ONR GUIDE			
CIVIL ENGINEERING			
Document Type:	Nuclear Safety Technical Assessment Guide		
Unique Document ID and Revision No:	NS-TAST-GD-017 Revision 3		
Date Issued:	May 2013	**Review Date:**	May 2018
Approved by:	David Senior	Director Regulatory Standards	
Record Reference:	Trim Folder 1.9.3.645. (2013/0168369)		
Revision commentary:	Revision and update to take account of SAPs 2006, WENRA Safety Reference Levels and IAEA Standards. Title revised to reflect content. This is also a reformat of previous guidance T/AST/017, Issue 002 into the format for ONR's How2 process management system.		

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Comments on this guide, and suggestions for future revisions, should be made and recorded in accordance with ONR's standard procedures. Comments made from outside ONR should be sent via onrenquiries@hse.gov.uk.

1. INTRODUCTION

1.1. ONR has established its Safety Assessment Principles (SAPs) [1] which apply to the assessment by ONR specialist inspectors of safety cases for nuclear facilities that may be operated by potential licensees, existing licensees, or other duty-holders. The principles presented in the SAPs are supported by a suite of guides to further assist ONR's inspectors in their technical assessment work in support of making regulatory judgements and decisions. This technical assessment guide (TAG) is one of these guides.

2. PURPOSE AND SCOPE

2.1. This TAG contains guidance to advise and inform ONR staff in the exercise of their regulatory judgment. TAGs are intended to provide guidance for inspectors to carry out their regulatory duties. They are also part of the demonstration on how ONR meets the WENRA RLs and how ONR links its guidance to that contained in the WENRA Safety Reference Levels and IAEA safety standards. TAGs are not written for duty holders, and although they may be used as a source of guidance or good practice, they should not be taken by duty holders as a prescriptive set of legal requirements.

2.2. This guide provides guidance on the interpretation of those HSE Safety Assessment Principles for Nuclear Facilities. 2006 Edition Revision 1 (SAPs) [1] which relate to civil engineering works and structures at nuclear licensed sites. The scope includes structures supporting safety related plant and equipment and founding materials supporting those structures. Although this guide specifically addresses the Civil Engineering section of the SAPs, assessors should recognise the importance of the Key Principles (EKP) at the beginning of the Engineering Principles section. These are covered in other TAGs. The guidance contained in this document is intended for use in the assessment of new and existing nuclear plant.

2.3. For the purposes of this document the term "civil engineering works and structures" applies to site infrastructure (roads, bridges, earthworks, drainage, railways etc) and structural steel, concrete and masonry structures:

- which support safety related plant and equipment, contain nuclear matter, provide shielding, retain liquids or gases (eg ponds and concrete pressure vessels and containments), protect the plant from external hazards; or

- whose failure threatens safety related structures and plant.

2.4. The term "civil engineering works and structures" also includes the materials such as soil and rock which support these structures.

2.5. This guide does not address steel pressure vessels and their internal structures, pipework and metal tanks. These are covered in T/AST/016 [2]. Guidance on the assessment of containments for reactor plant is contained in T/AST/020 [3] and for chemical plant in T/AST/021 [4]. General guidance and advice to ONR Inspectors on aspects of civil engineering construction assurance is given in T/AST/076 [5] which highlights typical construction assurance items that a licensee would be expected to address during the design and construction phases of a construction project. This guide:

- identifies the SAPs which relate to civil engineering (See Appendix 1);

- provides an interpretation of these principles; and,
- identifies the areas assessors should consider when reviewing a safety case.

2.6. This TAG contains guidance to advise and inform ONR inspectors in the exercise of their professional regulatory judgement. Comments on this guide, and suggestions for future revisions, should be recorded on the appropriate TRIM file and the Civil Engineering Professional Lead informed.

3. RELATIONSHIP TO LICENCE AND OTHER RELEVANT LEGISLATION

3.1. Under the Nuclear Installations Act 1965, a set of 36 Standard Conditions, covering design, construction, operation and decommissioning, is attached to each nuclear site licence [6]. These conditions require licensees to implement adequate arrangements to ensure compliance. The licence conditions (LCs) considered to be applicable to the SAPs covered in this TAG are as follows:

- LC 14 Safety documentation
- LC 12 Duly authorised and suitably qualified and experienced persons
- LC 15 Periodic review
- LC 16 Site plans, designs and specifications
- LC 19 Construction of new plant
- LC 20 Modification to design of plant under construction
- LC 22 Modification or experiment on existing plant
- LC 23 Operating rules
- LC 25 Operational records
- LC 28 Examination, inspection, maintenance and testing
- LC 29 Duty to carry out tests, inspections and examinations
- LC 34 Leakage and escape of radioactive material and radioactive waste
- LC 35 Decommissioning

3.2. The provisions of the Construction (Design and Management) Regulations 2007 (CDM2007) [7] and L144 Approved Code of Practice (ACoP) Construction (Design and Management) Regulations 2007 [8] are relevant to civil engineering works and structures referred to in this TAG.

3.3. Prestressed concrete pressure vessels must comply with the Pressure Systems Safety Regulations 2000 [9].

3.4. Within the UK, HSE is mandated to apply building regulations to Nuclear Licensed sites. The Building Regulations 2000 (as amended) [10] set out the kinds of work that are exempt from the Regulations:

> *"Any building (other than a building containing a dwelling or a building used for office or canteen accommodation) erected on a site in respect of which a licence under the Nuclear Installations Act 1965 is for the time being in force"*

3.5. The requirements within Part A of the building regulations (2004) [11] can be met by the use of what are termed 'approved documents'. These are listed in the back of the building regulations, and are currently listed as extant British standards. It is not mandatory to use them, however they have a 'deemed to satisfy' status. It has been recognised however that these will be withdrawn in the near future to be replaced by Eurocodes and it is further stated that there will be periodic updates to the building regulations to reflect this:

3.6. In January 2010, the department of communities and local government wrote to all Building Control Bodies (BCB's) advising the following "When assessing compliance with the Building Regulations, BCBs should continue to consider the appropriate use of relevant standards on a case by case basis. This may include the use of the new BS ENs, which formally became the new national standards in April 2010 reflecting the changes made by the standards organisations"

3.7. Interpreting the current part A document and the letter addendum, it is clear that the use of Eurocodes with UK national annexes is an automatic satisfaction of the requirements. However it should be noted that it is not mandatory. In other words other standards and codes may be used. Approved document A [11] states that "Thus there is no obligation to adopt any particular solution contained in an Approved document if you prefer to meet the relevant requirement in some other way."

4. RELATIONSHIP TO SAPS, WENRA REFERENCE LEVELS AND IAEA SAFETY STANDARDS ADDRESSED

4.1. Standards exist for many engineering and operational features and it is a feature of new designs that a licensee will set out design standards, which may be based on non-UK standards, and these standards will be subject to assessment by ONR to ensure they represent relevant good practice. There are also several international bodies which produce standards or guidance documents: where the UK is tied by international agreements (e.g. EU, the standards have the same status as UK ones); where such agreements do not exist the guidance issued may be considered as authoritative, but subsidiary to UK requirements. Important elements of Relevant Good Practice for ONR are the documentation from the IAEA and the Safety Reference Levels developed by WENRA for reactors [12], decommissioning [13], and the storage of radioactive waste and spent fuel [14]. IAEA documents are developed by international consensus and the UK may use them as the basis, inter alia, for good practice requirements. The IAEA Safety Standards were used to benchmark the 2006 SAPs [1] and ONR policy is that guidance in IAEA Safety Requirements should always be included in our SAPs and TAGs (though this may need to be adapted to fit with the UK legal framework); guidance contained in Safety Guides should normally be included (i.e. only omitted if there is a compelling reason); while guidance in lower tier Safety Standards (such as Safety Reports) should be considered for inclusion if viewed as particularly relevant.. The WENRA Safety Reference Levels for reactors are much more specific and only apply to existing civil nuclear reactors. The decommissioning safety reference levels apply to all types of nuclear facilities and cover all stages in the lifecycle. The storage reference levels apply to facilities where radioactive waste or spent fuel is stored for a significant period of time. The UK is a member of WENRA, has formally signed on to the reference levels and, in line with the HSE enforcement policy [15] in relation to Relevant Good Practice, it is an expectation that the reference levels are followed (See also Appendices 2 and 3).

