CEOCOR 2016 CONGRESS
International Conference and Exhibition in the Field of Corrosion and Cathodic protection
17-20 May 2016, Ljubljana (Slovenia)

CEN ISO/TS 12747:2013 - Pipeline transportation systems - Recommended practice for pipeline life extension. Gas transmission offshore pipeline life extension case.

Dr. Joan Soldevila
Procainsa SA
Terrassa (Barcelona), Spain
joan@procainsa.com

JJ Leandro Gomez CEng MIE
Procainsa SA
Terrassa (Barcelona), Spain
jleandro@procainsa.com

ABSTRACT

Many pipelines are approaching or have exceeded their original design life. Many companies want to continue with the operation of these assets; recovering oil and gas reserves or carry on with the transmission or distribution of products. And also, the current climate does not help to afford new projects.

The aim of this paper is to present the CEN ISO/TS 12747:2013 [1] approach, as one of the Recommended Practice that provides guidance to follow, as a minimum, in order to assess the feasibility of extending the service life of a pipeline system and to demonstrate continued safe performance beyond the original design life.

The paper will present a Life extension case for one offshore gas transmission pipeline in the North Sea following the guidance of CEN ISO/TS 12747:2013 [1]. This case is focused in the anode retrofit to provide recommendations for a Cathodic Protection retrofit scheme in one protection frame.

INTRODUCTION

The Oil & Gas is a mature sector in Europe, where many pipelines are in service for more than 25 years that is classically specified as the design life for this asset. The oil prices stay in the $30-$40 per barrel and the forecast is that the prices stay low; thus this climate does not permit to afford new projects.

On the other hand, the World needs Oil & Gas to continue with the activity; therefore these “old” pipelines shall be operated to carry on with their duties. Certainly, in some instance, the operational life of these pipelines shall be extended and Operators and Government are obliged to assure that these installations can continue with the operation safely.

REGULATORY PRATICES OF THE ASSET LIFE EXTENSION (ALE)

a) Regulatory Practice in Norway

In 2010 Norway Regulator published the Y-002 Life Extension for Transportation Systems [2], Edition 1. The standard was prepared to support the process of assuring technical integrity of the transportation system beyond the design life.

This standard adds the Norwegian regulator as a stakeholder. The Operator shall obtain consent prior to using the installations beyond the design lifetime and document how adequate safety is achieved in the face of continued operation of older facilities and pipelines.

Figure 1 shows the estimation of time in connection with the requirement to apply for consents to the Regulator. The time scheme is 4 years, therefore the Operator should start the life extension process 4 years before the end of the pipeline design [3].

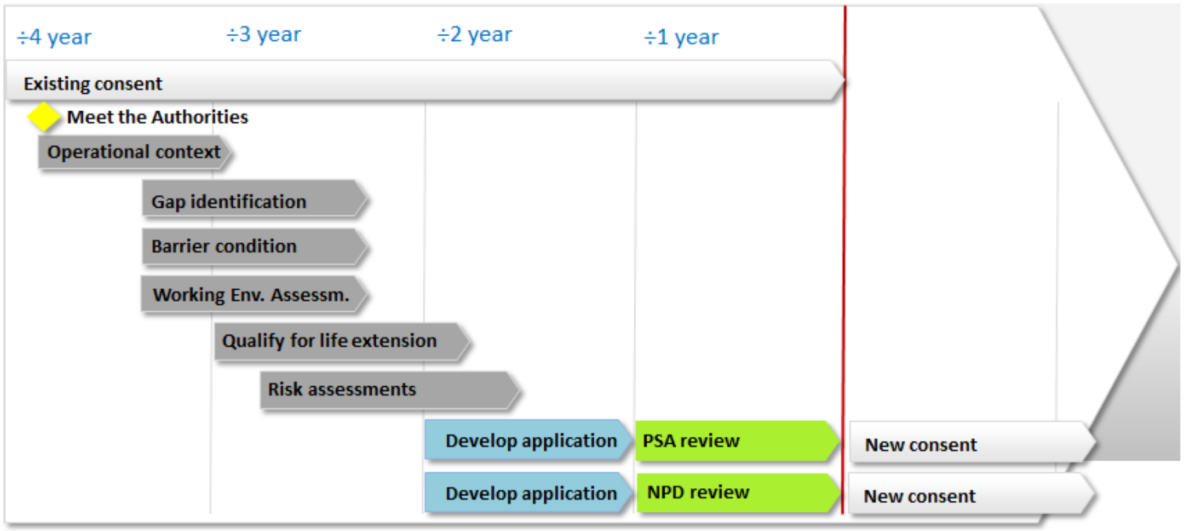

Figure 1: Example of a process to evaluate life extension seen in connection with the requirement to apply for consent [3]

b) United Kingdom Continental Shelf

The Operator shall present an annual assessment report to the Health Safety and Environmental (HSE). A formalised review of the pipeline system condition and fitness assessment for continued operation shall be performed. Recommendations and actions from review shall be clearly recorded and implemented.

c) CEN Standard in Europe

In 2013 a new EN was developed regarding pipeline life extension. It is the PD CEN ISO/TS 12747:2013. Petroleum and natural gas industries – Pipeline transportation system – Recommended Practice for pipeline life extension (ISO/TS 12747:2011).

