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been incorporated and
addressed.

Construction for Nuclear Installations

DRAFT SPECIFIC SAFETY GUIDE XXX

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New Safety Guide

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DRAFT

1. INTRODUCTION

BACKGROUND

1.1 The goal of construction is to build correctly an approved design. This Safety Guide sets out an appropriate management process that focuses on the implementation of various aspects of construction activities. It provides specific guidance and recommendations to meet the requirements established in The Management System for Facilities and Activities [1], and supplements the recommendations provided in Application of the Management System for Facilities and Activities [2] and The Management System for Nuclear Installations [3]. Appendix V of Ref. [3] provides some guidance on the specific processes to be covered in the management system for the construction of a nuclear installation.

1.2 This Safety Guide is broadly applicable to nuclear installations and is intended for application in the construction of new nuclear installations and in carrying out major design modifications¹ and refurbishments of existing nuclear installations. Nuclear installations vary greatly in type, size, radiation risks, utilization and other characteristics, so that judgement has to be exercised as to the degree of applicability of this Safety Guide to specific installations and sites.

¹ Reference [4] provides guidance on the control of activities relating to modifications at nuclear power plants and deals with the intended modification of structures, systems and components, operational limits and conditions, procedures and software, and the management systems and tools for the operation of a nuclear power plant.

1.3 To ensure that newly constructed structures, systems and components or nuclear installations can be commissioned and operated safely, it is necessary to meet the relevant safety requirements established in Safety of Nuclear Power Plants: Design [5], Safety of Nuclear Power Plants: Commissioning and Operation [6], Safety of Research Reactors [7], Safety of Nuclear Fuel Cycle Facilities [8] and Predisposal Management of Radioactive Waste [9]. For example, Requirement 11 of Ref. [5], on provision for construction, states that “Items important to safety for a nuclear power plant shall 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.” This Safety Guide provides recommendations on how the objective of “achievement of the design specifications and required level of safety” can be met in practice.

1.4 In addition, the regulatory authorization described in Governmental, Legal and Regulatory Framework for Safety [10] is granted for specific installations in accordance with each State’s regulatory framework. It is recognized that even if the design and commissioning are fully compliant with all safety requirements, a high level of safety can only be achieved when the construction is carried out with high quality and care, since commissioning cannot test all aspects of the design. Therefore, all construction activities have a potential impact on safety, even though there may be no nuclear material present during the construction.

OBJECTIVE

1.5 The objective of this Safety Guide is to provide recommendations and guidance based on international good practices in the construction of nuclear installations, as currently followed in Member States, which will enable construction to proceed with high quality,

consistent with the design requirements, and as agreed by the regulatory body in issuing the authorization for construction.

SCOPE

1.6 This Safety Guide is applicable to the construction stage of a new nuclear installation and to major modifications and refurbishments of an existing nuclear installation, including the processes of manufacturing and assembling of components, carrying out of architectural and civil works, installation and maintenance of structures, systems and components, and performance of the associated tests to demonstrate their acceptability. Neither the design stage nor the commissioning stage is addressed 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 State.

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

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

- To support the development, implementation and assessment of construction methods and procedures and the identification of good practices for ensuring the quality of the construction to meet the design intent and ensure safety;
- To assist the regulatory body in its oversight and evaluation of the construction activities performed;
- To assist the licensee in providing specifications to a contractor, via contractual

documentation;

- To assist the licensee in understanding the management aspects that should be considered when assessing contractors' qualifications and performance;
- To assist the licensee in its oversight of the whole supply chain and its verification of the compliance of contractors with the licensee's quality and safety requirements;
- To assist interested parties in understanding the roles and responsibilities of different types of contractors.

Contractors may be construction organization, technical support organizations and/or consultants responsible for independent review and assessment and organizations responsible for performing third party inspections.

1.9 In this Safety Guide, it is considered that all relevant safety requirements have to be complied with in accordance with a graded approach.

1.10 While this Safety Guide focuses on achieving high quality during construction, which is a prerequisite for the safe and reliable operation of a nuclear installation, nuclear security aspects should also be considered and evaluated during construction. Publications in the IAEA Nuclear Security Series provide guidance on nuclear security issues and should be taken into consideration throughout the lifetime of the installation, including during site selection, design and construction [11 – 16].

STRUCTURE

1.11 Section 2 sets out general considerations including explanations 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 the management system for construction. Section 5 provides recommendations for the management of construction activities, focusing on construction works on the site and at off-site locations.

2. GENERAL CONSIDERATIONS

USE OF TERMS

Construction

2.1 Construction is the process of manufacturing and assembly the components of a facility, the carrying out of civil works, the installation of components and equipment and the performance of associated tests [17]. The associated tests are those carried out to ensure that the structures, systems and components have been constructed, manufactured and installed in accordance with design specifications. Guidance on such tests can be found in the annex of Ref. [18]. Owing to differences in the construction schedule for each item, the commissioning and construction stages for the installation may take place concurrently. Hence it is difficult to define a precise ‘end of construction’, but the licensee should ensure that items have been installed, inspected and tested and should obtain an authorization from the regulatory body before carrying out significant steps in the commissioning process [19].

