

IAEA SAFETY STANDARDS

for protecting people and the environment

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Construction of Nuclear Installations

DRAFT SAFETY GUIDE

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1. INTRODUCTION

BACKGROUND

1.1 The fundamental goal of construction is to correctly build an approved design. In order to accomplish this, this Safety Guide provides appropriate management process which focuses on various aspects of construction activities and supplements the recommendation and guidance provided by The Management System for Facilities and Activities [1], Application of the Management System for Facilities and Activities [2] and The Management System for Nuclear Installations [3] on implementation of construction activities in accordance with management system. Appendix V of Ref. [3] provides some guidance on the specific processes to be developed for the construction stage.

1.2 This safety guide is broadly applicable to nuclear installations and is intended for application to both the construction of new and the modification of existing nuclear installations. Nuclear installations vary greatly in type, size, utilization and other characteristics so that judgement has to be exercised on the measure of applicability to a specific installation.

1.3 To ensure that newly constructed structures, systems and components or nuclear installations can be commissioned and operated safely, it is necessary to fulfil the relevant requirements such as “Safety of Nuclear Power Plants: Design” [4](will be updated later), “Safety of Nuclear Power Plants: Commissioning and Operation” [5], “Safety of Research Reactors” [6] and “Safety of Nuclear Fuel Cycle Facilities” [7]. In addition, the regulatory authorization described in “Governmental, Legal and Regulatory Framework for Safety” [8] must be granted according to each country’s regulatory framework. It is recognized that even if the design and commissioning is fully compliant with all of the above requirements, a high

level of safety can only be achieved if the construction is carried out with high quality and care, since commissioning cannot test all aspects. Therefore all construction activities have a potential impact on safety, although no nuclear material during the construction may be present.

1.4 Contracted services are an integral part of the construction. Contractor oversight challenges have equal applicability to operating facilities and to new construction. Less availability of nuclear expertise, the expansion of the international supply chain, the first-of-a-kind and turn-key projects tend to increase the use of contracted services. These create challenges related to the retention of expertise, the effective management of the interfaces between the licensees and contractors, and the oversight of contractor manufacturing quality in the context of greater multinational diversity.

OBJECTIVE

1.5 The objective of this Safety Guide is to provide recommendations and guidance based on international good practices in construction of nuclear installations, as currently followed in Member States, which will enable construction to proceed with high quality, consistent with applicable codes, standards, and design requirements as part of the demonstration that the product can be commissioned and is capable of operating safely and reliably over its lifetime.

SCOPE

1.6 This Safety Guide is applicable to the construction stage of a nuclear installation including the process of manufacturing and assembling the components, carrying out of civil and architectural work, installation and maintenance of components and equipment, and performing the associated tests. The design or commissioning stage is not included in this

Safety Guide, although these stages may overlap with the construction stage. The specific definition of each stage may vary for each organization or country.

1.7 This Safety Guide identifies and explains safety significant construction activities which should be considered, checked and reviewed for ensuring quality of a new nuclear installation.

1.8 This Safety Guide may be applied to nuclear installations in the following ways:

- To support the development, implementation, assessment and improvement of the construction methods, procedures and techniques for ensuring the quality of the end product to meet the design safety intent;
- To assist the regulatory body in oversight and evaluation of the construction activities performed;
- To assist licensee and construction organization in providing technical specifications to a contractor, via contractual documentation, that are pertinent to the supplied product;
- To assist licensee and construction organization in understanding of the technical aspects that should be considered when assessing contractors' qualifications and performance.

1.9 In this Safety Guide, it is considered that all relevant safety requirements must be complied with, in all applications of the graded approach.

1.10 While this Safety Guide focuses on achieving high quality during construction which is a prerequisite for a safe and reliable operation of nuclear installations, it is noted that security aspects should also be considered and evaluated during construction. The IAEA's

Nuclear Security Series covers security issues at authorized installations.

STRUCTURE

1.11 Section 2 provides general considerations including definitions of terms used and prerequisites before the start of the construction. Section 3 provides guidance on the regulatory oversight of construction activities. Section 4 provides recommendations on management system for construction. Section 5 provides recommendations for the management of construction activities focusing on actual construction works at off-site and on-site.

2. GENERAL CONSIDERATIONS

DEFINITIONS

Construction

2.1 Construction is defined as the process of manufacturing and assembling the components of a facility, the carrying out of civil works, the installation of components and equipment and the performance of associated tests [9]. The associated tests are referred in this guide as pre-commissioning tests. Pre-commissioning tests are functional tests of individual subsystems of components and they are prerequisites for performing pre-operational tests during commissioning [10].

Construction organization

2.2 The “construction organization” is intended to mean the licensee, or that part of the licensee, or contracted organization that is responsible for construction. This construction organization should be established as the sole entity managing the construction activities of civil and architectural works, manufacturing, assembling, installation and testing of items

important to safety. Where the licensee is unable to fulfil this role in all its aspects, it may appoint a contractor or contractors to carry out specific roles for a part or the whole of an installation. The responsibilities of the contractor(s) should be clearly defined, controlled and inspected by the licensee. The use of contractor(s) should in no way reduce the responsibility of the licensee in regard to safety.

