Health and Safety Executive

HSE Information Sheet

Guidance on management of ageing and thorough reviews of ageing installations

Offshore Information Sheet No. 4/2009

Contents

Introduction

This information sheet provides guidance for asset managers, safety managers and safety engineers in the offshore industry on taking account of ageing of the installation during thorough review, which is required by the Offshore Installations (Safety Case) Regulations 2005 (SCR05) [1].

Background

SCR05 requires the dutyholder to carry out a 5-yearly thorough review of the safety case[2]. The purpose of the thorough review is to confirm that:

- the safety case as a whole continues to be fundamentally sound;

- the relevant statutory provisions[3] are being complied with taking account of all relevant changes and new knowledge since the case was last accepted; and

- the safety case continues to demonstrate the effective identification, management and control of major accident hazard risks on the installation.

In effect this means that the review must ensure that the case demonstrates that the installation can continue to be safely operated and that the structure, together with its associated plant, can continue to meet the necessary performance standards to enable compliance with the relevant statutory provisions. This involves consideration not only of new knowledge and current good practice, but of the changes which may have occurred as a result of the ageing of the installation.

This document provides guidance on incorporating ageing issues into thorough reviews. It discusses the thorough review process and how this is related to the effective control of hazards on ageing installations, covering fire and explosion, structural integrity, organisational and other ageing issues. The safety management system (SMS) of the installation needs to address ageing and the thorough review is one tool to assist the process (see Figure 1). It may also be appropriate to address ageing issues when there is a revised safety case to address a material change.

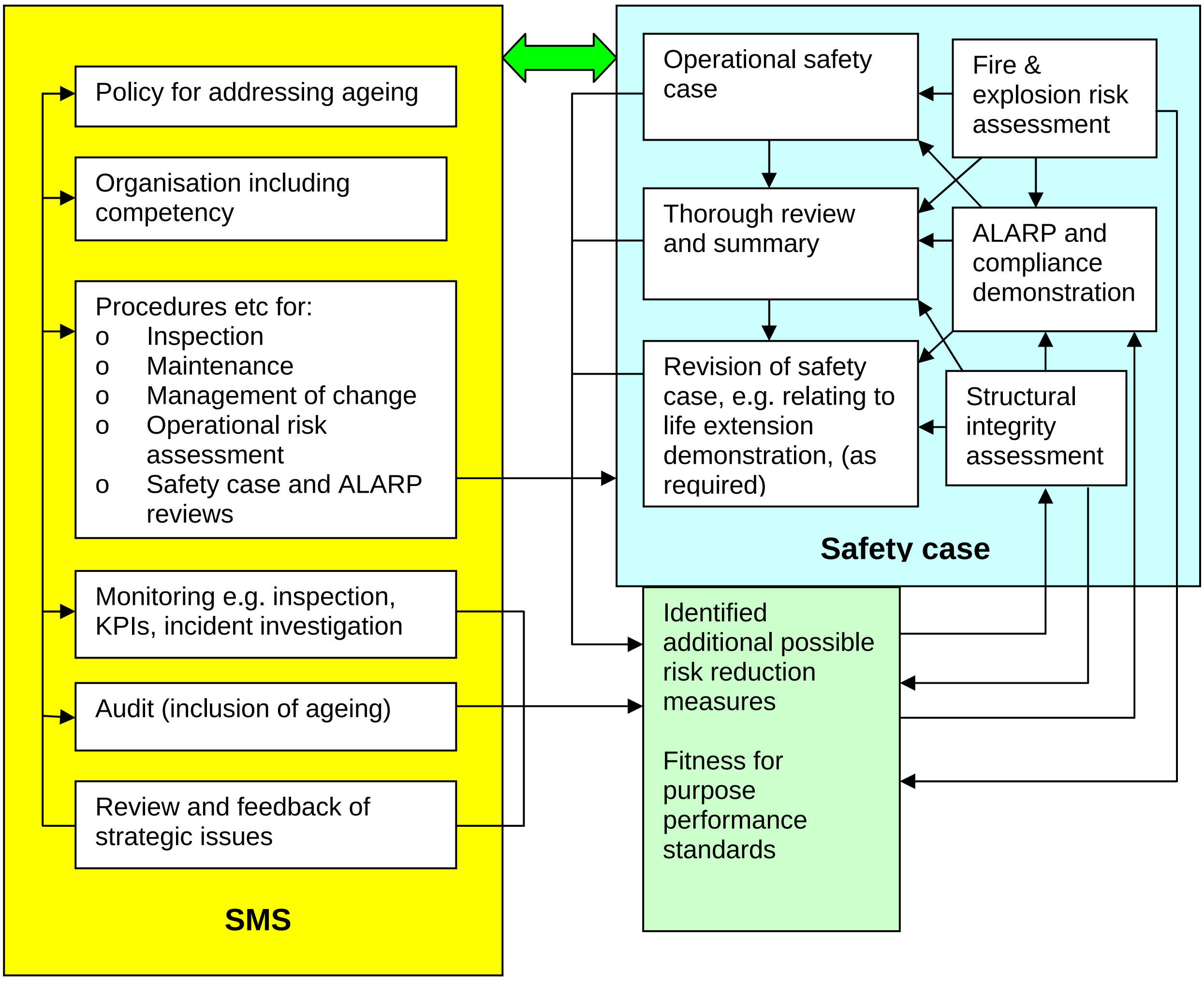

Figure 1: Relationships between SMS and safety case in terms of management of ageing

This document is intended to help operators and technical authorities to review the impact of ageing of an offshore installation on the risk from major accidents involving the structure, wells, process, export and interfacility fluids (pipelines) for inclusion in the demonstration required in the safety case. It will form a frame of reference that can be used by all interested parties to ensure the best available knowledge is used in that demonstration. It particularly addresses ageing issues relevant to 5-yearly thorough review of the safety case.

