

Life extension for transportation systems

This NORSOK standard is developed with broad petroleum industry participation by interested parties in the Norwegian petroleum industry and is owned by the Norwegian petroleum industry represented by The Norwegian Oil Industry Association (OLF) and The Federation of Norwegian Industry. Please note that whilst every effort has been made to ensure the accuracy of this NORSOK standard, neither OLF nor The Federation of Norwegian Industry or any of their members will assume liability for any use thereof. Standards Norway is responsible for the administration and publication of this NORSOK standard.

Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum

Copyrights reserved

Foreword	4
Introduction	4
1 Scope	6
2 Normative and informative references	6
2.1 Normative references	6
2.2 Informative references	6
3 Terms, definitions and abbreviations	7
3.1 Terms and definitions	7
3.2 Abbreviations	9
4 Assessment methodology	9
4.1 Objective	9
4.2 Integrity management system (IMS)	9
4.3 Life extension process	10
4.4 Degradation	11
5 Life extension premises	12
5.1 Objective	12
5.2 Authority regulations	12
5.3 Design standards	12
5.4 Design premise	13
5.5 Threats to the transportation system	13
5.6 System overview	14
6 Integrity assessment	17
6.1 Integrity management system (IMS)	17
6.2 Data collection	17
6.3 Condition assessment	17
6.4 Remedial actions	19
7 Reassessment	19
7.1 Objective	19
7.2 Process overview	19
7.3 Acceptance level	21
7.4 Design based reassessment	21
7.5 Condition based reassessment	21
8 Modifications	23
8.1 Mitigation	23
8.2 Intervention	23
8.3 Repair	23
8.4 Replacement	23
9 Document	23
10 Implement	23
Annex A (Informative) Illustration of re-qualification schemes for life extension	26
Annex B (Informative) Work process paradigm	31
Annex C (Informative) Condition based assessment	33

Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Introduction

The transport system in this context is facilitating transport through pipelines, risers and loading hoses intra-field, inter-field and as trunk pipelines offshore and onshore. For more description on application of this NORSOK standard, see clause 1 and 5.6. This NORSOK standard is prepared for the industry as a means to support the process of assuring technical integrity of the transportation system beyond the service life, which is a premise in the original consent for operation of the system from the authorities (PSA and NPD).

OLF is developing standards and guidelines to provide requirements for the industry. The following segments are defined with the purpose of life extension:

Segment	Status
• Load bearing structure • Transport systems (pipelines, risers) • Subsea systems • Drilling and well systems	• NORSOK N-006 • This NORSOK standard • Under development • Checklist developed by OLF "Drilling Managers Forum" • Check list developed by OLF
• Risk management, technical safety systems and working environment • Topsides process and utility systems	• Check list developed by OLF

Formalities regarding application process toward authorities are prepared through OLF guideline no. 122.

There are multiple design standards in the industry that provide requirements for transport systems. There is also a wide range of materials that are used for pipe, with new materials being continuously qualified. The main groups of pipes are identified as

- metallic pipes,
- unbonded flexible pipes,
- bonded flexible pipes.

Each of these groups has a range of properties that characterise the transportation system, and which need to be assessed when quantifying the expected lifetime.

Transportation systems on the Norwegian Continental Shelf are dominated by offshore systems. The onshore sections of the systems are generally short in comparison. This NORSOK standard is a national standard and

the identified requirements are based on available knowledge and experience provided by the systems in the national domain.

The difference between service life and design life may be illustrated by the following example: The design life of a system is 25 years. However, the system was intended to operate 15 years (limited by the reservoir predictions), and the operator applied for a 15 years permission, which becomes the original service life.

Later the operator wants to extend the service life with 5 years, for a total of 20 years.

Service life and design life are defined slightly differently in identified standards. Some examples are quoted below:

Pipeline design standards:

ISO 13623:2009	Design life is the period for which the design basis is planned to remain valid.
DNV-OS-F101:2007	Design life is the initially planned time period from initial installation or use until permanent decommissioning of the equipment or system. The original design life may be extended after a re-qualification.
ASME 31.8:2003	<i>(does not define a design life, but uses design life and service life as dimensional limits for design with respect to cyclic loading and cathodic protection systems.)</i>
ASME 31.4:2006	Design life is a period of time used in design calculations selected for the purpose of verifying that a replaceable or permanent component is suitable for the anticipated period of service. Design life does not pertain to the life of the pipeline system because a properly maintained and protected pipeline system can provide liquid transportation indefinitely.

Metallic risers:

DNV-OS-F201	Service life, the length of time assumed in design that a component will be in service
API RP 2RD	Service life is defined as the length of time that a component will be in service. Design fatigue life is the life predicted by cumulative fatigue damage ratio calculations.

Unbonded flexible pipe design standards:

API 17J	Service life: The period of time during which the flexible pipe fulfils all performance requirements
---------	--

Bonded flexible pipe guideline:

OCIMF	<i>(does not define design life and service life.)</i>
UKOOA	<i>(Flexible Hose Management Guidelines does not define design life and service life.)</i>

1 Scope

This NORSOK standard defines general principles for assessing an extension of the service life beyond the original service life of risers and pipeline transportation systems, see Figure 1.

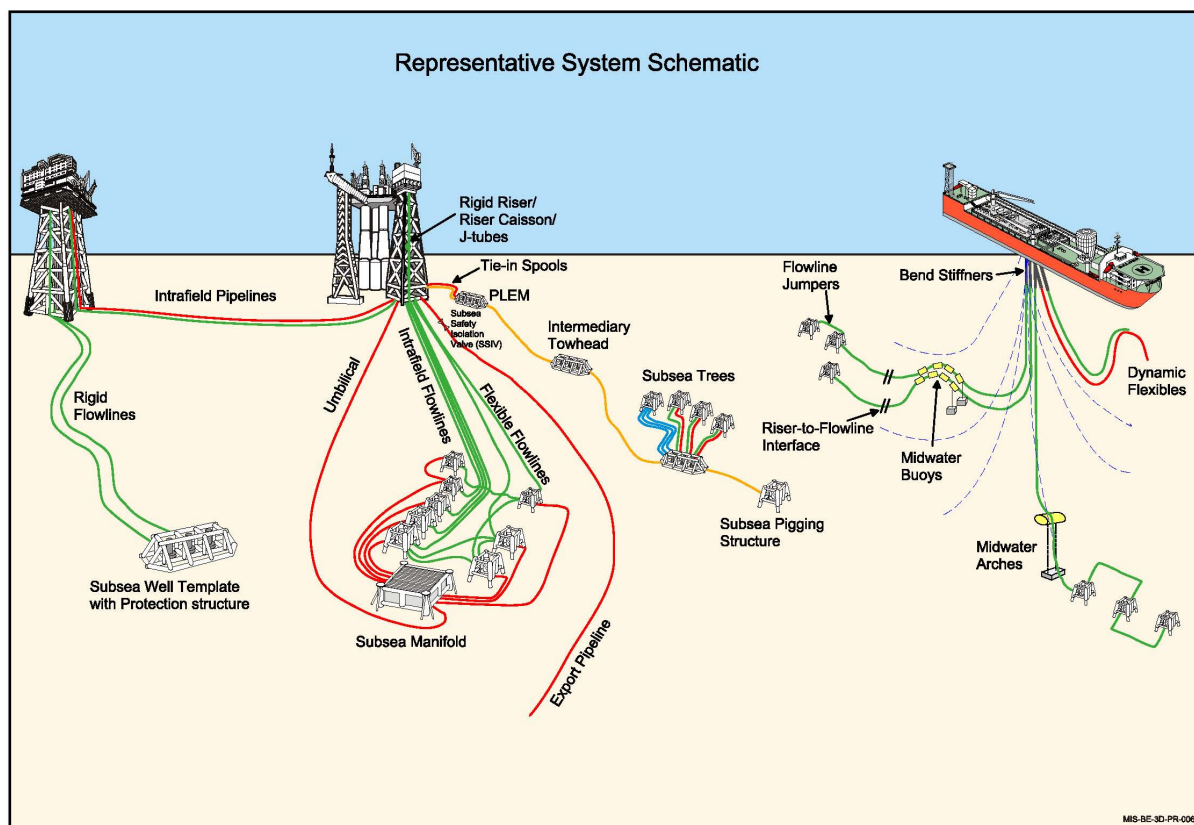


Figure 1 - Overview of transportation systems applicable for this NORSOK standard

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet the requirements of the referenced standards.

2.1 Normative references

NORSOK N-006,	Assessment of structural integrity for existing offshore load bearing structures
OLF guideline no. 122,	Recommended guidelines for the assessment and documentation of service life extension of facilities

2.2 Informative references

API RP 2RD,	Design of Risers for Floating Production Systems (FPSs) and Tension Leg Platforms (TLPs)
API 17J,	Unbonded Flexible Pipe
ASME 31.4,	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
ASME 31.8,	Gas Transmission and Distribution Piping Systems
DNV OS-F-201,	Dynamic Risers

DNV-RP-F101,	Corroded Pipelines, 2004
DNV-RP-F113,	Pipeline Subsea Repair, 2007
ISO 13623:2009,	Petroleum and natural gas industries – Pipeline transportation systems
OCIMF,	Guidelines for the handling, storage, inspection and testing of hoses in the field, Rev. 2 1995
OLF Process,	Topside process and utility systems (Check list developed by OLF)
OLF Drilling,	Drilling and well systems (Check list developed by OLF "Drilling Managers Forum")
OLF HSE	Risk management, technical safety systems and working environment (Check list developed by OLF)
OLF Subsea,	Subsea systems (Under development)
UKOOA,	Flexible Hose Management Guidelines. 2003

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

acceptance level

maximum level of risk that is acceptable for the system at any time during its operation

NOTE A defined acceptance level is based on governmental regulations, design code or company requirements.

3.1.2

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.3

degradation

gradual breakdown of components or of a material, as a result of being exposed, i.e. to time and environment

NOTE Sections and components degrade as a function of time and exposure, and the rate of degradation will vary. The components in the system have been qualified as a minimum to the design life.

A system may also consist of components that are not intended to be in service for the design life. These components are planned to be replaced throughout the operational life based on specific intervals or condition based intervals. They are then a part of a maintenance plan.

3.1.4

degradation model

model which shall describe how the integrity level of the system evolves over time and exposure

NOTE The degradation model can also be called "risk evolution model". Typically the integrity will decrease, in other words the risk inherent in the system will increase.

The degradation model is typically centered on the structural integrity of the system. Important factors are corrosion, fatigue, stress levels, temperature, pressure, erosion, operational environment etc.

The degradation model is usually defined by the design standard, known technology and industry practice. This model can change over time, due to new technology and research, as well as changes in industry practice and updated design standards.

In cases where the risk to/integrity of the system is defined more broadly (i.e. not only structural integrity, but also operational integrity, economic performance etc), other factors may play an important role in the degradation model.

3.1.5**design life**

specified period for which the integrity of the system is documented in the original design with anticipated maintenance, but without requiring substantial repair

3.1.6**integrity assessment**

documents the present system integrity level, and forms a basis for further life extension work

3.1.7**integrity life**

period during which the system or component may be operated without infringing the integrity acceptance level

NOTE The integrity life is longer than the design life, and in most cases the integrity life can not be documented.

Conservatism in design and material data is the background for much of the difference between integrity life and design life. In the design process the focus is on documenting an acceptable integrity level for the specified design life. The design process is often conservative when choosing parameters for calculations and qualifications.

The integrity life is the upper theoretical limit for the design life.

3.1.8**integrity level**

expression of the absence of risk inherent in the system

NOTE The risk can be of various natures; human, environmental, economic or political. Different systems have different failure modes or critical situations, and the risk associated with each of these can vary from system to system.

3.1.9**life extension**

documented justification for operating a system beyond its original service life

3.1.10**may**

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.11**modification**

changes, improvements or repairs of a system

3.1.12**re-qualification**

re-assessment of design due to modified design premises and/or sustained damage

NOTE Life extension is a design premise modification.

3.1.13**service life**

time length the system is intended to operate

NOTE The service life is a part of the application toward authorities.

EXAMPLE:

The design life of a system is 25 years. However, the system was intended to operate 15 years (limited by the reservoir predictions), and the operator applied for a 15 years permission. Later the operator wants to extend the service life with 5 years, for a total of 20 years. In this case the design supports the application for service life extension with respect to design life.

3.1.14**shall**

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.15**should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.2 Abbreviations

API	The American Petroleum Institute
ASME	American Society of Mechanical Engineers
CP	cathodic protection
DNV	Det Norske Veritas
HSE	health, safety and working environment
ID	identification
IMS	integrity management system
ISO	International Organization for Standardization
NPD	Norwegian Petroleum Directorate
OLF	Oljeindustriens Landsforening
OCIMF	Oil Companies International Marine Forum
PoF	probability of failure
PSA	Petroleum Safety Authority
UKOOA	United Kingdom Offshore Operators Association

4 Assessment methodology**4.1 Objective**

This clause describes the general methodology to be applied to a life extension process. The remaining sections of this NORSOK standard are built up according to this methodology.

4.2 Integrity management system (IMS)

The operators follow up the transportation systems through an IMS. The objective of the IMS is to ensure that the technical integrity of the transport system is continuously maintained at an acceptable level. The structure of an IMS is illustrated in Figure 2.

The activities and assessments carried out as a part of the IMS is not part of the life extension process. A continuous integrity assessment is an inherent part of the integrity management process, where data from inspection, monitoring and testing are evaluated against the need for mitigation, intervention or repair. The integrity management process is carried out within the constraints of the original design, and is not necessarily sufficient to document and justify a life extension. However, the data provided by the IMS is beneficial in order to perform a life extension process.