Contractor

2.3 The contractor refers to any individual or organization who furnishes items or services in accordance with a contract or procurement document. An all-inclusive term used in place of any of the following: vendor, seller, supplier, subcontractor, fabricator, consultant, and their sub-tier levels.

PREREQUISITES FOR THE CONSTRUCTION OF NUCLEAR INSTALLATIONS

2.4 The construction should start only after the licensee has satisfied itself by means of verification that the main safety issues in the design have been resolved; and after the regulatory body has satisfied itself, by means of review and assessment, of the adequacy of the safety analysis submitted, and the adequacy of the proposed arrangements, procedures and quality assurance programmes for implementing the design throughout construction.

2.5 The highest level of safety that can be achieved in construction of nuclear installation requires: a sound legal basis; a well resourced and technically competent licensee; qualified vendors, manufacturers and construction organizations; and an appropriate governmental infrastructure, including a regulatory body with well defined responsibilities and functions. The legal and governmental framework should be sufficiently implemented for proper regulation during construction.

2.6 All licences required to initiate construction activities should be in place.

Recommendations and guidance for the construction license requirements are provided in “Licensing Process for Nuclear Installations” [11]. Before construction starts, a preliminary safety analysis report should be updated as appropriate and authorized by the regulatory body. The preliminary safety analysis report may include information on site evaluation, the design basis, nuclear and radiation safety, deterministic analyses and complementary probabilistic safety assessment.

2.7 All efforts should be taken to ensure that an adequate level of safety consciousness and the acceptance of personal responsibility for safety are achieved by all parties. This includes licensee, regulatory body, contractors, and other stake holders.

2.8 Adequate completion of design, including acceptance criteria, and engineering work commensurate with the authorization process should be checked and verified prior to start of construction. The future forecast on remaining design and engineering works with necessary and available resource should be confirmed before construction begins. Late completion of design work may put involved parties under time and cost pressures which may affect quality and ultimately safety. Design changes should be minimized after construction starts.

2.9 Qualification of a method of construction, transportation, inspection or testing should be done before commencement of the activities, especially for a first-of-kind technology. More quality non-conformance and re-works are expected when new methodologies are applied for the first time.

2.10 Security requirements should be identified and taken into account in addition to safety considerations. Conflicting requirements should be identified and resolved. According to those requirements, on-site arrangements should be implemented, including physical protection against sabotage in use and storage of items important to safety.

2.11 At an existing site the emergency preparedness arrangement should be modified by appropriate responsible parties to take into account of the nuclear installation construction, taking into consideration the following:

- The amount and peak of manpower during the whole construction period;
- The various phases of construction and commissioning with their inherent and different major risks.

2.12 The regulatory body should ensure that the licensee(s)¹ should carry out a risk assessment to determine the possible risks of the construction site to the existing facilities and the effect of existing facilities on the construction site. These risks depend on the site and construction method which therefore should be analysed for each individual site. Possible risks are caused by, but not limited to, dredging, quarrying, excavation, blasting, transportation and lifting. Preventive measures should be taken to manage the construction related risk. Further guidance on effect on and from existing facilities is provided in paras 5.42 – 5.44.

2.13 Installations which handle, process or store potentially hazardous materials such as explosive, flammable, corrosive, toxic or radioactive materials should be identified. The maximum amount of hazardous material present at any given time and the process in which it is used should be taken into consideration. Pipelines for hazardous materials should be included in the category of items to be identified. Other sources to be considered are construction yards, mines and quarries which use and store explosives and which may cause the temporary damming of water courses, with possible subsequent flooding or collapse of

¹ In some cases multiple licensees on the same or nearby site may exist

ground at the site. For other potential sources of human induced external events, refer to paras 3.9 – 3.11 of Ref. [12] for more details.

2.14 Necessary fire protection measures at the construction site should be available until final plant fire detection, protection, and suppression systems are installed and operational.

2.15 In addition, the following issues should be considered before on-site construction begins to ensure quality of the construction:

- Licensee's manual on site construction Quality Management;
- Design reports of items important to safety having reference to construction consent;
- Arrangements to accommodate specialized nuclear installation work force to the site (labour colony);
- Location and approach/exit roads especially for large component transportation;
- Work hazard analysis report;
- Construction safety management manual (radiation source handling and hazard);
- Security aspects within and around the site;
- Plan for radiation safety of workers (for construction with existing installations);
- All infrastructure support systems should be in place including required electricity, gas and water supply, protection or coverage after work completion and environmental qualification.