Each country has a different implementation to this standard, such as in Spain, the Spanish Energy ratified the PD CEN ISO/TS 12747:2013 Recommended Practice in 2014 as UNE (Spanish Standard Nomenclature). At the moment, it is a recommended practice or quality standard.

CEN ISO/TS 12747:2103

Historically the “pipeline life extension” process was applied with different criteria around the world. These approaches depend on the Regulators, Operators and the levels of detail delivered were too diverse.

The purpose of this Recommend Practice was to provide a consistent approach to pipeline life extension assessment that can be applied by Operators (or parties acting on their behalf) across the industry.

This Recommend Practice is concerned with the proof of technical integrity of the pipeline system for the justification of extended operation. The Pipeline Integrity Management Systems (PIMS) documents are related with the life extension process and it is the first step during the initial assessment. The current version of the EN 16348:2013 [4] can be consulted for such purposes and for further detail regarding any of the PIMS topics.

Pipeline Life Extension Overview

The life extension process illustrated in Figure 2 [1] involves an assessment of the current pipeline system integrity and an assessment to determine the suitability of the pipeline system for life extension.

The history process begins with a requirement for pipeline extension and an assessment of the current integrity of the pipeline system. The life extension needs should then be defined, prior to commencement of the life extension assessment.

The chart is divided in two stages: history and future.

