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| ONR Technical Assessment Guide  Nuclear lifting operations and lifting equipment |



ONR Technical Assessment Guide (TAG)

Nuclear lifting operations and lifting equipment

**Head of Profession**: Mechanical Engineering and Structural Integrity (MESI)

**Authored by**: Nuclear Safety Inspector

**Approved by**: Head of Profession

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# Introduction

1. ONR has established its [Safety Assessment Principles](http://www.onr.org.uk/saps/saps2014.pdf) (SAPs) [1] which apply to the assessment by ONR specialist inspectors of safety cases for nuclear facilities that may be operated by potential licensees, existing licensees, or other dutyholders. The principles presented in the SAPs are supported by a suite of guides to further assist ONR’s inspectors in their technical assessment work in support of making regulatory judgements and decisions. This technical assessment guide (TAG) is one of these guides.

# Purpose and scope

1. TAGs are intended to provide guidance for inspectors to carry out their regulatory duties. They are also part of the demonstration on how ONR meets the Western European Nuclear Regulators Association (WENRA) Reference Levels [2] and how ONR links its guidance to that contained in International Atomic Energy Agency (IAEA) safety standards [3] [4].   
   TAGs are not written primarily for dutyholders, and although they may be used as a source of guidance or good practice, they should not be taken by dutyholders as a prescriptive set of legal requirements.
2. This TAG contains guidance to advise and inform ONR staff in the exercise of their regulatory judgment during assessment of nuclear safety case submissions for **lifting operations** and **lifting equipment**.
3. In this guide, lifting equipment means work equipment for lifting or lowering loads and includes the attachments for anchoring, fixing or supporting the load. This definition is consistent with the Lifting Operations and Lifting Equipment Regulations (LOLER) [5].
4. Nuclear lifting applies when lifting operations have potential for detrimental nuclear consequences. This may be lifting radioactive materials or a lifting operation (where the load is not nuclear) but which could detrimentally affect nuclear safety related plant, or radioactive materials.
5. The TAG applies to:

* New plant – throughout the design, construction and commissioning phases;
* Operating plant – through life including modification, through to its use for post-operative clean out and eventual decommissioning; and
* Loading/unloading of radioactive materials for purposes of transport.

1. **Notes**:

* As for all guidance, inspectors should use their judgement and discretion in the depth and scope to which they employ this guidance.
* Comments on this guide, and suggestions for future revisions, should be recorded on the appropriate registry file and brought to the attention of the ONR topic lead specialist.

# Relationship to licence and other relevant legislation

1. There are no Licence Conditions (LCs) dealing explicitly with lifting operations or lifting equipment but many can be applied:

* **LC 7: Incidents on the Site**. These incidents should be recorded, investigated and notified to ONR. Where required by other legislation (e.g., Reporting of Injuries, Diseases or Dangerous Occurrences Regulations: 2013 (RIDDOR)), such incidents must also be reported to ONR.
* **LC 10: Training**. Those undertaking, supervising and responsible for lifting equipment and lifting operations should be adequately trained.
* **LC 12: Duly authorised and other suitably qualified and experienced persons.** Licensees shall ensure only suitably qualified and experienced persons perform duties involving lifting equipment and lifting operations. Further a licensee should appoint duly authorised persons to control and supervise operations which may affect plant safety.
* **LC 14: Safety Documentation.** This relates to the arrangements for producing the safety case for lifting operations and lifting equipment.
* **LC 15: Periodic Review.** Analysis should be undertaken to consider whether there have been any significant changes or deterioration that is sufficient to invalidate the safety case. For example, corrosion, wear, fatigue and damage.

Existing plant may not fully comply with current standards. A gap analysis between earlier and current standards should be undertaken and any reasonably practicable safety improvements identified implemented. In such cases, other factors such as the age of the plant and projected lifetime may be considered when determining if risks are reduced ‘As Low As Reasonably Practicable’ (‘ALARP’).

* **LC 17: Management Systems.** This relates to the suitability of the quality assurance measures that are implemented for all lifting operations. The measures should include the supply and use of lifting equipment throughout its lifetime.
* **LC 19: Construction or Installation of New Plant.** This relates to the design of the lifting system at the early stage. It also looks at the suitability of testing to ensure that the systems meet the safety case requirements.
* **LC 20 and 22: Modification to Plant.** This relates to modifications to ensure that they do not impact adversely the design and capability of the lifting system or the related nuclear safety case.
* **LC 21: Commissioning.** This relates to the commissioning tests carried out, So Far As Is Reasonably Practical (SFAIRP), to ensure that the design criteria and the safety functional requirements claimed within the safety case have been met.
* **LC 23 and 24: Operating Rules and Instructions.** This relates to the safe limits of operation for lifting equipment and lifting operations. For example, working load limits, maximum operating speeds, lifting machinery and rigging configurations, location of lifting operations and transfer routes.

External factors and hazards that can affect the performance of the plant when setting such operating rules and instructions should be considered. For example, extreme weather, temperature conditions, ice, snow, storm, and the availability of external electrical power. The actions to be taken in the event of abnormal occurrences or loss of such services should be specified.

* **LC 25: Operational Records.** This relates to keeping the operational records of the key operating parameters that may impact the safety of lifting systems. For example, records of operating history (weights lifted and number of cycles) and number of hours in service for lifting systems. The automatic recording of measurements of any of the derived parameters (that are important to safety) should be considered.
* **LC 26: Control and Supervision of Operations.** This relates to the proper planned, supervision and carrying out of lifting operations; by Suitably Qualified and Experienced Persons (SQEP).
* **LC 27: Safety Mechanisms, Devices and Circuits (SMDC).**   
  This relates to the suitability and sufficiency of the lifting equipment protection systems. The plant should not be operated unless the necessary systems are properly connected and in good order.
* **LC 28: Examination, Inspection, Maintenance and Testing (EIMT).** This relates to all of the lifting equipment that could deteriorate or become damaged in service. Full and accurate report of every examination, inspection, maintenance or test should be completed by a SQEP. Where this reveals any matter indicating that the safe operation or safe condition of the plant may be affected, appropriate action should be taken under LC 7.
* **LC 30: Periodic Shutdown.** This relates to the periodic shutdown of the plant to carry out EIMT under the requirements of LC 28.   
  Lifting equipment may provide essential EIMT support during such shutdown periods. This should be addressed by the safety case.

1. The following statutory instruments apply to the supply, provision and use of lifting machinery and equipment:

* The Supply of Machinery (Safety) Regulations 2008 (SM(S)R) [6];
* The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) [5];
* The Provision and Use of Work Equipment Regulations 1998 (PUWER) [7];
* Health and Safety at Work etc. Act 1974 (HSWA) [8]; and
* The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) [9].

1. More detailed guidance on applying the SM(S)R, LOLER and PUWER, is given in Appendix 1, and further guidance on SM(S)R in the guide to the application of the machinery directive [10].
2. The following statutory instrument applies to all work activities:

* The Management of Health and Safety at Work Regulations 1999 (MHSWR) [11].

It requires every employer to make a suitable and sufficient assessment of the risks to health and safety. It also deals with the principles of prevention and includes details concerning the effective planning, organisation, control, monitoring and review of preventive and protective measures.

1. The following statutory instruments may be relevant and applicable for the supply, provision and use of certain lifting machinery and equipment:

* The Construction (Design and Management) Regulations 2015 (CDM2015) [12];
* The Electromagnetic Compatibility Regulations 2006 [13] (revoked in 2016 but continues to apply to relevant products placed on the market or put into service prior to this date);
* The Electricity at Work Regulations 1989 [14]; and
* The Work at Height Regulations 2005 [15].

# Relationship to Safety Assessment Principles, WENRA Reference Levels, and IAEA Safety Standards and Guides

## Safety Assessment Principles

1. There are no SAPs that specifically mention lifting operations or lifting equipment. The following SAPs may apply to the assessment of lifting operations and lifting equipment:

### Engineering SAPs

* EKP – Key principles
  1. A suitable plant configuration and layout that considers the hazards presented by lifting operations can minimise risk, optimise defence in depth and stop the progression of fault sequences. This can reduce the demands (safety functional requirement) being placed on a lifting system and its interaction with related Structures, Systems and Components (SSCs) EKP.1 to EKP.5 (key principles).
* ECS – Safety classification and standards
  1. Safety functions of lifting systems should be assigned commensurate with its contribution to nuclear safety (ECS.1).
  2. Safety classification of SSCs for lifting systems should be assigned commensurate with its ability to fulfil an assigned safety function (ECS.2).
  3. Avoiding any failure of a structure, system or component which could impair the safety function of other systems (ECS.2 – para 167).
  4. SSCs for lifting systems important to nuclear safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to appropriate codes and standards (ECS.3 to ECS.5).
* EQU – Equipment qualification
  1. Lifting equipment should perform its allocated safety functions in all normal operation, fault and accident conditions for the duration of its operational life (EQU.1).
* EDR – Design for reliability
  1. Lifting equipment should be designed to fail to safety or in a safe manner, incorporating redundancy and diversity, wherever practicable (EDR.1 and EDR.2).
  2. Appropriate segregation should be provided for electrical, control and instrumentation (Electrical Control and Instrumentation (EC&I) systems (EDR.2)).
  3. The load path for most lifting systems will be vulnerable to common cause failure, e.g. ropes and rope terminations. This will also apply to dual rope systems (EDR.3).
  4. A lifting system alone may not be capable of meeting the single failure criterion. It is expected that it would be achieved through combination with other equipment, e.g., package withstand claims (EDR.4).
* ERL – Reliability claims
  1. Reliability claims for lifting systems may be based on suitable analysis and generic data. When adequate reliability data is not available demonstration of reliabilty should be considered on a case-by-case basis which includes – examination of issues, review of historical data, independent third-party views, consideration of precedent and relevant good practice (ERL.1).
  2. Include measures to ensure the onset of failure will be detected such as hoist gearbox oil monitoring, regular crane structure and load path SSC inspection (ERL.2).
  3. Where reliable and rapid protection action is required automatically initiated engineered safety measures should be provided. The choice of safety measure should take into account the hierarchy in ERL.3 para 155.
  4. Where safety related SSCs are relied upon a margin of conservatism should be included in the safety case to allow for uncertainties (ERL.4).
* ECM – Commissioning
  1. Satisfactory operation of lifting equipment’s safety features and mechanisms should be validated via a combination of works testing and on-site commissioning activities. Commissioning should show that the lifting system is capable of meeting the operational demands of the facility. It should also show satisfactory performance and interaction with other equipment to meet the requirements of the safety case. Commissioning should also prove the satisfactory performance of any recovery systems (ECM.1).
* EMT – Maintenance, inspection, and testing
  1. Examination, Inspection, Maintenance and Testing (EIMT) should be able to be carried out throughout the plant lifetime. This should include the provision to lift heavy assemblies that require replacing or repair. For example, motors and gearboxes. The ability to test performance of Safety Mechanisms, Devices and Circuits (SMDCs) should be incorporated into the lifting system design (EMT.1 to EMT.8).
* EAD – Ageing and degradation
  1. The safe working life of equipment that is important to safety should be evaluated and defined at the design stage. This is important particularly for large lifting system structures that would be difficult or impracticable to replace during the plant lifetime (EAD.1).
  2. Due allowance should be made in the design for degradation processes, including corrosion, erosion, creep, fatigue, and ageing, and for the effects of the local environmental conditions.   
     This includes spares items which are held in stores (EAD.2).
  3. Lifting systems are likely to be required for the complete operating lifetime of a facility. For example, an overhead crane may be required to support construction/installation and final deconstruction activities. Processes should be in place to deal with obsolete equipment (EAD.5).
* ELO – Layout
  1. Lifting systems can have a major influence on the layout of a facility. These principles should also be applied to the lifting system   
     (ELO.1 to ELO.4).
* EHA – External and internal hazards
  1. Lifting systems such as overhead cranes can be a source of internal hazards that result from structural collapse, collision or release of a load. These can often be of greater consequence than the initiating internal or external hazard (EHA.1, 5, 6, 7, 10, and EHA.13 to 18).
  2. Large lifting systems: can be subject to significant loadings from external hazards such as seismic and wind. The lifting system self-weight and physical size may have the potential to significantly affect how the overall building structure responds. They can also generate significant reactions that must be resisted by both building and lifting system. Displacement and relative movement between lifting systems and the other SSCs they interact with should be addressed. Ground conditions for mobile lifting systems directly affect stability and must be considered (EHA.2 to EHA.11, 15 and 18).
* EMC – Integrity of metal components and structures
  1. Lifting machines are made up of metallic structures and mechanisms (e.g., ropes, gears, shafts and linkages). A demonstration of their integrity will be required (EMC.1 to EMC.22 and EMC.24 to EMC.34).
* ENC – Integrity of non-metallic components and structures
  1. For some applications, non-metallic slings may be more appropriate than chain or wire rope slings (e.g., as a means of securely slinging items with no engineered lifting features). Storage of slings is important to avoid damage and degradation. Seals, guide bushings should be designed for the loads and environmental conditions (ENC.1 and ENC.2).
* ESS – Safety systems
  1. Lifting systems should include protection systems that prevent them entering an unsafe state. These may include mechanical and electrical based devices such as mechanical interlocks, torque limiters, braking systems, buffers, end stops, load cells, overspeed monitoring and end of travel limits (ESS.1 to ESS.27).
* ESR – Control and instrumentation of safety-related systems
  1. Lifting systems should be provided with a suitable control systems that maintains the lifting system within its safe operating envelope, reducing the likelihood of a demand on a safety system.   
     The systems should also provide information to assist the operator (ESR.1 to ESR.7 and ESR.9 and ESR.10).
* EHF – Human factors
  1. The potential for human interaction with lifting systems can be considerable. This can have a positive or negative contribution to safety. For example, the crane driver, the signaller to guide the load and the operator/rigger who attaches the load to the lifting device, all have a safety role (EHF.1 to EHF.10).
* ENM – Control of nuclear matter
  1. Arrangements for the storage of nuclear matter in a form and manner that allows it to be retrieved might include the provision of mechanical handling and lifting systems (ENM.7).

