GUIDANCE NOTE

Ageing assets and life extension

Document No: N-04300-GN1975 A783718

Date: 24/06/2021

Core concepts

- *"Ageing is not about how old your equipment is; it is about its condition, and how that is changing over time. Ageing is the effect whereby a component suffers some form of material deterioration and damage (usually, but not necessarily, associated with time in service) with an increasing likelihood of failure over the lifetime."* [1]
- *"…just because an item of equipment is old, it does not necessarily mean that it is significantly deteriorating and unsafe. Take the analogy of a vintage car, lovingly maintained by an enthusiast in fully serviceable condition well past any date that the manufacturer could have anticipated. Such wonderful cars can still be safely driven, but their upkeep is time consuming, spare parts difficult and expensive to source, braking performance and emissions probably not meeting current standards, and different driving skills to modern cars are needed. An ageing offshore facility is similar."* [2]
- *"A step-change in safety could be achieved if duty holders fully utilised the trending capabilities, that many of their maintenance management systems offer, to proactively address potential failures before they occur by using trends to predict reduction in performance rather than simply applying the binary 'pass/fail' approach to performance standards."* (Stakeholder feedback)
- Australia's regulatory system requires that the risks associated with ageing facilities, plant and equipment, and well infrastructure assets need to be understood, addressed throughout the lifecycle of the facility, and methodically managed to ensure they are as low as reasonably practicable.
- Work in the North Sea by the UK's Health and Safety Executive and Norway's Petroleum Safety Authority identified problems arising from ageing assets. NOPSEMA inspection activity has found similar issues in the Australian regime. [16-19, 22-25, 27]
- Operators should ensure that their safety, environment and well integrity management systems contain a specific focus on ageing assets to identify opportunities for improvement and, if required, instigate recovery plans.

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1. Introduction

The requirement to properly manage the risks from ageing are not new but are an inherent part of operators' existing duties under the regulatory regimes covered by NOPSEMA. This guidance contains example approaches used around the world and does not introduce new regulatory requirements.

1.1. Intent and purpose of this Guidance Note

The intent of this guidance note is to promote industry practices that ensure risks associated with ageing assets are managed to be as low as reasonably practicable.

The purpose of this guidance note, therefore, is to identify sources of information on the subject, promote good practice based on lessons learned internationally, and putting this information into the legislative context of the *Offshore Petroleum and Greenhouse Gas Storage Act*.

A breakdown of relevant issues against an example safety management system based on a typical ***plan-do-check-act*** cycle is provided as an indicative framework for operator self-assessment. This approach is consistent with current quality and safety management system standards such as AS/NZS ISO 9001 and AS/NZS ISO 45001 and should be compatible with management systems described in accepted permissioning documents such as safety cases, environment plans and well operation management plans.

The guidance should also be of use to Health and Safety Representatives (HSRs) when performing their roles, and to interested parties wanting an overview of ageing asset management in the Australian offshore oil and gas regulatory regime. Appendix A.2 includes some specific guidance for HSRs.

References to further sources of more detailed technical guidance are included in Section 7.

1.2. Background

When a new gas or oil field is developed, the anticipated production life is a factor in the design of the associated facilities and equipment, such as process plant and pipelines.

For fixed assets, like production platforms, it is common that further fields are discovered, or new field development techniques applied that extend the required working life of the facility beyond that originally anticipated.

Mobile facilities, such as FPSOs are not as limited to a specific location, and their working life is less dependent on particular fields, but can remain in use for extended periods in circumstances where typical marine engineering approaches such as regular dry docking are not used.

While MODUs tend to operate for comparatively short periods within the Australian offshore regime, their operators, and the titleholders that contract them, still need to ensure that the effects of ageing don't impair the risk control measures preventing harm to people and the environment when they are used in Australian waters.

The wide range of factors affecting the decision to extend the life of a facility, combined with the equally varied site-specific design, engineering and operational issues for any given facility mean that it is impossible to offer detailed guidance for any particular facility types or circumstances. Where possible, links to relevant specific technical guidance are provided for further reading.

Instead, as is consistent with the goal setting (objective-based) nature of the offshore petroleum and greenhouse gas storage legislation in Australia, the focus of this guidance is on how operators can use their safety, environmental and well integrity management systems to ensure that:

- the duty holder is organised and resourced to properly manage risks from ageing assets
- the ageing effects and failure modes relevant to their operation are fully understood and strategies to deal with them are in place, including identification of appropriate performance indicators
- the condition of equipment and structures, and how these have been changing is known and properly recorded and monitored
- appropriate mechanisms for retaining suitable levels of expertise and knowledge within the workforce are in place
- these competent people have access to the relevant information to inform decision making.

1.3. International Work on Ageing Asset Management

Internationally, the issue of ageing assets has been the subject of a lot of research and analysis over many years.

In November 2007, the UK Health and Safety Executive's (HSE) Offshore Division published the results of the Asset Integrity Key Programme (KP3)[carried out between 2004 and 2007. KP3 examined the condition of offshore assets, focusing on the maintenance requirements of installations' critical technical controls , the management systems and processes which should ensure that critical technical controls would be available when required throughout the entire lifecycle of the installation. Following KP3, HSE released the Ageing and Life Extension Key Programme (KP4) in 2013, which focussed on the Ageing and Life Extension (ALE) challenges that are faced when installations are approaching or exceeding their originally anticipated field life. The findings of KP3 and KP4 both indicate that installation age is not necessarily a reliable indicator of condition or likelihood of hydrocarbon leak frequency. In place of installation age, KP3 and KP4 indicated a number of other factors led to degraded plant status, including:

1. The lack of understanding regarding the state of the plant, due to complex equipment, that was either overdue for maintenance or found to be defective
2. Insufficient management plans in place to manage the consequences of creeping changes
3. Insufficient use of data trending in order to forecast potential failures, obsolescence, or inability to meet Key Performance Indicators (KPIs).