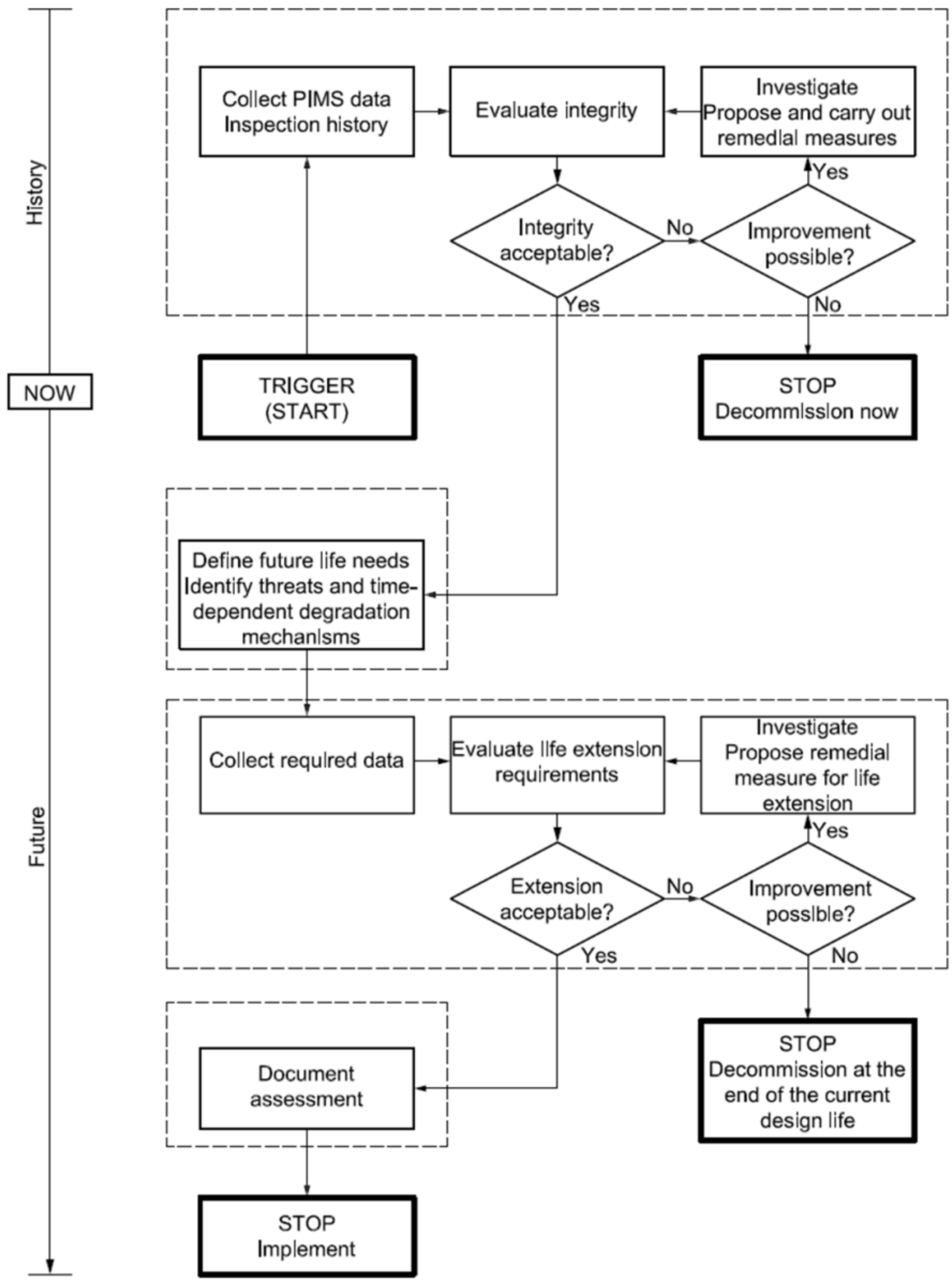

Figure 2: Pipeline Life Extension Process [1]

History

It is essential that a complete and accurate set of records are produced and retained which identify the pipeline's route, construction details, modifications, repairs, material certificates, test records etc., in order to confirm that the pipeline is suitable for operating within its declared safe operating limits and maximum operating pressure.

All inspection and monitoring results shall be recorded in accordance with the requirements of the specific plan governing the activity.

Typically pipeline records should:

- Demonstrate that the pipeline system is operated and maintained in accordance with the operating and maintenance plans, through the results of the in-service inspections, surveillance, monitoring and assessment activities
- Provide the information necessary for reviewing the effectiveness of the operations and maintenance plans (i.e. details of accidental events, and damage to the pipeline system, repair and modifications)
- Provide the information necessary for assessing the integrity of the pipeline system, including operational data affecting corrosion and other deterioration mechanisms (i.e. fluid composition, flow rate, pressure, temperature etc.)

Wherever possible, data required for the pipeline integrity should be readily available from the PIMS. Data should be collected and analysed for its quality, consistency, accuracy and completeness.

Table 1 presents some documents that are necessary for carrying on the life extension assessment.

Table 1: Gap Analysis Documentation

Data	Description
Design Documents	Design data, drawings, assessments, material specification, CP design, HAZID & HAZOP reports…
Process and Operation Data	Pressures, Temperatures, Flow, Corrosion inhibitor injected (type, injection data, frequency…), Product composition… Specific process/operating requirements Fluid and well chemistry change, summary of annual reports, chemistry analyses, routine operation, possible future process/operating issues…
IMR Records	In line inspection, Cathodic Protection survey, verification reports, ... Remote Operated Vehicles (ROV) data: videos, anomalies list with details,… another inspection, repair or replacement order details, …

Future

- **Future Threats Identification**

First of all, the threats to the pipeline during the extended life period shall be addressed. These threats are: Design, fabrication and installation features, incorrect operation, Corrosion (External and Internal), fatigue, overpressure, spans… and particularly for an offshore pipeline: hydrodynamic instability, pipe collapse, scour, fishing interaction, dropped objects, vessel impact and dragged anchors.

- **Life Extension Assessment**

The pipeline life extension assessment shall be based on a thorough understanding of the threats that the pipeline is subject to and the consequent risk to technical integrity. A risk assessment, considering the threats to the pipeline system during the extended operating period, shall, therefore, form a major part of the life extension assessment.

The outcome of the risk assessment shall be an estimate of how long the pipeline system can be operated before the risk of failure exceeds an acceptable level.

The acceptability of the risks identified by the risk assessment shall be assessed and remedial measures prescribed where necessary to reduce risks to acceptable levels. The assessment of risk acceptability for a pipeline life extension, however, is not a trivial process.

- Operators, regulators and the general public have different views on acceptability of risk
- The acceptability of risk changes with time and what was acceptable 20 years ago may not be now
- The acceptability of risk changes with geographical location

Risk management is the process of risk assessment, mitigation and periodic review as shown in Figure 3, [1].