INTEGRITY MANAGEMENT SYSTEM

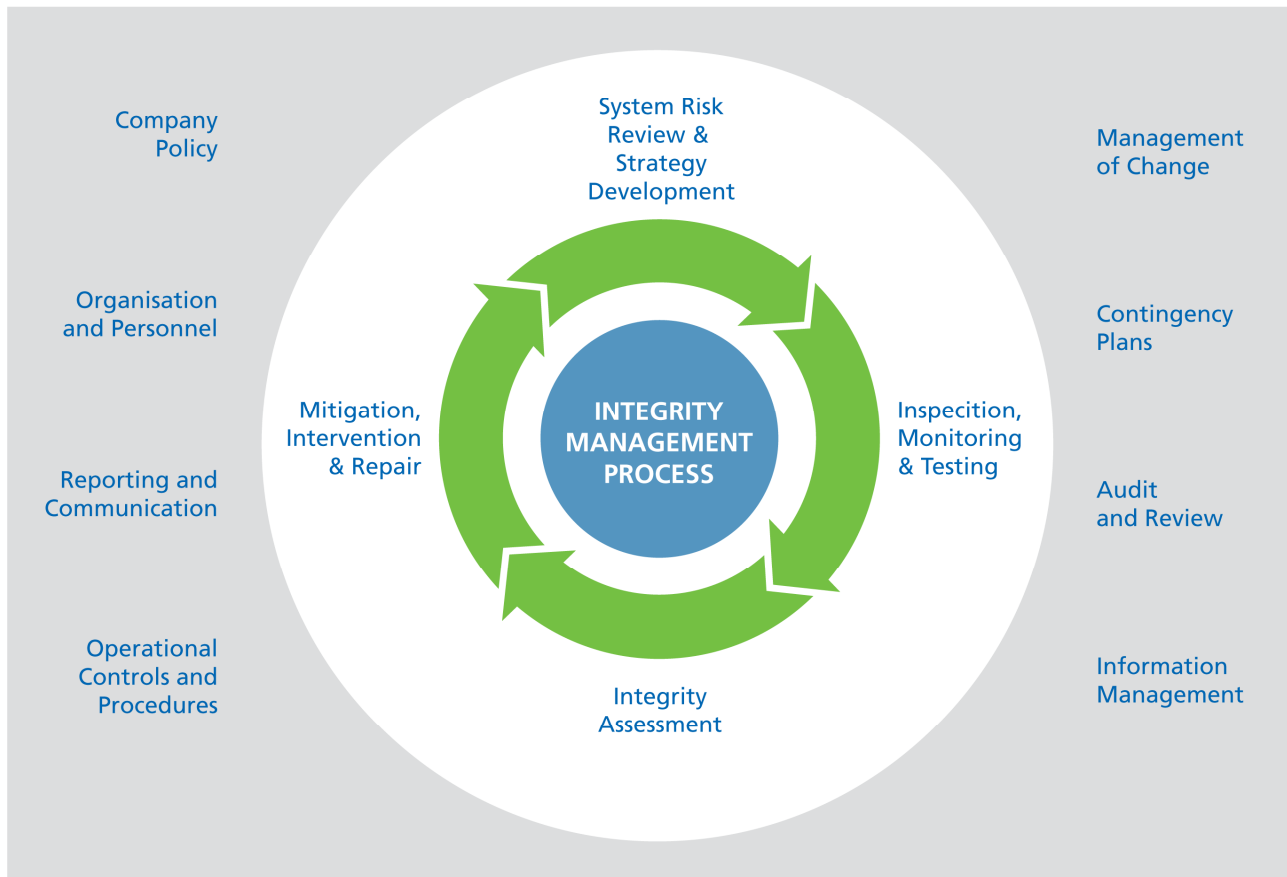


Figure 2 - The structure of an IMS and process

4.3 Life extension process

The life extension process can also be called a re-qualification. It is triggered by the decision that the operation of the system will be continued beyond the original service life. The process that may be followed in a life extension is outlined in Figure 3.

The purpose of the life extension process is to document an acceptable system integrity to the end of the extended service life.

The overall life extension process is as follows:

- define the premise for the extended operation, and identify new threats to the system;
- assess the integrity of the system, in other words as far as possible quantify the current condition;
- carry out a reassessment of the system based on the available information from integrity assessment and established life extension premises, current industry practice and available technology;
- the reassessment can conclude that the integrity of the system is acceptable up to the end of the extended life, in which case the process moves on to documentation and implementation. If the integrity is not acceptable, modifications shall be considered together with the feasibility of the entire life extension.

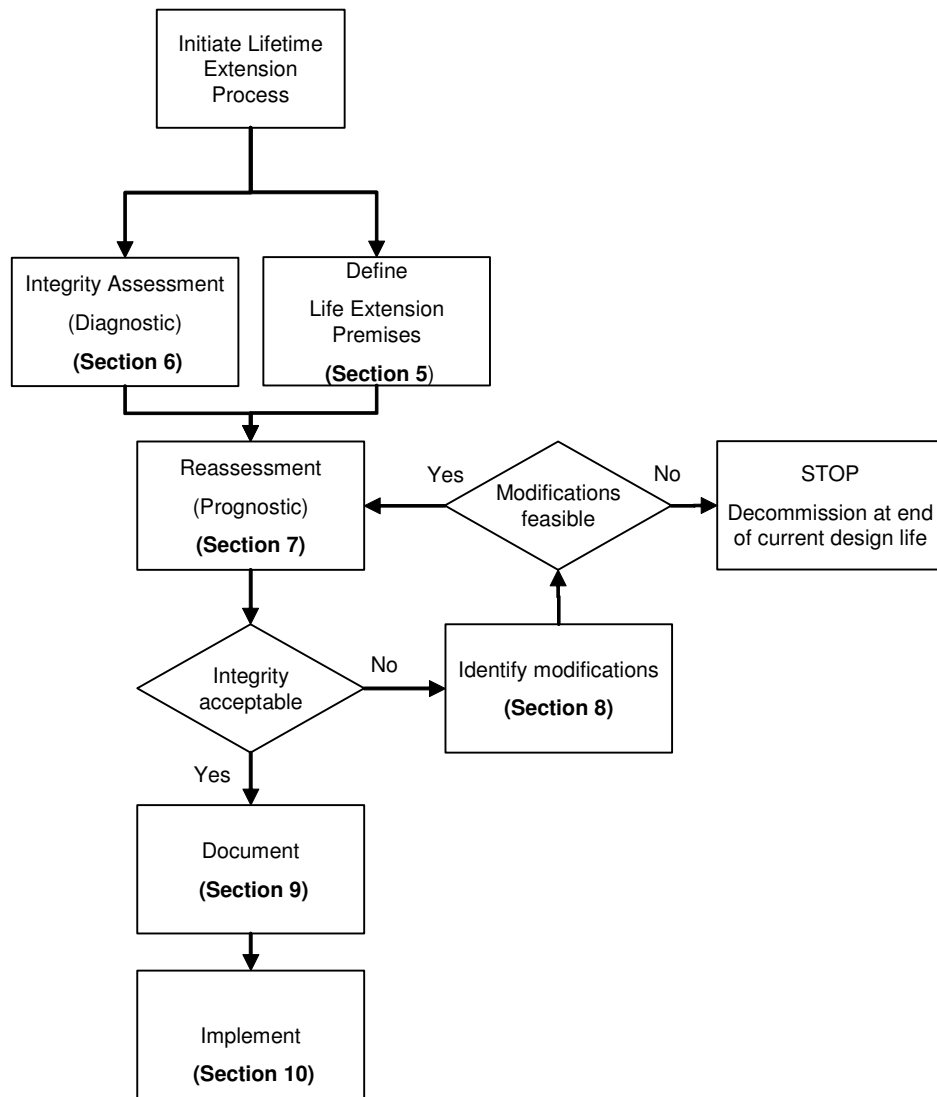


Figure 3 - Life extension process

The following subclauses in this NORSOK standard are based on this work process, and references are included in the relevant boxes.

4.4 Degradation

The life extension process shall take into account the degradation that has taken place since the installation of the system.

Figure 4 is an example of degradation and integrity assessment. A life extension evaluation is initiated well ahead of the end of the original service life. Figure 4 illustrates that the original service life is not limited by the original design life, but the operator requested service life shorter than design life. In the original design, a given degradation model was used, which does not provide sufficient design life for the desired extended service life.

At the time of the life extension evaluation, an integrity assessment is performed. In this example it was found that the degradation model was conservative, and the current condition of the system is actually better than anticipated. In the reassessment, a new degradation model is introduced based on new technology and/or industry practice. Based on this new degradation model, the new extended design life is established, which exceeds the desired extended service life. Subsequently a life extension application for the system can be submitted to the authorities, and service life for this system may be extended toward the extended design life without requirements to repair or modifications.

Note that in this example the first degradation model limited the original design life. Without the integrity assessment and the new degradation model, the life extension would not have been possible, since the extended service life was beyond the original design life.

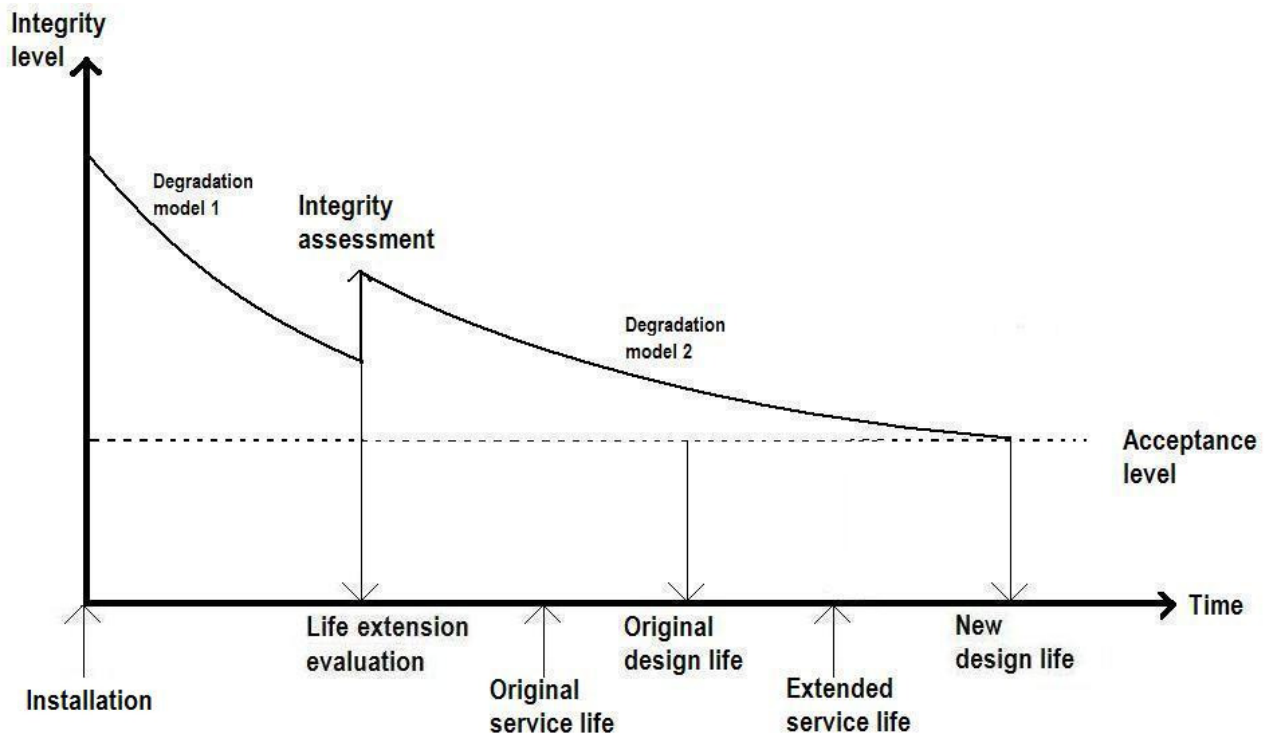


Figure 4 - A schematically sketch of the identified integrity level vs. time

5 Life extension premises

5.1 Objective

The original design premises shall be reviewed to assess whether they are still applicable for the life extension period. Revisions may be required, e.g. authority regulations. Changes or updates to the premises can lead to solutions that are more reliable and more cost-effective.

5.2 Authority regulations

The latest authority regulations apply to the transportation system.

Implementation of a life extension for a transportation system requires consent from the authorities, which are represented by the PSA.

The consent application process is presented in OLF guideline no. 122.

5.3 Design standards

The transportation system is designed according to applicable standards that were selected at time of design. The same design standards may be used throughout operation of the system, also when changes to this system are introduced. This includes life extension.

When initiating a life extension process other standards may be commonly used for design of new transportation systems. Gaps between the original design standard (original revision shall be used) and applicable other standards at time of life extension shall be identified. Such gaps can indicate changes in the integrity acceptance level, and the transportation system operator shall assess the risk associated with these gaps.

5.4 Design premise

The design premise is the basis for the original design, and describes the operational and design limits for the system at time. The design premise also outlines the functional requirement/ constraints to the system.

In the context of this NORSOK standard, the primary premise is the design life, and this will be changed in the life extension process. Other premises may also be changed or updated, or they have already been changed during the operation of the system.

The operator shall ensure that all premises relevant for the life extension are addressed.

Table 1 gives examples of parameters premised for design. The table is not intended to be complete.

