Health and Safety Executive

Key Programme 4 (KP4)

Ageing and life extension programme

A report by the Energy Division of HSE's Hazardous Installations Directorate

Contents

Preface

This report communicates the results and recommendations of the Ageing and Life Extension Key Programme (KP4) carried out between 2011 and 2013 by the Health and Safety Executive's Energy Division.

The report is available on HSE's Offshore Oil and Gas website at www.hse.gov.uk/offshore/ageing.htm.

Glossary

AIM	asset integrity management
ALARP	as low as reasonably practicable
ALE	ageing and life extension
COMAH	Control of Major Accident Hazards
CoP	cessation of production
DECC	Department of Energy and Climate Change
EC&I	electrical, control and instrumentation
ESDV	emergency shutdown valve
ED	Energy Division
FPI	floating production installations
HCR	hydrocarbon release
HP/LP	high pressure/low pressure
HSE	Health and Safety Executive
HVAC	heating, ventilation and air conditioning
ISO	International Standards Organization
KP4	Key Programme 4
KPI	key performance indicator
MODU	mobile offshore drilling unit
OEM	original equipment manufacturer
OGRE	oil and gas release elimination
OGUK	Oil & Gas UK
ORA	operational risk assessment
PMR	planned maintenance routine

RACI	responsibility, accountability, consultation and information
RIDDOR	Reporting of Injuries Diseases and Dangerous Occurrences Regulations
SCE	safety-critical element (as defined in the Offshore Installations (Safety Case) Regulations 2005)
SMS	safety management system
SRE	safety-related equipment (equipment supporting SCEs)
TR	temporary refuge
UKCS	United Kingdom Continental Shelf

Executive summary

This is a report of the inspection findings of the Health and Safety Executive's (HSE's) Energy Division's (ED's) Key Programme 4 (KP4) covering the ageing and life extension (ALE) challenges facing hydrocarbon exploration and production installations on the UK's Continental Shelf (UKCS). The programme investigated the impact of ALE on the risk of major accidents involving the death or serious personal injury to people on an offshore installation.

The UKCS is a mature oil and gas producing province, with about half the fixed platforms approaching or exceeding their originally anticipated field life. There are potentially significant future challenges to be met associated with the prospect of some installations operating beyond their original cessation of production date, plus the likelihood of a further five years for decommissioning.

Management of ageing requires a good understanding of the condition of safety-critical elements (SCEs), how that condition is changing over time, and carrying out maintenance in a timely manner to minimise risk of major accidents. There is evidence that installation age is not necessarily a reliable indicator of condition or likelihood of hydrocarbon leak frequency.

Management of life extension requires the advanced, and continuing, assessment of SCEs to ensure they are fit for purpose, and safe to use when required to operate longer than their anticipated service, with particular consideration for primary structures.

HSE's KP4 Ageing and Life Extension (ALE) programme was initiated in 2010 and followed the KP3 Asset Integrity Management (AIM) programme which reported in 2007 (www.hse.gov.uk/offshore/kp3.pdf).

KP4 was a forward-looking programme of work. Its purpose was to:

- raise awareness of ALE in the offshore industry of the need for specific consideration of ageing issues as a distinct activity within the AIM process;
- undertake a programme of inspections of dutyholder approaches to ALE management;
- identify areas for the improvement of ALE management;
- encourage the development and sharing of good practices.

During KP4, HSE undertook 33 onshore and offshore inspections covering all major dutyholders using structured templates across 10 topics:

- Safety management systems;
- Structural integrity;
- Process integrity;
- Fire and explosion;
- Mechanical integrity;
- Electrical, control and instrumentation;

- Marine integrity;
- Pipelines;
- Corrosion;
- Human factors.

KP4 engaged with industry using several approaches:

- developing an HSE website portal for disseminating information (www.hse.gov.uk/offshore/ageing.htm);
- encouraging workforce involvement through Step Change in Safety (www.stepchangeinsafety.net/);
- promoting ALE understanding with workers on their installations;
- initiating the development of guidance through Oil & Gas UK (OGUK) (www.oilandgasuk.co.uk/);
- raising the profile of ALE by presenting at technical seminars and conferences.

Industry has welcomed and responded positively to the KP4 initiative, with HSE acting as a catalyst for improvements on the UKCS and worldwide through its KP4 website (www.hse.gov.uk/offshore/ageing.htm).

There is good evidence that industry leaders have recognised the importance of ALE, but there is much to do to ensure arrangements are implemented in practice, and there is no room for complacency.

KP4 findings

The KP4 programme found a range of areas where ALE management was developing well, and areas where extra focus is required. From the programme, a number of illustrative case studies were developed by dutyholders to elaborate good practices, which can be found in the Appendix.

The findings of KP4 were broken down into a series of strategic issues identified below:

Leadership and preparedness for ALE

- Dutyholders' response to KP4 was very positive.
- No mature ALE policies and procedures; however, dutyholders were in the process of developing and integrating them into their AIM systems.
- Early uncertainties over distinctions between ALE and AIM were soon resolved.
- Good corporate AIM processes and procedures, although the observed physical condition of offshore assets combined with very large backlogs suggests problems implementing them.
- Leaders were developing plans for the long-term consideration of AIM, including inserting ALE management into procedures.
- Occasional insufficient clarity of responsibilities for safety-related equipment (SRE).
- Insufficient plans in place to manage the consequences of creeping changes ('normalisation of deviance').
- Dutyholders are developing plans to link ALE management to decommissioning.
- Creation of 'life of field manager' positions to assist ALE management.
- Dutyholders expressed concerns over the availability of skilled personnel in the industry now and for the future.
- Expenditure on the UKCS in 2013 was the highest ever (www.oilandgasuk.co.uk/forecasts.cfm) indicating positive leadership for offshore assets for the future, and reinforcing the need for sound ALE management.

Asset integrity management

- Industry feedback was that KP4 had a positive impact on approaches to asset integrity.
- ALE concepts were becoming embedded into AIM programmes.
- There was no evidence to suggest that the derogation given to floating production installations (FPIs) to stay on station adversely affects dutyholders' ability to determine the asset's integrity.
- There were significant plans in place by dutyholders to manage fabric maintenance and external condition of hydrocarbon process equipment, with walk-to-work vessels being brought alongside installations to accommodate extra workers to manage the backlog.
- Some SCE and SRE lists, and engineering drawings, needed updating.
- Some redundant equipment was not identifiable on site or on drawings.
- Some primary structural analyses needed updating.
- More focus is needed on forecasting potential long-term future failure mechanisms.
- Not enough ALE consideration at the component level.
- There is industry awareness of the need to address the potential risks associated with difficult to inspect components of primary structures.
- For rotating equipment, there was a reliance on historical performance from original equipment manufacturers (OEMs), but a need for more forward-looking risk-based assessments to revise planned maintenance routines (PMRs) and so improve safety and integrity management.

Obsolescence

- Obsolescence is an area of concern, particularly for electrical, control and instrumentation (EC&I), and to a lesser extent for mechanical equipment.
- Evidence of missing data, and insufficient data trending – this should be improved to help anticipate potential future failures of SCEs, EC&I degradation and obsolescence management.
- Dutyholders and suppliers are working together to anticipate obsolescence and manage the long-term issues.

Audits and KPIs

- Insufficient leading ALE key performance indicators (KPIs), which could be used to help forecast potential future problems.
- Dutyholders were commencing targeted audits on ALE management.
- Developing understanding of the beneficial influence of maintenance management programmes on equipment failure frequencies within an installation's life cycle.
- Approaches to audits were generally to follow what had gone before, rather than addressing what is needed in the future.

Data management

- Insufficient use of data trending to enable forecasting of when equipment is likely to fail its criteria of non-conformance.
- Insufficient use of data and information, which could lead to a better understanding of the consequences of creeping change.

Development of ALE guidance

- The offshore industry recognises the importance of managing ALE better, and engaged well with HSE's initiative.

- New approaches to asset integrity and obsolescence management were being developed.
- OGUK published management systems guidance in 2012, and both OGUK and the Energy Institute will publish further ALE guidance in 2014.

KP4 recommendations

The offshore industry is expending significant time, effort and money on offshore asset integrity management, and has responded well to KP4. However, there is a considerable amount of work to be done to implement new ALE processes and procedures to ensure the offshore hydrocarbon installations remain safe to cessation of production, and beyond to decommissioning.

Industry should use the existing high-quality incident root cause analysis processes to make the lessons learned more easily available to new entrants to avoid repetition of past failures; Judith Hackitt (HSE Chair) commented at the Piper 25 conference in 2013: '*..there are no new accidents. Rather there are old accidents repeated by new people*.'

From analysis of the KP4 inspection templates a range of recommendations for the offshore industry and HSE were developed, for which each party will need time to consider and take forward. HSE will need to continue to be involved with the industry, and maintain the positive dialogue which has taken place during the KP4 programme for the long-term safety of offshore workers.

The existing OGUK ALE Steering Group provides a mechanism for reviewing recommendations and developing effective improvement strategies and plans, and could consider becoming the hub for allocating tasks to address the recommendations for industry.

Key recommendations for industry

- Continue promoting industry-leading ALE management practices.
- Develop and encourage a corporate culture which embeds an ALE philosophy into AIM for the long-term future.
- Improve focus on obsolescence management.
- Early preparation for life extension, enabling the identification of key issues to be managed to assure continued safe operation.
- Incorporate decommissioning into ALE management.
- Develop leading ALE KPIs to help prevent future loss of integrity.
- Undertake periodic ALE management audits.
- Improve data management, eg maintaining complete SCE and SRE lists, and contemporaneous engineering drawings.
- Improve data trend analysis.
- Further promote workforce involvement through Step Change in Safety.
- Further develop approaches to recruit and retain the skilled workforce necessary to sustain the viable long-term future of the offshore oil and gas industry.

Key recommendations for HSE

- Continue to recognise the importance of ALE management through interventions.
- Continue to work with Step Change in Safety to encourage workforce involvement.
- Monitor and review dutyholder ALE performance.

- Continue to collaborate and support the offshore industry to identify and share good practices.

Introduction

Between 2011 and 2013, HSE undertook targeted inspections of 33 dutyholders and offshore assets across a range of installation types (www.hse.gov.uk/offshore/ageing/kp4-programme.htm) to establish how prepared the industry is for the future management of ALE, and to identify and promote good practices. The inspections were undertaken using templates drawn up for the onshore and offshore inspections for each of the topics:

- Safety management systems;
- Structural integrity;
- Process integrity;
- Fire and explosion;
- Mechanical integrity;
- Electrical, control and instrumentation;
- Marine integrity;
- Pipelines;
- Corrosion;
- Human factors.