Construction organization

2.2 The construction organization is the entity managing the construction activities, such as civil and architectural works and manufacturing, assembly, installation and testing of items

important to safety at the installation itself. The construction organization may be part of the licensee or may be a separate, contracted organization (see Fig. 1). If the licensee appoints a contractor or contractors to carry out specific functions for construction of part or all of the installation, the responsibilities of the contractor(s) should be clearly specified and the work of the contractor should be controlled by the licensee. The licensee retains the prime responsibility for safety and this responsibility cannot be delegated through the use of contractors [20]. The licensee, in order to meet this responsibility, should put in place an oversight process that covers the management of activities by the contractor and any subcontractors and the activities themselves.

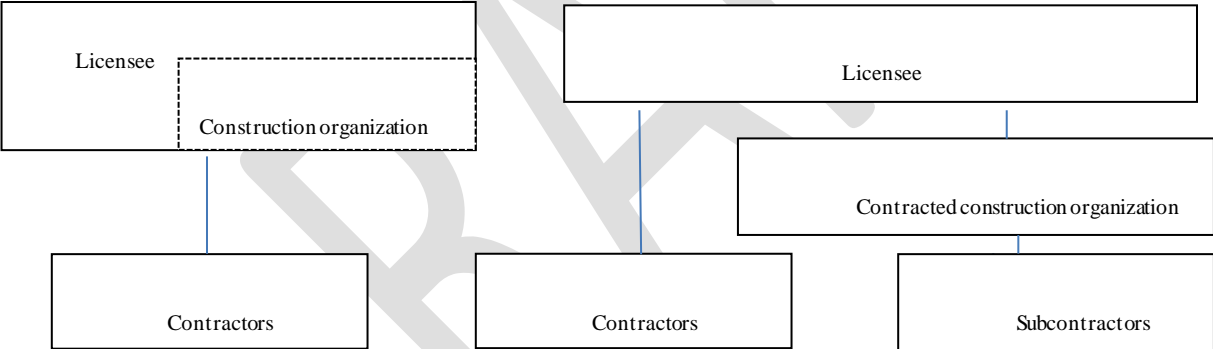


FIG. 1: Possible different organizational structures for a construction organization.

Contractor

2.3 A contractor is any individual or organization that provides items or renders services in accordance with a contract or a procurement document. Contractors may include designers, architects, engineers, manufacturers, assemblers, installers, distributors, importers, suppliers, technical support organizations and other consultants and their subcontractors or subsidiaries.

Design organization

2.4 The design organization is the organization responsible for preparation of the detailed design of the installation to be built.

PREREQUISITES FOR THE CONSTRUCTION OF A NUCLEAR INSTALLATION

2.5 To ensure the highest level of safety in the construction of a nuclear installation, the following are necessary:

- An appropriate legal and governmental infrastructure, including an independent regulatory body with well-defined responsibilities, authority and functions;
- An established regulatory framework, including necessary regulations and guides, to ensure competent regulation during construction;
- A well-resourced and technically competent licensee;
- Well-established safety culture in all involved parties;
- Suitably qualified and experienced contractors;
- A technical support infrastructure for the regulatory body and the licensee, as necessary.

2.6 All relevant authorizations should be obtained before construction starts. If this is not done, the licensee bears the risk that structures, systems and components may fail to meet the necessary regulatory requirements. However, in some instances, manufacturing of some items with a long lead time begins before authorization for the construction is granted by the

regulatory body. Such activity should be brought to the attention of the regulatory body. The licensee should verify that the design of such items with a long lead time is of the appropriate standard and is sufficiently complete before construction starts. Any major safety issues should be resolved prior to construction, when there is greater flexibility for design changes.

2.7 All applicable licences, permits and approvals required to initiate construction activities should be in place before construction starts. Recommendations and guidance for the processes for granting a licence for the construction and for the required documentation are provided in Ref. [19].

2.8 The licensee should identify and understand jurisdictional boundaries and responsibilities in cases where there is more than one regulatory body governing a particular area (e.g. regulation at national and provincial levels for occupational health and safety; regulation of pressure boundaries; regulation of protection of the environment and regulation of nuclear security.)

2.9 All efforts should be made to ensure that an adequate level of safety culture is achieved by all parties. This includes the licensee, the regulatory body, contractors and other interested parties.

2.10 A design schedule, including acceptance criteria verification and engineering work, commensurate with the authorization process should be drawn up by the design organization and should be verified by the licensee prior to the start of construction, so that late procurement will not adversely affect the construction process. Before construction starts, a review of readiness should be carried out by the licensee or its construction organization to verify that the design is sufficiently complete and that all engineering documents are

available, and to identify any areas where the design is incomplete. The design organization should develop an action plan covering any remaining design and engineering work, and the necessary resource requirements should be agreed with the licensee and monitored by the licensee as construction proceeds. Changes to the action plan should be agreed only if safety would not be compromised by any time and cost pressures resulting from the late completion of design work. Design changes that could have an impact on safety should be minimized after construction starts and should be recorded by means of a well-defined process, so that demonstration of the safety of the as-built design is achievable.