# Advice to inspectors

## Introduction

1. This guide supports the assessment of safety cases that involve the use of lifting equipment and lifting operations that are on or adjacent to nuclear licensed sites; and includes transport of radioactive materials activities.   
   It covers all lifting operations whose failure could affect nuclear safety.   
   The guidance is therefore not limited to the lifting and movement of nuclear material.
2. A nuclear lift can be defined as any lift with the potential to either directly   
   (or indirectly) result in radiological consequences. Indirect radiological release is normally related to high energy impacts onto safety critical plant.
3. Inspectors should recognise that the lifting and transport of a load introduces the potential to disrupt the safety of radiological processes, barriers, safety mechanisms and devices that are designed to protect such systems in normal or faulted process conditions.
4. The safety case should:

* Demonstrate that risks related the lifting operations are reduced to ALARP;
* Identify the strucrures, systems and components of the lifting system important to safe operation;
* Identify normal operating and potential fault conditions, including internal and external hazards that could affect the lifting system and other plant and equipment;
* Consider human factor influences that affect the safety of lifting operations; and
* Demonstrate that the integrity of structures, systems and components important to safety are adequately managed. This applies throughout the projected life of the installation, through to the point at which it no longer has any nuclear safety consequence. This should take account of potential ageing and degradation mechanisms.
* Demonstrate adequate consideration to nuclear site safety for the lifting operation entirety.

1. At an early stage in the assessment process, the inspector should establish how the lifting system fits within the safety case.   
   The assessment should:

* be targeted and proportionate to the risk;
* be relative to the nature of the hazards that relate to the lifting operations;
* consider the risks to other safety significant plant and equipment; and
* balance the safety claims made against the lifting equipment safety measures against the drop load protection offered by the load or equipment impacted.

1. The lifting system’s level of reliability depends on a wide range of technical areas. For example: materials, fabrication, stress analysis and electrical, control and instrumentation systems. Human factors must also be considered.
2. An inspector may need to consider a different weighting of the safety case claims to that presented by a dutyholder, if for example in possession of wider industry knowledge. Where a balanced ONR judgement is required, inspectors may consult with other specialists/ Heads of Regulation to consider broader factors for regulatory consistency and proportionality reasons.
3. Section 4.6 of SSR 2/1 defines three fundamental safety functions that align with SAP ERC.1 (design and operation of reactors) [3]. Any of these safety functions might be affected by a lifting system failure:

* control of the reactivity;
* removal of heat from the core; and
* confinement of radioactive materials, shielding against radiation and control of operational discharges, as well as limitation of accidental releases.

1. How a safety case decides to address these fundamental safety functions will vary. For example:

* The catastrophic failure of a lifting system onto a critical item of equipment, such as a Reactor Pressure Vessel (RPV) of a large power plant, may result in unacceptable radiological consequences.   
  Hence, high levels of quality and conservative levels of engineering would be required throughout the life of such a lifting system. In this case the significant claim is likely to be against the lifting equipment; and
* The radiological consequences of a dropped nuclear package (flask) may be less significant. The package might be able to withstand the drop impact, maintaining adequate containment and shielding.   
  Hence, appropriate industrial, national or international standards may suffice for the lifting system. In this case the significant claim is likely to be against the flask.

1. It is possible that safety critical equipment might be concealed.   
   For example, emergency feed pumps in turbine halls and electrical cables located under the ground. The vulnerability of this equipment during the lifting operations should be considered.
2. The assessment of lifting operations should consider the likely failure mechanisms of lifting equipment and the results of human error.   
   The assessment of probability of failure and the consequences of failure should ensure that risks are tolerable and ALARP (SAP FA.4 (Fault Tolerance) and FA.14 (Probabilistic safety analysis)).

## Lifting safety case philosophy

1. Health and safety legislation (e.g., MHSWR, LOLER, PUWER and Supply of Machinery (Safety) Regulations), set out the dutyholders’ legal responsibilities. Approved Codes of Practice (ACoP)) if followed allow dutyholders to demonstrate compliance with the law, (e.g., LOLER ACoP [16]).
2. Optioneering is a key element to showing that risks have been reduced ALARP. Eliminating the lifting operations altogether and adopting potentially safer methods of mechanical handling should be considered early in the design (SAP EKP.1 and 2 (key principles)).   
   However, ONR recognises that lifting may be the only effective means of moving materials and equipment, e.g. maintenance operations.
3. Nuclear lifting safety cases generally fall into one of two strategies:

* ‘Dropped load/impact’ safety case; or
* Low probability of lifting system failure safety case.

### ‘Dropped load/impact’ safety case (limited consequence claim)

1. The ‘dropped load/impact’ safety case can offer a more robust safety case strategy. This is because it can provide defence in depth against the consequences of lifting system failures (SAP EKP.2 (Fault tolerance)). However, it should be recognised that it may not be an easy case to make. The reason for this is that lifting operations often involve complex interactions with other safety critical plant and equipment.
2. To achieve this, lifting operation fault analyses should show that the fault:

* does not result in an unacceptable release of nuclear material   
  (SAP ECV.2 (Minimisation of releases));
* does not compromise heat removal (SAPs EHT.1 to EHT.5 (Heat transport systems)); and
* does not lead to a criticality event (SAP ECR.1 (Safety measures)).

1. In such cases, the assessment should also consider whether all reasonably practicable steps have been taken to prevent accidents and mitigate consequences when lifting and handling (SAP FP.6 (Prevention of accidents)).
2. If the principal nuclear hazard has been mitigated, the assessment of the lifting equipment may then be limited to examining the internal faults in the lifting system.
3. A ‘dropped load/impact’ safety case may be argued on the basis of limited consequences. For example, the lifting of an IAEA licensed transport package, where there is a sound and detailed justification of its impact resistance. The safety case should justify the suitability of all nuclear transport packages used within the facility.
4. A dropped load/impact can often damage other plant and equipment.   
   If the damage cannot be tolerated the impacted structures should be justified against such an impact. For example, a reactor pile cap or containment structure.
5. A ‘double blocking’ event, where the hook block contacts the underside of the crane (or comes into contact with another object that is immovable), can often result in a dropped load (from rope snap). To make a limited consequence claim, it should be shown that it is not physically possible to lift the underside of the load (such as the package) to a height greater than the justified impact withstand of the load and/or the plant and equipment below. Other faults may be applicable, shown in Appendix 6.

### Low probability of lifting system failure safety case (high consequence low probability of failure claim)

1. Demonstrating that a lifting system has a sufficiently low probability of failure is a significant challenge. Greater dependence will be claimed on the robustness, integrity and reliability of the lifting equipment. The use of operational experience (OPEX) data is important but in support of high levels of reliability inspectors should ensure the claims made are appropriate and robust.
2. These type of safety cases should be scrutinised in greater detail by the inspector.
3. A protection system that is intended to protect against one fault may introduce a fault condition that requires another protection system.   
   Design enhancements that increase the lifting system mass and energy may increase the severity of other hazards such as seismic. This addition may result in further detrimental consequences to other plant and equipment.

## Fault analysis

1. SAPs FA.1 to FA.24 (Fault analysis) and NT.1 and NT.2 (Numerical targets and legal limits) detail the requirements to carry out the safety analysis of plant. They cover a range of conditions, from normal operation to severe accidents, where major plant damage may be sustained leading to significant nuclear safety consequences. In this case, a proprietary type of lifting system (Commercially Off-The-Shelf (COTS)) may not fully satisfy the fault conditions identified.
2. Experience and judgement are required to assess the extent of the Design Basis Analysis (DBA) [17] required for lifting operations. The extent of the assessment should be based on the nature of the nuclear hazard. The mixture of passive design features, mitigation measures and engineering features is likely to differ in each safety case.
3. The DBA should show that in combination, the proposed design and use of the equipment, has been thoroughly examined. It should be shown to be acceptable and tolerable against dutyholder site wide derived criteria that reflects the potential nuclear risk.
4. It is important to consider all reasonably foreseeable fault sequences (set out in Appendix 6). The collapse of the structure itself should also be included. Crane structures can be expected to have significantly greater potential energy than the loads being lifted. This is due to their greater mass and position (height). SAP ECS.2 safety classification para 167 is applicable for equipment (of a lower class) providing the function to prevent propagation of failures (to plant of a higher class); it should be assigned to the higher class.
5. Principal lift load path failures may have potentially major consequences. The fault analysis (and the conclusions drawn from it) should recognise and validate the assumptions made in any supporting analysis (SAPs FA.19 and FA.22 (Fault analysis)).
6. The internal faults that can develop into overloads and uncontrolled motions should be assessed. Such effects should be quantified, and mitigations justified in detail (SAPs FA.7 and FA.8 (Fault analysis)).
7. Appendix 6 identifies fault conditions that are considered to be common to most lifting systems. It also details some risk reduction measures that may be considered by dutyholders.

## Internal hazards

1. Internal hazards assessment/inspection considers the effects of dropped loads and impacts to SSCs (any equipment important to nuclear safety).
2. The potential consequences of dropped loads in nuclear plant include damage to containment of nuclear material into hazardous configurations (leading to a criticality event), loss of bulk shielding leading to shine paths or increased radiation dose, or damage to SSCs important to safety. As loss of control of loads can result in impacts to SSCs, they should be considered as a potential initiator of fault sequences with nuclear safety consequences. Further guidance can be found in the TAG on criticality safety [18].
3. The energy of the impact from a dropped load is directly proportional to its mass and the height of the drop. The severity of the impact on SSCs depends on the energy of the impact, the geometry and shape of the dropped item and the characteristics of the target.
4. The energy of the impact from swung loads and drop loads can be estimated via relatively simple calculations. However, inspectors should check that adequately conservative assumptions have been made, for example, the mass of the load dropped includes that of any attachments and lifting devices where applicable, and that the specific vulnerabilities of SSCs have been included.
5. The use of cranes and other lifting equipment is covered within this TAG, however, the threats associated with dropped loads and impacts as an internal hazard and the potential consequential hazards such as fire, explosion and flooding are considered in more detail within the TAG on internal hazards [19].

## Strength and stability

1. Adequate strength and stability are requirements of LOLER [5] (Regulation 4). For nuclear applications, non-nuclear specific design codes and standards may need to be further supplemented or modified as necessary. Where relevant, any enhancements should be done to a level that is commensurate with the importance of the relevant safety function(s)   
   (SAP ECS.3 codes and standards, para 170). Safety case claims made should be checked for adequate substantiation evidence.
2. Design codes for lifting systems are discussed in Appendix 5.
3. Lifting systems that lift loads within their supporting wheelbase are generally stable as there is no overturning moment. For cranes such as jib cranes and dockside cranes that lift loads outside their supporting wheelbase, overturning is more likely. Hence, overturning may be the limiting state and therefore sufficient counterbalance and/or anti-toppling features will be required. These features should maintain the stability in both normal and fault conditions (e.g., overload and seismic). Counterbalance will add significant mass which in the case of dockside cranes presents an impact risk to docked boats – here integrity of the supporting structure and fixings may be inspected.
4. A possible consequence of enhancing design codes is the increase in mass, inertia, and stiffness of the lifting system. This increases the risk of lifting systems damaging other plant and equipment. For example, more powerful drive motors may be required, crane booms and their counter-balances heavier but their resultant impact forces will be greater. Hence, all equipment that is related to the lifting system faulted conditions should be assessed against their ability to deliver against their safety function requirement   
   (SAPs FA.7 and FA.8 (Fault analysis)).
5. De-rating lifting equipment may have a variable effect on the design margins throughout the system. For example, faulted loads are normally generated by the drive system or application of a brake, not the load being lifted. Hence, the effects of both the static and the dynamic forces that are generated by faulted conditions (if they are not satisfactorily terminated) should be fully analysed.
6. Increasing the power of the hoist motor may not improve safety. Although it might have greater reserve capacity for lifting the load, in a fault condition a greater force can be generated (e.g., restrained load fault) which may complicate the control system mitigating the risk.

### Proof load testing

1. The requirement for load testing (e.g. proof) of lifting systems is derived from LOLER [5] with further guidance in LOLER ACoP [16]. Proof load test alone should not be assumed to provide assurance against defects. The proof load test should be supported by suitable inspection and fracture mechanics assessment, as is considered appropriate.
2. Proof load testing is normally only carried out at the time of installation and setting to work. Where regular proof load testing is used to provide assurance, the effects of this testing should be analysed for any detrimental effects (e.g. potential damage and shortening the fatigue design life of the lifting system).
3. Where regular proof load testing of the lifting systems is required the rated capacity of the lifting system should be equal (not below) the specified test load. For example, to support reliability claims.
4. Conventional lifting machinery proof tests that are typically 125% of the safe working load may not be sufficient to prove that the lifting system can withstand dynamic faulted conditions that may arise from:

* A failed rope in a dual reeved system, where an increase of 200 to 300% or greater in load may be developed in the remaining rope system;
* Loads generated by the inertia of the hoisting system in a snagged or restrained load fault condition that cannot be limited by an overload detection trip;
* Loads that are ledged and then drop suddenly (often described as a ‘hangman’s drop’); and
* Seismic loadings where there may be significant horizontal accelerations and magnification of the vertical load.

1. Such fault loadings can result in catastrophic modes of failure.   
   These may result in simple tensile failures, buckling or loss of stability.   
   The limitations of proof tests should be considered. Also, justifying a design solely on the basis of theoretical analysis may not be appropriate, unless additional testing strategies are devised.

