenance, repair, and replacement costs over the long run.

Pipeline Integrity Management System is an innovative approach to generate a suite of activities required to properly manage pipeline assets so as to deliver greater safety by minimizing risk of failures, higher productivity, longer asset life, increased asset availability from improved reliability, lower integrity related operating costs, and ensure compliance with the regulations. Pipeline Integrity Management Systems are developed to serve unique operational needs peculiar to particular pipeline system. For new pipelines systems, the functional requirements for integrity management shall be incorporated into the planning, design, material selection, and construction of the system. However, for pipelines which are already in operation, the integrity management plan is drawn after baseline assessments and data integration. An integrity management program provides the operator with information to effectively allocate resources for appropriate prevention, detection and mitigation activities that will result in improved safety and reduction in the number of incidents [2].In the development of the Pipeline Integrity Management Systems, the integration of information from some relevant sources with the evaluated results of integrity assessment on the pipeline system is necessary. The operator will normally use a risk-based approach in prioritizing repair and maintenance activities, and thus the need to identify the location, nature and relative risk of features that could threaten the integrity of each pipeline segment beforehand. In Nigeria's oil and gas industry, the development of a plan for the maintenance of the pipeline system is a requirement for the grant of Oil Pipeline License to the pipeline system. On this instance, the Pipeline Integrity Management System is preferred to any other form of plan: it has the capacity to manage all known type of operational difficulties with pipeline failures.

2. Methodology

2.1 The Pipeline System

This work relied on System A (Table 1), a major crude oil export pipeline, to show the effectiveness of the Pipeline Integrity Management System (PIMS) in providing availability, reliability, and regulatory compliance for oil and gas pipelines. The pipeline system was commissioned in 1971 with a crude oil export capacity of 550 Kbpd and had operated till 2005 without a formal integrity management plan. External corrosion, internal corrosion, and fatigue cracking were the most likely deterioration mechanisms for this pipeline system. CO_2 and Sulfate Reducing Bacteria (SRB) are the key internal corrosion agents. Stagnant water is swept from pipeline by high flow rates thus making water unavailable to sustain SRB growth.

2.2 The Process

The process could be summarized in the chart below:

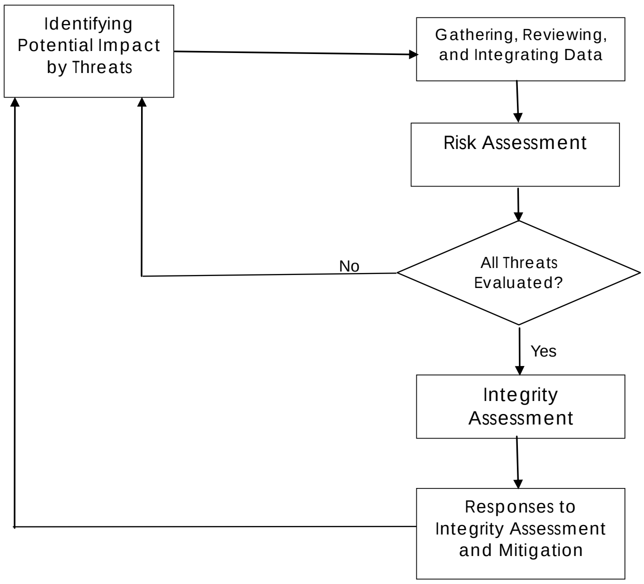

Fig. 1 Integrity Management Process Flow Diagram [2].

Based on the Chart above, the following tools were generated for the pipeline:

i. Segment Data for System A (Table 1) shows the necessary pipe attributes, design and construction information as well as some vital operational data. These information are required to fully define System A.

ii. Integrity Assessment Plan (Table 2) which is focused on the major threats on the system: external corrosion, internal corrosion, fatigue cracking, and to a lesser extent third party damage. Operational information and regulatory compliance were used as guides in determining integrity assessment intervals for the identified threats. Mitigative measures suggested were also dependent on the outcome of the assessment and are as stated in the plan. The Failure Mode and Effect Analysis (FMEA) is evaluated using the Risk Matrix in the Appendix B. The Likelihood of Occurrence (LOO) and the Consequence of Failure are obtained from the Risk Matrix and recorded on the MRP.