This document is aimed at engineers of all disciplines and safety practitioners. It is supported by more detailed reports, which focus in particular on fire and explosion issues[4] and the structural integrity issues[5], and which make reference to specific standards and guidance.

Thorough review of the safety case

The objectives of the thorough review are:

1 to confirm that the safety case, with any necessary updates, is still adequate, and is likely to remain so until the next thorough review;

2 compare the case against current standards, HSE guidance (such as APOSC[6], GASCET[7], offshore safety case guidance[3]) and industry practice for new installations; to evaluate any deficiencies; and to identify and implement any reasonably practicable improvements to enhance safety;

3 identify design parameters, ageing processes, changes in operating conditions and hence performance standards that may limit the life of the installation, or of its safety critical elements; and

4 check that the management of safety is adequate, in particular that performance standards and key performance indicators (KPIs) are relevant and effective.

The thorough review is therefore expected to not only confirm that issues concerning ageing have been identified, but also that they are being adequately managed, and that reasonably practicable improvements are identified and implemented. This should include addressing the information in this guidance and the more detailed reports[4,5].

Relevant examples of the arrangements expected to be considered in the thorough review include, but are not limited to:

- design and operational parameters of the structure and plant, together with actual operational experience and projected operational status and lifetime, e.g. fatigue and corrosion life of the topsides and structure, use of measured corrosion rates and measured structural loading parameters, changes to metocean parameters and accidental loading criteria;

- taking account of the findings of the Key Programmes, including Key Programme 3 – Asset Integrity Programme[8];

- prevention of degradation becoming so serious that improvements become impossible;

- maintenance, inspection and testing experience of safety critical elements (SCEs) and consideration of whether test intervals are adequate given the testing history etc.;

- modifications to the installation or plant including SCEs to ensure that the installation hazard profile remains tolerable and as low as reasonably practicable (ALARP);

- changes to, and to the current role and behaviour of, SCEs and their associated performance standards;

- how structural degradation affects the performance of SCEs;

- the history of incidents and abnormal / unexpected events, e.g. the updating of task and operational risk assessments to include known hazards from past incidents;

- new knowledge and understanding, e.g. awareness of risks highlighted by industry or HSE safety alerts (for example on temporary repairs[9]); recognition and inclusion of findings from relevant research;

- changes in safety standards or safety methodology / assumptions, e.g. the publication of new codes and standards;

- changes in management of safety and human factors aspects affecting the installation, e.g. arrangements for ensuring competence and adequate staffing levels.

Systems and procedures should be in place to identify and rectify issues arising from ageing (see section below on management of ageing) by means of, for example:

- Inspection
- Planned maintenance
- Change control procedure (modifications)
- Operational risk assessment (e.g. in the event of failures)
- Incident investigation

In addition to this the duty holder is encouraged to conduct regular reviews of ageing issues so that strategic solutions can be developed. The 5 yearly thorough review of the safety case will provide one such opportunity. The dutyholder needs to be aware of the current condition and remaining life of the structure and equipment, particularly SCEs, in relation to the anticipated installation life. This is particularly important for older installations receiving new hydrocarbon streams. Strategic decisions need to be made in sufficient time about maintenance, repair and replacement against a background of well and process changes and improvements in technology and good practice.

"Ageing is not about how old your equipment is; it's about what you know about its condition, and how that's changing over time"[10]

Asset life extension

Many of the offshore platforms in the UK sector are nearing the end of their originally intended design life. However, with the depletion of hydrocarbon reserves, the increased use of enhanced oil recovery technologies, and the advent of carbon dioxide sequestration, there is an increasing requirement to extend the life of the existing platforms. Other installations, although no longer producing oil from their own wells are being modified to act as production hubs, taking hydrocarbons from other sub sea wells in the area and processing it there, often with new or modified topsides plant, for export to pipeline or tanker.

Asset life extension raises several issues in relation to hazard management, for example:

- the need for specific demonstration of fitness for purpose beyond the original design life of the structure and of equipment;
- design and operational issues relating to integration of new plant, processes or materials with old;
- effect of new fire and explosion scenarios from new plant etc. on existing mitigation systems, HVAC, fire and gas detection, active and passive fire protection systems;
- repair and use of passive fire protection and provision of integrity insurance for ageing piping/structure/equipment;
- degradation of emergency equipment and facilities;
- equipment obsolescence leading to substitution, modification or plant outage;
- the effects of changes resulting from ageing on the installation's risk assessment, particularly that related to fire and explosion hazards;
- increases and decreases in operational loads and their effect on structural safety and foundation failure;
- understanding of degradation processes;
- the need for detailed knowledge of the current state of the structure;
- the need for better understanding of the structural response in the aged condition.

The effective management of ageing requires the understanding of a number of factors, and the application of a range of techniques to assess and manage the ageing situation. These are illustrated schematically in Figure 2.

It is best to plan in advance for any future life extension of the installation. Any reduction in maintenance regime in anticipation of end of life requires careful consideration as it will make any subsequent life extension more difficult and costly. Any change from a programme of scheduled maintenance to a regime of "on-condition" maintenance will require the necessary design changes to enable the required level of condition monitoring. This includes adequate plant access for monitoring and robust models of wear rates etc

Systems and procedures should also be in place to:

- Carry out an extended life assessment when required and include this in the current revision of the safety case;
- Consider the need for a revised fire and explosion assessment to be carried out and included in the current safety case.

