Pipeline Life Extension

ISO Recommended Practice

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standard bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for whom that technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

ISO 13623 – 'Petroleum and natural gas industries – pipeline transportation systems' is scheduled for revision in 2007. As part of this process ISO/TC67/SC2 Steering Group invited a nomination of pipeline experts to review and make a recommendation on how the issue of lifetime extension of existing pipeline systems should be addressed in the context of the planned revision of the standard. A task group WG17 (working group) was established and their recommendation was that a recommended practice guide should be developed out with of ISO 13623 document. The guide should have sufficient clarity and detail to capture learning and enable the work of pipeline life expectancy to be executed in a consistent manner.

Annex A and B of this recommended practice are for information only.

Introduction

Within ISO there has been a series of discussions concerning both the needs and level of prescription required to address pipeline life extension issues.

A position paper by H. Vestre of the Norwegian Petroleum Directorate observed that lifetime extension requests are becoming more frequent and that operators approach the justification for these by different methods with differing levels of detail. The consequences of this are:

- an inconsistent approach which may lead to inefficient use of both operator and Authority resources
- the assessment and upgrading of existing facilities may be based on deterministic methods found in design standards, probabilistic / reliability – based methods or a combination of these
- the level of detail delivered varies

The paper concluded that there was a need for a common approach to ensure the necessary high level of safety is demonstrated and to promote the capture of learning for future applications.

The purpose of this document is to define the scope that this guideline is applicable to and when its application should be triggered. It then gives guidance on what information should be gathered and evaluated in order to determine what measures are required to be put in place to allow the pipeline system design life to be extended. It also gives guidance to what should be included within a report that would give the technical credibility required to provide acceptance to extending the life of the pipeline system.

Note for the purposes of this document operator is defined as the owner or joint owners or a company who has been appointed by the owners to be the operator.

1 Recommended practice

1.1 SCOPE

This Recommended Practice gives guidance that should be followed, as a minimum, in order to evaluate pipeline systems used for the transportation of hydrocarbons within the petroleum and natural gas industries for the purpose of extending its design life beyond the current specified design life.

It applies to pipeline systems on land and offshore, connecting wells, production plants, process plants, refineries and storage facilities, including any section of a pipeline constructed within the boundaries of such facilities for the purpose of its connection. The extent of pipeline systems covered by this document is the same as defined in ISO 13623:200(E), but excludes pumps stations, compressor stations, pressure-reduction stations and depots as illustrated in Figure 1.

It applies to rigid metallic pipelines. It is not applicable for flexible pipelines or those constructed from other materials such as glass reinforced plastics.

It is applicable to all new pipeline systems, may be applied to modifications made to existing ones and in addition is applicable retroactively to existing pipeline systems.

It excludes pipeline systems that require any pressure up-ratings exceeding the original design MAOP.

1.2 NORMATIVE REFERENCES

The following normative documents contain provisions which through reference in this text, constitute provisions of this Recommended Practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Recommended Practice are encouraged to investigate the possibility of applying the most recent additions of the normative documents indicated below. For updated references, the latest edition of the normative document referred to applies. Members of the ISO and IEC maintain registers of currently valid International Standards and Recommended Practices.

ISO 13623:2000(E) - Petroleum and natural gas industries – Pipeline transportation systems
ISO 16708:2006 - Petroleum and natural gas industries – Reliability based limit state methods

