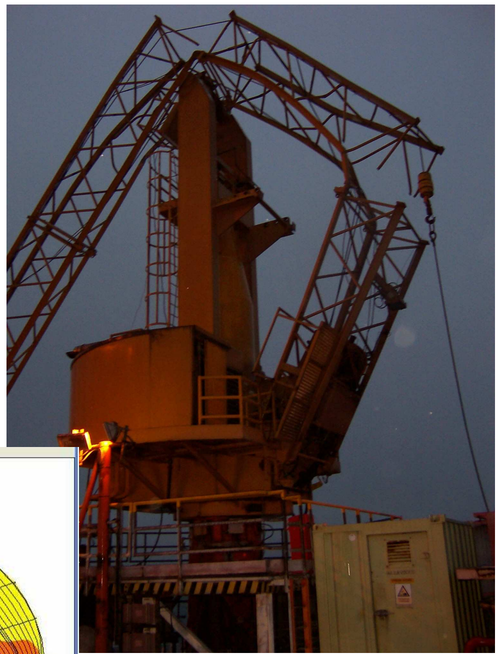
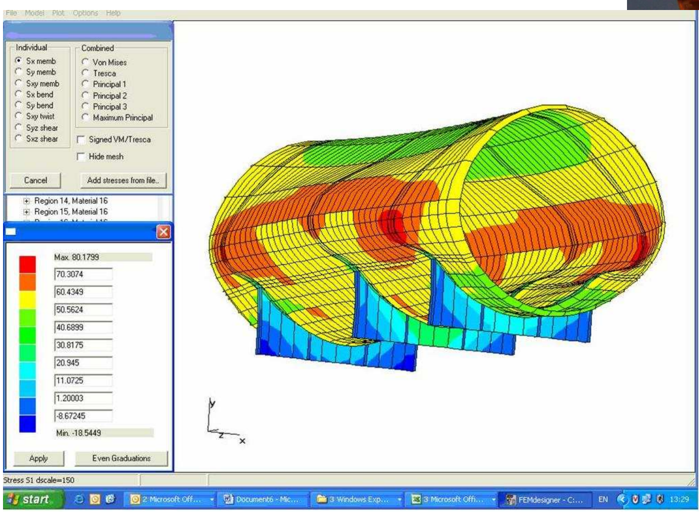
HEALTH AND SAFETY EXECUTIVE

OFFSHORE DIVISION

MECHANICAL SYSTEMS

TOPIC STRATEGY 2008 – 2011





Rev	Date	Details of Revision
1	28 August 2008	First draft for internal comment
2	26 January 09	Internal comments added MB
3	12 February 09	Identification of how our interventions contribute to the 4 OSD priority areas of Leadership, Asset Integrity, Competence, and Safety Culture
4	26 May 09	Update for publication on HSE web pages
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1. INTRODUCTION

OD3.4 has responsibility for topics relating to topsides mechanical engineering systems. For convenience, these systems can be divided into four broad areas:

- pressure systems integrity,
- lifting operations,
- rotating plant, machinery and utilities, and
- mechanical input to other topic work.

Integrity issues are considered throughout the whole life cycle of the plant including design, procurement, installation, operation, inspection, major repairs and modifications to plant, maintenance, and decommissioning. The team’s work covers both major accident hazards and hazards giving rise to ‘occupational’ injuries.

Our intended outcomes include:

a) Decision making based on evidence from intervention activities, research, accident analysis, and dialogue with industry stakeholders,
b) Provision of advice and guidance that is fit for purpose and provides a benchmark for enforcement, and
c) Reduced number of accidents, dangerous occurrences and hydrocarbon releases associated with topsides mechanical systems.

The topic strategy describes our intervention activities in each topic area, together with our work in partnership with industry and regulatory stakeholders. The strategy also gives details of our anticipated future challenges over the next five years.

2. PRESSURE SYSTEMS INTEGRITY

2.1 Background

A significant proportion of the UK offshore infrastructure is approaching or exceeding its original anticipated design life. At the same time demands to reduce costs with mature assets have resulted in rationalisation of plant and equipment maintenance arrangements. Unless effectively managed there is concern that this situation will significantly increase the risk of major accidents.