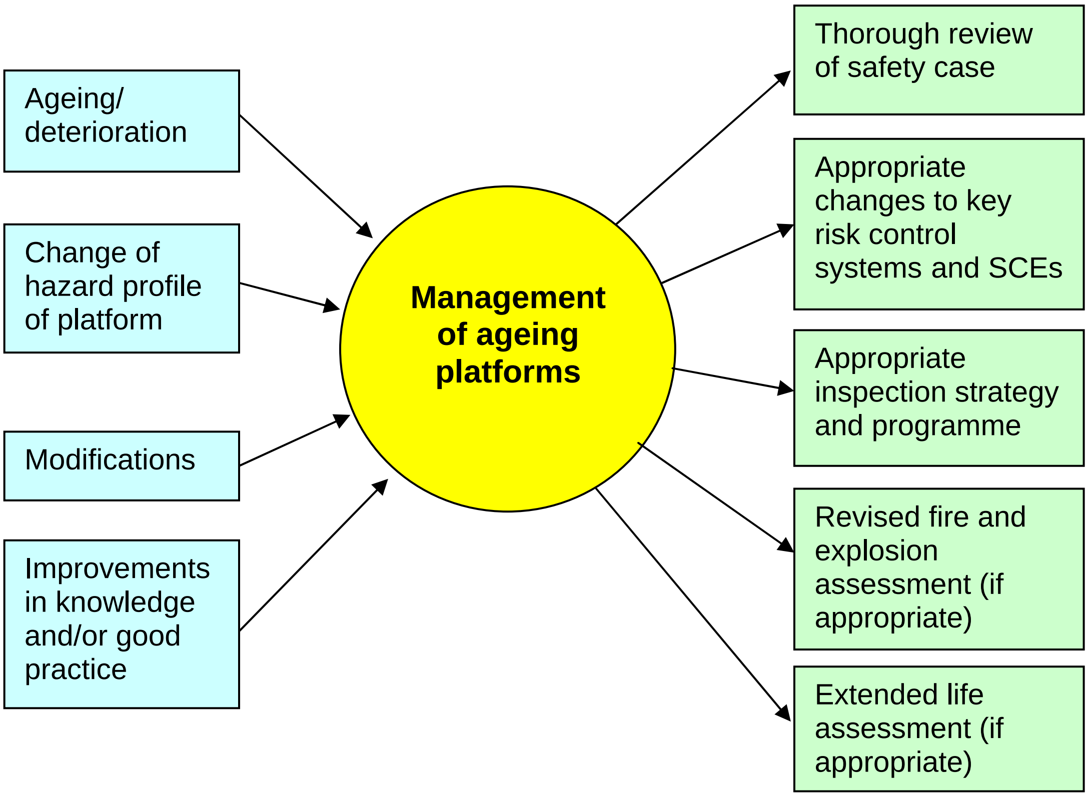

Figure 2: Overview of management of ageing considerations

Thorough review summary

It should be clear that the thorough review has included consideration of ageing and the summary submitted to HSE should include brief details of:

- the ageing issues, which have been considered in the review;
- any extended life assessment or revision to the fire and explosion risk assessment;
- any changes to the management arrangements to take into account ageing; and
- the conclusions as to the impact on the case for safety.

Issues with ageing

This section gives information about technical issues which need to be considered when managing ageing. Further details are given in the detailed reports for fire and explosion[4] and structural integrity[5]. The following issues are pertinent to the consideration and management of ageing:

- **Ageing/deterioration.** This includes the effects of wear and tear, external and internal corrosion, structural fatigue, obsolescence of equipment, and reduction of equipment reliability. Table 1 shows some indicators of ageing which were identified in HSE Research Report RR509[10], together with examples relevant to offshore installations[4]. In the UK sector of the North Sea, gas production started in 1968 and oil in 1974. Most of the facilities are still in place and in use, many beyond their original design life, and hence deterioration is very relevant to many installations.

Table 1: Some aspects of ageing and deterioration of offshore installations

Indicator of Ageing	Examples relevant to offshore installations
External indicators of corrosion or deterioration	Paint blistering, rust streaks, evidence of corrosion at screwed joist or bolts, softening of passive fire protection (PFP). Surface corrosion of blast walls may indicate that their structural response has been adversely affected.
External indications of incomplete reinstatement.	Loose covers, ill fitting enclosures, loose bolts, missing equipment, incomplete systems, e.g. F&G
Variations in standards	Modifications carried out to a higher standard such as double block and bleed or non screwed fittings while the original plant has earlier, lower standards
Lack of commonality/ incompatibility	Replacement equipment of a later design or from an alternative supplier. Interface problems between modern and older control systems
Deterioration in plant performance	Difficulty in achieving a seal in isolation and ESD valves; Deterioration in pump performance, lower flow rates in deluge systems due to blockage, loss of sensitivity of detectors. Bearings may heat up and form previously unrecognised ignition sources.
Deterioration in structural performance	Initiation and propagation of fatigue cracks in structural members.
Deterioration of uninspectable SCEs,	For example foundations, ring stiffened and single sided joints
Increasing congestion and lack of optimal layout	Location of new plant such as pig traps in non optimal locations because of the lack of available space. Use of outer walkways for laydown and siting of new equipment. This leads to increased overpressures, new potential failures and routes to escalation
Breakdown and need for repair	Repeat breakdowns and need for repair suggests that the equipment has reached Stage 3 of its life (See Table 2.1). It is good practice to establish the underlying reasons for breakdowns and repairs.
Increasing backlog of maintenance actions	An increase in the number of repairs that remain unresolved can be an indicator that ageing is taking place. As the maintenance backlog grows it can become increasingly difficult to get maintenance back on track.
Inspection results	Inspection results can indicate the actual equipment condition and any damage. Trends can be determined from repeat inspection data. Water deluge performance parameters may be tracked through trend analysis.