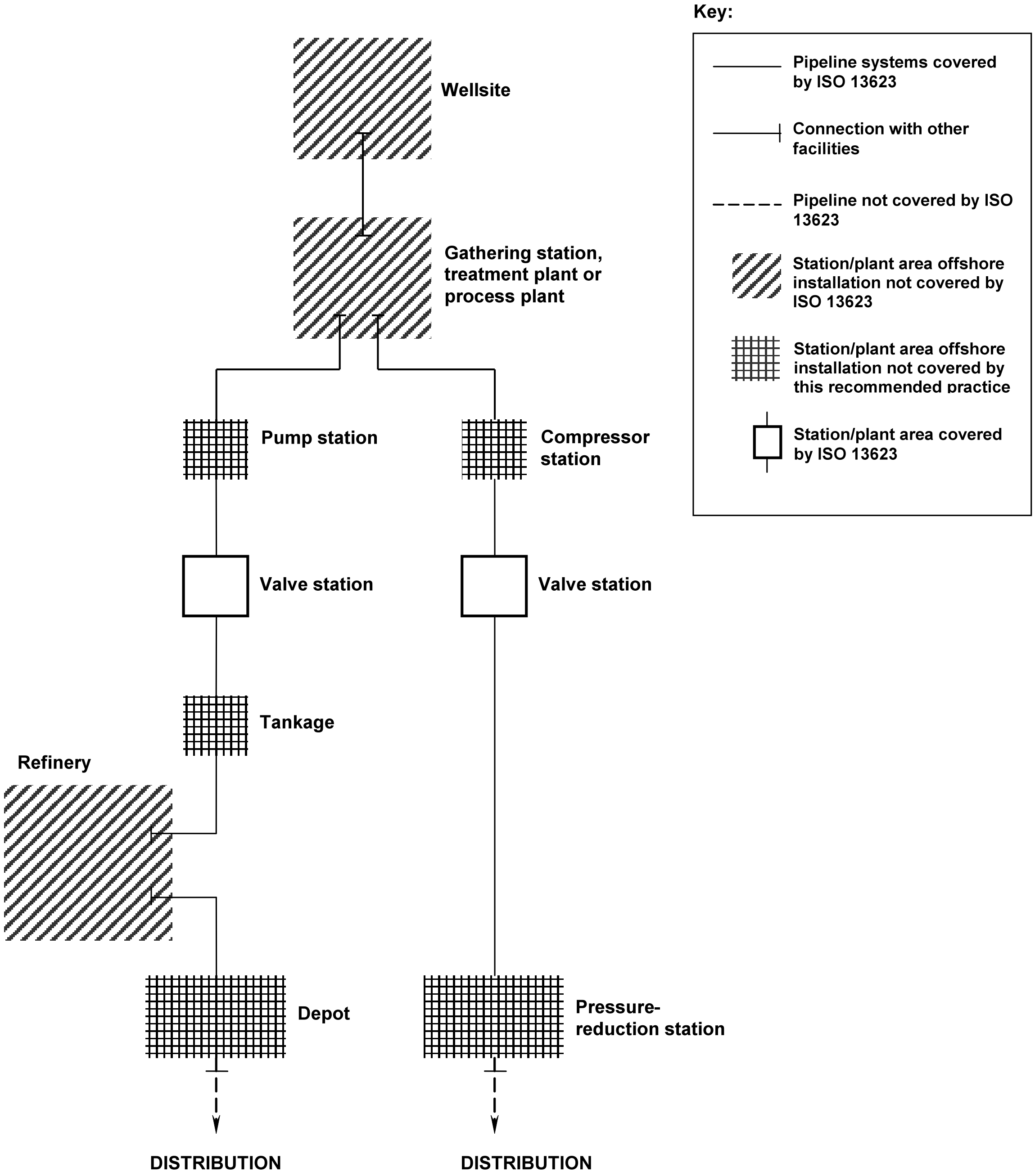

Figure 1 – Extent of pipeline systems covered by this Recommended Practice

1.3 PROCESS DESCRIPTION: FLOW CHART

The following flow chart Figure 2 details the lifetime extension process that is followed during the assessment of a pipeline. The numbered blocks within the flow chart cross reference the sections within this as guide which describe the due process.