The KP4 programme aimed to ensure the ALE risks to offshore installations are being effectively controlled, supporting HSE's strategic priority on avoiding catastrophe (www.hse.gov.uk/strategy/strategy09.pdf), and ED's priority of asset integrity (www.hse.gov.uk/offshore/priorities.htm). KP4 also links with HSE's Energy Division's new Offshore oil & gas sector strategy 2014 to 2017 (www.hse.gov.uk/offshore/strategic-context.pdf), in which Objective 9 requires dutyholders to apply the learnings from KP4.

The objectives of KP4 were to:

- raise awareness of ALE in the offshore industry, with specific consideration of ageing issues as a distinct activity within the AIM process;
- undertake a programme of inspections of dutyholder approaches to the management of ALE;
- identify areas for improvement of ALE management and encourage improvements;
- encourage the development of good practices.

Approximately half of the fixed and floating installations on the UKCS have exceeded their originally anticipated service lives, and with continued business and national interest, the majority of UKCS installations are likely to remain operational for many years.

If not managed effectively the consequences of ageing-related deterioration are extremely serious, with the worst case being the loss of an installation and those onboard. Thus, ALE and AIM management are imperatives, with the need to understand asset condition, factors affecting degradation, and mitigation strategies throughout an installation's life cycle.

Ageing concerns extend to procedures, software, control equipment, and perhaps most importantly to the skills and experience of people working in the offshore industry, and the need to bring new people into the industry to be trained to manage future challenges.

There are significant differences between KP4 and its predecessor KP3, which assessed the condition of assets (AIM) at the time of the inspections. KP4 is forward-looking, inspecting dutyholders' abilities to anticipate and prepare for the integrity challenges of the future, up to cessation of production (CoP).

An effective ALE AIM system is the principal barrier safeguarding those working offshore. The system is typically risk-based, requiring the dutyholder to have a good understanding of the degradation processes and an accurate knowledge of both the condition of a structure and its response in the aged condition. There is also a need to understand obsolescence issues, and an implementation strategy to deal with the likely increasing risk of failure with time, thereby enhancing predictability of deterioration, its detection and assessment.

The KP4 programme engaged with offshore stakeholders across the industry, and in particular:

- dutyholders;
- Oil & Gas UK;
- Step Change in Safety;
- other North Sea regulators;
- suppliers to the offshore industry.

KP4 encouraged sharing good practices to deliver improvements in ALE, which led to OGUK setting up an ALE Steering Group.

Previous HSE ALE publications: *Plant ageing* RR509 (www.hse.gov.uk/research/rrhtm/rr509.htm), and *Plant Ageing Study* RR823 (www.hse.gov.uk/research/rrpdf/rr823.pdf), defined ageing and ageing plant as:

'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.

Ageing equipment is equipment for which there is evidence or likelihood of significant deterioration and damage taking place since new, or for which there is insufficient information and knowledge available to know the extent to which this possibility exists. The significance of deterioration and damage relates to the potential effect on the equipment's functionality, availability, reliability and safety. Just because an item of equipment is old does not necessarily mean that it is significantly deteriorating and damaged. All types of equipment can be susceptible to ageing mechanisms.'

This statement is equally true of the offshore industry, which KP4 supplements with: 'the need to develop ageing mitigation strategies and implement them'.

Dutyholders should ensure AIM systems include ALE considerations, with the ageing mechanisms identified and the consequences evaluated and monitored to ensure risks are as low as reasonably practicable (ALARP) to ensure safety, and legal compliance, for the life of the asset.

Normalised UKCS data (www.hse.gov.uk/offshore/statistics/hsr1213.pdf) from the Reporting of Injuries Diseases and Dangerous Occurrences Regulations (RIDDOR) system (www.hse.gov.uk/riddor) does not indicate a significant correlation between platform age and increased leak frequency, a finding mirroring a Norwegian study,* and supporting the definition of ageing. The Norwegian study found most leaks (60%) occurred during human interventions.

Recent studies in the Norwegian sector used statistical regression techniques to study leak frequency with platform age;†‡ the studies found no significant correlation, other factors were more important.

The rate of hydrocarbon releases on the UKCS fell after OGUK introduced the Step Change in Safety programme in early 2011. However, comparison of the hydrocarbon release (HCR) data for 2012/13 and 2013/14 shows a 20% increase in leak frequency, meaning much more work needs to be done to resolve the root causes.

Challenges in hydrocarbon containment are likely to grow as plant and equipment age, reinforcing the message of the need for early consideration and management of ALE.

ALE is a global issue, with other offshore regulators active:

- Bureau of Safety and Environment Enforcement (www.bsee.gov), and Bureau of Ocean Energy Management (www.boem.gov), USA;
- National Offshore Petroleum Safety and Environmental Management Authority (www.nopsema.gov.au), Australia;
- Petroleum Safety Authority (www.ptil.no), Norway;
- State Supervision of Mines (www.sodm.nl), Netherlands.

ALE is not confined to the offshore industry, but is also experienced in other potentially hazardous industries: onshore COMAH (Control of Major Accident Hazard) sites (www.hse.gov.uk/comah/), nuclear, and aerospace.

* 'Analysis of Hydrocarbon Leaks on Offshore Installations' Vinnem JE, Seljelid J, Haugen S and Husebø T Chapter from *Risk, Reliability and Societal Risk* Aven and Vinnem (eds) Taylor & Francis Group, London

† 'Analysis of Root Causes of Major Hazard Precursors (Hydrocarbon Leaks) in the Norwegian Offshore Petroleum Industry' Vinnem JE, Hestad JA, Kvaløy JT and Skogdalen JE *Reliability Engineering and System Safety* Volume 95, Issue 11, November 2010, pp 1142–1153

‡ 'Safety Climate and Hydrocarbon Leaks: An Empirical Contribution to the Leading-Lagging Indicator Discussion' Kongsvik T, Johnsen SÅK and Sklet S (2011) *Journal of Loss Prevention in the Process Industries* 24/4, pp 405–411

Topic findings

From the assessment of the topic specialist findings, strengths, and areas needing additional focus, were identified and collated into groups. A number of dutyholders prepared case studies, which are contained in the Appendix and help to articulate some of the programme's findings.

Safety management systems

www.hse.gov.uk/offshore/managementsystems.htm

Safety management systems (SMSs) are crucial to the delivery of offshore safety. A positive ALE SMS would be forward-looking to anticipate long-term risks and consequences, for which Case Studies 2 and 3 in the Appendix set out good practices.

Important SMS elements are:

- effective safety leadership;
- competence;
- supervision;
- work control.

Strengths

The KP4 inspections found that senior management reacted positively to the need to consider ALE in SMSs, and were conducting structured offshore visits using checklists which included ALE issues.

The inspections found good ALE leadership vision, with developing policies and plans well communicated to all levels. Dutyholders were developing new ALE human and organisational factors strategies, strengthening the existing policies, and plans were in place for installation crew succession.

There was good safety leadership guidance addressing asset integrity and process safety management. There was good onshore and offshore senior management awareness, and significant interest, of SCE maintenance needs, including appreciation of the challenges of operating legacy equipment alongside new technologies.

KP4 found evidence of good organisational structures, with roles and responsibilities clearly defined. Detailed assessments of integrity management systems had led to significant improvements in procedures.

Senior management created ALE focal points/life of field manager positions to lead, steer, strategise and manage ageing installations through to cessation of production and subsequent decommissioning. ALE management was becoming embedded in

AIM, with clear allocation of responsibilities and dutyholders were revalidating integrity programmes to assure their fitness for purpose going forward, which is a good integrated example of industry commitment and consideration of the need to manage ALE to improve AIM.

Dutyholders were undertaking annual reviews and verification of SCE registers, and the associated performance standards. There was generally a good balance between leading and lagging AIM KPIs; however there need to be more leading ALE-specific KPIs. Dutyholders were developing good-quality KPI dashboards to aid management decision making.

There was good management of organisational change procedures. Deviation registers and processes are in place to control changes which may affect design, technical or operating integrity, with changes being assessed for their impact on safety cases and with key documents being updated accordingly.

For mobile drilling units (MODUs) in particular, KP4 found senior management were given unbiased installation condition assessments with comprehensive evaluations, and a traffic light system identifying the critical, major and minor items to be rectified.

There was good evidence of positive efforts to involve the workforce with ALE issues, with dutyholders engaging the workforce with presentations, town hall meetings, bulletins, and ALE workshops.

Areas for additional focus

ALE and obsolescence strategies and policies should be developed further, and integrated into operations so they can be identified proactively, with comprehensive lists identifying equipment or components which are or could become obsolete.

For some degraded SCEs there is a need to accelerate remedial action to reduce the risk of future failure, a finding echoed in Case Study 3.

Improving data storage and retention, especially of SCEs, and including engineering drawings, will help long-term AIM, particularly for when assets change ownership.

SCE performance data should be trended to forecast when they are likely to reach their criteria of non-conformance, so that mitigating programmes are put into place in a timely manner.

There is a need to standardise approaches to SMS auditing, which includes a systematic approach to audit specifically for ALE management compliance. Although there are some leading and lagging ALE KPIs, there is a need to develop more leading ALE-specific KPIs.

There should be early preparation for detailed ALE studies of assets potentially operating beyond the originally anticipated CoP date (Case Study 2), to capture potential risks and generate timely solutions.

Many dutyholders expressed concerns over current and future availability of good-quality technical expertise; in particular, some EC&I backlogs were blamed on lack of available skills. There is evidence of additional recruitment into the industry, including graduates and apprentices; however, more needs to be done to ensure there is adequate succession planning to capture knowledge from the experienced specialist workforce, to ensure awareness of legacy issues, and pass on knowledge to new entrants.

Structural integrity

www.hse.gov.uk/offshore/structuralintegrity.htm

A good approach to ALE management of structures is to have up-to-date mathematical models, capable of being modified to theoretically stress the structures to reveal a response, with the data being used to identify weaknesses.

The approach would also include the ability to trend integrity data to determine potential future risks so that solutions can be implemented in a timely manner.

Structural analyses for life extension should commence sufficiently early to allow for the size and complexity of the primary structure.

Strengths

There was evidence of dutyholders placing more emphasis on ALE considerations in their structural integrity management plans, largely in response to KP4. In general, this entails structural reanalysis to current design codes, the review of inspection programmes and remedial structural work for life extension.

Dutyholders were found to be using leading KPIs to provide early warning of potential catastrophic failure. Peer reviews were in place to enhance understanding of structural performance. Dutyholders were undertaking reanalysis of structures to confirm compliance with current standards (principally ISO 19902 for fixed steel structures).

There was good evidence of concise structural reports from inspection data, and anomaly trend analyses, with the findings reported to aid senior management decision making.