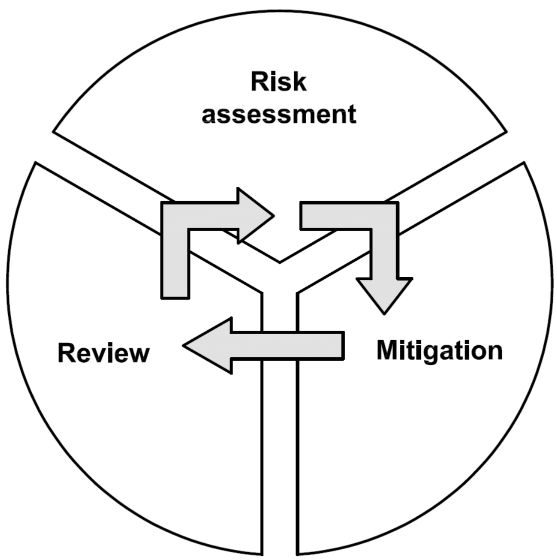

Figure 3: Risk Management Process [1]

- **Assessment of remnant life**

The assessed remnant life of the pipeline system governs the allowable life extension. The assessment of remnant life shall account for all of the time-dependent threats. The main assessments are:

- Corrosion
- Fatigue
- Remediation

Documentation

Record management provides the basis for integrity assurance and is a key element of Pipeline Life Extension. Historical, current and future data are essential for the successful evaluation of pipeline integrity.

The Recommended Practice ISO/TS 12747:2011 gives a guideline for developing the final documentations. The final report shall summarise the life extension assessment activities. This report shall include the sections listed in Table 2 below, [1].

Table 2: Contents of the Life Extension Report [1]

Section	Description
Executive summary	Overview of life extension process
Introduction	Description of pipeline location, history and the purpose of the life extension requirement
Conclusions	The findings of the life extension assessment, including – remnant life and associated life extension period; – required legislative approvals; – deviations from original design basis and non-conformances; – deviations from current legislation and codes; – corrosion, fatigue and wall thickness assessment results; – any residual risks; – risk mitigation measures
Recommendations	Recommendations for remedial measures or further inspection and assessment, necessary to justify life extension
License, permit agreements and organizations	License holder, owner and operator structures and agreements; past, present and future regulatory agreements should also be addressed
Design and construction	Summary of pipeline system design and construction, including – original design requirements, codes and specifications; – review of original design against current design codes; – description of any difficulties or unforeseen events prior to start-up; – construction methods (particularly new or non-standard methods)
Operation	Review of operational history and a summary of future operations
Current integrity of the pipeline system	Review of the current integrity of the pipeline system, including – condition of the pipelines, risers and tie-in spools; – condition and functionality of safety critical items such as ESDVs; – internal corrosion assessment, accounting for any chemical injection; – condition of coatings and CP systems; – assessment of the effects of any repairs or modifications; – fatigue assessment; – assessment of the effects of any changes in land use or settlement; – review of identified anomalies
Life extension assessment	Description and findings of the life extension assessment
Studies	Identification of any specific work or studies (past and future) that may have an impact on the pipeline and its life extension
References	References to all documentation used during the compilation of the report
Appendices	Useful information, such as – inspection and monitoring records used to assess pipeline integrity; – calculations performed during the life extension assessment

PIPELINE LIFE EXTENSION CASE STUDY

To avoid confidentiality issues, some details were omitted or distorted.

The subject pipeline is a 18” pipeline commissioned in the 90’s which transports gas from Station A to Station B. This pipeline is constructed from API 5L X52 steel and has a maximum allowable operating pressure (MAOP) of 120 bar.

Currently the pipeline operates at a pressure of 55 bar.

The basic data relating to the pipeline design and operation are summarised below in Table 3.

Table 3: Pipeline Details and Operation Conditions

Basic Pipeline Details	Data		
Pipeline Code	Gas Pipeline		
Length (km)	24.2		
Outside Diameter (mm)	457.2 (18")		
Nom. Wall Thickness (mm)	11		
Pipe Grade	Grade API 5L X52		
SMYS (MPa)	359		
SMUTS (MPa)	460		
Commissioning Year	90's		
Pipeline Location	Offshore		
Design Life (years)	25		
Operational Data			
DP (bar)	120	52.7 %	SMYS
MAOP (bar)	120	52.7 %	SMYS
Actual OP (bar)	55	24.1 %	SMYS
Product Details			
Product	Dry Gas		
Status	In service		

ASSESSMENT OF PIPELINE INTEGRITY FOR LIFE EXTENSION

History

Unfortunately the full pipeline history is not always collected on one document. All the process/operational and design record were available, however the inspection, maintenance and repair activities were missing or too old to be considered in the life extension assessment. Due this issue the life extension assessment was delayed a few months. During the summer window, the ROV survey and in line inspection were performed.

After review of the design and operational data, the pipeline is found working within the design envelope.

Future

- **Future Threats Identification**

Operation change are not expected, therefore the time dependent threats continue to be corrosion, third party damage and the fatigue.

- **Life Extension Assessment**

The pipeline life extension assessment was based on corrosion, third party damage and fatigue threats.