3. REGULATORY OVERSIGHT OF CONSTRUCTION ACTIVITIES

3.1 Four interrelated IAEA Safety Guides provide recommendations on satisfying the

requirements in Ref. [8] concerning particular responsibilities and functions of the regulatory body in the regulation of nuclear facilities. These four Safety Guides cover, respectively, the organization and staffing of the regulatory body [13], regulatory review and assessment [14], regulatory inspection and enforcement [15], and documentation relating to the regulatory process [16]. The following recommendations provide a means of meeting the requirements in Ref. [8] for the regulatory oversight of nuclear installations during construction. They are supplementary to, and should be read in conjunction with, the recommendations provided in Refs [11, 13-15].

3.2 Well in advance of the beginning of the construction, the regulatory body should schedule resources to ensure a consistent and responsive oversight, according to the progress of the construction activities. Inspectors should be suitably trained and experienced in order that their competencies are consistent with the planned construction activities.

3.3 The regulatory body should develop requirements governing its oversight of construction activities including inspections according to graded approach. This extends to contractors manufacturing and assembling items important to safety.

3.4 The regulatory body should implement an oversight programme consistent with the construction programme provided by the licensee.

3.5 To properly implement an oversight programme during construction, the communication between the licensee and regulatory body should be formally defined before construction begins. The communication should be performed on a regular basis and include detailed scheduling information such that the regulatory body can plan to inspect specific construction activities and review relevant documentation.

3.6 During construction, the regulatory body should review and assess:

- on a systematic basis, the development of the design of the nuclear installation as demonstrated in the safety documentation submitted by the applicant or licensee;
- the progress of research and development programmes relating to demonstration of the design, if applicable; and
- how these design issues are incorporated into the licensee's construction programme.

3.7 To gain assurance that the licensee has met the regulatory requirements and can move forward in the construction programme, the regulatory body should make use of hold points or witness points such as first concrete, major safety significant equipment installation, fuel on site, entering commissioning, or a major deviation from the requirements. The hold or witness points should be carefully selected to assure:

- observability or testability especially before irreversible steps are made;
- construction organization preparedness for next stage.

If there are non-conformances, an action plan may be needed to correct deficiencies to allow progress beyond witness or hold points.

3.8 The regulatory body should have a system of accepting any concerns or allegations related to the safety of construction.

4. MANAGEMENT SYSTEM FOR CONSTRUCTION OF A NUCLEAR INSTALLATION

4.1 The following recommendations provide a means of meeting the requirements in Ref. [1] for the construction of nuclear installations. They are supplementary to, and should be read in conjunction with, the recommendations provided in Ref. [2] and Ref. [3]. Since

construction work has significant impact on future safety of nuclear installation, a successful management system during construction ensures that safety matters are not dealt with in isolation but are considered within the context of all construction activities.

SAFETY CULTURE

4.2 Safety culture is important in all phases of nuclear installation life cycle. In the construction stage, it implies characteristics and attitudes pursuing high quality construction to ensure safety in the commissioning and operational phases. This involves an understanding that deviations from procedures and specifications, or failure to understand the safety significance of structures, systems and components may have unforeseen consequences in the future.

4.3 A construction process involves challenges such as planning and execution under time and budget pressures, temporary workers with various skills, numerous contractors and works influenced by weather conditions and external environments. In addition, construction activity necessarily involves change on a constant basis. These factors are known to be some of the prime conditions that can induce poor safety culture. Goal conflicts between schedule, cost and safety should not adversely affect conservative decision-making and the maintaining of a questioning attitude. Application of safety culture attributes should be implemented in all participating organizations and individuals.

4.4 Construction programmes and methodologies should be developed and implemented to help all interested parties involved in the construction project strengthen safety culture particularly in organizations less familiar with nuclear requirements. A system to train personnel who have transferred to or employed on nuclear projects from other industries should be established to make them aware of the additional issues associated with nuclear safety.

4.5 The licensee should ensure all contractors and subcontractors in the supply chain are fully aware of the safety significance of what they have been contracted to supply. The licensee should encourage them to demonstrate a questioning attitude if any aspect of the work specified seems unusual or is not fully understood, or if any situation occurs during the course of the supply that could affect the quality of the finished component or service.

4.6 Safety culture and its promotion should be considered as part of contractor evaluation and monitored during the construction stage. The monitoring and evaluation should be done not only to contractor's organizations but also to contractor's individuals.

4.7 To support the safety culture principles, there should be a process for reporting concerns directly to management and the regulatory body. This process should include the capability of anonymously reporting a non-conformance or concern.

APPLICATION OF GRADED APPROACH

4.8 The grading process should determine the extent of the application of the management requirements to the construction activities.

4.9 In developing the grading approach, the following should be considered:

- (a) The qualification of special construction processes such as non-destructive testing and the qualification of the personnel that will carry them out;
- (b) The necessary level of detail and the need for inspection and test plans;
- (c) The level of traceability for items important to safety should extend through all equipment, materials, procedures, records, and other documents to ensure that the items are constructed to the appropriate quality level for their safety classifications;

- (d) The level of in-process controls and the need for hold or witness points;
- (e) Level of complexity;
- (f) First-of-a-kind activity.