KP4 found life extension projects underway (Case Study 1), including remedial structural work.

For older jack-up MODUs (>30 years), owners were performing fatigue assessments beyond the ‘class rules’ requirements.

Structural integrity management analyses were linked to KPIs, with regular reviews and trending.

The KP4 structures inspections found no evidence that the class rules derogation on the requirement for FPIs to dry dock every five years has adversely affected dutyholders’ approach to structural integrity management.

Areas for additional focus

The KP4 inspections found not all structural analyses were up to date; some fatigue and redundancy analyses were incomplete or missing, and there was a need to clearly identify all the safety critical risks. Some installations designed to older rules had no fatigue assessments carried out.

While not a KP4 finding, there have been recent reports of incidents of cracked teeth on jack-up MODU legs.

MODU operators should consider the implications of ALE management beyond the Classification Society requirements, by:

- developing ALE-specific policies setting out how the issues are to be dealt with;
- creating a better understanding of the fatigue lives of the individual installations;
- demonstrating that inspection schedules are suitable and sufficient for ageing installations; and
- developing data trending analyses.

The assessment, inspection and maintenance regimes should reflect operational experience, with the potential for data trending and extrapolation to forecast when the future criteria of non-conformance will be met. To assist this process there should be a reassessment of the current and potential future failure and deterioration mechanisms, and a reassessment of the barriers to failure to ensure they are suitable for ageing structures, and the anticipated remaining life of the installation.

Reviewing the inspection schedules to ensure they are suitable and sufficient for ageing installations would be helpful for future integrity management, which should be combined with anomaly assessments to determine whether ageing is a common factor.

The offshore industry is aware of the potential risks associated with un-inspectable components (eg storage tanks in jacket legs), and difficult to inspect components (some jacket nodes), for which more attention should be given to quantification of the potential risks, and inspection methods which could be used to address the likely degradation issues.

Structural integrity management ALE policies could be developed further to include the identification of potential failure and deterioration mechanisms, and the identification and reassessment of barriers to failure to ensure they are suitable for ageing structures and the anticipated remaining life of the installation.

There is a need for the Classification Societies to review jack-up fatigue assessment requirements to take into account:

- installations designed to older rules, which lack fatigue assessments;
- long tows where the legs are jacked high during sea transport, creating large bending moments;
- smaller support jack-ups with more frequent relocations.

Process integrity

www.hse.gov.uk/offshore/processintegrity.htm

Process integrity management involves preventing the uncontrolled loss of containment of hydrocarbons, which may result in a fire and/or explosion.

For ALE, the process integrity system should anticipate future risks, and consequences of the loss of containment, and put plans into place at an early stage to ensure risks are ALARP. Case Studies 2 and 4 offer good ALE management examples.

Strengths

KP4 found that while not having explicit ALE procedures, dutyholders were managing process safety throughout an installation's life cycle as a function of day-to-day activities. These were supported by good procedural adherence, revisions of the piping and instrumentation diagrams during integrity inspections of the pressure envelope, and the regular updating of hazard and operability studies.

Dutyholders were reviewing process systems for the life of the field to identify which equipment to keep, modify, or replace, and there was evidence that some obsolete equipment was being replaced by modern equivalents.

As part of their AIM/ALE programmes dutyholders were performing high pressure/low pressure (HP/LP) interface studies, reassessing process safety valves, debottlenecking process plant and upgrading drilling areas in preparation for future field developments.

A particularly good practice was the use of the 'responsibility, accountability, consultation and information' (RACI) communications protocol, and oil and gas release elimination (OGRE) tools for asset life extension (Case Study 2). This dutyholder commenced reappraisal of an installation's condition two years before the originally anticipated service life, capturing, among many issues, process integrity management.

Areas for additional focus

To anticipate future process safety challenges, dutyholders should use predicted reservoir characteristics information to feed topsides process safety management plans, so that potential risks can be identified and managed in advance.

The offshore industry uses operational risk assessments (ORAs) to assess and manage the risks associated with degraded SCEs/barriers, until they can be repaired (www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/HS071.pdf). Dutyholders should minimise the number of ORAs by putting into place long-term repair and maintenance strategies, and where an SCE has more than one ORA, the consequences should be considered in combination to ensure they do not unduly increase the risks to the installation.

ORAs in place for extended periods should be regularly reviewed to ensure they remain fit for purpose, do not cause creeping changes ('normalisation of deviance'), and do not adversely affect the long term integrity of the asset.

Staff performing ORAs should be suitably trained to ensure they are competent. Dutyholders are encouraged to align risk decision making with established risk tolerability criteria (Offshore Information Sheet 2/2006 (www.hse.gov.uk/offshore/is2-2006.pdf)) to remove potential bias towards risk tolerability ('normalisation of deviance').

Dutyholders are encouraged to generate explicit leading ALE KPIs, particularly for operational dysfunction, and process isolations requiring repeated risk assessments. Because of the potential difficulties of creating leading ALE KPIs, consideration should be given to the creation of an industry-led guidance document, an observation also made in other specialist KP4 findings.

Industry should also consider generating guidance for performing gap analyses of ALE process safety systems against which to judge ageing/impaired performance.

To understand future challenges of long-term AIM/ALE management, dutyholders should ensure there are complete records of re-rated or downgraded plant, so the current status is clear and understood. The information could be placed on a 'dashboard' with historic data and developing trends which are visible to senior management.

The KP4 inspections found that there would be risk benefits in improving plant identification, and in particular the identification of redundant equipment, both physically on the installation by suitable signage, and in SCE lists.

Fire and explosion

www.hse.gov.uk/offshore/assessment.htm

An effective fire and explosion management system requires early leak detection to initiate control, protection and shut down measures. It also needs effective deluge and passive fire protection to manage the consequences of fire, and a temporary refuge (TR) to keep the workforce safe in the event of fire and/or explosion.

The system should anticipate the degradation and obsolescence issues of monitoring and shut down equipment, and trend degradation data with a view to forecasting when they will reach their criteria of non-conformance, and put early measures into place to manage risks to ALARP.

Strengths

Dutyholders were undertaking TR impairment studies to review the adequacy of the performance standards for future compliance, and were following the principles of Offshore Information Sheet 1/2006 (www.hse.gov.uk/Offshore/trhvac.pdf) on TR leakage rates, and HVAC fire dampers were being tested regularly.

The inspections found dutyholders had good planned maintenance routines with data being trended, not just relying on the recording of tests in a pass/fail format.

There were plans in place for the inspection and maintenance of metallic firewater deluge systems, with some dutyholders replacing some or all systems with fire-resistant non-metallic pipework for greater longevity.

Equipment failure and notification procedures were in place, and root cause analysis for inspection deviations was used to understand ALE failure mechanisms and to take decisions for the longer term.

Areas for additional focus

TRs are key to offshore worker survivability in the event of fire and explosion. The KP4 inspections found that more focus is needed on the future degradation and management of TR structures. There should be clear identification of the risks and consequences, and a preventative maintenance management programme in place, including:

- corrosion inspection, and management strategy, of the structure behind passive fire protection coating;
- KPIs for performance testing the TR and its monitoring systems (smoke, gas etc);
- data trending of TR performance, and monitoring systems to forecast future criteria of non-conformance;
- reviews of the reliability and obsolescence status of monitoring devices.

While plans were in place for integrity management of firewater deluge systems, there were widespread internal corrosion problems, and nozzle blockages of galvanised carbon steel systems.

To guarantee availability of firewater at times of need, there must be reduced reliance on defined life repairs. To overcome compromised integrity there should be greater forward planning to ensure pipework is managed to minimise corrosion, perhaps by chemical treatments.

Performance data should be trended to avoid 'fix on fault' maintenance of gas detection and emergency shutdown equipment, to ensure long-term risks are predicted and proactively managed.

Mechanical integrity

www.hse.gov.uk/offshore/mechengineering.htm

Effective ALE management of mechanical equipment requires a comprehensive equipment list with PMRs in place, which consider long-term degradation risks and obsolescence.

Strengths

A number of dutyholders considered that their existing AIM systems implicitly addressed ALE management, and for floating installations compliance with 'rules of class' provided additional benefits to ALE and AIM management not normally found on fixed installations.

The KP4 inspections found broad recognition in the industry of the importance of understanding and controlling ALE issues, with specialist subcontractors and original equipment manufacturers undertaking ALE studies for dutyholders.

KP4 found evidence of increased inspection and maintenance routines on ageing installations, as well as for those installations with proposed hardware changes or increased throughputs. There was also considerable investment in replacing work equipment, with dutyholders setting aside significant budgets for the repair and maintenance of SCEs. This included the replacement of cranes, rotating equipment (including power generation equipment), gas compressors, firewater pumps and export pumps.

There was evidence of the creation of in-house core integrity teams, life of field teams, and system custodians for specific SCEs.

Life of field asset integrity projects and teams were found to be reviewing maintenance and ALE management systems, feeding the information to operations and maintenance teams to improve the state of plant and equipment condition.

One dutyholder was found to be operating a system of maintaining equipment without limit of life, requiring it to be in good condition until decommissioning.

Areas for additional focus

There are benefits to be gained by strengthening machinery PMRs to incorporate ALE risks and consequences.

All SCEs and SREs should be included in ALE reviews and audits.

While considered low likelihood, dutyholders should consider the potential pressure and thermal fatigue risks to pressure vessels (high-consequence event).

There are integrity and safety benefits to be gained by addressing the potential fatigue risks of rotating equipment operating beyond the originally anticipated service life, to ensure that the likelihood and consequences of failure are ALARP.

To anticipate the potential risks of ageing rotating machinery, dutyholders are encouraged to perform risk-based assessments to supplement the customary approach to developing PMRs, which is usually based upon original equipment manufacturer recommendations combined with historical consideration of previous failures and maintenance findings. The risk-based assessments could be used to determine near, mid-, and long-term risks, and used to manage the effects of changes in fluid properties and quantities, pressures, souring, as the reservoir declines, and the consequences. An example of this could be a main oil line pump initially designed to handle a large throughput, but actually used on high recycle due to smaller oil production.

Electrical, control and instrumentation

www.hse.gov.uk/offshore/controlsystems.htm

A good EC&I ALE programme forecasts equipment obsolescence, and trends performance data to predict when the criteria of non-conformance is likely to occur, so that pre-emptive action can be implemented. The EC&I ALE concerns fell broadly into four groups: obsolescence; data trending; availability of competent persons; and corrosion degradation of EC&I related equipment.

Strengths

The KP4 programme seems to have acted as a positive catalyst for improved ALE awareness, as a result most dutyholders had initiated ALE EC&I reviews and projects.

