NUCLEAR SAFETY DIRECTORATE - BUSINESS MANAGEMENT SYSTEM		
TECHNICAL ASSESSMENT GUIDE **NUCLEAR LIFTING OPERATIONS**		**T/AST/056** ISSUE 001
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Open Government Status: Fully Open		Review Date: 07/07/2009

1. Purpose & Scope

1.1 This TAG discusses NII's approach to the assessment of nuclear lifting operations and lifting equipment.

1.2 Lifting equipment and systems are used in a variety of ways on nuclear licensed sites ranging from new construction, commissioning and operation, through to final decommissioning.

1.3 Lifting systems are used routinely for the handling and movement of nuclear material during the operation of the plant, the manufacture of components, and also for lifting inert loads during maintenance or repair, where the movement of the load may present a hazard to the surrounding equipment and operations and thus affect nuclear safety. Lifting systems may have many different safety demands placed on them at different plant states, and at different phases in the plants life.

1.4 Licence Condition 23 requires that the Licensee should "in respect of any operation that may affect safety, produce an adequate safety case to demonstrate the safety of that operation and to identify the conditions and limits necessary in the interests of safety". A nuclear safety case is therefore necessary to cover all lifting operations at nuclear licensed sites, be it within the audit trail from a safety report for normal operation or within a modification proposal process for non-routine operations.

1.5 This TAG contains general guidance to advise and inform NII Inspectors in the exercise of their professional regulatory judgement. This document is not a guide on how to design lifting systems, or to develop safety cases but identifies issues that NII Inspectors should consider when assessing the adequacy of such safety cases. Assessors will need to use this TAG in combination with their existing experience and discussions with peers in NII to understand the breadth and depth of some aspects of the NII assessment process in this technical area.

1.6 The assessment of lifting systems and operations will rely heavily on the structural integrity aspects of the load path, the mechanics of the hoist and travel systems, the behaviour of the controls and the dynamic response of motors and drives. Consideration must however also be given to the wider nuclear hazards created by the lifting operation in order to assess the acceptability of the proposed operation.

1.7 It is impossible to define all the safety issues that need to be considered in an assessment of lifting operations given the variety of applications, but assessors need to be aware that dropped loads, the uncontrolled movement of loads, the collapse of lifting structures and other mishaps have the potential to disrupt safety systems and components on a large scale within a nuclear installation. Assessors should be aware that criticality control, shielding, containment, cooling, reactor control systems and nuclear chemical plant process equipment and control amongst others, could be disrupted by such activities, and need to be alert to such hazards and ensure that they have been appropriately assessed.

1.8 Comprehensive reference is therefore essential to the NII's Safety Assessment Principles [Reference1] and the other TAGs when assessing such operations and equipment.

1.9 Comments on this guide, and suggestions for future revisions, should be recorded on the appropriate registry file.

2. SAPs Addressed

2.1 There are no SAPs that specifically mention nuclear lifting operations but the following SAPs cover the movement and handling of nuclear matter.

P311 The plant and equipment and the systems of work for storage, handling and transporting nuclear matter on the site should be such that the risk of damage to the containment of such materials, to the materials themselves and to any adjacent plant, is minimised.

P278 Nuclear matter should not be generated on or brought onto a site unless suitable facilities and arrangements exist for its safe transport, handling, processing, storage and/or disposal. In particular:

a. the arrangements should ensure that the type and form of the nuclear matter and the maximum inventories of that matter are within specified limits consistent with the safe operation of the plant, including where appropriate, plant sub-divisions or individual plant items;
b. the facilities and associated arrangements should be sufficiently flexible to enable the handling and storage of abnormal items which might be produced on or arrive at the site (eg damaged or faulty fuel or containers, and material of non-standard physical or chemical composition).

P310 The operational limits to be applied during the storage, handling and transport of nuclear matter should be specified.

P111 Manipulation of items exhibiting high surface radiation dose rates should be carried out using remote handling devices. Manipulation of highly contaminated items should wherever possible be carried out in enclosures which provide adequate protection against the spread of contamination.

P232 Where facilities are required for bringing nuclear matter out of the plant containments, the number of such facilities should be minimised and the design should ensure that the overall containment and ventilation standards are not degraded and, where appropriate, it should:

a. provide remote handling devices and means to facilitate their operation, decontamination and repair; and
b. provide additional containment, local ventilation, and shielding.

2.2 So whilst there is no specific mention of lifting in the SAPs, such operations are covered by the generic term of handling; meaning the lifting and movement of loads. There is clearly a requirement to minimise the potential risk for damage from such operations, both to the containment of the nuclear matter and to the surrounding equipment. There is also a requirement to consider remote handling where appropriate and to contain such operations where possible.

2.3 The following SAPs are also considered particularly relevant to the assessment of nuclear lifting operations and the design of nuclear lifting equipment.