The HSE found that, in order to ensure critical technical controls continue to meet KPIs, facilities must continue to be fully maintained throughout the entirety of their field life.

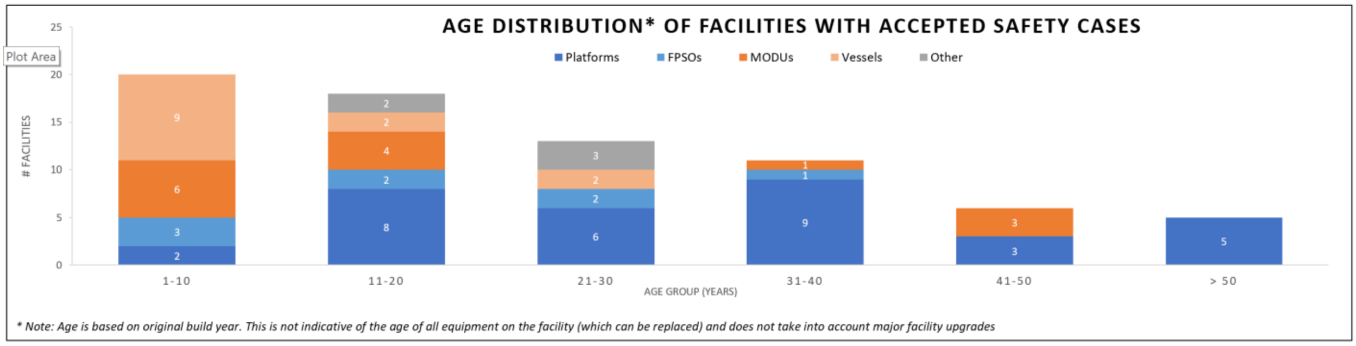
Norway carried out similar activities between 2006 and 2009, where similar issues were found. [16, 17]

While it is not uncommon for well-managed ageing assets to show no deterioration that increases the likelihood of a major accident event occurring, and some relatively new facilities display accelerated degradation, in general, age is a relevant proxy indicator for the likelihood of ALE risks becoming more prevalent.

1.4. Ageing Assets in Australia

The age profile of facilities in Australia is similar to that of facilities in the North Sea, ranging from 4 years to over 50 years old. NOPSEMA's inspection activities across Australia over the last ten years have confirmed that the issues identified in the North Sea research are present here as well. [36, 37, 38]

Figure 4.1 – Age distribution of facilities



2. Relevant Legislation

At a high level, the regulatory regime covering the safety of offshore petroleum facilities in Australia requires operators to:

- identify hazards that could lead to harms to the environment and people
- establish technical and other control measures to prevent incidents where the hazards cause harm, and to reduce or mitigate the effect of any incidents that do occur
- develop standards that allow operators to measure that these controls are fit for their function and use, and reduce any residual risk to as low as reasonably practicable.

Appendix 1 identifies some specific regulations and legislative requirements relevant to ageing asset management.

This guidance note is primarily focused on safety management issues, but titleholders with duties under Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 may find the concepts useful when developing a well operations management plan. Ageing effects should be taken into account when considering the description and explanation of the design, construction, operation and management of the well, and conduct of well activities, and should show how risks to the integrity of the well will be reduced to as low as reasonably practicable (OPGGS (RMA) Regulations 2011, Part 5).

This guidance should also help titleholders to meet the objective to reduce risks to the environment to as low as reasonably practicable under Regulation 3(b) of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. The acceptance criteria in the OPGGS (Environment) Regulations requires titleholders to demonstrate the activity will be carried out to acceptable levels, as low as reasonably practicable and consistent with the principles of ecologically sustainable development. Following the practices described here will assist in demonstrating that this can, and will be, the case.

It is also relevant to Section 572 of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act), which places duties on titleholders in relation to the maintenance and removal of structures, equipment and property brought onto title.

To meet this duty, titleholders are required to describe in relevant permissioning documents how they are maintaining property in good condition and repair, and planning to execute removal when no longer in use.

This guidance note supports the obligation to maintain all structures , equipment, and property in a title area in good condition and repair, and should be read in conjunction with NOPSEMA's policy on the matter. NOPSEMA's decommissioning compliance strategy and decommissioning compliance plan and may also be relevant.

For facilities that are vessels, Section 572 requires consideration of the ability of the vessel to be removed if required, including the integrity of the hull, control of hull fouling, and maintenance of through-fittings and non-petroleum related machinery and equipment required to move the facility.

This document will be revised as required to reflect Australian Government offshore decommissioning policy.

The requirements of the regulatory regime comprehensively cover the activities required to manage the effects of ageing. Another aspect of the regime that is specifically aimed at managing changes over time is the requirement to revise permissioning documents under certain circumstances, and periodically every five years, which must describe the means by which the operator will ensure the ongoing integrity of the technical and other control measures identified by the formal safety assessment for the facility.

NOPSEMA expects that the description of risks associated with ageing assets in each 5-year revision should be appropriate to the age and outlook for the facility, and reflect the events and lessons of the previous 5 year period.