2.11 The development and qualification of well-defined methods of construction, transport, inspection or testing that are relevant to safety should be done before commencement of these activities, especially for the application of first-of-a-kind technology². Non-conformances and deviations should be minimized by early planning. Adequate resources should be provided for qualification activities such as research and development activities or verification tests using mock-ups or full-sized models. The design and construction should take into consideration the future decommissioning of the installation, as stated in Requirement 12 of Ref. [5].

2.12 Particular consideration should be given to nuclear security arrangements on sites with existing nuclear installations. Guidance on nuclear security measures is provided in Refs [11 – 16].

² Increases in non-conformances and rework are expected when new methodologies are applied for the first time.

2.13 For sites with existing nuclear installations, the regulatory body should ensure that the licensees³ of all installations carry out a risk assessment to determine the possible effects of the construction site on the existing nuclear installations and the effect of existing installations on the construction site. Each site should be analysed for site specific risks and for construction methods risks. Possible risks are presented by, but are not limited to, dredging, quarrying, excavation, blasting, piling, dust, transport and lifting and creation of connections between the existing installations and the construction site. Preventive measures should be taken by the affected licensee(s) of the construction site and of other installations to manage the risks associated with the construction. Further guidance on interaction with existing installations is provided in paras 5.48 – 5.50.

2.14 Construction processes and methods should take account of internal and external hazards. Installations on the site in which potentially hazardous materials such as explosive, flammable, corrosive, toxic or radioactive materials are handled, processed or stored should be identified in the risk assessment. The maximum amount of hazardous material present at any given time and the process in which it is used should be taken into account. The aggregate effects of such materials should also be considered. Pipelines for hazardous materials should be included in the category of items to be identified in the risk assessment. Other sources of hazards that should be considered are construction yards, mines and quarries in which explosives are used and stored, which may cause the temporary damming of water courses, with possible subsequent flooding or collapse of ground at the site. References [22] and [23] provide further guidance on other potential sources of external human induced events. To

³ In some cases, there may be multiple licensees on the same site or on nearby sites.

ensure adequate mitigation of environmental effects and effects from generation of waste from construction activities at the site, measures for environmental monitoring and protection and processes to minimize generation of waste should be put in place.

2.15 Necessary fire protection measures at the construction site should remain available until the final fire detection, protection and suppression systems for the installation are installed and are operational. Details of these measures should be included in the arrangements for emergency preparedness and response.

2.16 For sites with existing nuclear installations, the licensee is required to put in place arrangements for emergency preparedness and response to ensure the safety of workers and the public in the case of an accident occurring at or affecting the construction site [21].

2.17 For sites with existing nuclear installations, arrangements for emergency preparedness and response should take into account the following:

- The average and peak employment at the site throughout the construction or modification project;
- Training of construction site personnel;
- Appropriate provision of alarms to alert all personnel at the site, with account taken of specific construction activities;
- The risks associated with the various phases of construction.

2.18 In addition, the following issues should be taken into account by the licensee and the necessary arrangements should be made subject to approval by the regulatory body, as

appropriate, before on-site construction begins, to ensure quality of the construction:

Infrastructure

- The location of the site and the transport routes, especially for the transport of large components;
- All arrangements necessary to accommodate the work force for the construction site and later operation of nuclear installation;
- All necessary infrastructure support systems, including electricity, gas and water supply;

Site characteristics

- The marking of the site boundary within which the authorized installation will be constructed and operated;
- Procedures for protection or coverage of the site from the weather and other external conditions after completion of the work and the necessary environmental qualification;
- Special construction processes and equipment for which there is a specific nuclear safety issue. In other cases, normal construction processes and equipment can be used;

The management system and the safety of workers

- Provisions of the management system relating to on-site construction activities;
- The work hazard analysis report;
- The manual on construction safety management, including for management of the handling

of radiation sources;

- The plan for radiation protection of workers, if relevant (for construction at sites with existing nuclear installations);

- Design reports of items important to safety identified in the authorization for construction.

2.19 In cases where construction is being resumed on a suspended project, special consideration should be given to factors that may affect the restart of construction. More detailed information can be found in Refs [24] and [25].

2.20 Some site preparation activities, such as geologic investigation, may be carried out before a licence has been granted. Arrangements should be put in place by the potential applicant for a licence to ensure that, if the results of these activities are to be incorporated into the permanent works or can have an influence on them, they are planned, executed, monitored and documented to standards equivalent to activities that would later be carried out under the licence.

INTERACTIONS WITH INTERESTED PARTIES

2.21 It is recognized as relevant good practice, that interaction with interested parties of all kinds is continued from the siting stage throughout the construction stage by both the regulatory body and the licensee.