## Safety measures

1. A safety case for a nuclear lift may determine that a standard industrial designed lifting system may not provide adequate fault tolerance (SAP FA.4). This may relate to the suitability of safety measures and robustness of the design. Additional safety systems might be required as identified by the safety case.
2. To protect against an uncontrolled lowering event, additional hoist braking may be required. For example, an extra brake may be added to the input side of the hoist gearbox. An emergency braking (or a retardation system) that acts directly, (or as close as possible), on the rope drum should be considered to protect against mechanical failure of the hoist gearbox, coupling. Here, BS EN 13135:2013+A1:2018 - Cranes, Safety, Design, Requirements for Equipment Cranes Safety [20] may be considered.   
   The performance of such features should be shown throughout the operating life of the lifting equipment and include relevant maintenance requirements (SAP EQU.1 (Equipment qualification)).
3. Normally all brakes should be applied on loss of power to the lifting machine or drive motors. However, this feature may not initiate the emergency braking/restraint in response to a mechanical failure or an electrical fault. Hence, failure/fault detection may be required, which may take the form of over-speed detection and/or speed comparator. These can then monitor the output speed relative to input speed.
4. Extra braking/restraint systems may enhance safety. Yet, they may also impose greater dynamic loadings on the hoist drive components that are above the normal design code requirements. Hence, the design analysis should consider the faulted condition of any spurious operations.   
   Application of the emergency braking, or a retardation system, should also be considered when assessing the fatigue life of the drive components.   
   For example, during testing and spurious tripping.
5. Such arrangements may not fully remove the potential hazard of a dropped load. A protection system may be part of the recovery system so, for example, when the emergency brakes are released to make a recovery action there may be no defence in depth (SAP EKP.3 (Defence in depth)). The operation of lifting systems in any foreseeable degraded state should be justified showing risks are reduced ALARP, within the safety case.
6. Another recognised method of reducing the risk of uncontrolled lowering is the ‘single failure-proof’ hoist system (refer to guidance from the U.S. Nuclear Regulatory Commission (NRC) on single failure-proof cranes for nuclear plants [21]). In these systems, load paths are duplicated. This aims to ensure that no single failure will result in loss of capability of the system to support the load. The increased complexity of the ‘single failure proof’ system may introduce new fault modes that are not present in conventionally reeved hoist systems and need to be considered. The effects of these faulted conditions should be assessed to ensure that they do not compromise the ‘single failure-proof’ principle.
7. The ‘one fault safe’ approach has been incorporated into the American Society of Mechanical Engineers (ASME) Standard, NOG-1 [22] which is recognised as international good practice. Such standards have been developed for cranes used at nuclear facilities and components of cranes at nuclear and other high-risk facilities. Nuclear facilities can include nuclear power plants (NPP), small modular reactors (SMR), and advanced reactors. NOG-1 may not bound all potential hazards, therefore the application of it should consider all potential hazards identified in appendix 6, and U.S. Nuclear Regulatory Commission (NRC) guidance on the control of heavy loads at nuclear power plants [23].
8. Another safety case method for lifting is to rely on some form of redundancy or diversity. This goes beyond the ‘one fault safe’ approach. In such cases, there is an independently operable load path that is capable of supporting the load that is being lifted. For example, an independent load follower or similar device. These systems offer redundancy and diversity type benefits when judged against ONR’s SAPs. However, they should be assessed, and the dynamic loading effects of primary lifting system failures considered. Issues to be considered with respect to high reliability systems are covered by SAPs EDR.1 to EDR.4 (Design for reliability).
9. Whatever solution is adopted, the claimed engineering benefits should be achieved in practice (SAPs SC.4 to SC.6 (Safety cases)). Appendix 6 considers some of the detailed technical issues that need to be considered when assessing such systems.

### Recovery philosophy

1. The hazards associated with a suspended load and the risks associated with the actions necessary to return to a safe condition should be considered. Certain systems lend themselves to an emergency action to remove the main hazard. For example, the reactor may be tripped, the process is stopped and made safe, or there may be a suitable evacuation, prior to recovery. In other situations, the hazard will remain until the load is finally grounded. To avoid leaving a suspended load over safety critical plant, there should be an effective means of safely recovering a broken-down crane to a safe position. This means equipment is available preferably in support of a recovery plan.
2. If the rope fails in a ‘single failure-proof’ system, it may affect the ability to raise or lower the load safely. Recovery of the suspended load may need to be carried out by an adequately sized fit for purpose alternative lifting system which may itself introduce additional risks.
3. Radiological hazards may restrict access to both the load, and lifting equipment, during recovery type operations. Lifting equipment that is operated remotely may require the recovery systems to also be operated remotely. The recovery systems should be shown to work during commissioning and include all foreseeable recovery situations.   
   This equipment should also be subject to an in-service maintenance regime to ensure that it can operate on demand.

## Reliability

1. The failure rate data associated with lifting equipment and lifting operations is often difficult to establish. This is due to the variety of cranes and other devices in use, the variability of usage, and a significant element of operator error in many of the failures. Crane failures can be caused by many different faults. For example, operator error, loss of stability, insufficient mechanical strength, fatigue, wear and EC&I-based equipment failures. Where failure rate data does exist, it should be relevant to the lifting system and how it is operated (SAP ERL.1).
2. Uncertainties, stemming from imprecision in knowledge and reliability data, should be regarded as an intrinsic part of the risk assessment under ONR’s precautionary approach to decision making. These uncertainties may be handled by introducing conservatisms, sensitivity analysis, or by a variety of explicit uncertainty analysis techniques.
3. Low reliability may come from inadequate initial design, rather than time based failure mechanisms. Adopting early on design for reliability practices could increase relevant structure, systems and component reliability. Inspectors should use judgement when evaluating evidence supporting assumptions or estimates in the licensee’s case (refer to Fault Analysis SAPs, particularly para 613).
4. Reliability studies may be helpful when looking at aspects of the design where the data may be more robust for example, human factors aspects and control and instrumentation systems. The results, alongside the need to balance the hierarchy of controls (refer to SAP EKP.5, para 155), may indicate a requirement to reconsider operator action or improve . the control system reliability, in more hazardous applications.

## Human factors

1. The human contribution to nuclear safety during nuclear lifting operations should be acknowledged and adequately substantiated by the dutyholder in its relevant safety case.

* Human error is a contributory factor in many lifting accidents;
* Humans may have to actively participate in the lift to ensure it is completed in the manner expected; and
* Human action may be claimed within safety measures in the safety case, contributing to the delivery of safety functions should they be demanded.

1. Where possible, safety measures from the upper levels of the hierarchy of control (EKP.5), which reduce the reliance on humans to maintain nuclear safety, should be implemented. In some cases, it may not be reasonably practicable to provide fully engineered safety measures and administrative safety measures may be required. In most nuclear lifting operations, some reliance on humans to maintain nuclear safety will remain.
2. Human factors considerations should therefore be systematically integrated within dutyholder arrangements (SAP EHF.1):

* Design (the lifting operation, the lifting equipment and the work environment in which the operations will be undertaken);
* Lift planning (further guidance can be found in British Standard,   
  BS 7121 [22]);
* Control, supervision and completion of lifting operations; and
* EIMT of lifting and associated equipment.

1. In addition, where reliance on humans is required and proportionate to risk:

* Allocation of safety actions to humans should be substantiated (SAP EHF.2);
* Human actions that can impact safety should be identified (SAP EHF.3);
* Operating rules (SAP SC.4) and associated administrative controls, to ensure compliance, should be identified (SAP EHF.4);
* Proportionate analysis should demonstrate how the human contribution to safety functions will be delivered (SAP EHF.5);
* The design of the workspace (SAP EHF.6), user interfaces   
  (SAP EHF.7) and procedures (SAP EHF.9) should support reliable human performance;
* There are sufficient personnel (SAP EHF.11), who are demonstrably competent (SAP EHF.9) and fit to fulfil (SAP EHF.12) their safety roles; and
* Human reliability assessment should be completed on all human actions and administrative controls necessary for safety   
  (SAP EHF.10).

1. Further assessment guidance on human factors can be found in the following TAGs:

* Human reliability analysis [23];
* Human factors integration [24]; and
* Allocation of functions between human and engineered systems [25].

# Appendix 1 – Guidance on the application of statutory legislation

1. This guidance explains to inspectors how the statutory legislation applies to a nuclear licensed site and a nuclear safety case. Inspectors should consult the relevant HSE approved code(s) of practice (ACoP) for more detailed guidance.

## The Supply of Machinery (Safety) Regulations 2008 (SM(S)R)

1. SM(S)R [6] includes the supply of lifting equipment and lifting accessories (e.g., slings and shackles). It defines ‘lifting accessories’, as components or equipment (including slings and their components) which:

“are not attached to lifting machinery; allow a load to be held; are placed between the machinery and the load or on the load itself, or are intended to constitute an integral part of the load; and are independently placed on the market”.

1. Manually operated lifting equipment falls within scope of SM(S)R as:

“an assembly of linked parts or components, at least one of which moves and which are joined together, intended for lifting loads and whose only power source is directly applied human effort”.

## Nuclear exclusion

1. Equipment provided in accordance with relevant regulations provides confidence that it is safe for conventional industrial applications.
2. SM(S)R, Schedule 3 states these regulations do not apply to in this case - 3(1c) [6], “machinery specially designed or put into service for nuclear purposes which, in the event of failure, may result in an emission of radioactivity.
3. The exclusion recognises that the regulations may not cover the hazards associated with radioactivity. The inference is that the duty holder may need to do more given the severity of the hazards and risks, determined on a case by case basis.
4. In practice, the exclusion needs careful consideration because the two components making up the exclusion are open to interpretation,   
   i.e., ‘specifically designed’ for nuclear use and ‘failure may result in an emission of radioactivity’. Inspectors must consider each application in turn; some guidelines are as follows:

* A lifting system ‘specifically designed’ for nuclear use and where reasonably foreseeable failure leads to an ‘emission of radioactivity’.   
  This system would clearly be excluded from the regulations.
* A lifting system ‘put into service’ for nuclear use and where reasonably foreseeable failure leads to an ‘emission of radioactivity’. This system would clearly be excluded from the regulations.
* A lifting system ‘specifically designed’ or ‘put into service’ for nuclear use and where reasonably foreseeable failure does not lead to an ‘emission of radioactivity’. This system would not be excluded from the regulations.
* A lifting system not ‘specifically designed’ or ‘put into service’ for nuclear use but where reasonably foreseeable failure leads to an ‘emission of radioactivity’. This system would not be excluded from the regulations.

1. In practice it may be that a dutyholder applies the SM(S)R anyway to its lifting equipment, despite the nuclear exclusion, as a starting point from which additional measures are incorporated proportionate to the associated risks. This would then enable the lifting equipment to be used in both nuclear and non-nuclear applications (for example as part of the construction of a fuel store, then used in normal operations to undertake nuclear material lifting in the store).
2. Inspectors should note, the Essential Health and Safety Requirements (EHSR) laid down in SM(S)R schedule 2 are mandatory. However, “taking into account the state of the art, it may not be possible to meet the objectives set by them. In that event, the machinery must, as far as possible, be designed and constructed with the purpose of approaching these objectives.”
3. SM(S)R regulation 7 sets out the requirements for a conformity assessment in which the dutyholder sets out standards and legislation the machinery has been produced to. Additionally, regulation 7 states a supporting technical file is required. These items may be sampled by inspectors to determine SM(S)R compliance adequacy.

## Technical File

1. The Technical File must contain all information that is necessary to demonstrate the conformity of the product to the applicable requirements and must be kept for at least ten years from the last date of manufacture of the product. This is the responsibility of the manufacturer, or its authorised representative.
2. The required contents of the Technical File can be found in Schedule 2, Part 7 of SM(S)R [6]. The documentation should cover the design, manufacture, operation and maintenance of the equipment. The details included in the documentation depend on the nature of the product and on what is considered as necessary, from the technical point of view, for demonstrating conformity of the product.
3. Files must be kept up to date and may be stored in paper/electronic format. Whenever there are modifications to the product, or when there are amendments in the regulations, the content of the Technical File must be updated.
4. Inspectors may request to inspect the Technical File and use any findings as part of their adequacy judgements; including demonstration that the machinery (Lifting equipment) meets EHSRs of (SM(S)R) [6].

## The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)

1. The definition of ‘lifting operation’ and‘ lifting equipment’ are clearly defined in these regulations. The following advice highlights specific issues associated with the use of lifting equipment on a nuclear licenced site.

### LOLER Regulation 4 – Strength and stability

1. This requires the following:

* lifting equipment is of adequate strength and stability for each load, having regard in particular to the stress induced at its mounting or fixing point;
* every part of a load and anything attached to it and used in lifting it is of adequate strength.

1. The term ‘adequate strength’ is open to interpretation. This is especially true where proprietary equipment is used. Inspectors should therefore consider the requirements of the TAG on integrity of metal structures, systems and components when significant claims are being made on the structural integrity of lifting systems [26].
2. The means of attaching the load to the lifting device (e.g., crane) should be considered to ensure it is attached correctly and cannot become detached during the lifting operation.
3. The stability of lifting equipment will need to be assessed by suitable analysis and testing if it is appropriate. Testing has the advantage that uncertainties in weight and weight distribution can be removed. The test conditions will have to address any faulted loads and any dynamic effects that are imparted to the load. This is important if the testing is to be truly representative and robustly support claims made in the safety case.
4. Where the conventional and nuclear safety risks associated are such that the test cannot be carried out on a nuclear licensed site, consideration should be given to the validity of off-site testing.

### LOLER Regulation 6 – Positioning and installation

1. It may be possible to reduce the risks that are associated with lifting operations and lifting equipment. This may be done by controlling the plant layout and also suitably positioning and installing the lifting equipment   
   (SAP ELO.4 (Minimisation of the effects of incidents)).
2. The approach of adopting a low-level lift is recognised as relevant good practice by GB site licensees. This requires lift heights not to exceed the safe drop withstand of the load being lifted or the structural withstand of any SSCs below the load. Care does need to be taken not to make the lift more complex, i.e., continually moving the load up and down along a profile.
3. The physical presence of lifting equipment when it is not in use needs to be considered. This is because it may pose a threat to other systems or operations. Hence, it may be reasonable to park out of use, lifting equipment in a position where the risk or consequence of collapse is reduced.
4. The potential collapse zone of a tower crane or mobile crane can extend over a considerable area. Cranes should be selected and positioned to minimise the effects of a possible collapse.

