Abstract

This paper will describe, supported by examples and case studies, a structured and holistic methodology to support the extension of the life of an offshore platform or onshore terminal beyond that indicated by original design philosophy. The approach identifies the key asset reliability, integrity, vulnerability and process safety risks that need to be addressed to allow an asset to be operated beyond its design life. This methodology captures the generally accepted key issues that arise in operating assets at or beyond design life, including; corrosion, obsolescence of equipment, change in design duties, change in oil or gas properties or production profiles etc. It also considers the impact of other less obvious key issues, such as people competence, availability of historic information, maintenance practices, outsourcing, use of 3rd parties and ownership of corporate knowledge.

This methodology and has been applied to extending the life of the offshore oil and gas platforms in the UK, Danish and Norwegian shelf of the North Sea. In Norway it is a requirement to gain consent from the regulatory body prior to extending the life of a platform or field beyond original design. In the UK, the regulatory body sees such an extension in life as a significant and material change to the "Safety Case" and is in process of introducing Ageing & Life Extension Inspection Programme (KP4), to determine the extent to which asset integrity risks associated with ageing & life extension are being managed effectively by duty holders. In other parts of the world the shareholders, legislators and other stakeholders require assurance on the reliability and integrity of the asset.

In addition to identifying the programme of activities that operators need to carry out to extend and continue to maintain the asset life, the approach also provides a profile of CAPEX and OPEX expenditure through to the end of field.

With the volatile oil price and ageing profile of existing offshore platforms, the ability for operators and prospective investors to run assets beyond the original design life, whether for the short, medium or long term and still maintaining high standards of HSE and Integrity Management, is of paramount importance and forms a key part of any strategy to manage current and future business risk.
Introduction

The offshore industry faced and overcome considerable challenges in opening up the North Sea. The "easy oil and gas" has by now been largely recovered. Oil and gas are now being recovered from more marginal fields and from more challenging fields in deeper water in areas such as West of Shetland and extending further north in the Norwegian sector into the Norwegian and Barents Seas. Even so many of the companies operating on the UK continental shelf are talking of production for a further 20 to 25 years. The Norwegian Petroleum Directorate is anticipating continuing production from the Norwegian continental shelf well into the 2040s (Source FACTS 2008).

Mature fields are generally characterized by falling production rates and increasing unit production costs set against a background of infrastructure that is already operating way beyond its intended design life and, typically, may be required to operate for anything up to another 30 years.

The Norwegian Petroleum Safety Authority has identified Ageing and Life Extension as a key issue since 2002 and the topic is a key element of the ‘Consent Applications for Lifetime Extension of Facilities’ operating in the Norwegian sector.

Between 2000 and 2007, the UK Health and Safety Executive ran a number of initiatives to improve safety in North Sea Sector Operations. Key Programme 1 investigated all reported offshore hydrocarbon releases and analyzed the size, type and causes of the releases to provide information useful to industry and the Health & Safety Executive about ways of reducing the number of releases. Key Programme 2 was initiated in 2003 in response to unacceptable accident statistics from deck and drilling operations. Key Programme 3 ran from 2004 to 2007 and focused on current standards of Asset Integrity defined as the ability of an asset to perform its required function effectively and efficiently while protecting health, safety and the environment. In July 2010, the UK Health and Safety Executive launched Ageing & Life Extension Inspection Programme (KP4) to determine the extent to which asset integrity risks associated with ageing & life extension are being managed effectively by duty holders.

The need for continued production well into the future combined with increasing levels of regulatory compliance featuring ageing asset issues is presenting significant challenges to the Operators, Duty Holders and Stakeholders in all sectors of the North Sea and the topic of Asset Life Planning, Strategies and Extension is assuming ever increasing importance and driving the need for resource efficient solutions that satisfy the demands of all stakeholders. The ‘best practice’ inherent in these solutions should be of interest to all operators, irrespective of region.