HSE places strong emphasis on ensuring that duty holders effectively manage the risk of any failure of plant, equipment or systems, which could cause, contribute to, or mitigate the effect of a major accident. Effective maintenance and inspection of the hydrocarbon containment envelope is essential to ensure that risks associated with the major hazards of hydrocarbon release are logically and systematically controlled.

2.2 Intervention Strategy

We focus upon the integrity of vessels and piping systems (including valves, flanges etc) as this is primary safeguard against the major accident hazard of hydrocarbon release and subsequent escalation.

2.2.1 Initial integrity of vessels and piping

With new installations, we assess their safety case and undertake inspections to verify compliance with the Pressure Equipment Regulations and with recognised design codes including ASME B31.3, ASME VIII, BSI PD 5500 and EN 13445 etc.

The Pressure Equipment Regulations includes a requirement for a third party 'Notified Body' to complete an assessment, verification and qualification process for the majority of new pressure equipment. BS EN 1S0 17020 (replacing BS EN 45004) provides a baseline of competencies for inspection bodies and BS EN ISO 17025 provides competence requirements for testing facilities.

2.2.2 In-service integrity of vessels and piping

We undertake inspections to monitor the effectiveness of the duty holder's arrangements for managing in-service integrity. We liaise with our corrosion specialists in OD4.1. Typically, the following topics are addressed:

> We inspect the suitability of duty holder maintenance and inspection regimes to ensure that deterioration arising from known failure mechanisms such as erosion, corrosion and fatigue is detected and remedied in good time. (e.g. dead legs, corrosion under insulation, local erosion, piping supports, safety valves, wall thinning, and inspection of welds). Where appropriate, we refer to relevant benchmarks such as API Standards 510, 570, 572 and 574.
>
> We challenge assumptions made during the implementation of Risk Based Inspection schemes, concentrating on the identification of deterioration mechanism,

probability of defect detection, the suitability of inspection techniques selected, and the interval between inspections. Typical benchmarks employed include API 580 on Risk-Based Inspection and HSE contract research report CRR 363/2001 ‘Best Practice for Risk Based Inspection as Part of Plant Integrity Management’.

We inspect duty holder arrangements to protect piping against vibration induced fatigue by reference to the Energy Institute guidelines.

We also inspect duty holder arrangements to manage the risk of hydrocarbon leaks arising at small bore tubing connections, bolted joints, and flexible hoses against industry guidelines.

We inspect duty holder proposals to extend the life of ageing vessels by challenging assumptions against fitness for purpose justification benchmarks such as API 579 and BS 7910.

We inspect duty holder arrangements for temporary repair of piping systems. We challenge the justification for a temporary repair, its design basis and defined life, its inspection regime, and compliance with HSE Safety Notice 4/2005 and industry guidance.

We monitor the adequacy of thorough examination activities and question duty holder arrangements to assess the competence of organisations that undertake their thorough examinations using recognised benchmarks such as BS EN ISO 17020 and UKAS RG2.

The HSE Plant Ageing Guide: ‘Management of Equipment containing Hazardous Fluids or Pressure’ provides valuable guidance in the majority of areas covered during in-service integrity.

2.3 Work with Stakeholders

2.3.1 Piping materials

There is likely to be more extensive use of non-metallic piping. GRE piping has been used in the safety critical systems, for example: fire water and ballast system etc. ISO 14692 was produced in 2000 based on UKOOA guidance “Specifications and recommended practise for the use of GRP piping offshore”. This standard is in four parts,

part 1 – application and material
part 2- qualifications and manufacture
part 3 - system design
part 4- fabrication, installation and operation.

However, at present there is gap in technology with respect to NDT for composites. Hence a programme of looking into new or existing NDT processes is being undertaken in a Joint Industry Project under HOIS programme and OD 3.4 is working closely with OD 4.1 on this issue.

2.3.2 Flexible risers

In the last 5 years, a number of offshore installations that utilise flexible risers for single phase gas service have experienced high levels of piping noise and vibration. This has resulted in at least two piping failures. The problem has been attributed to flow induced pressure pulsations from the flexible risers.

A joint industry project, involving a number of operating companies and HSE is currently addressing this technical issues associated with high amplitude pressure pulsations generated by gas flow through flexible risers. Combining actual offshore data; part and full scale test results at low medium and high pressures; and both theoretical acoustic and flow simulation, a good understanding of the phenomenon has been achieved. Guidelines for existing and planned developments have been developed, based on precautionary measures, i.e. how to minimise risk of this phenomenon occurring at the design stage, and practical assessment and mitigations measures for existing assets.