P4	All reasonable steps to prevent accidents
P6	The requirement to predict radiation doses
P15 - P19	Fault Analysis
P20 - P27	Design Basis Accidents
P28, P29	Severe Accidents
P32, P33	Probabilistic Safety Analysis
P55	Plant Performance Data Response
P61, P62, P65 - P81	Key Engineering Principles
P82 - P85	Categorisation Codes & Standards
P86 - P90	Design Data and Models
P91 - P94	Human Factors
P74, P95 & P96	Plant Layout
P97 - P101	Maintenance Inspection and Testing
P102 - 103	Plant Ageing
P104 - P113	Radiological Protection
P114 - P118	Reliability

2.4 It should be noted that some of the principles provide broad guidance, and need to be applied to a range of engineering applications and issues, thus some interpretation will be necessary in the application of each principle.

3. Relationship to licence and other relevant legislation

3.1 There are no primary licence conditions that specifically address lifting operations although the following conditions cover issues relevant to such operations:

LC 4	Restriction on Nuclear Matter on The Site
LC 6	Documents, Records, Authorities and Certificates
LC 9	Instructions to Persons on Site
LC 10	Training
LC11	Emergency Arrangements
LC 12	Duly Authorised and other Suitably Qualified and Experienced Persons
LC 14	Safety Documentation
LC 15	Periodic Review
LC 19	Construction or Installation of New Plant
LC 20	Modification to Design of Plant Under Construction
LC 21	Commissioning
LC 22	Modification or Experiment on Existing Plant
LC 23	Adequate Safety Case and Operating Rules
LC 24	Operating Instructions
LC 26	Control and Supervision of Operations
LC 27	Safety Mechanisms, Devices and Circuits
LC 28	Examination, Inspection, Maintenance and Testing
LC 29	Duty to carry out Tests Examinations and Maintenance
LC 34	Leakages and Escapes of Radioactive Material & Waste

It should be noted that Licence Condition 24 specifically states that the "licensee shall ensure that all operations which may affect safety are carried out in accordance with written instructions hereinafter referred to as operating instructions. The licensee shall ensure that such operating instructions include any instructions necessary in the interests of safety and any instructions necessary to ensure that any operating rules are implemented.."

Lifting operations should therefore be appropriately controlled in accordance with written instructions. They should be suitably planned and performed in a controlled manner, using approved methods, routes, heights, equipment and lifting tackle that are deemed suitable and safe for the load being lifted to ensure that lifting hazards are kept as low as reasonably practicable.

4. Statutory Legislation

4.1 Whilst nuclear safety assessments are primarily concerned with nuclear hazards, assessors of nuclear lifting operations should be aware of the statutory requirements relating to the design, supply and use of lifting equipment. Correct application of the statutory requirements should also help identify any potential nuclear hazard and the need for suitably competent persons to assess the nuclear risk.

4.2 The main regulations used to control lifting operations and equipment are as follows:

1. The Lifting Operations and Lifting Equipment Regulations 1998 LOLER. Statutory Instruments 1998 No. 2307
2. The Provision and Use of Work Equipment Regulations 1998 PUWER. Statutory Instrument 1998 No. 2306
3. The Management of Health and Safety at Work Regulations 1999
4. The Supply of Machinery (Safety) Regulations 1992. Statutory Instrument 1992 No. 3073

4.3 The above legislation mainly addresses the significant physical hazards that can arise from lifting operations and equipment. The nuclear site licence, and/or the nuclear safety case in no way exempts the licensee from such legislation and the use of the associated ACOPs. Advice on the enforcement of such legislation and standards within NSD is given in G/INS/030. The requirements regarding the use ACOPs are covered in the HSWA Section 17.

4.4 It should be noted that the Safety Assessment Principles [Reference 1] Para 20 specifically states that "The principles presented here relate only to nuclear safety. Other conventional hazards are excluded except where they have a direct effect on nuclear safety." Such hazards therefore need to be considered appropriately.

4.5 Assessors should note that a variety of other statutory legislation may apply to lifting equipment such as The Pressure Systems and Transportable Gas Containers Regulations 1989 Statutory Instrument 1989 No. 2169 to the hydraulic and pneumatic systems of some lifting systems and The Electricity at Work Regulations 1989 Statutory Instrument 1989 No. 635 to the design of electrical systems etc. Assessors should be aware of the need for the Licensee to comply with such legislation and to consider the nuclear hazard when referring to such legislation as appropriate.

4.6 LOLER contains the main statutory regulations related to lifting operations. The associated ACOP [Reference 2] gives useful general guidance on the application of these regulations.

4.7 LOLER must not be considered in isolation from other statutory regulations. For example LOLER Regulation 8 requires that lifting operations are properly planned by a competent person, appropriately supervised, and carried out in a safe manner. The associated ACOP advises that a risk assessment is required under the MHSW Regulations and this needs to reflect the nature and level of risk (conventional and nuclear hazard) and that a proportionate response according to the risk is required.