ABB has been active in the area of Asset Life studies for North Sea offshore installations for over 5 years and has experience with the same issues for high hazard onshore oil, gas, petrochemical and chemical operations for approaching 20 years. The output from these studies presents learning opportunities for operators of oil and gas facilities in all regions, particularly where the assets are already operating beyond their nominal design life.

What are the issues that impact on Asset Life Extension?

The asset life and extension issues for areas such as platform jackets, sub-sea structures and well assets are critical. Addressing these issues may not always be easy, but the investigations and solutions are generally equipment related. However, this is not always the case for topside equipment where the impact of other issues can be equally important as traditional equipment deterioration based approaches. This is best illustrated by looking at the list of typical issues compiled from a number of asset life extension studies delivered over the last few years for North Sea installations, ranging in age from over 30 to less than 10 years.

- Removal of redundant equipment – simplification, loadings or new berths
- Increased congestion of equipment from operational strategy changes (e.g. production platform to hub)
- Replacement of obsolete equipment
- Operation outside a defined equipment operating envelope
- Turn down capacity of key equipment as process requirements change
- Reducing equipment reliability, particularly machines and rotating equipment
- Newly emerging corrosion/deterioration mechanisms, i.e. changes in process fluids, e.g. sand, H2S
- Integrity of minor structures (handrails, walkways, ladders)
- Neglect of utility systems (air, nitrogen, HVAC, cooling water etc.)
- High cost, usually due to age related unreliability of key systems, such as fire mains and pumps
- Electrical power limitations affecting current and future operations
- Compliance with current and future environmental legislation
- Upgrading Safety and Escape equipment and Active/Passive Fire Protection to meet latest standards
• Competencies against ageing workforce; need to substitute technology for skills and loss of corporate knowledge
• Changed or reduced manning regimes and leaner organisations with increased reliance on sub-contractors
• Lack of clarity for ownership of knowledge between operator and sub-contractors
• Loss of ‘Corporate Knowledge’ and ‘unfriendly’ documentation systems

This list illustrates how managing the impact of ageing assets is not simply equipment related, but also is highly reliant on effective management systems supported by commitment at all levels in the organisation. In the introduction, the UK Health and Safety Executive Key Programme initiatives (KP 1 to 4) were briefly described. KP1, 2 and 3 were broadly equipment related, but KP4, the Ageing & Life Extension Inspection Programme, covers a wide range of non-equipment related topics.

The Health and Safety Executive give the specific objectives of KP4\(^{(1)}\) as:

• to raise awareness within the offshore industry of the need for specific consideration of ageing issues as a distinct activity within the asset integrity management process
• to inspect individual duty holder approaches to the management of ageing and life extension to ascertain the extent of compliance with the regulatory requirements
• to identify shortcomings and enforce an appropriate programme of remedial action
• to work with the offshore industry to develop a common approach to the management of ageing installations and life extension (through research, networking and the development of guidance, codes and standards) to ensure the continued safe operation of all ageing offshore installations on the UKCS

This clearly demonstrates the importance in the eyes of the UK Regulator of the commitment to and demonstration of capability in the management of ageing assets. This is further reinforced in Figure 1, which shows a typical process for managing asset life given in the UK Health and Safety Executive HSG65 report on Asset Life Management\(^{(2)}\). Key areas of emphasis include clear, open strategies and a committed, planned programme of any necessary remedial or mitigating actions.

A robust approach to the management of asset ageing assets is becoming a clear and consistent requirement from regulators or stakeholders. Essentially, managing asset life is not simply equipment focussed, but must take into account the full range of activities, as illustrated in Figure 2.

**Basics of an Asset Life Extension Methodology**

An Asset Life Extension Methodology needs to address two areas:

• The effectiveness of the management organisation
• The integrity of the equipment relative to present and future demands
The effectiveness of the management organization

There are many options for assessing Risk Management capability in terms of the people, practices, procedures and systems aspects of the current regime. Methodologies, often called Health Checks, in this area are usually in the form of a gap analysis, using a combination of quantified measures, such as benchmarking or best practice KPIs in combination with the semi-quantification of qualified assessments, using word models to assess areas such as the quality of the inspection process, availability of expert technical support or the levels of people competency. A typical gap analysis could look something like that shown in Figure 3.