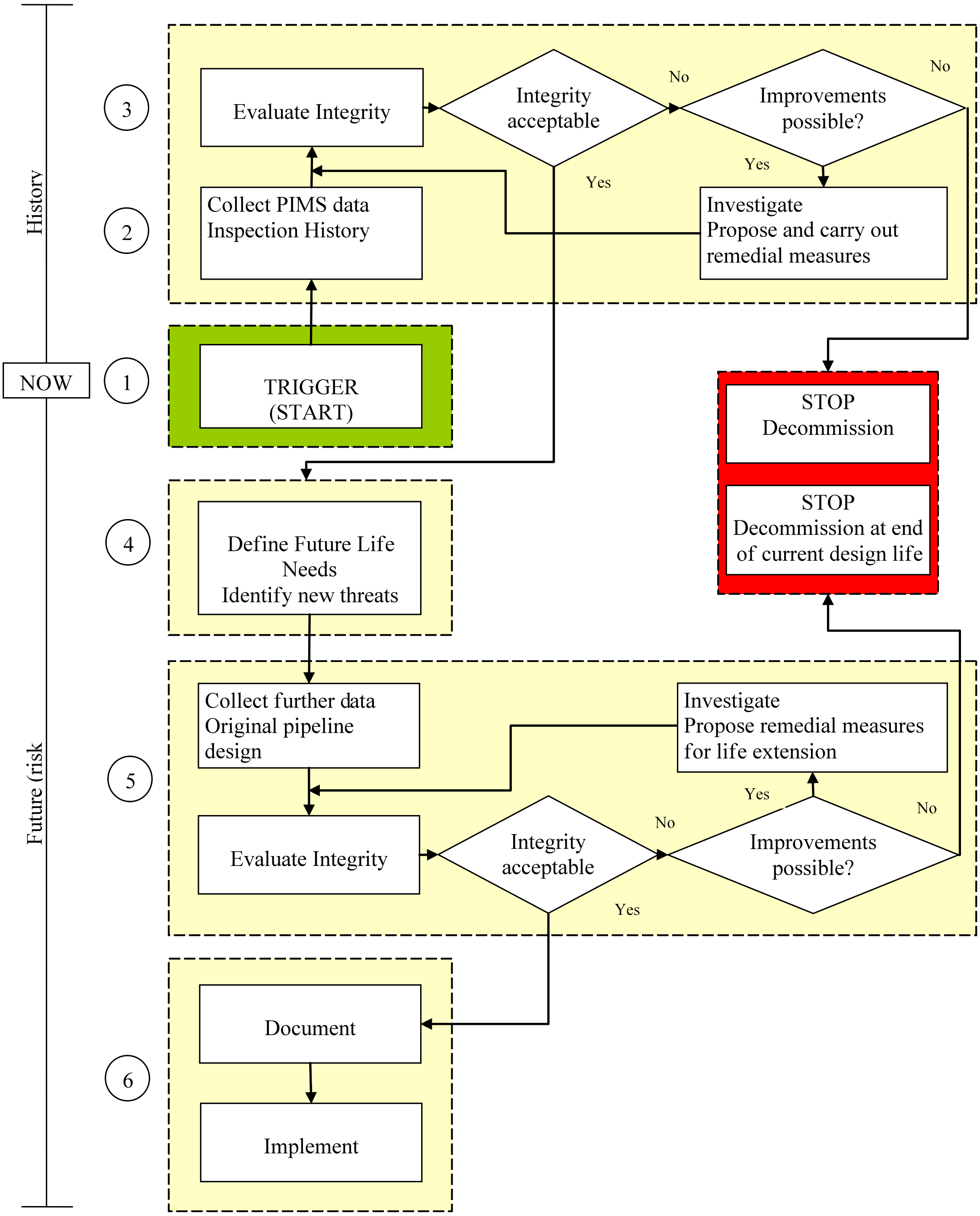

Figure 2 Flowchart detailing pipeline life extension process

The process starts with a trigger to the pipeline extension process at time now (item 1). The initial evaluation will be looking at historical data to determine the status of the pipeline as is (items 2 and 3). Item 4 will fully define the life extension needs prior to the risk assessment being carried out under item 5. On acceptance of the risk the life extension process is fully documented and implementation set up as shown in item 6.

1.4 EXTENT OF ASSESSMENT

Once the intention is known, the level of assessment should be made in respect to the length of pipeline life extension that is required. The assessment should be limited to critical elements of the pipeline system which would include:

- Pipe, risers, spools, crossings
- Valves to 1st off pig trap or ESDV
- Insulation joint
- Flanges
- Instrument tappings and inline instruments
- Ancillary equipment – pipe supports, clamps
- Relief valves
- HIPPS
- SCADA
- Leak detection systems

Short life extensions (in the region of 1 to 3 years) would typically undergo an initial qualitative assessment which could satisfy the required life extension period. If not, further quantitative assessment would be required (steps 1 to 6). Longer life extensions would typically undergo both qualitative and quantitative assessments.

It is important to note that the purpose of the evaluation is to provide the necessary confidence that the pipeline system can continue to be operated safely, without generating a burden of administration or paper work which is unnecessary.

2 Data compilation

2.1 GENERAL

The purpose of this section is to identify information within a pipeline system (as defined in figure 1) that would be required in order to carry out the appropriate level of assessment within the overall evaluation of the pipeline life extension. It forms an essential part in the gathering of information to provide the evidence of the condition of the pipeline system.

Pipeline systems may have a lack of relevant data required for a sufficient qualitative or quantitative assessment. The degree of missing data will, in itself, have to be assessed and remedial actions identified.

2.2 SYSTEM OVERVIEW

The operations and safety systems are concerned with ensuring the pipeline is operating within the defined operating envelope and that safety systems are inspected, maintained and tested to ensure safe operation and optimum performance shall be included (based upon old section 5.3)

Further, the instrumentation and controls that are used within all these areas need to be appropriate and are able to monitor, control and record the information required for accurate assessments to be made. It is important to reinforce that there is sufficient instrumentation and control, whether continuous or intermittent, that is well maintained and will give confidence to the outputs they give which will form part of accurate data gathering and monitoring that is required for integrity assessments.

2.3 ORIGINAL DESIGN INTENT

The original design intent documents should be reviewed against the design conditions that have been specified for the period of the proposed pipeline extension. The documentation should include the following:

Data	Notes
Original codes and standards	Are they current?
Design, fabrication and installation details	Only relevant data
Design basis	
Material specification and certification	Only relevant data compliance with current codes and standards
Analysis calculations and reports	Fatigue, corrosion, stress
Hydrotest certificates	
Environmental Impact Assessments (EIA)	
Risk assessments	Include criticality assessments

Pressure safety systems	
Inspection and test certification and reports	
Documents relating to authorisation and permits to operate	Do they require renewing / updating?
Regulatory requirements	Compliance with current regulations
Land ownership details	Any issues, change of ownership
Surveys and route documentation, including location of other services	Addition of third party services
As-built route alignment maps, special crossing details, detailed pipework and instrumentation diagrams	Only relevant data
Deviations and non-conformities	Are they acceptable?
Loads and load combinations	

Table 2-1 Original design data

2.4 HISTORY OF PIPELINE SYSTEM

A key element of the lifetime extension is the actual operation of the pipeline throughout its life. It would include the maintenance and repair actions that have been carried out to ensure the continued operation. It is important to assess the relevant details appropriate for the assessment; the latest inspection/survey records, for example, would be the most appropriate as opposed to survey data carried out at the start of the pipeline design life. In addition, there may be other external factors which may have a direct impact on the assessment.