3. REGULATORY OVERSIGHT OF CONSTRUCTION ACTIVITIES

3.1 Four related IAEA Safety Guides provide recommendations on meeting the requirements in Ref. [10] concerning particular responsibilities and functions of the regulatory

body in the regulation of nuclear installations. These four Safety Guides cover, respectively, the organization and staffing of the regulatory body [26], regulatory review and assessment [27], regulatory inspection and enforcement [28], and documentation relating to the regulatory process [29]. In addition, Ref. [19] provides details of the documentation that is required for obtaining an authorization for construction from the regulatory body. Reference [30] provides guidance on the use of external expert support by the regulatory body. The recommendations in this present Safety Guide refer specifically to regulatory oversight of construction and are supplementary to, and should be read in conjunction with, the recommendations provided in these publications.

3.2 The aim of regulatory oversight is to verify that the licensee is in compliance with the conditions set out in, for example, the authorization or regulations. In addition, regulatory oversight should take into account, as necessary, the activities of contractors of services and products to the licensee. Regulatory oversight does not relieve the licensee of its prime responsibility for ensuring safety [20].

3.3 Regulatory oversight during construction should cover management system of the licensee and its control of contractors and subcontractors, as well as the monitoring and direct observation of construction work practices and items and equipment used in construction. It should include inspection and assessment of safety related construction activities through such methods as: discussions and interviews with relevant personnel; examination of procedures, records and documentation. The oversight should also include inspection of results of measurements and tests, and witnessing selected activities.

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

3.5 The regulatory body should develop requirements or guidelines governing its oversight of construction activities in accordance with a graded approach (refer to 4.8). The graded approach should extend to contractors manufacturing and assembling items important to safety.

3.6 The regulatory body should implement an oversight programme that is consistent with the construction plan detailed by the licensee as part of its application for authorization for construction.

3.7 In order to properly implement an oversight programme during construction, the arrangements for communication between the licensee and the regulatory body and any other authorized bodies, as appropriate, should be formally defined and agreed before construction begins. Communication should take place on a regular basis and detailed information on scheduling should be transmitted, so that the regulatory body can plan to inspect specific construction activities and review relevant documentation.

3.8 Prior to authorizing construction, the regulatory body should review and assess the arrangements, procedures and quality assurance programmes for implementing or modifying the design.

3.9 During construction, the regulatory body should review, assess and inspect the following, as appropriate:

- Proposed design changes, non-conformances or safety significant events, as reported through the licensee's management system;
- On a systematic basis, the development of the design of the installation as demonstrated in the reports and safety documentation submitted by the applicant or licensee in accordance with an agreed schedule;
- The progress of research and development programmes relating to demonstration of the design, if applicable;
- Documents relating to the detailed design to ensure that they are adequate and produced in a timely manner so that they can be properly incorporated into the construction project.

3.10 To gain assurance that the licensee has met the regulatory requirements and may be permitted to move forward in the construction project, or following a major deviation from the requirements, the regulatory body may impose 'hold points' or witness points on the licensee, such as excavation to rock head or formation level, first concrete, installation of major safety significant equipment, fuel on site or entering commissioning. Hold points should be specified by the regulatory body and communicated to the licensee as early as possible to allow them to be taken into account in planning and scheduling activities. Hold points should be carefully selected to:

- Enable observability or testability of the construction, especially before irreversible steps of safety significance are made;
- Check preparations of the construction organization to progress to the next stage.

If non-conformances are identified, the regulatory body may require the licensee to establish an action plan to correct deficiencies, in order to be permitted to progress beyond a hold point. The provision of timely information by the licensee to the regulatory body of all non-conformances is key to the timely addressing of such issues.

3.11 The regulatory body should put in place provisions to receive and address any matters raised by other parties concerning the safety of construction.

3.12 The regulatory body should require appropriate corrective actions to be carried out by the licensee to correct non-conformances and to prevent the recurrence of safety significant events.

3.13 The regulatory body should make arrangements for analysis to be carried out to identify lessons that may be learned from the experience gained by the regulatory body and by the licensee during construction. The regulatory body should establish arrangements to disseminate lessons learned within the regulatory body and to authorized parties and other relevant interested parties.

4. THE MANAGEMENT SYSTEM FOR THE CONSTRUCTION OF NUCLEAR INSTALLATIONS

4.1 The following recommendations provide a means of meeting the requirements of Ref. [1] for the construction of nuclear installations. They are supplementary to, and should be

read in conjunction with, the recommendations provided in Refs [2] and [3]. Since construction work has significant impact on the future safety of a nuclear installation, an integrated management system covering construction should be implemented to ensure that safety matters are not dealt with in isolation but are considered within the context of all construction activities.

SAFETY CULTURE

4.2 A strong safety culture is important for all stages of the lifetime of a nuclear installation. In the construction stage, a strong safety culture implies that the characteristics and attitudes that promote high quality construction to ensure safety in the future commissioning, operation and decommissioning stages. This involves an understanding by all individuals that deviations from procedures and specifications or a lack of appreciation of the safety significance of structures, systems and components may have unforeseen consequences in the future.