LICENSEE RESPONSIBILITIES

4.10 Reference [5] states:

“During construction and commissioning, the plant shall be monitored, preserved and maintained so as to protect plant equipment, to support the testing stage and to maintain consistency with the safety analysis report“ (para. 6.14).

This requirement is implicitly applicable to the licensee for the construction of nuclear installations.

4.11 The licensee has responsibility for the nuclear installation being built in accordance with all legal and regulatory requirements. The licensee may contract construction but retains the primary responsibility for safety, quality and security.

4.12 The licensee should develop and maintain its capability to control all activities for which the license has been granted.

4.13 The licensee should take the responsibility during construction for all activities that could affect safety of the installation regardless of location. This includes:

- Developing and implementing a management system covering construction activities to assure the required quality. The licensee should establish a construction supervision plan with consideration for the safety importance of the items important to safety that includes audits, product quality surveillance, witness/hold

points, and field walk downs;

- Defining and retaining its core capability to be an “intelligent customer”² in its oversight and contracting processes;
- Taking ownership of the safety case for the nuclear installation especially for the information provided by contractor(s) or design/construction organization;
- Internal and external audits on the management system of contractors based on the graded approach. The licensee should perform surveillances to verify that the contractors’ activities are in compliance with requirements from both technical and management system perspective;
- Having a construction programme with hold points in the construction processes, where approval may be required (possibly by the regulator) prior to continuing to the next stage;
- Reporting safety significant non-compliances and events as required by the regulatory body;
- Ensuring that appropriate records relevant to safety are preserved;
- Preparing the commissioning programme;
- Transfer of documentation when moving from construction to commissioning.

4.14 The licensee should formally appoint an individual from its own organization as the

² An ‘intelligent customer’ is which the organization has clear understanding and knowledge of the product or service being supplied.

construction manager to be responsible for construction activities.³ The construction manager has the responsibility to ensure that the construction meets safety requirements.

Construction organization

4.15 The construction manager should have access to the necessary resources to establish a construction organization which may be or include contracted staff. The role and responsibilities of the construction organization should be defined and documented by the licensee. The management structure of the construction organization should define the level of responsibility for groups within it, including the responsibilities among contractors.

4.16 The principal activities of the personnel in the construction organization should include, as a minimum:

- (a) Controlling and supervising contractors both on-site and off-site;
- (b) Ensuring that contractors are established on the site in a controlled manner in allocated areas and are provided, where appropriate, with the necessary site services, information and instructions with regard to the applicable industrial safety requirements;
- (c) Identification of generic construction activities, develop and maintain guides about the use of standardized instructions and procedures and best practices;
- (d) Preparing safety related working procedures, including industrial safety procedures, to issue to the personnel of both the construction organization and

³ The individual formally appointed to be responsible for construction activities may be the head of the construction organization.

the contractors, and establishing that both the construction organization and the contractors' industrial safety arrangements on the construction site comply with the applicable requirements;

- (e) Monitoring the industrial safety policies and activities of all personnel on the construction site to ensure compliance with statutory and regulatory requirements with regards to quality and safety;
- (f) Planning and monitoring the progression of work to fulfil the construction programme, including, where appropriate, coordinating the activities of contractors responsible for constructing interfacing structures, systems and components;
- (g) Ensuring that contractors' work is carried out in accordance with procedures, specifications and drawings, that quality requirements are specified and implemented and that inspections and tests at the suppliers' facilities are appropriate and in accordance with inspection and test plans and associated surveillance schedules;
- (h) Carrying out maintenance for equipment as required;
- (i) Proper care of equipment that could deteriorate during construction, such as dehumidification of electrical equipment and preservation of critical surfaces that could rust;
- (j) Carrying out inaugural inspection for systems or components and obtaining relevant baseline data for comparative purposes in in-service inspection;
- (k) Carrying out adequate housekeeping activities to protect open equipment against

foreign materials intrusion and contaminants;

- (l) Arranging the controlled handover of completed work from one group to another or to the construction organization;
- (m) Acquiring, installing or maintaining material sample for a long-term material ageing monitoring and analyses;
- (n) Ensuring that relevant regulatory requirements are incorporated into work related documents.

PROJECT MANAGEMENT

4.17 The following safety recommendations are provided in addition to those provided in Ref. [3] paras 5.43-5.60.

Construction management

4.18 Construction management is a leadership function primarily concerned with the organization, co-ordination and control of large human, equipment and material undertakings, with the aim of achieving technical excellence, by working to quality standards, by optimizing, the schedule and the supply chain.

4.19 Construction management processes as well as construction work processes should be defined and documented. They should take due account of safety.