Table 1 - Examples of parameters premised for design

Category	Subject
Operational parameters	Flow Pressure Temperature Density Shut in characteristics Cyclic operations of the system with respect to above mentioned data. Chemical composition
External parameters	Fisheries (trawling) Anchoring Metocean data Subsidence Earthquake Geotechnical Vessel motion characteristics
Methodologies for response and capacity calculations	Cyclic/fatigue capacity Design/operational load capacity

5.5 Threats to the transportation system

5.5.1 General

The transport system shall be designed with an acceptable safety to failure. A transport system is exposed to external as well as internal threats. The threats also have the following different characteristics:

- event based: e.g. dropped objects, dragged/dropped anchor, land slide, etc.
- condition based: e.g. change in operational parameters
- time based: e.g. excavation/scouring (causing fatigue), ineffective corrosion protection or corrosion control

The combined effect of threats shall also be considered. New threats based on new or changed design premises shall be identified.

5.5.2 Containment and integrity

The main service/criterion for a transport system is containment. Failure of the transportation systems are identified by

- leak,
- rupture/burst,
- collapse.

To ensure that these events do not occur, acceptance criteria are prescribed by design standards. These criteria may be expressed through allowable stress design format or limit state design format.

5.5.3 Internal threats

The potential internal threats to a pipeline may be dependent of the transported medium. Typical threats are

- corrosion,
- erosion,
- wear,
- chemical and physical ageing,
- creep,
- overpressure,
- underpressure,
- changes in flow characteristics.

5.5.4 External threats

The potential external threats to a pipeline will be the same independent of the transported medium. The various threats will vary along the pipeline. Typical threats are

- external corrosion,
- free spans (wrt. fatigue),
- free spans (wrt. trawl pullover and hooking),
- lateral buckling,
- upheaval buckling,
- expansion,
- on-bottom stability,
- collapse,
- compression,
- design, fabrication and installation “shortcomings”,
- installation damage (e.g. dents, abrasions, etc.),
- natural hazards,
- other third party damages (e.g. sinking ships, dropped objects etc.),
- incorrect operation,
- deteriorating integrity of supporting components/structures (e.g. buoyancy elements, mid-water arch, pipe support etc.),
- deteriorating integrity of surrounding infrastructure (e.g. tunnels, bridges, etc).

5.6 System overview

5.6.1 General

The transportation system for which a life extension process is carried out shall be described in such detail that battery limits are clearly defined. All sections and properties of the system associated with the life extension shall be described, as well as components along the system.

The system may consist of components that are subject to other standards with respect to life extension than this NORSOK standard. These components are still an integral part of the transportation system and should be included in the transportation system life extension assessment. The integrity of these components will be based on the requirements provided by other standards and guidelines for life extension. Guidance is provided in 5.6.5.

In cases where the system is operated by several companies, clear reference to the battery limits for operation should be given. Cross reference between the life extension studies by the various operators shall be given, if applicable.

5.6.2 System battery limits

The transportation system is primarily identified by the parts of the transport systems that have the function of pressure containment. A wide selection of transportation systems are illustrated in Figure 1, this include export, production, gas lift and water injection systems. A general principle is that the transportation systems consist of all the components from pig-trap to pig-trap, or wellhead valve to pig-trap. Systems may deviate from this definition and system boundaries should be clearly defined and coordinated with neighbouring systems.

Battery limits for the transportation system are in general at contact point with the systems as given below. The relevant standard for life extension is referred for each of the systems.

Subsea

- Manifolds – OLF Subsea
- Subsea X-mas tree – OLF Subsea
- Subsea wellhead – OLF Drilling
- Pipeline end manifold (PLEM) – OLF Subsea

Load bearing structure/topside

- Riser Caissons – NORSOK N-006
- J-tube – NORSOK N-006
- Riser hang-off support structure – NORSOK N-006

The entire system within the battery limits shall be considered in the life extension process, not only parts therein.

5.6.3 Configuration and support systems

Components that are not pressure containing may still be important parts of a transportation system by maintaining the configuration and support of the transportation system. These components shall be defined as integral parts of the transportation system since they are barriers against failure of the transportation system.

Examples of components are as follows:

- mid water arches;
- bend restrictors/flex joints;
- buoyancy elements;
- rock dumps;
- burial depth;
- free span intervention;
- expansion areas;
- spool support configuration;
- external corrosion protection system;
- etc.

5.6.4 Spare parts and repair system

Spare parts (e.g. line pipe, flexible pipe, components) and repair systems that are system specific and stored onshore shall also be included in the diagnostic phase of the life extension process. This is provided that they will be part of the system into the life extension period. Their condition and storage facilities shall be evaluated, and the consequence of continued storing shall be assessed. In case any changes are made to the system (system parameters, improvements/reconstruction) the fitness-for-purpose of the parts shall be re-evaluated.

Spare parts:

- Line pipe
- Riser joint
- Buoyancy elements
- Components

Repair systems:

- Clamps
- Sleeves
- etc

5.6.5 Pipeline components and support systems

It is important to distinguish between standard defining the overall scope for the life extension, and the standard providing the technical requirements.

This NORSOK standard defines the transportation system, and which elements shall be included in the life extension assessment. But for a number of subsystems and components in a transportation system, technical requirements to life extension shall be found in referenced documents. See below a list of the scope for supporting OLF documents/NORSOK standards.

Distinction between subsea systems and transportation systems:

Subsea valve station	OLF Subsea
Sub sea isolation valve (SSIV)	OLF Subsea
Subsea pig-trap	OLF Subsea
CP system	Transportation systems are responsible for assuring coverage of own system (often electrical contact between the systems).
Riser base	Transportation system. OLF Subsea address valves
Pumps and compressors	OLF Subsea
Protection structures	OLF Subsea.

Distinction between process system, topside and transportation system:

Topside pig-trap	OLF Process
Isolation joint	Transportation systems (separate subsea and topside CP system)
Riser hang-off component on riser	Transportation systems
Pipe supports	Transportation systems

Distinction between technical safety systems and transportation system:

Emergency shut-down valve/isolation valve	OLF HSE
Vent gas systems	OLF HSE (topside the flexible risers will vent gas from annulus. This gas shall be released safely). Functionality of vent system is within transportation system.

Distinction between onshore processing plant and transportation system:

Topside pig-trap	OLF Process
Isolation joint	Transportation systems (separate offshore and onshore CP system)
Pumps and compressors	OLF Process
Pipe supports	Transportation systems

Distinction between load bearing structures and transportation system:

Riser/pipeline support	Load bearing structures
CP system	Transportation systems are responsible for assuring coverage of own system (often electrical contact between the systems).
Riser hang-off support structure	Load bearing structures

Ancillary components:

Bend stiffener/restrictor	Transportation systems
Mid-water arches	OLF Subsea
Floating elements	Load bearing structures
Anchor flanges	Transportation systems
Tethers	OLF Subsea
Subsea anchors for tethering systems	Load bearing structures
Rock dumping (potential scouring)	Transportation systems

Trench cover
Direct electrical heating
Buoys and support structures

Transportation systems
Transportation systems
OLF Subsea

The following areas are also to be covered:

Landfall constructions
On-shore pipe support
System specific repair systems

Spare linepipe/components stored onshore
Monitoring data

Transportation systems (e.g. tunnels)
Transportation systems (e.g. bridges)
Depends on the equipment type reference to list above
(emergency preparedness repair/replacement systems).
Transportation systems
Transportation systems. With changing systems making
sure all relevant data from inspection and monitoring is
available during the entire, extended lifetime

6 Integrity assessment

6.1 Integrity management system (IMS)

The transportation system should have an established IMS. Different integrity management systems can have different scope. The IMS will be the most important source of information and will form the basis of a life extension process. The IMS is used to carry out

- data collection;
- condition assessment.

6.2 Data collection

A well developed IMS can produce and store a large quantity of data. For assets without an IMS, very little information is available (i.e. operational parameters, other).

Information relevant for a life extension process captured from the IMS may be

- structural analyses,
- flow assurance,
- operational procedures,
- risk and hazard evaluations,
- inspection data,
- monitoring data,
- maintenance program,
- modifications/changes,
- environmental loads,
- historical data and event logs, e.g. damages.

The quality of the inspection, monitoring and maintenance program is of vital importance for the ability to perform a condition assessment and assess the future life of a transportation system. The collected data should be thoroughly reviewed to ensure quality and relevance for use in a life extension process.

Any identified gaps should, if possible, be closed by remedial measures, e.g. additional inspections or improved monitoring.

6.3 Condition assessment

6.3.1 Condition control

The design premise defines the operational envelope for the system (i.e. the allowable limits on various parameters). In general, condition control is focused on identifying aspects of the operation or system that are outside the defined envelope. This means that the design assumptions are compared with the observations and data provided by monitoring and inspection activities.

A large part of the condition control activities are directed toward confirming that system operation is inside the operation envelope defined in the design process. Direct observation of the system condition is in general not sufficiently detailed to allow a check/calibration of the degradation model used in design.

As long as the observations and data from the condition control are inside the operation envelope defined in the design process, it is likely that the integrity life exceeds the design life.

The challenge is to document that the integrity level is higher than assumed in the design process, so that there is a basis for further operation of the system.

Based on the quality or strategy of the integrity management system, the status of the condition could be

- unknown, no IMS established,
- by design, operational parameters monitored to be within design limits,
- by operational experience, operational data available and structural integrity may be assessed,
- quantified through direct measurements, physical condition of structure measured.

Controlling condition by design requires that the degradation models are identified and correctly understood in the design. In such cases there are no barriers against failure from unknown failure mechanism or misunderstood degradation model.

The different types of condition control will have different impact on the ability to assess current condition, see Figure 5.

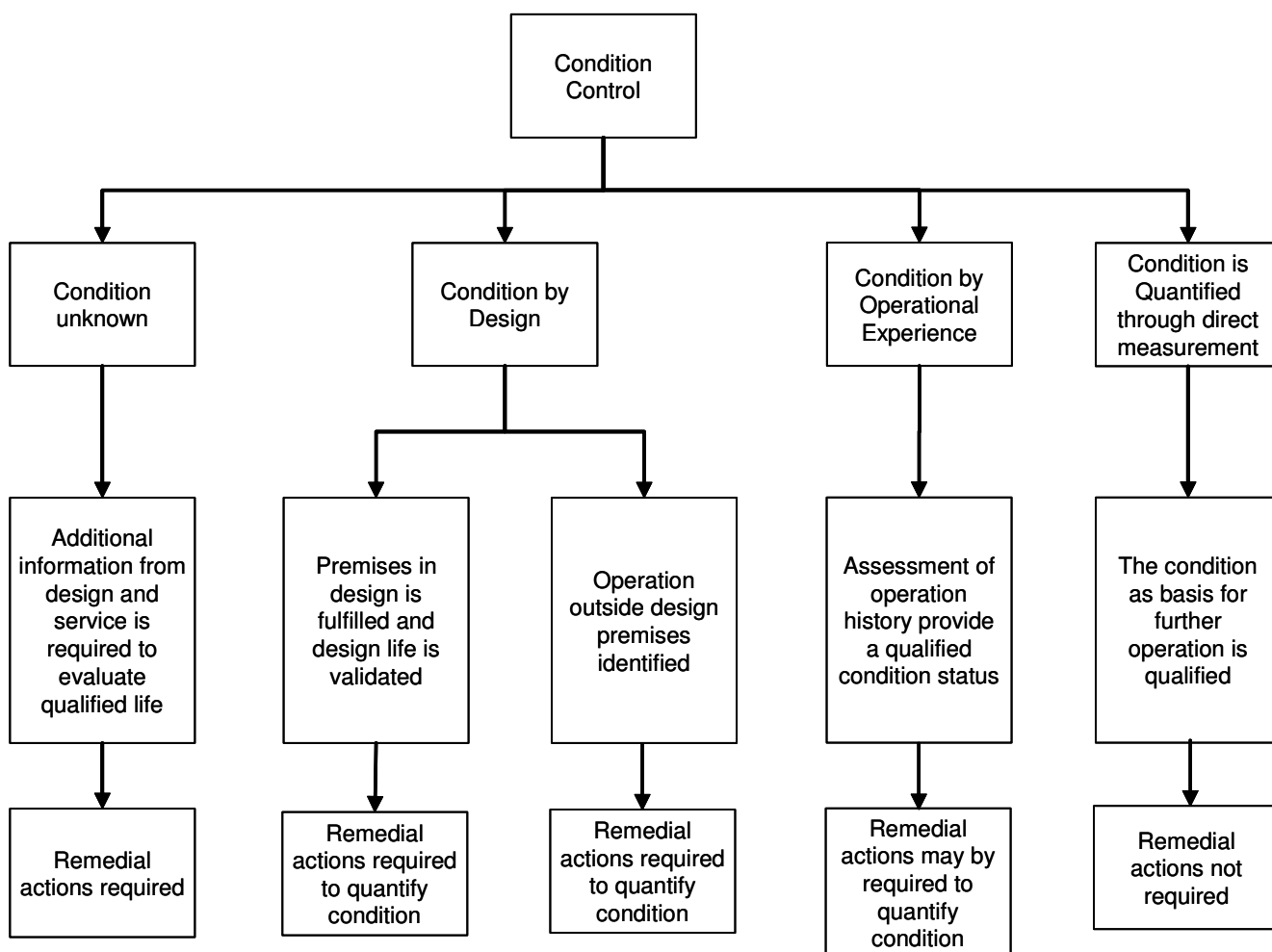


Figure 5 - Types of condition control

6.3.2 Requirement to condition

Threats to the transportation system lead to limitations in operation or other requirements. The condition identified for the system should be checked to be in compliance with these requirements. The requirements to current condition are given by the original design documentation and revisions documented in the integrity management system.

