Technical Assessment Guide

Nuclear Lifting Operations

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Contents

1. Purpose and scope

1.1 This Assessment Guide is intended to support the Safety Assessment Principles[1] (SAPs) and to provide general guidance on the main issues to be addressed by nuclear inspectors in the assessment of safety submissions relating to lifting operations and lifting equipment in nuclear plant. "Lifting equipment" means work equipment for lifting or lowering loads and includes the attachments used for anchoring, fixing or supporting the load. The integrity of the load must also be considered in so far as it affects the safety of the lifting operation.

1.2 The Guide is broadly applicable both to new plant throughout the design, construction and commissioning phases, and to existing operating plant originally built to the design codes applicable at the time of their manufacture, through to their use for post-operative clean out and eventual decommissioning. Because of developments in national and international standards, existing plant may not comply in every respect with current standards. Where this is the case, other factors such as the age of the plant and projected lifetime may be taken into account in demonstrating ALARP.

1.3 The Guide does not extend to the detailed design, categorisation, qualification or specification of individual components or systems, particularly in relation to their ability to perform their safety function. What it does do is consider the performance and behaviour of lifting components and systems in relation to the broad safety functional requirements of lifting equipment intended for use within a nuclear licensed site. It also considers the generic safety issues that may influence the performance of such systems.

1.4 More detailed guidance on the various types of lifting equipment that can be used, their components and features is given in Appendix 1. Guidance on the relevant statutory regulations affecting the use and provision of lifting equipment is given in Appendix 2, with guidance on the available design codes in Appendix 3. Appendix 4 provides a tabular summary linking the SAPs, TAGs and Statutory Regulations to the types of issues that may arise during assessment.

1.5 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.

2. Relationship to licence and other relevant legislation

2.1 Licence Conditions

The following licence conditions are particularly relevant to the assessment of lifting systems:

LC 7: Incidents on the Site – Any incidents involving faults or mal-operation of lifting equipment which had or may have had a significant effect on nuclear safety should be recorded, investigated and notified to ONR. Where required by other legislation (i.e. RIDDOR), such incidents must also be reported to HSE.

LC 14: Safety Documentation – The safety case for the plant, including the justification of lifting operations and lifting equipment, is produced and assessed by the licensee under this condition, which also requires documentation to be submitted to HSE on request.

LC 15: Periodic Review – The adequacy of the Licensee’s safety case, where it addresses lifting operations and lifting equipment, should be reviewed against the current operating conditions and statutory requirements and modern analysis techniques to ensure that there have been no significant changes or deterioration (e.g. corrosion, wear, fatigue and damage) sufficient to invalidate the safety case.

LC 17: Quality Assurance – Adequate quality assurance arrangements shall be implemented for all lifting operations and the supply and use of lifting equipment.

LC 19: Construction or Installation of New Plant – The design of the lifting system should be considered at an early stage, and appropriate testing should be carried out to ensure that the systems meet the design specification.

LC 20 and 22: Modification to Plant – Such modifications should be assessed to ensure that they do not impact adversely on the design and capability of the lifting system or the nuclear safety case.

LC 21: Commissioning - Appropriate commissioning tests should be carried out to ensure, for example, that design criteria, and where practicable, the safety functional requirements claimed within the safety case have been met (e.g. measurement of motor currents, operating speeds, deflection, pressure and over-speed).

LC 23 and 24: Operating Rules and Instructions – These will be required, for example, in respect of the availability and capacity of lifting systems.

Safe limits of operation should be clearly defined e.g. working load limit, maximum operating speed, lifting machinery and rigging configurations, location of lifting operations, transfer routes, etc.

Consideration should also be given to external factors and hazards that can affect the performance of the plant when setting such Operating Rules and Instructions. For example, extreme weather, temperature conditions, ice, snow, storm, and the availability of external electrical power, etc, and the actions to be taken in the event of abnormal occurrences or loss of such services should be specified e.g. Emergency Operating Procedures, recovery method, etc.

LC 25: Operational Records – Operational records of the key operating parameters affecting the safety of lifting systems should be maintained.

These may include, for example, records of operating history (weights lifted and number of cycles), number of hours in service, etc. for lifting systems.

Consideration should be given to the automatic recording of measurements of any derived parameters that are important to safety, e.g. overloading, lifetime operating history, etc.

LC 26: Control and Supervision of Operations – The licensee should ensure that lifting operations are properly planned, supervised and carried out by SQEP persons.

LC 27: Safety Mechanisms, Devices and Circuits – The suitability and sufficiency of the lifting equipment protection systems should be assessed to comply with this condition.

The licensee should ensure that the plant is not operated unless the necessary systems are properly connected and in good order.

LC 28: Examination, Inspection, Maintenance and Testing – It is expected that lifting system assemblies and components such as structures, mechanisms, ropes, chains, etc. that could deteriorate or become damaged in service would form part of the licensee's site-wide arrangements under this licence condition.

The licensee should ensure that a full and accurate report of every examination, inspection, maintenance or test is completed by a suitably qualified person and where this reveals any matter indicating that the safe operation or safe condition of the plant may be affected, appropriate action should be taken by him under (LC) 7 – Incidents on Site.

LC 30: Periodic Shutdown – This condition requires the periodic shutdown of the plant for the purpose of enabling any examination, inspection, maintenance or testing of the plant or process to take place in accordance with the schedule referred to in (LC) 28. Hence the performance of the plant should be periodically and comprehensively monitored.

3. Relationship to SAPs, WENRA Reference Levels and IAEA Safety Standards addressed

3.1 Safety Assessment Principles

There are no SAPs that specifically mention lifting operations or lifting equipment. ENM.2 considers the arrangements for the safe management of nuclear matter. Such arrangements may include the provision of handling and lifting systems.

3.1.1 EKP.1 to EKP.5 consider the key engineering principles that underpin the safe design of a nuclear facility. Good plant layout taking into consideration the hazards presented by lifting operations can minimise risk, optimise defence in depth and, in doing so, stop the progression of fault sequences that could lead to a significant demand (safety functional requirement) on lifting systems and interactions with associated equipment.

3.1.2 The following Engineering Principle SAPs may also have particular application to the assessment of lifting operations and lifting equipment:

SCS.1 to SCS.8 (Regulatory assessment of safety cases) ECS.1 to ECS.5 (Safety classification and standards)
EQU.1 (Equipment qualification)
EDR.1 to EDR.4 (Design for reliability)
ERL.1 to ERL.4 (Reliability claims)
ECM.1 (Commissioning)
EMT.1 to EMT.8 (Maintenance, inspection and testing)
EAD.1 to EAD.5 (Ageing and degradation)
ELO.1 to ELO.4 (Layout)
EHA.1 to EHA.17 (External and internal hazards)
EMC.1 to EMC.22 and EMC.24 to EMC.34 (Integrity of metal components and structures)
ESS.1 to ESS.27 (Safety systems)
ESR.1 to ESR.7 and ESR.9 to 10 (Control and instrumentation of safety-related systems)
EHF.1 to ENF.10 (Human factors)

3.1.3 Additional or related issues not directly addressed in the SAPs may be of equal importance in specific circumstances and these aspects of a thorough nuclear safety assessment may need to be identified and considered by an experienced and qualified nuclear assessment inspector.

3.2 WENRA Reference Levels

3.2.1 The Western European Nuclear Regulators Association (WENRA) Reference Levels[2] are relevant to this TAG and they feature a number of technical and other requirements that are relevant to the design and operation of lifting systems. It is expected that assessments carried out in line with the HSE SAPs in combination with this guidance will encompass the specific requirements of Western European Nuclear Regulators Association (WENRA) Reference Levels.

3.2.2 In particular, it is expected that the analysis will cover the issues raised in Appendix E of the Reference Levels related to the use of lifting systems and their associated effects on reactor systems.

3.2.3 In addition the analysis conducted to satisfy the HSE Principles in combination with Licence conditions, particularly LC 23, 24 and 27 is also expected to lead to Emergency Operating Procedures and Severe Accident Management Guidelines. These should be equivalent to or better than those required by WENRA Reference Levels Issue LM Emergency Operating Procedures and Severe Accident Management Guidelines in respect of issues related to the design and operation of lifting systems.

3.3 IAEA Safety Guides

3.3.1 The IAEA Safety Standards provide specific guidance on design[3] and the assessment of lifting systems[4 & 5] and their associated systems. It is expected that the application of such advice to reactor systems will result in equivalent levels of safety (i.e. integrity, reliability, redundancy and diversity, etc.) to those that will be achieved by the detailed application of the ONR Safety Assessment Principles and this guidance.

3.3.2 The IAEA Safety Guides provide similar generic guidance on nuclear fuel cycle facilities and their lifting systems and has similar purposes and objectives to the HSE SAPs.

3.4 Statutory Requirements

3.4.1 The following Statutory Instruments are directly applicable to the supply, provision and use of lifting machinery and equipment:

Supply of Machinery (Safety) Regulations
Statutory Instrument 2008 No. 1597
http://www.opsi.gov.uk/si/si2008/uksi_20081597_en_1

Lifting Operations and Lifting Equipment Regulations
Statutory Instrument 1998
http://www.opsi.gov.uk/si/si1998/19982307.htm

The Provision and Use of Work Equipment Regulations 1998
Statutory Instrument 1998 No. 2306
http://www.opsi.gov.uk/si/si1998/19982306.htm

3.4.2 More detailed guidance for inspectors on the application of the Supply of Machinery (Safety) Regulations, LOLER and PUWER is given in Appendix 2 and the Guide to the Application of the Machinery Directive[6].