4.20 The licensee, construction organization and other contractors should have adequate organization, resources, experience, competence and procedures to manage a nuclear installation construction project. Recent experience has shown that a construction project can involve the use of temporary workers with various skills, multi-layered and multi-national contractors with various languages, cultures, legal and regulatory backgrounds, and different

conventions for measurements. These differences should be taken into account in developing the project management. Project managers should have competences to function successfully in this environment.

Requirements management

4.21 A system should be established to ensure that applicable inputs such as legal, regulatory and licensee requirements are correctly translated into specifications, drawings, procedures and instructions. The requirements and changes thereto should be controlled, so that safety related activities and item important to safety are consistent with the applicable requirements.

4.22 The regulatory body and the licensee in the country where the components will be used might each impose requirements that differ from the specification that would be normal for the country in which the component is manufactured or assembled. It should be ensured that the relevant requirements are known and understood by all those within the supply chain.

4.23 The licensees should ensure that all information supplied by the design organization is sufficiently clear and explicit to convey all the requirements to the contractors chosen to construct and, where appropriate, test and commission items important to safety.

Traceability

4.24 Traceability of items important to safety from initial design through construction is an important aspect of ensuring safety. The licensee should ensure that processes are in place and should collect and store such records as required by itself and the regulatory body. The aspects of this traceability include:

- (a) As built drawings;

- (b) Manufacturing and assembling details;
- (c) Inspection reports;
- (d) On-site traceability including marking and tagging;
- (e) Construction and test records.

The construction organization should be responsible for ensuring that the traceability records required by the licensee are provided to them.

4.25 Comprehensive photographic and, where appropriate, video records and computer simulations should be compiled, particularly in areas that will be eventually inaccessible or will be subject to intense radiation. This information will facilitate the planning of work in areas of high radiation levels during commissioning and operation which would shorten working times. These visual construction records of as-built conditions should show identification marks and should be comprehensively catalogued with descriptive captions. This will ensure that similar photograph taken or tapes made during subsequent inspections or maintenance work can be easily compared, and will help in any work planning and familiarization of personnel that are undertaken before the start of maintenance work.

INTERFACE MANAGEMENT

4.26 Interface arrangements should be identified and agreed between the licensee, construction organization (if appropriate), design organization, contractors and other organizational units performing the work. The interface arrangements should be specified in management system documentation and should be included in procurement documents as appropriate.

4.27 The construction organization should establish and implement a method to maintain

an adequate and timely communication to link on-site and off-site construction activities. This communication should also involve the design organization as appropriate.

4.28 To avoid any risk of compromising the quality of work, the construction organization should define processes for identifying and resolving conflicts and misunderstandings between contractors, for instance concerning conflicts with construction schedules, activities, tools, work spaces. The construction manager should have the final authority to resolve potential conflicts at the construction site.

TRANSFER OF RESPONSIBILITY

Transfers during construction

4.29 Appropriate rules and procedures should be established and documented for transfer of responsibility and working. Access control for items important to safety and working areas should also be written and implemented for the transfer.

4.30 When items important to safety and working areas are to be transferred between groups within the construction organization, both concerned groups should make inspections together at the location in consideration. Configuration of the items and working areas should be agreed by both groups.

4.31 After transfer, further work or corrective actions by the previous group should only be done with appropriate authorization by the new group.

Transfers to commissioning

4.32 The licensee should ensure provisions are made to control and coordinate the handover from the construction to commissioning. These provisions should include the following activities:

- (a) Documentation relating to the items transferred should be reviewed by the construction organization for completeness and accuracy.
- (b) Pre-commissioning inspection and functional tests should be carried out and the results recorded.
- (c) Any non-conformances or incomplete items should be identified and the issues resolved; and it should be ensured that the status of such items is clear and does not have the potential to affect safety during commissioning activities.
- (d) Termination points identifying the boundaries of transferred systems and equipment, or transferred parts of systems and equipment, should be clearly identified in transfer documentation.
- (e) An inspection of transferred items and associated records and documents.
- (f) Transfer of responsibilities should be recorded.

CONSTRUCTION RESOURCES

Provision of construction resources

4.33 The licensee and construction organization, if necessary, should ensure that sufficient suitably qualified and experienced people are available as required by the construction programme. Processes should be in place to ensure continuous qualification of the workers.

4.34 Requirements for resources should be estimated, planned and secured for the construction of items important to safety, particularly for the long lead items.

Training of human resources

4.35 Licensee personnel who will be involved in commissioning, operating and

maintaining nuclear installations should be involved during the construction, so that they undergo hands-on training to gain special expertise in operation, maintenance and technical support.

CONTROL AND SUPERVISION OF CONTRACTORS

Evaluation and selection of contractors

4.36 The construction organization should be responsible for contracting activities for construction and the licensee should be notified and approved as necessary.

4.37 The graded approach should be applied to the development of criteria for the evaluation and selection of contractors and suppliers providing materials, products and service. The activities that they will perform should be established and documented.