The following example of records are some of the key elements of the pipeline system data that may form part of the assessment. They are divided in Operations, Maintenance & Inspection and External data.

2.4.1 Operations

Data	Notes
Pipeline Process Philosophy and data sheets	
Operations philosophy	
Operating cycles	Pressure, temperature, flow and content analysis
Operational pigging results	Any liquid hold up, pig trash analysis
Corrosion monitoring	
Erosion / sand monitoring	
Microbial monitoring	
Chemical management	Including dosing regimes
Process monitoring records	Including gas composition
Leak detection	
Safety systems	HIPPS etc
Control systems	SCADA etc
Pressure systems	
Incident records	
Service conversions	Operational data – content, dew point at inlet and outlet, liquid, hydrogen sulphide content, carbon dioxide content etc.

Table 2-2 Operations data

2.4.2 Maintenance & Inspection

Data	Notes
Pipeline and material specifications	
Acoustic / video records	Latest reports
Cathodic protection surveys	Latest reports
Thermography	
Ground penetrating radar	
Geographic information	
Settlement monitoring	
Crossing surveys	
Span monitoring	
Metocean data	
Pigging runs	Operational and intelligent runs
Coating	
Anomaly records	All
Repairs and modifications	All major modifications and repairs including operational changes e.g. change in operating pressure, temperature and flowrate etc
Mechanical integrity	Valves
Inspection methods and techniques	
Corrosion records	

Table 2-3 Maintenance and inspection data

2.4.3 External

Data	Notes
Regulatory	Government, health and safety
Design codes	National and international
Pipeline registration documentation	Permits, licenses
Building development and proximity distances changing the class of the pipeline system	
Geological faults	
Earthquakes, mudslides, subsidence	

Table 2-4 External data

3 Integrity evaluation under current conditions

3.1 GENERAL

If the pipeline system under review has its own Pipeline Integrity Management System (PIMS) in place, this shall be reviewed as part of the overall evaluation. The review should look at the history and results and should identify any deviations and non-conformities.

It is important to note that integrity management practice varies with different operators in different parts of the world. In some case it is a live on-going risk assessment process, in others assessments are done less frequently. Consequently the level of detail required to justify lifetime extension will vary. Pipeline Integrity Management Systems would typically include the following:

- Operations and safety systems
- Structural integrity evaluation
- Corrosion monitoring
- Fatigue and stress
- Modifications management
- Flow assurance
- Instrumentation and control
- Risk management

3.2 ACCEPTABILITY OF THE PIPELINE CURRENT STATUS

Through the analysis and evaluations of the collected data together with the application of design codes and standards, it should be possible to establish an "as-is" condition for the pipeline system.

After the assessment of the pipeline system remedial actions may be required to determine the integrity of the pipeline in terms of its current operating status. It may be that the integrity of the pipeline is not at a sufficient level - this would warrant further remedial action for existing use.

3.3 REMEDIAL ACTIONS FOR CURRENT USE

In the case when the pipeline structural integrity cannot be sufficiently determined to allow the process of life extension to continue, it will be necessary to carry out remedial measures in order to achieve a suitable pipeline status. This is described in detail in section 5.

4 Trigger – define life extension needs

4.1 TRIGGERS

It is important to identify the key elements or "triggers" that will prompt the execution of the pipeline life extension assessment. The main key element is the intention to operate the pipeline system beyond its stated or intended design life conditions. The triggers, often as a result of change of ownership and or capital funding, would typically be:

- As a result of extended field life beyond that initially predicted.
- Tie-in of pipelines which are to be operated beyond the design life of the pipeline system that they are tying in to.
- Change of operations or loads outside of the allowable design envelope of the existing pipeline system that will affect the design life.
- Change of operations or loads outside of the allowable design envelope as a result of tie-ins to the existing pipeline system that will affect the design life.
- Changing the process and design conditions or changing use to carry another product, or
- Reuse in combination with new end tie-ins for new production runs or for bi-directional flow or reverse flow.

4.2 NEW DESIGN AND FUTURE CHANGE REQUIREMENTS

In order to assess the life extension, details of changes to the original design premise need to be identified. These would typically include:

Data	Notes
Design life requirements	
Operational requirement	
Process and operations requirements	Change of process conditions from the fields (sweet to sour, waster cut, sand, CO_2, wax content / temperature change and tie-ins.
Design code application	Current legislation
Safety case	
Design basis review including changes in design and environmental loads	Trawl boards, land use, crossings building development / proximity distances changing the class of pipeline system etc.
Additional data requirements	
Inspection and existing known defects	
Condition of coatings (internal and external)	
Modifications	Landscaping, changing ground loadings, new 3rd party crossings etc.