4.2. The specific SAPs which should be considered in the assessment of civil engineering works and structures are contained in the Civil Engineering section (ECE.1 to ECE.24) of the Engineering Principles. Further SAPs that should be considered are given in the section of the Engineering Principles relating to the integrity of metal components and structures (EMC). However, not all these principles are applicable since some are only relevant to steel containment type structures and their penetrations and attachments. Those excluded are: EMC.1 to EMC.4, EMC.8 to EMC.10, EMC.12, EMC.15, EMC.18, EMC.20, and EMC.22 to EMC.24. Other SAPs to be considered from the Engineering Principles include ECS.1 to ECS.5 (safety classification and standards), EAD.1 to EAD.5 (ageing and degradation), ELO.1 to ELO.4 (layout), EHA.1 (external and internal hazards – Identification) and EHA.17 (use of fire resistant materials). In addition to the Engineering Principles, SAPs relating to decommissioning (DC.1, DC.4 and DC.5) and radioactively contaminated land (RL.2) should be considered.

4.3. A list of ONR Safety Assessment Principles (SAPs) to be considered when assessing civil engineering works and structures is given in Appendix 1.

4.4. This section provides an outline of the intent of the relevant principles. Since some of the principles link together and others are self explanatory, interpretation is in some cases for groups of principles which cover a similar topic such as analysis or manufacture and construction. In general the interpretation applies to the assessment of both new and existing plant. Where there are exceptions these are identified.

4.5. When interpreting the SAPs it is important for the assessor to recognise that the general lack of adequate reliability data for civil engineering structures has led to their design or assessment being based primarily upon established and proven engineering practice. The assessor should adopt a sceptical attitude towards any case which attempts to substitute probabilistic analysis for a proper deterministic analysis or which attempts to justify questionable engineering on probabilistic grounds. However, the full safety case should include civil engineering aspects within the plant PSA as far as is practical.

4.6. In support of the SAPs, this section also identifies the relevant Safety Reference Levels developed by WENRA for reactors, decommissioning, and the storage of radioactive waste and spent fuel and the relevant IAEA standards.

For the purposes of interpretation, the SAPs applicable to this guide have been grouped into the following areas:

- general;
- stress analysis (structural analysis);
- design;
- manufacture and construction;

- operation;
- pre and in-service inspection and testing.

General:

4.7. EHA.17: This principle advises that consideration be given to materials used in the construction of nuclear facilities and their contribution to the fire loading in the structure.

4.8. ECS.1 to ECS.5, EMC.5 and EMC.6: The purpose of these principles is to determine whether safety related structures were designed, and constructed or manufactured to the standards determined from the design and construction specifications. These specifications should be determined from the safety function requirements. In civil engineering it is common practice to use external contracting organisations for the construction of the works. The selection and control of these contractors will be fundamental to the successful completion of the work and to the ultimate standard of construction and hence structural integrity achieved. For civil structures arrangements for inspection should be made by the licensee to confirm continued "fitness for purpose" during the plant lifetime. The methods should be capable of identifying deviations, eg defects, from the design intent.

4.9. ECA.4: The purpose of this principle is to demonstrate stability of the soil and rock which provide support for the foundations and superstructure of a nuclear plant. To determine the suitability of these materials site investigations are normally carried out. These should follow the appropriate codes and standards applicable to the safety function of the structures proposed. Natural site materials may be used for engineering purposes such as backfill or sea defences. In such cases, the investigations should ensure the materials will be fit for purpose for the safety function required and duration needed.

Stress analysis (structural analysis)

4.10. ECE.12 and EMC.32: The applicability of these principles to civil engineering structures warrants special consideration. The analysis of civil structures, typically constructed from structural steel or concrete, uses idealised stress models to determine characteristic "stresses" that can be used to select the size of structural elements and/or the disposition of reinforcement. This process, known as structural analysis, differs from that envisaged by EMC.32. There are certain classes of civil engineering structures that can benefit from a detailed stress analysis, eg concrete vessels and containment. However, reinforced concrete presents particular difficulties for the stress analyst because it does not behave elastically. Similarly complex structural frames may be analysed using structural analysis techniques to determine the response of the structure to complex loading regimes such as thermal, dynamic and impact. (See also WENRA E4.1)

4.11. EMC.33: The purpose of this principle is to advise that in the stress or structural analysis due consideration has been given to uncertainties in material properties and that the methodology and loading data have been verified to ensure that the analysis is demonstrably conservative. This is particularly important when analysing safety critical reinforced or prestressed concrete or steel structures.

4.12. ECE.14: The purpose of this principle is to advise that the uncertainty and variability of input data and methodology do not have a disproportionate effect on the results of an analysis and that the analysis takes account of any such variability or uncertainty.

4.13. ECE.15: The purpose of this principle is to advise that where computer analyses have been carried out to determine structural loadings, the methods have been adequately validated. This should be done using alternative methods where possible or alternative, previously validated, computer codes. In cases where data are sparse and uncertainty exists in the validation process it may be necessary for model tests to be carried out.

Design

4.14. General - Design codes are generally applied to new designs. The codes make allowances for uncertainties in knowledge of loading conditions, material properties, degradation and assumptions in analysis. However, in assessment of existing structures, there can be a better understanding of some or all of these issues and it may be considered appropriate to make a corresponding allowance in the application of codes. (See also WENRA D15, D16, G1.1, G3.1 and S19 to S25)

4.15. ECE.1, EMC.7 and EMC.11: The purpose of these principles is to establish initially whether the licensee has identified the safety function of structures and their performance requirements. If this procedure has been adopted, then a schedule of all design basis loading conditions for construction, testing, normal and accident conditions should be produced. Predicted failure modes should be gradual and detectable. This is to ensure that the structure fails in a ductile rather than brittle mode under higher loadings. 'Failure' may range from excessive deflection to overall structural collapse. The failure criterion needs to be defined for each structure and loading condition. Levels of unacceptable structural performance should be determined through the risk assessment and risk control measures.

4.16. ECE.5: This principle concerns whether the foundation design has taken into account the results of the site investigation report and incorporated the recommendations for material properties for the soil and rock into the design calculations. Where a structure is required to resist seismic loading the soil and rock properties for use in dynamic analysis should be determined. Consideration should also be given to the possibility of liquefaction of the foundation material under seismic loading. Investigation into ground water levels and flow characteristics should be considered.

4.17. ECE.7: This principle seeks demonstration has been provided which shows that the foundation design has considered the effects of normal operation and fault loading. The integrity of the foundations should be demonstrated using the material properties derived from the site investigations (see also ECE.5).