3.4.3 The following Statutory Instrument is applicable to all work activities and requires every employer to make a suitable and sufficient assessment of the risks to the health and safety. It also deals with the principles of prevention and the arrangements for the effective planning, organisation, control, monitoring and review of preventive and protective measures.

Management of Health and Safety at Work Regulations
Statutory Instrument 1999 No. 3242
http://www.opsi.gov.uk/si/si1999/19993242.htm

3.4.4 The following Statutory Instruments may be relevant and applicable for the supply, provision and use of certain lifting machinery and equipment:

Construction (Design and Management) Regulations
Statutory Instrument 2007 No. 142
http://www.opsi.gov.uk/si/si2007/uksi_20070320_en_1

Electromagnetic Compatibility Regulations
Statutory Instrument 2005 No. 281
http://www.opsi.gov.uk/si/si2005/uksi_20050281_en.pdf

Low Voltage Electrical Equipment (Safety) Regulations
Statutory Instrument 1989 No. 728
http://www.opsi.gov.uk/si/si1989/Uksi_19890728_en_4.htm

Work at Height Regulations
Statutory Instrument 2005 No. 735
http://www.opsi.gov.uk/si/si2005/uksi_20050735_en.pdf

4. General advice to Inspectors

4.1 Introduction

4.1.1 This guide is concerned with the assessment of safety cases involving the use of lifting equipment and lifting operations on nuclear licensed sites. It covers all lifting operations where failure to carry out such operations in a controlled and safe manner could affect nuclear safety. It is therefore not limited solely to the lifting and movement of nuclear material.

4.1.2 The philosophy for the assessment of nuclear safety is set out in the HSE SAPs. This guide interprets this philosophy and provides advice on the engineering assessment of lifting systems. More detailed guidance is given in Appendix 1.

4.1.3 The safety case should:

i) demonstrate that the lifting operation and the lifting equipment provided reduces risk so far as is reasonably practicable.

ii) identify the structures, systems and components of the lifting system that are important for the safe operation of the installation.

iii) identify normal operating and potential fault conditions, including internal and external hazards, that could affect the lifting system and other plant and equipment.

iv) consider human factor influences on lifting operations that could affect safety.

v) demonstrate that the integrity of the structures, systems and components of the lifting system important for the safe operation of the installation are maintained for the predicted life of the lifting system. Ultimately this will be the projected life of the installation, including any period of safe storage through to the point at which it no longer has any nuclear safety consequence (e.g. end of decommissioning), taking due account of potential ageing and degradation mechanisms.

4.1.4 The purpose of ONR assessment is to come to a view whether the design, manufacture, operation, monitoring, inspection and maintenance of a lifting system is adequate to demonstrate that it will deliver its assigned safety functional requirements commensurate with its classification. The Inspector needs to be aware of how the lifting system fits within the safety case and, therefore, the assessment should consider the hazards that could result from lifting operations and any effects on other safety significant plant and equipment. The overall safety case would deal with a potential hazard but the detailed fault analysis of the lifting system would be concerned with the likelihood, or frequency of occurrence, of an event and its consequences. This might be in terms of an operator error, control/protective system failure, structural integrity related initiating event or as an internal hazard. Or, it could be a failure in a system designed to cope with another initiating event. The Inspector needs to understand what reliability is claimed by the safety case for the lifting system, i.e. the less likely the lifting system failure needs to be, the greater the confidence required in the ability of the lifting system to deliver its safety function performance. The HSE SAPs provide the numerical risk targets and legal limits that should be used to judge whether the duty holder is controlling radiological hazards and reducing risks ALARP. SAPs Targets 1 to 9.

4.1.5 Assessment of lifting systems relies on a wide range of technical areas, for example: materials, fabrication, stress analysis, electrical, control systems, human factors; as well as consideration of statutory legislation. An Inspector may be experienced in a number of these areas, but should be alert to those aspects of an assessment where they may need to consult with colleagues. Inspectors should be proportionate and avoid giving undue attention to those aspects with which they are most familiar. It is unlikely that a lifting system safety case could be made on one feature alone. Lifting system safety cases can have a wide and complex content and the Inspector may need to reach a conclusion on the acceptability of the case using a different weighting of the features of the safety case to that presented by the Licensee.

4.1.6 ECS.1 and ECS.2 deal with the fundamental requirements for categorisation of Safety Functions (Categories A, B and C) and safety classification of Structures, Systems and components (Classes 1, 2 and 3). Safety Functions of lifting systems are often related to avoiding a failure of a component or structure which could impair the Safety Function of another system (this might often be classified as an ‘internal hazard’ issue).

4.1.7 The use of lifting systems to move nuclear materials and other non-nuclear loads 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.

4.1.8 IAEA Safety Requirements document NS-R-1 defines three fundamental safety functions in its section 4.6.

4.1.9 The safety classification of structures, systems and components is dependent on the loss of safety function and radiological consequences of their failure, and on the failure frequency requirements placed on them in the safety analysis. Safety Function categorisation and safety classification of structures, systems and components is discussed above in relation to ECS.1 and ECS.2. The standards of design, manufacture, installation and testing, in-service maintenance, inspection and testing, and operation will vary accordingly. For example, the catastrophic failure of a lifting system on to a Reactor Pressure Vessel (RPV) of a large power plant would likely lead to unacceptable radiological consequences, and hence high levels of quality and conservative engineering need to be applied at each stage of the life of such a lifting system. On the other hand, the radiological consequences of a dropped nuclear package (flask) may be less significant, provided there is confidence in the package to maintain containment and shielding to allow recovery from the situation. In this latter case relevant industrial, national or international standards for the design, manufacture and use of lifting systems may be sufficient.

4.1.10 Nuclear lifting systems are often unique, (for example nuclear fuel handling systems or control rod lifting systems), where there is a direct possibility of affecting nuclear safety, and the lifting system may form a permanent or temporary part of a larger nuclear system (e.g. reactor). However, other lifting systems may be more general in nature, for example cranes that handle nuclear loads or carry non-nuclear loads over sensitive equipment such as nuclear reactors, nuclear chemical plant or nuclear safety related equipment.

4.1.11 Inspectors need to be aware that sensitive plant and equipment may be located in remote locations e.g. emergency feed pumps in turbine halls, cooling pipes and electrical supplies located under ground etc. where their safety function may not be immediately obvious. It is therefore important to ensure that a comprehensive review of the vulnerability of such systems is undertaken.

4.1.12 Lifting systems may comprise uniquely designed equipment or simply consist of proprietary lifting equipment which has been deemed fit for its purpose given the consequences of failure. The term crane is generally used to define a self contained device comprising a hoist and some form of supporting structure which will allow movement of the load, whereas lifting systems may include dispersed equipment attached to building structures, beams, floors, walls etc. that may perform a similar function.

4.1.13 The assessment of lifting equipment will have to consider the likely failure mechanisms of such lifting operations, the probability of failure, and the consequences of failure to ensure that hazards have been minimised, SAP FA.14. Inspectors should not apply the findings of one assessment to another apparently similar system, unless they have a full understanding of all the safety issues, operating rules, etc. SAPs FA.17 to FA.24.

4.2 Lifting assessment philosophy

4.2.1 The justification of lifting operations will depend on a particular approach to assessment of the radiological hazards, in normal and faulted conditions, combined with an assessment of the integrity of the lifting equipment and the adequacy of the lifting procedures. The inspector of lifting systems must make a judgement on the adequacy of the Licensee's complete case, taking into account all aspects of the operation and the frequency of such operations.

4.2.2 Inspectors should note that lifting operations present a significant conventional safety hazard as well as a potential threat to nuclear safety. They should therefore be assessed for compliance with conventional health and safety legislation (e.g. MHSWR, LOLER, PUWER and Supply of Machinery (Safety) Regulations).

4.2.3 Given the hazards associated with lifting operations, the options to avoid them by plant layout, or to adopt potentially safer methods of lifting or working should be considered at an early stage, SAPs EKP.1 and EKP.2. Examples are the avoidance of sensitive plant areas, plant shutdowns, the layout of loading bay areas, provision of impact resistance and the use of passive means of lifting, air skates, jacks etc.

4.2.4 Various approaches have been used in developing nuclear safety cases for lifting operations, ranging from that of a "dropped load case" where it can be demonstrated that the consequences of such a failure is acceptable, through to cases where the probability of equipment failure is reduced by protection systems and engineering/design enhancements.

4.2.5 Wherever practicable, the nuclear safety case should demonstrate defence in depth against the consequences of lifting system failures (e.g. provision of diverse containment), SAP EKP.2. These fault conditions should be robustly analysed to demonstrate that nuclear material remains contained, SAP ECV.2. In these cases, the assessment should consider whether the fundamental principle has been met that all reasonably practicable steps have been taken to prevent and mitigate accidents, SAP FP.6.

4.2.6 An example of such a case could be in the simple movement of nuclear fuel, where the quantity and nature of the nuclear material within a single element or component is such that failure or inadvertent movements of the load cannot cause a nuclear hazard. This is because the quantity of fuel, and its configuration, are arranged to prevent criticality; it is fully contained and shielded; there is no cooling requirement; and there is no venting requirement (e.g. from hydrogen generation). It is important to ensure in such cases that the appropriate criticality assessment has been documented, see Technical Assessment Guide T/AST/041[7] on the assessment of criticality issues. It should however be noted that more hazardous fuel handling operations may be subject to very detailed safety analysis and the precautionary principle as described in R2P2 “Reducing risks, protecting people” [8] should also be exercised when considering the potential outcome of such operations or the probability of its occurrence.

4.2.7 Providing the principal nuclear hazard has been addressed as referred to above, the assessment of the lifting equipment will largely be that of examining the internal faults in the lifting system, to ensure that they cannot give rise to any additional hazards e.g. structural collapse, disruption etc.