Indicator of Ageing	Examples relevant to offshore installations
Increasing failure to meet minimum functionality and availability performance standards	Reduction in efficiency, in pumping capability (e.g. fire water pumps) or heat up rates can be due to factors such as product fouling or scaling. Engines may become difficult to start. The temporary refuge (TR) may fail to maintain a seal when tested with blower doors, or dampers may fail to close more often.
Instrumentation performance	Lack of consistency in the behaviour of detection and process instrumentation can suggest process instability and may indicate that the equipment has deteriorated. It could also indicate a fault with the instrumentation, e.g. Pellistor gas detector set points tend to drift more with age. Process instrumentation may become less reliable in the presence of increasing water and sand.
Experience of ageing of similar equipment	Unless active measures have been used to prevent ageing of similar plant, it will be likely that the same problems can occur again. Particularly on vessels, PFP is known to delaminate with age and structural movement.
Repairs and plant outage.	May indicate that ageing problems are already occurring. Also a risk factor since if repairs have been needed during the life of the plant/ structure, the integrity and necessity of the repair will indicate the potential for further problems, e.g. water deluge ring mains have 'temporary' repair clamps to mitigate through wall pitting corrosion. Records for availability may show that SCEs are having a greater downtime.

- **Changes of well and/or process conditions.** Reservoir conditions change over the life of an installation and this affects the processing conditions. In most cases, the reservoir pressure will drop and, at some point, a form of enhanced oil or gas recovery will be needed, perhaps requiring compression. The gas/oil/water ratio may change possibly leading to more slug flow/vibration and there may be enhanced corrosivity if H_2S levels rise. These changes might increase the frequency of blowouts and other loss of containment events but might also reduce release rates.

- **Modifications** may include: use of a platform as a hub to import fluids from adjacent platforms, sub sea wells and other fields; changes to processing equipment; and changes to staffing levels or occupancy. Modifications can change the loading on the structure and change the fire and explosion hazard profile.

- **Obsolescence.** Components of older plant might become obsolete, leading to replacement parts becoming unavailable. This requires the use of non like-for-like replacements, which will require a thorough safety review in order to ensure that the safety implications of such changes are properly understood.

- **Advances in knowledge and technology.** There have been developments in the understanding and techniques for explosion modelling, leading to higher predicted overpressures than was known during the design of many installations, and for certain types of fire including the effectiveness of deluge mitigation. There have also been developments in structural assessment, particularly in system strength, improved understanding of system performance following single and multiple member failure, and the effects on fatigue life due to load redistribution. Technology developments include improved gas and fire detection, active fire protection systems including foam and dual systems and passive fire protection systems.

- **Improvements in good practice.** The ISO 1990X suite of standards for offshore structures[12] introduce the need for specific demonstration of fitness for purpose beyond the original design life. Hazard management and improvements in good practice are discussed in the UKOOA (now Oil & Gas UK) Management Guidance[14].

Consideration of whether there is a problem and what to do about it needs to take account of all the above issues and the balance between them. The thorough review of the safety case will need to identify such issues and determine the appropriate solution which reduces risk as low as reasonably practicable.

Some further information about relevant issues for some example SCEs is provided in Table 2 and additional detail is provided in the detailed reports[4,5].

Management of ageing

Fire and explosion

Risk assessment

All mature platforms will have undergone some degree of modification since they were commissioned. They will also have a different and usually reduced hazard profile, due to reductions in flammable fluid flow rates and pressure reductions. However some installations have received new reservoir fluids and may have an increased hazard profile. Additionally, plant and equipment may have degraded to a greater or lesser degree and will not therefore be as effective in maintaining integrity. Assessment of risks to persons on mature installations needs to take account of these two situations: reduction (or possibly an increase) in hazard profile but with a reduction in plant integrity.

The degree of change will determine whether a reappraisal of the fire and explosion hazards is necessary. It is only essential either where there is a new hazard with a significant inventory, such as a riser, compressor or separator, or else where the modifications significantly change the effects of the hazard or the exposure of personnel and critical plant. The ageing of the plant may have also led to an irreversible deterioration such that the frequency of an event has increased or the barriers to the consequences may be ineffective. It may be that these changes on their own do not warrant a revision of the analysis but when combined with other changes and new knowledge, the overall effect is significant.

Figure 3, which is fully explained in the detailed report[4], is a flowchart to determine whether a reappraisal of the fire and explosion risk assessment (FERA) is required. The detailed report also gives guidance on carrying out a reappraisal and refers to OSD guidance on risk assessment[11].

Table 2: Ageing issues for some example SCEs

Example SCE	Ageing / deterioration issues	Relevant changes in process conditions and modifications	Advances in knowledge, technology and good practice
Installation structure	• Corrosion especially in splash zone and topside • Fatigue cracking underwater • Fatigue of topsides structure (which may be modified by corrosion) • Accelerating local fatigue beyond design limits • Widespread fatigue damage and subsequent loss of redundancy • Maintenance of corrosion protection and allowances • Accumulated accidental damage. • Geological and geotechnical hazards • Seabed scour eroding foundation resistance/pile integrity – changes to foundation soil strength • Marine growth • Extreme weather - changes to criteria	• Life extension increases time for events such as dropped objects to impact structure • Modifications will change loading	• ISO standards require specific demonstration of fitness for purpose beyond the original design life. • technology developments in: o structural assessment, particularly in system strength o understanding of system performance following single and multiple member failure o effects on fatigue life due to load redistribution o structural reliability analysis for determination of inspection plans and evaluation of system reliability o metocean data o materials performance o foundation failure criteria
Hydrocarbon containment	• Internal and external corrosion • Accelerated corrosion due to enhanced corrosivity of well fluids, e.g. if H_2S increases as well becomes depleted • Blockage of well production tubing and process plant with scale • Sand and water erosion/corrosion in bottom of J-tubes/risers	• Reduced reservoir pressure, possibly too far below the rating of the plant; • Changes in the produced hydrocarbon composition, particularly where gas lift is used, and changes in the proportion of gas to liquid; and water to hydrocarbon • Changes in likelihood of release due	• Improved understanding of explosion mechanisms and modelling leading to higher predicted overpressure and highlighting importance of congestion/confinement • New EI/IP guidance on severe fires and improved understanding of different types of fire