2.3.3 Elastomeric seals to prevent rapid gas compression

Seal damage and observed gas leaks to atmosphere caused by Rapid Gas Decompression (also known as explosive decompression) in elastomeric seals have been reported in many types of equipment in the oil and gas industry. These failures have had costly financial, safety and environmental implications for the operators and equipment suppliers.

A research report produced by HSE in 2006 “Elastomeric seals for rapid gas decompression applications in high pressure service” (based on a work carried out in a JIP) provides the guidelines to designers, specifying engineers and operational managers with a systematic approach towards the prevention of decompression damage in elastomeric seals.

In order to draw the attentions of stakeholders towards these guidelines, a paper was presented in the ‘international fluid sealing conference’ in 2007.
While carrying out investigations of leaks through elastomeric seals offshore, stakeholders are reminded on a regular basis about these guidelines.

2.3.4 Safety valves

Safety valves on process plant must have high reliability and must operate properly on demand. Research is ongoing at HSL to understand the underlying reasons and assumptions underpinning traditional fixed interval maintenance to assist HSE to challenge more effectively the assumptions adopted by duty holders in their risk based inspection methodologies to increase maintenance intervals. This will include a review of API 581 that has recently been updated to provide a rigorous quantitative approach to underpin RBI of safety valves. It aligns with the qualitative approach many duty holders have adopted in recognising the importance of test and inspection history in establish future maintenance intervals whilst also ensuring that high consequence valves are identified. API 576 provides guidance on the testing and inspection of safety valves.

2.4 Future challenges

2.4.1 Fitness For Service (FFS) demonstrations

Some offshore installations will be approaching or even exceeding their original design life in the next five years. A significant proportion of existing plant such as large pressure vessels will be very difficult and costly to replace. OSD is likely to face many more challenges to extend the life of such plant using arguments based on complex fitness for service justifications using a variety of methodologies. Assessment of FFS justifications is resource intensive. We will need to maintain our competency in their use and develop improved awareness of the comparative merits of the different emerging FFS methodologies. We are currently sponsoring research at HSL to compare the merits of DNV F101 with API 579. Further research to compare other methodologies is possible.

2.4.2 Repairs to Hydrocarbon Containment systems

Repair of hydrocarbon containment systems is likely to become more prominent, using both conventional welded repairs and temporary composite wraps. We will need to challenge effectively that the integrity of such repairs is adequate. There will be continued demands to treat temporary composite wraps as permanent repairs by extrapolating the guidance in the recent *ISO technical note ISO/PDTS 24817 – "Petroleum, petrochemical and natural gas industries –composite repairs for pipework – Qualification and design, installation, testing and inspection"*. The offshore industry has very limited practical experience of how these repairs deteriorate in the longer term. Non destructive test and examination instrumentation used to measure such deterioration is in its infancy and not fully proven. We need to keep abreast of developments in instrumentation technology and practical working knowledge of how effective the new generation of nde equipment is at detecting defects. This includes current work by HOIS. We may consider a Joint Industry Programme to remove ageing composite repairs from service and destructively test to assess the true condition of the substrate and bonding. The information gleaned could be used to assess the effectiveness of nde equipment and the associated maintenance strategies for composite repairs.

2.4.3 In-service maintenance of safety critical valves

Valve failure accounts for a significant proportion of offshore hydrocarbon releases and can increase the risk of a major hazard event due to its effect on process conditions, e.g. passing valves. Research is required to determine best practice for an effective in-service valve inspection and maintenance strategy. We need to develop our knowledge of the effectiveness and reliability of acoustic technology to detect process fluids passing through valves.

3. LIFTING & MECHANICAL HANDLING OPERATIONS

3.1 Background

Crane operation is an inherent part of offshore oil and gas operations, lifting a multitude of supplies and materials to and from offshore facilities. Lifting and mechanical handling operations can pose a major accident hazard should a suspended load or crane boom fall onto processes piping. Injuries and dangerous occurrences arising from lifting operations account for about 20% of the total of those occurring offshore.

A study by the International Regulators' Forum (IRF) showed that the most significant root causes were:

- Inadequate maintenance,
- Lack of competence, and
- Poor planning and management of lifting operations,

In recent years OSD has focused industry attention on lifting operations through the implementation of key inspection programmes, notably KP2 and TP5. Such programmes have proved effective in raising awareness of the hazards associated with offshore lifting and securing compliance with LOLER.