iii. Maintenance Reference Plan (Table 3) activities are scheduled with keen interest on checking external corrosion, internal corrosion, and 3rd party damages [4]. CO_2, H_2S, and SRB are key internal corrosion agents and thus were be properly monitored through the plan to ensure reliability and availability of the pipeline system. Pigging, CP installation and upgrade, inhibition, and other corrosion control activities are included in plan [3,4].

iv. The Integrity Verification Plan (Table 4) considered a five-year review period for the system (2005 – 2009). The Technical Integrity Indicators and Performance Indicators (PI) for the various activities were calculated and recorded to indicate the integrity status of the pipeline and the degree of execution of the prepared MRP. The overall integrity of the pipeline indicates that it is still fit for purpose at its de-rated operating pressure of 400 psi.

v. The performance Measurement Plan (Table 5) shows a 5-year plan which could lead to verifiable deductions that PIMS leads to improved monitoring and management of the system's failures and repairs. There is marked reduction in failure rates, leaks, and volume of fluid spilled and subsequently the total number of repairs but an increase in the percentage of planned of planned activities completed as well as action that impacted safety as the year progressed.

3. Results

The summary of the recorded effect of PIMS is shown in the table below:

Indices for Evaluation	Year					
	2000	2005	2006	2007	2008	2009
Volume of Fluid Spilled (Barrels)	4000	2400	1100	600	400	100
Repair Actions due to Direct Assessment Results	3	7	6	5	4	2
Leaks due to Pipeline Failures (willful damage not included)	4	2	1	1	1	1
Actions Completed which Impact on Safety	1	4	6	9	10	12
Anomalies Found Requiring Mitigations	12	8	7	6	5	4

4. Conclusions

The current continuous and sustained increase in the price of steel has placed the cost of steel pipes in international markets in a continuous hike and thus the reason for series of cost reviews in most recent pipeline projects. The availability and reliability of pipelines for operations are threatened by pipeline failures. Environmental degradation due to spills from line failures has also created a regulatory demand for new and operating pipeline systems to be appropriately monitored. These are obvious reasons why generation and implementation of Pipeline Integrity Management System for oil and gas pipelines is necessary.

This research work generated Pipeline Integrity Management Systems for System A, an operating pipeline system. The effectiveness of PIMS was monitored over five years period using the information from the operating System A whose operator has been taking some actions considered components of PIMS in the last six years to ensure reliability and availability of the pipeline. Evaluation of the results generated from the PIMS for the operating pipeline system using the review period indicated improvement on the threat situation and failures observed as the years progressed. This corresponds to decrease in anomalies requiring repairs not minding that the pipeline system is already past its design life. It is an indication of how important PIMS is to the life of an operating pipeline. In all, PIMS has been found to be effective tool for resources allocation in the prevention, detection, and mitigation activities that will lead to improved safety and reduction in the number of incidents on pipeline systems.

References

[1] Pittalwala, S.H and Wittas, D. J (2006) "System and Method for Pipeline Reliability Management" Patent No: US 7,043,373 B2.

[2] ASME B31.8s (2001). "Managing System Integrity of Gas Pipelines" Supplement to ASME B31.8.

[3] Mobil Producing Nigeria Unlimited (2008): Presentation to Department of Petroleum Resources (DPR) on "Critical Crude Pipeline Segments Replacement".

[4] Shell Petroleum Development Company of Nigeria Limited (2006): A Presentation to the Department of Petroleum Resources on "PIMS Engagement".

[5] API Recommended Practice 1160: "Managing System Integrity for Hazardous Liquid Pipelines" First Edition (August 2001).

APPENDIX A

Table 1 Segment Data for System A

Segment Data	Type	
Pipe Attributes	Pipe Grade	API 5L X60
	Nominal Diameter	42”
	Wall Thickness	12.7mm
	Manufacturer	N/A
	Date of Manufacture	N/A
	Seam Type	Spiral Welded
Design/Construction	Operating Pressure	280 psi
	Design Pressure	720 psi
	Coating Type	Coal Tar/Cement
	Coating Condition	Good
	Pipeline Commission Date	1971
	Joining Method	Electric Arc Process
	Medium Type	Offshore
	Hydrostatic Test	890 psi
Operation	Design Temperature	0 - 80^{o}C
	Process Fluid Temperature	25^{o}C
	Crude Quality	^{o}API=36.8
	Flow Rate	550 KBPD
	Planned Repair Method	Replacement
	Leak/Rupture History	3rd Party Damage / Corrosion
	Cathodic Protection	Sacrificial Anode
	SCC Indications	Yes