Example SCE	Ageing / deterioration issues	Relevant changes in process conditions and modifications	Advances in knowledge, technology and good practice
	• Abrasion of coatings on piping and equipment in the splash zone leading to enhanced corrosion	to changes in fluid composition, pressures and phase variations causing surge • Changes in the frequency of wire lining and work over, increasing workover blow-out frequency • Modification to the process plant and its operating conditions, e.g. gas-lift, submersible pumps, gas, water or CO_2 injection to enhance recovery • Higher gas flows (gas-lift) • Increased inventories to achieve separation • Redundant equipment • Changes in staffing and module occupancy	• New guidance on plant ageing (RR509) • Changes in risk and hazard management strategy including safety case regime, and new guidance on risk assessment and ALARP demonstration.
Detection & control systems (e.g. gas and fire detection; blowdown systems)	• Corrosion of detectors, cable trays, Ex enclosures, electrical bonding points etc • Drift in detector response • Poisoning of catalytic sensors • Blockage of sintered metal screen in catalytic sensors • Open path detectors blocked by obstructions such as scaffolding • Obsolescence leading to non-availability of like-for-like spare parts and lack of vendor support. • Old application programs may be incompatible with current hardware	• Modifications may impact detector positioning	• Older detection systems, particularly those using some types of catalytic detector, cannot achieve the performance of modern systems (e.g. acoustic, infra-red, open beam, combination with CCTV) • IEC61508/61511 standards are now applicable to control systems
Active fire protection	• Deluge systems may suffer	• Changes in process conditions may	• Protection against jet fires excluded

Example SCE	Ageing / deterioration issues	Relevant changes in process conditions and modifications	Advances in knowledge, technology and good practice
(deluge)	degradation and nozzle blockage due to corrosion • Older systems may not be compatible with current standards • Vulnerability to explosion damage • Leaks in air trigger systems • Wear and tear of pumps and valves • Obsolete components • Deterioration/dilution of foam concentrate	reduce severity of fires and increase effectiveness of deluge • Modifications may obstruct deluge and impact on coverage and effectiveness	in ISO 13702 but included in early standards • Improved information on effectiveness and application rates for different types of fire • Better understanding of nozzle configuration for good coverage • Foam and dual systems available • New information on deluge mitigation of explosions
Passive fire protection (PFP)	• PFP often provided with no design safety factor • Poor application leading to disbonding from the protected structure • Weathering • Damage • Cracking of edge features • Ingress of water e.g. to penetration seals or failure of topcoat • Corrosion of substrate • Poor fire resistance of joint between old and new PFP unless suitable procedures adopted	• Changes in process conditions may reduce severity of fires • Modification to PFP requires matching materials and suitable procedures	• Better understanding of fire types, heat flux and duration • Better understanding of critical temperatures/failure criteria for pressure vessels • Old standard for A60 inadequate for hydrocarbon fires • New standard for PFP for jet fires • Better understanding of fire resistance of damaged and weathered PFP • Better procedures for repair of PFP • Issues with blast resistance, use with deluge and application to hot or cold surfaces
Blast Walls	• Corrosion and fatigue at joints to main structure	• Adequacy of penetration through walls and appurtenances attached to wall impairing strength	•
HVAC	• LEV deterioration	• Modifications will affect air flow	• New guidance on fire damper testing

Example SCE	Ageing / deterioration issues	Relevant changes in process conditions and modifications	Advances in knowledge, technology and good practice
	• Corrosion • Deterioration of fan performance • Contamination of ductwork with grease, mould etc • Deposition in ductwork • Deterioration of TR sealing: doors, penetrations, panel joints etc • HVAC damper shutdown deterioration	patterns • Modifications to ductwork may leave it out of balance	regime • Improved understanding of location of air intakes (in non-hazardous areas)