### LOLER Regulation 8 – Organisation of lifting operations

1. The requirements of LC 12 to check those planning and supervising operations are suitably qualified and experienced persons (SQEP) should be considered. This should be with respect to both the lifting issues and the nuclear safety case. Operating instructions (LC 24) should include the actions to be taken in the event of failure or other incidents.
2. The ability to carry out lifting operations in a safe manner is intrinsically linked to plant layout. SAP ELO.4 (Minimisation of the effects of incidents) is relevant as are each of the human factor series of principles (EHF).

### LOLER Regulation 9 – Thorough examination and inspection

1. LOLER specifies the requirements for thorough examination, covering:

* putting equipment into service;
* examination periods for equipment types; and
* exceptional circumstances that could jeopardise safety.

1. Lifting equipment should be thoroughly examined. This allows deterioration to be detected in sufficient time. This then allows remedial action to be taken. A Competent Person is required to determine the level of thorough examination required that is based on an assessment of the risks.
2. The purpose of a thorough examination is to:

* reveal if deterioration is present;
* in areas where the Competent Person would reasonably expect to find it; and
* judge whether it is dangerous.

1. Thorough examination by a competent person is usually limited to finding deterioration. This may not provide assurance of the lifting equipment’s suitability for nuclear use. Hence, assurance should be sought that the scope and extent of a thorough examination is proportionate to the nuclear safety risk.
2. It should be noted that independent competent persons are unlikely to have: detailed information on bespoke lifting equipment; knowledge of the nuclear safety significance of the equipment; and the nature of the operations performed. They should be instructed and directed by a dutyholder competent person who should be identified in the dutyholder’s arrangements. However, independent third parties usually have a wide experience and knowledge of the inspection of similar lifting equipment in a range of other industries. Hence, they should be a valuable independent source of practical and theoretical advice on lifting equipment and inspection processes and defects.
3. The safety case may need to specify additional in-service inspections that are design informed. This should ensure that the condition of equipment remains consistent with the claims made of it. These inspections may be targeted at areas where there is no degradation expected, but where they may be highly stressed or safety critical.
4. Most sensitive nuclear equipment should have a detailed EIMT regime.   
   Further guidance can be found in the TAG on EIM&T of items important to safety [27]. This should be developed from the design, through manufacture and operation. This reflects the requirements found in the TAG on integrity of metal structures, systems and components to achieve an appropriate structural reliability [26].
5. In addition to carrying out thorough LOLER examinations, dutyholders should appoint SQEP who should be capable of assessing the nuclear lifting operations and lifting equipment. This assessment allows the continued fitness for purpose to be confirmed within safety cases. Hence, inspectors should recognise that lifting equipment may need to be thoroughly examined more frequently than the statutory minimum periodicity. This is because concerns may exist with the condition of the equipment (e.g., rate of deterioration, environment conditions, poor maintenance record, etc.). It may also be appropriate to carry out a thorough examination before a significant nuclear lift.
6. LOLER identifies a complementary system to the specified period approach. The written examination scheme can be particularly relevant and proportionate for equipment used for nuclear lifting operations.
7. Risk-based inspection schemes may be considered for safety critical items. These inspections can give greater control and focus to the examination process. They may also reduce exposure of those undertaking examinations to radiological hazards. This is important to ensure the risk to the Competent Person and their activities are considered, especially when the risks to operational personnel is low or discounted. The risk-based examination scheme should address the nuclear and radiological hazards. The inspection should also include any dose burden from potential recovery operations that may result from lifting equipment failure.

### LOLER Regulation 10 – Reports and defects

1. LOLER requires written reports to be provided for all thorough examinations.
2. Where, in the opinion of the ‘Competent Person’, a defect is present in the lifting equipment that involves an existing or imminent risk of serious personal injury; a copy of the report must be sent as soon as is practicable to the relevant enforcing authority.
3. For nuclear licensed sites the authority is ONR. This is in addition to any reporting or other requirements required under LOLER, PUWER or any other regulation (e.g., Reporting of Incidents Diseases and Dangerous Occurrences (RIDDOR)).
4. It is recommended that the inspector consider the thorough examination reports when assessing the safety case. Whilst the presence and nature of any defects may not affect the nuclear safety case, they could present a serious conventional hazard.

## The Provision and Use of Work Equipment Regulations 1998 (PUWER)

1. PUWER applies to all work equipment including lifting equipment [7].   
   LOLER addresses the specific aspects of lifting operations and lifting equipment.

### PUWER Regulation 4 – Suitability of work equipment

1. PUWER contains significant regulations that relate to the:

* suitability;
* maintenance;
* guarding;
* training;
* Conformity with community requirements (EHSRs);
* emergency stops;
* control systems; and
* other features of work equipment that are fundamental to the safe design of lifting equipment and lifting operations.

# Appendix 2 – Guidance for Mechanical Engineering specialist inspectors

1. The guidance explains to inspectors the possible issues that might arise when inspectors assess the safety of nuclear lifting systems. Where there is any uncertainty or doubt, assessors should seek more detailed technical advice from topic leads.

## Load effects

1. The design analysis of lifting systems requires a detailed understanding of the engineering mechanics and dynamics of their hoist and travel drive systems, and the resultant fault conditions that can be generated by them.
2. A detailed knowledge of the applicable design codes and standards is required to understand their inbuilt design margins and how the design factors can be applied and supplemented to address normal service and fault conditions.
3. The dynamic effects of faulted conditions should be examined separately to normal service conditions. The loads created by fault conditions, load path failure and emergency braking might be significantly greater than a controlled lifting operation.
4. The load effects and claimed benefits that the dutyholder is making for any protection system should be closely examined. The lifting system should be able to respond to a fault condition in a manner that transfers the load into the redundant system or senses the failure and arrests the load within safe limits. The effect on the load, the lifting system and any impacted structure should be considered.
5. It is often useful to request a summary of system stresses developed against all load cases (stress schedule) from the dutyholder.   
   This schedule should identify and summarise the principal loads, stresses, deflections, design criteria and design margins of the key structures and mechanisms of the lifting system.

## Dual load path systems

1. An effective dual load path system offers consistency with SAPs EDR.1 (Failure to safety) and EDR.2 (Redundancy). These systems can be complex and need to be suitably engineered to ensure that the intended safety benefit is realised. The use of two hoisting ropes is an example of this. The potential for common cause failure should therefore be considered   
   (SAP EDR.3 (Common cause failure)).
2. There are broadly two approaches to designing dual load path systems. Either:

* a diverse backup system which is normally unloaded, or
* some form of redundancy within the normal operating system which results in a sharing of load during normal operation and a shedding of load on to the parallel system in the event of failure.

1. Some of the issues that need to be considered in assessing such systems are as follows:

* A lifting system with a duplicated load path introduce greater complexity. It also might be difficult to engineer successfully;
* It may be technically challenging to incorporate a normally unloaded redundant system into a lifting system. For example, it is normal practice to incorporate a means of load equalisation into rope reeving systems;
* Regardless of load sharing, the potential for either system to fail and disrupt the other needs to be considered in the fault analysis and the engineering design. Operating failures in either drive chain must not load the parallel system in a manner that leads to its catastrophic failure;
* Both systems must be capable of responding to transient conditions during the full range of motion of the load. For example: starting, stopping, ledged loads, snagging, zero load, overload and the transient initial pickup of the load;
* Both systems need to be reliably synchronised and controlled;
* The redundant/diverse system must be capable of holding the maximum dynamic loads resulting from failure of the primary/first system;
* The requirements for recovering the load need to be established;
* The response of the system to internal faults must not challenge the overall reliability and operability that is required for the complete system; and
* Nuisance tripping - Fault diagnostic methods need to be available to ensure that control of the load is not lost during a trip, e.g. during power failure and hang up. Adequate information for fault diagnosis should be provided to ensure that the lifting system and its load can be recovered safely.

1. The requirements and arrangements to test such systems should be established. The testing should show the claimed performance of safety function to a level commensurate with their classification (SAP EQU.1 (Qualification procedures)).

## Ropes and reeving systems

1. Appendix 7 provides guidance to inspectors for the use of wire ropes in lifting systems. Wire ropes are complex structures that are designed and configured in a wide range of applications. Selection of the wrong rope type may result in operational problems, an increased rate of deterioration and possible damage to the rope and winding equipment. These factors are likely to reduce the rope strength and life. SQEP technical advice should always be sought when assessing the detailed behaviour of wire rope systems for lifting particularly with complex reeving systems.

## Use of proprietary devices

1. Lifting systems are likely to include proprietary equipment. For example, gearboxes, brakes, couplings, bearings, load cells and ropes/rope terminations. The design justification of such equipment may not be readily available, and it is likely that reliance will be placed on commercial rated capacities, etc.
2. In some cases, the only available evidence is a type test certificate. For high integrity type application, this may not be adequate to demonstrate the required level of reliability, design life or tolerance to the fault conditions identified by the safety case.
3. Dutyholders should show that the equipment that has been selected adequately supports the requirements of the safety case. This may involve additional testing and qualification particularly where environmental conditions differ from those foreseen by the original equipment manufacturer (examples may include conditions which promote hydrogen embrittlement).

## Gears, drive shafts and bearings

1. Gearboxes invariably contain a large number of components.   
   These components are subject to relatively complex forces, moments and torques. The failure of any one of these geometrically complex components may result in uncontrolled lowering of the load.
2. Gearboxes should be of rigid construction. They will generally consist of gears that are mounted between bearings. Novel gearing arrangements often introduce more complex loading conditions and failure modes.   
   Hence, they will often require more extensive and technically challenging analysis to justify the design.
3. Fatigue failure of mechanical and structural components within a hoisting mechanism is a major concern. Changes in section and keyways introduce stress concentrations and should be suitably designed to minimise this effect.
4. Focus should be given to the design and set up of drive shafts.   
   Poor alignment of the equipment and lack of rigidity in the supporting structure might introduce additional load cycles. Design assumptions should therefore be suitably communicated (e.g., set up instructions). This should ensure they are not compromised by construction/ assembly and are maintained throughout the life of the equipment (e.g., maintenance instructions).
5. Gearboxes and shafts need to be suitably mounted. This is because they should not be inadvertently loaded due to structural movement in normal operation or faulted conditions.
6. Ball and roller bearings that support such shafts may fail catastrophically. Shafts can be redundantly mounted on simple solid plain bearings.   
   This maintains gear engagement in the event of failure of the rolling element in critical applications.
7. The load carrying capacity of gears can be increased by heat treatment, surface treatment and surface finish. Process variations might affect mechanical properties. Hence, it is essential to achieve a high standard of quality control. For novel and complex heat treatments, parallel manufacture for destructive testing purposes should be considered.
8. Interface components (couplings, clutches) which transmit drive between gearboxes drum rotors and motors should be adequately substantiated in support of the safety case. SAPs Integrity of (metal) components EMC.1 to 34, non-metal ENC.1 and 2 being applicable.
9. Relevant good practice commonly used for gear design for lifting systems can be found in British Standard, BS ISO 6336 [28], noting previously used BS 433 is withdrawn.

## Hooks, lifting features and lifting accessories

1. Hooks, lifting features and ‘below the hook’ lifting accessories   
   (e.g., lifting beams, shackles and slings) provide a means of attaching the load to the lifting device. The system should not generate a reaction that overcomes the attachment retention mechanism inadvertently releasing the load.
2. Positive latching may not be practicable for remotely operated equipment. This is because it may prevent remote disconnection of the load. In such cases, the engagement interface should be configured to reduce the risk of accidental disconnection.
3. Powered attachment mechanisms should be designed so that the load cannot be released if power is lost.
4. Magnetic or vacuum lifting systems should normally only be used where the consequence of a dropped load is tolerable. Where such systems cannot be avoided, redundant support features should be considered.
5. Relevant design codes and standards should be selected and supported by adequate design substantiation, which may include physical testing. It may be beneficial to consider non-nuclear industry good practice given the vast and diverse design options possible in this area.

## Welding

1. The lifting systems mostly include welded structures. Particular attention should be given to the justification and detailing of welds. As fillet welds have poor fatigue performance they should be avoided wherever reasonably practicable.
2. Suitable design codes and standards should be used for assessing the fatigue life of welded structures, e.g., British Standard, BS 7608 [29].
3. The potential for lamellar tearing in a welded structures should be considered. This phenomenon occurs through inclusions in the parent plate material under the weld. Measures should be taken to prevent this occurring (e.g., material selection and non-destructive testing techniques).
4. Inspection is a key aspect in weld assurance given its sensitivity to a number of factors including welder performance, cleanliness, material type, position (accessibility), and welding process used. Inspectors may wish to consider allowable defect sizes, inspection sampling percentages (10, 50, 100%), and Non-Destructive Testing (NDT) technique used.

## Cast iron

1. The suitability of cast iron, especially in tension should be carefully considered. Grey cast iron is prone to brittle fracture, and uncertainty exists in its behaviour under fatigue loading. Proof testing will therefore have limited value when compared to similar tests performed on ductile materials. NDT examination of such materials can be problematic.
2. Cast iron should not be used for load bearing components.   
   However, inspectors should be aware that cast iron might have been used in the load path of older cranes, e.g. hoist gear boxes. The suitability of cast iron should be justified in such applications.