There was widespread recognition and concern in the industry over the loss of expertise from the EC&I skills pool, as a result of which dutyholders had positive action plans in place for the retention of key personnel with ALE skills.

Dutyholders were performing ALE reviews of EC&I equipment and systems to identify obsolescence issues, including assessing the effect on production availability.

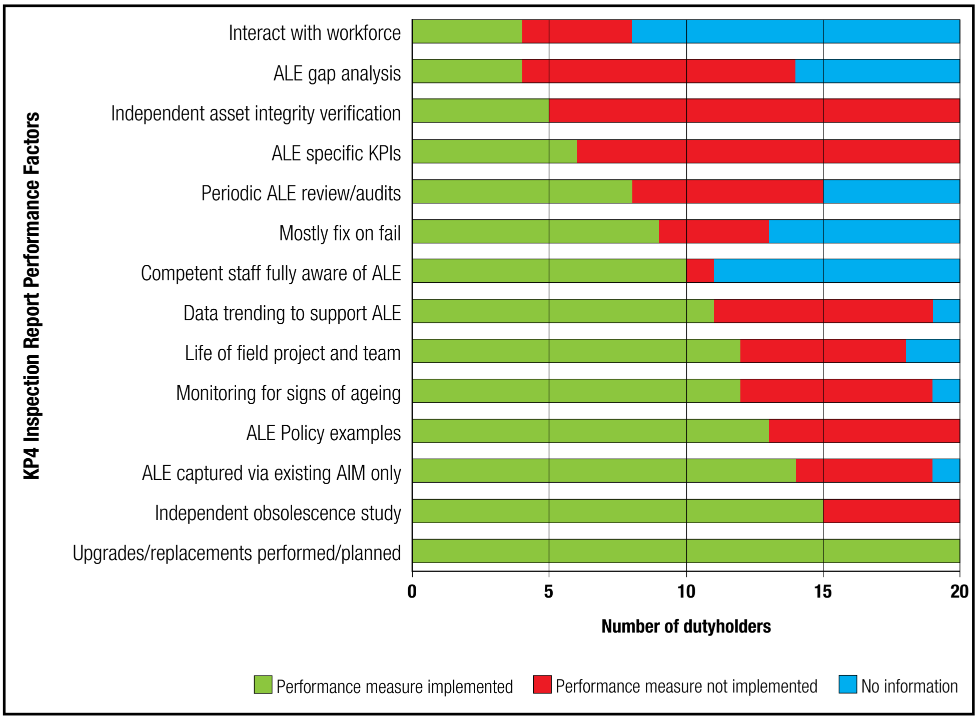
There was independent verification of EC&I SCE integrity, with engineers performing annual assessments to demonstrate continued fitness for service.

All dutyholders were found to have implemented EC&I equipment replacement programmes.

Dutyholders were monitoring signs of ageing including:

- transient earth voltage measurement and acoustic techniques to detect partial discharges in electrical switchgear;
- thermography to detect hotspots in low-voltage switchgear;
- vibration monitoring of rotating equipment.

Figure 1 Good practice performance measures distilled from the EC&I inspections



Areas for additional focus

Greater attention should be given to equipment obsolescence. KP4 found that while there were problems sourcing spares for older equipment, the rapid changes in digital equipment were creating some stresses. Closer working ties with suppliers should help, as described in Case Study 4.

There should be comprehensive lists identifying equipment and components which are, or may shortly become, obsolete, with vendors interacting better with dutyholders to provide information on when product support will cease, providing additional help with availability of spare parts, and guidance on cost-effective alternatives (Case Study 4).

There was widespread use of the 'fix-on-fail' approach, where dutyholders upgraded equipment and systems based on past failure data, rather than trending performance data to predict potential future problems, potentially resulting in an unforeseen SCE failure.

To help resolve the fix-on-fail approach industry should develop leading (and lagging) KPIs specifically for EC&I ALE management.

There needs to be improved detailed recording of the presence and understanding of the status of degraded EC&I equipment.

There needs to be improved preventative maintenance management of electrical containers, particularly Ex boxes, many of which in open modules were found to be suffering external corrosion.

Marine integrity

www.hse.gov.uk/offshore/maritimeintegrity.htm

A marine integrity ALE strategy would be expected to consider the long-term hull integrity risks based upon analysis of theoretical (fatigue) studies supported by physical measurements, with inspection data being trended to forecast future threats so they can be managed in a timely manner.

The marine KP4 inspections addressed those issues relating to the ability of floating installations to maintain hull integrity, stability and positioning.

Strengths

There were good policies in place for marine integrity, with ALE KPIs and dashboards under development, and clear risk matrices showing allocation of key responsibilities up to senior level.

The five-year inspection programmes and dry docking required by the Classification Societies for hulls and marine systems were well defined and in keeping with the aims of managing ALE. There were annual marine integrity summary reports, and more detailed three-yearly marine integrity reviews additional to class requirements.

There was no evidence that the derogation allowing production FPIs to be inspected in-situ had an adverse impact on integrity management.

MODU owners used long-term planning for equipment replacement, and there were high-level risk matrices with specific responsibilities allocated. Both FPI and MODU dutyholders were generally committed to long-term maintenance of assets, with commitment to ongoing maintenance and repair, rather than a managed decline to cessation of production which can occur for fixed production installations. To aid this, structural modelling and real-time monitoring was in place, including hull acoustic monitoring, together with metocean and vessel motion monitoring to provide real-time fatigue loadings to feed predictive life assessments.

Areas for additional focus

The main ageing mechanism related to maritime integrity of jack-up fleets is corrosion, particularly of preload tanks. Improving the identification and early resolution of corrosion will significantly improve ALE management.

There should be clear quantitative rejection criteria of marine SCEs, and improved inspection programmes of secondary marine systems and drilling rig sea fastenings.

Coincident with the KP4 programme there were incidents where FPI anchor chains failed during severe weather, highlighting the need for improved, and well-maintained, monitoring systems to identify degradation, and to trend data to forecast when criteria of non-conformance will occur in the future so preventative maintenance can be undertaken.

Other than for classification and verification schemes, dutyholders should take the opportunity to clarify responsibilities for approving condition assessments and life-extension studies, and for determining limitations on future use.

Project planning and implementation should be focused, and once started should ideally be finished to avoid potential adverse consequences for future integrity management.

Pipelines

www.hse.gov.uk/offshore/pipelines.htm

A suitable pipelines ALE management system would include long-term prediction of likely degradation mechanisms and their rates. The inspection programmes, including in-line intelligent inspection pigging, should be designed to reflect the predicted analysis combined with historical data.

A significant number of offshore pipelines in the UK continental shelf are nearing or have exceeded their planned service lives, so their integrity is a critical issue.

Strengths

Dutyholders had good AIM procedures in place, and were increasing the frequency of in-line inspections to gain hard evidence of pipeline integrity. Dutyholders were taking ownership of ALE issues, were aware of the risks from ageing processes, and had control systems in place. Dutyholders were producing comprehensive annual AIM pipeline reports to justify continued use of assets, using pipeline-specific KPIs. Associated with this, dutyholders were aware of the need for clear long-term focus on degradation processes, and were developing structured approaches to life extension, with replacement of ageing assets where necessary.

Dutyholders were undertaking specific life extension studies, typically using approaches such as NORSOK Y-002:2010 *Life Extension for Transportation Systems* (www.standard.no/nettbutikk/produktkatalogen/produktpresentasjon/?ProductID=476408), and ISO/TS 12747:2011 *Recommended Practice for Pipeline Life Extension* (www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51657).

Dutyholders were performing internal and external audits, along with independent verification.

There was improving cross-industry collaboration on life extension, for example, of flexible riser inspection and integrity management.

Areas for additional focus

Dutyholders should formally reassess the basis for continued safe operation before a pipeline reaches its planned service life, and for those lines already beyond this point reassessment is recommended.

There is a need for further development of pipeline-specific ALE policies, which may benefit from industry-wide collaboration.

While it is recognised the offshore hydrocarbon industry has developed sophisticated corrosion modelling programmes to forecast degradation rates, they should be validated at suitable intervals with non-destructive testing data and in-line inspections tools. This will enable more accurate estimates of when pipelines are likely to meet their criteria of non-conformance, and so enable timely proactive maintenance.

The inspections found dutyholders did not always match cleaning pig frequencies to the designated KPIs, to the potential detriment of both corrosion management and fluid flow.

Pipeline audits should be undertaken in compliance with corporate requirements, and ALE-specific audits need to be developed to clearly identify future risks to enable them to be managed in a timely fashion.

While it is recognised that some data trending is done, there needs to be greater use of riser emergency shutdown valve (ESDV) trending data, eg closure times, leakage rate, pressure, temperature etc to estimate when they are likely to fail their KPIs and so undertake pre-emptive maintenance, repairs or replacement.

Corrosion

www.hse.gov.uk/offshore/corrosion.htm

A good corrosion ALE management programme considers future reservoir profiles and the effects the changing fluid properties will have on topsides corrosivity. Fundamental examples would include changes in water cut and reservoir souring. This should be supplemented by assessing risks associated with fluids coming onto an existing installation from another field.

Strengths

There were well-developed corrosion threats assessments feeding risk-based inspection programmes and corrosion management strategies, usually following the Energy Institute guidelines (www.energyinst.org), which were forward-looking and subject to regular review. Corrosivity risks associated with new hydrocarbon streams initiated assessment revisions. However, the contribution of corrosion to hydrocarbon leaks indicates a need to improve understanding and take greater control.

On older assets there was increasing use of corrosion-resistant alloy process piping, and fire-resistant elastomeric materials for deluge pipework, to minimise future degradation risks.

KP4 found increased expenditure on offshore fabric maintenance, including use of walk-to-work vessels; however, there remains much to do.

KP4 found good interaction between the onshore and offshore integrity management teams, with AIM increasingly being brought in-house to give greater control.

Areas for additional focus

To fully assess the corrosion risks there should be complete lists of equipment and lines, with up-to-date engineering drawings and isometrics.

To comply with the requirement for risk assessments, equipment such as OEM packages, air receivers, hydraulic accumulators etc must be consistently included in corrosion threat assessments and risk-based inspection programmes.

To supplement the existing forward-looking corrosion threat assessments, longer-term corrosion mechanism predictions and management methods are recommended, probably requiring greater integration of predictive information between reservoir and topsides engineers.

To monitor degradation and prevent future failures there needs to be further development of non-destructive testing equipment to improve accuracy in specific areas such as corrosion under pipe supports, under insulation, and of nuts and bolts.

From the RIDDOR data it is evident the contribution of corrosion to hydrocarbon leaks is increasing, suggesting immediate thought, and action, should be given to implementing the documented corrosion management strategies into a positive physical outcome.