3. Ageing Effects

A comprehensive overview of ageing and degradation modes is beyond the scope of this guidance, and references are given in section 6 which cover the subject in depth. This section gives a brief overview of the effects of ageing, and NOPSEMA expects operators to have detailed knowledge about this issue on their facilities. This includes having a clear strategy to reach the anticipated end-state and a clear understanding of the amount of time and resource needed to achieve it.

Over time the nature of major accident events and the magnitude of their consequences can change. The composition of product can vary as fields mature, with increased gas, water fraction or sulphide content, as well as the inventory and location of hydrocarbons stored. All these changes should be identified within the periodic reviews of permissioning documents, and their impact on the adequacy of technical control measures assessed. For example, a fire protection system designed for oil may not be sufficient where there is more gas.

As equipment ages, the ability of safety-critical technical controls to achieve their performance standards, in terms of functionality, availability, reliability, survivability and interdependence (FARS-I), can decline. There is potential for all aspects of FARS-I performance to be affected. Functionality can be reduced, sometimes progressively or predictably, but also spontaneously or rapidly with little warning. The availability of safety-critical technical controls tends to reduce as equipment ages, due to a need for increased maintenance.

For older equipment, spare parts may become more difficult to obtain and maintenance teams may lose familiarity with it. This can result in delays to repair, and the equipment remining in a failed state for longer periods. This is an issue that has been particularly noticeable in legacy programmable control equipment.

For some types of equipment, reliability can decline as ageing occurs, which can cause critical technical controls will become more likely to fail to respond on demand, or fail during operation. Failures tend to occur more frequently as individual components wear out at about the same time, and accelerate wear-out elsewhere.

Some systems can suffer longer term deterioration, thus becoming less resistant to the effects of an MAE such as fire or explosion, and overload, therefore the survivability of critical technical controls could then be compromised. Interdependency between critical technical controls or dependency of critical technical controls on the same support equipment, (like electricity supply or cooling water) means that failure of one component could lead to weakening or failure of several critical technical controls simultaneously.

Critical technical controls perform different functions that jointly provide barriers to the occurrence and escalation of MAEs. Understanding their function as barriers and their relative performance when ageing is important to ensure safety requirements are met.

There are also organisational effects that are more likely with the passage of time. Critical information required to properly understand the equipment may have been lost through a combination of staff turnover, changes of operator, or changes to information storage systems. The knowledge required to maintain equipment in a safe condition, or to identify the early signs of degradation may have been lost through retirement, staff turnover, or changes in contracted third parties or consultants.

4. Managing Ageing Asset Risks

As discussed in Section 2, operators with accepted safety cases and safety management systems that comply with the legislation should already have a framework in place for managing the challenges arising from ageing assets. This section focusses on the specific issues that international experience and research in life extension and ageing asset management have identified as important to serve as an example of what issues safety management systems should cover. While some of the phrases used come from a variety of jurisdictions, they do not introduce new legislative requirements on Australia's goal-setting regime.

Once ageing damage becomes significant, rapid, and widespread, existing approaches to managing critical technical controls may not be sufficient, and a more proactive and integrated approach is required. Often the new approach requires duty holders to evaluate the actual condition of the elements and establish what resources, including skills and knowledge, are needed to rectify the problem. A framework of management processes can help organisations assess whether their response is appropriate to match the scale and dynamics of the ageing threat.

Duty holders' HSE Management Systems and/or Asset Integrity Management Systems should incorporate lifecycle management principles to asset ageing and life extension.

4.1. Management Framework

Current practices in quality and safety management typically use the plan-do-check-act model as an iterative process for driving continuous improvement, which aligns with the object of the Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009. Typical standards that cover this approach in Australia are AS/NZS ISO 9001 for quality management systems and AS/NZS ISO 45001 more specifically for safety management systems.

Whichever standard their management system is based on, operators need to ensure that their approach adequately address the specific issues arising from ageing assets.

The Energy Institute published a research paper [5] describing a framework for managing ageing assets that follows the ***plan-do-check-act*** approach. It is used here as an example framework for an operator to structure an analysis of its capabilities for managing ageing assets or carrying out a life extension.