4.8 Hence the risk assessment undertaken for the purpose of the nuclear deterministic safety assessment under the SAPs may establish the extent of any nuclear hazard, but is unlikely to be a substitute for the risk assessment required by the MHSW Regulations, which must cover all the reasonably foreseeable hazards created by the lifting operation e.g. collapse, toppling, explosion etc. that may lead to other physical as well as radiological hazards.

4.9 PUWER as its name indicates covers the provision of the actual work equipment and therefore covers the provision of all lifting equipment.

4.10 Assessors should appreciate that PUWER and LOLER are intended to interface with each other, both being derived to enact the Amending Directive (95/63/EC) to the Use of Work Equipment Directive (89/655/EEC) (AUWED) in the UK; PUWER addressing work equipment in general, and LOLER the specific aspects of lifting operations.

4.11 Hence whilst LOLER includes planning, strength and stability of the load and load path, and thorough inspection, PUWER covers issues relating to the design and fitness for purpose of the equipment, provision of controls, training and maintenance etc.

4.12 PUWER Regulation 4 requires the suitability of equipment to be examined, whilst LOLER Regulation 4 requires there is adequate strength. Hence in combination the equipment needs to be suitable for it is proposed use, and needs to have adequate strength. Similarly issues relating to maintenance and conventional safety (e.g. guarding) are covered by PUWER and the more general thorough inspection by LOLER.

4.13 Nuclear lifting operations create unique hazards due to the nature of the material being lifted or the nuclear plant equipment or services that may be damaged in the event of a failure in the lifting operation. It is therefore important that the competent persons appointed under LOLER and MHWSR have the knowledge and experience such that they understand the nuclear hazards, as well as those created by the lifting operation. They should also ensure that they have been assessed by suitably qualified, and competent persons (SQEPs) for the roles to which they are appointed as detailed in the above regulations and required by LC 12. It is to be expected that the Licensee will formally appoint SQEPs to examine nuclear lifting operations, equipment and loads so that continued fitness for purpose can be confirmed within safety cases.

4.14 Assessors should note that those persons whose primary function is the safe operation, maintenance and inspection of conventional lifting equipment, and who are frequently employed by third party organisations, may not be familiar with nuclear hazards and the plant's detailed design, the requirements of the site licence conditions, and may not therefore be authorised under the site licence conditions to authorise such operations. Reassurances given by such organisations therefore need to be treated cautiously and considered in the context of the site licence.

Licence Condition 28 (8) additionally 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." Hence this is in addition to any reporting or other requirements required under LOLER.

4.15 Appendix 2 and FOD Operational Circular OC 234/11 also gives further guidance on the application of LOLER.

4.16 The main purpose of this TAG is to ensure that the nuclear hazards created by lifting operations are appropriately addressed. Assessors should however have an understanding of the statutory regime and it is for the licensee to develop procedures that comply both with the site licence conditions, and the statutory requirements.

4.17 The Supply of Machinery (Safety) Regulations 1992 also covers the supply of equipment intended for lifting. Assessors should be aware that Schedule 5 of these regulations excludes "Machinery specially designed or put into service for nuclear purposes which, in the event of failure, may result in an emission of radioactivity", hence certain equipment on nuclear licensed sites is technically exempt from these regulations.

4.18 This exemption means that the onus is placed on the licensee to use SQEPs to demonstrate that nuclear equipment is uniquely justified as fit for its nuclear use. This may require considerable enhancement of the design, construction and inspection standards usually undertaken by the suppliers of such proprietary equipment normally purchased under these regulations.

4.19 This exemption also means that the licensees need to ensure that any such equipment is not only fit for its nuclear use, but is also adequate against conventional hazards. Since most active nuclear plants undergo inactive commissioning, maintenance and other work, when normally unmanned areas could be occupied, the potential hazards to such workers must be accounted for.

Specific Issues SMS Regulations:

4.20 Assessors should note that the static and dynamic testing requirements of the SMS Regulations have been significantly enhanced from those specified in some older British Standards.

4.21 Assessors should also note that the minimum factors of safety specified by the SMS Regulations, especially for ropes, might also exceed those in some of the older British Standards.

British Standards

4.22 BS 7121 Code of Practice Safe Use of Cranes

The general advice on crane operation and inspection in this standard should be noted. It provides the main UK generic advice on crane operations, including advice on the following:

a Management of the Lifting Operation
b Planning of the Lifting Operation
c Selection and Duty of Personnel
d Minimum attributes of Personnel
e Selection of Cranes
f Siting of Cranes
g Erection and Dismantling
h Procedures and Precautions
i Operating Conditions
j Testing and Examination
k Legal Requirements
l Thorough Examination
m Testing as Part of Through Examination
n Data Logging
o Assessment of wire rope and discard criteria

5. BMS Guidance

5.1 Finally the assessor of lifting equipment and lifting operations needs to be aware of NII's expectations more generally for Licensees' safety cases and how they are produced. The following TAGs are a selection that may be relevant to lifting operations, a full index can be found at Technical Assessment Guide.