## Seismic considerations

1. Lifting structures and mechanisms are vulnerable to seismic accelerations. They also have complex interactions with the supporting structure and other SSCs. The dynamic seismic loading often frequently dominates the design of such structures. The TAG on external hazards should be consulted with respect to seismic design [30].
2. The seismic analysis might identify the requirement for special engineered features. These features aim to limit and control the effects of seismic events. Inspectors should review the tangible benefits of such systems and ask whether they improve safety, by delivering their design intent.   
   Seismic features that might be considered are:

* Plain (un-flanged) wheels on one rail may be used to accommodate any relative displacement of the two gantries/rails either side of the building. Guide rollers may also be used, instead of flange wheels, to limit skewing effects and sideways movement of the crane. Whether flanged wheels or guide rollers are used, these should withstand the normal service loads, fault conditions and horizontal seismic reactions;
* Seismic restraints provide a redundant and diverse means of preventing crane derailment. The restraints should be of sufficient depth to accommodate any uplift that might occur;
  + For overhead cranes, it may not be necessary to prevent vertical movement as any uplift should effectively isolate the crane from the seismic acceleration. It should be noted that overhead crane gantry systems will need to be designed to react the uplift forces.
  + For cranes that lift outside their wheelbase (e.g., dockside cranes and jib cranes) vertical uplift on one side might occur.   
    A suitable restraint system will be required to prevent overturning.
* Seismic triggers (sensors which provide a switching function) might be required to isolate a crane, cutting power to the drives and applying the brakes. Inspectors should be aware that normal braking systems themselves may not offer sufficient frictional resistance to prevent horizontal movement along the crane rails. Additional braking systems (e.g., seismic rail clamps) may be required. The effects of spurious operation of the brakes/clamps should be assessed as they might generate significant reactions between the crane and the supporting building structure;
* Where seismic triggers are used, the equipment that isolates the plant must be seismically justified to maintain the isolation throughout the event. For example, electrical contactors and brakes will need to be seismically qualified against the maximum dynamic loadings. In addition, plant and control systems that are not seismically justified may be damaged and so will not be serviceable during any subsequent recovery of a suspended load.

## Wind pressure

1. It is often difficult to justify external cranes and temporary lifting systems.   
   In particular, it may be difficult to justify in-service and maximum out-of-service wind loads to the level of confidence that is expected in a nuclear safety justification. For example, lifting gantries, mobile cranes and tower cranes. The peak gust loadings, that apply to such structures that may be intensified by the local topography and surrounding buildings, should be considered (SAP EHA.11 (Weather conditions)).
2. The wind pressure on the load itself can significantly affect the stability and strength of external cranes. The implications for such systems, if the load or crane cannot be moved or removed from the lifting system in the event of high winds, should be considered. This may be established as a limit and condition of operation (LC 23).

## Wheels and rails for Electric Overhead Traveling (EOT) cranes

1. The correct alignment of crane wheels and gantry rails is critical for satisfactory operation. Incorrect alignment can result in accelerated wear of wheel flanges. This then reduces their resistance to skewing and side loadings. Lubrication systems (e.g., graphite) may help to slow down the rate of wear to the wheels and rails.
2. Inspectors may wish to evaluate the adequacy of the dutyholder's EIM&T regime for these features.

# Appendix 3 – Guidance for Electrical, Control and Instrumentation (EC&I) specialist inspectors

1. The guidance explains to inspectors the EC&I aspects for safety of nuclear lifting systems. Where there is any uncertainty or doubt, assessors should seek more detailed technical advice from topic leads/specialists.   
   This appendix indicates the importance of such issues and how they apply to the assessment of lifting systems.

## Introduction

1. Lifting systems incorporate a variety of EC&I systems and, in that respect, are no different to any other powered mechanical system. This section provides guidance to inspectors on aspects of the EC&I systems that are relevant to lifting operations. Inspectors should apply the appropriate SAPs and TAGs relevant to the EC&I specialism in their assessments.

## Motor drives

1. A wide range of electric motor drives have been used on crane systems over the years, ranging from Direct Current (DC) motors to Alternating Current (AC) synchronous induction motors. The torque speed characteristics of each motor type and its failure modes will be different.
2. Modern applications of AC motors may incorporate frequency control to give variable torque and speed characteristics. Such systems are usually based on software and failures of both hardware and software should be considered. Safety Function Class (SFC) claims made on software/ electronics-based protections systems should be carefully assessed   
   (SFC 1 and 2 claims should not be made unless adequate substantiation can be provided).
3. When considering stalled conditions, such as those brought about by restrained loads or double-blocking, the complete drive system inertia and motor characteristics should be examined. Energy dissipating devices and/or torque limiters may be necessary. This equipment limits the loads applied to the lifting machinery and any other equipment and structures that could be affected, e.g. nuclear fuel stringers or reactor cores.
4. During faulted conditions the maximum drive torques within the drive system could arise from the crane motor rather than from the load at the crane drum. Reverse torques may also be generated. The characteristics of the motor and its control system therefore need to be thoroughly understood if the design is to be tolerant to motor faults, e.g., snagged loads, double blocking, spurious brake applications and other faulted conditions.
5. Hydraulic and pneumatic motors and actuators may be used.   
   This equipment may have different characteristics and failure modes to electrical drive systems, e.g., mobile cranes (hydraulic motors) and air hoists.

## Software in motor controllers and other devices

1. Modern frequency-controlled drives incorporate software driven control systems. These systems vary the frequency of supply to the motor and other parameters and is in response to the motor and system inertia and torque. The failure modes of such software driven systems should be established.
2. Software changes should be controlled (LC 20 and 22) and the effect of such changes on the drive characteristics should be assessed including changes to operating limits and conditions.

## Control instrumentation and protection

1. Most industrial cranes will have simple control systems. These systems combine control, protection and motor circuits into a single system.   
   There will be little or no segregation or diversity in such systems and they may be vulnerable to spurious movement. These systems are there to protect the crane from damage. It is unlikely that they will protect the process or other plant and equipment.
2. Various approaches have been taken to addressing the problem of hoist drive train failure. These approaches range from redundant and duplex systems to the provision of emergency braking and protection systems that detect drive train failure or discrepancies in drive ratio between the input and output speed. The response of the mechanical system should be considered.
3. Zoning systems and crash/collision protection systems should be considered. These systems should prevent the initiation of faults that could challenge the integrity of the lifting system or other SSCs within the facility.
4. Such protection systems will typically be found on fuel handling systems, in cell cranes and other sensitive nuclear lifting equipment where out of sequence movements and other faults need to be detected and prevented (further guidance can be found in IAEA Safety Guide, SSG-63 [4]). These are likely to comprise multi-channel protection systems (refer also to the TAG on safety systems [31]).

# Appendix 4 – Guidance on the use of mobile lifting equipment

1. The guidance explains to inspectors, aspects relevant to the use of mobile lifting equipment. Where there is any uncertainty or doubt, assessors should seek more detailed technical advice from the ONR topic lead specialist. This appendix indicates the importance of such issues and how they apply to the assessment of lifting systems.

## Introduction

1. Mobile lifting equipment might be used where there is no suitable permanent lifting option alternative. In specific cases it could offer a solution which, if implemented adequately and safely, can reduce long term risk and facilitate hazard reduction.
2. Using mobile equipment to carry out lifting operations, that are potentially hazardous, dutyholders need to show that the risks are tolerable and ALARP.   
   Any ALARP justification should include optioneering. This is particularly important for activities with the potential for significant off-site release. Examples of such operations includes:

* refurbishment;
* decommissioning; and
* emergency type situations.

1. The ALARP justification should demonstrate that:

* the procedural control arrangements are suitable;
* the risks associated with use of mobile lifting equipment, which should include the effects of catastrophic failure, are tolerable and risk is ALARP;
* all reasonably practicable measures to reduce the consequences of mobile lifting equipment failure have been identified. Examples of such measures include the removal of nuclear inventory, plant shutdown and exclusion of personnel within the collapse zone of the lifting equipment;
* an adequately resourced emergency plan, in the event of catastrophic failure, is in place; and
* Ground conditions have been assessed and are adequate for the specific lifting equipment and specific lifting operation, including set up. Adequate lifting equipment can proceed rapidly to a fault condition through inadequate ground conditions.

## Planning of lifting operations and site preparation

1. Adequate communication between all parties is required.   
   The aim is to ensure the hazards and risks associated with the lifting operation are fully understood, planned by competent person, appropriately supervised (proportionate to the risk) and carried out safely.
2. BS 7121 [22] is a source of relevant good practice for the safe use of cranes. Appendix E provides additional recommendations for operation of cranes on or adjacent to a site of exceptional hazards. This is relevant to nuclear sites and adjacent (e.g., construction) sites. It recommends:

* To limit the maximum load that can be lifted to 75% of the manufacturer's specified rated capacity for the crane configuration chosen. An alternative figure can be derived based on the risk assessment.
* Where possible, the rated capacity indicator and limiter should be programmed with the reduced duty and relevant calibrations verified by testing.

1. The Construction Plant-hire Association (CPA) produces guidance that covers different types of mobile lifting equipment such as mobile and tower cranes:

* CIG 1001 – Maintenance, Inspection and Thorough Examination of Mobile Cranes [32];
* CIG 1901 – Guide to Maintaining Roadworthiness of Mobile Cranes [33]; and
* CPA 1801 – Requirements for Mobile Cranes Alongside Railways Controlled by Network Rail [34]. Details can be found via: [www.cpa.uk.net](http://www.cpa.uk.net)

1. All types of mobile lifting equipment are vulnerable to environmental hazards (e.g., strong wind, lightning strikes, flash flooding and extreme weather). Dutyholders should have arrangements in place to ensure that lifting operations are not carried out on or near a nuclear licensed site if there is any possibility of adverse or extreme weather conditions. These should identify the actions, and timeframe, to make the lifting equipment and load safe.
2. Mobile lifting equipment might be damaged or weakened by seismic accelerations and other forms of earth movement. These events are unpredictable. The safety case should identify, if necessary, the actions to be taken following such events in terms of load recovery.

## Mobile cranes

1. The wide range and capacities of mobile cranes available provides a considerable lifting capability. However, mobile cranes should only be used where the safety case demonstrates that risks are ALARP.
2. Dutyholders may have generic procedures for determining if a mobile crane is to be permitted to work on specific jobs on individual sites.   
   These procedures do not take away the requirement for an adequate safety case or ONR specialist assessment.
3. The vulnerability of mobile cranes should be recognised. Hence, the nuclear and non-nuclear consequences of a collapse should be adequately assessed by the safety case.
4. Many accidents that involve mobile cranes are due to inadequate ground conditions. Mobile cranes will overturn if the ground subsides (fails to support). The ground conditions should be suitably evaluated.
5. Underground services and areas of inadequate localised ground strength should be identified. Adequate load spreader plates (also termed outrigger support pads), should be provided under crane stabilisers and support legs. Outrigger support pads should be substantiated and used/stored/inspected in accordance with safety case requirements (onsite issues in their placement, outrigger positioning on them should not be trivialised as it can affect the design intent). Civil engineering foundations may need to be constructed to support the load imparted by the mobile crane (including counter-balance) and its load.
6. Most mobile cranes are fitted with Automatic Safe Load Indicator (ASLI) systems. These systems aid the operator in setting the working load limits with respect to rigging and outrigger configuration. These systems might be used favourably to reduce risk ALARP. For example, they may enable a smaller and lighter mobile crane to be used.
7. ASLIs are computer-controlled systems. As such they should not be relied upon as the sole means of establishing safe operating limits. The lifting plan should show how the lifting operation is to be safely maintained within the rated capacity of the mobile crane for its rigging and outrigger configuration.
8. The rigging and erection of mobile cranes requires careful attention to be paid to the manufacturer's procedures. The procedures should safeguard that the crane is level (in accordance with manufacturer’s limits), adequately supported and correctly configured for the required lifting operations.
9. Human error can lead to equipment failure. Failure to follow manufacturer’s requirements correctly, or failures in the rigging system under the hook, can result in catastrophic collapse of the crane. This can result in toppling of the complete crane or buckling of the main boom.
10. Mobile cranes have complex boom extending features with slewing.   
    They include luffing capability (boom angle) that operate by non-redundant hydraulic systems. The operating instructions should show the actions and safety measures to be taken should these fail.
11. Mobile cranes are vulnerable to damage and abuse unless their operation and maintenance is strictly controlled. It should be demonstrable that a crane is in satisfactory working condition. It should not have undergone any form of unjustified repair or modification prior to its arrival on site; if at the last minute another model is used then that also being confirmed adequate. Inspectors should give regard here to LC 26 arrangements (Control and supervision of operations).
12. The scope and extent of EIMT of mobile cranes should be shown to be proportionate to the risk. Evidence should be sought that EIMT has been carried out in accordance with the manufacturer’s instructions and by competent persons prior to use.
13. Mobile cranes often contain hydraulic oils. They are also mounted on a vehicle chassis that contains fuel and lubrication systems. The potential risk of fire should be addressed.
14. Mobile crane collapse radii should be determined and where reasonably practicable nuclear materials removed from the zone with fixed nuclear safety equipment related impact assessed and equipment safeguarded.

## Tower cranes

1. Tower cranes are likely to be in located in the same position for extended periods. Hence, the safety case should address the effects of extreme weather conditions on their strength and stability.
2. To minimise wind loadings, tower cranes are normally allowed to weather-vane (this is termed free slew (free to rotate)). The siting and configuration of a tower crane should allow for this free movement. This then protects against collision with other plant and equipment, e.g., other tower cranes and high structures (permanent and temporary).
3. A tower crane may be able to self-erect. This situation introduces added risk of human and software errors during the assembly. This may impact extension and retraction assembly operations. The crane manufacturer’s instructions should be followed and those carrying out erection tasks should be shown to be competent. The safety case should identify the potential for extension or retraction faults, risks from support vehicles (including mobile cranes to aid assembly) with suitable actions and safety measures identified, with adequate substantiation.