Assurance requirements New hazard identification	

Table 4-1 Future change requirements

5 Integrity evaluation for extended use

5.1 INTEGRITY EVALUATION FOR EXTENDED USE

The integrity evaluation for extended use shall be evaluated using current codes. Typically the following shall be incorporated as part of the integrity evaluation and should include reference to analysis techniques and inspection standards.

5.2 INSPECTION

As part of the assessment, existing inspection records should have been reviewed as evidence to determine the condition of the pipeline system. In addition there may be points within the pipeline system both internally and externally that will require further inspection as part of the pipeline life extension. However some areas within the system may not be accessible through normal inspection techniques and alternative inspection methods such as digs or cutting a section of the pipeline may be required. Areas of the pipeline which are inaccessible to inspection should undergo a risk assessment to determine their continued suitability.

As detailed in ISO 16708:2006 advanced numerical calculations and modelling/monitoring (DA, Direct Assessment) may be applied as a supplement and/or alternative to other inspection procedures, e.g. intelligent pigging, in order to assess the technical integrity of the pipeline during operation.

5.3 NEW HAZARDS IDENTIFICATION

As part of the evaluation a new hazards identification study should be carried out that will identify any areas requiring assessment as part of the overall integrity evaluation for extended use.

5.4 OPERATIONS AND SAFETY SYSTEMS

The operations and safety systems are concerned with ensuring the pipeline is operating within the defined operating envelope and that safety systems are inspected, maintained and tested to ensure safe operation and optimum performance.

5.5 STRUCTURAL INTEGRITY

The structural integrity activity is concerned with the monitoring, measurement or prediction of internal and external pipeline condition, the assessment of structural integrity of the pipeline based on its actual condition and the implementation of controls to ensure that the structural integrity is maintained. This area includes the major activities of pipeline inspection and corrosion assessment. Structural integrity should be monitored against but not limited to the following criteria.

- Corrosion
- Fatigue
- Subsidence
- Scouring
- Geological changes
- Hydrology changes
- Faults
- Spans
- Crossings (road, river, railway other pipeline infrastructure)
- Supporting systems (clamps anchors guides)

Pipeline inspection is focused on monitoring and control of the external condition of the pipeline and the associated protections systems such as coatings and CP. Potential threats include low CP, damaged coatings, dents, failure of joints etc.

5.6 CORROSION

Corrosion is the most significant internal degradation mechanism for pipelines and needs to be assessed, monitored and controlled throughout service life and will form a critical element in the pipeline life extension assessment.

Pipelines will corrode during their lifetime and it is important to determine the type(s) of corrosion within the system and its extent and depth. As part of this process it is equally important to assess the corrosion prevention that has taken place throughout the existing life and what measures are required for the future operation of the pipeline. Assessing the current wall thickness is key and then maintaining it above the minimum allowed for the duration of the life extension. Corrosion modelling may be required to ensure that the corrosion rate predicted is not going to compromise the stated minimum wall thickness.

5.7 FATIGUE AND FLAW ASSESSMENT

Critical areas within the pipeline system will have undergone fatigue analysis to determine compliance over the original design life. These would typically include:

- Cyclic operation
- Risers
- Critical joints / tie-in locations
- Nozzle loadings

In addition further assessments may have been carried during its operating life as a result of:

- Spans
- Dents
- Defect assessment / engineering critical assessments (ECA)
- Change in cyclic operation
- Surge
- Thermal relief

These time dependent analyses may show that the fatigue life is used up during the intended life extension of the pipeline. Re-evaluation would be required to determine whether the fatigue life had actually been used up by recalculating using actual stress ranges if available.

5.8 DEGRADATION OF MATERIALS

Certain materials that are used within the pipeline and in particular polymer based materials which are used for coatings are subject to degradation over a period of time. This can be through heat, light or chemical reaction. Hydrolysis is the most common which weakens the bonds within the polymer structure causing embrittlement.

5.9 MODIFICATIONS MANAGEMENT

Major modifications and rectification work on the pipeline systems can pose a significant threat to the ongoing integrity of the pipeline systems if not managed and controlled in the context of the whole system. Modifications and additions to the pipeline system have to be integrated into the PIMS.

5.10 FLOW ASSURANCE

The purpose of flow assurance is to provide the optimum operating process parameters (flow velocities, pressures, temperatures, product composition). It should also identify critical process/flow upset conditions that may threaten integrity. The flow conditions have a significant influence on corrosion rates and forces produced within the pipeline (e.g. water cut, slugging flow, changes in temperature) and may change over the service life of the pipeline. An understanding of past and present history and how conditions may change in the future is needed.