The integrity of the equipment relative to present and future demands

Studying the asset life limitations for equipment requires an understanding of the likely deterioration modes and assessment of the capabilities of the equipment to resist the deterioration, largely based on a life cycle based approach and the capability of the organisation to manage the risks.

A key step is to decide which systems or individual items of equipment are to be covered by the study. An obvious route is a conventional criticality assessment, maybe incorporating some assessment of vulnerability or management of risk as shown in Figure 4.

The HSE (A) and Production (B) Consequences together with the Likelihood (C) are assessed using a conventional approach using word models ranking the scenario on a scale from 1 to 5, where 5 represents the worst case, such as an outage measured in weeks through to 1 where the outage is minimal and measured maybe in hours.

A further refinement is to include Safety Critical Systems and Elements\(^{(3)}\). A typical structure for Safety Critical Elements is given in Figure 4.

A typical list of the deterioration modes relevant to static equipment (vessels, piping and storages) offshore is:

- Corrosion, particularly those arising from changing operations and production profile
- Fatigue, particularly where corrosion and material loss results in stress increases
- Creep
- Structural and Fabric Integrity
- Wear Out
- Obsolescence
- Thermal induced deterioration
- Overstress as loadings change over time
- Blockage and Choking resulting in dead legs for corrosion and overstress
- Explosion which is an extreme view but often relates to inadequate management of risk from equipment in potentially explosive atmospheres
- Reduction in reliability or operability
- Compliance with legislation

This is fine for static equipment where the consequences of failure dominate, but less helpful for other equipment groups such as rotating equipment, instruments, electrical equipment or similar systems where reliability (frequency of failure) dominates. However the same approach can be used, but deterioration is defined against the performance of the various management, maintenance and engineering activities that reduce the likelihood of failure, such as maintenance practices, condition monitoring and others similar to the risk factors shown in figure 4. In essence, physical deterioration is substituted with deterioration of the systems.

However, the basic process for assessing the equipment integrity, irrespective of equipment type is fairly standard and is shown in Figures 6 and 7.
Figure 7 illustrates an assessment of asset life of an item of equipment, in this case a deaerator vessel. The process of establishing the technical specification for the vessel, the original design criteria, construction materials and operational/inspection history is not as time consuming as it might appear and can often be achieved electronically or worst case as a clerical exercise. The deterioration stage is similar to that used for a RBI (Risk Based Inspection) study and is a top down approach rather than a remnant life assessment. The difference between a top down approach and a remnant life assessment will be explained later.

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The deterioration review leads to the identification of actions either to manage the risk in terms of best practice actions from the gap analysis, further activities to clarify the risk, such as further inspections, or repair/replacement activities. Each action is allocated a cost and an implementation date, such as that shown in Figure 8, and this allows the production of a budget histogram, such as that shown later in this paper as Figure 10.
Asset Life Extension and Remnant Life

The methodology and approach to asset life extension described in this paper is often confused with and not the same as a remnant life assessment.

Effectively a remnant life assessment is an estimate of the remaining life by calculation or quantification of the effect of the deterioration mechanisms in comparison with the original design. They are governed by specific guidelines and standards, such as API RP 579, for each type of equipment and can be extremely time consuming.

The principal difficulties with remnant life assessments can be summarised below:

- Remnant Life assessments depend on predictable (usually linear) deterioration and consistent operations.
- Hence they are only sensibly accurate over short time periods and usually only add value towards the end of the Asset Life Cycle as shown in Figure 2.
- The accuracy needs to be greater than the shutdown interval.
- They need a lot of fundamental design information to do the calculations for each deterioration mechanism.
- Our experience suggests that it is best to only use them when you have to!