4.3 A construction project involves challenges such as planning and execution of work under time and budget pressures, managing the employment of temporary workers with various levels of skills, on some occasions from various cultures and with various languages, and of numerous contractors, and undertaking work influenced by weather conditions and the external environment. In addition, construction necessarily involves managing change and people on a continual basis. Such factors are known to be some of the main challenges to safety culture. Conflicts between schedule, cost and safety goals should not adversely affect conservative decision making and the upholding of an open and questioning attitude by all individuals.

4.4 Safety culture should be developed in all individuals in all participating organizations, with account taken of their roles in terms of safety significance. The construction project and the construction methods should be developed and implemented in such a way as to help all interested parties involved in the construction project to strengthen safety culture, particularly in organizations less familiar with nuclear safety requirements. A system should be established for the training of personnel who have transferred to projects for the construction of a nuclear installation from other industries, to make them aware of the additional issues associated with nuclear safety.

4.5 Safety culture and its promotion should be considered as part of the evaluation of contractors by the licensee. Evaluation should cover not only contractors' organizations but also their staff. The licensee should put in place adequate systems and procedures to monitor the safety culture in contractors' organizations and among their staff throughout the construction process.

4.6 The licensee should ensure that all contractors and subcontractors are fully aware of the safety significance of the work that they have been contracted to do. Such awareness of safety should be ensured for all tasks, including common construction work such as anchoring or cable sheathing, since contractors may not have experience of working for the nuclear industry. The licensee should encourage contractors 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 work that could affect the quality of the finished component or service.

4.7 The licensee should put in place a process that enables workers to report non-conformances and safety concerns to the contractor management, the construction organization or the licensee itself. A good safety culture would encourage open reporting, but some States have determined that it is good practice to enable anonymous reporting. All workers should also be aware of the process for reporting safety concerns directly to the regulatory body.

APPLICATION OF A GRADED APPROACH

4.8 A graded approach to the application of the safety requirements, based on the relative importance to safety of each item, service or process, should be taken during all construction activities. The graded approach should reflect a planned and recognized difference in the application of specific management system requirements, for example those on quality assurance.

4.9 In developing the graded approach, the following aspects should also be considered:

- (a) The qualification of special construction processes, such as welding or non-destructive testing, and the qualification of the personnel that will carry out these processes;
- (b) The need for and extent of plans for inspection and testing and the necessary level of detail;
- (c) The safety significance of equipment, materials, procedures, records and other documents;
- (d) The extent of in-process controls and the need for hold points;

- (e) The level of complexity of the activity;
- (f) Whether the activity is a first-of-a-kind activity;
- (g) The risks associated with the activity.

RESPONSIBILITIES OF THE LICENSEE

4.10 Reference [6] 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 applicable to the licensee for the construction of nuclear installations in general.

4.11 The licensee has responsibility for ensuring that the nuclear installation is built in accordance with all legal and regulatory requirements.⁴ The licensee may contract construction but it retains the prime responsibility for safety, quality and security.

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

4.13 During construction, the licensee should retain responsibility for all activities that could affect the safety of the installation, irrespective of the location where the activities are

⁴ Where multiple jurisdictions and requirements exist, requirements or standards may not be aligned in all cases. In such cases, all applicable legal and regulatory requirements have to be met.

carried out. This includes:

- The development and implementation of a management system covering construction activities to assure the required quality for safety of the installation (Refs [1][2][3]). The licensee should establish a plan for supervision of construction for the items important to safety that includes independent audits, surveillance of the quality of products, hold points and walk downs;
- The specification and retaining of its core capability to be an ‘intelligent customer’⁵ in its oversight and contracting processes;
- The taking and maintaining of ownership of the safety case, especially for the information provided by contractors, the design organization or the construction organization;
- Internal and external audits [2, 3] of the management system of contractors on the basis of a graded approach. The licensee should conduct surveillance to verify that the contractors’ activities are in compliance with all relevant safety requirements from both a technical perspective and the perspective of the management system;
- The establishment of a construction project with hold points in the construction processes, where approval may be required (possibly by the regulatory body) prior to proceeding to the next stage;

⁵ An ‘intelligent customer’ capability is the capability of the organization to have a clear understanding and knowledge of the product or service being supplied. The ‘intelligent consumer’ concept mainly relates to capability required of the organization when using contractors or expert support [30].

- Inspections, tests and verification of items important to safety. The regulatory body verifies such inspections, tests and verifications but this does not remove the licensee's responsibility for performing them;
- A process for dealing with design changes, non-compliances and events;
- The reporting of safety significant design changes, non-compliances and events, as required by the regulatory body;
- Ensuring that appropriate records relevant to safety are established and preserved, in particular appropriate records that are relevant to each stage in the lifetime of the installation and to ageing management;
- The preparation for the commissioning programme, with account taken of tests performed during construction;
- The transfer of documentation when moving from construction to commissioning.

Construction manager

4.14 The licensee should formally appoint an individual from its own organization as the construction manager to be responsible for construction activities. The construction manager has the responsibility of ensuring that the construction meets all relevant safety requirements.