4.2.8 Safety cases considering the effects of dropped loads may be argued on the basis of limited consequences as a result of the transport package containing the radioactive material being able to withstand severe hazards, as required by IAEA transport safety requirements. Such claims are based on a robust transport package eg spent fuel flask, where there is a sound and detailed understanding and justification of the impact resistance of the transport package, and it is lifted well within its withstand capability. Moreover any structures that could be impacted on by a dropped package or load, e.g. a reactor pile cap, pond etc. should be robustly constructed, and justified against such an impact.

4.2.9 The nuclear safety case should address the suitability of all packages to be used within the facility. Wherever practicable, the package should withstand the “dropped load”. Inspectors should be aware that a packaging licensed for off-site use does not necessarily justify its use within a nuclear facility. Where it is not possible to justify the adequacy of a package, greater reliance may be placed on the robustness of the lifting system’s engineering and protection systems. It should also be noted that the radiological and chemo-toxic nature of the contents of a package may vary significantly, e.g. from metallic solids to liquids, from trace active to fissile material, from inert to combustible materials, etc. and the radiological hazards from the damage to a package will therefore vary considerably.

4.2.10 When assessing such nuclear lifting systems it is important to ensure that all the reasonably foreseeable fault sequences are considered, and that the collapse of the structure itself has been included. Crane structures will frequently contain significantly greater potential energies, resulting from its normally greater mass and position (height), than the loads being lifted. SAPs FA.1 to FA.23 and NT.1 and NT.2 cover the requirements for detailed safety analysis of plant through normal operation to severe accidents where major plant damage may be sustained.

4.2.11 Given that principal load path failures of lifting equipment will have potentially major consequences (i.e. structural collapse, load drop, etc.) it is therefore important, when assessing lifting operations, that the sensitivity of the fault analysis (and the conclusions drawn from it) to the assumptions made in any supporting analysis are adequately validated, SAPs FA.19 and FA.22. Assessments must address internal faults in the crane system that can frequently develop into overloads and uncontrolled motions, and such effects should be justified in detail, SAPs FA.7 and FA.8.

4.2.12 Where the consequences of failure are not acceptable, and it is not possible to provide alternative protection, greater dependence will be placed on the robustness and integrity of the lifting equipment. Various approaches have been used to develop equipment with enhanced safety and reliability features. These range from simple conservatism (i.e. derating), through to designs that are fail-safe, "one fault safe" or "single failure proof".

4.2.13 Derating can range from simply lowering the Safe Working Load of the device, through to derating of the code to give enhancement of the design margins within the code. Inspectors should be aware that de-rating, whilst simple, will have a variable effect on the design margins through the system, due to the combination of live and static loads in the various components of the system, and the effects of normal and faulted loads. For example, faulted loads may arise more from the prime mover or application of braking systems, rather than from the load being lifted, moved, etc. and may be significantly greater than the effects of the SWL. It is therefore important, when assessing lifting systems, that the effects of the static and dynamic forces generated by faulted conditions are fully analysed.

4.2.14 A likely consequence of enhancing design codes is increased mass, inertia and stiffness of the lifting system. This will increase its capability to damage other plant and equipment (e.g. increased power required for motors, greater inertia to be arrested, shock loadings, etc.). It is therefore important that all plant and equipment associated with the lifting system faulted conditions are assessed for their ability to deliver the safety function requirement, SAPs FA.7 and FA.8.

4.2.15 Proof tests (e.g. overload) may give little protection against defects, unless appropriate fracture mechanics and inspection standards have been developed. Inspectors should note that current industry practice is to limit proof load testing to acceptance testing of lifting systems at the time of installation and setting to work. The effects of regular proof load testing should be analysed for any detrimental effects (e.g. potential damage and shortening the fatigue design life of the lifting system). Where the safety case requires regular load testing of lifting systems (e.g. to support reliability claims), the rated capacity of the lifting system should be equal to or greater than the specified test load to comply with LOLER.

4.2.16 Inspectors should be aware that typical lifting machinery proof tests of around 125 % may not conservatively bound the worst case dynamic faulted conditions arising from the following;

i) 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.

ii) 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.

iii) Loads that are ledged and then drop suddenly.

iv) Seismic loadings where there may be significant horizontal accelerations and magnification of the vertical load.

Such faulted conditions should be analysed to establish the peak loadings that are developed from them.

4.2.17 Inspectors should note that catastrophic modes of failure could arise with such fault loadings. These may result in simple tensile failures, buckling or loss of stability. It is important therefore to consider the limitations of proof tests on lifting equipment, and recognise that the design may in fact be justified solely on the basis of theoretical analysis, unless additional testing limits are devised.

4.2.18 A Design Basis Analysis or Safety Case may determine that the robustness and safety measures offered by a conventionally designed lifting system cannot provide adequate fault tolerance, SAP FA.4. It may therefore be necessary to ensure that failure in the hoisting mechanism, for example, is tolerable, and that the hoist will be arrested in a safe manner, without dropping its load.

4.2.19 To reduce the likelihood of uncontrolled lowering, additional hoist braking may be provided. This may take the form of an additional brake on the input side of the hoist gearbox. An emergency braking or restraint system that acts directly, or as close as possible, on the rope drum, should be considered as it may give a level of protection against mechanical failure of the hoist gearbox. The equipment and procedure for demonstrating the required performance of such features throughout the operating life of the lifting equipment should be provided. SAP EQU.1.

4.2.20 It is standard practice for all brakes to be applied on loss of power to the lifting machine or drive motors. However, this feature may not initiate emergency braking/restraint in response to a mechanical failure or electrical fault. Failure/fault detection may therefore be required, which may take the form of over-speed detection and/or speed comparator (output to input). Although additional braking/restraint systems can enhance safety, they may impose greater dynamic loadings on the hoist drive components than normal design code requirements. Design analysis should therefore consider the faulted condition of spurious operations. Unnecessary dynamic application (e.g. spurious tripping) of the emergency braking or restraint system should be considered when assessing the fatigue life of the drive components.

4.2.21 Another method of reducing the risk of uncontrolled lowering is the ‘single failure proof’ hoist system, see “Single Failure Proof Cranes for Nuclear Plants” NUREG-0554[9]. In this system, load paths are duplicated with the intent that that no single failure will result in loss of capability of the system to support the load. Consideration should be given to the increased complexity of the ‘single failure proof’ system, which may introduce new fault modes that are not present in conventionally reeved hoist systems. The effects of these faulted conditions should be assessed to ensure that they do not compromise the ‘single failure proof’ principle.

4.2.22 It should be noted that whilst such arrangements may be acceptable in the short term, they do not 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. The operation of lifting systems in a foreseeable degraded state should be justified within the safety case.

4.2.23 The consequences of rope failure in a ‘single failure proof’ system may affect the ability to raise or lower the load safely. Recovery of the suspended load may need to be carried out by an alternative lifting system.

4.2.24 Inspectors therefore need to be aware of the remaining hazard of loads left suspended, and the risks associated with the actions necessary in making them safe. Certain systems will lend themselves to emergency action to remove the main hazard (e.g. the reactor may be tripped, the process is stopped and made safe, or there may be a suitable evacuation, prior to recovery). In others the hazard will remain until the load is finally landed.

4.2.25 There may be radiological constraints on access to the load and lifting equipment during recovery operations. Remotely operated lifting equipment will require remotely operated recovery systems that protect the operator. These systems should be proven during commissioning for all predictable recovery scenarios and the equipment subject to an in-service maintenance regime to ensure they will function on demand.

4.2.26 There may also be restrictions on the time that nuclear materials and packages can remain suspended for such reasons as fuel cooling, hydrogen venting and weather conditions including wind, snow or lightning.

4.2.27 It is important therefore to consider these aspects when assessing the adequacy of safety systems that may trip the crane during the lifting operation, and when considering the provision of any redundancy or means of recovery.

4.2.28 The "one fault safe" approach has been developed in the US and incorporated in the US NRC ASME NOG-1 Standard[10]. It should be noted that such standards have been developed for specific types of reactor and lifting operations, namely shutdown and refuelling operations associated with civil PWR and BWR reactors. These may not bound all potential hazards, such as those created by on-load refuelling or lifting in less contained environments, see NUREG-0612 “Control of Heavy Loads at Nuclear Power Plants” [11].

4.2.29 The final approach used for developing lifting safety cases is to rely on some level of redundancy or diversity that goes beyond the "one fault safe" approach. That is, there is an independently operable load path capable of supporting the load (e.g. by using some independent load follower or similar device). Whilst such systems have advantages and comply with the nuclear safety principles in terms of redundancy and diversity, it is important that they are adequately assessed, including the dynamic loading effects of primary lifting system failures. Issues to be considered with respect to high reliability systems are covered by SAPs EDR.1 to EDR.4

4.2.30 Whatever solution is adopted by the Licensee, it is important that the claimed engineering benefits are achieved in practice, SAPs SC.4 to SC.6. Some of the detailed technical issues that need to be considered in the assessment of these systems are indicated in Appendix 1.

4.2.31 Human factors are frequently a significant factor in lifting accidents and their importance should not be overlooked either in the operation of the crane, planning the lifting operation or in securing the load to the crane. Where it is not possible to remove operator action from the design of a lifting system, and claims are made on operators as part of a safety measure, then a detailed assessment of the human factors aspects will need to be undertaken. Particular attention should be given to training and instructions to operators and supervisors on the safe use of equipment including recognition of faulty/damaged equipment, planning of lifting operations, management and control, and selection of equipment for lifting operations, see also SAPs EHF.3 to EHF.10.