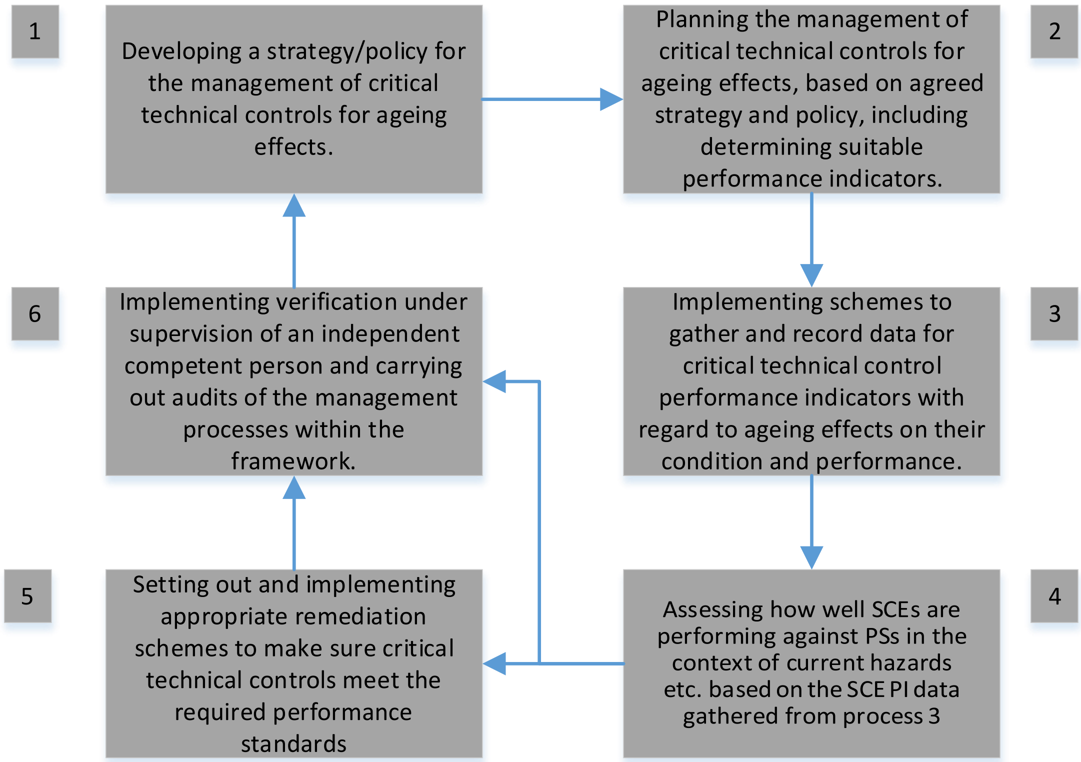
The example subject headings and discussions included here are a starting point only, and are not comprehensive. Duty holders will need to carry out their own analysis to determine which approaches need to be deployed in their specific circumstances.

The main management processes are:

1. Developing a strategy/policy for the management of critical technical controls for ageing effects. Showing leadership in driving these strategies.
2. Planning the management of critical technical controls for ageing effects, based on agreed strategy and policy, including determining suitable performance indicators.
3. Implementing schemes to gather and record data for critical technical controls performance indicators with regard to ageing effects on safety-critical element condition/performance.
4. Assessing how well critical technical controls are performing against performance standards in the context of current hazards etc. based on the safety-critical element performance indicator data gathered from the implementation process.
5. Setting out and implementing appropriate remediation schemes to ensure critical technical controls meet the required performance standards.
6. Implementing verification under the supervision of an independent competent person (ICP) and carrying out audits of the management processes within the framework.

Figure 4.1 shows these six processes within a process flow model and the links between them. Each of the six processes is described in more detail in 4.1.1 – 4.1.6.

Figure 4.1 - Framework of processes for the management of ageing effects



4.1.1. Leadership, Strategy and Policy Development

The main activity in this process is the development of a corporate strategy/policy for the management of ageing of critical technical controls within the organisation as a whole. This is usually led by senior management in the organisation. It includes the following three sub-processes:

1. Define top level strategic goals for the management of ageing effects on critical technical controls for generic hazards during continued operation or life extension
2. Develop a corporate strategy/policy for management of ageing effects on critical technical controls
3. Allocate responsibilities to people with suitable resources to meet requirements.

The policy sets out the principles for the organisation as a whole and the strategic vision that would apply to a regional group of assets. It requires a prediction of the field maturity and future operating life required, with an analysis of the economics invested in the assets, and for maintaining them in a safe and reliable condition until they are removed or repurposed.

The policy would normally draw asset managers' attention to the need to strengthen the management of critical technical controls for ageing during the wear-out or life extension phase, and would recommend areas for performance indicators implicit in meeting strategic goals. The leadership, strategy and policy development process allocates appropriate resources and responsibilities to achieve the agreed strategic goals, and ensures that the operating company has sufficient competencies and technical capability for managing ageing effects. It would seek ways to build synergy between the management of ageing assets at different geographic locations and to share experience and good practice.

The extent to which senior managers drive company efforts in these key areas, significantly influences successful implementation of ALE related activities.

The following areas are relevant to strategic leadership:

Ownership & accountability

Arrangements for the delivery of the duty holder's policy with respect to ALE should be via defined roles, responsibilities and accountabilities within the company's management system. Company leadership needs to assign clear ownership and accountability for matters relating to ALE. That accountability primarily rests at a senior level but leaders also need to ensure that arrangements are in place to manage ALE throughout the organisation and these arrangements need to clearly define accountability for ALE related issues and activities. Leaders should identify their own individual or collective roles and responsibilities in relation to ALE and communicate those to affected personnel within the organisation. Duty holders may also consider the appointment of a senior management "sponsor" or similar role for ALE issues.

Senior leadership commitment & engagement

Leaders should be engaged in appropriate processes that enable them to understand and contribute to the company's ALE efforts. There are requirements for senior leadership involvement in many cross-discipline ALE related activities, from strategic planning through to review. Senior leaders should also take an active interest in the management of ageing during site visits, and take those opportunities to identify any particular challenges arising from ageing effects.

Business strategy & life of field planning

Oil and gas exploration and production business strategy and life of field planning has a very obvious linkage to asset ageing and life extension.

Life of field strategies need to include medium- to long-term business plans. The intended date for discontinuation of use of an asset, such as when production is planned for termination, should be communicated to appropriate parties to make a true connection to ALE management.

Conversely, the outputs from ALE management activities should influence life of field planning. The organisation directly involved in operating, inspecting and maintaining assets needs to be aware of its intended life span in order to manage ALE accordingly.

Leaders setting life of field expectations should review asset condition over time, understand risks and take account of any threats to the date they plant to discontinue use and associated field life extension planning. This will form a key part of due diligence associated with any production commitments made for the late life or life extension period.