T/AST/051	Guidance on the Purpose, Scope and Content of Nuclear Safety Cases
T/AST 003	Safety Systems
T/AST/005	Demonstration of ALARP
T/AST/006	Deterministic Safety Analysis and the Use Of Engineering Principles In Safety Assessment
T/AST/008	Safety Categorisation and Equipment Qualification
T/AST/011	The Single Failure Criterion
T/AST/016	Structural Integrity
T/AST/017	Structural Integrity: Civil Engineering Aspects
T/AST/031	Safety Related Instrumentation
T/AST/036	Diversity, Redundancy, Segregation and Layout of Mechanical Plant
T/AST/039	Management for Safety
T/AST/041	Control, Storage, Handling and Transport of Nuclear Matter Including Fissile Materials
T/AST/046	Computer Based Safety Systems

6. Advice to assessors

Introduction

6.1 This guide is concerned with the assessment of lifting equipment and lifting operations on nuclear licensed sites. It covers the lifting and movement of nuclear material, and other material that could affect nuclear safety. For example the movement of nuclear fuel, nuclear waste, neutron sources, control rods, flasks and other loads that have the potential to disrupt the radiological processes, barriers, safety mechanisms and devices that are designed to protect such systems.

6.2 The purpose of NII assessment of lifting equipment and the lifting operations aspects of safety cases is to establish whether the design, construction, operation, monitoring, inspection and maintenance regime is adequate to fulfil the required safety functions for the proposed operation, and establish that the hazards created by such operations are tolerable and ALARP. The assessor of lifting equipment and lifting operations therefore needs to consider the adequacy of the complete lifting system, in the context of the nuclear safety case.

6.3 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 reactor system. However, other systems may be more general in nature, for example cranes that occasionally handle nuclear loads or carry non-nuclear loads over sensitive equipment such as nuclear reactors, nuclear chemical plant or nuclear related equipment.

6.4 Assessors 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 such systems is undertaken.

6.5 Lifting equipment 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.

6.6 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 P311. Assessors should be careful about comparing apparently similar systems, unless they have a full understanding of all the safety issues, operating rules etc.

7. Engineering Background

7.1 Assessors should note that lifting operations are generally considered as dangerous activities, and therefore need to be carefully regulated when undertaken on nuclear facilities. Because lifting operations are potentially hazardous, they should also undergo careful scrutiny to comply with conventional health and safety standards (e.g. MHSWR, LOLER, PUWER).

7.2 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 i.e. SAPS P61, P62. 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.

7.3 Various approaches have been used in developing nuclear safety cases for lifting operations, ranging from that of a "dropped load case" where the consequences of failure is perceived to be acceptable, through to cases where the probability of equipment failure is perceived to be incredible by significant enhancements in the engineering design.

7.4 Clearly the simplest nuclear cases are those of the dropped load type, where the consequences of failure of the lifting system have been robustly analysed, the nuclear material remains contained (SAP P311) and the consequences have been shown to be tolerable. The lifting system design is then primarily aimed at meeting the statutory requirements and the requirement of SAP P4 that "all reasonably practicable steps shall be taken to prevent accidents" have been taken.

7.5 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. That is the quantity of fuel, and its configuration are arranged to prevent criticality, it is fully contained, there is no cooling requirement, and the process is inherently safe by passive design. It is important to ensure in such cases that the appropriate radiological analysis has been documented and assessed, see Technical Assessment Guide T/AST/041 on the assessment of such 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 should also be exercised, when considering the potential outcome of such operations or the probability of its occurrence.

7.6 Providing the principal nuclear hazard has been addressed in the above fashion, 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.

7.7 Similar consequence type "drop load cases" may apply to robust transport flasks or containers (or in IAEA terms nuclear packages which may contain nuclear packaging), where there is a sound understanding of the impact resistance of the flask or container, and it is lifted well within its withstand capability. It may also apply to the structure that is targeted, i.e. a reactor pile cap, pond etc. if it has been robustly constructed, and can be justified against such impact. Again limited reliance is placed on the integrity of the lifting system, but there is a requirement to perform a rigorous dynamic and structural analysis of the containment or package. This may include dynamic testing of the design or protective boundaries. The justified nuclear package will need to be uniquely identified and its continuing integrity demonstrated as required by Licence Condition 34. This unique identification can also assist with control of movement of nuclear materials (the nuclear packaging and its nuclear materials content).

7.8 It should be noted that many on site nuclear packages are not constructed to the same integrity standards as those used for off site road/rail/sea transport and significant reliance is then be placed on the robustness of the cranes engineering and protection systems as outlined below. It should also be noted that the contents of such packages and the radiological nature of the material within them may differ widely e.g. from metallic solids to liquids etc. and the radiological hazards from their damage or destruction will vary considerably.