4.2.32 Whatever approach is used it is important to note that the requirements of SAP SC.6 are achieved. The relevant limits of safe operation should be identified for any design basis fault sequence and the integrity of the physical barriers to radioactive release maintained (i.e. SAPs FA.1 to FA.7). In addition, no safety-related component (or structure or system) required to prevent or mitigate the fault sequence should be caused to operate outside the conditions for which it has been qualified.

4.3 Detailed consideration of the SAPs

4.3.1 There are specific TAGs that deal with the content of safety cases, the use of deterministic safety analysis, and various aspects of assessing structural integrity, safety systems, human factors etc. It is therefore not necessary to reproduce them but inspectors should consider how they may also be applicable to lifting operations.

4.3.2 The requirements of SAP FP.6 that all reasonably practicable steps shall be taken to prevent and mitigate nuclear or radiation accidents should be applied when developing and planning lifting operations. The assessment should consider the hierarchy of hazard avoidance, the use of inherently safe and passive features and the avoidance of fault sensitive systems contained in SAPs EKP.1 and EKP.2 should be noted.

4.4 Fault analysis

4.4.1 The assessment of nuclear lifting operations should include an assessment of the radiological risk. SAPs FA.1 to FA.24 define the HSE requirements for fault analysis.

4.4.2 Most lifting systems will simply be designed for normal operating loads in accordance with crane and lifting equipment design codes. However, such codes do not normally consider internal faulted conditions, or require the structure or mechanisms to survive such conditions. They simply address such events by enhanced design margins, but do not quantify them or give guidance on how to address a specific fault condition. Other codes and standards give guidance on operating such equipment with the objective of avoiding failures e.g. BS 7121[12].

4.4.3 The HSE SAPs describe a far more detailed and structured analysis of operations and equipment on nuclear licensed sites, which should be proportional to the nuclear safety significance of failure. This requires a comprehensive consideration of fault sequences and events. The HSE SAPs describe this Design Basis Analysis (DBA) as a robust demonstration of the fault tolerance of a facility, and the effectiveness of its safety measures. SAPs Para 498. T/AST/006[13] gives guidance on this approach and the degree of rigour that is expected based on the level of hazard, ranging for example from operating reactor cores to dealing with low level waste.

4.4.4 Inspectors will need to use their experience and judgement to assess the extent of the DBA required for lifting operations based on the nature of the nuclear hazard. As discussed previously, the mixture of passive design features, mitigation measures and engineering features will differ in each safety case. The DBA should however demonstrate that in combination, the proposed design and use of the equipment has been thoroughly examined, and shown to be acceptable and tolerable against a recognised range of criteria that reflect the potential nuclear hazard. This is significantly more challenging than simply establishing that a piece of lifting equipment is adequate for its duty and within its rated safe working load.

4.4.5 A principal objective for any lifting operation should be to demonstrate that risks are reduced such that they are ALARP, SAP FA.7. That is, “Analysis of design basis fault sequences should use appropriate tools and techniques, and be performed on a conservative basis to demonstrate that consequences are ALARP”. The analysis should demonstrate, so far as is reasonably practicable, that:

“a) none of the physical barriers to prevent the escape or relocation of a significant quantity of radioactivity is breached or, if there are, then at least one barrier remains intact and without a threat to its integrity;

b) there is no release of radioactivity; and

c) no person receives a significant dose of radiation.”

4.5 Engineering principles

4.5.1 The engineering principles within the SAPs represent a range of features and concepts that are desirable where nuclear activities are expected to achieve the highest levels of safety. They comprise features that can be considered as relevant good practice when applied to hazardous nuclear activities, and should therefore be used in the design and assessment of nuclear lifting equipment and operations, where appropriate and reasonably practicable.

4.5.2 The full range of principles will need to be considered in assessing both the lifting operation and its potential effects on the surrounding systems and components. Of particular relevance to the design of cranes and lifting systems are the following principles.

4.5.3 SAPs EKP.1 to EKP.5 define the key principles for inherent safety, fault tolerance, defence in depth and the identification of safety functions and the safety measures to achieve them

4.5.4 SAPs ECS.1 and ECS.2 deal with the fundamental aspects of categorisation of Safety Functions (Categories A, B and C) and safety classification of Structures, Systems and Components (Classes 1, 2 and 3). Safety Functions of lifting systems are often related to:

i) Maintaining safe lifting, lowering and transport of loads within prescribed limits.

ii) Avoiding a failure of a structure, system or component which could impair the Safety Function of another systems

4.5.5 SAPs ECS.3 to ECS.5 deal with the application of design codes and standards for structures, systems and components commensurate with their safety classification.

4.5.6 SAP EAD.1 The safe working life of Structures, Systems and Components that are important to safety should be evaluated and defined at the design stage. This is particularly important for large lifting system structures that would be difficult or impracticable to replace during the plant lifetime. Crane design codes provide a means of setting design criteria based on the predicted use of lifting equipment, which should be conservatively estimated and take into account commissioning, operation (including inventory removal) and decommissioning through to final disposal.

4.5.7 SAP EAD.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. The design should allow for any uncertainties in determining the initial state of components and the rate of degradation. This is especially important in crane mechanisms, reeving systems, etc. and, particularly, where such elements are exposed to potentially degrading conditions e.g. external environments, pond water chemistry, decontamination operations, etc.

4.5.8 Inspectors should note that there are no European or British Standards developed specifically for nuclear lifting appliances, although standards such as BS2573[14], BS EN 13001[15], BS EN 13155[16], etc. and European equivalents (DIN, FEM etc) are frequently used. These standards were primarily developed for commercial cranes, and may adopt less conservative reserve factors for lifting equipment that has low usage and/or operates infrequently at or near to the safe working load. The Licensee should demonstrate that the design code and design factors used achieve an adequately conservative design. This may require enhanced design margins to be applied to a design code.

4.5.9 SAPs EMC.1 to EMC.34 addresses the assessment of metal components and structures. T/AST/016[17], the technical assessment guide for structural integrity, gives detailed advice on the assessment of nuclear structures and the use of codes. It is important to realise the full extent of such assessment through design, selection of materials, manufacture, inspection and testing etc. if components are to be justified to the highest standards. Such analysis may be significantly more comprehensive than that undertaken using simple elastic analysis design codes.

4.5.10 SAPs EHA.1 to EHA.17 outline a range of external and internal hazards for which the design basis event (DBE) should be determined, SAP EHA.3. Hazards that may not be amenable to the derivation of a DBE, which may include fire and lightning, are addressed through the application of design codes and standards. For earthquakes and climatic conditions, an operating basis event (OBE) should be determined, SAP EHA.9 and Paragraph 221. These may need to be considered when assessing lifting operations.

4.5.11 SAPs ESS.1 to ESS.23 relate to the design of safety systems and safety related instrumentation systems on nuclear plants. Inspectors should note the detailed requirements for designing such systems and that the standards expected on hazardous nuclear plant may be considerably more onerous than those normally associated with conventional lifting equipment. TAGs T/AST/003 Safety Systems [18], T/AST/046 Computer Based Safety Systems [19],T/AST/011 The Single failure Criterion [20] give detailed advice on the assessment of such systems.

5. References

5.1. Safety Assessment Principles for Nuclear Plants 2006 Edition Revision 1.

5.2. Western European Nuclear Regulators Association WENRA Reactor Safety Levels 2008

5.3. IAEA Safety Standard NS-R-1 Safety of Nuclear Power Plants: Design

5.4. Design of Fuel Handling and Storage Systems in Nuclear Power Plants - IAEA Safety Guide Ref No. NS-G-1.4

5.5. Core Management and Fuel Handling for Nuclear Power Plants - IAEA Safety Guide Ref No. NS-G-2.5

5.6. Guide to the Application of the Machinery Directive 2006/42/EC (1st edition December 2009) http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide_application_directive_2006-42-ec-2nd_edit_6-2010_en.pdf

5.7. T/AST/041 – Criticality Safety

5.8. Reducing Risks Protecting People – HSE's Decision Making Process

5.9. NUREG-0554 – Single Failure Proof Cranes for Nuclear Plants US Nuclear Regulatory Commission

5.10. ASME NOG-1 2010 – Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge Multiple Girder)

5.11. NUREG-0612 – Control of Heavy Loads at Nuclear Power Plants

5.12. BS7121 – Code of practice for safe use of cranes

5.13. T/AST/006 – Deterministic safety analysis and the use of engineering principles in safety assessment

5.14. BS2573 – Rules for the design of cranes

5.15. BS EN 13001 – Cranes. General design

5.16. BS EN 13155 – Cranes. Safety. Non-fixed load lifting attachments

5.17. T/AST/016 – Integrity of metal components and structures

5.18. T/AST/003 – Safety Systems

5.19. T/AST/046 – Computer based safety systems

5.20. T/AST/011 – The single failure criterion

5.21. BS 7608 – Code of practice for fatigue design and assessment of steel structures

5.22. T/AST/013 – External Hazards

5.23. Operational Circular OC 234/11 – The lifting operations and lifting equipment regulations 1998

5.24. BS466 – Power driven overhead travelling cranes, semi-goliath and goliath cranes for general use

Appendix 1 – Further technical guidance to inspectors

A1.1 Introduction

A1.1.1 The assessment of lifting systems requires a wide and detailed knowledge of engineering mechanics and dynamics of drive systems and fault conditions in order to understand the loads and forces acting on a crane or lifting system in both normal and faulted conditions. In addition a detailed knowledge of the application and limitations of applicable design codes with respect to the design of structures and individual mechanical components and their properties is required to understand their design margins and failure mechanisms.

A1.1.2 It is recommended that Inspectors carrying out design assessments obtain a stress schedule from the Licensee. 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.