4.18. ECE.9 and ECE.10: The purpose of these principles is to advise that excavated or embankment slopes of material adjacent to a nuclear installation are shown to be stable under normal and external hazard loadings to ensure plant safety The SAP refers only to excavated slopes, but the stability of man made embankments is also relevant in this context. Consideration should also be given to variations in ground water level resulting from either climatic change or construction activities in order to ensure settlement of structures is within acceptable safety limits.

4.19. ECE.11 and EHA.1: The purpose of this principle is to advise that if naturally explosive gases or vapours could occur (see EHA.1) then the design of underground basements, foundations and tunnels should take the possible consequences of the presence of such gases or vapours into account. The design should include measures to prevent the ingress and build up of gases.

4.20. ECE.22: The possible requirement for secondary containment should be considered in the design. (See also WENRA K3.13)

4.21. DC.1, DC.4, DC.5 and RL.2: The purpose of these SAPs is to advise that designs incorporate measures that facilitate decommissioning and dismantling. This may include the use of suitable surface materials for ease of decontamination, and structural materials and details which facilitate dismantling (See Appendix 6). Changes to the design and plant modifications should incorporate provision for decommissioning which should be included in decommissioning plans. The facility should be made passively safe before entering a care and maintenance phase and this may involve the design and modification of structures or the construction of new barriers and containment. If civil engineering works and structures have an ongoing role in the decommissioning of a nuclear facility, then the safety case should demonstrate their continuing safety for the periods required, in line with the principles for passive safe storage of radioactive material and waste. An assessment of the continuing safety of the nuclear facility involves determining the current physical condition and establishing how it will change in the future. This is particularly relevant to decommissioning strategies involving the deferral of dismantling. The safety case should describe the arrangements for the continued surveillance, maintenance and monitoring of the facilities that will ensure that any unexpected degradation will be detected. Similarly, adequate arrangements should be made for detecting leakage of radioactivity and to ensure that unforeseen incidents are detected (for example, damage caused by natural events, failure of systems, intrusion). Where earthworks or excavation are required particular attention should be paid to the possibility of contaminated land or spoil. (See also T/AST/026)

Manufacture and Construction

4.22. EMC.13 and DC.1: These principles concern the selection of materials for manufacture and construction. It is normally impractical to replace civil engineering components, other than glazing, cladding and roofing, and therefore materials should be shown to be suitable in all respects for the purpose of enabling an adequate design to be constructed, operated, inspected and maintained throughout the life of the plant.

4.23. EMC.17: This principle requires inspection during construction of civil engineering works.

4.24. EMC.19: Any remedial work following identification of construction defects or non-conformities with procedures should be carried out to an approved procedure and subject to the same design requirements as the original work.

4.25. EMC.25: This principle concerns the detection, location, monitoring and management of leakage. It links with LC34.

4.26. ECE.17 and ECE.19: The purpose of these principles is to minimise defects during construction and advise that the safety case should, at all times, reflect the plant as designed and constructed. Procedures should be in place to control design changes throughout the design and construction process and assess their effects on the safety case. These design changes and modifications should be incorporated into the safety case, and ‘as built’ drawings and a health and safety file should be maintained throughout the life of the plant. Further guidance is available in the Technical Inspection Guide to Licence Condition 22 (T/INS/022).

4.27. The provisions of the Construction (Design and Management) Regulations 2007 (CDM2007) [7] and L144 Approved Code of Practice (ACOP) Construction (Design and Management) Regulations 2007 [8] should be complied with as appropriate.

Operation

4.28. EMC.21 and EMC.25: The purpose of these principles is to guide the assessor to determine whether the licensee has:

- arrangements for detecting, locating, monitoring and managing leakage; and,
- that adequate margin exist on safety related components to ensure the plant remains within its operating envelope throughout its operating life.

4.29. Pre- and in-service inspection

4.30. EMC.27 to EMC.30: These principles guide the assessor to determine whether the licensee has:

- arrangements for in-service inspection to demonstrate "fitness for purpose";
- considered the need for diversity of inspection and testing techniques; and,
- carried out proof testing where it is a recommendation of suitable codes or otherwise essential for the safety case.

(See also WENRA K1 to K3.13 and S50 to S55)

4.31. Designs that do not allow key load bearing elements to be inspected and if necessary maintained should be avoided. The design should take account of hindrances to inspection, such as radiation. For prestressed concrete reactor pressure and containment vessels the LC 28 arrangements should include the appointment and responsibilities of an Appointed Examiner and insurance inspections. For prestressed concrete reactor pressure vessels, licensees are also required, under the Pressure Systems Safety Regulations 2000 [9], to demonstrate that they know the safe operating limits (principally pressure and temperature) of their systems, and that they are safe under those conditions. They need to ensure that a suitable written scheme of examination is in place before the system is operated. They also need to ensure that the system is actually examined in accordance with the written scheme of examination.

4.32. They need to ensure that a suitable written scheme of examination is in place before the system is operated. They also need to ensure that the system is actually examined in accordance with the written scheme of examination.

4.33. ECE.22: The purpose of this principle is to advise that for liquid or gas retaining structures leak tightness tests should be carried out prior to plant operation. This is to ensure that the design intent has been met. For liquid retaining structures drainage systems would be expected to collect and quantify leakage. For gas retaining structures detection or monitoring systems should be available to monitor leakage. (See also WENRA K3.13)

4.34. ECE.23: The purpose of this principle is to advise that under LC28 arrangements should exist for the inspection and maintenance of any sea and river defences which protect a nuclear licensed site from flooding. The inspections should be carried out to confirm the condition of the materials or structures are still within the design intent. This would involve consideration of erosion protection and material degradation. Local changes which may affect the integrity or function of the defences, such as new development, should be considered. Climate change effects should be considered when defining the design load cases. (See also WENRA K1 to K3.13)

5. ADVICE TO INSPECTORS

5.1. This section identifies the key elements which an assessor should consider in a safety case submission from a licensee for each relevant SAP. The topics identified for consideration in the following paragraphs should not be considered as a checklist, but as important areas which may be addressed when assessing a safety case. There may be good reasons for a licensee not meeting a SAP. In these cases the assessor should ascertain the validity of the arguments and evidence presented.

5.2. Since the principles are not prescriptive the assessor will need to judge the extent to which the safety submissions presented satisfy the principles. For many areas this will rely on the skill and expertise of the assessor. In the case of existing plant there may well be some areas where the SAPs would not be satisfied. The assessor would be expected to judge the significance of the shortfall against the overall safety case for the plant and ALARP considerations.

5.3. In assessing a licensee's submission the following points should be considered when interpreting the SAPs.

General

5.4. Design, construction and inspection

ECE.1, ECE.2, ECE.16, ECE.18 and ECS.3

WENRA D15, D16, G1.1, G2.2 and G3.1

IAEA SSR-2/1 [16]

- Has a design intent been produced and is it consistent with the safety function and performance requirements?
- Has a construction specification been produced?
- Have the design intent and the construction specification been met?
- Are or were the arrangements for inspection during construction sufficient to identify defects?
- If several standards have been applied to design or construction of the works, are they compatible with each other?

- Are the materials used in manufacture / construction compatible with the design standards? Where optional parts of codes are used, is their use appropriate and has this been justified in the safety documentation? Where foreign codes and standards are used, are they compatible for use with UK materials and UK materials practice? (For example compare the use of ACI 318 with the use of UK specified concrete and bar bending shapes.)

- Have the nuclear safety and nuclear security measures be designed, constructed and implemented in an integrated manner so that they do not compromise one another?