Contractor oversight

4.38 A rational judgement on the extent of licensee's and/or construction organization oversight of contractor's activities should be based on the graded approach. The choice will depend on:

- Safety significance of the item or service;
- The experience of the licensee and the contractor in relation to the products or services being procured;
- The presence of any first-of-a-kind features;
- The extent of evidence available that the appropriate quality can be demonstrated;
- Regulatory requirements and related legal/statutory laws.

The licensee should be notified of the results of the oversight performed by the construction as necessary.

4.39 Before initiating any activity following the award of subcontract(s), a meeting should be convened between the contractor(s) and the construction organization to ensure that the contractor(s) is fully aware of all relevant requirements for the activities. The requirements should include:

- (a) Interface arrangements;
- (b) Methods of communication;
- (c) Documents and information to be submitted;
- (d) The management system including oversight and supervision.

In addition, if the contractor(s) is working on the site, additional requirements include:

- (e) Housekeeping;
- (f) Site security;
- (g) Site training.

The meeting should also finalize the arrangements that the contractor(s) will make to satisfy these requirements and demonstrate its appreciation of safety culture. The licensee should be notified of this meeting and attend as appropriate (in case the construction organization is not the licensee).

4.40 The construction organization should be informed, ideally during this meeting, of all the subcontractors used by the contractor. Any new subcontractors appointed after this meeting should be made known to the construction organization before relevant work begins.

4.41 The construction organization should frequently organize meetings with contractors and subcontractors to review and ensure implementation of the construction organization requirements.

4.42 Contractors should ensure that each contractor organizes daily tool-box meetings where work process, schedule, any deviation, and any other important aspects of work that is relevant to safety and quality should be discussed and confirmed.

CONTROL OF DESIGN INFORMATION

4.43 Reference [5] states:

“During construction and commissioning, a comparison shall be carried out between the as built plant and its design parameters. A comprehensive process shall be established to address non-conformities in design, manufacturing, construction and operation. Resolutions to correct differences from the initial design and non-conformities shall be documented” (para. 4.16).

Furthermore, Ref. [7] states in paras 7.6 and 7.6 that:

“The operating organization shall specify a formal procedure for design changes such that those made to the facility during construction are accurately recorded and their impacts are assessed.

“‘As built’ drawings of the facility shall be provided to the operating organization. Following construction of the facility, the operating organization shall review the as built drawings to confirm that, as far as can be assessed, the design intent has been met and the safety functions specified will be fulfilled. The operating organization shall, as required, seek agreement by the regulatory body to proceed to the commissioning stage.”

These requirements are also implicitly applicable to the licensee for the construction of nuclear installations.

4.44 The licensee should control the drawings, design codes and documentation which describe the basis for licensing the construction, commissioning and operation of the nuclear installation in order to maintain design configuration control.

4.45 Arrangements for communication should be established between the design and construction organization and between construction organization and the contractor(s) and to deal with queries on the design information from contractor(s).

4.46 A process should be established to address change proposals from the contractor(s) with regard to the design information issued. If the proposal has an implication for safety, its resolution should involve the design organization, licensee and regulatory body as appropriate.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

Assessment of management system

4.47 Project management processes and their performance should be periodically assessed. Progress assessment should also be done to provide early diagnosis of performance problems or schedule and cost overruns. Early remedies, adjusting human resource, renegotiation of contracts should be considered to avoid compromising the quality of the product.

4.48 Independent review programmes should be established and implemented, and address project management competence.

Non-conformance and corrective actions

4.49 A system which collects all identified non-conformances, records and processes them

should be implemented. Everyone engaged in construction should be made aware that they are expected to identify and report non-conformances.

4.50 The process of determining the safety significance and the corrective actions of the non-conformance should include appropriate experts including the design organization.

4.51 Actions that are determined for corrective actions should be assessed in relation to their significance to the construction programme and dealt with appropriate management level.

4.52 The recording of the corrective actions taken for the non-conformances should be maintained. The effectiveness of the process to implement corrective actions should be determined by monitoring for non-conformances reported.

4.53 Pending non-conformances should be tracked to completion.

Construction experience feedback

4.54 Construction experience and best practices not only from specific nuclear installations but also from nuclear and non-nuclear construction should be collected and lessons learned implemented for the enhancement of quality and safety. Criteria should be established for the selection and timing of the reporting of experiences related to construction.

4.55 The licensee should be pro-active and open in reporting safety relevant experiences internationally through appropriate databases.

5. MANAGEMENT OF CONSTRUCTION PROCESSES

GENERAL CONSIDERATIONS

Planning, scheduling and work sequence

5.1 Construction activities should be planned. The plan should specify:

- The activities to be performed, including verification and validation for integrated digital I&C system, environmental and seismic qualification of items important to safety, in manageable units;
- The planned sequential order and duration of these activities;
- The resources allocated for each activity.

5.2 The construction schedule should be managed continuously by the construction organization during the construction and communicated by the construction manager to relevant parties.