Table 2 Integrity Assessment Plan

Threat	Criteria/Risk Assessment	Integrity Assessment	Mitigation	Interval
External Corrosion	Some external corrosion observed	Conduct hydrostatic test or perform Direct Assessment	Replace / Repair locations where CFP is below 1.25 x MAOP.	10 Years
Internal Corrosion	Internal corrosion is suspected	Conduct in-line inspection	-do-	5 Years
Fatigue Cracking	Potential concern for fatigue cracking of spiral weld pipe	Conduct hydrostatic test	Replace / Repair pipe at failure locations	10 Years
Manufacturing	No Manufacturing issues	-do-	-do-	N/A
Construction/Fabrication	No Construction/ Fabrication issues	None Required	N/A	N/A
Equipment	No Equipment issues	-do-	-do-	-do-
Third Party Damage	3rd party damage is observe	Conduct hydrostatic test, perform ILI and observe repaired locations	Replace / Repair pipe at failure locations	After every repair/replace ment due 3rd damage
Incorrect Operations	No incorrect operation issues	None required	N/A	N/A
Weather & Outside Force	No Weather/Outside Force issues	-do-	-do-	-do-

Table 3 Maintenance Reference Plan

Line	System A Export Pipeline		
Pacer ID	SYS A 003	Dia (")	42
Service	Oil	Installation Date	1971
Environment	Offshore	MRP Review Date	

Failure Mode and Effect Analysis

Failure Mode	LOO	COF	Remarks
External Corrosion	M	5	
Line Blockage (Sand)	L	4	
Line Blockage (Scale)	L	4	
3rd Party Damages	M	5	
Internal Corrosion	H	5	
Line Piggability (Y/N)	Yes	Last IP (2005)	Next IP (2010)
	No	Last UT ( )	Next UT ( )

MRP Activities

No	Activity Title	Frequency	Comment
001	Offshore CP Potential profile and anode condition survey	Six Monthly	Replace missing / faulty anodes
002	Offshore CP shore approach survey	-do-	
003	Offshore risers CP survey	-do-	
004	Offshore riser coating survey	Annually	
005	Offshore line position survey	-do-	
006	Non-supported span survey	5 Yearly	
007	Routine pigging	Monthly	Debris > 0.5 kg; Mechanical de-scaling before IP.
008	Non-routine pigging	As Required	
009	Third party damage	Monthly	
010	H_2S Monitoring (MIC)	Six Monthly	H_2S and pH Measurement
011	Biocide Treatment & Bacteria Count	-do-	Check effectiveness on SRB
012	Water Chemistry	Six Monthly	
013	CO_2 corrosion rate prediction	-do-	
014	Oxygen Ingress Control	As Required	
015	Acid Corrosion Control	-do-	pH check
016	H_2S Monitoring (Sour Service)	Six Monthly	
017	Impingement /Erosion Monitoring	As Required	
018	Intelligent Pigging	5 Yearly	
019	ROW Surveillance & Maintenance	Quarterly	
020	Valve Maintenance	Annually	
021	Inspection of offshore manifolds and piping	-do-	
022	CP System Upgrade	-do-	Follow the recommendation of CP System Audit
023	Pipeline equipment condition survey maintenance	Annually	
024	Operational Control	As Required	
025	Manifold painting	5 Yearly	
026	Corrosion Inhibition	As Required	
027	Corrosion Monitoring	Six Monthly	
028	Protection of Mothballed pipelines	-do-	
029	CP System Audit	-do-	