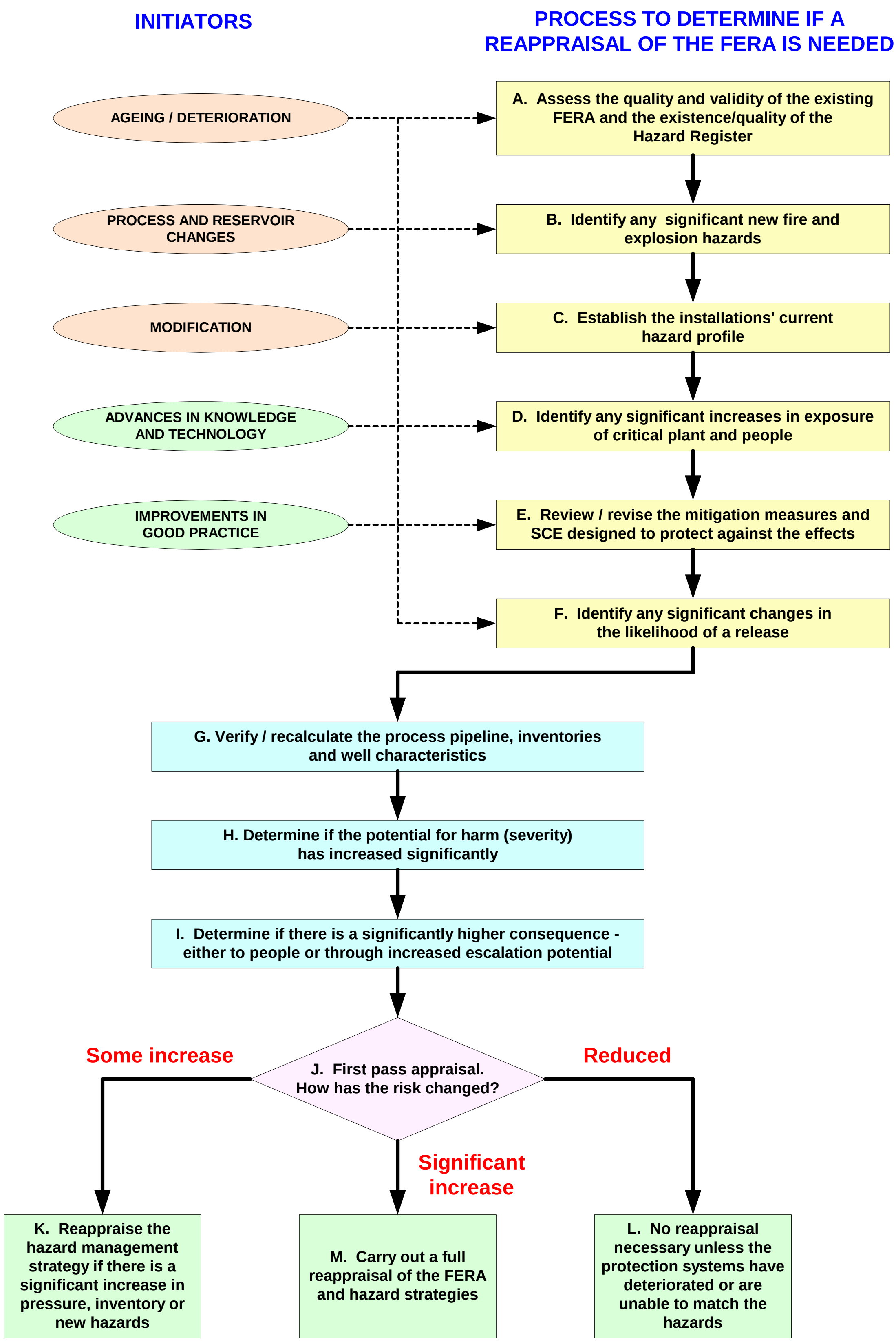

Figure 3: Flowchart for deciding whether reappraisal of the fire & explosion risk assessment is required

Options for addressing ageing

Risk reduction should be prioritised as follows:

1 Identification of those hazards with the potential for effects beyond the module and focussing resources on minimising their occurrence and severity (see 3); thereby reducing the dependence upon the TR and evacuation systems.

2 Improvement in the existing operational and integrity management systems.

3 Reduction in the severity of the fire and explosion events; in particular; optimisation of the depressurisation system to reduce release rates and pressures of liquids in order to hasten the spray liquid transition point, combined with the enhancement of liquid containment and deluge disposal to minimise the size of pool fires.

4 Limitation of the severity of explosions by the removal of redundant plant and the control of transient congestion such as lay down, scaffolding and habitats.

5 Optimisation of active protection systems so that their full potential can be realised by clearly identifying their role and design with respect to the hazards. This should reflect the predominance of pool fire hazards on older oil installations.

Once the existence, extent and mechanism of damage in a component of equipment or plant and have been established, a process for evaluating the range of options is as follows:

- Assess the overall condition and performance of the equipment to determine its remaining life and the performance which it could realistically achieve for the rest of that life;
- Determine what role and contribution it could make to controlling or mitigating each of the fire and explosion hazards on the facility;
- Determine if a viable strategy can be developed without the equipment or with reduced long term performance;
- Compare its life expectancy with the estimated life of the facility;
- Select and implement options from the following:

    - Scrap and decommission the equipment, with or without replacement; i.e. develop a strategy which does not rely on it;
    - Revise the role and live with the reduced performance for the remainder of the lifecycle; i.e. by placing greater dependence on other systems either to reduce the likelihood or consequence;
    - Remove the damage, with or without a repair, if necessary revising the role and performance standard as above;
    - Repair the component temporarily, with or without removing the damage;

- Provide alternative means to fulfil the equipment role or to reduce risk in the short term while the equipment is brought back to full performance;
- Develop a long-term programme to replace or refurbish the plant, bringing it back to its original performance. Note that current good practice might call for a higher performance such as jet rather than pool rated PFP or more sensitive detection;
- Monitor the component to ensure that the revised performance standards are achieved in the long term and to identify any terminal decline before it becomes critical.

Several of these actions may be needed to manage the problem; they are not mutually exclusive. The course of actions needed usually depends on the role and criticality of the system, nature of the damage, economic factors associated with the operation and repair/replacement of the equipment and the costs of assessment and monitoring. It may be necessary to use appropriate expertise to assess the situation and decide what to do. In many situations, an initial assessment of fitness-for-service can indicate the most cost effective and safest course to take.

Further information on options relating to gas and fire detection, active (deluge) and passive fire protection, and HVAC systems is given in the detailed report. Options for the management of ageing of equipment containing hydrocarbons is given in the HSE research report RR509[10].

Structural integrity

Ageing and life extension of offshore installations raises safety issues relating to structural integrity that go beyond those typically covered by current safety cases and structural integrity management plans and current practice in the offshore sector. While duty holders are generally aware of the need to manage the effects of ageing on structural integrity, the issue is not necessarily addressed beyond routine inspection, maintenance and repair activities. There is a need for better awareness of the hazards arising from ageing processes to prepare for the onset of accumulating and accelerating damage to the structures that might be expected to occur in the life extension phase.

Structural integrity management

Dutyholders should have a Structural Integrity Management (SIM) plan which incorporates all the elements of the lifecycle of the installation. It is of utmost importance that deterioration and degradation are incorporated into a well-formed SIM system and associated plan. The purpose of a SIM plan is to provide a link between the assessment process; and the inspection strategy and implementation for the installation. SIM plans are designed to maintain structural integrity on an ongoing basis but have not until recently (see below) addressed explicitly the extension of operation beyond the original design life. The structural integrity management plan also needs to consider the reduction in integrity arising from structural degradation caused by, for example:

- damaged and corroded members
- cracked members and joints
- repaired and strengthened members and joints.