- Refer to T/AST/076 [5] for advice on safety management of contractors.

5.5. Identification of defects

ECE.3, ECE.8, ECE.19, EMC.5 and EMC.6

WENRA I2.1

- Has the structure been inspected for defects or sub-standard workmanship? Are these within the design intent?

- Are the inspection arrangements during the structure’s operational life sufficient to detect defects of structural significance?

- What are the consequences of a defect becoming worse?

- Are adequate records of defects maintained?

Design

5.6. Structural Design

ECE.6, EMC.7 and EMC.11

IAEA SSR-2/1 [16]

The design process should consider the robustness of the structure. Robustness is the ability of a structure to withstand events without being damaged to an extent disproportionate to the original cause. (See also Appendix 4).Emphasis should be placed on the provision of a ductile design, with margins to elastic design considered only if a ductile response cannot be achieved

- Have the applied loads been correctly identified?

- Has load development and a schedule of load combinations been determined?

- Does the schedule include construction, normal, accident and test conditions?

- Has the schedule of load combinations been used for design?

- Should more severe loadings than the design basis have been considered? To preclude cliff-edge effects, margins to failure should extend beyond the design basis fault (or hazard) requirement by an amount appropriate for the uncertainty in estimating the effects of the fault or hazard. The behaviour under beyond design basis loadings should be considered before the plant design is fixed.

- Is the behaviour of the structure beyond the design basis elastic, ductile or brittle?
- Has the design established a set of serviceability or performance limits and conditions for the civil engineering works and structures?
- For prestressed concrete pressure vessels and containment vessels, has the design established a set of operational limits and conditions for safe operation?
- Have other regulatory requirements applicable to Civil Engineering work been taken into account in the design and construction of the work, eg Construction (Design and Management) Regulations, Control of Substances Hazardous to Health Regulations, Building Regulations?

Manufacture and construction

5.7. Choice of construction materials

ECE.4, ECE.16 and EMC.13

- Have material tests been carried out? Did the results comply with the requirements of the design?
- Has the material been widely used before?
- If novel materials or innovative processes are used, have they been adequately justified including testing, installation and durability?
- Are the materials suitable for the operating environment and expected structural life?
- Are there any limitations on construction, inspection and maintenance for the materials proposed?

5.8. Construction methods

ECE.17, ELO.1 and EMC.14

Additional information is available in T/AST/076, HSE RR834, HSE GS49 [5, 17, 18]

- Is the construction technique novel?
- Are there limitations on the use of the material in construction?
- Have procedures been produced for the material production, construction or fabrication?
- Have the requirements of the Construction (Design and Management) Regulations 2007 been taken into account in the construction phase?

- Are the proposed layout and construction method compatible? The layout should make provision for construction, assembly, installation, erection, decommissioning and demolition. (See also Appendix 4).

- Have constructability issues been fully addressed?

- Has the use of mock-ups to reduce risk been considered?

- Does the proposed method minimise the occurrence of defects?

5.9. Inspection during manufacture

ECE.18 and EMC.17

T/AST/076 [5]

- Have procedures been produced for the manufacture of components?

- Are there procedures for in-house testing, verification and quality control and/or the procurement and control of external inspection and testing services?

- How have these been monitored to ensure compliance against the specification?

- Does the licensee have adequate control of the inspection process?

5.10. Non conformances

ECE.3, ECE.17, ECE.19 and EMC.19

T/AST/076 [5]

Additional information is available in HSE RR175, RR184, RR185, RR186 [19, 20, 21, 22]

- Are there procedures for identifying, assessing and sentencing non-conformances?

- Are there arrangements for repairing defects?

- Do these arrangements ensure the same standards of construction?

- Are records of non-conformances kept?

- Have the effects of aggregation of defects been addressed?

5.11. Design changes

ECE.17

- Are procedures in place to ensure that design changes/modifications are/have been assessed as to their safety significance and effect on the safety case, and referred back to the Design Authority?

- Is there evidence to show that these procedures have been implemented correctly?

- Have the design changes/modifications been incorporated into the safety case?
- Does the safety case as presented reflect the as-designed, as-built plant?

Operation

5.12. Leakage during operation

ECE.22 and EMC.25

- Should there be arrangements in place for detecting, locating, monitoring and managing leakage?
- Should there be clearly defined allowable leakage levels?
- Should there be clearly defined procedures if action levels are exceeded?

5.13. Safe operating envelope

ECE.1, ECE.20 and EMC.21

WENRA K3.13, S26 and S27

- Are the monitoring arrangements adequate to ensure safety margins are not reduced?
- Should the operating envelope allow sufficient margin for the distribution of instrumentation used for monitoring parameters?
- Are operating rules or limits clearly defined and controlled?

5.14. Pre and in-service inspection

ECE.18, ECE.20, EMC.27 and EMC.28

WENRA I3.2 and S50 to S55

- Are adequate inspection arrangements available for demonstrating that the structure meets the design specification?
- Are arrangements in place for inspection of the structure during its operational life?
- Are these arrangements sufficient to demonstrate compliance with the design intent?
- Is instrumentation required and is it sufficient to monitor the structure?

5.15. Inspection techniques

ECE.8, EMC.29 and EMC.30

- Should there be sufficiently redundant and diverse inspection techniques?
- Should the equipment procedures be validated?

- Are inspection personnel suitably qualified and experienced?
- Is the detail and level of inspection proportionate to the risk associated with the structure?
- Is the inspection interval appropriate to the anticipated rate of degradation and the safety categorisation of the structure?
- Does the inspection report state features that were not inspected as well as those that were?
- Is there appropriate record keeping?
- Is follow-up action being taken?

5.16. Testing

ECE.18, ECE.21 and ECE.22

WENRA K3.13

- Does the design code require component testing before service?

Stress Analysis

5.17. Analysis

ECE.12, ECE.14, ECE.15 and EMC.32

- Is a detailed stress analysis required? This could include Soil-structure Interaction Analysis, 2D or 3D dynamic or static structural analysis.
- If novel structure and/or first of type, is model testing deemed necessary?
- What alternative methods have been used to validate the analysis? Are they relevant? Are they adequate?

5.18. Use of data

ECE.13 and EMC.33

- Have the input data represented the structure or part of structure under consideration?
- Should possible variations in material properties be considered in the analysis?
- Have uncertainties in the input data been adequately addressed in the calculations and have these been acknowledged in design?
- Should the potential material degradation throughout the plant life be taken into account in the analyses?

5.19. Sensitivity studies

ECE.14

- Have sensitivity studies been carried out which assess the significance of variations of input parameters on results?
- Have different methods of analysis been carried out? Are the results compatible?
- Which analysis results have been recommended for design?

Additional aspects

5.20. Site investigations

ECE.4, ECE.5, ECE.10, ECE.11 and RL.2

WENRA D53

- Has a site investigation been carried out?
- Has the site investigation report recommended material properties?
- Are the materials suitable for the loadings considered?
- Have the appropriate codes and standards applicable to nuclear plant been considered?
- Has the site investigation included water table levels, hydrogeology, contamination (all hazardous materials as well as radiological)?

Sufficient investigations and tests should be carried out to enable the behaviour of the foundations and sub-surface structures under extreme loading, and beyond design basis fault conditions, to be evaluated.