7.9 When assessing such cases 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 than the loads being lifted, especially if lift heights have been restricted. SAPs P6 to P55 cover the requirements for detailed safety analysis of plant through normal operation to severe accidents where major plant damage may be sustained.

7.10 Given that failures of lifting equipment will generally be catastrophic (i.e. structural collapse, load drop etc) it is 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 (P51, P52). 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 P325.

7.11 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".

7.12 Derating can range from simply lowering the Safe Working Load of the device, through to derating of the code (i.e. additional duty factors) to give enhancement of the safety margins within the code. Assessors should be aware that derating, whilst simple, will have a variable effect on the safety 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 from the prime mover or brakes, rather than from the live load etc. and may not be in proportion to the SWL. Proof tests may give little protection against defects, unless appropriate fracture mechanics and inspection standards have been developed.

7.13 Assessors should be aware that typical proof tests of around 125 % may not conservatively bound the worst case dynamic faulted conditions arising from detailed analysis of fault sequences; e.g. for 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 system. In the event of the overload protection failing to limit the loads when the load is snagged, the load is ledged and dropped, or with seismic loading where there may be uncontrolled movements or reversed loadings etc.

7.14 Assessors 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 that the design may in fact be justified solely on the basis of theoretical analysis, unless additional testing limits are devised.

7.15 In the case of single failure proof cranes the system is designed so that no single failure will result in loss of capability of the system to retain the load, see [Reference 3]. The additional features provided are usually restricted to those in the hoist load path and ensure that failure in the crane mechanism is tolerable, and the crane will come to rest in a safe manner, without dropping the load. It is usual for the crane brakes to be applied on loss of power, and to provide braking close to the drum, to remove the structural integrity demands placed on gearbox components, and to provide dual reeving etc. Other load bearing items are conservatively designed.

7.16 It should be noted that whilst such an arrangement may be acceptable in the short term, it does not reduce the potential hazard of a dropped load, when the brakes are released to make a recovery action for example, and there is no defence in depth P65.

7.17 Assessors therefore need to be aware of the danger of loads remaining suspended, and 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.

7.18 There may be radiological constraints on access to the load and lifting equipment, during recovery operations.

7.19 There may also be restrictions on the time that hung loads can remain suspended for such reasons as fuel cooling, and weather conditions including wind, snow or lightening etc.

7.20 It is essential 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.

7.21 The "one fault safe" approach has been developed in the US and incorporated in the US NRC ASME NOG Standard [Reference 4]. 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 [Reference 5].

7.22 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 SAP P68. That is there is an independently operable load path capable of supporting the load. This may take the form of a dual load path within the lifting system, either by using a parallel lifting system e.g. multiple reeving and drum systems, or 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 dynamic loading, and that the claimed engineering benefits are achieved in practice, SAPs P325 to P327. Some of the issues that need to be considered in the assessment of these systems are indicated in Appendix 1.

7.23 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 reliance is placed on operators for important safety critical functions, then detailed assessment of the human factors aspects will need to be undertaken. Particular attention should be given to training and instructions to operators 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 Para 4.22 and SAPs P91 to P44.

7.24 From the above discussion it will be noted that justification of lifting operations will depend on a unique 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 assessor 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.

7.25 Whatever approach is used it is important to note that the requirements of P325 are achieved. That is 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 is maintained (ie P25) and no safety-related component (or structure or system) required to prevent or mitigate the fault sequence will be caused to operate outside the conditions for which it has been qualified.

8. Detailed Consideration of the SAPs

8.1 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. and it is not proposed to reproduce them all here other than to note how they may be applied to lifting operations.

8.2 The requirements of SAP P4 that all reasonably practicable steps shall be taken to prevent accidents and SAP P5 that all reasonably practicable steps shall be taken to minimise the radiological consequences of any accident should be noted when developing and planning lifting operations. The hierarchy of hazard avoidance, the use of inherently safe and passive features and the avoidance of sensitive systems contained in SAPS P61,P62 should be noted.

Safety Analysis

8.3 The assessment of nuclear lifting operations should include a safety assessment of the radiological risk. Principles P6 to P55 define the NII requirements for safety analysis and as indicated by principles P15 to P31 a full range of accident and fault conditions should be considered.

8.4 Most lifting equipment will simply be designed to meet normal operating loads in accordance with design codes such as BS 2573. Such codes usually require limited consideration to be given to generic internal faulted conditions, and for the structure or mechanism to survive such conditions. Other codes and standards give advice on operating such equipment with the objective of avoiding failures e.g. BS 7121.

8.5 The NII SAPs require a far more detailed and structured analysis of operations and equipment on nuclear licensed sites. This requires a comprehensive consideration of fault sequences and events. This approach is described as deterministic safety assessment, (DSA). The main objective of DSA is to produce a balanced assessment of equipment and operations, and provide a robust demonstration of the fault tolerance of the complete activity. T/AST/006 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.