Table 4 Integrity Verification Plan

Line	42” System A Export Pipeline				Wall Thickness (mm)	12.70
Pacer ID	SYSB 03	Coating	Coal Tar /Concrete		Diameter (“)	42
Service	Oil	Length (Km)	35.00		Commissioning Year	1971
Environment	Offshore	Grade	API 5L X60		Reviewer	SN
Third Party	*Technical Integrity Indicator*			*PI*	*Comments*	
	Period	Sabotage	Mech. Damage			
	09/04-08/05	4	1	70%		
	09/05-08/06	3	1	60%		
	09/06-08/07	2	0	50%		
	09/07-08/08	2	1	60%		
	09/08-08/09	2	1	60%		
Internal Corrosion	*Technical Integrity Indicator*			*Last IP*	*2005*	*Comments*
	Year	Repairs	MRP	Yes/No	PI	
	2005	3	CO_2 Meas.	Y	100%	
	2006	2	H_2O Chem	N	0%	
	2007	2	H_2S Check	Y	50%	
	2008	1	pH Check	Y	60%	
	2009	1	Biocide Treatment	Y	75%	
			Bacteria Count	Y	50%	
			Sampling	Y	100%	
			Inhibition	Y	75%	
External Corrosion	*Technical Integrity Indicator*					*Comments*
	Year	Repairs	MRP	TII	PI	
	2005	0	CP main stations		75%	
	2006	2	Test post checks		100%	
	2007	0	CIPS		50%	
	2008	1	CP Audit		50%	
	2009	1	Riser Survey		75%	
			Coating Survey		100%	
Failure of Ancillary Equipment				*Operational Error*		
	During period of review four (4) ancillary equipment failures occurred				None	
Overall Integrity Status						
	The pipeline which has been de-rated to 400 psi is still fit for purpose.					

Table 5 Overall Performance Measurement Plan

S/N	Description	2005	2006	2007	2008	2009
1	Km of pipeline inspected Vs Integrity Management Program requirement	40%	50%	70%	80%	85%
2	Integrity Management Program Changes requested by authorities	8	5	3	2	1
3	Percentage of planned activities completed	40%	55%	70%	75%	80%
4	Fraction of the system included in Integrity Management Program	0.4	0.5	0.7	0.8	0.85
5	Actions completed that impact safety	4	6	9	10	12
6	Anomalies found requiring repairs / mitigation	8	7	6	5	4
7	External corrosion leaks	2	0	1	0	0
8	Internal corrosion leaks	3	2	2	1	0
9	Leaks due to equipment failures	2	1	1	1	1
10	Leaks due to third party damage	3	4	4	2	2
11	Leaks due to manufacturing defects	0	0	0	0	0
12	Leaks due to construction defects	0	0	0	0	0
13	In-service Leaks due to stress corrosion cracking	1	0	0	0	0
14	Repair actions taken due to In-Line Inspection results	0	0	0	0	0
15	Repair actions taken due to direct assessment results	7	6	5	4	2
16	Hydrostatic test failures caused by external corrosion	0	1	0	0	0
17	Hydrostatic test failures caused by internal corrosion	3	2	2	1	0
18	Hydrostatic test failures due to manufacturing defects	0	0	0	0	0
19	3rd Party damage events detected	3	2	4	2	3
20	Unauthorized crossings	2	0	0	1	0
21	Precursor events detected	1	2	3	3	4
22	ROW encroachments detected	1	2	2	3	2
23	Re-rating of pipelines	0	1	0	0	0
24	Segments with deeper pitting than before	0	0	0	0	0
25	Volume of fluid spilled	2,400	1,100	600	400	100

APPENDIX B

Risk Matrix for Pipeline Systems

	CONSEQUENCES				INCREASING LIKELIHOOD				
					A	B	C	D	E
Severity	**People**	**Assets**	**Environment**	**Reputation**	Never heard of in …… the industry	Heard of in …… the industry	Incident has occurre d in our compan y	Happens several times per year in our company	Happens so many times a year in a location
0	No health effect/ injury	No damage	No effect	No impact					
1	Slight health effect/ injury	Slight damage	Slight effect	Slight impact					
2	Minor health effect/ injury	Minor damage	Minor effect	Limited impact		Low Risk			
3	Major health effect/ injury	Localise d damage	Localised effect	Considerabl e impact			Medium Risk		
4	PTD or 1 to 3 fatalities	Major damage	Major effect	National impact					
5	Multiple fatalities	Extensiv e damage	Massive effect	Internation al impact				High Risk	

Note: The Risk Matrix has three (3) risk classes: Low (L), Medium (M), and High (H).
The Likelihood of Occurrence (LOO) uses these 3 classes of risks.