5.21. Foundation design

ECE.4, ECE.5, ECE.7, ECE.10, and ECE.24

WENRA I2.2 and K2.1

HSE RR319

- Has foundation stability been considered in design?
- Have the material properties been taken from appropriate data sources such as the site investigation report?
- Has the guidance of appropriate codes of practice been used?
- If dynamic soil properties are required have appropriate methods been used to obtain them, is the extent of uncertainty adequately addressed and has data from literature been used to validate the data?
- Should the potential for liquefaction be considered?

- Have external influences on the integrity of the foundation been considered?

Additional information is available in HSE RR319 “Safer foundations by design” 2005 [23]

5.22. Foundation integrity

ECE.7 and ECE.10

- Has the design considered all the specified normal loading conditions?
- Has the design considered all appropriate fault-loading conditions?
- Do the founding materials, under normal and fault loadings, provide an appropriate margin against failure?

5.23. Slope stability

ECE.9, ECE.10, and ECE.23

- Should there be arrangements for monitoring slope stability of embankments and excavated or natural slopes adjacent to nuclear installations?
- Should there be monitoring arrangements for the water table and / or the settlement of structures?
- Have calculations been carried out to establish tolerable levels of settlement?

5.24. Explosive gasses or vapours

ECE.11

- Has the possibility of naturally occurring gasses and vapours been considered?
- If they are shown to occur have they been considered in the design of underground structures?

5.25. Safety categorisation

ECE.1

- The safety function of civil works and structures should be identified.
- The performance requirements to meet the safety function should be identified eg shielding and radiological protection.
- The structural classification and categorisation should be identified from the performance for structural types as appropriate.

5.26. Methods of analysis

ECE.15

- Has a validation package been produced?
- Has the method of analysis been widely used?
- If the methodology is novel are model tests proposed?
- Is the extent of uncertainty in the methodology clearly defined?

5.27. Structures containing liquids or gases

ECE.21 and ECE.22

- Is leakage tolerable? If so are the criteria available and do they conform to the safety function requirements?
- Are arrangements available for determining leakage?

5.28. Flood defences

ECE.23

- Are arrangements available for inspection and monitoring the condition of flood defences?
- Are these arrangements consistent with the design intent?
- Is material degradation and erosion taken into account?
- Is the frequency of inspection adequate?
- Have the effects of climate change been allowed for?

Consideration should be given to the overall resilience to flooding, with appropriate safety classification, by ensuring defence in depth and avoiding single lines of protection where possible. Where practicable, the design of sea defences should make provision for future modification in response to developments in climate change predictions and other unknowns. Consideration should be given to the safety classification of sea defences and to parts of sea defences which may be intercepted by plant, for example outfalls and which therefore may compromise overall resilience.

5.29. Effects of Plant Ageing

ECE.8, ECE.23, ECE.24, EAD.1

WENRA D43, D44 and I1.1 to I5.1

IAEA SSR-2/1 [16]

The safe working life of structures and systems should be evaluated as part of the design. Particular attention should be paid to those areas which are difficult to replace such as the main structural components. Typically, consideration should be given to issues such as the following:

- Corrosion of structural steel
- Corrosion protection of high tensile pre-stressing tendons and ground anchors
- Carbonation of concrete
- Effects of corrosion of reinforcement in concrete
- Cladding fixings degradation
- Effects of additives to concrete
- The effects of chemical attack from groundwater or aggressive environments
- Exposure of masonry to weathering or chemical attack
- Relaxation of pre-stressing tendons
- Creep of concrete
- Effects of settlement
- Monitoring instrumentation and logging systems

For effective ageing management, ageing should be systematically taken into account at each stage of the plant life cycle; that is, during design, construction, commissioning, operation (including long-term operation and extended shutdown) and decommissioning.

Decommissioning

5.30. Decommissioning and dismantling

DC.1, DC.4, DC.5 and RL.2

WENRA D15, D16 and D42 to D44

IAEA SSR-2/1 [16]

T/AST/076 [5]

Special consideration should be given at the design stage of a nuclear facility to the incorporation of features to facilitate radioactive waste management and the future decommissioning and dismantling of the plant

- Have materials been selected which can be dismantled and disposed of in the safest manner?
- Has the structure been detailed so that it can be easily decontaminated?
- Has the structure been designed and detailed so that it can be safely dismantled?

- Have any specific health and safety control measures been identified for the decommissioning and dismantling stage.

(See also Appendix 6).

6. REFERENCES

1 *Safety Assessment Principles for Nuclear Facilities. 2006 Edition Revision 1. HSE. January 2008. www.hse.gov.uk/nuclear/SAP/SAP2006.pdf.*

2 *ONR How2 Business Management System. Guidance: T/AST/016 Integrity of Metal Components and Structures http://www.hse.gov.uk/nuclear/operational/tech_asst_guides/index.htm*

3 *ONR How2 Business Management System. Guidance: T/AST/020 Containment: Reactor Plant http://www.hse.gov.uk/nuclear/operational/tech_asst_guides/index.htm*

4 *ONR How2 Business Management System. Guidance: T/AST/021 Containment: Chemical plants http://www.hse.gov.uk/nuclear/operational/tech_asst_guides/index.htm*

5 *ONR How2 Business Management System. Guidance: T/AST/076 Construction Assurance http://www.hse.gov.uk/nuclear/operational/tech_asst_guides/index.htm*

6 *Licence condition handbook. Office for Nuclear Regulation. October 2011. www.hse.gov.uk/nuclear/silicon.pdf.*

7 *The Construction (Design and Management) Regulations 2007*

8 *The Construction (Design and Management) Regulations 2007: The Approved Code of Practice (ACoP) http://www.hse.gov.uk/construction/cdm/acop.htm*

9 *Pressure Systems Safety Regulations 2000 (PSSR) http://www.hse.gov.uk/pressure-systems/law.htm*

10 *The Building Regulations 2004*

11 *The Building Regulations 2004: Approved Document A (Structural safety) http://www.planningportal.gov.uk/buildingregulations/approveddocuments/*

12 *Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Reactor Reference Safety Levels. WENRA. January 2008. www.wenra.org*

13 *Western European Nuclear Regulators' Association. Working Group on Waste and Decommissioning. WENRA Decommissioning Reference Safety Levels. WENRA. November 2011. www.wenra.org*

14 *Western European Nuclear Regulators' Association. Working Group on Waste and Decommissioning. WENRA Waste and Spent Fuel Storage Reference Safety Levels. WENRA. February 2011. www.wenra.org*

15 *HSE 41 Enforcement Policy Statement http://www.hse.gov.uk/pubns/hse41.pdf*

16 IAEA Specific Safety Requirements Series No. SSR-2/1 Safety of Nuclear Power Plants: Design, 2012. ISBN:978-92-0-121510-9 http://www-pub.iaea.org/books/IAEABooks/8771/Safety-of-Nuclear-Power-Plants-Design-Specific-Safety-Requirements

17 *HSE RR834 - Preventing catastrophic events in construction http://www.hse.gov.uk/research/rrpdf/rr834.pdf*

18 *HSE GS49 Pre-stressed concrete - www.hse.gov.uk/pubns/books/gs49.htm*

19 *HSE RR175 - Field studies of the effectiveness of concrete repairs - www.hse.gov.uk/research/rrpdf/rr175.pdf*

20 *HSE RR184 Field Studies of the Effectiveness of Concrete Repairs www.hse.gov.uk/research/rrhtm/rr184.htm*

21 *HSE RR185 Field Studies of the Effectiveness of Concrete Repairs www.hse.gov.uk/research/rrhtm/rr185.htm*

22 *HSE RR186 Field Studies of the Effectiveness of Concrete Repairs www.hse.gov.uk/research/rrhtm/rr186.htm*

23 *HSE RR319 - Safer foundations by design www.hse.gov.uk/research/rrpdf/rr319.pdf*

24 *Institution of Structural Engineers Practical guide to structural robustness and disproportionate collapse in buildings (2010) ISBN 978-1-906335-17-5 http://shop.istructe.org/practical-guide-to-structural-robustness-and-disproportionate-collapse-in-buildings-2010.html*

Note: ONR staff should access the above internal ONR references via the How2 Business Management System.