Human factors

www.hse.gov.uk/offshore/humanfactors.htm

Reducing error and influencing behaviour HSG48 states: *'Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety'* (www.hse.gov.uk/pubns/books/hsg48.htm).

To manage health and safety effectively it is important to consider how the work environment influences human behaviour. For ALE, this means a need to better understand how current organisations could affect future health and safety management, and in particular, the indicators of what may potentially be a major accident, so they are addressed in a timely manner and have effective responses to prevent escalation.

Strengths

KP4 found good communication between onshore and offshore management, including daily conference calls to discuss current maintenance status with transparent reporting of asset conditions to senior management. This information can be used to feed ALE management programmes.

Dutyholders used human factors in incident investigations to dig deep into the causal factors of the way people behave and the decisions they make.

Areas for additional focus

KP4 found that while there is consideration of how the 'system' can harm the person, there is a need to consider in more detail how the person can harm the system.

Offshore staffing levels should be commensurate with the current high workloads, with some additional flexibility for peak periods.

The industry may find it helpful to apply human factors engineering standards, philosophy and resources to hydrocarbon production operations in a similar manner as exist for new projects.

Discussion

AIM and ALE are overlapping facets of the same requirement to ensure offshore safety, with the former principally concerned with contemporaneous integrity management, and the latter requiring a forward-looking approach anticipating future changes, challenges and threats, and forecasting the consequences on an installation's risk profile.

At the start of KP4 dutyholders concentrated on AIM, with insufficient focus on ALE. This changed significantly with AIM and ALE merging towards the long-term objective of improving offshore asset integrity management along with health and safety. While the KP4 programme has helped to catalyse this approach, the offshore industry understands the importance of ALE management.

KP4 has encouraged the sharing of good practices to deliver improvements in ALE, which led to OGUK setting up an ALE Steering Group, which in 2012 published *Guidance of the Management of Ageing and Life Extension for UKCS Oil & Gas Installations* (www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=436).

From the KP4 programme a series of strategic ALE issues arising from the topic specialists findings have emerged, these issues apply across the industry and will require further work to address and maintain the industry-leading practices developing on the UKCS.

Leadership

Senior management set the priorities for investment and asset integrity, while considering health, safety and financial reward. To do this effectively they must have clear information to enable decision prioritisation, which means receiving accurate information containing both good and bad news.

There is good evidence that industry leaders have recognised the importance of ALE but there is much to do to ensure arrangements are implemented in practice, and there is no room for complacency.

KP4 found dutyholder senior management closely engaged with the AIM and ALE process, were involved in technical issues; had oversight of reviews and audits; and held monthly integrity meetings. There was investment in the creation of ALE managers and life of field managers.

KP4 found the offshore industry investing considerable time and funds improving ALE management, a finding echoed by OGUK's 2013 Economic Report (www.oilandgasuk.co.uk/2013-economic-report.cfm).

AIM focus has been on the pressure containment envelope, with fabric maintenance often having had little recognition, resulting in a legacy of degradation. KP4 found leadership investing significant effort to improve the situation.

For ALE management to be effective industry leadership should continue to:

- give AIM high priority to cessation of production;
- invest in the skills required for a safe industry for the long term;
- challenge staff to ensure safety is the number one priority.

Industry readiness for ALE

Anticipating and forecasting future integrity threats is good ALE management, and HSE found dutyholders reacted rapidly and positively to the KP4 ALE initiative, developing fresh ALE policies and procedures. However, there was a need to strengthen understanding of the differences between ALE and AIM, and the requirement to integrate them into long-term integrity programmes.

For MODUs and FPIs, while the dutyholders did not have explicit ALE policies and procedures, it was usually found to be implicit in their corporate AIM approaches, helped by other drivers such as Classification Society requirements and business imperatives.

For long-term safety management industry should:

- continue to anticipate future risks;
- integrate ALE into AIM management;
- ensure that new entrants have the required competencies.

Asset integrity management

Good AIM is essential for offshore safety, and there was widespread evidence of dutyholders prioritising AIM to assure health and safety, with senior managers receiving regular integrity updates. However, hydrocarbon leaks remain high (www.hse.gov.uk/offshore/statistics/hsr1213.pdf), indicating more preventative work needs to be done. This being the case, even more effort is required now to anticipate and prevent future unsafe events.

There should be greater use of predicted reservoir data to guide future topsides equipment AIM performance by advance consideration of changes in produced fluids.

Inspection of rotating equipment is generally time-based using original equipment manufacturers' recommendations and historic failure patterns. This may have been largely successful, but it is not in keeping with a risk-based assessment approach, and does not anticipate the changes of fluid properties as reservoirs are depleted, and the consequences of those changes on equipment performance and reliability. The industry is missing an opportunity to improve upon both safety and reliability management.

The KP4 inspections found examples of ultrasonic data erroneously recorded – accurate data is critical for safety calculations, and for data trending to predict when SCEs may fail their criteria of non-conformance.

The inspections found some incomplete SCE and SRE lists, and out-of-date engineering drawings, making effective long-term AIM planning difficult. This fell into two groups:

- where the dutyholder had operated the installation since commissioning but had failed to update SCE registers, history, and drawings. In some cases original design data was either difficult to find or unobtainable;
- subsequent to changes of installation ownership where data was not transferred effectively.

It was found that dutyholders were significantly increasing effort and funds to resolve historic fabric maintenance issues, including bringing walk-to-work vessels alongside installations.

The regulatory and economic drivers for floating assets are subtly different from fixed installations, particularly the business and Classification Society issues, which combine to generate an environment in which ALE management is intrinsic to their AIM processes, and seems to work reasonably well.

Sir Ian Wood's March 2014 report for the Department of Environment and Climate Change (DECC) (www.woodreview.co.uk/) on maximising production from the North Sea identified '*the need for significantly improved asset stewardship*', a concern echoed in this KP4 report, and previously identified in the KP3 report.

For long-term safety management industry should:

- maintain SCEs to cessation of production, with primary structures fit for purpose to the time of removal;
- ensure SCE information is complete;
- consider risk-based assessment of rotating machinery;
- trend data to forecast long-term asset integrity management;
- continue to develop non-destructive testing accuracy.

Obsolescence management

Managing obsolescence effectively ensures greater reliability and availability of SCEs.

KP4 found equipment obsolescence management to be an area of considerable concern, with the need for dutyholders to significantly improve.

Industry ALE guidance is needed to help decision making for when to repair, replace, or purchase extra spares in anticipation of when vendors will cease support. There should also be improved interaction between suppliers and end users to anticipate obsolescence and generate solutions in a timely manner.

The EC&I area was most affected by obsolescence issues (Case Study 4), with significant overlaps into other technical areas, for example such as temporary refuge integrity management, where there is a need to improve the functionality and reliability of obsolete gas detection systems to ensure performance standards will be met in the future.

To develop obsolescence management, dutyholders should improve data trend analysis of equipment performance so that future repair and replacement requirements can be identified and resolved early.

Obsolescence is not restricted to EC&I, KP4 found the concerns extend to mechanical equipment.

For long-term safety management industry should:

- identify and manage obsolescence in a timely manner;
- work together to improve prediction and develop solutions;
- use data trending to improve equipment performance prediction.

ALE audit and review

Audits are a useful tool to identify gaps and encourage solutions.

The use of audits was widespread. However, they need to take account of ALE issues, and all SCEs and SREs should be included. Audits should be undertaken to schedule, be sufficiently deep and searching, and the findings acted on in a timely manner.

KP4 saw independent ALE installation audits commencing, with most companies allocating a manager to oversee ALE criteria to encourage visibility and action. A good example of an AIM life extension audit is in Case Study 2.

The KP4 inspections have highlighted the importance of operational risk management audits and reviews, of which the number of operational risk assessments are a lagging indicator of ageing issues. OGUK guidance (www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/HS071.pdf) provides useful direction for managing degraded barriers.

Dutyholders have good procedures in place to manage the consequences of significant changes in the operational environment. However, more consideration should be given to the management of 'creeping changes', which can lead to the 'normalisation of deviance'. This finding may lead to an opportunity for audits to be used to capture creeping changes, leading to their early assessment and resolution. Perhaps one example of the effects of creeping change is when HSE inspectors find unsafe conditions offshore (physical changes), or the need to improve procedures (systemic changes), subsequent to which dutyholders frequently state 'a new pair of eyes' is always helpful.

For long-term safety management industry should:

- undertake ALE audits;
- use audits to identify and manage creeping change.

Key performance indicators

KPIs are used to measure the success of an organisation to achieve its targets, and identify deficiencies.

The use of KPIs is deeply embedded in the offshore industry. However, the KP4 inspections identified a need to develop ALE-specific KPIs, particularly leading KPIs.

KP4 found good use of KPI 'dashboards' to present AIM information to senior management to aid decision-making. However, there needs to be greater use of leading KPIs for SCEs and SREs.

For long-term safety management industry should:

- develop leading ALE KPIs;
- develop SCE ALE dashboards.

Data management and trending

Accurate data management and its trending are important to forecast future threats to enable mitigating measures to be put in place in a timely manner.

The KP4 programme found a need for better data collection and trending to improve predictions of equipment residual life to support ALE decision-making, and to facilitate proactive equipment maintenance, avoiding the risk of 'fix on failure'.

Most computerised maintenance management systems can perform data analysis and trending, although it was found dutyholders frequently use separate specialist analytical software tools. There was widespread use of Excel spreadsheets, often stored on local computer drives. To improve ALE/AIM management dutyholders should consider locating key spreadsheets on intranet systems.

A particular ALE challenge found during KP4 related to equipment identification. Computer systems usually identify equipment systems based on a functional location rather than the specific equipment items that make up that system. So, for example, if the equipment system comprises a motor+gearbox+pump, all are covered by the same tag – if the pump is replaced, the new one is labelled with the same tag ID as the previous, losing traceability and the potential for confusing performance histories, making performance trending difficult. A unique tagging system (a kit level tag) would enable dutyholders to track equipment performance more accurately, and in so doing assist ALE management.

Considerable quantities of information are stored on computer systems in text format making trending difficult.

Increasing the collection and trending of SCE performance data would enable improved forecasting of when they are likely to meet their criteria of non-conformance, and so allow early plans to be put into place to undertake maintenance or replacements.

For long-term safety management industry should:

- collect and trend data to forecast future risks of failing to comply with KPIs;
- consider more detailed equipment identification systems.

ALE guidance

KP4 generated significant industry interest and activity developing technical guidance to promote and share ALE practices, particularly OGUK and the Energy Institute (www.energyinst.org). HSE's KP4 website contains links to a number of useful ageing documents (www.hse.gov.uk/offshore/ageing.htm).