A1.1.3 The following are a selection of issues that frequently arise when assessing the safety of lifting systems for more critical nuclear operations. Where there is any uncertainty or doubt, assessors should seek more detailed technical advice from topic specialists. This list is only intended to highlight the nature of such issues that need to be considered when assessing lifting systems.

A1.2 Ropes

A1.2.1 Steel ropes are complex structures comprising multiple strands and wires that are usually constructed around a central core. There is a wide range of ropes available from the manufacturers with differing construction (lay), each designed and best suited for differing applications. Selection of the wrong rope type may result in operational problems and/or an increased rate of deterioration and possible damage to the rope, reducing its strength and life.

A1.2.2 When selected, installed and maintained correctly, hoist ropes usually deteriorate in a progressive and predictable manner under normal operating and environmental conditions. That is by fatigue of individual wires, usually at the extreme fibres due to bending and contact stresses. Such deterioration is usually detectable by visual inspection of the outer cores before catastrophic failure, given the normally large design safety margins.

A1.2.3 Inspectors should be aware that rope structures can also be subject to a variety of more complex failure mechanisms as a result of overload, torsion, corrosion, crushing and wear and such effects may be more localised and less predictable.

A1.2.4 Failures may occur at local positions such as socket terminations or where the rope is subjected to additional stresses at suspension points, sheaves, etc. Incorrect selection or application of a rope termination type can result in significant reduction of strength.

A1.2.5 Multi layered drums should be avoided wherever possible due to the complexity of the layering mechanism, fault mechanisms and greater potential for damage and reduced rope life. However, where there is a large range of lift and/or space limitations they may be unavoidable. Knowledge and experience of these systems is critical and expert advice should be sought in respect of their failure mechanisms.

A1.2.6 Corrosion may also occur more generally throughout the rope structure and internally within strands and wires, especially in exposed marine environments or where ropes enter and leave water (e.g. ponds with chemical additives). Stainless steel ropes may be less susceptible to corrosion effects. However, this should be compared with the more severe internal abrasion mechanism that occurs between stainless steel surfaces. This will affect and cause deterioration of the internal wires of the rope. Expert advice should be sought for critical applications to determine the most suitable inspection technique and discard criteria.

A1.2.7 Whilst ropes are usually designed to have large safety factors these usually relate to simple tension and do not include any localised effects such as bending or degradation in the rope. The correct selection of fleet angles, pulley and drum diameters, groove shapes and radii will reduce such effects. Reverse and transverse bends in rope systems should also be avoided.

A1.2.8 Ropes may also lose their torsional stability under axial load. That is they may rotate individually or as a system. It is therefore important to demonstrate the stability of the rope system in all modes of operation, especially where dual reeving is used and claims are made regarding its redundancy. Torsional stability of the rope may also be affected by the type of rope termination used.

A1.2.9 Certain types of ropes have rotational resistant constructions that resist rotation under an applied axial load. Pairs of ropes of opposite lay (twist) may be used to balance the rotation effect of a single rope.

A1.2.10 Expert technical advice should be sought when assessing the detailed behaviour of rope systems for critical applications.

A1.2.11 BS7121 Part 2 gives guidance on rope failure mechanisms and discard criteria. However, it should be noted that on a typical rope, only 5% of the cores are visible. Where there is any doubt about the internal condition of the rope, expert advice should be sought. Intrusive inspection of the internal core structure may damage the rope and is not recommended for certain types of rope construction e.g. ropes with compacted strands (dyform) or plastic inserts. Consideration should therefore be given to a programme of periodic replacement supported by destructive testing and surveillance of discarded ropes.

A1.3 Justification of proprietary devices, type testing etc

A1.3.1 Inspectors should be aware that crane designers frequently make use of proprietary equipment for gearboxes, load cells and similar equipment. The design justification of such equipment may not be readily available and reliance will be placed on commercial rated capacities, etc.

A1.3.2 In some cases, the only available evidence is a type test certificate, which may not be adequate to demonstrate its reliability, design life or tolerance to fault conditions. The need for more detailed justification of such equipment will therefore need to be considered for the more hazardous operations.

A1.4 Gears, drive shafts and bearings

A1.4.1 Gearboxes invariably contain a large number of components that are subject to relatively complex forces, moments and torques. They therefore represent a potential weakness in any load path if inadequately designed and constructed as the failure of any one of a large number of geometrically complex components may release the load.

A1.4.2 Gearboxes generally need to be of simple and sound, rigid construction and be conservatively designed. This will generally consist of spur gears mounted between bearings. Novel gearing arrangements will introduce more complex loading conditions and failure modes. They will therefore require more extensive and technically challenging analysis to justify the design.

A1.4.3 Particular attention needs to be given to the design and set up of drive shafts to avoid fatigue failure. Changes in section and keyways cause stress concentrations, whilst poor alignment of equipment and lack of rigidity in the supporting structure may introduce load cycles not catered for by the design.

A1.4.4 Ball and roller bearings that support such shafts may fail catastrophically. Shafts can be redundantly mounted on simple solid plain bearings to maintain gear engagement in the event of failure of the rolling element in critical applications.

A1.4.5 The requirements for heat treatment and surface treatment of gears means there is always some uncertainty in a gear's mechanical properties. These processes must have good quality control. Destructive testing is clearly not possible unless parallel manufacture of destructive samples is arranged.

A1.4.6 Gearboxes and shafts need to be suitably mounted so they are not inadvertently loaded due to structural movement in normal operation or faulted conditions.

A1.5 Hooks, lifting features and lifting accessories

A1.5.1 Hooks, lifting features and ‘below the hook’ lifting accessories (e.g. lifting beams, shackles, slings, etc.) provide a means of attaching the load to the lifting machinery. Regular use of these items will therefore subject them to greater wear and risk of damage.

A1.5.2 All lifting equipment should, where possible, be provided with a positive latching mechanism to prevent accidental release. The suspension of the load should provide mechanical advantage to engage the load and not apply loading to the latching mechanism.

A1.5.3 Positive latching may not be practicable for remotely operated equipment where this does not provide a means of disconnecting the load. In these circumstances, the engagement interface should be configured to reduce the risk of accidental disconnection.

A1.5.4 Powered engagement mechanisms may be considered, designed so that the load cannot be dropped as a result of loss of power.

A1.6 Motor drives

A1.6.1 A wide range of electric motor drives have been used on crane systems over the years, ranging from DC motors to AC synchronous induction motors. The torque speed characteristics of each motor type and its failure modes will be different.

A1.6.2 Inspectors should be aware of such issues and note that the more modern designs of AC motors may incorporate frequency control to give variable torque speed characteristics. Such systems are usually based on digital software and failures of both hardware and software should be considered.

A1.6.3 Where detailed fault analysis requires the examination of stalled conditions such as those arising from stuck loads or double-blocking, inspectors should be aware of the need to examine the complete drive system inertia and motor characteristics. Energy dissipating devices and/or torque limiters may be necessary to limit loading conditions on sensitive loads and structures, e.g. nuclear fuel stringers or reactor cores.

A1.6.4 Inspectors should be aware that 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 develop in the drive. 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.

A1.6.5 Hydraulic and pneumatic motors and actuators may be used, which will have different characteristics and failure modes to electrical drive systems. Typical examples are mobile cranes, which have hydraulic motors, and air hoists used in potentially explosive atmospheres.

A1.7 Software in motor controllers and other devices

A1.7.1 Modern frequency controlled drives incorporate software driven control systems that vary the frequency of supply to the motor and other parameters in response to the motor and system inertia and torque. The failure modes of such software driven systems need to be understood and the requirement for controlling software changes and their effect on the drive characteristics needs to be appreciated.

A1.8 Control Instrumentation and Protection

A1.8.1 Most industrial cranes will have simple control systems that 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 motion etc. Where such systems incorporate protection systems they are usually designed to protect the crane from damage rather than to protect the process.

A1.8.2 Where protection systems are necessary to protect against failures such as inadvertent motion or failures in mechanical systems, detailed attention will need to be given to the design of such systems such that they can deliver the required level of protection expected.

A1.8.3 Various approaches have been taken to addressing the problem of hoist drive train failure, ranging from redundant and duplex systems, to the provision of emergency braking and protection systems that detect drive train failure or discrepancies in drive ratio.

A1.8.4 In assessing such systems inspectors need to consider the sensitivity of the system to free travel and the claimed benefits that the Licensee is making for the system. That is the ability of the system to transfer the load into the redundant system or to sense the failure and to apply the brake and arrest the load within safe limits. Such events may affect the load, the crane, and any impacted structure.

A1.8.5 Crane zoning systems and crash/collision protection systems should be considered.

A1.8.6 Such protection systems will be found on fuel handling systems, in cell cranes and other sensitive nuclear lifting equipment where spurious motion and other faults need to be detected and prevented and are likely to comprise multi channel protection systems. See T/AST/003.

A1.9 Reliability

A1.9.1 Failure rate data relating to cranes and lifting operations is difficult to establish due to the variety of cranes in use, the variability of usage, and a significant element of operator error in many of the failures. Crane failures can be caused by a wide range of different fault mechanisms such as operator error, loss of stability, lack of mechanical strength, fatigue, wear and control and instrumentation failures. Where failure rate data does exist, it is not easy to rationalise it to a single lifting operation to obtain statistically relevant data.

A1.9.2 Inspectors should therefore note the advice given in T/AST/006 for items where the availability of failure rate data is limited and should be cautious where unrealistic data is used to justify short duration lifting operations. See also the advice in the SAPs, especially Paragraph 536.

A1.9.3 Reliability studies may be useful in studying specific aspects of the design where the data may be more robust (e.g. human factors aspects, control and instrumentation systems) and this may indicate a requirement to remove operator action or improve control system reliability in more hazardous applications. However reliability data for uniquely designed mechanical parts needs to be treated with caution as failure in design is perhaps more likely than simple time dependant failure mechanisms.