## Mobile gantry lifting and jacking systems

1. Mobile gantry lifting and jacking systems may be used to support temporary lifting operations. These systems can often provide a greater lifting capability than a mobile crane. These systems present similar hazards to mobile and tower cranes but a different level of risk. For example, a structural collapse may be more energetic but confined to a limited area. The safety case should demonstrate that the risk of using a gantry lifting or jacking system reduces risk ALARP.
2. Gantry systems can often be large and heavy. They may also be in position for several weeks or months. Hence, it is often necessary to design/ construct or confirm civil foundations to support them.
3. The safety case should consider that gantry systems need to be designed to withstand a variety of climatic conditions. These conditions include wind, rain, snow, degradation mechanisms (e.g., corrosion) and external hazards (e.g., seismic).
4. Specialist knowledge is required to install and operate these systems.   
   Dutyholders should ensure SQEP individuals are involved and available during lifting operations and set up, particularly to resolve issues and aid recovery operations should issues develop. This avoids increased risks of for example suspended loads.

## Site considerations

1. Mobile lifting equipment by its very nature needs access on sites and space to allow manoeuvring into position. Arrangements should include assessment of access and egress, set up including any support vehicles and associated equipment. Vehicle and equipment weights are generally high so any ground conditions, bridges and below ground services tunnels (including manhole covers) will need careful consideration in terms of load ratings.
2. Certain sites will require security checks for vehicles and personnel. In the event of lifting equipment breakdown support (particularly important for suspended load recovery) staff will also require prior security clearances to access the lifting operation.

# Appendix 5 – Guidance on ‘codes and standards’ for nuclear lifting

1. ONR recognises that there are many international, national and internal codes and standards which may be applicable to nuclear lifting. As codes and standards are not mandatory, it is for the dutyholder to select those best suited to their particular circumstances on a case by case basis.   
   ONR inspectors should seek to understand from dutyholders which codes and standards have been selected and why.
2. There is no legal requirement to follow relevant codes and standards for nuclear lifting. It may be that a dutyholder follows no published standard; this may then however warrant more in depth assessment by ONR inspectors.
3. ONR generally considers codes and standards as relevant good practice at an establishedlevel; this is used in enforcement action decision making.   
   For example, a shortfall found against an establishedstandard has the potential to raise the enforcement level. Further details about this can be found in ONR’s Enforcement Management Model (EMM) [35].
4. This guide provides ONR inspectors advice on the use of British standards and European harmonised standards typically used for nuclear lifting applications. Where there is uncertainty or doubt, inspectors undertaking assessment work should seek more detailed technical advice from ONR’s subject matter expert (specialism lead for nuclear lifting).
5. There are no nuclear specific lifting application UK codes and standards. The codes and standards considered relevant good practice are those used by general industry. Should a licensee use such general industry standards for nuclear applications, it is the responsibility of the dutyholder to take into account the additional requirements a nuclear application may present.   
   For example, the dutyholder may deem it appropriate to increase design/ safety conservatisms/margins beyond general industry recommendations.
6. Compliance with harmonised standards provides a presumption of conformity with EHSRs that are set out in Schedule 2 of the SM(S)R [6].
7. BS 466 [36], BS2573 series [37] for example, have been used by GB licensees and crane manufacturers for many years. These standards were the principal design standards for overhead cranes, and other similar types of mechanical equipment. These standards are withdrawn; ONR considers these would not generally be used for new lifting equipment on nuclear licensed sites, rather modern standards being adopted.
8. Gap analysis to modern standards – if a dutyholder opts to use a withdrawn standard, inspectors may undertake more detailed assessment to understand the justification. **Note**: a withdrawn standard may have been withdrawn due to inadequacy.
9. Modern standards emerge to address such shortfalls and as a result ONR may ask dutyholders to undertake a gap analysis between the old and new standards applied to the specific nuclear lifting scenario. Resulting risk reduction improvements identified in the gap analysis should be considered for implementation where reasonably practicable.
10. BS EN 13001 [38] is a currentseries of crane design standards applicable to all types of lifting machinery, considered a modern standard. Other EN standards address specific equipment types. For example, BS EN 15011 [39] is specifically for bridge and gantry cranes and is used in conjunction with BS EN 13001, e.g., for structural strength and rope system design.
11. Comparing old and new standards - Direct comparison of old and new standards may not produce equivalent design outputs. e.g. BS EN 13001 adopts a ‘limit state’ approach. This differs to the ‘allowable stress’ approach taken by BS 2573. A comparison of the two standards will result in different reserve margins when comparing elastic and plastic limits for example.
12. The application and interpretation of design codes and standards relevant to lifting equipment is complex. Inspectors should confirm this work is undertaken by SQEP workers, with design due process followed and independent verification as considered necessary. This may include design review and design change management. Further guidance can be found in the TAGs on the validation of computer codes and calculation methods [40] and design safety assurance [41].
13. Interchangeability - BS 2573 design factors are not interchangeable with BS EN 13001 [38]. Hence, these design factors and related design enhancements are not equivalent. Analysis that is supported by use of a combination of design standards should therefore be avoided, or adequately justified as to why it is appropriate (refer to SAP ECS.3 - Codes and standards para 173).
14. The dutyholder safety case should take account of how the lifting equipment could fail. Codes and standards adopted for nuclear lifting equipment design should be suitably applied to provide a gradual and predictable failure mode (SAP EMC.11 (Failure modes)).
15. The suitability of a design code and standard should be considered against the requirement of LC 15 - Periodic Review [42], which should:

* Carry out a comparison against the current codes and standards for new plant;
* Evaluate any shortfalls;
* Implement any reasonably practicable improvements that will enhance safety; and
* Consider impending changes to design codes and standards.   
  A comparison should be made of these standards to show that appropriate conservatisms and safety margins are maintained.

## Design classification of lifting equipment structures and mechanisms

1. The design of lifting equipment is safety classified recognising the differences in lifting operations. These differences affect SSC fatigue life and component wear; and must be addressed by design. The classification of the lifting system, its structures and mechanisms should be demonstrably conservative (refer to SAPs ECS.2 and EMC.30).
2. The working cycles of a lifting system start from the day it is installed, and continue through all activities to the day it is taken out of service. It should therefore include the following factors:

* Loads that are imposed during the installation of the lifting system.
* Lifting equipment that is used for construction and installation of other plant and equipment.
* Setting to work, testing and commissioning. This is particularly important for store cranes, where the full range of system capability has to be proved before the store inventory is first introduced.
* Normal plant operation.
* Plant faulted conditions e.g. control and protection system trips and recovery actions.
* Post-Operative Clean-Out operations (POCO).
* Decommissioning operations.
* Maintenance and testing requirements for other plant and equipment it may support.
* In-service inspection requirements for other plant and equipment.
* Lifting system maintenance and in-service testing requirements.

1. A key area for nuclear lifting assessment is ‘lift planning.’ BS 7121 – Code of practice for the safe use of cranes [22], provides guidance in this regard. This states all lifting operations should be planned, to ensure that they are carried out safely and that all foreseeable risks are taken into account. BS 7121 states the competent person for planning lifting operations is referred to as the appointed person.

1. Lift planning should include:

* The load, its characteristics and the method of lifting;
* Adhesion between the load and its supports;
* The stability of the load;
* Motion, acceleration / deceleration speeds;
* Selection of the lifting equipment and associated clearances;
* Selection of suitable lifting accessories;
* Position of the lifting equipment, load, ground conditions and proximity to hazards;
* Zones or restrictions;
* Set up/testing requirements;
* Selection of persons undertaking and managing the lifting operation;
* Environmental conditions.

# 

# Appendix 6 – Guidance on failure modes, protection and mitigation

## Introduction

1. The guidance provided intends to identify the principal faults that can occur during lifting operations. It also identifies the measures that might be taken to address them. These measures may be physical design features and/or operational measures and should be subject to ALARP consideration. Inspector judgements should therefore be proportionate to the severity of the hazard and its consequences.
2. Where there is any uncertainty or doubt, assessors should seek more detailed technical advice from the ONR topic lead specialists.

## Safety case

1. The safety case should clearly identify:

* how the faults may propagate,
* what are the possible consequences; and
* what actions are required to achieve a safe condition.

## Faults

1. The tables below provide worked examples of the preventative and mitigation measures that may be in place to support lifting operations.   
   They also include operator actions. These tables serve as a guide only, not a definitive list. Each case should be reviewed and assessed individually.   
   The tables cover:

* the planning of lift layout and equipment design;
* indication and warning systems;
* the protection and mitigation systems;
* operator instructions and SQEP;
* the recovery to safety; and
* the reporting of incidents.

1. This appendix focuses on individual faults. However, interactions with other plant and equipment may cause other faults. Inspectors should use their judgement and experience to adequately assess each situation to arrive at an informed judgement. Inspectors should review fault schedules and hazard analysis from which inspection sampling can be determined.   
   Consultation with ONR Fault Studies specialists is recommended for additional guidance.
2. Diagrammatical examples are presented in tables 1-12. These examples provide inspectors with a general appreciation of the lifting faults that can occur. In most cases, these are represented by an overhead crane. Inspectors should use their judgement to understand how these faults will affect the lifting system. Where necessary, the ONR topic lead specialist should be consulted for further specific guidance.

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Table 1 - Fault condition: Double blocking

| Double blocking | |
| --- | --- |
| Hook block, lifting accessory or load connects with underside of lift (raise direction).  Leads to catastrophic hoist component failure and uncontrolled lowering. |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. The lifting system design does not require loads to be lifted to the full height of lift available. 2. Adequate clearances is in place between load, lifting accessory and underside of crane. 3. The lifting configuration provides adequate clearance. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Visible indication is in place to show when the hook and assembly are approaching the top of lift. 2. The limit switch only allows lowering when hook is fully raised. 3. A height indication system is in place. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Over raise limits are in place. 2. Mechanical torque limiter is in place (with over lower protection system). 3. Crushable element (one time use) system is in place.   **Note** - electrical overload systems should not be considered as a suitable means of protecting against double blocking) |
| Operator Instructions (LOLER Reg 8) | 1. Loads are restricted from lifting to full height of lift (e.g., sufficient to clear obstructions only). |
| Recovery to Safety | 1. Procedure is in place for the safe set down of the load. 2. The lifting zone is clear of personnel. 3. Thorough examination is carried out by a Competent Person. 4. A review is carried out and prevention actions implemented. 5. Incidents are reported and the Competent Person involved. |
| Report incident  (LC 7) (LOLER Reg 10) | 1. An incident report is raised. 2. ONR is informed as appropriate under site licence arrangements and RIDDOR. |

Table 2 - Fault Condition: Overload

| Overload | |
| --- | --- |
| Item (including lifting accessories) to be lifted heavier than the safe working load (SWL) of lifting device. |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Schedule of loads to be lifted is in place. 2. Lifting plans are available. 3. The weight of item being lifted, and weight of lifting accessories is known (e.g., marking). 4. Dedicated/fixed lifting equipment is in place for items that are regularly lifted. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Load cells and displays are in place either on the lifting device or incorporated into the lifting arrangement. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Overload trips which are typically set at 105 to 110% SWL of lifting device. The trips should be set no greater than proof load = 125% SWL. They should trip all motions except lower. 2. A mechanical torque limiter is in place. |
| Operator Instructions (LOLER Reg 8) | 1. The load is progressively pickup. No movement should take place before the weight is confirmed as safe to lift. 2. A lifting supervisor is in place. 3. A rigger is in place for loose lifting equipment. |
| Recovery to Safety | 1. Recovery procedure is in place. Thorough examination is carried out by a Competent Person. |
| Report incident (LC7) (LOLER Reg 10) | 1. An incident report is raised. 2. ONR is informed as appropriate under site licence arrangements and RIDDOR. |

Table 3 - Fault Condition: Restrained load

| Restrained load | | |
| --- | --- | --- |
| Item cannot be lifted freely |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Any potential restraining features are removed. 2. The release/break of any retention features/effects is confirmed before the lift is carried out. For example, cutting and jacking operations. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Load cells and displays are in place either on the lifting device or incorporated into the lifting arrangement. 2. Compliant lifting systems. For example, spring arrangement that indicate the load being applied. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Overload trips which are typically set at 105 to 110% SWL of lifting device. The trips should be set no greater than proof load = 125% SWL. They should trip all motions except lower. 2. A mechanical torque limiter is in place. |
| Operator Instructions (LOLER Reg 8) | 1. The load is progressively pickup. No movement should take place before the weight is confirmed as safe to lift. 2. A lifting supervisor is in place. 3. A rigger is in place for loose lifting equipment. |
| Recovery to Safety | 1. Procedures are in place for the safe set down. 2. Procedures only allow lowering unless it is initially safe to raise. 3. Override facility is in place which either resets automatically or is subject to management control. |
| Report incident (LC 7) (LOLER Reg 10) | 1. An incident report is raised. 2. ONR is informed as appropriate under site licence arrangements and RIDDOR. |
| **Note:** Inspectors should note that the response time of electrical overload systems may not respond prevent a major overload such as loads that are likely to exceed 125% SWL). | |

Table 4 - Fault Condition: Load snagging

| Load snagging | | |
| --- | --- | --- |
| Load connects with overhanging obstruction during lift (RAISE DIRECTION) |  | |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Obstructions are designed out. For example, there are no overhanging obstructions, and the vertical sides are smooth. 2. There are adequate clearances in place between the load and other plant and equipment. 3. The load is aligned to ensure adequate clearances. For example, north, south, east and west. 4. There are detailed zones in place to ensure the loads lifted are clear of obstructions. 5. The operator is able to control the position to optimise visibility. For example, a wireless controller is used. Wireless signal is present and arrangements include failsafe action in the event of a loss of signal. | |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Indication is in place that the crane hook is in correct position. For example:    1. A marker board system is in place.    2. Indicator lamps are in place to show control position (tested prior to lift to confirm working).    3. Laser and floor mounted targets are in place. 2. Overload indication is in place, noting they do not offer protection. | |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. A weight tare system is in place that sets the weight after it has been lifted and is able to detect any change, noting their effectiveness may be limited. 2. A tilt detection system is in place, noting their practicability. | |
| Operator Instructions (LOLER Reg 9) | 1. Should look to eliminate or limit load swing. 2. Operators should take a caution approach. The use of prerequisite conditions, hold points, and banksman is encouraged. Reliable communication methods should be in place. 3. The load and obstruction should be fully visible by taking the most advantageous viewing position. 4. Non-essential people should be restricted from access using exclusion zones. | |
| Recovery to Safety | 1. Set load down safely. 2. Emergency plan available.    1. Establish exclusion zone.    2. Review hazards (e.g., external damage).    3. Establish recovery strategy. | |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). | |
| **Note:** Inspectors should note that the response time of electrical overload systems may not respond prevent a major overload such as loads that are likely to exceed 125% SWL). | |