KP4 encouraged sharing good practices to deliver improvements in ALE; OGUK set up an ALE Steering Group, which in 2012 published *Guidance of the Management of Ageing and Life Extension for UKCS Oil & Gas Installations* (www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=436), and will soon be publishing the following documents:

- *Guidance on the Management of Ageing and Life Extension of Offshore Structures;*
- *Guidance on the Management of Ageing of UKCS Floating Production Installations; and*
- *Guidance on the Management of Ageing and Life Extension Aspects of Electrical, Control & Instrumentation Equipment.*

OGUK plans to develop further guidance in 2014 on the management of ageing and life extension of subsea systems and pipelines, and wells.

The Energy Institute anticipates publishing the following guidance:

- *Technical Guidance and Information Relating to Ageing and Life Extension of Installations in the Upstream Energy Sector (with Guidance Gap Analysis);*
- *Technical Guidelines for Life Extension of Offshore Installations;*
- *Guidelines to address Ageing and Life Extension Issues for Offshore Structures and Structural Components;*
- *Research Report on Risk Management of Ageing Facilities in the Oil and Gas Industry.*

There have been other ageing studies around the world on potentially hazardous equipment, which contribute to the overall understanding of ageing and life extension management, including:

- The Australian offshore regulator (www.nopsema.gov.au/):
  - www.nopsema.gov.au/assets/Publications-2/Final-the-Regulator-Issue-1-2013.pdf;
  - www.nopsema.gov.au/assets/Publications-2/The-Regulator-Issue-2-2013-web-version.pdf;
- Norwegian offshore regulator (www.ptil.no);
- US Nuclear Regulatory Commission (USNRC) http://www.nrc.gov/;
- Military Tornado planes (http://ftp.rta.nato.int/public//PubFulltext/RTO/EN/RTO-EN-014///EN-014-06.pdf).

Lord Haddon-Cave's report into the 2006 RAF Nimrod MR2 disaster over Afghanistan identified ageing as a contributory factor (www.gov.uk/government/uploads/system/uploads/attachment_data/file/229037/1025.pdf).

For long-term safety management industry should:

- review the available knowledge on ageing with a view to learning from other parts of the world and other industries;
- continue to encourage the sharing of good practices using suitable industry fora.

Skills, training and competence

Competent onshore and offshore staff are essential for a safe offshore industry, and dutyholders spend considerable sums on training. However, the current and future skills shortages need to be resolved to overcome some of the current and future upgrade projects if ALE is to be managed successfully to cessation of production of UKCS installations.

For long-term safety management industry should:

- encourage the development of ALE skills training and competencies through industry associations and other bodies.

Workforce involvement

Step Change in Safety was helpful in facilitating HSE KP4 presentations at major workforce events, including a large safety representatives event, and at the Piper 25 conference.

The KP4 programme found good workforce involvement, which improved as the inspections progressed. Dutyholders were capturing ALE information and disseminating it to the workforce by use of ‘road shows’, poster campaigns, technical information bulletins, product bulletins and safety alerts. Town hall meetings were held with ALE awareness presentations, and offshore personnel were involved in ALE projects.

Offshore personnel were being made aware of ALE and its management, and becoming involved with ageing studies, often through the five-yearly thorough review process, and also change request systems to identify areas for improvement, replacement, and obsolescence.

For long-term safety management industry should:

- continue to use the skills of the offshore workers to gather information, feedback improvements, contribute to guidance, and to promote the importance of ALE.

Decommissioning

Dutyholders should link ALE management with decommissioning. Ageing equipment can become redundant or obsolete as processing requirements change, and of course, fabric maintenance is an ongoing requirement. Early, targeted, expenditure to achieve long-term benefits while revenues are relatively healthy will reap safety and business rewards when fields become marginal towards the end of field life.

For long-term safety management industry should:

- encourage ALE teams to interact more closely with decommissioning teams to get the best benefit for offshore safety through cessation of production to removal of the asset from the sea.

Recommendations

HSE's KP4 ALE programme has identified areas of industry strengths, and areas for additional focus, which will deliver improvements for the long-term management and assurance of workforce safety on offshore installations on the UKCS through to cessation of production and into decommissioning.

Working with industry has brought a high level of positive engagement, resulting in the development of industry-leading ALE practices. Further work is required by industry to continue to improve these practices, and hence offshore safety.

ALE guidance

The development of ALE technical guidance is important, setting benchmarks to tackle the issues and develop solutions. As the KP4 findings touch on decommissioning, there may be an opportunity to work with key groups in this area.

Obsolescence

KP4 identified potential obsolescence vulnerabilities. Suppliers and users should collaborate to identify the potential impacts of obsolescence on safety, what early options are available, and when technical support is likely to cease.

Information management

Dutyholders were using information management systems, although on occasion not all SCE information was available. Information should be complete, and exploited to manage future risk, with data trending being used to forecast future potentially unsafe conditions.

Preparation for life extension

Early preparation for life extension is advisable to identify and manage potential safety risks, particularly of primary structures. It is unlikely that all life extension studies should start at a fixed time before the original CoP date, this being a function of size and complexity of the installation.

Workforce involvement and training

Dutyholders and the workforce have a collective interest in the secure long-term management of offshore ageing and life extension. Industry, and its training partners, should develop the skills required for ALE integrity management.

HSE will need to continue to work with the offshore hydrocarbons industry, and maintain the positive dialogue which has taken place during the KP4 programme for the long-term safety of workers on the UKCS.

To develop an environment in which offshore health and safety is assured for the future, industry should work together for mutual benefit, including using the strengths available in the offshore workforce. There should be consideration given to OGUK's ALE steering group taking on a broader guiding role, overseeing technical ALE working groups generating guidance for continuous improvements.

From the analysis of the KP4 inspection templates a range of recommendations for the offshore industry and HSE have been developed, for which each party will need time to consider and take forward.

For industry

- Continue promoting industry-leading ALE management practices.
- Develop and encourage a corporate culture which embeds an ALE philosophy into AIM for the long-term future.
- Improve focus on obsolescence management.
- Early preparation for life extension will enable the identification of key issues to be managed to assure continued safe operation.
- Incorporate decommissioning into ALE management.
- Develop leading ALE KPIs to help prevent future loss of integrity.
- Undertake periodic ALE management audits.
- Improve data management, eg maintaining complete SCE and SRE lists, and contemporaneous engineering drawings.
- Improve data trend analysis.
- Further promote workforce involvement through Step Change in Safety.
- Further develop approaches to encourage and train people with the required skills to join, and remain in, the oil and gas industry.

For HSE

- Continue to recognise the importance of ALE management through interventions.
- Continue to work with Step Change in Safety to encourage workforce involvement.
- Monitor and review dutyholder ALE performance.
- Continue to collaborate and support the offshore industry to identify and share good practices.

Appendix: Case studies

Case Study 1: Structural integrity

Problem

The dutyholder was concerned with the fatigue life of a steel jacket platform installed in 1977 with a planned service life of 30 years. However, current projections showed production continuing for a further 25 years. Particular issues were the original fabrication quality, and failure of some braces. Statistical studies indicated an increasing probability of further brace failures over the projected life period, making detection and repair critical to preserve integrity.

Solutions

The dutyholder worked with contractors to develop inspection and weld repair methods to provide greater integrity confidence, and to reduce risks during inspection and repair. Structural monitoring was introduced to provide continuous structural integrity information, providing improved knowledge of the structure's behaviour and performance.

The life extension strategy had two principal themes:

- jacket integrity, inspection and monitoring;
- jacket repair readiness.

The integrity strategy combined analysis of the reliability of the structure with inspection and monitoring of hardware. The repair readiness strategy included a rapid response system for the jacket, involving building and testing a unique underwater welding repair system.

Analyses indicated ca 40% of the underwater jacket brace members had a reserve strength ratio less than 1.85 (reference ISO 19902), and ca 40% of the underwater brace members had welds with fatigue lives less than the operational life. These risks required a special approach to integrity management including:

- analytical structural studies to better model and justify strength and fatigue integrity for intact and potentially severed brace scenarios;
- annual ultrasonic weld inspections of sample critical welds for crack initiation;
- biannual flooded member detection surveys of all braces to check for through thickness propagation of cracks;
- a wave and structural monitoring system to measure environmental conditions and detect changes in structural stiffness.

A non-linear analysis model of the jacket was developed for the critical areas to demonstrate code compliance (to ISO 19902) of deck loading from a one in 10 000 year wave, and also that the platform was capable of withstanding a high-energy ship collision. Jacket node weldment configurations were assessed, revealing just 7 from 333 were common.

Contractors built and tested a modular hyperbaric habitat, and weld repair procedures were written, to enable repairs to 78% of the node weldment configurations. The remaining welds had restricted access for which microhabitat weld repair technology was developed. Because the primary consideration was diver safety, a diver safety module was also developed for two divers should support services fail.

Diverless inspection technology using a remotely operated vehicle was developed for safer and cost-effective weld inspection, and a weld cleaning attachment is being funded.

A jacket monitoring system was designed to detect brace failure, using above-water strain gauges and below-water stress probes, from which data will be fed into the analysis models to verify accuracy and quantify the response of the structure to degradation over the life extension period.

It is intended to complete high-quality weld repairs within three months of failure detection, which, combined with the jacket non-linear analysis meets the ISO 19902 damage tolerance requirement.

The jacket life extension strategy is subject to regular internal and third-party audit. The integrity management scheme is undergoing major review based on the results of the latest non-linear analysis to deliver a revised inspection plan to increase the number of welds inspected each year, and increase confidence in the structural monitoring system.

Detailed documentation has been prepared to ensure knowledge retention. Annual documentation reviews, habitat testing and replacement of spares will be undertaken to ensure future availability.

A weld repair development group has been set up, including underwater contractors, consultants and welding specialists, to explore improvements for executing repairs.

Consultation and support from contractors was integral to the development and implementation of the jacket life extension strategy and repair readiness. The team delivered a repair system that met the key project drivers of safety, speed and quality of repair, and cost. The independent competent person was involved in progress meetings, and review of key documentation.

ALE benefits

The development and implementation of a life extension strategy delivered a number of significant achievements:

- development and construction of a unique modular hyperbaric habitat system for conducting underwater weld repairs;
- a continuous structural monitoring system providing 'health check' data on jacket integrity;
- diverless remotely operated vehicle for weld inspection;
- improved response time for weld repairs and brace failure;
- improved detection of changes in status of structure;
- improved knowledge of structural behaviour and performance.

Case Study 2: Process safety

Problem

The dutyholder's assets were approaching the end of their planned service lives, requiring reappraisal of structural and process integrity.

Solutions

Systematic health checks were performed using a gap analysis tool as part of a process that began two years before the end of the originally planned service life. Life extension plans were produced for normally unmanned installations, and the tool will be applied to manned installations.