Examples are

- applicable design standards,
- required wall thickness,
- allowable degradation of material (i.e. polymer coupon),
- corrosion allowance,
- erosion allowance,
- wear limit,
- global configuration (i.e. location of sag and hog for flexible riser),
- seabed location (i.e. touchdown area, pipeline route),
- scour criteria,
- criteria for freespan length and height,
- etc.

6.3.3 Current condition

The collected data should be reviewed in order to map how the system has been operated and maintained. The current physical condition should be identified. This will form the basis for the life extension reassessment.

Depending on the possibility to quantify the condition, the integrity level may also be quantified. This may then be used as a baseline for the development of the degradation mechanism into further operation. Depending on the type of condition control used for the transportation system the level of condition is quantified, see Figure 5.

The assessment of the condition may provide information that improves the understanding of the degradation mechanisms and the rate of the degradation mechanisms, i.e. calibration of degradation model. This should be incorporated in the reassessment for life extension.

6.4 Remedial actions

If the condition of the system can not be quantified or the system has been operated or maintained outside the intended use, the gaps in information shall be given as input for reassessment. Recommendations to the reassessment activity about how to close these gaps shall be provided.

7 Reassessment

7.1 Objective

This subclause describes the reassessment process in the life extension project. The reassessment is the activities related to analysis of the generated information (i.e. inspection and monitoring data, as well as life extension premises), and establishing the integrity of the system through the full extended lifetime.

7.2 Process overview

The input to the reassessment process is provided by the condition assessment (diagnostic) and the determination of the life extension premises.

The output of the reassessment process provides the basis for the documentation of the system integrity over the extended lifetime or required modifications.

The reassessment process is illustrated in

Figure 6, and should be regarded as a part of the life extension process described in Figure 3. The dotted line indicates the reassessment part of the process.

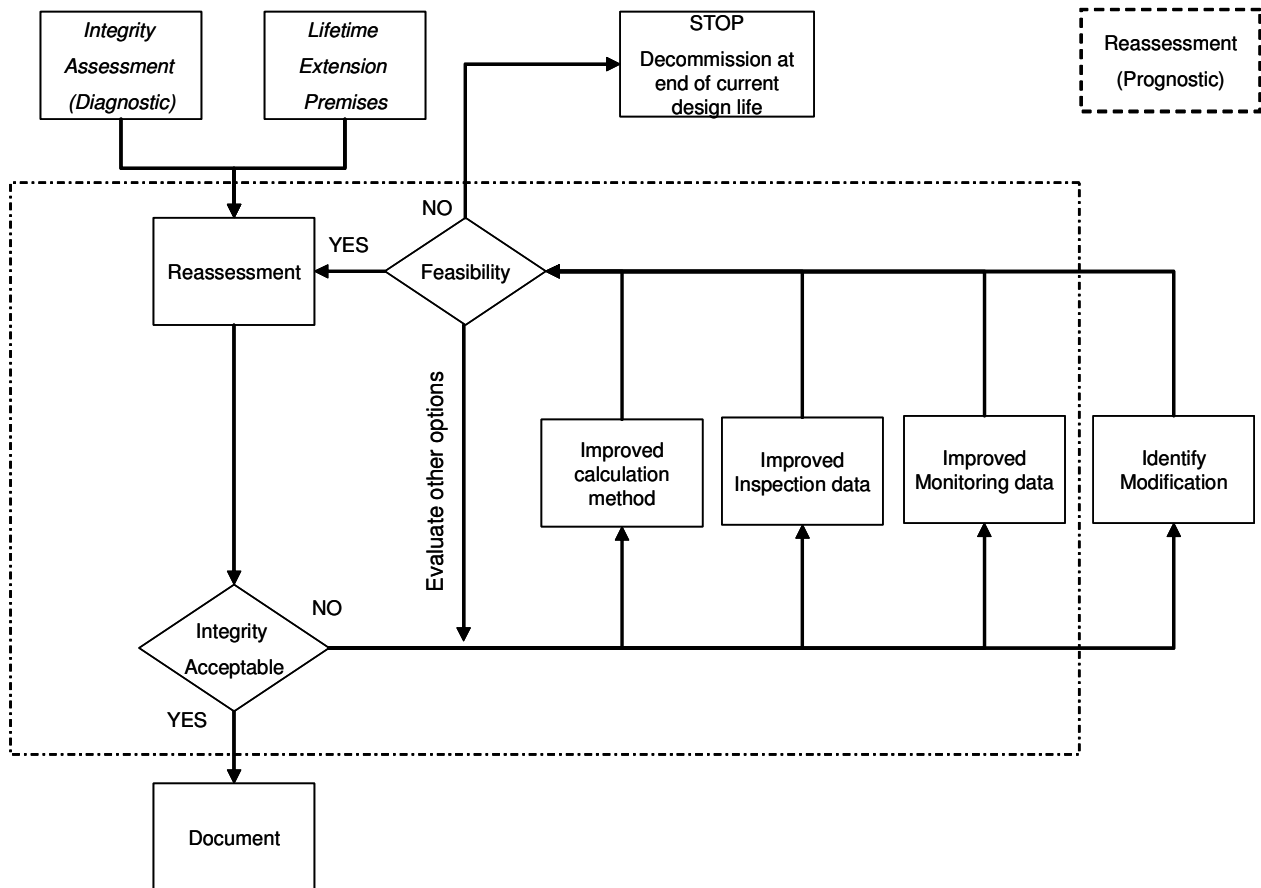


Figure 6 - Flowchart of the reassessment process

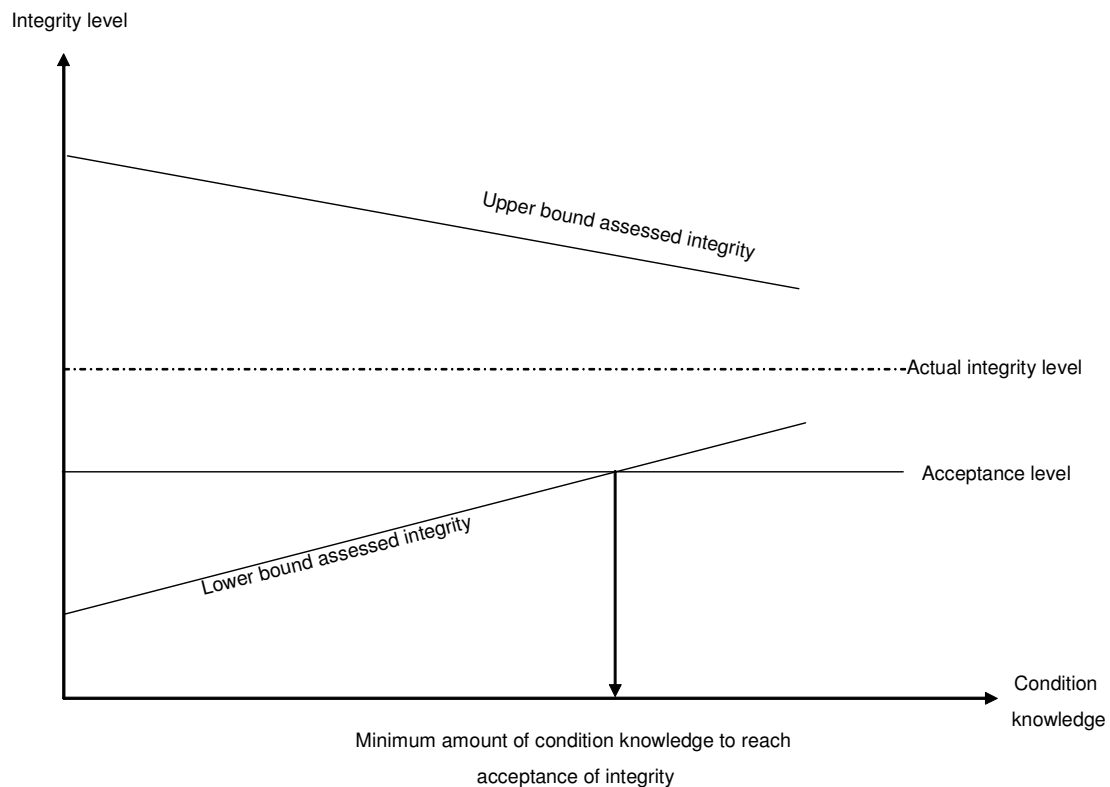


Figure 7 - Accuracy of the assessed integrity level relatively to the condition knowledge of the system

The actual integrity level of the transportation system can never be fully known. The condition assessment is based on inspection and monitoring data, as well as an understanding of materials and system models. These have all inherent uncertainties and inaccuracies.

The actual integrity of the system is not a variable, even though it is unknown. On the other hand, the assessed integrity (i.e. the result of condition analysis) is a variable, which depends on the accuracy and quality of the available information.

The assessed integrity, as illustrated in Figure 7, has a lower and an upper bound. In other words, based on the available information all possible condition assessments will most likely position themselves between the lower and upper bound. However, good engineering practice and proper conservative assumptions should result in a lower bound integrity assessment. Hence the lower bound integrity level shall be compared with the acceptance level.

There are two potential situations at the end of the reassessment:

- a) the assessed integrity level is equal to or exceeds the acceptance level. The reassessment is complete and the life extension project proceeds to documentation;
- b) the assessed integrity level does not meet the acceptance level. As illustrated in
- c) Figure 6, several options are available in order to increase the assessed integrity level:
 - 1) improved calculation method;
 - 2) improved inspection data;
 - 3) improved monitoring data.

The feasibility of the chosen options should be assessed. The feasibility is based on the need to reach a defined acceptance level. In special cases modifications to the system may be required, see clause 8. However, if no option is feasible, the result from the reassessment will be to not recommend life extension.

7.3 Acceptance level

The design standard chosen for the transportation system defines the acceptance level, see 5.3.

The acceptance level for a life extension evaluation shall be the same as for a new design with respect to acceptable risk for the system. This means that at the end of the extended service life, and at all times during the operational phase, the integrity of the system shall not be lower than that required by the applicable design standard.

Common for all acceptance levels is ensuring a sufficiently low risk, in other words a sufficiently high safety level. The risk is expressed as a product of the PoF and the consequence of failure. The probability may be stated explicitly, or it may be implicit, i.e. design standards based on "best engineering judgment" or "good industry practice". In order to properly carry out a reassessment of the transportation system, it may be necessary to determine the probability requirement implicit in a design standard, and use this as the acceptance criteria for the life extension.

7.4 Design based reassessment

Design based reassessment makes use of industry best practice. No information about the current condition is available, which means that there is no updated baseline for the development of the degradation mechanism into further operation. The integrity level shall be assessed through the timeline from installation until the end of the life extension.

Industry best practise changes continuously and improved knowledge about failure mechanisms and degradation models shall be implemented when original design is identified to be non conservative. These may also be implemented in the life extension reassessment to reduce conservatism.

7.5 Condition based reassessment

Condition based reassessment makes use of operational experience data. The data provides condition knowledge of the system, and should be integrated in the reassessment models. In new design uncertainties regarding operation are incorporated in the premises and assumptions. For the systems that have been in operation experience data provide additional information that may give enhanced understanding of the system response.

The methods used to assess the system capacity are constantly being developed. Data processing capacity is also increased with time. This gives possibilities to perform assessments with improved representation of the system.

Inclusion of information from operation providing a condition based assessment is illustrated by Figure 8. The design process starts with a number of premises and assumptions, as well as functional requirements. A model is developed and used to calculate the global and local behaviour of the system, which gives information about local conditions in individual sections. Based on these local conditions materials and components are specified and manufactured, and degradation estimates can be established. Both general technology development and condition based data can influence this process, as illustrated in Figure 8.

Monitoring and inspection data can refine the design premise and assumptions, and make them less conservative. Direct measurements of load conditions and local system response can calibrate the models, and also expose excessively conservative results. The models and calculations benefit from continuous improvements in computer technology and from research into models and general system understanding. It is important to note that the material and components can not be changed in a life extension, unless a modification/replacement is carried out. Still, the damage/degradation estimates can be updated based on the possible input illustrated in Figure 8.

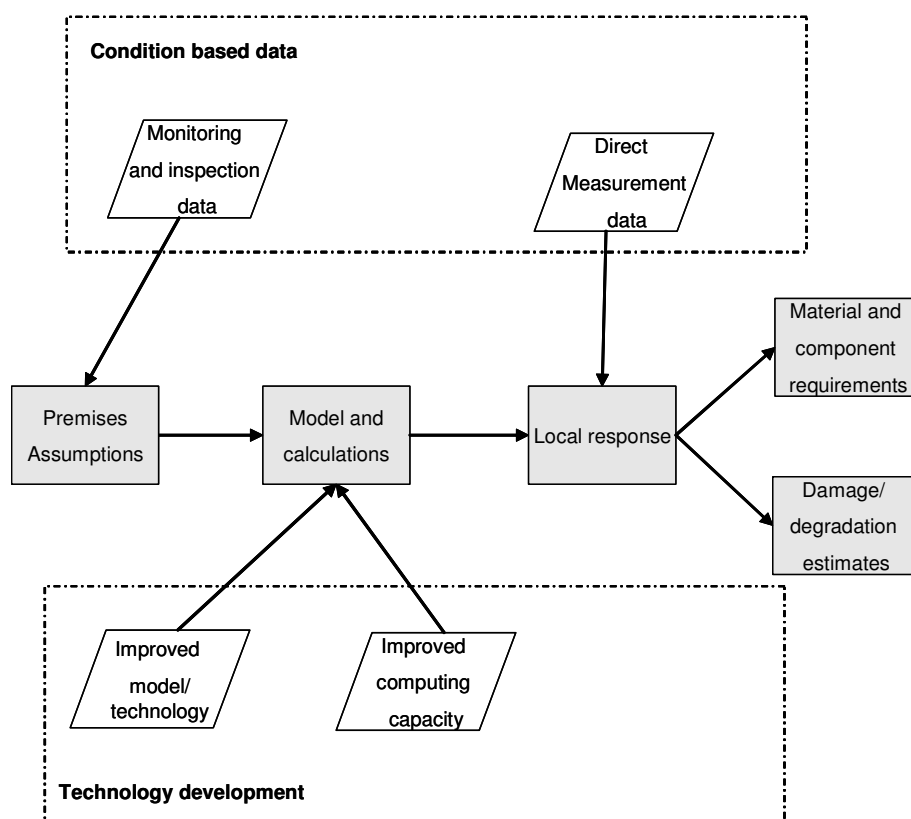


Figure 8 - Influence from condition data for the assessment of life extension

Condition based assessment brings to use all the available information about the transportation system. In the design of a new system, the operational and environmental parameters are estimated, and these estimates are used in a model in order to calculate the system requirements. Condition based assessment utilise information from operation of the system, which means that both the estimates and the models may be improved as follows:

- monitoring and inspection data can improve or replace the original premises and assumptions, and a new calculation can be carried out. A more accurate estimate of the system condition will be obtained;
- direct measurements in the transportation system can give data that makes some of the calculation models less necessary or improved. The models convert external influences to effects internally in the system. If these internal effects are measured directly, the uncertainties and conservatism in the models are reduced.