A1.10 Dual Load Path Arrangements

A1.10.1 Dual load paths are consistent with the SAPs requirements for redundancy and for systems to fail in a safe manner, EDR.1 and EDR.2. Such arrangements when incorporated into lifting systems are invariably complex and need to be carefully engineered to ensure that the safety benefits are actually realised in practice. The potential for common cause failure should be considered, SAP EDR.3.

A1.10.2 There are broadly two approaches to designing such systems. Either, a diverse backup system which is normally unloaded, or there is some form of redundancy within the normal operating system, resulting in a sharing of load during normal operation and a shedding of load on the parallel system in the event of failure.

A1.10.3 Some of the issues that need to be considered in assessing such systems are as follows:

i) The comparative merits of both systems being balanced in normal operation or one system being unloaded needs to be considered.

ii) 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 catastrophically load the parallel system.

iii) Both systems must be capable of responding to transient conditions during the full range of motion of the load. That is starting, stopping, ledged loads, snagging, zero load, overload, transient initial pickup of the load etc.

iv) Both systems need to be reliably synchronised and controlled.

v) The redundant/diverse system must be capable of sustaining the maximum dynamic loads.

vi) The requirements for recovering the load need to be established.

vii) Systems will generally be complex. The response of the system to internal faults therefore, must be consistent with achieving the overall reliability and operability of the complete system.

viii) 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, hang up etc. Adequate information for fault diagnosis needs to be provided.

ix) It should be noted that the dynamic loads created by load path failure and subsequent arresting of the load may be large. Cranes are normally designed to accommodate dynamic loads in the normally slow lifting process, by the use of an impact factor placed on the SWL of the crane. These are usually quite small in the range of about 1.1 to 1.5 and exceptionally up to 2.0. Such factors therefore are unlikely to accommodate faulted conditions, such as the responses due to rope failure, or emergency action due to say a load runaway, which must be examined separately.

A1.10.4 The requirements and arrangements to test such systems, needs to be established if they are to achieve the claimed performance of safety function to a level commensurate with their classification, SAPs EQU.1.

A1.11 Welding

A1.11.1 Welding is used widely in crane structures. Particular attention should be given to the justification and detailing of welds, especially any fillet welds e.g. BS 2573 Part 1 Section 6.1.4.

A1.11.2 The requirements of BS 7608[21] and similar codes should be observed when assessing the fatigue of welded structures.

A1.11.3 The potential for lamellar tearing in welded structures should be noted and avoided where possible.

A1.12 Cast Iron

A1.12.1 It should be noted that cast iron might have been used in the load path of older cranes. Careful consideration should be given to the suitability of such materials, especially in tension. Grey cast iron is prone to brittle fracture. There is also uncertainty 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 is also very problematic.

A1.13 Seismic Considerations

A1.13.1 The requirement to consider external events on nuclear lifting operations results in the need to consider the effects of earthquakes on the lifting operation and on any other plant in the vicinity and on any system or service which may have a bearing on safety, SAPs Paragraph 222.

A1.13.2 Lifting structures and mechanisms may be vulnerable to seismic effects and have complex interactions with the building and its processes. Where seismic analysis is deemed necessary the dynamic seismic loading will frequently dominate the design of such structures. The External Hazards TAG T/AST/013 [22] should be consulted with respect to seismic design.

A1.13.3 The seismic analysis SAPs EHA.5 to EHA.7 may lead to the requirement for special engineered features on the cranes to limit and control the effects of seismic events. Features that have been used include the following:

i) Seismic restraints to prevent lateral movement of the cranes trolleys and wheels.

ii) Additional restraints to prevent uplift.

iii) Friction sliders to allow free lateral movement where an item cannot be fully restrained.

iv) Load fuses to allow relative vertical motion between the crane structure and the load.

v) Seismic triggers to isolate and brake the crane’s hoist and travel motion during a seismic event to reduce loadings and maintain safety.

Note: Where seismic triggers are used to isolate the electrical supplies, the equipment that isolates the plant must be seismically justified to maintain the isolation during the event, e.g. contactors, brakes etc. need to be seismically qualified against the maximum dynamic loadings. In addition plant and control systems that are not seismically justified may be damaged, so will not be serviceable during any subsequent recovery of a suspended load.

A1.14 Wind Forces

A1.14.1 Inspectors should be aware of the difficulties of justifying mobile, tower and other external cranes against in-service and maximum out-of-service wind loads to the level of confidence expected in a nuclear safety justification. Inspectors should seek detailed advice on the peak gust loadings that should apply to such structures and which may also be modified by the local topography and the location of surrounding buildings. SAP EHA.11.

A1.14.2 Inspectors should also note that the wind forces on the load itself can significantly affect the stability and strength of such cranes. It is therefore necessary to consider the implications for such systems if the load or crane cannot be moved or removed in the event of high winds.

A1.15 Wheels and Rails for EOT Cranes

A1.15.1 It should be noted that in certain circumstances wheels and rails are sensitive to their correct alignment and that such components can be vulnerable to wear if they are not correctly aligned and/or lubricated.

A1.16 Planning and organisation of lifts

A1.16.1 Laydown areas where loads are set down should be assessed against the applied load.

A1.16.2 Lifting routes should be planned with the objective of minimising hazards.

A1.16.3 The weights and centre of gravity of items being lifted needs to be established and verified. For the lifting of existing plant and equipment, the effects of plant modifications and additions should be considered.

A1.16.4 The potential hazard from toppling of unstable loads should be recognised.

A1.16.5 Correct slinging is vital to safe lifting operations. Attachment points should be suitably tested for normal and any faulted conditions.

A1.16.6 The dynamic loads developed by rigging failures may propagate into failure of the crane or lifting system especially on mobile cranes.

A1.16.7 Where long loads are lifted through confined spaces they may become trapped or snagged. The need for adequate overload protection should be considered. Such devices themselves should not create a ledging or snagging hazard.

A1.17 Mobile Cranes

Truck Mounted

A1.17.1 Mobile cranes bring considerable flexibility to performing lifting operations where there is no permanent crane provision. Licensees may have instructions for determining if a mobile crane is to be permitted to work on specific jobs on individual sites. These instructions should be considered within assessments but not negate the requirement for safety cases and assessment.

A1.17.2 Mobile cranes by their very nature are complex devices in that they are fitted on to a chassis which in itself is usually a vehicle containing diesel and fuel systems. They also incorporate complex boom extending features with slewing and luffing systems, all operated by non redundant hydraulic systems. Such cranes are now frequently fitted with computer control systems to aid the operator in limiting loads with respect to rigging configurations and limiting loads on out riggers etc.

A1.17.3 Many incidents with mobile lifting equipment are caused by the inadequate assessment of ground conditions. Even when ground conditions have been assessed, poor implementation of control measures can lead to overturning of equipment if the ground subsides. Typical examples are failure to locate underground services, inadequate localised ground strength and inadequate use of load spreader plates under stabilisers and support legs.

A1.17.4 Rigging such cranes requires careful attention to manufacturer's procedures to ensure that the crane is level, adequately supported and correctly rigged for the required duty. Failure to perform any of these requirements correctly, or failures in the rigging system under the hook, can result in catastrophic collapse of the crane. Frequently this involves toppling of the complete crane or buckling of the main boom due to overload or side loading.

A1.17.5 The Construction Plant-hire Association (CPA) has produced best practice guides covering different types of mobile lifting equipment such as mobiles and tower cranes. This advice is available from its website www.cpa.uk.net.

A1.17.6 Inspectors should be aware of the vulnerability of mobile cranes and ensure that the nuclear and non nuclear consequences of such collapse have been adequately assessed. Inspectors should be aware that failures frequently arise from human error leading to equipment failure. The relevance therefore of using mechanical reliability data alone in assessing risks caused by such operations needs to be treated with considerable caution.

A1.17.7 Given their mobile nature, such cranes are vulnerable to damage and abuse unless their operations are strictly controlled and they are correctly maintained. Even if the original design records of such a crane were made available to assess it to the requirements in the HSE SAPs for the higher levels of hazard, it may be difficult to ensure that a particular crane had not undergone some form of minor repair or modification prior to its arrival on site. Claims made therefore regarding the structural integrity of such machines may be difficult to justify.

A1.17.8 Such cranes are unlikely to be seismically justified and may be vulnerable to such occurrences and earth movement. They are also vulnerable to external events such as wind and lightning.

A1.17.9 The complexity of the hydraulic and diesel engine systems on such cranes also makes claims regarding their suitability and reliability for hazardous nuclear operations difficult to justify, despite the incorporation of various safety devices, e.g. hydro lock valves, computerised load management and control systems etc. There is a significant risk of fire in such systems that should be assessed within the safety case.

A1.17.10 The use of fly jibs, bracing systems, tandem lifts and other arrangements, to increase the capability of mobile cranes, further adds to the potential hazards of mobile crane operations on nuclear sites.

Tower Cranes

A1.17.11 Similar issues arise when assessing tower crane arrangements for nuclear use.

A1.17.12 To minimise wind loadings, tower cranes are normally allowed to weather vane (free slew). The siting and configuration of a tower crane must therefore allow for this free movement to prevent collision with other plant and equipment, e.g. other tower cranes and structures (permanent and temporary).

A1.17.13 Tower cranes may be in position for extended periods. The effects of extreme weather conditions on their strength and stability should therefore be considered.

A1.17.14 Self-erecting tower cranes present additional hazards during erection and retraction, with these sequences likely to be controlled by software. The potential for sequence errors and omissions should be considered.