8.6 Assessors will need to use their experience and judgement to assess the extent of the DSA 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 DSA 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.

8.7 The main objective however in any lifting operation will be to demonstrate compliance with SAP P25. That is, "It should be shown that, following any design basis fault sequence: none of the physical barriers to the escape of radioactivity is breached or, if any are, then at least one barrier remains intact;

there is no release of radioactivity except in the most severe cases and, even then, no person outside the site will receive an effective dose of 100 mSv or more; and

no person on the site will receive an excessive dose from the release of radioactive material or by direct radiation including that from criticality incidents."

Engineering Principles

8.8 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 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 practical.

8.9 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.

8.10 SAPs P69 P82 P83 P84 require that special attention be given to the design of nuclear structures and components as follows:

(P69) All structures, systems and components should be allocated a safety categorisation which takes account of the consequences of their potential failure and of the failure frequency requirements placed on them in the safety analysis.

The safety categorisation should be determined on the following basis:

Category 1 - any structure, system or component which forms a principal means of ensuring nuclear safety;

Category 2 - any structure, system or component which makes a significant contribution to nuclear safety;

Category 3 - any other structure, system or component.

(P82) The design should be conservative and follow appropriate national or international codes and standards and the plant should satisfy the requirements of the best practicable standards of manufacture, construction, inspection, maintenance and operation, commensurate both with the safety categorisation and with any relevant reliability requirements of its component parts.

(P83) All structures, systems and components should be designed, constructed and inspected to the highest standards commensurate with their safety categorisation as follows:

Category 1 - Conservative design and construction standards should be adopted for this, the highest category together with a strict interpretation of these assessment principles in line with the ALARP requirement. For some items (such as those whose failure would lead directly to an event beyond the design basis) the special case procedure P70 may need to be used;

Category 2 - Appropriate national or international codes or standards should be adopted, with particular consideration being given to demonstrating the ability of the item to perform the required safety function;

Category 3 - Normal industrial standards can be applied.

(P84) Where there is no appropriate code or standard a full justification should be given for the design method adopted. The combining of different design codes and standards for an individual component should be avoided where practicable and should be justified when used.

(P85) Due allowance should be made in the design for degradation processes, including corrosion, erosion, creep, fatigue, and ageing, and for the effects of the chemical and physical environment. The design should allow for any uncertainties in determining the initial state of components and the rate of degradation.

8.11 Assessors should note that there are no British Standards developed specifically for nuclear lifting appliances, although standards such as BS2573 and the European equivalents (DIN, FEM etc) are frequently used. These standards were primarily developed for commercial cranes, and allow for a reduction in reserve factors for equipment that operates infrequently at or near to the safe working load. It may therefore be necessary to enhance these codes significantly to achieve very high standards of structural integrity and reliability.

8.12 T/AST/016, 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.

8.13 SAPs P119 to P143 outline a range of external hazards that may need to be considered when assessing lifting operations. SAPs P128 to P131 specifically requires that potential seismic events be categorised, and that design basis and operating basis earthquakes are defined and are used in the analysis of safety systems and components. This may include the design of lifting systems and their controls.

8.14 SAPs P178 to P221 relate to the design of safety systems and instrumentation systems on nuclear plants. Assessors 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, T/AST/031 Safety Related Instrumentation, T/AST/046 Computer Based Safety Systems, T/AST/011 The Single Failure Criterion give detailed advice on the assessment of such systems.

9. References

1 Safety Assessment Principles for Nuclear Plants (HSE 1992)

2 ACOP Safe Use of Lifting Equipment Approved Code of Practice and Guidance L113 1998 ISBN 0 7176 1628 2

3 Single Failure Proof Cranes for Nuclear Plants NUREG-0554 US Nuclear Regulatory Commission

4 ASME NOG-1 - 2002 Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge Multiple Girder)

5 NUREG-0612 Control Of Heavy Loads at Nuclear Power Plants

10. Abbreviations

ACOP	Approved Code of Practice
ASME	American Society of Mechanical Engineers
ALARP	As Low As Reasonably Practical
BS	British Standard

EOT	Electric Overhead Travelling (i.e. Crane)
HSWA	Health and Safety at Work Act
LOLER	Lifting Operations and Lifting Equipment Regulations
NUREG	US Nuclear Regulatory Commission
MHSW	Management of Health and Safety at Work Regulations
PUWER	Provision and Use of Work Equipment Regulations
SAP	Safety Assessment Principles (i.e. NII)
SMS	Supply of Machinery Safety Regulations
TAG	Technical Assessment Guide

APPENDIX 1

Further technical guidance to assessors

The engineering 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 design of structures and individual mechanical components and their properties is required to understand their safety margins and failure mechanisms.