For examples of use, see Annex A and Annex C.

8 Modifications

8.1 Mitigation

Mitigation is a reduction in the severity of an operational parameter, i.e. pressure reduction, temperature reduction, other measures.

Pressure reduction mitigation may be achieved by assessing available recommended practices, e.g. DNV-RP-F101 based on a quantified metal loss.

Chemical composition of the transported fluid may be influenced by change in use of inhibitors. The inhibitors shall be qualified for compatibility and efficiency with the pipeline system.

8.2 Intervention

Intervention is activities performed indirectly to the containment part of the transport system. This is modifications to support systems, e.g. through installation of rock dumping, trenching, installation of riser supports etc.

8.3 Repair

Repair solutions may be assessed through use of available recommended practices, e.g. DNV-RP-F113.

Components to be replaced shall be designed according to chosen design standards and premises applicable for the transportation system in accordance with 5.1 through 5.4.

8.4 Replacement

A modification is categorised as a replacement when e.g. risers or larger sections of pipelines are replaced in the system. When designing a replacement the operator shall use the latest available design standard for the new part of the system.

9 Document

Delivery from a life extension project shall be

- integrity documentation,
- plan for modifications,
- input to plans for monitoring and inspection.

The potential for extension of service life beyond the extended service life should be provided.

The integrity of the transport system shall be documented based on the current condition assessment (diagnosis), the reassessment (prognosis) and required modifications. This includes the premises for the life extension, the present condition of the system's parts and components, as well as the condition at the end of the extended design life. Gaps in the risk level between the original design standard and the current applicable standards shall be documented.

The life extension project will in most cases identify a number of requirements related to modifications, monitoring and inspection. These requirements will also form a necessary input for updating the various documents and activities in the integrity management system, e.g. inspection plan, monitoring plan, maintenance plan, modification plan.

The plans for modifications, monitoring and inspection shall be clearly documented and are individual deliverables from the life extension project. The content of the plans shall state the actions to be taken and their respective time limits.

10 Implement

The life extension project may conclude with requirements that shall be met by the organisation responsible for operation of the transportation system. These requirements shall be integrated with the controlling processes in the operator's organisation in order to ensure that implementation will be carried out.

In effect, this requires that the requirements given by the life extension project are integrated into the IMS of the transportation system. Continued operation of the transportation system into and through the life extension period will then be within the acceptable safety level.

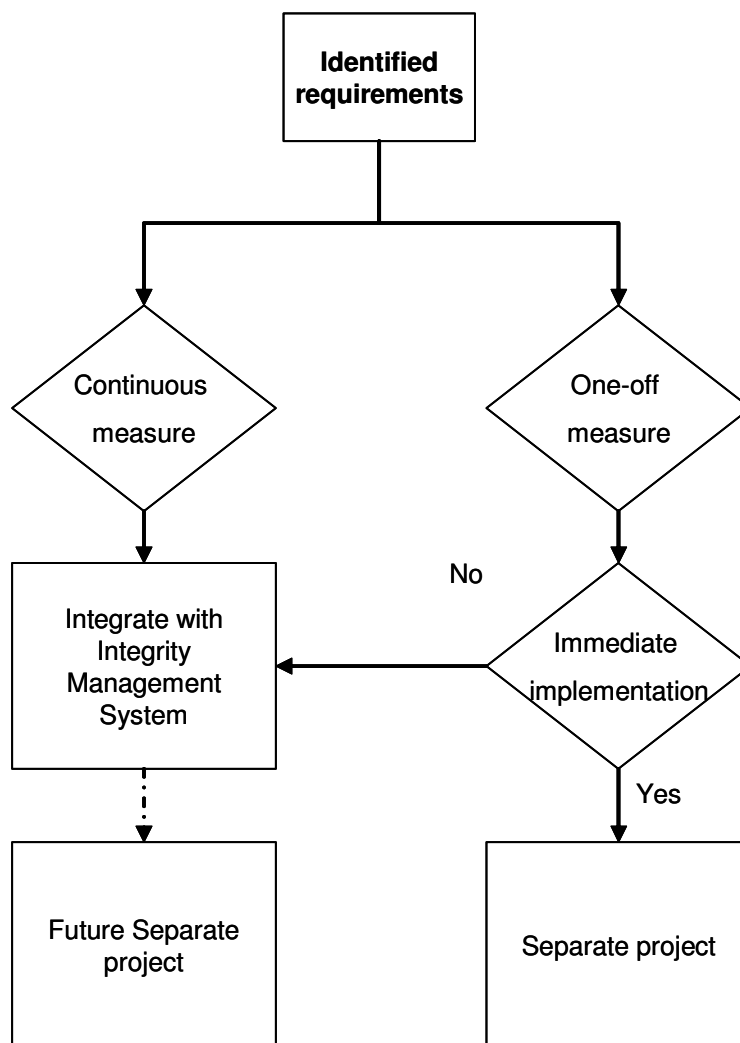


Figure 9 - Implementation strategy

Continuous measure:

This may be changes and updates to inspection and monitoring strategies. Such measures are activities that shall be repeated at regular intervals, and will be an inherent part of the operation of the transportation system.

One-off measure:

This may be unique modification activities, e.g. intervention, repair and replacement. These activities are either initiated immediately (possible as separate projects during the life extension projects), or responsibility for execution is handed over to the system operator. Such postponed modification activities may be initiated as a separate project even after the original design lifetime has expired (as determined by the life extension project).

Guidance note:

Not all modification activities are required to be carried out immediately. Some repair and replacement of components in the transport system may be required in order to extend the system lifetime. However, it may be that the activity itself can be executed at a later time.

EXAMPLE:

The original design life was 20 years, and the operator seeks a 15 year life extension (total 35 years). A component has a maximum re-qualified design life of 25 years. Hence this component shall be

replaced/repared 5 years into the extended lifetime. This activity is not carried out at the time of life extension, but has been identified as a requirement. Hence the requirement is entered into the IMS and the activity shall be initiated at the appropriate time.

Annex A (Informative)

Illustration of re-qualification schemes for life extension

The basic principle of life extension, integrity assessment and design life is illustrated through some schematic graphs. The intention is to put the definitions in this NORSOK standard into a context, and better explain their relationship.

The graphs are all in the same coordinate system: time along the horizontal axis, and the integrity level along the vertical axis. The timeline should start from the time of installation of the system. The integrity level is closely related to the risk in the system, i.e. it expresses the cumulative integrity of the system when taking into account all relevant failure modes and the condition of all components. The acceptance level is the minimum acceptable integrity level allowed by the authorities/design code. The operator and owner may have more strict requirements than the authorities/design code and this should then be accounted for toward the acceptable integrity level. The acceptance level can be expressed as a minimum integrity level or maximum risk allowed.

The degradation model can be considered the mathematical “function” that exists in the coordinate system “time vs. integrity level”. This “function” governs the evolution (normally a decrease) of the integrity level over time. The degradation model can be changed, if this is substantiated by industry practice or new knowledge. A condition assessment can be carried out during operation of the system, and this may appear as a sudden change (a jump or a drop) in the integrity level.

In the various scenarios included below, the acceptance level does not change. It should be noted that implementation of a new design code, or new requirements from the authorities, can lead to changes in the integrity acceptance level.

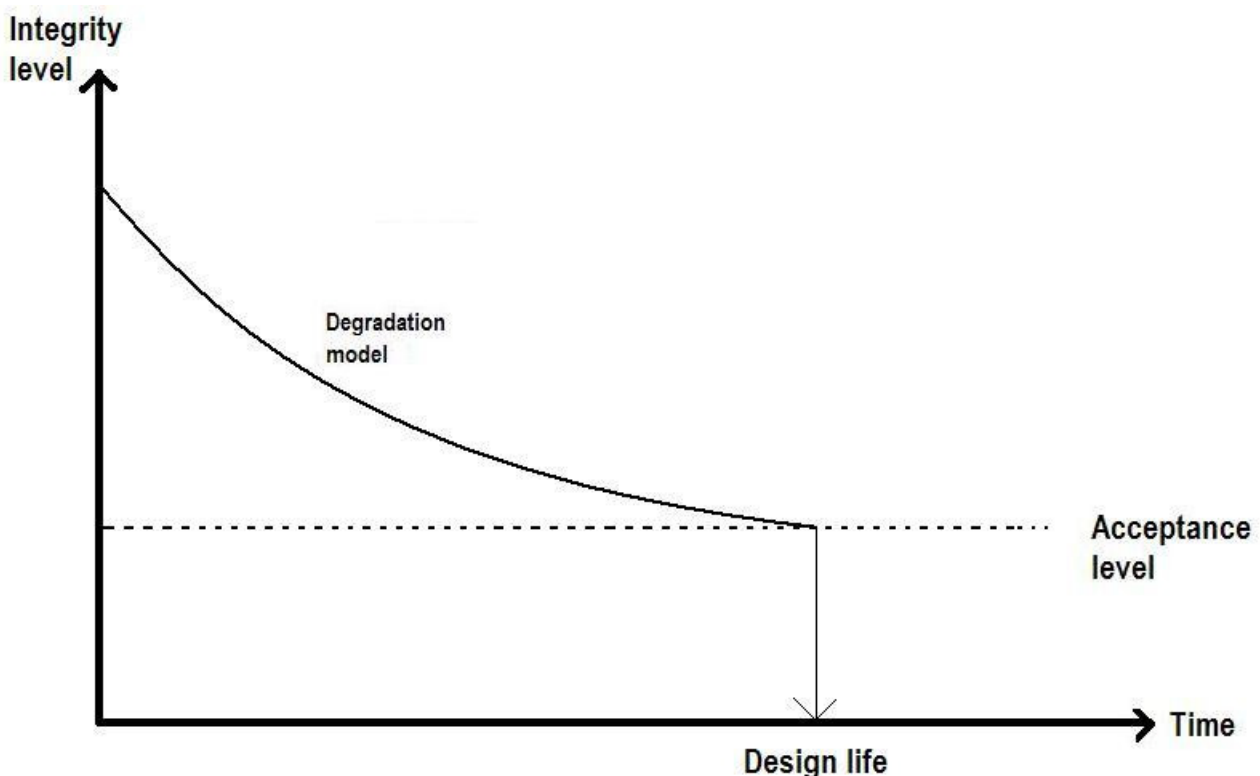


Figure A.1 - The design life is limited by the degradation model, Scenario 1

A base case is shown in Figure A.1, where the design life is limited by the degradation model. This means that starting from the as-installed condition (at time zero), the degradation model chosen for the system does not allow a longer design life.

A different case is illustrated in Figure A.2, where another degradation model is used. From the as-installed condition the integrity level of the system only slowly decreases, and the design life is not limited by the system integrity. The design life of a system is often linked to the design life of the entire field development, which means that the design life of neighbouring systems can be limiting. In Figure A.2 a life extension is not difficult to carry out, since the original documentation should be sufficient to show adequate integrity during the extended life. Still, it is advisable to carry out a condition assessment.