To evaluate the corrosion hazard the data collected during the latest ROV survey and the in line inspection were considered.

INSPECTION, MAINTENANCE, REPAIR AND OPERATIONAL ACTIVITIES

In Line Inspection

The ILI inspection identified a total of 97 metal loss features (reduction in the local wall thickness). These defects are caused either as a result of corrosion activity or due to the manufacturing or construction process.

Of the 97 metal loss anomalies, 90 were reported to be characteristic of mill/manufacturing faults. The 7 remaining anomalies were reported as external metal loss features, and all were conservatively assumed to be corrosion in nature.

The integrity assessment conducted in accordance with the DNV-RP-F101 [5] assessment established that all of the reported external corrosion features are acceptable for operation at the time of the last inspection.

External corrosion

The deepest external corrosion features is 27% wt in depth and it is located in spool 120 at an absolute distance of **** m (wall thickness ***mm).

The corrosion growth rate assessment was conducted and none of these features not expected to repair before next in line inspection (maximum 10 years).

Internal corrosion

The ILI inspection did not record any internal corrosion feature along the pipeline.

The pipeline has been in service for ** years without any failures, hence, under the current (dry gas) conditions the risk of internal corrosion is considered to be low.

Manufacturing/Mill Features

A total of 90 manufacturing features have been detected in the pipeline.

All of the manufacturing features were assessed in terms of their reported through wall thickness depth and axial length using the Shannon [6] approach and also through wall thickness depth and circumferential length using the Kastner [6] approach.

Manufacturing features do not have any associated growth mechanisms and they will have been present in the pipeline since construction and as such will have survived the pre-service pressure test.

Dents

The geometry inspection of the pipeline did not report any dents with a depth in excess of 2% outside diameter (OD).

The dents in this pipeline are all < 2% OD and are therefore acceptable in terms of their depth. However, if the pipeline is pressure cycled then an assessment to determine the significance of the reported dents in relation to the fatigue integrity of the pipeline should be conducted.

ROV Inspection

The pipeline and associated structures were found to be in good condition. No anomalous free spans, leaks or impact damage were recorded.

Two minors debris (soft ropes) were wrapped to the pipeline and no associated damage was observed.

Pipeline Cathodic Protection

The cathodic protection system was designed with bracelet anodes.

The ROV survey reported that a total of 15 anodes were observed during the survey. All 15 anodes were found to be active; depletion of all of the anodes was 25-50%. Their associated conditions are listed in Table 4 below.

Table 4: ROV Findings on Anode Condition

KP	Condition	CP Stabs (mV)
-.- - -	25-50%	- 995
-.- - -	25-50%	-980
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	-989
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	-981
-.- - -	25-50%	-982
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	No data was recorded
-.- - -	25-50%	-993

Note: An anode is classified to be anomalous in the ROV report when its condition exceeds 75% depletion.

The remaining life of the anodes has been estimated based on data provided in the ROV inspection report and none are expected to require replacement within the next 10 years.

The pipeline overall CP potential was recorded during the ROV inspection. The readings vary between - 978 mV and - 996 mV.

Figure 4 shows the CP trace readings on the pipeline recorded during the ROV survey.