Table 3 shows the processes in a SIM plan including the issues affecting life extension.

The structural integrity management of ageing offshore installations can be a complex process. The performance of ageing installations can be highly variable as deterioration can occur at any stage in the life cycle, depending on the design of the structure, the fabrication quality, the in-service inspection and repair activities and the quality and extent of structural assessment. There is also the issue of deterioration which is not known about, either because of inadequate inspection or because the component is unable to be inspected

Table 3: SIM processes and associated issues affecting life extension

SIM Process	Description	Main issues affecting life extension
Structural integrity strategy	Development of an overall inspection philosophy and strategy and criteria for in-service inspection	The strategy should include managing the approach to assessing ageing processes and the need to link inspection requirements to these
Inspection programme	Development of detailed work scopes for inspection activities and offshore execution to obtain quality data	A more detailed inspection may be required if a period of life extension is to be justified
Structural integrity evaluation	Evaluation of structural integrity and fitness for purpose, development of any remedial actions required	The evaluation should include assessment taking account of the original design requirement (which may have been less onerous than modern standards) as well as the consequences of ageing processes (e.g. fatigue, corrosion)
Managed system of data	Setting up and managing a system for archiving and retrieval of SIM data and other relevant records	Loss of key data from original design, construction and installation and early operational inspections

The understanding of structural and materials performance is an ongoing activity. As platforms age, the industry needs to make use of the information that becomes available to improve knowledge and current practices and assessment procedures. The inspection of decommissioned structures would provide particularly valuable information on structural and materials performance for all types of component but particularly for components which cannot normally be inspected.

Further information is given in the detailed report[5].

Life extension

A specific assessment will be required to support the safety case for life extension. Guidance on life extension is limited but is developing. The ISO 19900 series of standards provides a good basis for the assessment of life extension but the standards are still evolving. The ISO 1990X[12] suite of standards identify the need for specific demonstration of fitness for purpose beyond the original design life. Other codes, standards and guidance do not adequately cover life extension, although some industry codes and regulatory guidance (e.g. HSE Offshore Information Sheet 5/2007[13]) are becoming available in selected areas.

The main technical issues to be addressed are accelerating local fatigue beyond design limits, widespread fatigue damage and subsequent loss of redundancy, maintenance of corrosion protection and allowances, pile integrity, accumulated accidental damage. The considerable uncertainties associated with the structural integrity of ageing offshore installations highlight the need for detailed information on their performance. This requires further understanding of structural behaviour (characterised principally by the fatigue strength and system strength) and the importance of inspection strategies that provide accurate information on the condition of the structure. The effective management of ageing installations entails the effective application of inspection and maintenance strategies and structural analysis techniques. This also requires competency in the wide range of activities essential to the structural integrity management process and the importance of this cannot be overstated.

It is important that assessment for life extension takes account of new technology developments in structural assessment, particularly in system strength, to enable a better understanding of the structural capacity of ageing installations which are likely to have a higher incidence of deterioration. A considerable amount of research on the structural performance of offshore structures has been performed over the years. Much of this has been used in the development of current standards and guidance. The information is generally openly available and will be used in the next phase of standards development. Areas of particular progress include the understanding of system performance following single and multiple member failure, the effects on fatigue life due to load redistribution and structural reliability analysis for the determination of inspection plans and evaluation of system reliability. Other areas include the latest metocean data, materials performance (e.g. grade A ship steels and high strength steels used in jack-up construction) and foundation failure criteria.

Further information is given in the detailed report[5].

Key performance indicators

Measurable key performance indicators (KPIs) are required to facilitate management oversight, which is essential to ensure that ageing of the offshore installation is being adequately managed. The KPIs selected need to specifically address the issue of ageing. The number and nature of the KPIs required will differ according to the complexity of plant, age, and level of risk posed by the installation. Three levels of KPI are generally appropriate:

- **High level** – organisational level (e.g. issues of corporate memory)
- **Mid level** – management level (e.g. maintenance policy)
- **Lower level** – operational level (e.g. performance metrics for items of plant)

It is left to each dutyholder to determine appropriate KPIs for their installation. Guidance on the process for selecting KPIs is available[14]. Examples of some issues that might be considered when developing KPIs are provided in Table 4. Not all of examples given are actual KPIs – they are suggested topics for which KPIs could be developed. Actual KPIs would be **measurable** indicators for each topic.

Much information which might be used as KPIs will already be collected. For example, when assessing and managing the risks of ageing or conducting the thorough review it is necessary to know the condition of the plant, and how this has changed over time. Duty holders need full information about the state of their equipment and the state of the supporting systems, for instance corrosion rates in the splash zone, condition of PFP, fatigue life versus design life for welded components, history of deluge nozzle blockages in tests etc. Inspection, testing and other information gathering arrangements need to be in place and designed to obtain all the necessary information. KPIs are likely to be selected to be a subset of information which is already being gathered. The process of selection is illustrated in Figure 4.

Table 4: Example areas for the development of KPIs for ageing installations

High level	• Investment and long-term planning: a commitment to proactive investment • Planning for success: providing competent staff and sufficient resource • A role for technical engineering input into senior management decision making
Mid level	• Trend analysis of safety critical elements • Reviews of maintenance strategy • Root cause analysis for ongoing maintenance problems
Lower level	• Number of temporary repairs in place • ESD valve closure times • Deluge systems (KPI measure might be number of nozzle blockages per test or time taken for water to flow out of remote nozzles)