5.11 INSTRUMENTATION AND CONTROL INTEGRITY

Whilst we have highlighted areas of integrity with regards to instrumentation and control within the system overview, part of the life time extension will be to evaluate whether any new or upgrading of instrumentation and control integrity would be required as part of the approval to life time extension. This would need to be taken in context with length of pipeline extension required.

5.12 RISK MANAGEMENT

The activities within the PIMS serve the primary purpose of managing risk. The risk management process and assessments that have been carried out in the development of the procedures, plans and reviews that form part of the PIMS are recorded and include clear statements on the assumptions made, level of risk and actions needed to mitigate the risk. The assessments address both the threats and the consequences.

- The risk assessment process includes periodic reviews and updates as the risk profile changes with time and experience.
- Records are kept of the reviews carried out, the actions taken and how the risks have been mitigated in design, construction and operation.
- Using the information above together with the application of the original design standards and codes, establish an 'as-is' condition for the pipeline system prior to analysing impact of future changes arising because of extension of field life.

5.13 RISK EVALUATION

Using information from sections 2 to 4 together with the application of the accepted design standards and codes, establish the significance, (or risk), of the pipeline characteristics on the pipeline structural integrity. In the case where the pipeline structural integrity is ensured, it can be considered requalified and life extension can be documented as acceptable as outlined in section 6. Otherwise the activities outlined within this section should be performed.

5.14 RISK MITIGATION MEASURES

In this phase it is necessary to find and evaluate mitigation measures that may decrease pipeline structural failure rate (or risk). Those measures may either eliminate, control or accept the conditional failure rate.

5.15 SENSE CHECKS

As part of the evaluation a sense check should be carried out on the pipeline system. The follow criteria should be:

Data	Notes
Is the right system in place? Can we rely on the data – what is the quality? Is everything that should be measured, measured?	

Table 5-1 Sense checks

5.16 LIFE EXTENSION INTEGRITY EVALUATION

In the overall assessment it is important to evaluate the future pipeline integrity status considering the extended design life and operations under future conditions.

In the case where the proposed life extension is not acceptable either reduce life extension or identify other remedial measures. If the life extension time is reduced the pipeline integrity should be re-evaluated to determine acceptability. In the case where remedial measures are considered, there is the possibility that they are not applicable/accepted and this could end the requalification process to a pipeline and abandonment required at the end of the current design life. Otherwise, remedial measures as outlined below must be put in place and re-evaluation carried out based on the remedial measures.

5.17 REMEDIAL ACTIONS FOR EXTENDED USE

After the assessment of the pipeline system remedial actions may be required to determine the integrity of the pipeline in terms of its future operating status. It may be that the integrity of the pipeline is not at a sufficient level - this would warrant further remedial action for extended use. The following sections identify the remedial actions that should take place.

5.18 DESIGN CHECK VS LATEST CODES

Design codes (which are either based on allowable strength design or the newer limit state design) which the pipeline system was originally designed to may have been updated. As a result acceptable design conditions may change with later versions of the codes potentially having a different design criteria than those originally used. The **latest codes should be applied** to identify the areas of non compliance. In such cases a risk assessment should then be carried out to determine if remedial actions are required.

Nevertheless, the fact that a pipeline does not comply with a modern code, by itself, does not provide sufficient grounds to prevent its further operation.

In reviewing the design it is important to assess whether the design parameters have changed during the current lifetime of the pipeline and whether any future changes will occur either through the remainder of its current design life or during the proposed lifetime extension. Examples of this would include:

Data	Notes
Change of process conditions from the fields (sweet to sour, water cut, CO_2 increase, wax content, flow reduction, stratification, higher pressure and/or temperature)	To look at corrosivity and flow assurance
Change of process conditions as a result of tie-ins or change in predicted well process conditions	
Increase of external loading as a result of new / larger vessel fishing activity (e.g. trawl board size)	
Increase of external loading as a result of change in environmental conditions (e.g. higher water velocities due to wave or current action, soil motions/deformations, fatigue effect)	
Installation of new third party crossings or landscaping changing ground loadings on pipeline or effecting the surrounding hydrology	River diversions, motorway widening, major landscape changes such as landfill, land slides in the proximity of the pipeline, change in river course, coast line
Change of land use resulting in an change of location class (higher population density)	
Additional geological faults	
Discovery of damages (dents, damage to CP, weld defects, corrosion defects)	

Table 5-2 Changes to design circumstance

Loads that typically would not be considered as part of the assessment unless these activities were to be carried out as part of the pipeline assessment would be:

- Those associated with the installation of the pipeline system
- Loads applied as part of historical hydrotests

5.19 COMPONENT REPLACEMENT

In order to reach the point where the pipeline extension is acceptable certain actions may require the replacement or additions of elements within the pipeline system. These could include:

- Liners
- Anode replacement or addition
- Component upgrades including instrumentation and control
- Cut out and replacement of sections of the pipeline
- Valve replacement
- Risers, caissons, sleeves
- Pipework supports clamps and supporting structure
- Anchors

5.20 OPERATING CONDITIONS

In order to accept the pipeline for future operations it may be necessary to down rate the operating conditions in order to satisfy the integrity of the pipeline system for the duration of the extended life.