7. GLOSSARY AND ABBREVIATIONS

ACI	American Concrete Institute
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ONR	Office for Nuclear Regulation
SAPs	Safety Assessment Principle(s)
SCOSS	The Standing Committee on Structural Safety
SSC	Structures, Systems and Components
TAG	Technical Assessment Guide(s)
WENRA	Western European Nuclear Regulators' Association

8. APPENDICES

Appendix1	List of ONR Safety Assessment Principles (SAPs) to be considered when assessing civil engineering works and structures.
Appendix 2	WENRA safety reference levels
Appendix 3	Requirements of IAEA SSR-2/1 Safety of Nuclear Power Plants: Design
Appendix 4	Provision for robustness and resilience
Appendix 5	Provision for construction
Appendix 6	Provision for decommissioning
Appendix 7	Bibliography

APPENDIX 1: LIST OF ONR SAFETY ASSESSMENT PRINCIPLES (SAPS) TO BE CONSIDERED WHEN ASSESSING CIVIL ENGINEERING WORKS AND STRUCTURES

Principle	Title	Subtitle
Civil Engineering SAPs within the Engineering Principles		
ECE.1	Engineering principles: civil engineering	Functional performance
ECE.2	Engineering principles: civil engineering	Independent arguments
ECE.3	Engineering principles: civil engineering	Defects
ECE.4	Engineering principles: civil engineering: investigations	Natural site materials
ECE.5	Engineering principles: civil engineering: investigations	Geotechnical investigation
ECE.6	Engineering principles: civil engineering: design	Loadings
ECE.7	Engineering principles: civil engineering: design	Foundations
ECE.8	Engineering principles: civil engineering: design	Inspectability
ECE.9	Engineering principles: civil engineering: design	Earthworks
ECE.10	Engineering principles: civil engineering: design	Ground-water
ECE.11	Engineering principles: civil engineering: design	Naturally occurring gases
ECE.12	Engineering principles: civil engineering: structural analysis and model testing	Structural analysis and model testing
ECE.13	Engineering principles: civil engineering: structural analysis and model testing	Use of data
ECE.14	Engineering principles: civil engineering: structural analysis and model testing	Sensitivity studies
ECE.15	Engineering principles: civil engineering: structural analysis and model testing	Validation of methods
ECE.16	Engineering principles: civil engineering: construction	Materials
ECE.17	Engineering principles: civil engineering: construction	Prevention of defects
ECE.18	Engineering principles: civil engineering: construction	Inspection during construction
ECE.19	Engineering principles: civil engineering: construction	Non-conformities
ECE.20	Engineering principles: civil engineering: in-service inspection and testing	In-service inspection and testing
ECE.21	Engineering principles: civil engineering: in-service inspection and testing	Proof pressure tests
ECE.22	Engineering principles: civil engineering: in-service inspection and testing	Leak tightness
ECE.23	Engineering principles: civil engineering: in-service	Inspection of sea and

	inspection and testing	river flood defences
ECE.24	Engineering principles: civil engineering: in-service inspection and testing	Settlement
Other SAPs from the Engineering Principles		
EMC.5	Engineering principles: integrity of metal components and structures: general	Defects
EMC.6	Engineering principles: integrity of metal components and structures: general	Defects
EMC.7	Engineering principles: integrity of metal components and structures: design	Loadings
EMC.11	Engineering principles: integrity of metal components and structures: design	Failure modes
EMC.13	Engineering principles: integrity of metal components and structures: manufacture and installation	Materials
EMC.14	Engineering principles: integrity of metal components and structures: manufacture and installation	Techniques and procedures
EMC.16	Engineering principles: integrity of metal components and structures: manufacture and installation	Contamination
EMC.17	Engineering principles: integrity of metal components and structures: manufacture and installation	Examination during manufacture
EMC.19	Engineering principles: integrity of metal components and structures: manufacture and installation	Non-conformities
EMC.21	Engineering principles: integrity of metal components and structures: operation	Safe operating envelope
EMC.25	Engineering principles: integrity of metal components and structures: monitoring	Leakage
EMC.26	Engineering principles: integrity of metal components and structures: monitoring	Forewarning of failure
EMC.27	Engineering principles: integrity of metal components and structures: pre- and in-service examination and testing	Examination
EMC.28	Engineering principles: integrity of metal components and structures: pre- and in-service examination and testing	Margins
EMC.29	Engineering principles: integrity of metal components and structures: pre- and in-service examination and testing	Redundancy and diversity
EMC.30	Engineering principles: integrity of metal components and structures: pre- and in-service examination and testing	Control
EMC.32	Engineering principles: integrity of metal components and structures: analysis	Stress analysis
EMC.33	Engineering principles: integrity of metal components and structures: analysis	Engineering principles: integrity of metal components and

		structures: analysis
EMC.34	Engineering principles: integrity of metal components and structures: analysis	Defect sizes
EAD.1	Engineering principles: ageing and degradation	Safe working life
EAD.2	Engineering principles: ageing and degradation	Lifetime margins
EAD.3	Engineering principles: ageing and degradation	Periodic measurement of material properties
EAD.4	Engineering principles: ageing and degradation	Periodic measurement of parameters
EHA.1	Engineering principles: External and internal hazards	Identification
EHA.17	Engineering principles: external and internal hazards	Fire, explosion, missiles, toxic gases etc – use of materials
Other SAPs		
MS.2	Leadership and management for safety	Capable organisation
DC.1	Decommissioning	Design and operation
DC.4	Decommissioning	Planning for decommissioning
DC.5	Decommissioning	Passive safety
RL.2	Control and remediation of radioactively contaminated land	Actions to establish the existence of radioactively contaminated land
NOTE: Additional SAPs may be required in specific circumstances		

APPENDIX 2: WENRA SAFETY REFERENCE LEVELS

The Western European Nuclear Regulator's Association (WENRA) is an international body made up of the Heads and senior staff members of Nuclear Regulatory Authorities of European countries with nuclear power plants. The main objectives of WENRA is to develop a common approach to nuclear safety, to provide an independent capability to examine nuclear safety in applicant countries and to be a network of chief nuclear safety regulators in Europe exchanging experience and discussing significant safety issues. To accomplish these tasks two working groups within the WENRA have been established -Reactor Harmonisation Working Group (RHWG) and Working Group on Waste and Decommissioning (WGWD).

The safety reference levels (SRLs) are a set of requirements against which the situation of each country is assessed and it is each country's responsibility to implement actions to ensure that these levels are reached. Three sets of SRLs have been developed. and are given below:

- Western European Nuclear Regulators Association (WENRA) Reactor safety reference levels, Jan 2007. The SRLs for reactors only apply to existing civil nuclear reactors. The relevant reactor SRLs identified as applying to this TAG are E4.1, G1 to G4, I1 to I3 and K1 to K3.