4.15 The construction manager should have access to the necessary resources to establish a construction organization that may include contracted staff or even comprise a fully contracted organization (see Fig. 1). If the construction organization is a fully contracted organization, its roles and responsibilities and those of the licensee should be defined and

documented and should be subject to agreement by the licensee's construction manager. The management structure of the construction organization should specify the levels of responsibility of groups within it, including the responsibilities of all of its contractors.

ACTIVITIES OF THE CONSTRUCTION ORGANIZATION

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

- (a) Controlling and monitoring of contractors involved in safety significant issues both on the site and off the site, including in activities involving manufacturing and assembly;
- (b) Ensuring that the construction organization and 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 nuclear safety and industrial safety requirements;
- (c) The identification of generic construction activities, and the development and maintaining of guides on the use of standardized instructions and procedures and on good practices;
- (d) The preparation of safety related working procedures, including industrial, environmental and safety procedures, for issue to the personnel of the construction organization and contractors, and the verification that the industrial safety arrangements of the construction organization and contractors on the construction site comply with the applicable requirements;

- (e) The monitoring of nuclear safety and industrial safety policies and of the activities of all personnel, to ensure compliance with statutory and regulatory requirements with regard to quality and safety;
- (f) The planning and monitoring of the progression of work to fulfill the construction project and meet the schedule, including, where appropriate, coordination of the activities of contractors responsible for constructing structures, systems and components that interface with other installations on the site;
- (g) Ensuring work carried out by themselves or by its contractors is in accordance with procedures, specifications and drawings, that safety and quality requirements are specified and implemented and that inspections and tests, including those conducted at the facilities of suppliers, are appropriate and in accordance with inspection and test plans and associated surveillance schedules;
- (h) Ensuring preservation of installed equipment, by carrying out maintenance of the equipment as required, ensuring proper care of equipment that could deteriorate during construction, such as equipment for dehumidification of electrical equipment and preservation of critical surfaces that could rust, and the performance of adequate housekeeping activities to protect open equipment against intrusion of foreign materials and contaminants;
- (i) The conduct of inspections of structures, systems and components to obtain relevant baseline data for comparative purposes during in-service inspection;

- (j) Arrangement of the controlled handover of work and records from one group to another;
- (k) The acquisition, installation or maintaining of material samples for a long term monitoring and analysis programme of ageing material;
- (l) Ensuring that adequate documentation is produced to demonstrate such aspects as due diligence, compliance with regulations, non-conformance report filing and corrective actions through auditing of procedures and surveillance of construction activities.

PROJECT MANAGEMENT

4.17 The following recommendations are provided in addition to those provided in paras 5.43-5.60 of the Safety Guide “The Management System for Nuclear Installation” Ref. [3] and in the Technical Report “Project Management in Nuclear Power Plant Construction Guidelines and Experience” in Ref. [31]

Construction management

4.18 Construction management is a leadership function primarily concerned with the organization of processes, the co-ordination of activities and the control of resources (human, informational and material resources) on a large scale and under many external constraints, in order to build correctly an approved design.

4.19 The construction organization should put in place contingency plans for critical on-site construction activities, including measures to cope with electric power outages, loss of water supply, disruption of concrete batching or pumping and any other interruptions that may

cause unexpected deterioration in the quality of work.

4.20 Construction management processes as well as construction work processes should be defined and documented. They should take due account of safety, security and environmental impact.

4.21 The licensee, the construction organization and other contractors should have adequate organization, resources, experience, competence and procedures to manage the construction of a nuclear installation and should maintain documentation to demonstrate these. Experience has shown that construction projects can involve the use of temporary workers with various skills, multiple –layers of contractors and subcontractors, from various States, with various languages, cultures and legal and regulatory backgrounds, and different conventions for measurements (e.g. units, measurement methodologies, measurement equipment or devices). Such types of difference should be taken into account in developing the project management system and in selecting project managers.

Management to ensure compliance with all requirements⁶

4.22 A system should be established to ensure that applicable inputs, such as legal and regulatory requirements and requirements of the licensee for ensuring safety and quality, are correctly translated into specifications, drawings, procedures and instructions. The application of the technical design requirements in separate project disciplines should be reviewed for its

⁶ The word ‘requirements’ refers to the requirements not only from applicable laws and regulations, or derived from the IAEA Safety Fundamentals and Safety Requirements, but also from contractual agreements, applicable codes and standards, and any other source to which the licensee must conform.

coherence by competent personnel before the start of construction. The requirements and any changes thereto should be controlled, so that safety related activities and items important to safety are consistent with the applicable requirements.

4.23 Compliance with all relevant safety requirements, including establishment of a strong safety culture and quality management, should be ensured for all relevant parties, including contractors, from the time of awarding of contracts to completion of the work. Ref. [2] provides recommendations on procurement requirements.

4.24 The regulatory body and the licensee in the State in which components will be used may each impose specific requirements that differ from the specification that would be normal for the State in which the component is manufactured or assembled. The licensee should ensure that the relevant requirements are known, understood and accepted by all parties that make up the supply chain. Any conflict or difference of opinion should be resolved during planning stage.