5.21 EMERGENCY MAINTENANCE AND REPAIR

The longer a pipeline remains in service the risk of an unforeseen or unlikely event occurring increases. It is therefore essential that there is a robust emergency response system in place that can be activated quickly for both safety and economic reasons.

6 Document findings

Detailed documentation, that either justifies life extension or not, must be prepared and submitted for approval to Client and to Third Party Authorities if legally required to do so. The recommendation is that an output report is written which should as a minimum include the details as summarised below.

6.1 EXECUTIVE SUMMARY

This should summarise the life extension process for this particular pipeline.

6.2 INTRODUCTION

This should typically give location, history and the purpose of the life extension requirement.

6.3 LICENCE, PERMIT AGREEMENTS AND ORGANISATIONS

This section should detail the licence holders, owner and operator structures and agreements and other regulatory agreements that are in place historically, currently and those proposed for the pipeline life extension, if any different.

6.4 DESIGN AND CONSTRUCTION

This section should provide a general system description summary of the pipeline system and any associated plant or platform that it is connected to. It should summarise the design requirements and the design codes and specifications used for the pipeline system.

A summary of the construction method should be provided and highlight any new or non-standard methods that were used. It should also highlight any difficulties or unforeseen events that occurred. A typical example would be the length of time between hydrotest and start-up where the hydrotest water remained within the pipeline causing corrosion within valve components.

6.5 OPERATION

The operational summary should be highlighted from start up to normal operation and then summarise the operations on a yearly basis up to the present time. It should be high level, but highlight any significant changes in operation that have occurred including any shutdowns. It should show the actual gas specifications that have been recorded and any anomalies out with of the original design specification

There will also be a subsection which will summarise the intended future operations of the pipeline.

6.6 CORROSION PROTECTION SYSTEMS

One of the key areas within the lifetime extension process is the installed corrosion protection system. A more detailed summary of the corrosion protection systems that are in place should be described here and would include both the onshore and offshore sections of the pipeline. The systems would be:

- Cathodic protection systems
- Corrosion protection in the splash zone
- Corrosion inhibitor treatment

It would also highlight any changes that had occurred to the corrosion system in terms of anode depletion and replacement, and changes in treatment regimes.

6.7 CONDITION MONITORING

This section should provide the detail into the inspection methods, techniques and intervals used to monitor the pipeline and its components. It should define the various piping systems that would be found within a pipeline for which there will be various inspection techniques and inspection intervals.

For offshore this would be:

- Topsides piping
- Risers above and below water and splash zone
- General pipeline
- Near shore and beach approaches

For onshore this would be

- Above ground
- Below ground
- Crossings (rail, road and river)

It would also include the inspection results and experience for both internal and external inspections as well as the results from any other monitoring systems that were applied to the pipeline whether permanent or temporary. Typical systems would include:

- Gas composition
- Pressure and temperature monitoring
- CP systems
- Internal corrosion monitoring

6.8 REPAIR AND MODIFICATIONS

This section will identify any major repairs that have carried out during the life time of the pipeline. It would highlight any specific events or breakdowns.

6.9 STUDIES

This section would include (highlight) any specific work or studies that have been carried out or due to be carried out that would potentially have an impact on the pipeline and its life extension.

6.10 FUTURE LIFETIME ASSESSMENT

In this section the evaluations carried out to determine if the pipeline has sufficient integrity to warrant life extension are summarised. The analyses that should typically have been carried out will be deterministic or probabilistic, and should specify a likelihood to failure. It should state whether they are acceptable or not.

This section will also highlight any activities, remedial works or further assessments that are required to be carried out prior to acceptance of life extension. It should also summarise the predicted operating conditions that will occur during the period of the life extension.

6.11 CONCLUSIONS

As part of the data gathering, inspection and lifetime extension evaluation conclusions will be draw from the assessments and incorporated into the output report. Typical statements will include, inter alia:

- The deviations from the original design basis are as follows…….
- When evaluated against current legislation the deviations are……
- When evaluated against current codes the deviations are……
- The corrosion assessments are……….
- The fatigue assessments are……..
- The wall thickness assessments are……
- The residual risks are…………..
- The risk mitigation measures required are………
- The life extension period is……
- The required legislative approvals are…..

6.12 REFERENCES

This section will include the references to all the documentation that has been used in the compilation of the main report. It will also include references to additional data that supports the assessment for pipeline life extension. This would typically be:

- Reference codes, documents and regulations
- Dealing with missing data
- Mitred bends and other non-conformance issues
- Reanalysis work
- Risk assessments
- Supporting calculations
- Examples (case studies)
- Example plan / assessment
- Documentation requirements
- Bibliography

Annex A Corrosion assessment

This is an example that will run through the possible process that would be required in order to determine the extent of corrosion within a pipeline. The example will assume that there are internal corrosion pits as a result of CO_2.