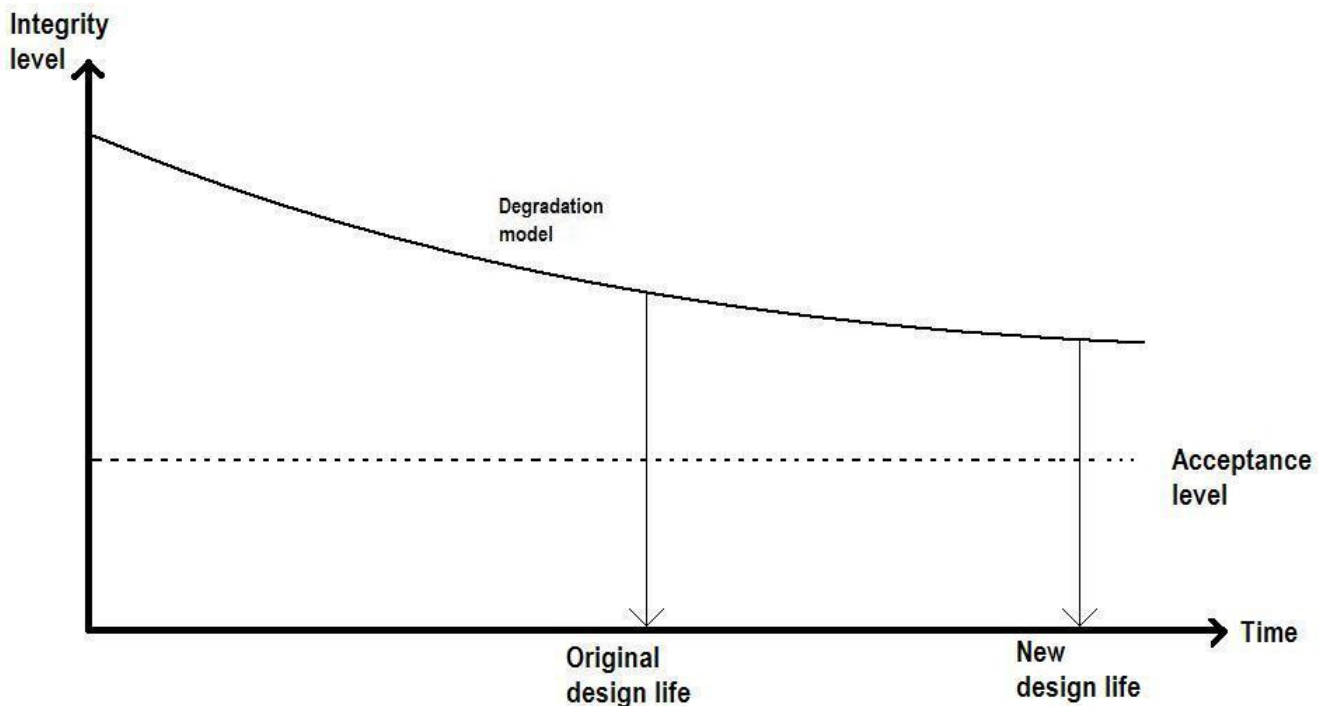


Figure A.2 - The degradation model does not limit the design life, Scenario 2

Please note that both in Figure A.1 and Figure A.2 the integrity life of the system has not been addressed. The integrity life exceeds both the design life and the extended life of the system. For Figure A.1 the degradation model limits the design life, but this does not necessarily mean that the system is close to failure at that time, i.e. it only means that the integrity is not be documented further. Possibly a better (i.e. less conservative) degradation model would allow a longer design life.

A life extension project is shown schematically in Figure A.3. The degradation model, starting from the as-installed condition/integrity level, gave a design life during the original design process. However, this design life is not sufficient, and a life extension project is carried out. The same degradation model for the system is used both for the original design and for the life extension, but an integrity assessment (current condition) is carried out. With this assessment it is documented that the integrity level is actually higher than anticipated with the degradation model. In addition, knowing the current condition of the system, it is possible to “recalculate” (i.e. make a prognosis) the remaining life. As a conclusion it is documented that the system can be safely operated longer than originally planned.

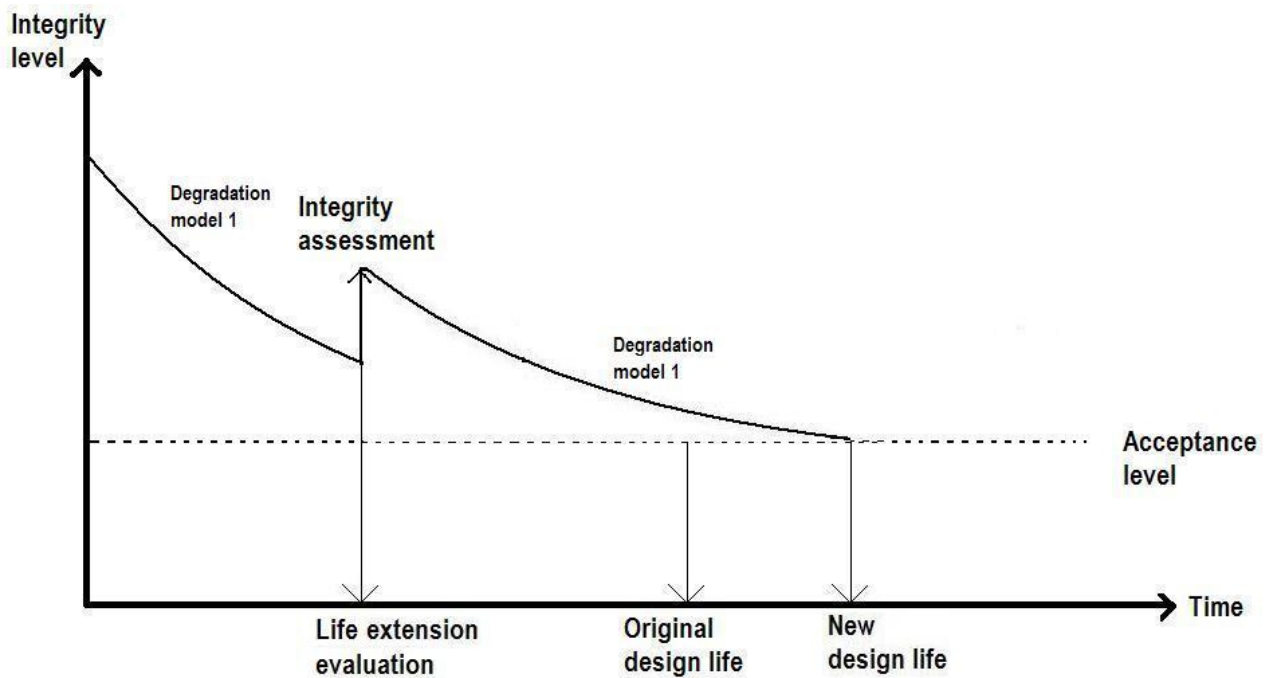


Figure A.3 - A life extension with integrity assessment, Scenario 3

Note that the increase in integrity level in Figure A.3 can also be due to a modification or through e.g. repair of the system.

It is possible that an integrity assessment will result in a drop in the documented integrity level of the system, as illustrated in Figure A.4. This will typically be the case if the operational parameters (e.g. loads, temperature, pressure, chemical environment) are outside of the operation envelope from the design process. It is also possible that an incorrect degradation model was used, for instance if a critical failure mode was overlooked. In the case of Scenario 4 in Figure A.4 the system can not be operated for the full original design life without initiating modifications.

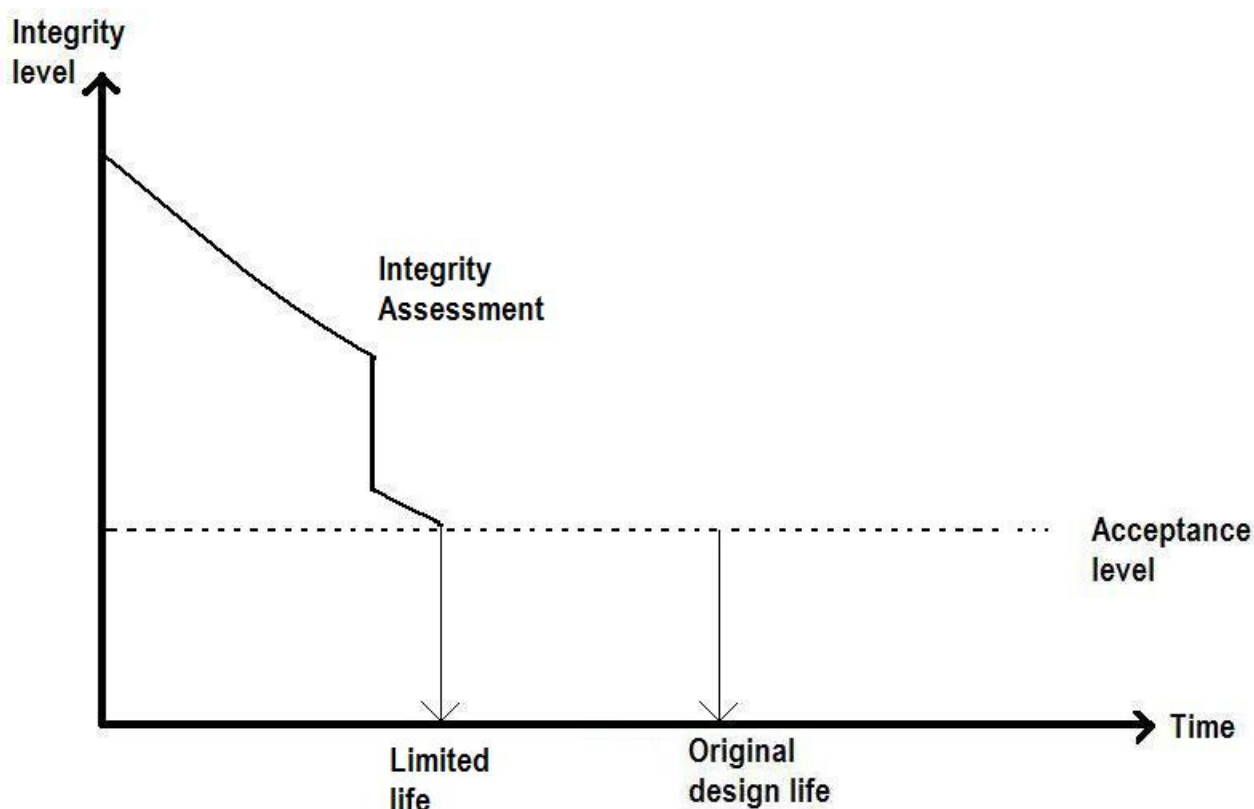


Figure A.4 - A drop in integrity level, Scenario 4

A new degradation model can also be chosen as illustrated in Figure A.5. The new degradation model can be based on new industry practice or updated research data. It is also possible that new operating conditions lead to a different degradation model. The operating conditions can be changes in temperature or pressure, or a new composition of transported fluids. It is also possible that the system has been moved to a different field (e.g. re-use of flexible pipe), where the design premises can be different.

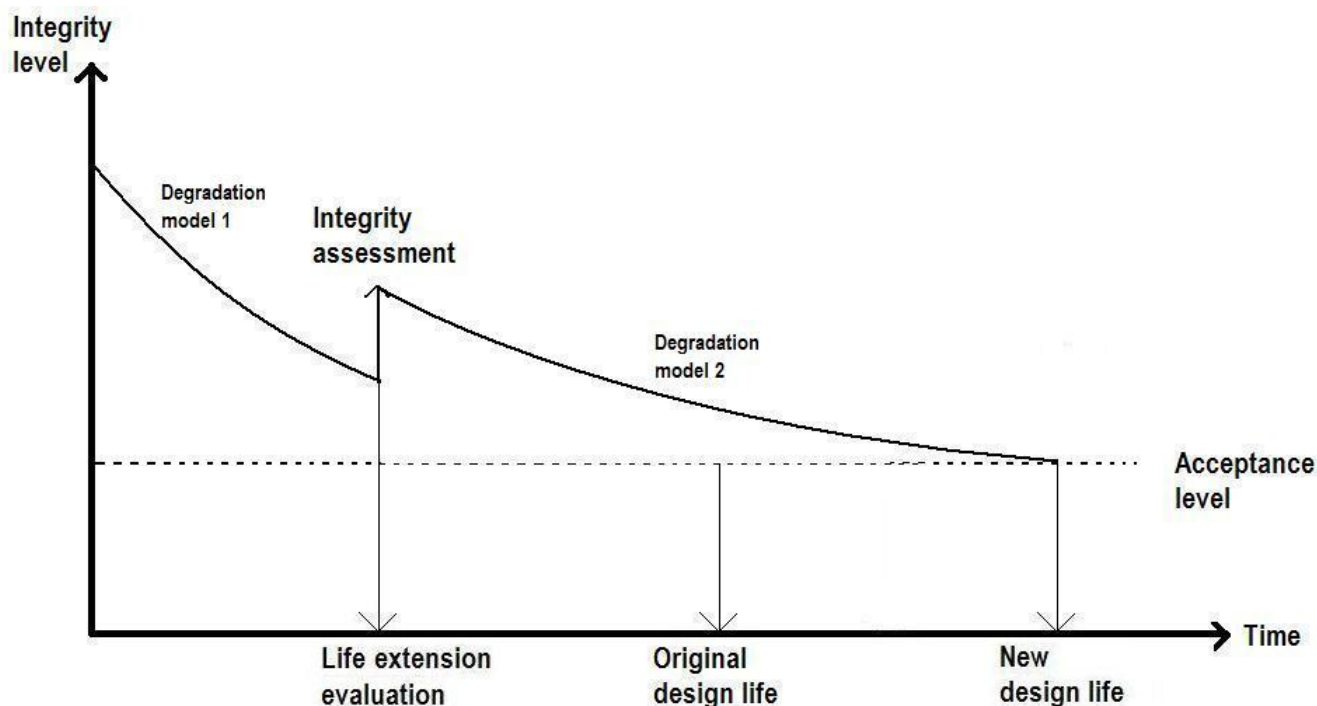


Figure A.5 - Life time extension with a new degradation model, Scenario 5

Integrity assessment, based on qualified inspection intervals, is not only carried out in connection with life extension. It is possible that the degradation model may be quite conservative, and it is not possible to document acceptable integrity for the system for the required design life. One solution (illustrated in Figure A.6), is to carry out regular integrity assessments, and document through inspection and monitoring a higher integrity level than predicted with the degradation model. This means that it will require regular qualified inspections and integrity assessments, which shall then be included in an appropriate integrity management system.