An alternative to the conventional remnant life assessment is the Top-Down approach. Here, starting from the normal design life, taken from design standards or best practice, the impact of deterioration mechanisms is estimated and an assessed life produced. This can appear to be a rather crude estimate, but when the limitations and accuracies of conventional remnant life calculations are taken into account, it is certainly comparable and has the considerable advantages of speed and much lower
resource usage. Top-Down approaches can give the impression that they are superficial and do not investigate the issues in sufficient depth. However, when they are done properly, they go onto the same level of necessary detail as other approaches, but only to the level of detail required to justify the required asset life extension. The fundamental objectives of any rigorous top-down approach are to avoid work that does not add value or simply tells the operator what they already knew! In effect, this approach takes the desired life extension date and assesses the reasons why it should not be suitable for operation to that date. If detailed calculations are required, then not only is the resource usage justified, but the process can be managed to an appropriate level of rigour. It should also be borne in mind that the assessment should be proportional to the Safety, Health, Environment and Business risks presented by the failure of the equipment.

An obvious question relates to what standards to apply when considering the asset life. Over the life of an installation, standards will change. Retrospective application of new standards can result in complex and expensive actions to maintain asset life. A better approach is to understand why the new standards were introduced and review the deterioration or future asset extension requirements in that context.

Case Study – Asset Life Extension for a North Sea Installation

An operator in the northern sector of the North Sea required an external risk based assessment of the expenditure required to provide continued operation of the installation until the end of the licence. At the time of the study, the platform and field had been in operation for about 25 years and a further 30 years. The main decision faced by the operator was to refurbish or replace and the primary objective of the study was to provide the essential inputs into their OPEX and CAPEX budgets to support the decision making process. A secondary objective was to assess the current vulnerability to identify any major issues not currently understood and covered by the budgets. Here vulnerability is defined as a measure of how well risk is being managed.

The scope of the study covered the topside equipment, including:

- Vessels/Storage Tanks/Sea sumps
- Piping, including risers from splash zone
- Valves, include wellhead valves/Christmas trees
- Machines and Rotating Equipment
- Structure including cranes, well supports and life boat davits/supports
- Control/instrumentation
- Electrical and Power Distribution
- HVAC

The scope excluded subsea assets such as pipelines and jackets, well and well operations, the drilling rig and helicopter/marine support. These areas had been covered previously by the operator either internally or via other 3rd party studies.

The study revealed no significant obstacles to the required life extension and showed many areas of good practice:

- Knowledgeable & committed workforce, on-shore & off-shore
- Key asset integrity issues largely covered by existing plans
- Standards of asset care generally good
- Management systems in place for effective asset care
- Evidence of high standards e.g. electrical cabling & cable racks, Pressure vessel inspection and housekeeping

There were some problem areas relating to management systems, such as:

- High turnover of key staff and inconsistent approaches to job holder handovers
- Managing of information and corporate knowledge losses through people reorganisation and documentation system restructuring
- Ownership of knowledge where work with 3rd parties
- Definition of responsibilities with the contractor organisations

Some of the key issues that required specific action are summarised as follows:

- Corrosion Protection
  - Assets showed evidence of a historically reactive approach to “Fabric Maintenance”
Observed levels of corrosion should not prevent life extension
Without a proactive & planned programme of fabric maintenance, it is unlikely that the asset life targets
would be met

- Piping
  - Only 20-50% of piping systems were inspected using a thorough scheme of examination and concerns arose
  relative to inspection of small bore systems and branches. Remediation or replacement was assessed as high
cost.
  - Registration required of all systems required to support risk based asset strategy
  - Utility piping CS corrosion allowance consumed e.g. Fire Water piping system
  - Some areas of hydrocarbon piping subject to Micro Biological Induced Corrosion (MIC) and will require
    replacement in Super Duplex
  - Integrity of lined utility pipework

- Vessels
  - Reduced life of internal protective coatings due to inappropriate application methods, driven by shutdown
duration rather than technical merit.
  - Fatigue life calculations required to determine remaining life of a pressure swing absorber on the instrument
  air system.
  - Future corrosion and deterioration management strategy required to manage increasing levels of H2S and
    Sulphate Reducing Bacteria as feedstocks change.