- Western European Nuclear Regulators Association (WENRA) decommissioning safety reference levels, Nov 2011. The decommissioning SRLs apply for nuclear reactors (of any power), fuel reprocessing facilities, fuel manufacturing facilities, uranium concentration and conversion facilities, uranium enrichment facilities, research facilities involving nuclear material. They may also be applied for waste storage facilities and other waste management facilities. These reference levels are not intended to be applicable to uranium mining and milling, and for isotope production facilities other than reactors. The relevant decommissioning SRLs identified as applying to this TAG are D15, D16, D43, D44 and D53.

- Western European Nuclear Regulators Association (WENRA) waste and spent fuel storage safety reference levels, Feb 2011. The SRLs are focussed on separate, purpose built or adapted storage facilities used to store spent fuel or radioactive waste in solid form. As the WENRA document is intended to cover a wide range of storage facilities, the reference levels will need to be implemented in different ways to be appropriate for the particular facility. The relevant waste and spent fuel storage safety SRLs identified as applying to this TAG are S19 to S27 and S50 to S55.

APPENDIX 3: REQUIREMENTS OF IAEA SSR-2/1 SAFETY OF NUCLEAR POWER PLANTS: DESIGN

IAEA SSR-2/1 establishes design requirements for the structures, systems and components of a nuclear power plant, as well as for procedures and organizational processes important to safety, that are required to be met for safe operation and for preventing events that could compromise safety, or for mitigating the consequences of such events, were they to occur.

IAEA SSR-2/1 was written with the expectation that it would be used primarily for land based stationary nuclear power plants with water cooled reactors designed for electricity generation or for other heat production applications (such as district heating or desalination). IAEA SSR-2/1 may also be applied, with judgement, to other reactor types, to determine the requirements that have to be considered in developing the design.

It is recognised in IAEA SSR-2/1 that it might not be practicable to apply all the requirements of that publication to nuclear power plants that are already in operation or under construction; in addition, it might not be feasible to modify designs that have already been approved by regulatory bodies. For the safety analysis of such designs, it is expected that a comparison will be made with the current standards, for example as part of the periodic safety review for the plant, to determine whether the safe operation of the plant could be further enhanced by means of reasonably practicable safety improvements.

The requirements of IAEA SSR-2/1 relevant to this TAG are given in the table below with the corresponding SAPs and other guidance which should be considered with this document during assessment.

Requirement	Subject	Documents
3	Safety of the plant design throughout the lifetime of the plant	ECS.1 to ECS.5, EMC.5 and EMC.6
4	Fundamental safety functions	ECE.1, ECE2 and FP.1 to FP.8
6	Design for a nuclear power plant	ECE.1, ECE2, EKP.1 to EKP.5 and EAD.1
7	Application of defence in depth	EKP.3
8	Interfaces of safety with security and safeguards	NS-TAST-GD-017
9	Proven engineering practices	ECE.2
11	Provision for construction	NS-TAST-GD-017
12	Features to facilitate radioactive waste management and decommissioning	NS-TAST-GD-017, T/AST/026

14	Design basis for items important to safety	ECE.1, EMC.7 and EMC.11
15	Design limits	ECE.1, EMC.7 and EMC.11
16	Postulated initiating events	ECE.6, EMC.7 and EMC.11
17	Internal and external hazards	T/AST/013, T/AST/014
18	Engineering design rules	ECS.1 to ECS.5
22	Safety classification	ECS.1 to ECS.5
23	Reliability of items important to safety	EDR.1 to EDR.4
24	Common cause failures	EDR.3
25	Single failure criterion	EDR.4, T/AST/011
26	Fail-safe design	EDR.1
29	Operational limits and conditions for safe operation	NS-TAST-GD-017, LC23 and LC24
30	Calibration, testing, maintenance, repair, replacement, inspection and monitoring of items important to safety	ECE.20, ECE.21, ECE.23, ECE.24, EMC.27 to EMC.30, T/AST/009, LC28 and LC29
32	Ageing management	ECE.8, ECE.23, ECE.24, EAD.1 to EAD.5, LC28 and LC29
43	Safety analysis of the plant design	T/AST/006, T/AST/030
54	Containment system for the reactor	ECE.21, T/AST/020

APPENDIX 4: PROVISION FOR ROBUSTNESS AND RESILIENCE

The required resilience of civil engineering structures should be quantified and specified. Margins should be such that civil engineering structures continue to provide their residual safety function following the application of beyond design basis loads by either having sufficient design margins, or by failing in a manner that limits the radiological consequences.

Civil engineering structures to be considered are those that are located within the nuclear licensed site and also those that are outside the nuclear licensed site but which nevertheless are determined to be necessary to ensure adequate self-sufficiency of the site in a beyond design basis fault condition.

The safety performance of civil engineering structures that are required for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, should be defined.

The required robustness of civil engineering structures should be quantified and specified Robustness is the ability of a structure to withstand events without being damaged to an extent disproportionate to the original cause. Good design involves looking beyond the minimum design requirements in a code or standard. SCOSS consider that the 3 Ps (People, Process and Product) have to be fully addressed to achieve a robust design.

To achieve robustness it is important to ensure that all the influencing stages and activities are included in the considerations, and that they are accomplished competently.

Issues to be considered at different stages of a project are given below:

1 Analysis and Design

• Ensuring that those involved are competent in this field.

• Identification of hazards and resultant risks affecting robustness in Stages 2-5.

• Quantification of significant residual risks.

• Choosing appropriate design details.

• Advising constructors and future owners of assumptions associated with the design detail adopted (via the drawings and health and safety file).

• The need for an independent review of design (supplementary to numerical checks).

• Having an overall point of responsibility.

2 Procurement

• Competency of those organisations procured.

• ‘best value’ tendering

• Clear lines of responsibility and authority.

• Clear reporting protocols.

• adequate information for planning and pricing construction phase.

• adequate specification.

• inclusion of adequate monitoring procedures (avoidance of self-certification approaches)

3 Construction

• ensuring that those involved are competent in this field.

• understanding the stated objectives and purpose of the design.

• identification of hazards and resultant risks having regard to temporary conditions.

• implementing the strategy outlined in the health and safety plan or elsewhere.

• ensuring contractor-design is co-ordinated.

• ensuring adequate monitoring, reporting and action where required.

4 Operation

• ensuring that those involved are competent in this field.

• implementing the strategy and requirements outlined in the health and safety file.

• ascertaining and managing the effects of changes/refurbishment.

• ensuring adequate maintenance of critical items.

• ensuring that those involved are competent in this field

5 Decommissioning

• identification of hazards and resultant risks, specifically those outlined in the health and safety file.

• having regard to temporary conditions.

Process: The process of achieving robustness has a number of facets that have the potential for allowing a weakness or serious fault to occur e.g.:

Analysis

Model

Does the model of the structure replicate actual behaviour with sufficient accuracy?

Has the model been validated and are the results verified?

Does the analysis allow for temporary conditions?

Actions

Have all foreseeable events been included (or knowingly omitted)?

Are dynamic actions likely?

Structural

Details

Do they meet current thinking in respect of robustness measures e.g. do they have sufficient ductility?

Is there likely to be a misunderstanding/omission of data between different designers (e.g. engineer/architect) or where design responsibility is often passed on to others e.g. steel detailing, reinforced concrete slab design?

Are the details practicable (i.e. buildability and maintainability issues)?

Use of Codes

Does the structural concept lie within the boundaries of code assumptions?

Good practice

Does the design make use of good practice and contemporary data (design codes do not necessarily reflect current thinking or knowledge)?

Multi-disciplinary co-ordination

Are the measures taken overall, complementary and co-ordinated?

Is there a party with overall responsibility?