Table 5 - Fault condition: Uncontrolled lower

| Uncontrolled lower | |
| --- | --- |
| Mechanical or EC&I System failure leading to high speed or free fall descent of load. |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Package drop withstand. 2. Structural withstand of Structures Systems and Components (SSCs) vulnerable to impact damage. 3. Minimisation of lift heights, height within deterministic drop withstand capability of load / SSCs below the load. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Hoist drive overspeed detection (only suitable for speed control system faults not mechanical failures). |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Overspeed trip (application of hoist brakes). 2. Emergency braking (on rope barrel). 3. Mechanical comparator (input vs output speed). 4. Load arrest system (on rope barrel). 5. Impact absorbers (in floor). 6. Dead man’s handle (only suitable for speed control system faults not mechanical failures). 7. Load follower system (separate to crane). 8. Dual load path. |
| Operator Instructions (LOLER Reg 9) | 1. Release of controls (only suitable for speed control system faults not mechanical failures). 2. Emergency stop (only suitable for speed control system faults not mechanical failures). 3. Examine load/lifting gear. 4. Operator instructions in response to event. |
| Recovery to Safety | 1. Facility emergency plan. 2. Establish exclusion zone. 3. Health Physics monitoring. 4. Identify and review long term actions. 5. Damage assessment. |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 6 - Fault condition: Ledged load

| Ledged load | |
| --- | --- |
| Lowered onto overhanging obstruction |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Design out obstructions (e.g., no overhangs). 2. Adequate clearances between load and other plant. 3. Control alignment of the load (e.g., north/south) to maximise clearances. 4. Detailed zones to ensure loads lifted are clear of obstructions. 5. Operator control position to optimise visibility (e.g., use of wireless control). |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Indication that the crane hook is in correct position, e.g. 2. Marker boards and pointers. 3. Indication lamps. 4. Laser and floor mounted target. 5. Load measurement display (N.B. not protection). |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Weight tare system\* – setting weight after it has been lifted and detection of change.  (N.B. effectiveness may be limited). 2. Tilt detection. |
| Operator Instructions (LOLER Reg 9) | 1. Ensure load swing eliminated before commencing lifting operation. 2. Operator diligence (e.g., use of banksman and reliable communication). 3. Ensure operator visibility of load and obstruction (most advantageous position). 4. Establish an exclusion zone for non-essential persons. |
| Recovery to Safety | 1. Emergency plans. 2. Establish exclusion zone. 3. Review hazards (e.g., external damage). 4. Establish recovery strategy. 5. Set load down safely. |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |
| **Note:** Inspectors should note that weight tare and slack rope detection may not be suitable as the ropes might still be under tension following a ledged load condition. | |

Table 7 - Fault condition: Load collision

| Load collission | |
| --- | --- |
| Load connects with overhanging obstruction during movement. | Fault condition, load collisiopn.  Load connects with overhanging obstruction during movement. |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Predetermined route identified. 2. Adequate clearance confirmed along route. 3. Potential for load movement/rotation and/or sway considered. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Control alignment of the load (e.g., north/south) to ensure adequate clearances. 2. Pre-determined routes to ensure loads are lifted clear of obstructions. 3. Ensure operator visibility of load and obstruction (most advantageous position) 4. Proximity alert system. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Physical barriers. |
| Operator Instructions (LOLER Reg 9) | 1. Lifting supervisor and banksman task definition. 2. Regain control if possible and assess integrity of load and crane. 3. Assess damage if fault occurs and notify supervisor of incident. 4. Reporting of incident and involvement of Competent Person (inspect for damage). 5. Exclude non-essential persons. |
| Recovery to Safety | 1. Procedure for safe set down. 2. Site Emergency planning (for breach of containment). 3. Health physics monitoring. 4. Identify and review long term actions. |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 8 - Fault Condition: High wind

|  |  |
| --- | --- |
| High wind | |
| Excessive wind pressure on lifting device or load | Fault condition, High Wind. Excessive wind pressure on lifting device or load. |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Procedure for establishing wind speed before undertaking lifting operations (consult weather forecast). 2. Nature of load (e.g., ‘sail’ area of load). 3. Appropriate wind speed/height consideration 4. Pre-determined allowable wind speed. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Wind speed detectors (anemometers). 2. Warning system if wind speed exceeds allowable during lifting operations. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Storm anchors for outdoor cranes. 2. Free slew (tower cranes). |
| Operator Instructions (LOLER Reg 9) | 1. No lifting to commence if wind speed exceeds defined limit. 2. Defined wind speed for stopping operations. 3. Procedure for load set down and making load and lifting device safe. 4. Exclude non-essential persons. 5. Essential persons at safe distance from lifting operation. 6. Instructions for controlling the load. |
| Recovery to Safety | 1. Procedure for safe set down of load. 2. Procedure for securing lifting device. |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 9 - Fault condition: Seismic

|  |  |
| --- | --- |
| Seismic | |
| Seismic acceleration increases forces acting on lifting device and load. |  |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Avoid interactions with building/other equipment. 2. Seismic restraints. 3. Lifting device and accessories seismically qualified. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Not practicable – no warning of event. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Seismic isolation triggers, cut power to lifting device. 2. Seismic qualification of critical systems. 3. Mechanical and electrical systems qualified against for seismic accelerations. 4. Friction clamps and locking systems (prevent movement). |
| Operator Instructions (LOLER Reg 9) | 1. Seismic event procedures. 2. Evacuation protocol if required. 3. Site emergency planning. |
| Recovery to Safety | 1. Procedure for safe making lifting system and load safe. 2. Procedure for lowering load. 3. Embargo of lifting operations (assess condition of lifting. system and load before return to service). |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report (site event reporting). 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 10 - Fault condition: Derailment

|  |  |
| --- | --- |
| Derailment | |
| Over travel or wheel failure of motor driving. Failure on crab resulting in potential slewing of lifting device. | Fault Condition: Derailment. Over travel or wheel failure of motor driving. Failure on cab resulting in potential slewing of lifting device. |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Physical end stops and buffers (energy absorbers). 2. Flanged wheels. 3. Guide rollers. 4. Side restraints (e.g., seismic). 5. Drive system has insufficient tractive effort to cause derailment. 6. Know physical limits, plan to work adequately inside these limits. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Control system inhibits fast speed when the lifting system is approaching end stops. 2. Proximity alerts when approaching end of travel, clear physical markings indicating working range. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Anti-skew detection. 2. End of travel limit switch protection (requires back out system). |
| Operator Instructions (LOLER Reg 9) | 1. Stop lifting operation. 2. Report to supervisor. 3. Plan recovery. |
| Recovery to Safety | 1. Procedure for safe set down of load. 2. Damage assessment (ensuring no further progression of fault). 3. Review and identify long term actions. |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 11 - Fault condition: Crane-to-crane collision

| Crane-to-crane collision | |
| --- | --- |
| Cranes or loads collide (also applicable to cranes running on the same gantry or one above each other, crane to building/object collision) | http://www.tac3000.com/Images/product/Anti-collision path protection/AntiCollisionDiagram.gif |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Coverage of each crane clearly defined and non-intersecting. 2. Adequate distance between cranes to avoid collisions. 3. Adequate clearance between crane jibs to allow for weather vaning (free slewing in wind). 4. Planning of lifting operations identifying potential for collision and measures to avoid, movement hierarchy established. 5. Risks reviewed if cranes relocated (e.g., mobile cranes). 6. Parking positions when cranes are not in use. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. Proximity alarms. 2. Visual indication – physical markings on ground, facility. 3. Exclusion zones. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Software tracking of crane/hook position. 2. Safe operating zone system. 3. Clear visuals for operator during lifting operations. 4. Avoid blind spots and/or obstructions. 5. Emergency stops. |
| Operator Instructions (LOLER Reg 9) | 1. Planning meetings (identification of risk). 2. Reporting of incident and involvement of Competent Person (inspect for damage). 3. Lifting supervisor – control and management of lifting operation. 4. Effective lift team, facility team communication. |
| Recovery to Safety | 1. Procedure for safe set down. 2. Assess damage and ensure fault sequences will not develop. 3. Thorough examination (Competent Person). |
| Report incident (LC 7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

Table 12 - Fault Condition: Mobile crane collapse

|  |  |
| --- | --- |
| Mobile crane collapse | |
|  | Fault condition. Mobile crane collapse. |
| Planning of Lift (layout and equipment design) (LOLER Reg 8) | 1. Detailed lift plan (loads and radius of lift established). 2. Ground strength and underground infrastructure (e.g., service ducts and drains) established. 3. Site layout and lifting restrictions established. 4. Restrict proximity to civil works. |
| Indication/Warning Systems (LOLER Reg 7b) | 1. On-screen display of mobile crane and its lifting configuration. 2. Load and moment indication (alarm). 3. Ground markings for outriggers and associated spreader plates. |
| Protection & Mitigation Systems (LOLER Reg 6) | 1. Automatic safe load indication. 2. Remove nuclear inventory from collapse zone / safety systems which could be impacted in the vicinity from projectiles. 3. Emergency stop. |
| Operator Instructions (LOLER Reg 9) | 1. Progressive pickup of load to confirm load safe to lift. 2. Lifting supervisor. 3. Effective communication (control of lifting operation). 4. Clear communication and knowledge of limits and conditions. |
| Recovery to Safety | 1. Operation for safe set down. 2. Site procedures. 3. Thorough examination (Competent Person). |
| Report incident (LC7) (LOLER Reg 10) | 1. Raise incident report. 2. Inform ONR (as appropriate under site licence arrangements and RIDDOR). |

# Appendix 7 – Guidance on wire ropes

1. The guidance supports the assessment of wire ropes used in lifting systems. Where uncertainty or doubt exists, assessors should seek more detailed technical advice from topic leads/specialists.

## Wire rope fundamentals

1. Inspectors should consider which wire rope fundamentals are suitable and appropriate for their assessment or inspection sample.
2. Wire rope fundamentals include:

* management systems;
* design;
* procurement;
* manufacture;
* assembly;
* verification and implementation testing;
* commissioning;
* examination, inspection, maintenance and testing (EIMT); and
* decommissioning.

## Wire rope management systems

1. Inspectors may wish to consider whether the dutyholder wire rope management arrangements:

* identify the safety case requirements (refer to the TAG on the purpose, scope and content of Safety Cases [43]);
* are understood and used by SQEP;
* demonstrate configuration control;
* identify the potential for unsafe or illegal operations;
* identify the wire rope’s:
  + categorisation and classification;
  + performance requirements;
  + equipment qualification (EQ) verification tests[[1]](#footnote-2).ONR SAP EQU.1 (Qualification procedures) [44] apply;
  + EQ implementation tests[[2]](#footnote-3); and
  + commissioning requirements. ONR SAP ECM.1 (Commissioning testing) [44] apply.

1. Inspectors may wish to refer to the TAG on asset management [45] when considering the wire ropes safety function at the required performance and reliability throughout service life.

## Procurement

1. Inspectors may wish to consider whether the dutyholder has adequately demonstrated the control of wire rope procurement. Examples include, construction, Safe Working Load (SWL), minimum breaking force, lubrication, material type and associated certification. The following applies:

* The TAG on supply chain management arrangements for the procurement of nuclear safety-related items or services [46]; and
* SAP EMC.3 (Evidence) [44].

1. Section 6.8 of [46] refers to Counterfeit, Fraudulent and Suspect Items (CFSIs). Indications of suspect CFSI may be incomplete or lack of documentation, and alteration of documentation. Inspectors may wish to consider whether the dutyholder has adequate arrangements in place to mitigate CFSI and can demonstrate an adequate intelligent customer capability. SAP MS.2 (Capable Organisation) [44] applies.

## Assembly

1. Inspectors may wish to consider whether wire rope system performance requirements are affected by the assembly. Where this is the case, inspectors should consider whether:

* Assembly processes that may affect safety case requirements are clearly identified in the work instructions;
* Adequate management of assembly requirements have been achieved; and
* Suitable testing is specified. SAP EMT.3 (Type-testing) [44] applies.

## Commissioning

1. Wire rope system commissioning may be a Site Acceptance Test, Factory Acceptance Test or Factory and Site Acceptance Test. SAPs EMT.5 (Procedures) and ECM.1 (Commission testing) apply [44].
2. Inspectors may wish to consider whether commissioning activities adequately demonstrate that:

* Assembly has been completed;
* Safety case requirements have been achieved; and
* Where appropriate, a third-party independent verification has been undertaken prior to nuclear use.

## Examination, Inspection, Maintenance and Testing (EIMT)

1. For high-risk applications it is considered relevant good practice for dutyholders to decrease the wire ropes probability of failure occurrence and increasing the wire rope reliability. British Standard, BS EN 13135 [20], provides further guidance. In such applications, inspectors may wish to consider whether the dutyholder has adequate maintenance instructions, which may incorporate:

* a reduction in periodicity between inspections;
* more rigorous inspection scope; and
* more accurate inspection methods.

1. Intrusive inspection of the internal core structure may damage the rope. It is not recommended for certain types of rope construction, e.g., ropes with compacted strands (‘dyform’) or plastic inserts. A programme of periodic replacement, supported by destructive testing and surveillance of discarded ropes, should be considered.

## Wire rope degradation

1. Inspectors should recognise that wire ropes can degrade and deteriorate in many ways, examples are:

* broken wires;
* working in the crossover zone resulting in broken wires and deformation;
* worn and/or abraided wires;
* rope elongation;
* diametetric decrease or increase;
* corrosion (internal and external);
* deformation and damage;
* waviness;
* bends;
* basket deformation;
* hydrogen embrittlement;
* damage due to excessive heat;
* fracture of strands;
* bird caging;
* core/strand protrusion or distortion;
* kink or tightened loop; and
* high stranding and unlaying.