5.3 The planning, scheduling and work sequence should include hold and witness points in particular those specified by the licensee and regulatory body in the overall construction programme.

5.4 The construction planning, scheduling and work sequence should include requirements for off-site manufacturing and assembling with adequate quality management programme.

5.5 The examination of specifications, documents and drawings, and plans and schedules should identify which on-site manufacturing, assembling, installation, and inspection and testing activities should be performed.

5.6 The construction organization should confirm the adequacy of construction methods with reference to the principal designer where necessary.

5.7 Construction sequencing should be reviewed and checked to ensure prior construction work would not be adversely affected such as embedded items in walls or

ground.

Procurement specifications

5.8 Procurement specifications should be developed to ensure that items important to safety will be provided in such a way that they can ensure the achievement of the design specifications and required level of safety including the generic guides developed by the construction organization.

5.9 The safety classification of items important to safety should be included in the procurement specifications so that the supplier can determine the necessary codes and standards (including inspection requirements).

5.10 An part of procurement document for items important to safety should be the requirement for an end of manufacturing (or assembling if appropriate) report. This should include:

- Compliance certificate;
- Inspection and test results;
- Non-conformance reports;
- Procurement records;
- Storage, installation and test instructions;
- Operation and maintenance manuals;
- Operating conditions and limits;
- As-built drawings.

Prerequisites for construction works

5.11 Design documentation should be completed with sufficient time in advance to assure

quality of instructions, procedures and drawings and to make appropriate preparation for the work.

5.12 Contractors should obtain approval of the licensee and construction organization before beginning work and ensure they have the relevant information including work schedule, instructions with drawings and compatible consumables.

5.13 The licensee should ensure that documentation to be used for construction activities is up to date, including latest design information, drawings and work procedures, and is in accordance with the approved design.

5.14 The construction organization should have in place contingency plans for on-site critical construction activities, including measures to cope with electric power outage, ceasing of water supply and any other interruptions which may cause unexpected deterioration in work quality.

Work and environmental conditions

5.15 Construction work and environmental condition should be monitored to protect safety significant mechanical, electrical & control equipment, and structures from internal and external damage or contamination.

5.16 The environmental conditions during construction work including manufacturing, assembling and transportation should be specified and periodically monitored to confirm that conditions are within their limits of: temperature, pressure, humidity, dust, dirt, airborne salt, wind, and electromagnetic conditions. Limits need only be developed for conditions applicable to a given work location and given work activities.

Cleanliness and Foreign Material Control

5.17 When procuring items for the installation, it should be ensured by the licensee or

construction organization that the requirements for cleanliness are included in the procurement documentation so that the items arrive on the site at an acceptable standard of cleanliness.

5.18 The construction organization should put in place measures and controls necessary to protect items important to safety from internal and external contamination by dirt, dust and foreign material. Those measures include:

- (a) Methods and techniques for control of the site area, individual structures and systems, the facilities, and the material and equipment being incorporated into the installation;
- (b) Methods for the control of environmental conditions;
- (c) The control of access of workers. Where clean zones are used to achieve this control, they should be clearly marked, and procedures or instructions should be issued to regulate their usage and maintenance;
- (d) Determination and control of allowable chemicals and consumables.

Receipt, handling, transport, storage, preservation and maintenance

Control of items and consumables

5.19 Items and consumables should be controlled from receipt through storage, handling and use, to prevent their abuse, misuse, damage, deterioration or loss of identification.

5.20 The construction organization should have on-site item and consumable inventory management.

Handling

5.21 The use of items such as special cartons, containers, protective devices, cranes, hoists, manipulators and transport vehicles should be considered where handling operations are of a nature likely to cause damage to the items important to safety. Operators and handlers of all such items should be competent. Equipment for handling items should be used and maintained in accordance with national regulations and standards.

Transportation

5.22 All transportation routes both off- and on- sites should be planned with appropriate protection measures for items important to safety whether they are being transported or on the transport route.

Storage

5.23 Storage should be provided as specified by the designers and manufacturers to protect items important to safety prior to their installation and use. This may require segregation of some items.

5.24 Storage areas should be established and controlled by the construction organization, with account taken of aspects such as:

- (a) Cleanliness and housekeeping practices;
- (b) Requirements for fire protection;
- (c) Protective requirements relating to coatings, preservatives, covers and sleeves;
- (d) Prevention of physical damage;
- (e) Environmental control (such as control of temperature and humidity);

(f) Preventive maintenance;

(g) Security;

(h) Physical and chemical characteristics of items.

5.25 Inspections should be performed by the construction organization as necessary to ensure that the specified conditions are maintained and that any non-conformances are dealt with. These inspections may need to be continued in the commissioning and operation stages in which case handover arrangements should be established.

5.26 Items important to safety and their constituents should be clearly identifiable by using appropriate marks. Marking materials should be compatible with material preservation. On-site physical protections against unauthorized removal in use and storage of items important to safety should be implemented.