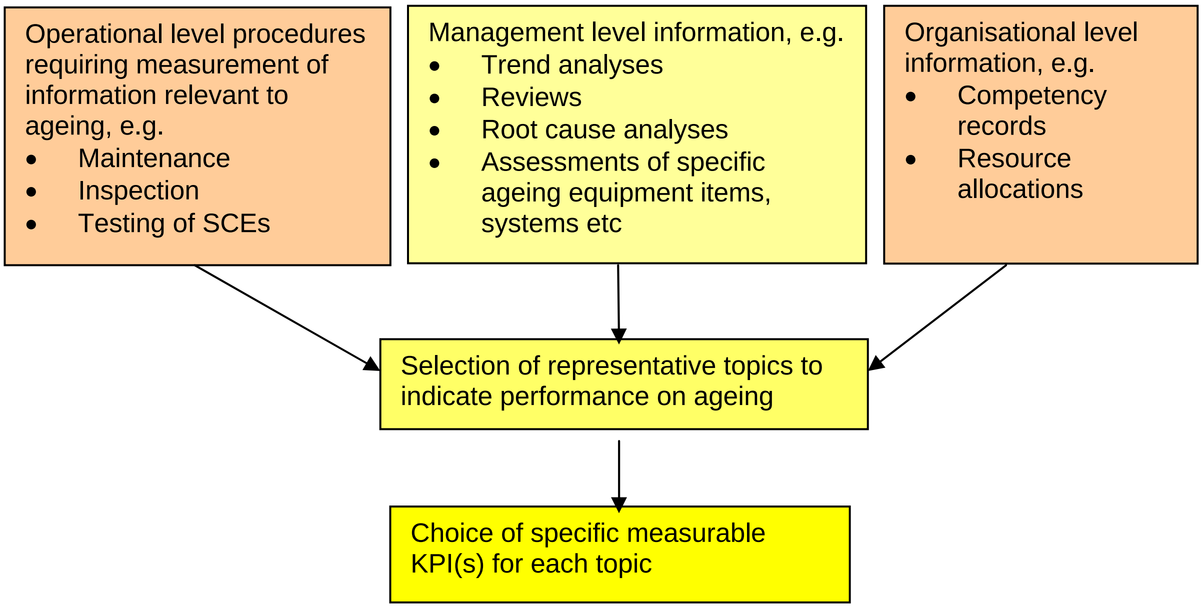

Figure 4: Indicative process for the selection of KPIs for ageing

The value of measurable KPIs is their ability to inform on current status and to track changes occurring over time.

Organisational issues

Competence is key to the management of ageing issues. Suitably competent people need to be employed in inspection and assessment activities, making any necessary judgments about remaining life (especially for equipment and components which cannot be inspected), defining remediation programmes and additional risk reduction, and making assessments in support of life extension. A range of specialist competencies will be required.

Some other organisational issues are illustrated in Table 5.

Table 5: Some organisational issues relevant to ageing of offshore installations

Organisational issue	Examples relevant to offshore installations
Loss of knowledge	• Increasing likelihood of loss of technical knowledge required for safe operation as installation gets older • Instruction manuals and documents deteriorate and get lost; electronic media degrade or are on obsolete formats • Staff with key operating experience of unusual operations or plant upsets are no longer available • Ownership change/contracting arrangements can exacerbate problems of lost knowledge

Knowing the limits	• Difficult to recognise signs and nature of failures if there is no prior experience of running plant past design life • Prior failures might not predict end-of-life failures, which are often different in nature, and this can lead to complacency and misdirected effort (e.g. monitoring oil condition or vibration will not predict catastrophic failure of pump casing caused by fatigue)
Redundant plant	• Can be confused with live plant and vice versa (this is a particular problem when live and redundant pipes or cable run alongside one another – a number of serious incidents have occurred when live wires have been mistakenly cut into) • Hazards posed by state of redundant plant
Working and living environment conditions	• Poor conditions in living and working areas lead to low morale, high staff turnover and poor safety climate If employee performance is to be kept up to standard the work environment must also be kept up to standard

References

1 Offshore Installations (Safety Case) Regulations 2005 SI 2005/3117 The Stationery Office 2005 ISBN 0 11 073610 9.

2 Offshore Installations (Safety Case) Regulations 2005 Regulation 13 Thorough Review of a Safety Case Offshore Information Sheet 4/2006 HSE 2008.

3 Offshore Installations (Safety Case) Regulations 2005, regulation 12 - Demonstrating Compliance with the Relevant Statutory Provisions Offshore Information Sheet 2/2006 HSE 2006.

4 Guidance on fire and explosion hazards associated with ageing offshore installations G Dalzell, T A Roberts, S Jagger, P Walsh HSL Report PS/07/06 2007

5 Structural integrity management of ageing installations A Stacey et al 2009

6 Assessment Principles for Offshore Safety Cases (APOSC) HSE 2006

7 Guidance for the topic assessment of the major accident hazard aspects of safety cases (GASCET) HSE 2006

8 Key Programme 3 Asset Integrity Programme Report HSE 2008

9 Weldless repair of safety critical piping systems Safety Notice 4/2005 HSE 2005.

10 Plant Ageing: Management of equipment containing hazardous fluids or pressure Research Report RR509 HSE Books 2006

11 Guidance on Risk Assessment for Offshore Installations Offshore Information Sheet 3/2006 HSE 2006

12 International Standards Organisation (2002-10), **Petroleum & Natural Gas Industries** 19900 General Requirements;19901-1 Metocean ;19901-2 Seismic; 19901-4 Foundations**;** 19901-3 Topsides; 19901-5 Weight Engineering**;** 19901-6 Marine Operations; 19901-7 Station Keeping; 19902 Fixed Steel;19903 Fixed Concrete; 19904-1 Floating MSS**; 19905-1/2 Jack Ups to be published May 2010,** BS EN ISO19900:200X

13 Ageing semi-submersible installations Offshore Information Sheet 5/2007 HSE 2007.

14 Developing process safety indicators: A step-by-step guide for chemical and major hazard industries HSG 254 HSE Books 2006 ISBN 0 7176 6171 8

15 Fire and explosion guidance Part 0: Fire and explosion hazard management Issue 2 UKOOA (now Oil & Gas UK) 2003

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