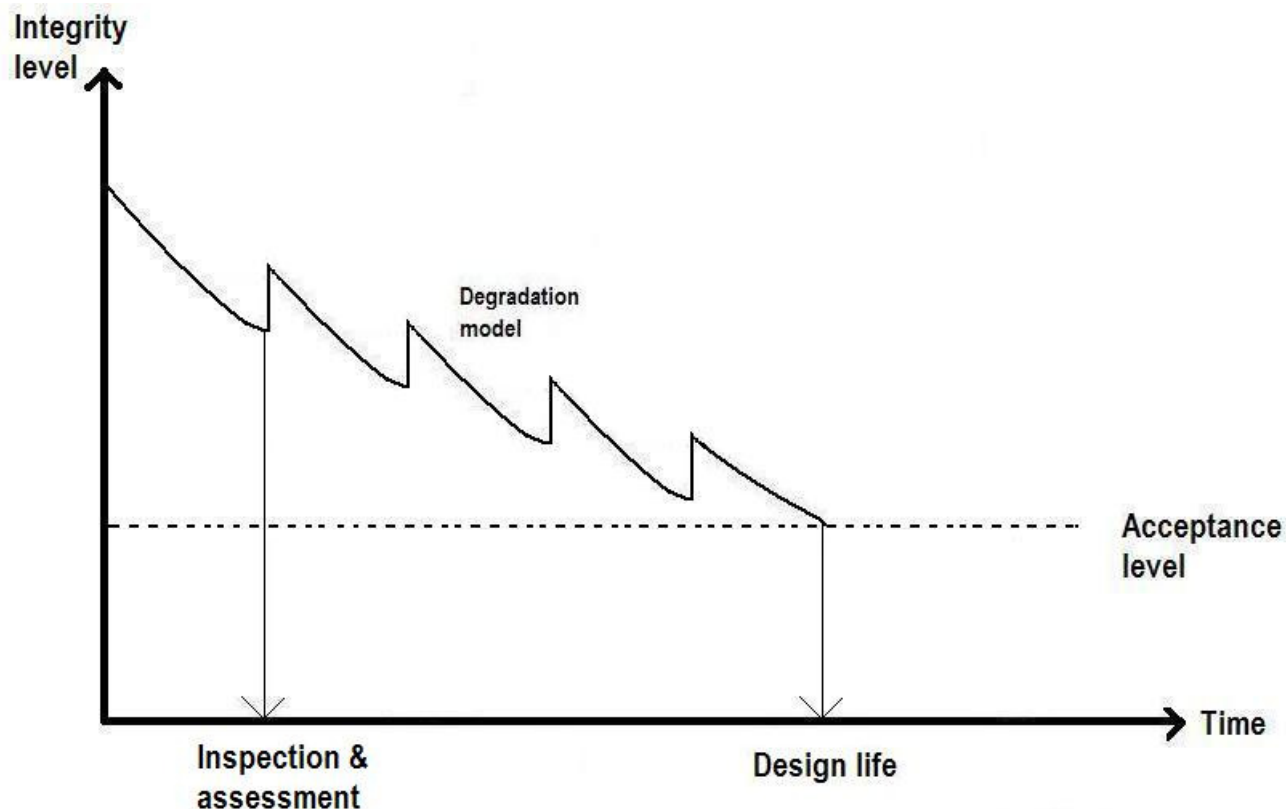


Figure A.6 – Regular inspection can be a condition in the design, Scenario 6

Annex B

(Informative)

Work process paradigm

B.1 General

Life extension of a transportation system requires a reassessment to document that the system can be safely (and cost effectively) operated. The life extension process shall be a structured and planned process ensuring that all equipment and their potential integrity threats are evaluated and documented.

This annex presents how a system may be identified and how screening of the system in view of life extension may be performed.

B.2 Life extension premises

The premises for the life extension shall be established. This may include the following:

- life extension period;
- battery limits (what to be included/system description);
- regulatory requirements (e.g. according to this NORSOK standard);
- reference to company specific procedures, if relevant (e.g. procedure for handling of deviations from design codes);
- reference to applied design codes;
- technical/functional requirements (e.g., design pressure, design temperature, product composition).

B.3 System review and identification (ID) of equipment scope

The objective of this activity is to identify all equipment associated with system, and whose failure affects the integrity and imposes un-acceptable risk. Risk is the product of PoF times the consequence of failure. The consequences are commonly divided into safety, environmental and economical consequences.

For each identified equipment, the following information is collected:

- equipment ID;
- equipment type;
- purpose and barriers;
- design basis, hereunder design code(s);
- main design documentation (e.g. design, fabrication and installation résumé);
- operational history (e.g. from an event log);
- inspection, maintenance and testing program and documentation from these activities;
- company or industry experience with this or equivalent equipment type (e.g. failure statistics);
- current design practice for this type of equipment (i.e. design code, recommended practices);
- future equipment loading, hereunder functional loads (e.g. dead load, pressure, temperature, flowrate), environmental loads (wave, wind, current, ice and internal fluid composition) or accidental loads.

The basis for and evaluation made to include or exclude an equipment/component from the life extension scope shall be documented. An example that could be used is shown in Table B.1.

Table B.1 - Equipment review form

Equipment ID	<Demo pipeline>	Type:	<Steel pipeline>
Section A Evaluation basis:			
A1	Purpose:	<Transport of content>	
A2	Barriers:	<Pipe wall>	
A3	Design code(s)	<Design code>	
A4	Design docs.	<Doc. No.1> <Doc. No.2>	
A5	History:	<Summary of important integrity events>	
A6	Inspection:	<Summary of inspection, maintenance and testing and evaluation of these>	
A7	Experience:	<Summary of company or industry experience with this type or comparable equipments>	
A8	Current design:	<Summary of current design practice compared to original design of this >	
A9	Future loading:	<Summary of equipment loading as compared to original design >	
Section B Questioner:			Yes
B1	Will the design life of the equipment be exceeded during the planned life extension period?		
B2	Have there been any events that could influence the planned life extension period?		
B3	Are there finding inspection, monitoring or testing that could influence the planned life extension period?		
B4	Is there company or industry experience with this equipment that should call for a re-qualification?		
B4	Have there been changes in the design practice resulting in reduction of the inherent safety level (former designs have been non-conservative) or has the code acceptance criteria been made more stringent?		
B5	Has the equipment loading increased?		
Section C Re-qualification is required?			
Evaluation: <.....>			

Annex C

(Informative)

Condition based assessment

C.1 General

The key issue in a condition based assessment is thorough exploitation of all available data from the operation of the system.

The service data come in many forms, e.g. monitoring of production parameters and environmental conditions, as well as inspection of the system. In addition, more targeted monitoring and inspection methods can be implemented if deemed necessary.

Below are some generic case-studies, outlining how input data can be useful in a condition based assessment. These case-studies are not meant to be comprehensive, but should give some guidance in the life extension process.

C.2 External corrosion

The corrosion resistance of a transportation system depends on the material selection, the coating system and the CP system. The primary protection is the coating system, and the CP system is a backup. The coating will break down over time, and the associated corrosion protection will be reduced.

Reassessment of the corrosion protection system should be based on inspection of the coating, as well as the anodes in the system. The important parameter is the coating breakdown factor, which can not be determined directly by inspection. However, based on the anode consumption it is possible to calculate “backwards” in time and estimate the coating breakdown already experienced during operation. This coating breakdown can then be extrapolated into future operation, and the future demand on the CP system may be quantified life extension.

The status of the CP system toward the end of the life extension period may then be quantified. The extrapolated coating breakdown should be evaluated to provide sufficient safety. In addition the CP system should cover the full transportation system in the extended lifetime.

Based on the evaluation of the coating and the CP system the estimated integrity level of the corrosion protection can be compared with the integrity acceptance level.

C.3 Fatigue

A relevant reference for fatigue is NORSOK N-006.

Fatigue is a time-dependent failure mode. Extending the design life of an existing transportation system, or individual component, may be challenging. In fact, based on the calculations from design phase, the accumulated damage may exceed a critical level already at the end of the design life. This alone does not disqualify a transportation system from being used beyond its design life, since conservative assumptions made during the design phase can overestimate the damage. Results from a reassessment of the system may show that a life extension can be justified with the same acceptance level (as required by the applicable design standard).

Figure C.1 shows an example of how the PoF for a system may evolve during its time in service, t_1 . The PoF will naturally increase with time due to the initiation and development of fatigue cracks. In order to maintain an acceptable integrity level, the PoF cannot exceed a maximum value (i.e. related to the acceptable risk level).

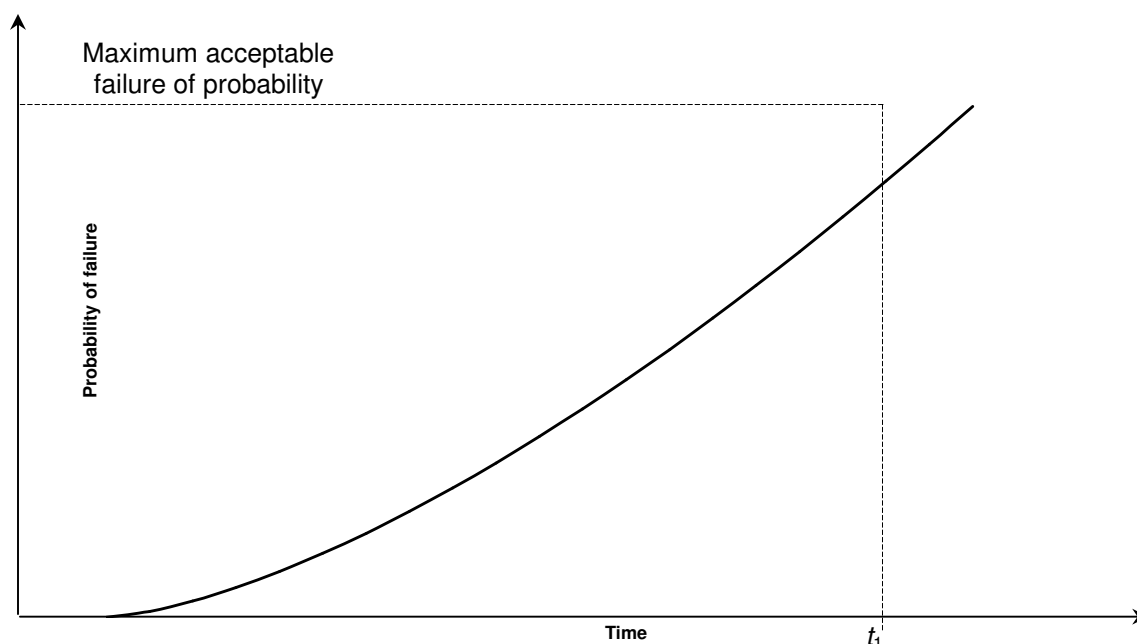


Figure C.1 - Illustration of the probability of failure (PoF) as a function of time

The PoF may reach the maximum acceptable failure level during the design life. Hence, extending the service life may pose a problem. Figure C.2 shows that the PoF related to the extended service life, t_2 , will exceed the PoF of the original design life, t_1 . If the increased risk is acceptable, the life extension is not a problem.

However, if the increased risk (i.e. lowered acceptance level) is not acceptable, alternative methods shall be applied in order to justify an extended service life without increasing the risk.

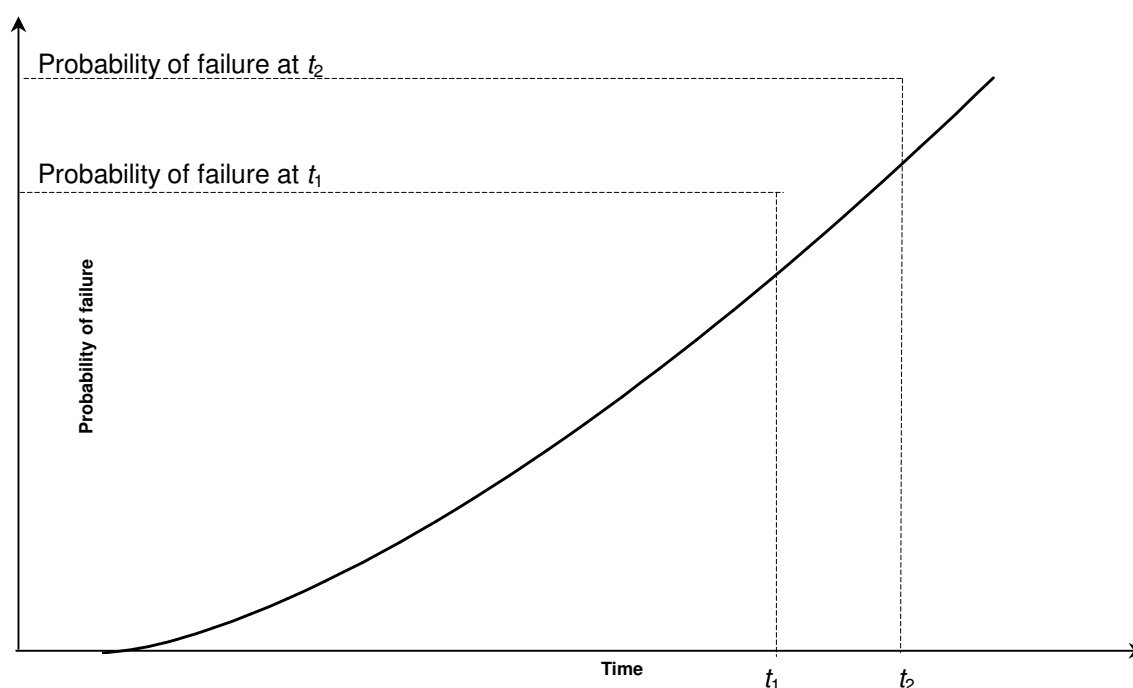


Figure C.2 - Increase in probability of failure (PoF) related to life extension

The PoF established in the original design shall be reassessed. An alternative method could be to obtain a curve that falls below the original curve, i.e. the predicted rate of fatigue crack development is decreased. A new PoF curve may be obtained by

- carrying out a new fatigue analysis (e.g. more powerful and detailed calculation and modelling tools),
- inspection of the structure,
- incorporating environmental monitoring data in the analysis (e.g. using the real-life data, instead of depending on models and forecast with inherent uncertainty and conservatism),
- monitoring structural components (e.g. measuring the stress at critical locations, instead of depending on models to calculate the local stresses),
- a combination of the above.