3.2 Intervention Strategy

3.2.1 Initial integrity of lifting equipment

Lifting equipment must be designed and manufactured to withstand substantial abuse under service conditions. We inspect new cranes and lifting equipment to ensure compliance with European standards supporting the machinery directive and equivalent API standards.

We use our guidance HS (G) 221*Technical guidance on the safe use of lifting equipment offshore* as a benchmark to assess the suitability of lifting equipment used offshore.

3.2.2 In-service integrity of lifting equipment

Pedestal cranes are used for the majority of offshore lifting operations and account for approximately 70% of offshore lifting incidents. Deterioration mechanisms which affect cranes include corrosion, fatigue, wear and mechanical damage. In addition technology may become outdated and spare parts obsolete for older models.

We place increased emphasis on the use of Failure Modes and Effects Criticality Analysis (FMECA) to ensure that duty holders focus their maintenance resource on the critical components and we continue to challenge whether duty holder maintenance strategies are appropriate to detect the expected forms of deterioration. We use HSE Safety Notice 2/2005 'Single line components in the hoisting and braking systems of offshore cranes' as a benchmark for inspection.

FMECA studies are essential in establishing a Reliability Centred Maintenance strategy (RCM) for ensuring the in-service integrity of both new and existing cranes offshore. RCM is the optimum mix of proactive, condition-based, interval-based and reactive maintenance practices, and can be seen as the equivalent to RBI for pressure vessels.

We focus on duty holder arrangements for integrity management with emphasis on how inspection, maintenance and thorough examination are integrated together under the auspices of a competent focal point using benchmarks such as the OMHEC guidance on the Enterprise of Competence. We monitor the adequacy of thorough examination activities and question duty holder arrangements to assess the competence of organisations that undertake their thorough examinations using recognised benchmarks such as BS EN 1S0 17020 and UKAS RG6.

3.2.3 Management of lifting operations

We inspect lifting operations to ensure that they are carried out in a safe manner and are effectively managed. This includes the suitability of the equipment selected, its physical condition and means of storage, the competence of persons engaged in carrying out and planning the lift, and the lifting plan and risk assessments. Our inspections cover both deck operations and lifting activities on the drill floor. We inspect to appropriate benchmarks such as, the LOLER ACoP, Step Change *Lifting and Mechanical Handling guidelines,* OGP 376 *Lifting and hoisting recommended safe practice,* and OSD's *Guide to the Management and Control of Portable Lifting Equipment and Lifting Accessories Offshore (Rigging Loft Guidance.)* We have input to a consistent set of inspection templates for the above issues that can be downloaded from http://www.irfoffshoresafety.com

3.2.4 Competency assurance

We work with stakeholders (see section 3.3) to provide consistent standards for training programmes and competency assurance schemes. The industry is becoming more aware of the benefits of using computer simulation in advanced crane operator training and periodic competency assessments. We are encouraging this trend as initial studies have demonstrated that simulation does reduce incidents.

3.2.5 Lifting of persons

Special care is needed when it becomes necessary to lift persons. We challenge the need for man riding in the derrick and inspect to ensure compliance with the Step Change *Best practice guide to manriding safety.* We have developed guidance on the hazards associated with personnel transfer OIS 1/2007 *Guidance on procedures for the transfer of personnel by carriers*.

3.3 Work with Stakeholders

3.3.1 International co-operation

Offshore lifting concerns are shared throughout the world and OSD will continue to co-operate with other offshore regulators through the International Regulators' Forum (IRF). The IRF is compiling a world wide database of offshore lifting incidents and their root causes. The root causes are classified using a common methodology (Human / Technology / Organisation) to ensure consist reporting of the findings. The aim is to reduce incident rates through the promulgation of learning and best practice.

We also contribute on lifting issues to the North Sea Offshore Authorities Forum (NSOAF), and the Offshore Mechanical Handling Equipment Committee (OMHEC). OMHEC has produced guidance on crane maintenance, the enterprise of competence, and a training standard for banksmen and slingers.

We participate in the organisation of the annual North Sea Offshore Crane and Lifting conference. We also occasionally attend other international conferences such as the API Crane Conference or IADC lifting conference as appropriate.