The dutyholder's AIM process anticipates, assesses and responds to potential asset degradation risks to:

- detect deterioration and respond before failure;
- identify trends;
- respond to performance issues and identification of ageing indicators;
- highlight ageing and obsolescence issues;
- focus on ensuring 'that integrity and reliability issues are properly considered at all stages in the asset lifecycle', with particular emphasis on major accident hazard prevention.

The assessments contributed to understanding asset condition risks during life extension, providing confidence that all ALE issues have been identified, supporting ALE budget preparation and asset decision making, and providing input to safety case thorough reviews.

The dutyholder had a mature OGRE gap analysis tool (cited in KP3 as good practice) to assess and demonstrate fitness for purpose of SCEs. An ALE adaptation of OGRE was applied two years before an asset's planned service life to:

- identify the issues to be addressed to secure life extension;
- develop plans to ensure risk profiles remain tolerable and ALARP;
- demonstrate suitability of the asset for life extension;
- consider ageing obsolescence;
- input to the safety case thorough reviews.

Life extension studies of installation jackets were undertaken, and asset integrity was re-baselined. An upgrade programme of asset refurbishment and fabric maintenance was implemented, and asset integrity knowledge status was developed.

The OGRE ALE process analyses systems critical to life extension, and develops work scopes based on:

1 Creation of a spreadsheet using a generic list of SCE life extension issues:

- Y-axis: plant and equipment line items grouped according to SCE type.
- X-axis: cross-reference to multiple variables:
  - availability of design basis, drawings, applicable codes and standards, and safe operating limits;
  - degradation threats: performance history and anticipated performance during

the life extension period, obsolescence, corrosion and fatigue;
- selection of life extension strategy:
  - preserve, repair, replace, run to failure;
  - revise: inspection, testing, maintenance and/or operating procedures.

2 The OGRE asset life extension assessment tool:

- Operations and engineering personnel with knowledge of the SCEs.
- Gaps were identified, analysed and colour coded, to provide a basis for scoping the asset life extension work required to mitigate the risks.
- The completed life extension assessment identifies:
  - threats to SCE functionality, availability, reliability and survivability;
  - risk mitigating actions required to support life extension;
  - risks to safety, environment, business and reputation of not implementing mitigating actions.

3 Development and implementation of a life extension plan:

- OGRE ALE assessment output.
- Basis of design and scope of work, including removal of redundant equipment.
- Work pack development.
- Thorough review of the asset safety case.

The AIM and ALE process are subject to three levels of audit:

- within the asset;
- independent of the asset but within the UK;
- independent of the UK but within the company.

The ALE project team's management system has been ISO 9001 certified and audited by a UKAS accredited body. ALE project progress is subject to management review and features in the senior management asset integrity assurance board meeting.

Asset life extension plans have been successfully completed for a number of normally unmanned installations, with the support of jack-up accommodation and work barges, including repair or replacement of some tertiary structures, pipework, helideck, painting and fabric maintenance scopes, and decommissioning and removal of redundant equipment.

The OGRE ALE assessment plans are being developed for manned offshore installations.

The operating management system life extension process, and its OGRE ALE tool will be reviewed in accordance with the schedule with revisions aligned to industry ALE developments.

ALE benefits

The ALE OGRE tool provides confidence in structural and process SCE integrity, and helps to develop work scopes needed for life extension.

Case Study 3: Integrity management

Problem

An increase in HCRs had been experienced, and with assets approaching their originally planned service lives, the leadership required a strong focus on ALE issues to ensure assets continued to be fit for life extension.

Solutions

The dutyholder's UK Operations Director stated: '[We] fully recognise the requirement to take a life cycle approach to all aspects of the management of our assets, not least their ongoing integrity. There is a clear expectation from myself and the rest of the senior management team that the medium- and long-term integrity of our North Sea assets shall not be compromised by short-term production gains.'

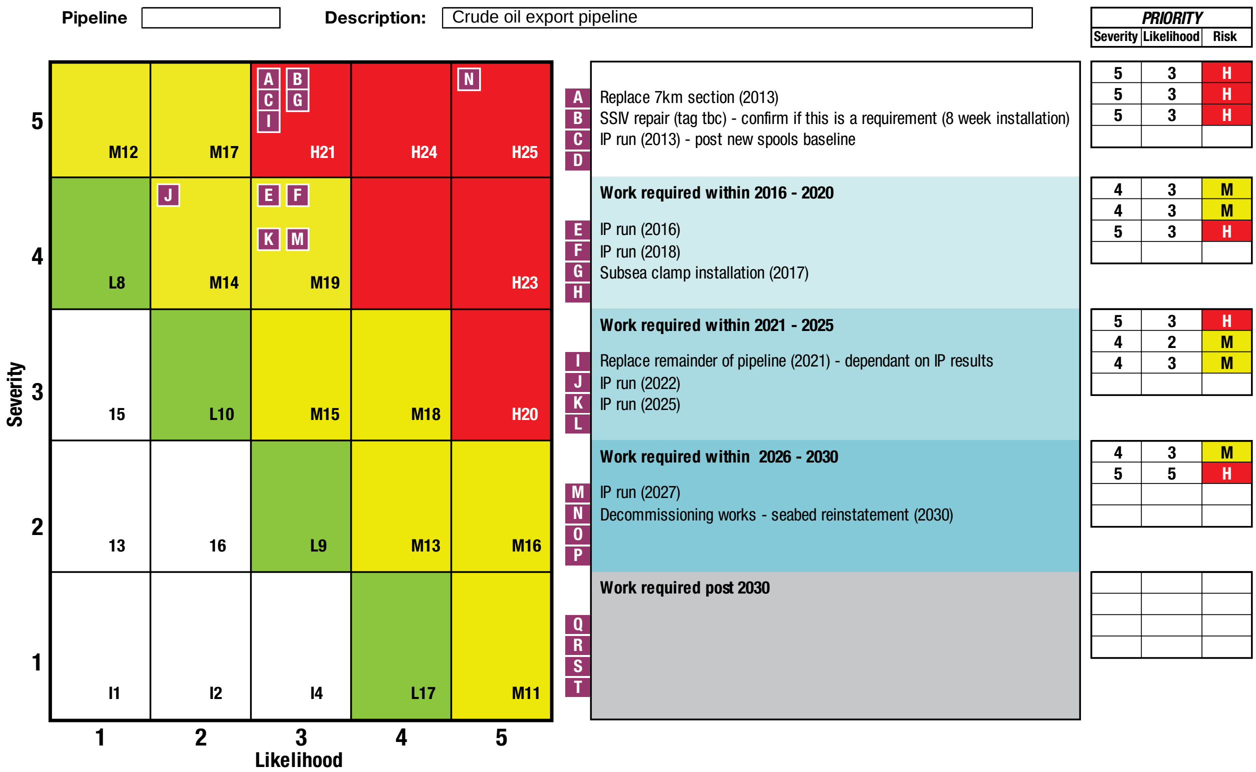
Consultants performed a gap analysis of the pressure system integrity management strategy, from which an ALE strategy was developed, which encompassed people, plant and processes.

The dutyholder's integrity management system follows the Energy Institute's AIM guidelines (www.energypublishing.org/publication/ei-technical-publications/installation-integrity/guidance-for-corrosion-management-in-oil-and-gas-production-and-processing) for which a gap analysis was carried out to identify ALE practice, and areas for improvement:

- Strategic asset life strategies to cessation of production +5 years to be developed and integrated with the field development plan.
- Clarity on the roles and responsibilities of technical authorities and design authorities.
- The competency matrix covering key integrity management roles to be expanded to cover all AIM positions.
- Continuing professional development to be enhanced for succession planning.
- Development of the risk-based assessments process to consider medium- to long-term degradation mechanisms and mitigation options.
- Authoritative reviews and annual summary reports to explicitly consider ALE.
- Process safety reviews to explicitly consider ALE.
- Technical and contractual KPIs to be reviewed to provide more ALE focus.
- Audit programmes to address ALE.

A key recommendation was to adopt strategic integrity plans to consider current and future threats to all SCEs and to align them with the field development plan. An example output for a hydrocarbon pipeline is shown in Figure 2, with traffic lights indicating the potential risk arising if work is not carried out. For example, major subsea work is flagged as 'HIGH' priority for 2021; however, the requirement and timing of the work is dependent on the findings of an intelligent pig run planned for 2018.

Figure 2 Strategic activities and risk-based priority



AIM and ALE integrity threats are summarised on an integrity risk radar, reviewed monthly by senior personnel. Integrity corrective works now consider life extension requirements, and the existing authoritative reviews of pressure systems have been expanded to reflect the extended life condition and concerns.

The dutyholder focuses on HCR risks and prevention through the promotion of a no-leak culture within the workforce, from which a hydrocarbon release reduction programme resulted in an 80% reduction in unplanned releases over a three-year period. The use of technical authorities to provide direct and impartial feedback on asset integrity has ensured that ALE and major accident hazards are being proactively managed.

ALE awareness presentations were given to the workforce, and staff and contractors experienced the potential consequences of hydrocarbon releases with fire and explosion awareness courses at Spadeadam, which resulted in a lower tolerance of unsatisfactory conditions offshore, and hence improved reporting.

The dutyholder is supporting the development of novel inspection techniques to identify difficult to detect defects, and as critical pressure vessels approach the end of their service life they are being modelled to provide confidence that pressure cycling has not caused fatigue issues.

As part of the integrity management process new process streams are assessed for both current and future corrosivity, taking into account changing process conditions and flow regimes. At the design stage materials are selected taking account of life cycle.

ALE benefits

The resulting programme of work led to a reduction in HCRs, increased workforce engagement and an improvement in the general condition of the asset.

Case Study 4: Electrical, control and instrumentation

Problem

The dutyholder was concerned about EC&I obsolescence and the need to take a proactive approach to ensure reliability and availability.

Control and instrumentation systems typically have much shorter lives than the installation. Some SCE EC&I systems use components with limited production runs, usually due to technological development and product line refreshes.

Solutions

Using a specialist contractor, a comprehensive view of the state and status of offshore control and instrumentation systems was established, with emphasis on major systems and software packages, including safety-specific systems and equipment. From this a control and instrumentation planning process based on an 'asset forecast lifecycle' was initiated.