Preservation of products

5.27 Before installation of any items important safety, they should be inspected against the requirements and if necessary remedial action taken.

5.28 Acceptable limits on the environmental and operational conditions to which equipment may be exposed after installation should be specified by designers and manufactures. The construction organization should monitor and control the environmental conditions of items important to safety after the installation to protect them against other work that is being carried out.

5.29 When a temporary structure or support is used, attention should be paid to ensure the required quality of the items important to safety affected by it.

5.30 During the on-site or off-site pre-commissioning tests, the relevant items important to

safety should be isolated or protected to avoid inadvertent actions.

Maintenance

5.31 During the entire construction phase, the licensee should ensure that the items important to safety are kept under an appropriate preventive or corrective maintenance plan to maintain their functionality as required by the design. This should be continued until operational maintenance programmes are initiated.

Verification and test of construction activities

5.32 The licensee and construction organization should develop a process to verify the completion of construction activities. This verification should be formally documented to confirm the items important to safety have been constructed to the specified requirements and comply with the acceptance criteria. A typical verification record should include:

- (a) Identification of the structure, system or component;
- (b) Description of the checks carried out and how the results were verified;
- (c) The date and time of the check;
- (d) Any special tools or calibrated equipment used;
- (e) Test results and comparison with acceptance criteria;
- (f) A list of deficiencies and outstanding items or work;
- (g) Confirmation that specified documentation and records are available and complete;
- (h) Confirmation by relevant parties that the check has been carried out.

5.33 Whenever relevant, test and verification should be performed by a qualified third

party.

5.34 The test plan, acceptance criteria and results should be documented such that they can be independently assessed. The adequacy of tests (contents, results and timing) should be justified and the test coverage analysed against the requirements specified for the system.

5.35 Any use of radioactive sealed sources and devices during such activities as radiographic examinations, gauging (density, thickness, moisture, etc.) or material analysis should consider protection of workers and sensitive items in the area as required by the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the Basic Safety Standards or BSS) [17].

MANUFACTURING AND ASSEMBLING

5.36 The licensee and construction organization should establish and implement requirements and procedures for the verification of manufacturing and/or assembling quality (including materials and procedures) of items important to safety as mentioned in paras 5.32-5.35.

5.37 All items important to safety should be inspected and tested by the manufacturers against applicable codes and standards including design standards.

5.38 If appropriate, before transporting to the site, pre-assembly and match-marking of the components should be done to ensure proper re-assembly at the site.

5.39 If the procurement is begun before construction licence is issued, the licensee should ensure procured items important to safety achieve the design specification and required level of safety.

ON-SITE CONSTRUCTION PROCESSES

Receipt

5.40 If appropriate, items that arrive at the construction site should be visually inspected before unloading to verify that there is no damage and rejected if necessary.

5.41 After items have been received, an inspection should be carried out by the construction organization to ensure that the relevant specifications are fulfilled, prior to acceptance and use in construction, such as that:

- (a) The item is configured correctly;
- (b) Identification and marking are adequate;
- (c) Manufacturing and assembling documentation is available as required;
- (d) The inspection record and/or certificate should be traceable to the inspected item for acceptance confirmation;
- (e) Protective covers and seals are intact;
- (f) Coatings and preservatives have not been damaged;
- (g) No physical damage has been sustained;
- (h) Cleanliness is of the correct standard;
- (i) Inert gas blankets and the condition of desiccants, where relevant, have not been compromised;
- (j) Non-conformances identified by receipt inspections;
- (k) Necessary tests of hardware characteristics have been performed;

- (l) Storage should be controlled to prevent inadvertent installation or use.

Effect on and from existing facilities

5.42 A construction site may already have operating facilities on-site, with the possibility of interdependent safety or support systems. Other critical facilities may also be present such as those for spent fuel storage in fuel pools or dry cask storage. Research reactor sites may already have associated laboratories, isotope production facilities and hot cells. The safety and security assessment during construction should be performed to take into consideration all on- or nearby site facilities and any interdependence of their safety systems. Such consideration includes consequence assessment of environmental discharges that are cumulative for all facilities on a site.

5.43 The responsibilities of the construction organization and of the existing operation organization should be defined before the start of construction activities at the site. Close communication between the construction organization and the existing operation organization should be established.

5.44 For installations adjacent to each other or those that share common buildings or services, the following boundaries should be put in place: radiological protection, physical, system, security, access boundaries and cleanliness. In utilizing resources of existing nuclear installations such as water, electric power, fire protection, emergency medical services and security, clear interfaces should be defined and understood by the construction organization.

On-site manufacturing and assembling

5.45 The construction organization should ensure that on-site manufacturing and assembling of items important to safety is capable of producing an acceptable product which meets applicable codes and standard and design requirement.

5.46 On-site manufacturing and assembling should be located such that these activities will not affect adjacent items important to safety or activities that may affect items important to safety.

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