Information

Has sufficient quality information regarding the design philosophy and details adopted been conveyed to the constructors and those who will maintain the facility?

Implementation Is the form of contract, the means of procurement, and the degree of control/supervision appropriate?

Is there an appropriate 'design change' control protocol?

Product:

The output should be a designed structure that incorporates the following facets of robustness:

Redundancy

Redundancy aids robustness

Load paths

Consideration of horizontal loads

Short load paths lead to robust structures

Sensitivity

Designs should not be sensitive to small changes in assumptions

Uncertainty

Greater uncertainty requires greater consideration

Failure modes and ductility

Are these correctly applied?

Progressive and disproportionate collapse

Must be avoided

Further Guidance

General guidance on structural robustness is available in the Institution of Structural Engineers publication, *“Practical guide to structural robustness and disproportionate collapse in buildings (October 2010)”*, but nuclear safety related structures may require further more detailed and specific consideration on a case by case basis.

HSE, RR834 - Preventing Catastrophic Events in Construction

(http://www.hse.gov.uk/research/rrhtm/rr834.htm)

The Standing Committee on Structural Safety (SCOSS)

http://www.structural-safety.org/

APPENDIX 5: PROVISION FOR CONSTRUCTION

Items important to safety for a nuclear facility should be designed so that they can be manufactured, constructed, assembled, installed and erected in accordance with established processes that ensure the achievement of the design specifications and the required level of safety.

In the provision for construction and operation, due account should be taken of relevant experience that has been gained in the construction of other similar plants and their associated structures, systems and components. Where relevant good practice from other relevant industries is adopted, such practices should be shown to be appropriate to the specific nuclear application. (See also ECE.17)

Based on IAEA SSR-2/1, Safety of Nuclear Power Plants: Design, 2012, Requirement 11, Page 17

The provisions of the Construction (Design and Management) Regulations 2007 (CDM2007) and L144 Approved Code of Practice (ACoP) Construction (Design and Management) Regulations 2007 are relevant to civil engineering works and structures.

APPENDIX 6: PROVISION FOR DECOMMISSIONING

Special consideration should be given at the design stage of a nuclear facility to the incorporation of features to facilitate radioactive waste management and the future decommissioning and dismantling of the plant.

Structural layout, designs and construction should be such that dismantling can be done using proven and simple working practices such as;

- Providing space and facilities on site for characterisation, decontamination and disassembly;

- Providing suitable access to allow intact removal of large plant items such as steam generators and large pumps;

- Minimising penetrations, cracks, crevices and joints that trap contaminants and sealing of all porous surfaces against ingress of activity. Chamfers, bevels and long radius bends should be used, where possible, rather than details employing 90° angles.

- The use of special surface finishes or treatments to prevent contamination from adhering to or penetrating the surface of materials

- Avoiding the overdesign of shielding bearing in mind that the design of a biological shield involves a balance between structural aspects and minimising activation.

Facilities should be designed to minimise infiltration, contain spills and releases and attenuate contaminant transport. This may be achieved by such methods as:

- minimising embedded pipework, ducts and equipment in floors and walls;

- minimising the use of potentially radioactive underground tanks, sumps, ducts and drains;

- lining sumps and trenches in concrete floors with corrosion resistant material, to protect from contamination and to facilitate clean-up and by providing corrosion resistant tanks;

- separation of radioactive and non-radioactive systems and areas (drainage systems should keep liquids separated according to their potential radioactivity);

- designing and installing pipes and ductwork to minimise the holdup and deposition of crud and active dust particulates.

  (See also DC.1 and RW2, 3 & 4)

The design should facilitate dismantling by means such as;

- developing designs that will facilitate construction as well as dismantling (by reversing the construction sequence);
- optimising the footprint of structures and reducing the amount of construction materials (concrete and steel);
- Considering (where necessary) the use of advanced techniques to remove active items.

Where irreversible construction sequences are used this should be justified and the decommissioning consequences examined.

Records

The availability of records relating to the plant is of importance to the development of safe and effective designs for decommissioning projects. Adequate arrangements should be implemented for the acquisition and maintenance of relevant information and records from the earliest stage of the life cycle of a facility in accordance with Principle DC.6. These should include, in addition to those records that are directly relevant to operation, other records that might be important for decommissioning including:

- Design basis
- Original design concept for decommissioning
- Design details and drawings
- Specifications
- Form, method and sequence of construction
- Construction materials and properties
- Design changes and concessions
- Construction records and photographs
- As-built records
- Inspection and test records
- Modifications
- Ageing management programme records
- Changes of use and configuration management records

In accordance with Principle MS.2 (Paragraph 60), specific attention should be paid to the retention of information during handover between lifecycle phases that involve changes in responsibility for records and information management. Key information transfer points include those between the following lifecycle phases;

- Design
- Construction and commissioning
- Operation
- Decommissioning

The provisions of the Construction (Design and Management) Regulations 2007 (CDM2007) and L144 Approved Code of Practice (ACoP) Construction (Design and Management) Regulations 2007 are relevant to civil engineering works and structures.

APPENDIX 6: BIBLIOGRAPHY

This appendix provides a list of publications that may, in appropriate circumstances, provide a useful source of information with regard to civil engineering works and structures on nuclear facilities.

1 Institution of Structural Engineers: 1991: Guide to Surveys and inspections of buildings and similar structures. ISBN 0 901297 14 3. Amended 1997.

2 Institution of Structural Engineers: 1996: Appraisal of existing structures. ISBN 1 874266 28 x. Second edition.

3 Institution of Structural Engineers Practical guide to structural robustness and disproportionate collapse in buildings (2010) ISBN 978-1-906335-17-5

4 Institution of Civil Engineers: Site Investigation Steering Group: Effective Site Investigation, 2013. ISBN: 9780727735058

5 Institution of Civil Engineers: ICE Manual of Construction Materials, 2009. ISBN: 9780727735973

6 CEB FIP Prestressed concrete: safety precautions in post-tensioning, 1989

ISBN: 9780727715357

7 CEB FIP Inspection and Maintenance of Reinforced and Prestressed Concrete Structures, 1986. ISBN: 9780727702616

8 HSE Research Report RR319 Safer foundations by design, 2005. ISBN 0 7176 2968 6

9 HSE Research Report RR834 Preventing catastrophic events in construction, 2011

10 HSE Research Report RR912 Management of ageing: A framework for nuclear chemical facilities, 2012

11 HSE Guidance Note GS49 Pre-stressed concrete, 1991. ISBN 978 0 1188 5597 6

12 The Royal Academy of Engineering: Engineering the Future: Nuclear Lessons Learned, 2010. ISBN 1-903496-60-8

13 The Royal Academy of Engineering: Engineering the Future- Nuclear Construction Lessons Learned Guidance on Best Practice: Concrete, 2012. ISBN: 1-903496-81-0

14 European Commission: Joint Research Centre: Institute for Energy - Summary Report on Nuclear Power Plants - Construction, Commissioning and Manufacturing Events, Benoit Zerger, 2011. ISBN 978-92-79-18973-9

15 IAEA Fundamental Safety Principles Series No. SF-1, 2006. ISBN:92-0-110706-4

16 IAEA Specific Safety Requirements Series No. SSR-2/1 Safety of Nuclear Power Plants: Design, 2012. ISBN:978-92-0-121510-9

17 IAEA Specific Safety Requirements Series No. SSR-2/2 Safety of Nuclear Power Plants: Commissioning and Operation, 2011. ISBN:978-92-0-115910-6

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