4.25 The licensee should ensure that all information supplied by the design organization is sufficiently clear and explicit to convey all the relevant requirements to the contractors selected for the construction and, where appropriate, for the testing and commissioning of items important to safety. Excessive reliance should not be placed on mere quoting of codes and standards. Additional supervision should be provided in cases where the supply of components for subcontracted equipment is further subcontracted down the supply chain, to ensure competence and compliance with the original requirements.

CONTROL OF DESIGN INFORMATION

4.26 Reference [5] states:

“The operating organization⁷ shall establish a formal system for ensuring the continuing safety of the plant design throughout the lifetime of the nuclear power plant” (Requirement 3).

“The formal system for ensuring the continuing safety of the plant design shall include a formally designated entity responsible for the safety of the plant design within the operating organization’s management system” (para. 3.5).

4.27 Reference [6] 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. 6.15).

4.28 Furthermore, Ref. [8] states in paras 7.6 and 7.7 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

⁷ In practice, for an authorized facility, the operating organization” is normally also the licensee [17].

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.”

4.29 Arrangements for communication should be established between the design organization(s)⁸ and the construction organization, and between the construction organization, its contractor(s) and the licensee where appropriate to deal with queries concerning the design.

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

4.31 A process should be established to address proposals from the contractor(s) for changes to the design. If a proposal has an implication for safety during commissioning, operation or decommissioning, the design organization(s), licensee and regulatory body, as appropriate, should be involved in its resolution.

4.32 Comprehensive photographic records and, where appropriate, video records and computer simulations should be compiled, particularly for areas that will later be inaccessible or will be subject to high levels of radiation. Such information will facilitate the planning of

⁸There may be a supply chain for the design in parallel to the construction supply chain.

work in these areas during commissioning, operation and decommissioning. Such visual records of as-built conditions made during construction should show identification marks and should be comprehensively catalogued with descriptive captions. This will ensure that visual records made during subsequent inspections or maintenance work can be easily compared, and will help in any preparation for work.

Traceability

4.33 The traceability of items important to safety from their initial design through to construction and then to commissioning and to later stages in the lifetime of the installation is necessary for ensuring safety. The licensee should ensure that processes are put in place to ensure traceability and should collect and store such records as required by itself and by the regulatory body. The records to be collected and stored to ensure traceability include the following:

- (a) As-built drawings;
- (b) Manufacturing and assembly details;
- (c) Inspection reports;
- (d) On-site traceability records including marking and tagging;
- (e) Construction and test records (to be used as baseline data);
- (f) Design calculations;
- (g) Documentation of design changes and non-conformances;

(h) Details of equipment qualification.

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

4.34 The requirements for traceability for items important to safety should extend through all equipment, materials, procedures, records and other documents, to ensure that items important to safety are constructed to the appropriate quality level for their safety classification.

MANAGEMENT OF INTERFACES

4.35 Interface arrangements should be identified and should be agreed between the licensee, the construction organization (if this is not part of the licensee), the design organization, contractors and other organizational units performing the work. The interface arrangements should be specified in documentation of the management system and should be included in procurement documents as appropriate.

4.36 The construction organization should establish and implement a suitable communications plan to link on-site and off-site construction activities in an adequate and timely manner. This communications plan should also include the design organization and the licensee as appropriate.

4.37 The construction organization should define processes for identifying and resolving conflicts and misunderstandings between contractors, such as conflicts concerning construction schedules, activities, tools or work spaces.

TRANSFER OF RESPONSIBILITY

Transfer of responsibility during construction

4.38 Appropriate rules and procedures should be established and documented by the construction organization to control and coordinate the handover of completed works from one contractor to another in order to maintain the integrity of the completed works. Rules and procedures for access control for items important to safety and working areas should also be documented and should be implemented for the transfer. Such rules and procedures should be made subject to approval by the licensee for use in the construction project.

4.39 When items important to safety and working areas are to be transferred between groups within the construction organization or contractors, both parties concerned should conduct a joint check of the transferred items and the associated documents together at the location of the transfer. Configuration of the items and working areas should be agreed to by both parties, along with any deficiencies that have been identified.

4.40 After transfer, any remaining work or corrective actions by the previous party should be carried out only with appropriate authorization by the new party.

Transfer to commissioning

4.41 The licensee should ensure that provisions are established and implemented to control and coordinate the handover from construction to commissioning. Such provisions include the following:

- (a) Documentation relating to the items to be transferred should be reviewed by the construction organization and the receiving party for completeness and accuracy.