- Electrical
  - The original Low Voltage Switchgear was obsolete and spare parts were difficult to obtain, requiring an
    action to replace original equipment with new switchboards
  - Most cables and cable support systems were in very good order but attention required to steelwork
    attachments
  - Power limitations and supply reliability related to generation equipment unreliability rather than capacity
    limitations.

- Structural
  - Process required for inspection, repair and replacement of weather and fire doors

- Rotating Equipment
  - Structural vibrations associated with replacement diesel generators was a major contributor to unreliability
  - HVAC Refrigeration – R22 conversion was required by 2010
  - Fire Water Pump long term unreliability is a significant threat and requires an investigation followed by
    equipment replacement
  - Export Compressor turn-down and low suction capability was inadequate against the predicted production
    profile
  - Gas turbine CO and NOX emissions were likely to be beyond future consent levels

The above issues were translated into a range of actions and recommendations, which were in turn allocated costs and timings. Timings were related not only to priorities but also to opportunities to perform the work, such as shutdowns or resource availabilities. The resulting cost histogram is shown in Figure 10. The underlying detail to this histogram also takes into account key areas such as the logistics of equipment replacement (when and how), people logistics (bed spaces and helicopter transfers) and other issues that ensure that the solutions will work and deliver value.

The profile showed a number of points worthy of note:

A large peak of expenditure was required in the first 5 years or so to replace certain piping systems & control or
instrumentation items, but once replaced, these should provide for continued operation with minimal on-going costs.

The profile includes maintenance costs, based on a strategy to ensure that minor issues do not accumulate to create major expenditure but accepting that maintaining old assets, even after major refurbishment, requires a different philosophy to maintaining new assets!
Failure to plan for major equipment replacement can easily result in extended shutdowns as inspections reveal unforeseen problems or general reduction in equipment reliability.

Invariably, a properly conducted asset life extension study will identify at least one ‘life threatening’ issue not covered by existing strategies and plans. Generally more are identified or at least incorporated into universal understanding. Often these issues relate to perceived ‘non-core’ systems, such as HVAC, potable water or basic utilities. Failure of these systems can have as significant impact as other, more obvious issues presented by front line systems or equipment.

A properly specified and conducted Asset Life Extension Study will identify

- Where & why deterioration is taking place
- What is needed to maintain equipment integrity to the end of field date

It will provide life cycle actions and budgetary plans with investment to prevent failure rather than as a reaction to it

As additional benefits, it will:

- Improvement of operating & maintenance practices
- Demonstration of pro-active management of assets
- Education of Plant personnel from exposure to the study
- Reduced risk of HSE incidents.

It allows the development of a strategy to control and manage the risk associated with extending the life of offshore installations based on a systematic process to support the case for life extension of an Offshore Installation that will satisfy stakeholders, shareholders, legislators and employees.

A frequent ‘by-product’ of this type of study is issues identified with people, practices, procedures and systems, some of which have been described earlier in this paper. A simple focus on purely equipment is unlikely to guarantee ongoing, long term operation. The impact of people competency and supporting current and historical information systems should never be underestimated.

Conclusions

Management of ageing assets is not just about equipment. It also requires a focus on management systems. Getting the management systems right before focussing on equipment life will maybe result in less equipment replacement over the long term. Focussing on equipment delivers value for now and the short term. Proactive approaches around how things are done and managed are key for managing assets in the longer term. Effective asset management starts before equipment deterioration takes place, not after.
References

3. Health and Safety Executive (United Kingdom) - Offshore Installations (Safety Case) Regulations 2005