Decisions on divestment and / or acquisition activity also have an impact on ALE management and ALE considerations should influence those decisions. The cost impact of managing asset ageing and extending the anticipated service life of assets is a business reality requiring the allocation of sufficient competent resources to manage asset ageing and life extension related activities.

Purchasers of older assets should recognise that operating costs of maintaining them in good condition are likely to be higher than those of a new asset. As well as ensuring adequate resource for physical integrity of the facility they intend to purchase, potential buyers of older assets should also ensure they have access to the appropriate expertise that understands the standards to which assets have been designed, built, operated, and maintained.

NOPSEMA's expectation is that obligations under Clause 9, Schedule 3 of the OPGGSA to maintain plant and equipment in a safe condition, without risk to health, no matter the stage of the facility's lifecycle, will not vary depending on the size and or liquidity of the particular operator.

Business plans should include adequate budget provision for ALE related scope.

4.1.2. Planning

The second process within the framework is planning the management of critical technical controls for ageing effects based on the agreed strategy and policy. This includes the specification, review and revision of risk control systems and the determination of suitable performance indicators.

Meeting asset life extension goals requires long-term planning that commences before the point at which an asset is required to operate beyond its original intended life, or beyond an already specified asset life extension period. The long-term plan for an asset, commencing at the design phase, should flag when the original intended life of an asset ends. Planning of life extension implications should be an integral part of the business decision to change the date on which an asset will cease to be used, and will therefore allow the current condition of the facilities (wells through to export systems), anticipated cross-discipline future integrity risks, assurance actions and an outline of a long term work programme to be identified and managed to ensure that the facility can continue to operate safely and efficiently through the extended life cycle to final removal or repurposing.

Planning done at the level of an individual facility by the asset management team includes five sub-processes which are:

1. Interpret the strategy for a particular facility and its critical technical controls
2. Update the definition of MAEs for the facility as affected by time and the facility's age
3. Review the suitability of the performance standards of critical technical controls with respect to updated MAEs.
4. Determine risk control systems for critical technical controls to ensure that they meet their performance standards
5. Define performance indicators as measures of the condition or performance of critical technical controls in relation to performance standards and as measures of the status and effectiveness of their risk control systems.

The planning process takes the strategy/policy from the first process, and interprets it for a particular facility taking account of individual features, age and future needs. It should be noted that this process includes updating the specifications of MAEs taking account of modifications to plant or process conditions or inventory and other changes to hazards arising from the age of the facility. It is a regulatory requirement that, as MAEs are revised or updated, the duty holder should review the performance standards it has assigned to the relevant critical technical controls and, as appropriate, report these updates in later revisions of their submitted safety cases.

The planning process includes undertaking an ageing modes, effects and criticality analysis (AMECA) on the critical technical controls. This understanding is used to specify, review and revise the risk control systems that assure integrity (such as inspection, maintenance and testing), and other control measures for the management of critical technical controls for ageing effects.

This should include a review of understanding the original design, operating and maintenance assumptions, and how changes to these may have impacted 'ageing' of the facility.

For example:

- Have the maintenance philosophies been adopted delivered the expected results?
- How many pressure or temperature cycles a vessel has undergone vs. design assumptions?
- Have process parameters changed over time? (For example, has there been a phase-change that would increase the likelihood of accelerated microbial corrosion?)
- Were all the damage mechanisms known from the initial design stage, or has something been degraded more than expected because it was not known?
- Is the field life of all sub-components, and their degradation mechanisms understood?

Performance indicators are defined relating to the condition or performance of critical technical controls in relation to performance standards and to the status and effectiveness of the risk control systems. Ideally, these should include static and dynamic elements assessing both current performance, and past and likely future trends.

The selection of critical technical control performance indicators needs to be appropriate to the relevant performance standards, and provides the knowledge to allow the operating company the time to take the necessary remedial actions before performance standards are contravened.

Performance indicators are typically set for three levels within the organisation. High level performance indicators would typically be aggregations of other performance indicators and used by senior management to detect systemic problems and major issues, middle level performance indicators would be useful at the asset level for supporting the safety case, while lower-level performance indicators would be equipment specific.

Duty holders should actively monitor trends in their performance indicators to help ensure that remedial action is taken before failure occurs.

The following organisational factors should also be considered during the planning process:

Resourcing

Personnel resourcing and allocation arrangements should ensure that adequate, competent resources are in place to identify, manage and execute ALE related activities.

Roles & responsibilities

Roles and responsibilities of personnel involved in the planning, management, execution and assurance of ALE related activities should be clearly defined, documented and communicated.

Access to suitable technical expertise

The need to identify suitable technical expertise should be stressed in duty holder organisational arrangements. The wider organisation should be aware of identified sources of technical knowledge, and understand how they should be involved in ALE related issues.

Training & competence

Personnel responsible for managing, inspecting, maintaining and assuring integrity of plant and equipment should have a demonstrable understanding of ageing mechanisms and mitigation measures. Basic professional and technical competence should be supplemented where necessary with training in the management of ageing. Competence levels should be maintained to take account of changes in technology and standards for example, so that personnel have a current understanding of ageing issues and their management.