Mobile gantry lifting and jacking systems

A1.17.15 Mobile gantry lifting and jacking systems may be used for temporary lifting operations as they can provide a greater lifting capacity than mobile cranes. These present similar hazards to other mobile temporary lifting systems. The stability of such systems, the alignment of the track, the applied travelling forces etc. need to be appropriately assessed. An adequate safety case should be provided that considers the potential for toppling of such systems. Other systems such as strand and tendon jacking have similar issues and there may be considerable stored energy in such systems.

A1.17.16 Gantry systems can be large and heavy and may be in position for several weeks or months. They may need to be assessed for climatic conditions (wind, snow, etc.), corrosion and external hazards, e.g. seismic.

Mobile Lifting Equipment Summary

A1.17.17 Given the potential hazards associated with mobile lifting equipment and the difficulty in assessing the probability and the possible failure mechanisms, it is not expected that such equipment will generally be used for routine hazardous nuclear operations, especially where they could create significant offsite radiological hazards.

A1.17.18 Where such use is deemed necessary, e.g. for refurbishment work, decommissioning activities or emergency requirements, their use needs to be subjected to detailed assessment, rigorous procedural control. The risks associated with use of mobile lifting equipment, including the effects catastrophic failure, need to be fully considered within the safety case and shown to be tolerable and ALARP.

A1.17.19 The need for additional measures, such as temporary evacuation, plant shutdown, etc. to reduce the consequences of the potential nuclear hazard to personnel and facilities not connected with the lifting operations should be considered.

A1.17.20 The nuclear hazard created by the lifting operation may require that an appropriately resourced emergency plan is in place in case of catastrophic failure.

Appendix 2 – Guidance to inspectors on the application of Statutory Regulations

A2.1 Supply of Machinery (Safety) Regulations

A2.1.1 The Supply of Machinery (Safety) Regulations SM(S)R is applicable to the supply of machinery and includes lifting equipment and lifting accessories (e.g. slings, shackles, etc.).

A2.1.2 It is unlikely that nuclear lifting equipment would be excluded from the Supply of Machinery (Safety) Regulations. Although the regulations do not apply to “machinery specially designed or put into service for nuclear purposes which, in the event of failure, may result in an emission of radioactivity”, the published “Guide to application of Directive 2006/42/EC” advises that “Machinery used in the nuclear power industry which does not give rise to a risk of emission of radioactivity is not excluded from the scope of the Machinery Directive”. (http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide_application_directive_2006-42-ec-2nd_edit_6-2010_en.pdf).

Section 4 of the SM(S)R contains “supplementary essential health and safety requirements to offset hazards due to lifting operations”

A2.1.3 Although not fitting the requirement for machinery to have a power source, manually operated lifting equipment is included as defined by:

“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”.

A2.1.4 The regulations also include ‘lifting accessories’, as defined by:

‘lifting accessory’ means a component or equipment not attached to the lifting machinery, allowing the load to be held, which is placed between the machinery and the load or on the load itself, or which is intended to constitute an integral part of the load and which is independently placed on the market; slings and their components are also regarded as lifting accessories

A2.2 Lifting Operations and Lifting Equipment Regulations LOLER

A2.2.1 The Lifting Operations and Lifting Equipment Regulations (LOLER) defines the statutory requirements for lifting equipment and lifting operations. The following advice highlights specific issues that may arise with lifting equipment associated with nuclear licenced sites.

LOLER Regulation 4 – Strength & Stability

A2.2.2 The above regulation requires the following:

i) 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;

ii) every part of a load and anything attached to it and used in lifting it is of adequate strength.

A2.2.3 The term "adequate strength" will be open to interpretation, especially where proprietary equipment is used. Inspectors will therefore need to consider the requirements of the TAGs on structural integrity, T/AST/016 when considering the more onerous applications, i.e. where there are significant claims being made on the structural integrity of lifting systems.

A2.2.4 The stability of items will need to be assessed by suitable analysis and testing if necessary. Testing has the advantage that uncertainties in weight and weight distribution will be removed. However test loads will have to bound any faulted loads and any dynamic effects imparted to the load, if they are to be truly representative, and are to robustly support claims made in the safety case.

LOLER Regulation 8 – Organisation of lifting operations

A2.2.5 The above regulation states that:

"Every employer shall ensure that every lifting operation involving lifting equipment is

i) properly planned by a competent person;

ii) appropriately supervised; and

iii) carried out in a safe manner.

A2.2.6 Inspectors need to note the requirements of LC 12 and LC 24 in ensuring that those planning and supervising operations are suitably qualified and experienced with respect to both the lifting issues and the nuclear safety matters. This should include the action to be taken in the event of a failure or other mishap.

A2.2.7 In this regulation "lifting operation" means an operation concerned with the lifting or lowering of a load.

A2.2.8 When assessing nuclear lifting operations the complete lifting or handling process needs to be considered. That is the lifting, movement of the load, and lowering process. Inspectors should note the advice in FOD circular OC 234/11[23] Para 30 that the HSE Solicitor has advised that a lifting operation includes all the activities associated with the lifting and lowering of the load; it therefore includes movement of the supported load.

A2.2.9 The mere presence of the lifting equipment also needs to be considered. That is, where its presence or construction, potentially posses a threat to other systems or operations, see also LOLER Regulation 6 Positioning and Installation.

A2.2.10 LOLER requires that lifting equipment which is exposed to conditions causing deterioration which is liable to result in dangerous situations is thoroughly examined so that deterioration can be detected in sufficient time to allow remedial action to be taken. A competent person is required to determine the level of thorough examination required based on an assessment of the risks.

A2.2.11 In other words, thorough examinations are intended to reveal deterioration in areas where the competent person reasonably expected to find it and judges it to be dangerous. That is generally visible processes such as wear in pulleys and ropes, corrosion, failures and looseness in fastenings, and fatigue in ropes and other components, where there is a reasonable expectation that the inspection method will find such deterioration prior to failure. LOLER Regulation 9 – Thorough Examination and Inspection.

A2.2.12 There therefore needs to be an expectation in the design that such degradation may occur and suitable conservatism incorporated in the design. For example, an excess number of strands have been provided in a rope, and there is a reasonable expectation that the failure mechanism will be slow and progressive and detectable. The maintenance regime should monitor such deterioration, and acceptable limits on deterioration and periods between inspections should be recommended in the design and maintenance guidance.

A2.2.13 Thorough examination is a precautionary measure to detect unexpected deterioration, it should not be relied on to find fundamental weaknesses in the design, which should have been considered during design, manufacture, testing and maintenance process, although the procedure may occasionally do so. Noting however that, if justified by the nuclear hazard and in order to demonstrate defence in depth, the nuclear safety case may need to specify additional design-informed in-service inspections to ensure that the condition of equipment remains consistent with the claims made of it and risks are reduced such that they are ALARP. These design-informed inspections may be targeted at areas where there is no degradation expected, but where they may be highly stressed or safety critical.

A2.2.14 Thorough examination can also reveal inappropriate use, such as overload, poor maintenance, corrosion or inadequate design, etc.

A2.2.15 It is expected that the most sensitive nuclear equipment would have a detailed inspection regime developed from the design, through manufacture and operation, and this would reflect the requirements of T/AST/016 to achieve an appropriate structural reliability.

A2.2.16 Inspectors therefore need to be aware of the limitations of cases based on the proprietary designs of equipment, merely supported by routine thorough examinations, when compared with the more rigorous approach to structural design and inspection contained in T/AST/016.

A2.2.17 It should be noted that independent third parties, often referred to as "insurance companies" frequently perform "thorough examinations" under LOLER Regulation 9, and for more general insurance purposes.

A2.2.18 Such persons are unlikely to have any detailed information, or knowledge of the nuclear safety significance of the equipment, or the nature of the operations performed, and should therefore be instructed and directed by an appropriately qualified person who is identified in the licensee’s arrangements. Such third parties will however, usually have wide experience and knowledge of the inspection of similar lifting equipment in a range of other industries, and will be familiar with its failure modes and other issues. They are therefore a valuable independent source of practical and theoretical advice on lifting equipment and on the inspection processes.

A2.2.19 It is to be expected that Licensees will appoint SQEPs to examine nuclear lifting operations and equipment so that continued fitness for purpose can be confirmed within safety cases. The requirements of LC 28 (8) states that, "When any examination, inspection, maintenance or test of any part of a plant reveals any matter indicating that the safe operation or safe condition of that plant may be affected, the suitably qualified and experienced person appointed to control or supervise any such examination, inspection, maintenance or test shall bring it to the attention of the licensee forthwith who shall take appropriate action and ensure the matter is then notified, recorded, investigated and reported in accordance with arrangements made under Condition 7."

A2.2.20 This is in addition to any reporting or other requirements required under LOLER, PUWER or any other regulation e.g. RIDDOR.

A2.2.21 Inspectors should note that LOLER specifies the following default thorough examination periods, Reg. 9 (3):

i) in the case of lifting equipment for lifting persons or an accessory for lifting, at least every 6 months;

ii) in the case of other lifting equipment, at least every 12 months; or

iii) in either case, in accordance with an examination scheme; and

iv) each time that exceptional circumstances which are liable to jeopardise the safety of the lifting equipment have occurred; and

v) if appropriate for the purpose, is inspected by a competent person at suitable intervals between thorough examinations, to ensure that health and safety conditions are maintained and that any deterioration can be detected and remedied in good time.

A2.2.22 Inspectors should therefore note that lifting equipment may need to be thoroughly examined more frequently than the statutory minimum periodicity. This may typically be due to concerns about the condition of the equipment (e.g. rate of deterioration, environment conditions, poor maintenance record, etc.). It may be also considered appropriate to carry out a thorough examination before a significant nuclear lift.