Information gathered included:

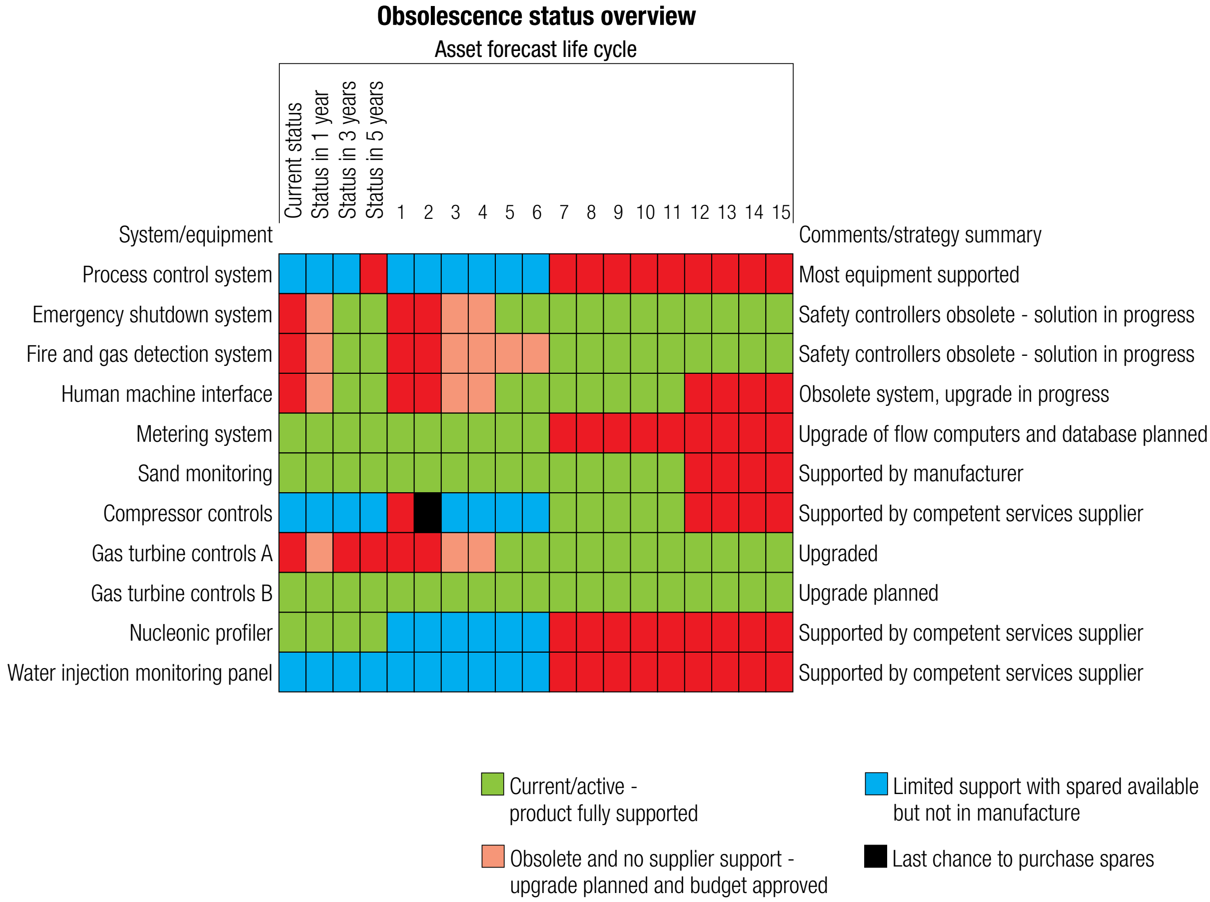
- description of the product/component;
- manufacturer;
- numbers/quantities involved;
- part numbers;
- status of the product/component (eg active, obsolete, impending obsolescence);
- availability of skilled personnel to repair and commission EC&I systems etc.

Common issues were identified, enabling global decisions to be made on replacement and refurbishment strategies at both component and system levels. The information allowed the production of an 'obsolescence status overview' chart showing the current and future status of key systems and equipment components projected up to five years into the future, and also over the projected life cycle of the asset. The obsolescence status overview uses a colour-coded system based on the following status categories:

- current/active – product fully supported;
- mature product – in production but not actively sold;
- limited support – spares available but not in manufacture;
- obsolete but supplier will try to support;
- obsolete and no supplier support;
- obsolete and no supplier support – upgrade planned and budget approved;
- last chance to purchase spares;
- status unknown.

Due to rapidly evolving C&I equipment, it is not always possible to purchase like-for-like replacements but it may be possible to reinstate or repair components. To take advantage of this the dutyholder entered into a partnership with a company specialising in the repair and reinstatement of electronic circuit board cards.

Figure 3 Example of an obsolescence status overview chart



The challenge is to turn the strategy into a continuous process integral to company operations. For example, the management of obsolescence with programmable logic controller-based control systems will depend on continuing to manage the hardware, software and firmware, plus the field devices. It is planned to extend the C&I approach to other types of equipment and systems, eg other types of electrical system, telecommunications systems, cranes, etc.

The dutyholder has set up a contract with a specialist support company to manage and repair spare components to help to address risks associated with loss of skilled personnel and equipment/spares availability.

ALE benefits

The outcomes of this new process were:

- fewer ad-hoc repairs, better forward planning and greater system availability;
- minimising reliance on platform personnel to implement ad-hoc repairs;
- allowing forward planning of the reliability of older installations;
- allowing offshore personnel to focus on other ALE-related issues;
- increasing control system availability, operating efficiency, and improving economic efficiency;
- helping the company in the transition into difference ‘eras’ as installations age;
- helping with the active management of wells.

Case Study 5: Hydrocarbon leak reduction

Problem

The dutyholder experienced a gradual increase in HCRs, and with a creeping change (normalisation of deviance) away from good practices, HCRs were coming to be viewed as inevitable. The dutyholder decided this was unacceptable and instigated a hydrocarbon leak reduction programme.

Solutions

A multi-disciplinary project team with leadership commitment targeted human factors and investigated the HCR root causes to implement corrective actions:

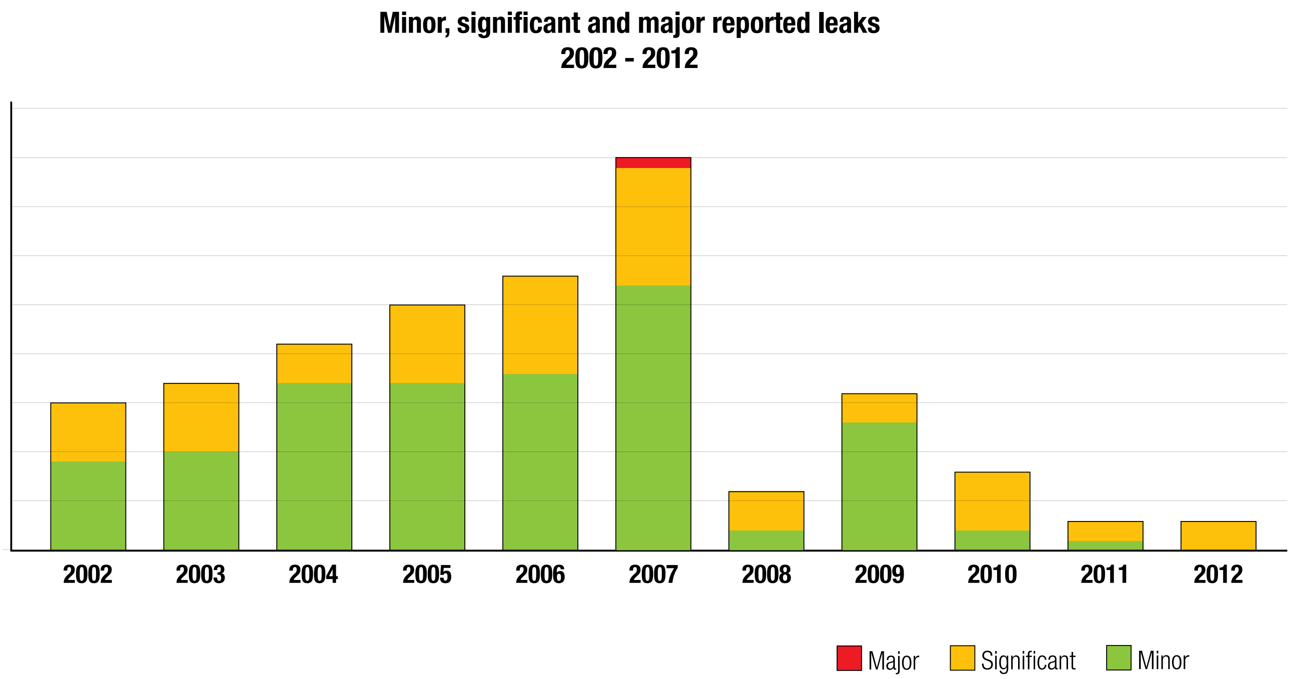
- **Area inspection programmes** – hydrocarbon systems were divided into inspection areas involving operations, safety representatives, area authorities, and a health safety, security, environment and quality specialist.
- **Identification and elimination of potential leak points** – engineering review and removal of dead legs, low points without drains and obsolete gauges.
- **A robust flange management system** – reviewed procedure in line with industry guidance.
- **Prevention of vibration-related failures** – vibration surveys to identify susceptibility, support strategies and design changes.
- **Small-bore tubing fitting competency and inspections** – identify and resolve leaks and inadequate joint make up. Small-bore tubing workshops were held.
- **Improved control for return to service** – cross-departmental cooperation and input during restart activities.
- **Flexible hose management** – regular third-party inspections and auditing, new database set up.
- **Integrity management system** – systems and procedures reviewed and updated, additional inspections conducted, and work orders raised and risk assessed to prioritise remedial work.
- **Process safety training** – for all new and existing onshore and offshore employees.
- **Hydrocarbon fire and blast awareness programme** – all employees visited the Spadeadam site to experience the effects of fire and explosions first hand, which was reinforced with workshops, offshore visits, presentations and communications.
- **Verification** – of adherence to procedures and best practices – captured by process safety audits using the Centre for Chemical Process Safety guidelines.
- **Audits** – carried out for small-bore tubing, flexible hoses, vibration measurements, flange management and permits to work.

The programme quickly became an embedded business activity, with scheduled hydrocarbon area inspections, regularly revised procedures and adherence to best practices audited. Regular Hydrocarbon Leak Prevention Days reaffirm the organisation's long-term commitment to *'keep the product in the pipes'*.

ALE benefits

The result was a step change in HCR performance. The programme led to improved asset integrity and procedures, as well as increased workforce engagement resulting in sustained low tolerance to HCRs, from which there has been a sustained reduction in HCRs. This work programme will ensure long-term integrity and safety benefits.

Figure 4 Minor, significant and major HSE reported leaks 2002–2012



Further information

For more information, and for previous programme reports, see www.hse.gov.uk/offshore/programmereports.htm

This document, and more information on KP4, can be found at: www.hse.gov.uk/offshore/ageing.htm