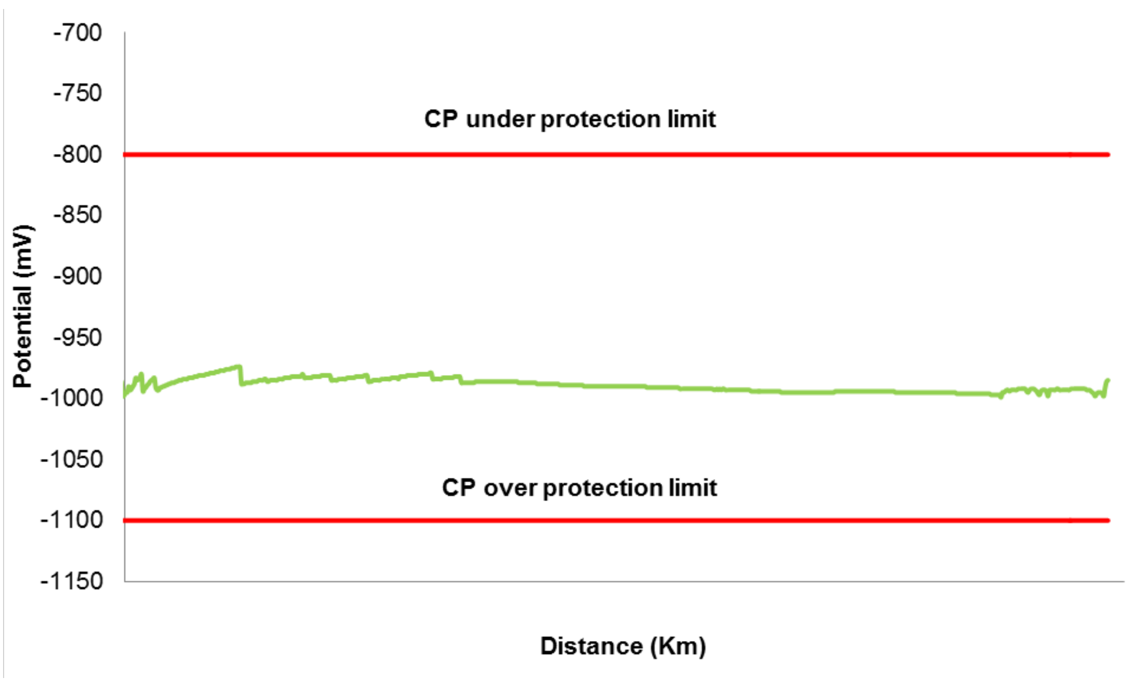

Figure 4: Overall CP Potential Reading on Pipeline

Cathodic Protection on Valves Protection Frame

The valves protection frame was found to be in poor condition, with multiple areas of paint coat loss and corrosion stains on the whole structure. All CP readings were found to be anomalous, indicating that the structure was freely corroding. See Figure 5 with more details.

Figure 5: Corrosion on Protection Frame Base

Two anode locations were identified and only the bar was remaining with no anode material (100% depleted). See Figure 6 with more details.

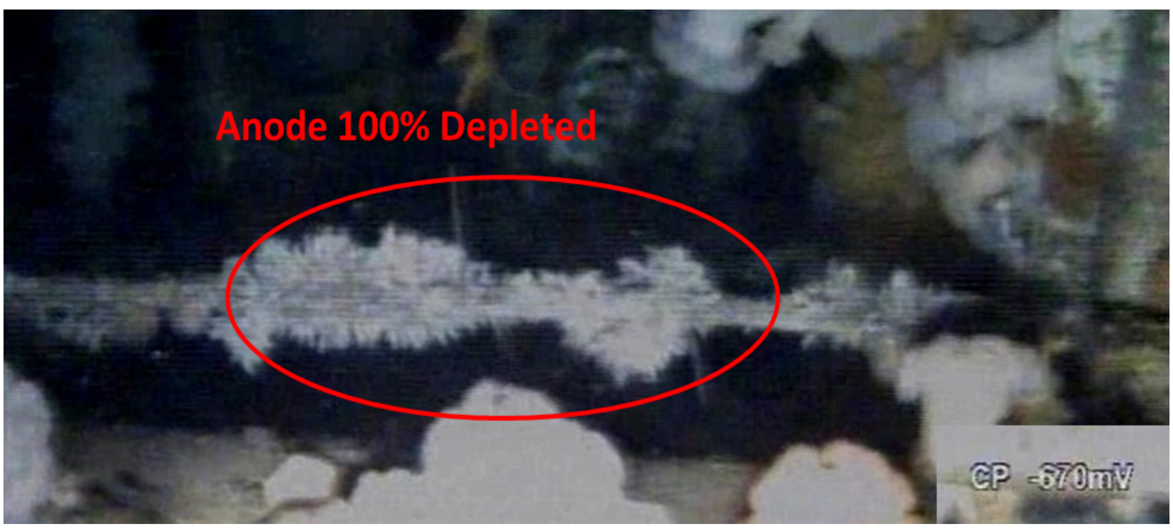

Figure 6: Anode 100% Depleted on Protection Frame

6 Anomalous contact CP readings were obtained on the protection frame; the readings were between - 662mV to - 674mV. All readings on the protection frame were below the accepted limits and recorded as anomalous. Table 5 shows the 6 CP readings.

Table 5: CP Reading on Protection Frame

KP	CP Reading (mV)
CP reading 1	-670
CP reading 2	-662
CP reading 3	-674
CP reading 4	-667
CP reading 5	-672
CP reading 6	-668

Note that Appendix A presents full details of the anode retrofit calculation.

Fatigue

Fatigue along longitudinal pipe seam welds due to operating pressure cycles has not been a significant issue for natural gas pipelines [7].

No operational mode changes were recorded. The pipeline is not subjected to pressure cycles, pressure differential, and rates of change of pressure fluctuations.

The inspections did not report major corrosion/dents, marine growth issues; therefore the fatigue is not considered a threat to this pipeline.