A pipeline has been found to have internal corrosion pits as a result of CO_2. The first line of assessment will come from the internal inspection results which will usually come from the intelligent pigging inspection. From the results we will get a measured value of the extent of corrosion. It is important to understand where the corrosion is occurring both globally within the pipeline system and locally within the pipeline for example is it at the six o'clock position, is it along the welds or HAZ? How it is changing. Looking at these and historical inspection records a current predicted growth rate can be determined.

In accessing the results it is important to determine the degree of certainty (or uncertainty) of the intelligent pigging results. Further information can be obtained from looking at corrosion probes, inspections of traps and a review of the corrosion management system which can provide further confidence of the results. If there is any doubt regarding the results spot checks should be carried out which could typically involve:

- Laboratory tests on actual corrosion rates
- Experts to review risk assessments
- Inspection of other similar lines

Once the degree of corrosion has been confirmed assessments will need to be carried out to determine that the loss of wall thickness still provides an acceptable level of strength within the pipeline. This would have to be done in conjunction with a fatigue analysis. Typical methods of assessment are:

- ASME B31.G
- RSTRENG
- DNV RP F101
- API 579
- Chell (or modified Chell)
- BS 7910

From the results predictions can be extrapolated over the required number of years for life extension or for a period of 25 years to determine if there is the likelihood of failure within the specified time frame. In order to do this a lower and upper bound on corrosion rates needs to be established in order to establish confidence in the range of predicted life that is being determined. To assist in the determination and to give further confidence in the boundary limits corrosion modelling could be carried out as well. Assessments carried out will either be deterministic or probabilistic.

If the corrosion assessment for lifetime extension presents an unacceptable risk it will be necessary to carry out remedial measures to reduce the risk to an acceptable level. The remedial measures could be:

- Introduce or change the corrosion inhibitor scheme.

- Modify the inspection regime to monitor the corrosion. This would apply to the inspection type and the frequency of inspection.
- The flow regime could be modified to reduce the likelihood of corrosion.
- Reduce the pressure in the pipeline.
- Insert a liner into the pipeline.
- Replace the pipeline or those section affected by the corrosion.

At the end of the assessment a full report will need to be written which will outline the objectives, the methodologies used for the analysis and the assumptions used. The conclusion will clearly state what the outcome of the assessment is and the recommendations proposed. This will then form part of the overall life extension documentation.

Annex B Fatigue assessment

This example runs through a fatigue load applied to a subsea pipeline as a result of spanning. The assessment will look at a weld within a pipeline whose steel specification has been superseded.

In carrying out any fatigue assessment it is important to establish the original fatigue criteria (if any) that where specified for the pipeline. It is also important to establish what were the acceptable defect criteria that originally applied to the pipeline.

In terms of assessing the fatigue load it will be important to establish what has happened during the lifetime of the pipeline and the pattern of spans that have developed and the predicted vibrations and corresponding stress patterns that could have occurred. This will then allow a reasonable prediction to the likely fatigue loading that should be applied for life extension of the pipeline.

It will be important to look at the radiographs to determine possible and actual defect sizes that the pipeline started out with. It is also important to establish if there has been any growth as a result of fatigue or corrosion and determine the most accurate defect size. A tolerance will then need to be established to cover the extent of uncertainty of defect size.

The fatigue analysis should be carried out to the latest available codes. This would typically be to BS7910 or similar. It is of critical importance that the correct application of data is carried out, and in particular the following areas:

- S-N curves
- Partial safety factors
- Stress concentration factors (SCF's)
- Stress ranges applied
- Fracture mechanics data including CTOD
- Weld profile assessment
- Other factors such as post weld heat treatment which affects the physical properties of the material

Once the results of the fatigue analysis are know a qualitative risk assessment should be carried out to ensure the robustness of the results and that the risk imposed to the integrity of the pipeline as a result of fatigue is acceptable.

The results of the fatigue analysis for this example would typically show the following results:

- That fatigue life was acceptable for pipeline life extension
- The fatigue life was acceptable for life extension but with remedial measures which could include:
    - Ongoing monitoring only
    - Sand bagging / mattressing areas of pipeline with unacceptable fatigue

- Retrenching part or whole of line
- Change the flow parameters
- Introducing VIV damping
- Renew sections of the pipeline
- Decommission pipeline

There will be cases where there will be little or no information available upon which a credible fatigue assessment can be carried out. If this is the case a QRA will have to determine whether the risk is acceptable and or carry out a fatigue analysis with very conservative factors applied to take into account the degree unknowns.

At the end of the assessment a full report will need to be written which will outline the objectives, the methodologies used for the analysis and the assumptions used. The conclusion will clearly state what the outcome of the assessment is and the recommendations proposed. This again would form part of the overall life extension documentation.