The difference between the PoF curve established during design and an updated, more realistic curve will depend on conservative assumptions from the design phase. If such conservative assumptions are present, a re-analysis may result in a less conservative PoF curve.

Figure C.3 shows how an updated PoF curve (dotted line) based on a re-analysis can justify an extended service life without exceeding the maximum failure probability.

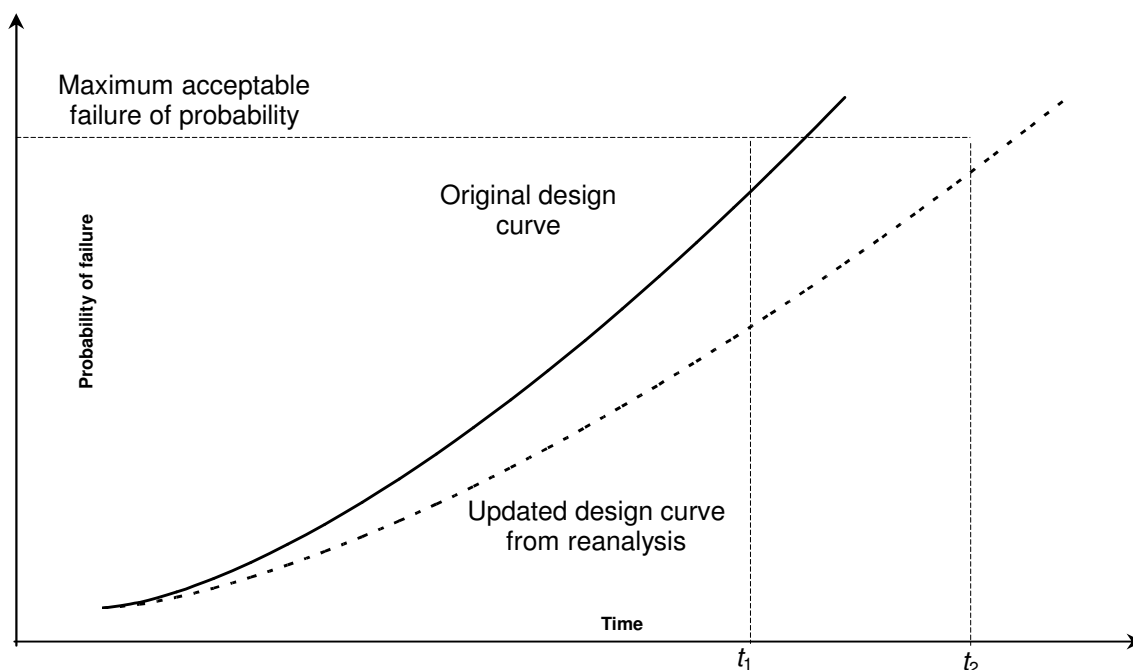


Figure C.3 - Probability of failure curves; original design and life extension re-assessment

Inspection of the system can also justify a life extension. The time-dependent defect distribution can be updated through inspection of locations and components that are assumed to be critical. Figure C.4 shows how the PoF curve can be updated based on results from the inspection. The defect distribution based on inspection at time, t_i , predicts smaller defects than assumed in the original design. In this case the result is a lower PoF curve. This is illustrated in Figure C.4 showing the assumed defect distribution (for original design) and the defect distribution based on inspection at time, t_i .

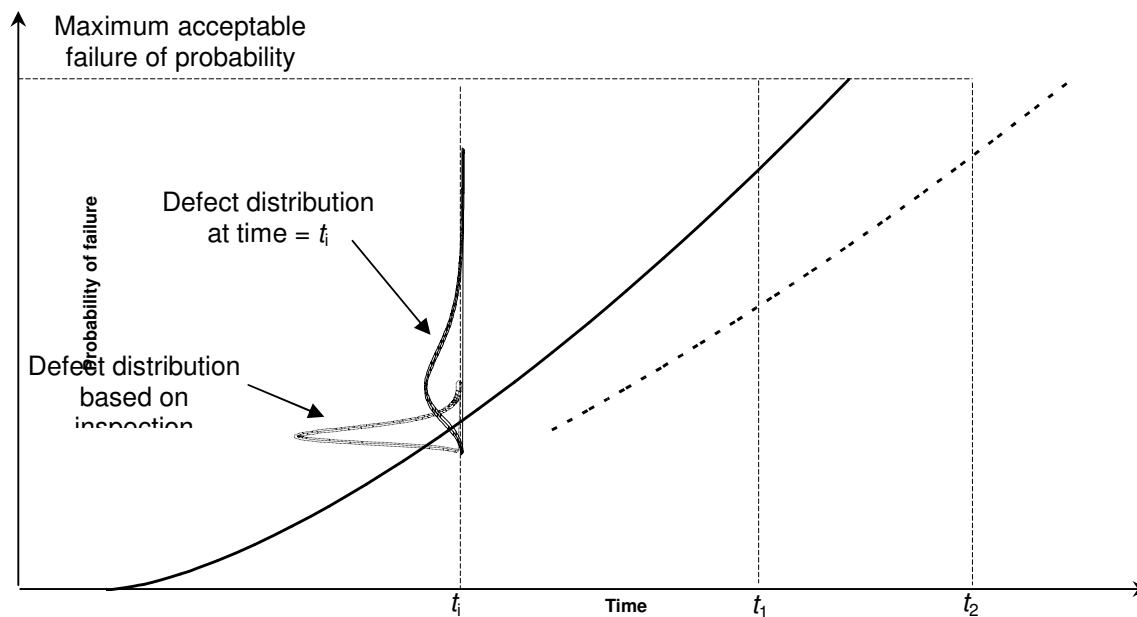


Figure C.4 - Illustration of how the PoF is updated based on inspection

C.4 Polymer material

Polymers are typically present in flexible pipes (both bonded and unbonded) and in seal/gasket functions.

A polymer material will during operation have deterioration of its properties, e.g. strength, ductility and chemical resistance. Temperature and fluid composition are important factors. However, research and new technology can give rise to new degradation models. Degradation of polymers is not reversible, and the components may have to be replaced.

Polymer materials are usually sensitive to operational parameters, e.g. temperature, pressure and chemical environment. Time dependent degradation leading to failure of polymers is often caused by operation conditions outside the assumptions used as basis for the qualification.

Design, as well as operational information, should be identified and assessed in a life extension project.

Based on such data it may be possible to determine the capacity of the polymer toward an extended lifetime.

The following information should be obtained:

- a) related to the component;
 - 1) identify type of polymer (elastomers/thermoplasts, composition, properties) in the system, their location and function;
 - 2) determine the material specifications and functional requirements that were used as a basis for the selection of the elastomer/thermoplastic components;
 - 3) use inspection data and monitoring data about operation conditions to evaluate the condition of the components.
- b) related to the operating environment.
 - 1) identify the operation condition limits in the original design, or design envelope of operational parameters that were also used for qualification of the polymer);
 - 2) identify expected/possible changes in operating conditions (life extension premise);
 - 3) review data from the operation of the system. Identify any deviation of the operating parameters outside the design envelope (e.g. max/min temperature, maximum pressure/pressure cycling and changes in chemical environment).

The failure modes are often related to expected degradation of the polymers (elastomers/thermoplasts) in the operation/service environment. An evaluation of the effects of prolonged exposure to the operating environment will identify the most likely damage mechanism for the components.

If elastomers/thermoplasts have been exposed to operating parameters outside the design envelope (i.e. outside of the parameters for which the materials were qualified), the integrity of the elastomer/thermoplastic components should be further evaluated. The PoF for the component increases if exposed to operation conditions close to or outside the design assumptions/envelope.

In a life extension project the premises shall be established, identifying failure modes based on any new/changed conditions or threats. Typical time dependent failure modes are listed in Table C.1.

Table C.1 - Time dependent failure mode

Degradation process	Parameters that may influence risk of failure
Chemical ageing (e.g. chain scissoring and cross linking of chains)	Temperature Chemical environment
Fatigue	Chemical environment Temperature Mechanical loads (cyclic/maximum values)
Rapid gas decompression	Pressure cycling Temperature Maximum pressure
Gas permeation	Temperature Concentration gradients
Physical ageing	Temperature
Creep	Temperature Pressure
Problems related to additives	Temperature Concentration gradients Pressure gradients Chemical environment
Stress relaxation	Temperature

Elastomer/thermoplastic components can be replaced. The composition and production route of any replacement elastomer/thermoplastic component shall be comparable to the old component. If this can not be verified a qualification of the replacement elastomer/thermoplast shall be performed, based on the life extension premises.

The integrity of spare parts shall be evaluated before use, since polymers normally have a limited shelf life.

C.5 Internal corrosion

Internal corrosion resistance depends on the material selection and the corrosive potential of the transported fluid.

Some internal corrosion damage will occur, but if the system is properly designed and operated it should not be a concern during the design life. For a life extension project, it is important to note that corrosion damage can not be reversed. However, the internal corrosion can be slowed down, e.g. inhibitors, other measures.

Depending on the margins in the system (i.e. wall thickness, corrosion allowance), it is important to start the life extension process early in the system life. Increased corrosion prevention measures can be introduced, which may extend the integrity life of the transportation system. If the remaining margins have become too small, such measures may not be sufficient to provide the required extension in integrity life.

Repair/intervention related to internal corrosion is normally not possible short of replacing large parts of the system, since the effect of corrosion is often evenly spread out in the transportation system. However, in some cases there can be severe local corrosion damage, and smaller sections/components can be replaced or repaired.

C.6 Flexible pipe

C.6.1 General

Unbonded flexible pipe are used as risers as well as flowlines. Their "composite" structure of a number of layers with different materials and functions makes flexible pipes very difficult to inspect as a means to

quantify condition. As a consequence, a life extension of flexible pipes may mainly be based on design data and monitoring data.

Certainly, inspection of flexible pipes is carried out regularly, but it is commonly limited to external visual inspection. This can confirm the correct global configuration of the system, as well as identify any leaks/bursts in the external sheath or other damages to the pipe. In some cases, internal visual inspection is carried out through various techniques, e.g. a camera is sent into the pipe and carcass (rough bore) or pressure sheath (smooth bore) can be visually inspected. In addition, the annulus volume and gas composition can be tested at regular intervals by pumping nitrogen into the gas relief valves, and afterwards recovering the gas. The leak rate through the annulus may be monitored by a vent gas monitoring system. Polymer as well as corrosion coupons may be used exposed to the flow to monitor the degradation developments.

Life extension will typically be concentrated on the pressure sheath and the armours located in the annulus, since these layers are the main pressure-retaining and load-bearing components. These layers are unfortunately very difficult to inspect during service. For the polymer pressure sheath it is important to determine the degree of degradation due to temperature, pressure and interaction with the transported fluid.

For the pressure armour and tensile armour it is important to establish the level of corrosion, fatigue and wear sustained by the materials. Depending on the type of materials chosen for the layers and the type of operation the pipe has been in, other considerations and degradation mechanisms can be equally important.

Lacking dependable inspection data for the materials in the flexible pipe, it is very difficult, if not impossible, to quantify the current condition based on inspection data. As a consequence, the current condition shall be estimated based on monitoring data from the operation of the system, in connection with accepted degradation models for the layers and materials.

C.6.2 Materials and degradation

The specific degradation mechanisms that are involved for a given pipe is not listed here and a case-specific evaluation shall be performed. It is important to keep in mind that materials used in flexible pipes are qualified and tested based on the load conditions and operational parameters typical for the flexible pipe. The materials themselves are typically not used in other applications or the operational parameters differ significantly. Hence, testing data from other fields of usage may not be used for design or re-evaluation of flexible pipe. This means that material life data (e.g. fatigue SN-curves, polymer degradation projections, annulus gas diffusion data) shall often be obtained from the manufacturer since the qualification and test data is typically kept on file by the manufacturer and not released to clients.

A strategy to obtain reliable material data and in order to precisely evaluate the current condition is to retire and dissect one flexible pipe, if there are a number of pipes of identical design that have experienced equal operating conditions.

C.6.3 End fittings and ancillary components

A flexible pipe also contains two end-fittings. The design and structure of the end-fittings are often considered proprietary information by the flexible pipe manufacturer. However, obtaining sufficiently detailed information about the materials, loads and conditions in the different areas of the end-fitting is necessary in order to carry out a life extension, since the end-fitting is an integral and critical component of the flexible pipe.

Flexible pipes are often installed with ancillary components, e.g. bend limiters, anchors, buoyancy elements, tethers and arches. These components are typically critical with regard to the global configuration of the flexible pipe system, and shall be included in the life extension assessment.

C.6.4 Re-qualification of flexible pipes

In general for flexible pipes there is a need to have a strategy for follow up of the system from the very beginning of operation. This is required in order to have a possibility for identifying trends and at least have information available when addressing integrity assessment of the flexible components.

Selection and implementation of monitoring and inspection techniques is required to be done at an early stage to provide the best possible basis for assessing the condition at a later stage, through integrity assessment.

It is important that the monitoring and inspections activities are selected with a defined objective for contributing to the condition assessment of such systems.