1. Corrosion can occur throughout the rope structure which affects the ropes internal strands and wires. This is especially relevant to consider for exposed marine environments or where ropes enter and leave water (e.g., ponds with chemical additives).
2. Although stainless steel ropes may be less susceptible to corrosion effects, they are vulnerable to internal abrasion (galling) that occurs between stainless steel surfaces. This damages the internal wires of the rope.   
   Expert advice should be sought for critical applications to determine the most suitable rope material, inspection techniques and discard criteria.

## Wire rope and reeving systems

1. Whilst a rope may appear to have a large reserve margin, this will be based on a minimum tensile breaking strength (confirmed by the destructive testing of a sample length). This reserve margin will reduce over time. Suitable fleet angles, pulley and drum diameters, groove shapes and radii will reduce fatigue and wear. Reverse and transverse bends in rope systems should be avoided wherever practicable.
2. Applicable standards/codes:

* BS ISO 16625: 2013 - Cranes and hoists - Selection of wire ropes, drums and sheaves [47] provides guidance on the termination selection for wire ropes. It also details that the different types of termination have different performance levels and efficiencies;
* BS EN 13001-3-2: 2014 - Cranes. General design - Limit states and proof of competence of wire ropes in reeving systems [48] provides minimal practical design factors for mechanisms, rope types, rope duties and types of spooling. Standard also provides selection factors for drums and sheaves;
* BS EN 13411 - Terminations for steel wire ropes. Safety [49]   
  (parts 1-9) provides further guidance on the different types of wire rope terminations;
* BS EN 12385-3:2020 Steel wire ropes. Safety - Information for use and maintenance [50]; and
* BS EN 13135:2013+A1:2018 - Cranes. Safety. Design. Requirements for equipment [20].

1. For some installations dutyholders may be unable to stay within the allowable maximum fleet angles recommended in British Standard,   
   BS EN 12385-3 [50]. In these circumstances, the dutyholder should undergo more frequent EIMT and demonstrate that its arrangements are ALARP. Paragraph 35 provides advice on high-risk applications and refers to British Standard, BS EN 13135 [20] for further EIMT guidance.

## Wire rope lubrication

1. Wire rope lubrication is important to provide protection against corrosion and mitigate friction that can occur within the wire rope construction and other lifting accessories (sheaves and drums).
2. A shorter rope life can be expected due to no relubrication. It is considered good practice for EIMT periodicity to be reduced accordingly to monitor the ropes condition.
3. The following standards provide additional information on lubrication:

* ISO 4346 [51] provides guidance on the nature and properties of lubricants used in the manufacture of wire ropes for general purposes; and
* BS ISO 4309 [52] provides further guidance on lubrication.

## Handling, storage and use

1. Inspectors may wish to consider whether dutyholder wire rope handling and storage is adequate.
2. Wire ropes do not have a defined shelf life, provided the rope has been stored and maintained appropriately to mitigate degradation.   
   Therefore, dutyholders should have arrangements which are suitable and adhere to RGP such as British Standard, BS ISO 4309 [52].
3. Inspectors may wish to consider whether the dutyholder has considered the operating environment. In detrimental environments, it is considered good practice to carry out pre-use checks, reduce the EIMT periodicity and regularly assess and monitor the rope condition. British Standard, BS EN 12385-3 [50] provides guidance of pre-use checks prior to installation.
4. British Standard, BS EN 12385-3 [50] provides guidance for wire rope used in exceptionally hazardous conditions such as radioactive high hazard applications. Inspectors may wish to consider whether the dutyholders has suitability undertaken a risk assessment which identifies the safe working load limit, suitable reduction or de-rating.

## Decommissioning

1. Wire ropes are likely to have a finite service life and degrade during use. Inspectors may wish to consider whether an adequate discard criteria is used by the dutyholder. British Standard, BS ISO 4309 [52] provides further guidance on wire rope discard criteria.

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# Appendix 8 – Guidance on conformity marking for the UK

1. Following the UK’s withdrawal from the EU, the United Kingdom (UK) government implemented legislation to continue recognition of current European Union (EU) requirements for a range of product regulations, including the CE marking (Conformité Européenne, or European Conformity marking) for a range of product regulations.
2. In addition, the UK conformity assessment (UKCA) marking was introduced and can be used on products placed on the market in Great Britain (GB).   
   It shows that products comply with requirements in legislation applying in GB.
3. This means businesses had the flexibility to use either the UKCA (UK Conformity Assessed) or CE marking to sell products in Great Britain (GB) until 31 December 2024.
4. Further information and explanation regarding conformity marking can be found at:

* <https://www.gov.uk/guidance/placing-manufactured-goods-on-the-market-in-great-britain>
* <https://www.gov.uk/guidance/ce-marking>

1. The above legislation makes it illegal to supply lifting equipment anywhere within either the EU or the UK unless the relevant regulations have been satisfied. There is also a duty to ensure that the equipment is safe regardless of any process followed.
2. It is important to note that if a dutyholder manufactures equipment for their own use, they are legally considered to be a manufacturer and the regulations will equally apply unless the nuclear exclusion applies as described in Appendix 1.

# References

|  |  |
| --- | --- |
| [1] | ONR, “Safety Assessment Principles (SAPs) for Nuclear Facilities - 2014 Edition (Revision 1),” 2020. |
| [2] | Western European Nuclear Regulators Association (WENRA), *WENRA Safety Reference Levels for Existing Reactors,* 2020. |
| [3] | International Atomic Energy Agency (IAEA), *IAEA Safety Standard, Specific Requirements No. SSR-2/1 (Rev.1) Safety of Nuclear Power Plants: Design,* 2016. |
| [4] | International Atomic Energy Agency (IAEA), *IAEA Safety Guide No. SSG-63 - Design of Fuel Handling and Storage Systems for Nuclear Power Plants.* |
| [5] | HSE, *Lifting Operations and Lifting Equipment Regulations (LOLER),* 1998. |
| [6] | HSE, *The Supply of Machinery (Safety) Regulations (SM(S)R), 2008.* |
| [7] | HSE, *Provision and Use of Work Equipment Regulations (PUWER),* 1998. |
| [8] | HSE, *Health and Safety At Work Act (HSWA),* 1974. |
| [9] | HSE, *Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR),* 2013. |
| [10] | European Commission, *Guide to application of the Machinery Directive 2006/42/EC - Edition 2.3.* |
| [11] | HSE, *Management of Health and Safety at Work Regulations (MHSWR),* 1999. |
| [12] | HSE, *The Construction (Design and Management) Regulations (CDM2015),* 2015. |
| [13] | HSE, *The Electromagnetic Compatibility Regulations,* 2006. |
| [14] | HSE, *The Electricity at Work Regulations,* 1989. |
| [15] | HSE, *The Work at Height Regulations,* 2005. |
| [16] | HSE, *Lifting Operations and Lifting Equipment Regulations: 1998 Approved Code of Practice (ACoP),* 1998. |
| [17] | ONR, *NS-TAST-GD-006, Design Basis Analysis, Issue 5.1 [CM9 2020/37019],* 2022. |
| [18] | ONR, *NS-TAST-GD-041, Criticality Safety, Revision 7 [CM9 2020/281118],* 2019. |
| [19] | ONR, *NS-TAST-GD-014, Internal Hazards, Issue 7.1 [CM9 2021/63258],* 2022. |
| [20] | BSI, *BS EN 13135:2013+A1:2018 - Cranes, Safety, Design, Requirements for Equipment.* |
| [21] | U.S. Nuclear Regulatory Commission , *NUREG-0554, Single-Failure-Proof Crane for Nuclear Power Plants,* 1979. |
| [22] | BSI, *BS 7121 - Code of practice for the safe use of cranes - Inspection, maintenance and thorough examination (multi-part standard).* |
| [23] | ONR, *NS-TAST-GD-063, Human Reliability Analysis.* |
| [24] | ONR, *NS-TAST-GD-058, Human Factors Integration (HFI).* |
| [25] | ONR, *NS-TAST-GD-064, Allocation of Function Between Human and Engineered Systems.* |
| [26] | ONR, *NS-TAST-GD-016, Integrity of Metal Structures, Systems and Components.* |
| [27] | ONR, *NS-TAST-GD-009, EIM&T of Items Important to Safety.* |
| [28] | BSI, *BS ISO 6336 - Calculation of load capacity of spur and helical gears.* |
| [29] | BSI, *BS 7608:1993, Code of Practice for Fatigue Design and Assessment of Steel Structures.* |
| [30] | ONR, *NS-TAST-GD-013, External Hazards.* |
| [31] | ONR, *NS-TAST-GD-003, Safety Systems.* |
| [32] | CPA, *CIG 1001 – Maintenance, Inspection and Thorough Examination of Mobile Cranes,* 2019. |
| [33] | CPA, *CIG 1901 – Guide to Maintaining Roadworthiness of Mobile Cranes,* 2019. |
| [34] | CPA, *CPA 1801 – Requirements for Mobile Cranes Alongside Railways Controlled by Network Rail,* 2018. |
| [35] | ONR, *ONR-ENF-GD-006, Enforcement (EMM).* |
| [36] | *BS 466:1984 Specification for Power Driven Overhead Travelling Cranes, Semi-Goliath and Goliath Cranes for General Use.* |
| [37] | *BS 2573 Series, Rules for Design of Cranes.* |
| [38] | BSI, *BS EN 13001-1: 2015, Cranes, General design, General Principles and Requirements.* |
| [39] | BSI, *BS EN 15011:2020, Cranes, Bridge and Gantry Cranes.* |
| [40] | ONR, *NS-TAST-GD-042 - Validation of Computer Codes and Calculation Methods.* |
| [41] | ONR, *NS-TAST-GD-057 - Design Safety Assurance.* |
| [42] | ONR, *NS-INSP-GD-015 - LC15 Periodic Review.* |
| [43] | ONR, *NS-TAST-GD-051, The Purpose, Scope and Content of Safety Cases.* |
| [44] | ONR, *Safety Assessment Principles (SAPs) for Nuclear Facilities - 2014 Edition (Revision 1),* 2020. |
| [45] | ONR, *NS-TAST-GD-098, Asset Management.* |
| [46] | ONR, *NS-TAST-GD-077, Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services.* |
| [47] | BSI, *BS ISO 16625 - Cranes and hoists - Selection of wire ropes, drums and sheaves,* 2013. |
| [48] | BSI, *BS EN 13001-3-2: 2014 - Cranes. General design - Limit states and proof of competence of wire ropes in reeving systems.* |
| [49] | BSI, *BS EN 13411 - Terminations for steel wire ropes. Safety.* |
| [50] | BSI, *BS EN 12385-3, Steel Wire Rope Series – Part 3: Information for use and maintenance.* |
| [51] | ISO, *ISO 4346:1997:+A2017, Steel Wire Ropes for general purposes, Lubricants, Basic requirements.* |
| [52] | BSI, *BS ISO 4309:2017, Cranes, Wire ropes, Care and maintenance, inspection and discard.* |
| [53] | American Society of Mechanical Engineers (ASME), “ASME, NOG-1, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder),” 2020. |
| [54] | U.S. Nuclear Regulatory Commision, *NUREG-0612, Control of Heavy Loads at Nuclear Power Plants,* 1980. |

# 

# Glossary and abbreviations

AC Alternating Current

ACoP Approved Code of Practice

ALARP As Low As Reasonably Practicable

ASLI Automatic Safe Load Indicator

BS EN British Standard Euro Norm

BWR Boiling Water Reactor

CBA Cost Benefit Analysis

CCF Common Cause Failure

CDM Construction (Design and Management) Regulations

CE Conformité Européenne

CNS Civil Nuclear Security (Office for Nuclear Regulation)

CPA Construction Plant-hire Association

COTS Commercially (available) Off-The-Shelf

DBA Design Basis Analysis

DC Direct Current

EC&I Electrical, Control and Instrumentation

EIMT Examination, Inspection, Maintenance & Testing

EMC Electro-Magnetic Compatibility

EMI Electro-Magnetic Interference

EN Euro Norm

EQ Equipment Qualification

EHSR Essential Health and Safety Requirements

GB Great Britain

FME Foreign Material Exclusion

HSE Health and Safety Executive

IAEA International Atomic Energy Association

HSWA The Health and Safety at Work etc Act

IAEA International Atomic Energy Agency

LEEA Lifting Equipment Engineers Association

LC Licence Condition

LOLER Lifting Operations and Lifting Equipment Regulations

MHSWR Management of Health and Safety at Work Regulations

NDT Non-Destructive Testing

OEM Original Equipment Manufacturer

ONR Office for Nuclear Regulation

OPEX Operational Experience

POCO Post Operations Clean Out

PSA Probabilistic Safety Analysis

PSR Periodic Safety Review

PUWER Provision and Use of Work Equipment Regulations

RGP Relevant Good Practice

RIDDOR Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

RPV Reactor Pressure Vessel

SAPs Safety Assessment Principle(s)

SFAIRP So Far As Is Reasonably Practicable

SFC Safety Function Classification

SFR Safety Functional Requirement

SMDC Safety Mechanisms Devices and Circuits

SM(S)R Supply of Machinery (Safety) Regulations

SQEP Suitably Qualified Experienced Person

SSC Structures, Systems and Components

SWL Safe Working Load

TAG Technical Assessment Guide(s)

UK United Kingdom

UKCA United Kingdom Conformity Assessed

WENRA Western European Nuclear Regulators Association

1. EQ verification tests demonstrate that the 1st article component or assembly can perform its allocated safety function(s). [↑](#footnote-ref-2)
2. EQ implementation tests demonstrate that the nth article component or assembly sufficiently aligns with the 1st article that has been verified. [↑](#footnote-ref-3)