The following are a selection of issues that frequently arise when assessing the safety of lifting systems for more critical nuclear operations.

Assessors should seek detailed technical advice on such issues and this list is only intended to highlight the nature of issues that need to be considered when assessing such systems.

1. Ropes

> Steel ropes are complex structures comprising multiple strands and wires that are usually constructed around a central core. When 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 fibre due to bending and contact stresses. Such failures are usually detectable by visual inspection before catastrophic failure, given the normally large design safety margins.
>
> Assessors should be aware that rope structures can also be subject to a variety of more complex failure mechanisms as a result of overload, corrosion, crushing and wear and such effects may be more localised and less predictable.
>
> Failures may occur at local positions such as socket terminations or where the rope is subjected to additional stresses at suspension points,

sheaves and on multi layered drums etc. Where possible such features should be avoided.

Corrosion may also occur more generally throughout the rope structure and internally within strands and wires, especially in exposed marine environments.

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 bends in rope systems should also be avoided.

Ropes may also loose 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.

Certain types of ropes have rotational resistant constructions that resist rotation under an applied axial load.

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

2. Justification of proprietary devices, type testing etc

Assessors should be aware that crane designers frequently make use of proprietary designs of 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. The need for more detailed justification of such equipment will therefore need to be considered for the more hazardous operations.

3. Gears/Gearboxes

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.

Various approaches have been taken to addressing this problem ranging from redundant and duplex systems, to the provision of emergency braking and protection systems that detect internal gearbox failure or minor discrepancies in drive ratio.

In assessing such systems assessors 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 sensitivity 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, and the implications from such events for the load, the crane, and any impacted structure.

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. More complex gearing arrangements will lead to additional failure modes and complications in justification.

Particular attention needs to be given to the design of gear shafts and keyways to avoid fatigue failure.

Ball and roller bearings that support such shafts may fail catastrophically. They 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.

The requirements for heat treatment and surface treatment of gears means there is always some uncertainty in a gear's mechanical properties. Destructive testing is clearly not possible unless parallel manufacture of destructive samples is arranged.

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

4. Motor Drives

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.

Assessors should be aware of such issues and note that the more modern design of AC motor may incorporate frequency control to give variable torque speed characteristics. Such systems are usually based on digital software.

Where detailed fault analysis requires the examination of stalled conditions such as those arising from stuck loads or double-blocking, assessors 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.

Assessors 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.

Mobile cranes will have hydraulic motors with different characteristics and failure modes.

5. Software in motor controllers other devices

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.

6. Control Instrumentation and Protection

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

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 TAG/AST/003.

7. Reliability

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.

Assessors should therefore note the advice given TAG/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 adivice in the SAPS s especially P38.

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.

8. Dual Load Path Arrangements

Dual load paths are consistent with the SAP requirements for redundancy and for systems to fail in a safe manner P67, P68, P69. 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. 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.

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

a. The comparative merits of both systems being balanced in normal operation or one system being unloaded needs to be considered.
b. 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.
c. 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.
d. Both systems need to be reliably synchronised and controlled.
e. The redundant/diverse system must be capable of sustaining the maximum dynamic loads.
f. The requirements for recovering the load need to be established.
g. 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.

h. 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.
i. It should be noted that the dynamic loads created by load path failure and subsequent arresting of the load will 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.
j. The requirements and arrangements to test such systems, needs to be established if they are to achieve the claimed high levels of reliability, SAP P66.

9. Welding

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.

The requirements of BS 7608 and similar codes should be observed when assessing the fatigue of welded structures.

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

10. Cast Iron

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.

11. Seismic Considerations

The requirement to consider external events on nuclear lifting operations results in the need to consider the affects 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 SAP P131.

Lifting operations frequently use tall, large and heavy structures that are vulnerable to seismic effects. Where seismic analysis is deemed necessary the dynamic seismic loading will frequently dominate the design of such structures. The TAG on External Hazards (i.e. when drafted) should be consulted with respect to seismic design.

The seismic analysis will frequently 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:

a. Seismic restraints to prevent lateral movement of the cranes trolleys and wheels.
b. Additional restraints to prevent uplift.
c. Friction sliders to allow free lateral movement where an item cannot be fully restrained.
d. Load fuses to allow relative vertical motion between the crane structure and the load.
e. Seismic triggers to isolate and brake the cranes 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.

12. Wind Forces

Assessors should be aware of the difficulties of justifying mobile, tower and other external cranes against inservice and maximum out-of-service wind loads to the level of confidence expected in a nuclear safety justifcations. Assessors 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.

a. Assessors should also note that the wind forces on the load itself may also signifcantly affect the stability and strength of such cranes. It is therefore necesary to consider the implications for such systems if the load or crane cannot be moved or removed in the event of high winds.

13. Wheels EOT Cranes

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.