- **Assessment of remnant life**

The pipeline has an MAOP of 120 bar and it is currently operating at 55 bar. The life extension for this pipeline was of 10 years. The assessment of remnant life was carried out for all of the time-dependent threats and the conclusion were:

- No internal corrosion features were detected during the last in line inspection.
- The corrosion growth rate assessment was conducted and none of these features would require repair before next in line inspection (maximum 10 years).
- No fatigue issue is predicted according to the operational and inspection data.

Therefore; based on the data sources reviewed and the assessment of the time-dependent threats, it is concluded that the pipeline is suitable for operating safely at up to the MAOP of 120 bar. If during the life extension, there are changes to the pipeline operating conditions this assessment shall be reviewed.

Recommendations

1. The identified remedial works on the protection frame and the recommended maintenance shall be conducted; more details are given in Table 6.

Table 6: Inspection, Maintenance and Repair Schedule

Threats	IMR Tasks	Inspection Frequency	Year									
			1	2	3	4	5	6	7	8	9	10
Corrosion	Anode replacement (Pipeline)	No required										
	Anode replacement[1] (Protection frame) and commissioning new CP systems	Asap	✓									
	A follow up survey should be considered within 1 year	As required	✓									
	CP Survey	5 yearly				✓					✓	

[1] Full details regarding this calculation are given in Appendix A.

Threats	IMR Tasks	Inspection Frequency	Year									
			1	2	3	4	5	6	7	8	9	10
	ROV survey	5 yearly				✓					✓	
	ILI Survey	Max 10 yearly									✓	
	Repair Pipe wall thickness	No required										
	Gas dew point	Monitoring										
Fatigue	Operational data (pressure, temperature, flow…)	Monitoring										

2. It is also recommended that the Operator develops the Pipeline Integrity Management Systems document with the entire history of this pipeline. The EN 16348:2013 [4] standard can be used as guideline.
3. Develop a KPIs system. The purpose of developing KPIs for Operations is to ensure the integrity management strategies, equipment and/or system performance developed during projects are operating as intended and that the performance objectives, targets and plans have met or exceed the acceptance criteria. Table 7 presents the typical traffic light presentation system.

Table 7: Traffic Light System

Status	Description
	Red - Non-compliance with regulations
	Yellow - Isolated failures
	Green - Fully compliant with regulations
	Blue - No data

The recommended KPIs are detailed in Table 8. Additional KPIs can be defined by the Operator.

Table 8: Recommended IM KPIs

Description	Frequency of Reporting (Months)	Target	Evaluation	Responsible Person
Hydrocarbon Release	1	0		Installations Manager
% Inspection plan completed on time	12	100%		Integrity Engineer
Number of non-conformity results from Inspection and Maintenance	12	0		Integrity Engineer
Inspection anomaly assessments are completed	12	100%		Integrity Engineer
Corrective actions and revalidation inspection	As required	100%		Integrity Engineer
Annual integrity and documented	12	100%		Integrity Engineer
Monitoring the CP system, offshore section (within limits)	60	100%		Corrosion Engineer
Anode depletion	60	<50%		Corrosion Engineer

CONCLUSIONS

Many pipelines are approaching or have exceeded their original design life and these pipelines continue to produce. Operators would like to extend safely the life of ageing pipelines.

In many cases, the pipeline life extension is perhaps a complex process. The pipeline data normally is filed in two or three different places, electronic format, hard copies or unreadable drawings. Therefore, the effective management of the pipeline documents are essential for carrying out an adequate life extension assessment. The EN 16348 [4] standard could be a starting point to help the Operator with this PIMS documentation process.

The operator shall ensure that these documents are updated and available. Keep safe the relevant documentation as part of the Integrity Management, because these documents will support the future life extension assessment process.

The ISO 12747 [1] provides guidance, in order to assess the feasibility of extending the service life of a pipeline beyond its specified design life.

REFERENCES

[1]	ISO 12747	Petroleum and natural gas industries - Pipeline transportation systems - Recommended practice for pipeline life extension (ISO/TS 12747:2011)
[2]	Y-002	Life Extension for Transportation Systems
[3]	122	Norwegian oil and gas recommended guidelines for the assessment and documentation of service life extension of facilities
[4]	EN 16348:2013	Gas infrastructure - Safety Management System (SMS) for gas transmission infrastructure and Pipeline Integrity Management System (PIMS) for gas transmission pipelines - Functional requirements
[5]	DNV-RP- B401	Cathodic Protection Design, October 2010
[6]	PDAM	The Pipeline Defect Assessment Manual (PDAM). A. Cosham and P. Hopkins.
[7]	Contract PR-302-03152	PRCI - Basics of Metal Fatigue in Natural Gas Pipeline Systems - A Primer for Gas Pipeline Operators
[8]	DNV-RP-F101	Corroded Pipelines, October 2010