A2.2.23 Inspectors should note that LOLER Regulation 9 identifies complementary system to the specified period approach. This involves having a written examination scheme drawn up for the lifting equipment in use and have it thoroughly examined in accordance with this scheme. Such schemes are particularly important for equipment used for high risk lifting operations or where the deterioration of the lifting equipment may be more rapid, e.g. due to environmental conditions, number of lifting cycles or severity of use. The examination scheme should specify the intervals for thorough examination of the lifting equipment and identify any parts that need to be tested. It should take account of the condition of the lifting equipment, the environment in which it is to be used; and the number of lifting operations and the loads lifted.

A2.2.24 Risk based inspection schemes may be more appropriate for safety critical items and give more control and focus to the examination process. This may also be beneficial in areas where the ‘competent person’ surveyors are put at radiological risk from performing the examination and there is limited hazard from lifting equipment failure due to the exclusion of personnel. However, the nuclear hazard needs to be appropriately assessed during the preparation of the risk based examination scheme including any dose burden from potential recovery operations.

A2.2.25 As part of the implementation of such examination schemes, when personnel enter such facilities they need to be aware of the hazards presented by the lifting equipment before they are exposed to any danger.

A2.2.26 During maintenance periods, etc. when the facilities can become routinely manned, the examination scheme may not be appropriate as the risk of injury to personnel may have changed. Alternative examination arrangements may need to be in place under LOLER, e.g. statutory periodicity.

A2.2.27 Switching from periodicity based inspection to risk based inspection is possible, however, the ‘competent person’ will require a thorough examination before an examination scheme is implemented. A risk based examination scheme should determine the most appropriate period between thorough examinations. This can extend the period but the scheme may require more frequent examinations to be carried out and/or that they are more extensive. It may also identify examinations that should be undertaken immediately prior to use.

LOLER Regulation 10 – Reports and defects

A2.2.28 LOLER requires written reports to be provided for all thorough examinations.

A2.2.29 Where there is, in the opinion of the ‘competent person’, a defect in the lifting equipment involving 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, i.e. HSE.

A2.2.30 Thorough examination reports should be considered in any assessments performed to support the nuclear safety justification. Whilst the presence and nature of any defects may not affect the nuclear safety case, they could present a serious conventional hazard.

A2.3 PUWER

A2.3.1 The Provision and Use of Work Equipment Regulations (PUWER) 1998 applies to all work equipment, and therefore applies to the design of lifting equipment. PUWER and LOLER are both derived to enact the Amending Directive (95/63/EC) (AUWED) to the Use of Work Equipment Directive (89/655/EEC) in the UK. PUWER addresses work equipment in general, and LOLER the specific aspects of lifting operations and lifting equipment.

A2.3.2 Equipment that is selected for nuclear lifting operations is ‘work equipment’ and must be suitably selected and designed for that purpose.

PUWER Regulation 4 – Suitability of Work Equipment

A2.3.3 PUWER states the following with respect to the suitability of work equipment.

i) Every employer shall ensure that work equipment is so constructed or adapted as to be suitable for the purpose for which it is used or provided.

ii) In selecting work equipment, every employer shall have regard to the working conditions and to the risks to the health and safety of persons which exist in the premises or undertaking in which that work equipment is to be used and any additional risk posed by the use of that work equipment.

iii) Every employer shall ensure that work equipment is used only for operations for which, and under conditions for which, it is suitable.

iv) In this regulation "suitable" means suitable in any respect which it is reasonably foreseeable will affect the health or safety of any person.

A2.3.4 PUWER contains significant regulations relating to the suitability, maintenance, guarding, training, emergency stops, control systems and other features of work equipment that are fundamental to the safe design of lifting equipment and lifting operations.

Appendix 3 – Guidance to inspectors on the selection and use of British Standards and European harmonised standards for the design of lifting equipment structures and mechanisms

A3.1 Overview

A3.1.1 Following the introduction of European Directives, the European standards bodies have been drawing up corresponding technical specifications, referred to as “harmonised standards” that meet the essential requirements of the relevant directives. Compliance with these standards should thereby provide a presumption of conformity with the essential requirements of the relevant directive.

A3.1.2 Inspectors should note that many existing British Standards were drawn up before the Machinery Directive came into effect. Therefore, compliance with a British Standard that is not an EN standard, should not be taken as a presumption of conformity with the essential requirements of the Machinery Directive. A significant number of harmonised standards for cranes and lifting equipment have now been published and these should be considered for their suitability and applicability. Licensees should therefore be able to demonstrate how a selected design code provides a means of compliance with the Machinery Directive for mechanical strength.

A3.1.3 BS466[24] and BS2573 Parts 1 and 2 have been used by UK site licensees and crane manufacturers for many years as the principal design codes for the design justification and assessment of overhead cranes and other similar types of mechanical equipment.   At the time of writing this guidance, BS2573 Parts 1 and 2 were classified as “superseded’, but still “current” standards, whilst BS466 was classified as a “current” standard. The standards were still available from the British Standards Institution and there is no known reason why these standards cannot still be used.

A3.1.4 EN 13001 is a new series of crane design codes applicable to all types of lifting machinery. Some parts have already been published whilst others are still being drafted. Other standards address specific equipment types, for example, provisional European standard prEN 15011 (scheduled for publication June 2011) is specifically for bridge and gantry cranes, but should be used in conjunction with EN 13001, e.g. for structural strength and rope system design.

A3.1.5 For nuclear lifting applications, licensees often apply additional design factors and code enhancements (e.g. designing for infinite fatigue life) to increase the margins available between the normal service loads and the limiting strength of a structure or component, to cater for fault load conditions. Although this approach provides greater conservative than the design code, it does not ensure adequacy for all fault load conditions. Inspectors should therefore apply the guidance in T/AST/016 Section 4.6 “Load analysis – the analysis of all load conditions within the design basis”. SAPs Para 159.

A3.1.6 Inspectors should be aware that EN 13001 adopts a limit state design approach that provides consistent design margins throughout a structure. This differs from BS2573, which is based on the allowable stress method. Consequently, a comparison of the two codes will result in different reserve margins compared to elastic and plastic limits. BS2573 design factors are therefore not interchangeable with EN 13001 and the application of previously adopted design factors and enhancements is unlikely to achieve an equivalent design. Analysis supported by a combination of design codes should therefore be avoided or justified when used, SAPs Paras 160 and 161.

A3.1.7 In assessing the suitability of a design code, inspectors should consider the requirement of LC15 (Periodic Review), in particular the need to carry out a comparison against current standards for new plant, evaluate any deficiencies and implement any reasonably practicable improvements to enhance safety. Where there are impending changes to current standards and/or a variety of existing standards that could be used, the comparison of standards should aim to demonstrate that appropriate conservatisms and safety margins are maintained.

A.3.2 Classification Methodology

A3.2.1 The purpose of classification is to take into account the huge differences that can exist in operating duties. These differences affect the wear and fatigue life of components, and must be considered in the design otherwise in-service failures can result.

A3.2.2 The EN 13001 classification methodology is different and more detailed than that used in BS466 and BS 2573. They are therefore non-interchangeable and equipment classifications based on one standard cannot be used to determine the design factors of another. Whichever, classification method is used, the classification of the lifting system and its structures and mechanisms should be demonstrably conservative.

A3.2.3 Inspectors should be aware that the working cycles of a lifting system start from the day it is installed through to the day it is taken out of service and should therefore include:

- Installation of lifting system
- Construction and installation of plant and equipment
- Setting to work, testing and commissioning (particularly applicable to store cranes where the full range of system capability has to be demonstrated before the store inventory is received)
- Normal plant operation
- Plant faulted conditions e.g. control and protection system trips and recovery actions
- Post-operative clean out operations (POCO)
- Decommissioning operations
- Plant and equipment maintenance and testing requirements
- Plant and equipment in-service inspection requirements
- Lifting system maintenance and in-service testing requirements

Appendix 4 – Relationship of Issues to SAPs, TAGs and Statutory Requirements

Issue	SAP	TAG	Statutory Instrument
Key principles	EKP.1 to EKP.5	T/AST/004	-
Safety functions	EKP.4 and EKP.5 ECS.1 to ECS.5	T/AST/008	-
ALARP	All	T/AST/005	MHSWA
Plant and equipment layout	ELO.1 to ELO.4	T/AST/036 T/AST/057	CDM PUWER
Planning of lifting operations	ELO.1 to ELO.4	T/AST/027	LOLER
Structural and mechanism design and integrity	EMC. EQU.1	T/AST/011 T/AST/016 T/AST/033 T/AST/042 T/AST/057	SM(S)R PUWER LOLER
Reliability	EDR.1 to EDR.4	T/AST/011	-

Issue	SAP	TAG	Statutory Instrument
	ERL.1 to ERL.4 EMT.6		
Control systems	EQU.1	T/AST/015 T/AST/033 T/AST/046	SM(S)R
Protection systems	EQU.1	T/AST/015 T/AST/033	SM(S)R
Electrical equipment	EQU.1	T/AST/015 T/AST/033	EMCR LVR
Commissioning	ECM.1 EQU.1	T/AST/028 T/AST/033	CDM
External hazards	EHA.1 to EHA.7 EHA.9 to EHA.12 EHA.15	T/AST/013	-
Internal hazards	EHA.1 EHA.3 to EHA.7 EHA.10 EHA.13 to EHA.17	T/AST/014	DSEAR
Examination, Maintenance, Inspection and Testing	EMT.1 to EMT.8 EQU.1	T/AST/009 T/AST/027 T/AST/033	PUWER LOLER CDM
Change control	EQU.1	T/AST/033 T/AST/057	PUWER
Ageing and degradation	EAD.1		PUWER LOLER