Communication & cross-functional coordination

Examples of types of communication in relation to ALE management include:

- senior leadership with technical personnel on strategic matters potentially impacting ALE management
- technical personnel with senior leadership on technical or operational matters potentially affecting business strategy or life of field planning activities
- sub-surface specialists with Technical Authorities or other relevant technical personnel on sub-surface issues potentially affecting ALE management (e.g. changes in production profile, reservoir characteristics or fluids)
- procurement functions with engineering disciplines to advise of potential obsolescence challenges (e.g. where Supply Chain has become aware of discontinuation of equipment spares availability).

Contracting strategy & interface management

The nature of ALE management dictates that some of the activities involved may be carried out by third-party service providers. The duty holder's contracting strategies should identify where such specialist support is necessary and appropriate. Robust contracting processes should then ensure that suitable contractors are identified, assessed for competence and selected to undertake ALE related integrity management activities. Also, a performance management system should be in place to quality check work carried out by these third-party contractors.

Pre-mobilisation activities should ensure that relevant contractors are suitably aware of the duty holder's ALE management processes and their role in successful delivery of those processes. Ongoing interface management and in-service monitoring should be geared to ensuring that contractors are aligned with the duty holder's ALE management arrangements. Control of, and accountability for ALE management remains with the duty holder and is irrespective of a contractor's responsibility for execution of ALE related activities.

Boards of duty holder organisations should have processes in place to ensure conflicts of interest with third party companies are not distorting information that they need to make sound decisions on safety and integrity of assets.

Staff turnover, succession planning & corporate knowledge retention

Arrangements should be in place to ensure that key competencies, skills, knowledge and experience relating to ALE management are not lost permanently when personnel leave or transfer within the organisation, (or when key consultancies change). This is of particular importance in relation to key roles such as Technical Authorities but the duty holder should identify all ALE sensitive positions and develop candidate selection criteria for the key integrity assurance positions with effective handover process. In addition to that form of planning, organisations need to ensure a disciplined approach to matters such as record keeping so that the loss of an individual from the organisation does not disproportionately impair operational capability. This is particularly critical to ALE management where local knowledge and an understanding of historical issues or data is often necessary in order to assess and respond to an ALE challenge for example.

Conflicts of interest

In developing organisational arrangements (e.g. departmental structures, reporting lines etc.), duty holders should seek to establish a degree of independence of personnel involved in key integrity assurance roles from operational line management. Personnel performing assurance activities may be part of a stand-alone function or of some other function suitably independent of the operational line.

4.1.3. Gathering Data for Performance Indicators

The third process is to implement schemes to gather and record data for safety-critical element performance indicators from the ageing condition and performance of the critical technical controls and the status and effectiveness of their risk control systems. There are two sub-processes which are:

a. Undertake activities to gather data for performance indicators (e.g. count maintenance actions outstanding, performance tests on safety-critical element, etc.)

b. Determine the values of performance indicators from the data gathered.

This process includes processing and use of the data gathered to determine values for the safety-critical element performance indicators defined in the planning process. It could involve obtaining data from performance tests (e.g. deluge or ESD systems) or laboratory tests (e.g. fire resistance of PFP tiles), or it could involve analytical technical assessments (e.g. of corrosion rate).

Processing of data could include trend analysis, reliability and availability reviews, an assessment of inspection and maintenance actions completed by due date or deferrals and backlogged, and predictive analyses of future changes in condition. Determining the values of performance indicators for assessment will usually be a distillation and collation of selected raw and processed data.

Operating companies should define their own performance indicators for critical technical controls and the frequency with which data are collected and assessed. Guidance to business leaders on the development of performance indicators is given in the UK Health and Safety Executive's publication HSG254 - Developing process safety indicators: A step-by-step guide for chemical and major hazard industries [21].

4.1.4. Assessment of Performance Indicators

The fourth process assesses how well critical technical controls are performing against performance standards in the context of current hazards, ageing, and the status and effectiveness of their risk control systems using safety-critical element performance indicators based on the data gathered from the data gathering process.

The two sub-processes are:

a. Identify any shortcomings in the achievement of performance standards of critical technical controls based on their performance indicators.

b. Assess and prioritise the shortcomings in safety-critical element performance and their risk control systems and determine the appropriate remediation to restore safety-critical element performance.

The input to this process is the set of safety-critical element performance indicator values obtained in the data gathering process. Ideally, this process will determine if critical technical controls currently meet their performance standards, the margins in hand or exceeded, and the rate at which safety-critical element performance is changing due to ageing effects, and the extent to which these are known.

The assessment will determine the status and effectiveness of the risk control systems and link this with level of achievement of safety-critical element performance. For example, it will identify where the performance of a safety-critical element may not be known because the required tests have not been carried out, or the safety-critical element is under-performing because it has not been maintained according to schedule or where the existing schedule is proving inadequate to counter ageing.

The process of performance indicator assessment also covers assessment of the criticality of shortcomings in safety-critical element performance and risk control systems in relation to maintaining the safety case and operational priorities. It provides the information necessary for the development of appropriate remediation schemes that address the priorities in a structured fashion. The determination of remediation requirements within this process leads directly into the next process.

4.1.5. Remediation Schemes

The fifth process specifies and implements appropriate remediation schemes to critical technical control hardware and risk control systems to ensure they continuously meet their required performance standards.

There are four sub-processes:

a. Remediate any shortcomings of critical technical control performance to meet required performance standards.

b. Assure that remediation schemes have been effective in restoring critical technical control performance standards.

c. Undertake appropriate action to restore the critical technical control risk control systems to ensure that critical technical controls meet performance standards.

d. Apply additional controls in the meantime.