ABBREVIATIONS

CEN	European Committee for Standardization
CP	Cathodic Protection
DP	Design Pressure
HSE	Health, Safety Executive
HAZID	Hazard Identification
HAZOP	Hazard and Operability
ILI	In Line Inspection
ISO	International Organization for Standardization
KPI	Key Performance Indicators
MAOP	Maximum Allowable Operating Pressure
OD	Outside Diameter
OP	Operational Pressure
PIMS	Pipeline Integrity Management Systems
ROV	Remote Operated Vehicles
SMS	Safety Management System
SMYS	Specified Minimum Yield Strength
SMTS	Specified Minimum Ultimate Tensile Strength
UNE	Una Norma Española (Spanish Standard Nomenclature)
wt	Wall Thickness

APPENDIX A

ANODE RETROFIT ON PROTECTION FRAME

This appendix presents the cathodic protection (CP) design by retrofit anodes for the protection frame. The CP design shall be in accordance with the requirements of DNV-RP-B401 [8].

The following table presents the design and environmental data.

Table 9: Cathodic Protection Design and Environmental Data

Parameter	Design Value
Design Life	20 years
Area (+15% contingency)	---
Seawater Resistivity	0.3 Ωm
Seabed sediment resistivity	1.5 Ωm
Aluminum Anode material electrochemical capacity at 20° C	2000 A*hr/kg
Aluminum anode design closed circuit potential (Ag/AgCl, Seawater)	-1.05 V
Design Protection Potential (Ag/AgCl, Seawater)	-0.8 V
Anode utilization factor	0.9
Aluminum Anode alloy type	Al-Zn-In
Aluminum Anode Material Density	2750 kg/m^3

- **Current Density**

Current densities are per DNV-RP- B401 [8] Annex A section 10.1

Table 10 lists the current densities used in the protection frame structure.

Table 10: Protection Frame Design Current Density

Description	Current Density (A/m^2)		
	Initial	Mean	Final
Protection Frame	0.200	0.100	0.130

- **Coating Breakdown**

The protection frame, the coating was reported in poor condition. For this calculation, conservative scenario is assumed thus the protection frame is considered bare.

Table 11: Protection Frame Coating Breakdown

Description	Coating Breakdown (%)		
	Initial	Mean	Final
Protection Frame	1	1	1

- **Current Requirements**

To ensure that adequate CP is supplied throughout the life of the system the initial, mean and final current required for CP are calculated generally as follows:

$$Ic = SA \times Fc. \times ic$$

Ic = current required for protection (amps)
SA = external area to be protected (m^2)

Fc = coating breakdown factors (dimensionless)
ic = current density for protection of bare steel exposed to seawater (A/m^2)

- **Anode Mass Requirement Calculations**

The total net anode mass (*Ma_T* (kg)) required for maintaining CP throughout the design life is calculated from the mean current requirement (*Icmean*);

$$M_{a\_T} = \frac{\left(I_{cmean} \times t_f \times 8760\right)}{U \times \varepsilon}$$

where:

tf = design life (yr)
U = utilisation factor
ε = anode electrochemical efficiency (A.hr/kg)

- **Anode**

The anode type is based on commercially available products from a local mill. Anode materials and manufacturing according to Det Norske Veritas DNV RP B401 [8].

Next Table presents the dimension of the propose anode and Figure 7 shows the anode deployment.

Table 12: Anode's Characteristics

Material Specification	Length (m)	W (m)	D(m)	Weight (kg)
Al-Zn-In Alloy	2.75	0.160	0.160	214

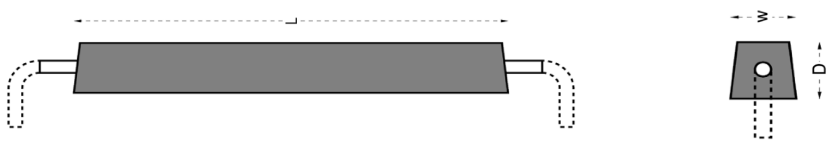

Figure 7: Anode Deployment

- **Final number of Anodes**

A sacrificial anode cathodic protection design has been performed in accordance with the requirements of DNV-RP-B401 [8]; the new design will protect the frame protection for 20 years. Two possible solutions have been studied:

- Two (2) new retrofit anode sleds. Each sled has included 6 anodes.
- Twelve (12) individual anodes, they will be clamped to structural steel components

Anodes shall be distributed evenly on the structures taking into account the relative areas requiring protection, to ensure, as far as is practical, a uniform distribution of potential.

On commissioning of the cathodic protection systems, potentials should be taken immediately to confirm operation of the system and to ascertain any isolated areas.

A follow up survey should be considered within 1 year.