We also participate in relevant local industrial forums and committees such as the Aberdeen Crane Forum and with the Lifting Equipment Engineers Association (LEEA).

3.3.2 Integrity of lifting equipment

Wire ropes are used in wide variety of lifting equipment and their integrity is essential to ensure safe lifting. In recent years there have been several developments in wire rope technology and in the understanding of wire rope deterioration and failure mechanisms. We worked with IMCA to produce up to date guidance on the integrity management of wire ropes used for diving bells and other sub-sea lifting operations. IMCA publication *Guidance on Wire Rope Integrity Management for vessels in the offshore industry.*

We maintain links with relevant standards organisations (BSI/ CEN / ISO) with regard to developments in product standards for offshore lifting equipment, such as offshore cranes, containers and lifting slings. We recently published a circular outlining OSD's position with regard to the adequacy of BS EN 13414 "*Wire rope slings*"

We conduct limited research at HSL with regard to the design and endurance of lifting equipment such as chain hoists, automatic crane hooks and steel wire ropes and their terminations. The results are fed back to the relevant standards committees.

3.3.3 Management of lifting operations

We work with relevant trade associations to produce guidance on safe lifting operations. Recent publications include the OGP 376 *Lifting and hoisting safety recommended* *practice* published by the International Association of Oil and Gas Producers (OGP) and SEL 019 *Guidelines for lifting operations* published by the International Maritime Contractors Association (IMCA).

3.3.4 Competency assurance of those carrying out and planning lifting operations

The North Sea oil and gas is perceived by some as a sunset industry and difficulties in the recruitment and retention of competent staff will continue to hinder any improvement in lifting accident rates. We are vigilant regarding the training and competency assurance of banksmen, signallers and load handlers. It doesn't take long to train new starters but developing competence takes time. Supervisors require adequate time and skills to help develop competence in the deck crew.

We have input to the Step Change *Lifting and Mechanical Handling guidelines* to support the consistent approach given by the four step wheel of competence comprising; initial training, supervised workplace training, workplace assessment, and ongoing performance development.

We are working with the International Association of Drilling Contractors (IADC) and the Offshore Petroleum Industry Training Organisation (OPITO) to provide consistent training and competency standards for persons engaged in deck lifting and drill floor lifting operations.

3.4 Future challenges

3.4.1 Wire rope non destructive examination (NDE)

Wire ropes form an integral single line component in a vast range of lifting machinery. Inspection of wire ropes is vital to ensure safety. Recent guidance from IMCA on the integrity management of wire ropes has identified a toolbox of measure for monitoring the strength and condition of wire ropes in service. One of the tools identified is ndt using electro-magnetic instrumentation to detect wire breaks and corrosion / abrasion through loss of metal area.

Wire rope ndt technology has been in service for many years in some industry such as mining and cableways, but is uncommon in the offshore environment. NDT is entirely appropriate for sub sea applications using long lengths (hundreds of metres) of large diameter (typically 150 mm) wire rope that are almost impossible to visually inspect. Research work started with HSL to represent OSD interests in an IMCA working group to devise guidance on the practicalities of using ndt for sub-sea lifting ropes

3.4.2 Human factors associated with lifting operations

Human factors are a significant contributory cause in the majority of lifting incidents. However, there is little practical experience and understanding within the crane and lifting industry about the principles underlying human factors and vice versa. The majority of lifting incidents occur on routine everyday lifts. There are practical difficulties in motivating personnel involved in routine lifts to maintain their hazard awareness. For example, a person handling a load above their heads and persons positioning themselves with no available escape route. Also, inexperienced personnel can think that every job is routine and may not recognise when a lift becomes non-routine. Research is required to assess how human factors principles can be best adopted to reduce incidents. There is also likely to be merit in researching how human factor principles can be embedded into the planning of lifting operations.

3.4.3 Incident analysis

We commission occasional long term reviews of incidents trends such as Research Report RR 183 "*Lifting incident review (1998-2003)".* It is likely that we will undertake another review in the near future.

3.4.4 Mechanical handling on NUIs

If current trends continue, operators will seek to recover hydrocarbons from smaller fields. There is likely to be an increase in the number of minimum facility Normally Unattended Installations (NUI) with no cranes provided. This will present issues with regard to mechanical handling for maintenance and of replacement of plant and possibly with the evacuation of injured people.