Remediation schemes may relate to equipment and/or the control systems relating to the equipment. These may be in the form of actions for maintenance, replacement, repair or upgrading, or actions changing test, maintenance and inspection schedules, increasing resources to resolve deferrals and backlogs. The commissioning of technical analyses, assessments and laboratory tests to provide additional information is also included.

Schemes should address both short-term remediation required to meet immediate safety and operational demands, and also longer-term remediation required in order to maintain the safety-critical element over its future life according to the strategy for the field set-out in first process of policy making. They should be time bound in relation to priorities and dynamics of the issue.

The aim of remediation schemes should be to manage the risks from ageing of critical technical controls in line with the operating company policy set out in the policy making process, and ensuring regulatory compliance. An understanding of the effects of ageing in relation to the consequences in the event of failure as determined in the planning process is central to the development, prioritisation and implementation of remediation schemes.

4.1.6. Validation, Verification and Audit

The sixth process in the framework is concerned with the processes of verification and audit within the context of existing quality management systems.

Validation in the context of this guidance is refers to general management practices, and not the specific use of the term set out in the OPGGS(S) Regulation 2.40. NOPSEMA has published specific guidance on the formal validation process required for that process.

Validation and verification should be undertaken to a written scheme to confirm whether the performance standards of the critical technical controls preventing harm on a specific facility are still appropriate to the MAEs, and that the hardware and software of the safety-critical technical controls is meeting the standards, both as isolated systems, or in concert with other critical controls. It is also to verify that the integrity assurance measures being applied are appropriate.

Audits are a part of the management systems outlined in permissioning documents. In the context of this guidance, duty holders should ensure that their periodic audits include the processes for managing ageing effects on safety-critical technical controls within this framework.

5. Case studies

5.1. Northern Endeavour FPSO

Steve Walker's report on his review [2] of the circumstances that led to the administration of the Northern Oil and Gas Australia (NOGA) group of companies contains useful information to anyone managing ageing assets.

The report says:

- *"Under Australia's goal setting offshore safety and environmental legislation, ageing assets can be managed well into extended late-life. However, this relies upon the operator and owner having a detailed knowledge of the condition of the whole asset, the consequences of any shortfalls (whether from its actual physical conditions or from other layers of protection such an overdue safety-critical maintenance and inspection), a systematic approach to identify remaining risks, and then an effective, rigorous and consistent approach to managing them. As the asset gets older those challenges increase with complex interactions."*
- *"The ageing challenges for the Northern Endeavour appeared to be not so much on the topside specialist process equipment or the hull integrity, but more on corrosion issues associated with structural carbon steel interfaces, non-process plant and general fabric. Galvanic corrosion was highlighted."*

Annex 2 of the Walker report contains a narrative of integrity and corrosion aspects of NOPSEMA inspections of this FPSO.

The Australian Maritime Safety Authority has produced a Marine Order 47 [39], outlining maintenance of hull integrity of FPSOs during the time the Navigation Act 2012 is disapplied by the Offshore Petroleum and Greenhouse Gas Storage Act 2009. This Marine Order prescribes matters in relation to the issue of safety certificates for regulated Australian vessels that are offshore industry units, provides requirements for foreign vessels including certification; and provides notification requirements for planned tows and other reporting matters.

5.2. UK Case Studies

A list of items of good practice identified by the HSE that are mostly can be seen in [22].

Case studies arising from ageing asset work done by the UK's HSE can be found in an appendix to the report into Key Programme 4 [27]
Acknowledgements

NOPSEMA would like to acknowledge and thank the following parties for their assistance in the preparation of this guidance:

- The Energy Institute for generous permission to use their material as an example framework in Section 4, and helpful advice on other reference material included in this guidance.
- The UK's Health and Safety Executive for their kind permission to include references to their work in the North Sea.

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36. Issue 3 of the 2019 edition of NOPSEMA's The Regulator' states the intention to focus on ageing asset management through inspection.
37. The 2018 review of NOPSEMA's activities included references to incidents linked to ageing assets.
38. Issue 2 of the 2013 edition of NOPSEMA's 'The Regulator' described enforcement action taken by inspectors on ageing asset issue.
39. Australian Maritime Safety Authority, Marine order 47—Offshore industry units.

7. Appendices

A.1: Appendix 1 – Details of Relevant Legislation

This section summarises some relevant provisions of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 that apply to management of ageing assets. The full text of the legislation can be accessed here.

Schedule 3 to the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* imposes the following duties on facility operators:

Offshore Petroleum and Greenhouse Gas Storage Act 2006 – Schedule 3
Clause 9 of Part 2 – Duties of Operator General Duties - The operator of a facility must take all reasonably practicable steps to ensure that the facility is safe and without risk to the health of any person at or near the facility; Specific Duties - The operator of a facility is taken to be subject, under subclause (1), to each of the following requirements: (a) to take all reasonably practicable steps to provide and maintain a physical environment at the facility that is safe and without risk to health; (c) to take all reasonably practicable steps to ensure that any plant, equipment, materials and substances at the facility are safe and without risk to health;

These duties places a legal obligation on operators to take reasonably practicable steps to ensure their facilities are safe, which includes managing the effects of ageing that could affect the health and safety of anyone at or near the facility.

The safety case aspect of the offshore regulatory regime also has provisions relevant to the management of ageing assets, as set out in Subdivision A of Division 1 of Part 2 of the Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009.

Regulation 2.5 requires that an operator of a facility, in developing a safety case, carry out a formal safety assessment that identifies all hazards having the potential to cause a major accident event, and identify the technical and other controls necessary to reduce the risk to a level that is as low as reasonably practicable.