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

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

16. The weights of items being lifted needs to be established and records kept of plant modifications and additions.

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

18. Correct rigging and hitching is vital to safe lifting operations. Attachment points should be suitably tested for normal and any faulted conditions.

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

20. 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.

21. Mobile Cranes

Truck Mounted

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.

Mobile cranes by their very nature are complex devices in that they are fitted on to a road chassis which in itself is usually an all terrain 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.

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 will invariably 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.

Assessors should therefore be aware of the vulnerability of mobile cranes and ensure that the nuclear and non nuclear consequences of such collapse have been adequately assessed. Assessors 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.

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 NII SAPs for the higher levels of hazard, it would 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.

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

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.

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

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

Mobile Gantry & Jacking Systems

Jacking systems are becoming increasingly popular for temporary lifting operations. 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. needs 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.

Mobile Lifting Equipment Summary

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.

> Where such use is deemed necessary on the basis of ALARP studies for say refurbishment work, decommissioning activities or emergency requirements, their use needs to be subjected to detailed assessment, rigorous procedural control and the potential for catastrophic failure needs to be fully recognized within the safety case.

22. The need for additional measures, such as temporary evacuation, plant shutdown etc. to reduce the potential nuclear hazard to exclude personnel not connected with the activity, during any such hazardous lifting operations, should be considered.

APPENDIX 2

Further guidance to assessors on the application of LOLER and PUWER

LOLER

> LOLER defines the statutory requirements for lifting operations. The following advice highlights specific issues that may arise with lifting equipment associated with nuclear licensed sites.

LOLER Regulation 4 Strength & Stability.

> The above regulation requires the following:
>
> a. 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;
> b. every part of a load and anything attached to it and used in lifting it is of adequate strength.
>
> The term "adequate strength" will be open to interpretation, especially where proprietary equipment is used. Assessors will therefore need to consider the requirements of TAG/016 TAG/017 when considering the more onerous applications, that is where there are significant claims being made on the structural integrity of lifting systems.
>
> 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.

> The above regulation states that:

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

a. properly planned by a competent person;
b. appropriately supervised; and
c. carried out in a safe manner.

Assessors need to note the requirements of LC 12 LC 24 in ensuring that those planning and supervising operations are adequately trained both with respect to 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.

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

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. Assessors should note the advice in FOD circular OC 234/11 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.

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.

LOLER Thorough Examination and Inspection Regulation 9.

Assessors should note that the purpose of the thorough inspection under LOLER is to inspect "lifting equipment **which is exposed to conditions causing deterioration** which is liable to result in dangerous situations".

In other words thorough inspections are intended to reveal deterioration in areas where the inspector 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.

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.

The main purpose therefore of the thorough inspection is a precautionary measure to detect unexpected deterioration, not 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 speculative in-service inspections. These speculative inspections may be targeted at areas where there is no degradation expected, but where they may be highly stressed or safety critical.

The thorough inspection can also reveal inappropriate use, such as overload, poor maintenance, corrosion or inadequate design etc.

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.

Assessors 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.

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

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 Licensees 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.

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 Licence Condition 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." should be noted.

This is in addition to any reporting or other requirements required under LOLER or any other regulation.

LOLER Thorough Examination and Inspection Regulation 9.

Assessors should note the more flexible approach to the periodicity of inspections in LOLER when compared to the previous Factories Act.

LOLER specifies the following thorough examination periods Reg. 9 Para 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.

Assessors should therefore note that equipment might require to be inspected more frequently than the statutory maximum period, if appropriate. For example immediately before a hazardous lift.

Additionally assessors should note that it is possible to develop a written scheme of inspection as opposed to the periodic system.

Risk based inspections may be more appropriate for safety critical items and give more control over the inspection process. This may also be beneficial in areas where inspectors are put at radiological risk from performing the inspection operation and there is limited hazard from the physical load due to the exclusion of personnel, however, the nuclear hazard needs to be appropriately assessed including any dose burden from any potential recovery operation.

Such arrangements require a written scheme to be in place under LOLER Regulation 9, and 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.

During maintenance periods etc., when the facilities can become routinely manned, alternative inspection arrangements may need to be in place under LOLER.

Switching from periodicity based inspection to risk based inspection is possible, however, third party examiners will require a periodic inspection to be completed immediately before an agreed scheme of risk based inspection is implemented. A risk based inspection regime is not an easier option, and indeed, may result in more frequent and stringent inspection requirements being put in place.

LOLER Reports and Defects Regulation 10.

Assessors should be aware of the requirements to comply with the above regulations regardless of any inspections or assessments performed for the sake of 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.

PUWER

The Provision and Use of Work Equipment Regulations 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 addressing work equipment in general, and LOLER the specific aspects of lifting operations. 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.

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

PUWER Regulation 4 Suitability of Work Equipment

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.

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.

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

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

Hence work equipment that is selected for nuclear lifting operations needs to be suitably selected and designed for that purpose.