4. MACHINERY, ROTATING EQUIPMENT, & UTILITIES

4.1 Background

Offshore platforms contain a large array of plant and machinery necessary to keep production running. Typical packages include power generation, emergency power generation, oil export pumps, gas compression for export and gas lift, and water injection plant. Utility systems include potable water, fire suppressant water deluge systems, and compressed air systems and hydraulic systems. Disintegration of high speed rotating plant presents a major accident hazard, as could the unavailability of essential utilities.

4.2 Intervention Strategy

We inspect rotating plant and machinery using RR 076 *Machinery and rotating equipment integrity inspection guidance notes* as a benchmark. Gas compression plant accounts for a significant proportion of hydrocarbon leaks offshore. Such plant is subject to high pressures and vibration.

We inspect gas turbine packages using RR 430 *Offshore gas turbines (and major driven equipment) integrity and inspection guidance notes* and PM 84 *Control of safety risks at gas turbines used for power generation* as benchmarks. Gas turbines have been associated with several fires due to leaks of fuel or lubricant, poor housekeeping and maintenance. We input to HSE Information Sheet 10/2008 relating to the fire and explosion risks posed by offshore gas turbines.

We advise on prevention of mechanical ignition sources (typical diesel exhausts and turbo-chargers) to ensure compliance with ATEX.

We inspect the arrangements for integrity management of the turret and swivel bearings of FPSOs.

4.3 Work with Stakeholders

In addition to the research guidelines listed above, we have sponsored research to reduce the risk of hydrocarbon release through failure of machinery seals, e.g. RR 485 *Elastomeric seals for rapid gas compression applications in high pressure services – guidelines.*

4.4 Future challenges

This section is under development.

5. MECHANICAL INPUT TO OTHER TOPIC WORK

5.1 Background

Mechanical engineering systems are used in nearly all engineering applications. Occasionally we are requested to provide support in areas normally outside of our remit. As such our work is reactive and dependent upon available resource.

5.2 Future challenges

This section identifies potential areas where we may be asked to provide support but may not be able to resource on a full time basis.

5.2.1 Decommissioning and dismantling

The UKCS is seeing an increase in the number of offshore installations being decommissioned. This will increase rapidly if the oil price reduces. Decommissioning is a high risk activity, involving a combination of heavy lifts using specialist heavy lift vessels and piece small dismantling. Piece small dismantling involves complex simultaneous operations and a multitude of lifting operations, many involving mobile plant and or novel lifting techniques.

5.2.2 Offshore wind farm technology

If current government targets for renewable energy generation are to be met, there needs to be a significant increase in the number of offshore wind turbines to be installed. There are supply chain issues at every stage of the development of the offshore wind farms, and this is unlikely to be resolved in the short term. There are problems with vessel availability to undertake the construction work, and with availability of competent personnel to manage the projects. Supply of the turbines themselves is also restricted. These issues will clearly have an impact on the ability to meet the power generation targets, and as the shortfall against targets becomes more severe, the pressure to deliver by whatever means will increase.

5.2.3 'Walk to work' access systems

There is a trend for more minimum facility NUI installations that require access by boat. Novel access systems are being put on the market, including complex hydraulic telescopic bridges and inflatable structures. These will need assessment by the mechanical engineering team.

Annex 1 Linkage to OSD priority areas

The tables below illustrate how OD3.4 contributes to OSD's four priority areas.

Safety Culture	
3.2.3 3.3.3	Management of lifting operations
3.2.5	Lifting of persons
3.4.2	Human factors associated with lifting operations
3.4.3	Incident analysis
3.4.4	Mechanical handling on NUIs

Leadership	
2.3.3	Flexible risers
2.3.3	Elastomeric seals to prevent rapid gas compression
3.3.1	International co-operation

Asset Integrity	
2.2.1	Initial integrity of vessels and piping
2.2.2	In-service integrity of vessels and piping
2.3.1	Piping materials
2.3.4	Safety valves
2.4.1	Fitness For Service
2.4.2	Repairs to hydrocarbon containment systems
2.4.3	In-service maintenance of safety critical valves
3.2.1	Initial integrity of lifting equipment
3.2.2 3.3.2	In-service integrity of lifting equipment
3.4.1	Wire rope nde

Competence	
3.2.3 3.3.4	Competency assurance for persons carrying out and planning lifting operations