It also requires a description of the activities that take place at the facility. This identifies the plant and equipment that are critical for the ongoing safety of the facility.

Regulation 2.5 (1) Facility description
The safety case for a facility must contain a description of the facility that gives details of: ... (b) the technical and other control measures identified as a result of the formal safety assessment; and (c) the activities that will, or are likely to, take place at, or in connection with, the facility. ... (e) any other relevant matters.

Regulation 2.5 (2) Formal safety assessment

The safety case for the facility must also contain a detailed description of the formal safety assessment for the facility, being an assessment, or series of assessments, conducted by the operator that:

identifies all hazards having the potential to cause a major accident event; and

is a detailed and systematic assessment of the risk associated with each of those hazards, including the likelihood and consequences of each potential major accident event; and

identifies the technical and other control measures that are necessary to reduce that risk to a level that is as low as reasonably practicable.

Having described the controls required to reduce risks on the facility to as low as reasonably practicable, the safety case also describes the management system intended to maintain safe operation.

Regulation 2.5 (3) Safety management system

The safety case for the facility must also contain a detailed description of the safety management system that:

is comprehensive and integrated; and

provides for all activities that will, or are likely to, take place at, or in connection with, the facility; and

provides for the continual and systematic identification of hazards to health and safety of persons at or near the facility; and

provides for the continual and systematic assessment of:

(i) the likelihood of the occurrence, during normal or emergency situations, of injury or occupational illness associated with those hazards; and

(ii) the likely nature of such injury or occupational illness; and

provides for the reduction to a level that is as low as reasonably practicable of risks to health and safety of persons at or near the facility including, but not limited to:

...

(ii) risks arising from equipment and hardware; and

provides for inspection, testing and maintenance of the equipment and hardware that are the physical control measures for those risks; and

...

provides for any other matter that is necessary to ensure that the safety management system meets the requirements and objects of these Regulations; and

specifies the performance standards that apply.

A.2: Appendix 2 – Guidance for Health and Safety Representatives

This guidance describes in general terms how legislative requirements require operators to have management systems that reduce the risks from ageing assets to as low as reasonably practicable. This appendix describes some simple steps health and safety representatives (HSRs) can take to allow them to contribute to the processes these management systems and legal duties require.

To allow constructive involvement with safety management system processes, HSRs should be familiar with the application of the safety management systems at the facility/ies they work on.

Safety case development

Operators must consult with members of the workforce when they develop their safety cases, so it is usual for HSRs to be involved in this process.

While members of the workforce must be consulted in the preparation of safety cases, it is likely that many HSRs have taken on the role after the safety case was first written. In this case, HSRs should make themselves familiar with the safety cases for the facilities they cover, and be prepared contribute to any revisions that take place during their tenure if the opportunity arises.

Performance Standards

Safety cases must describe performance standards that apply at a facility. If an HSR has not been involved in the initial creation of the relevant performance standards, they should make themselves familiar with the performance standards relevant to their facility, especially those that are relevant to their work group. HSRs should also be familiar with the safety management systems concerning the operation and review of performance standards.

HSRs often have valuable experience of the day-to-day operation of performance standards, and should be prepared to contribute to any reviews of them if the opportunity arises.

Abbreviations/acronyms

AIM	Asset Integrity Management
ALARP	As Low As Reasonably Practicable
ALE	Ageing Life Extension
CMM	Capability Maturity Model
EI	Energy Institute
FARS-I	Functionality, availability, reliability, survivability and Interdependence
FPSO	Floating Production Storage and Offloading
HSE	Health and Safety Executive
HSR	Health and Safety Representative
ICP	Independent Competent Person
IM	Integrity Management
KP3	HSE's Key Programme 3
KP4	HSE's Key Programme 4
KPI	Key Performance Indicator
MAE	Major Accident Event
MAH	Major Accident Hazard
MMS	Maintenance Management System
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
OGUK	Oil and Gas UK
OPGGSA	Offshore Petroleum and Greenhouse Gas Storage Act
OPGGS(S)R	Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations
PI	Performance Indicator
PS	Performance Standard
PSA	Norway's Petroleum Safety Authority
UK	United Kingdom
UKCS	UK Continental Shelf
UKOOA	UK Offshore Operations Association

Key definitions

Critical technical control: The various permissioning documents assessed by NOPSEMA require duty holders to identify control measures that are critical to preventing harm to people or the environment. For convenience, this guidance refers to any such critical controls that can be affected by ageing processes, such as hardware and software controls, as critical technical controls. This phrase has no legal definition or status.

Asset: Includes offshore structures, process plant, subsea equipment, connecting wells, pipelines and the full range of SCEs associated with oil and gas production.

Asset Integrity: Ability of an asset to safely perform its required function effectively and efficiently.

Ageing Asset Management: The ability to effectively control ageing mechanisms revolves around developing, implementing and auditing of the correct management techniques to ensure that ageing is being adequately addressed. Ageing asset management involves having the correct systems and processes in place to maintain the integrity a facility that is subject to ageing mechanisms.

Ageing and Life Extension (ALE): Ageing and life extension is the process that ensures the continued integrity of the facility is maintained and ageing mechanisms are appropriately addressed for the duration of the extension.

Permissioning documents: Documents that duty holders in the OPGGSA regime are obliged to submit to NOPSEMA for acceptance. Environment plans, well operations management plans and safety cases.