- (b) Tests to ensure that the structures, systems and components have been constructed, manufactured and installed in accordance with design specifications should be carried out and the results should be recorded.
- (c) Any remaining non-conformances or incomplete items should be identified and assessed to ensure that there will be no safety implications during commissioning activities.
- (d) Any outstanding work should be agreed, planned and scheduled.
- (e) Termination points, which identify the boundaries of transferred systems and equipment, or transferred parts of systems and equipment, should be clearly identified in transfer documentation, together with the associated required configuration (for example, open/close of valves).
- (f) An inspection of transferred items and associated records and documents should be conducted.
- (g) The transfer of responsibilities should be recorded.
- (h) Approved as-built plans should be transferred together with adequate and precise configuration details for the installation.
- (i) All structures, system and components transferred should be marked or tagged in accordance with the documentation.
- (j) All temporary devices should be identified.

4.42 In order to enable adequate maintenance and ageing management once the

installation is in operation:

- (a) The level of technical detail in the transfer documentation should be sufficient to allow the licensee to identify parts and order replacements for maintenance.
- (b) The licensee should be provided with a copy of all other relevant information, in addition to the transfer documentation.

RESOURCES FOR CONSTRUCTION

Provision of resources for construction

4.43 The licensee and the construction organization should ensure that sufficient suitably qualified and experienced workers are available as required for the construction project. Processes should be put in place to ensure initial qualification and continuous qualification of workers.

4.44 Resources should be estimated, planned and secured for the construction of items important to safety consistent with the project schedule, particularly for items that have a long lead time.

Training of the licensee's personnel

4.45 Licensee personnel who will be involved in the commissioning, operation and maintenance of the nuclear installation should be involved, as far as practicable, during the construction, so that they undergo hands-on training to gain additional expertise in operation, maintenance and technical support.

CONTROL AND SUPERVISION OF CONTRACTORS

Evaluation and selection of contractors

4.46 The licensee should be notified of the proposed contractors for the supply or manufacture of items important to safety, or for the provision of safety significant services. Depending on the agreement between the licensee and the construction organization, the licensee's approval may be necessary.

4.47 A graded approach should be applied to the development of criteria for the evaluation and selection of contractors and suppliers providing materials, products and services.

Oversight of contractors

4.48 Where contracted services are an integral part of construction, there are specific challenges to the oversight of contractors to ensure safety during all stages in the lifetime of the installation (see para. 4.3). The use of contracted services tends to be greater in the following situations: an insufficient availability of nuclear expertise within the licensee; a supply chain that extends to other States; first-of-a-kind projects; and turn-key projects. These situations create challenges relating to: the retention of expertise; the effective management of the interfaces between the licensee, the construction organization and its contractors; and the oversight of the quality of manufacturing by contractors in the context of greater multinational diversity and supply chains that extend to other States.

4.49 The extent of oversight of the contractor's activities by the licensee and/or the construction organization should be based on a graded approach. The extent of oversight will depend on the following:

- The 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 complexity of the work or service;
- The expertise needed to carry out the work or service;
- The extent of evidence available that the appropriate quality has been achieved;
- The use of independent third party inspections;
- Legal and regulatory requirements.

The licensee should be notified of the results of the oversight performed by the construction organization on safety related matters and, if necessary, should be able to present the results to other interested parties.

4.50 Before initiating any activity following the award of a subcontract, the contractor should demonstrate to the construction organization, and to the licensee if required by the licensee, that the contractor is fully aware of all relevant requirements for the activities. The safety requirements specific to the subcontract should be identified, which should cover the following:

- (a) Applicable safety requirements for the item to be manufactured or built;
- (b) Interface arrangements;
- (c) Arrangements for communication;

- (d) Documents and information to be submitted, including non-conformance reports and evidence that the as-built items meet the safety and quality requirements;
- (e) The management system, including adequate safety culture and oversight and arrangements for supervision.

In addition, if the contractor(s) is working on the site, additional requirements should be identified, which should cover the following:

- (f) Housekeeping;
- (g) Security of the site;
- (h) On-site training.

The arrangements that the subcontractor will make to satisfy these requirements should be finalized and agreed before the subcontractor starts the activity. The licensee should be notified of these arrangements, for its approval, as appropriate (particularly if the construction organization is not part of the licensee). An initial 'kick-off' meeting with the attendance of all parties, including the licensee, should be held to verify all these issues.

4.51 The construction organization should be informed of all the subcontractors selected by the contractor. Any new subcontractors appointed after the initial agreement is made should be made known to the construction organization and should be agreed before relevant work begins.

4.52 The construction organization should organize regular meetings with contractors and subcontractors to review and ensure implementation of the requirements of the construction

organization.

4.53 Each contractor should conduct regular pre-job meetings to discuss work processes, the schedule, deviations and any other important aspects of work relevant to safety and quality.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

Assessment of management system

4.54 Project management processes and their performance should be assessed periodically by the licensee or, where appropriate, by the construction organization. An assessment of progress should also be done to provide early diagnosis of problems in performance, planning or provision of resources. Techniques that should be considered to avoid compromising the quality of the work include the application of early remedies, adjustment of human resources, revision of the schedule and renegotiation of contracts.

4.55 Independent assessment programmes should be established and implemented to address issues of competence in project management [2].

Non-conformance and corrective actions

4.56 A system should be established by the licensee for collecting all identified non-conformances, and recording and processing them accordingly. All individuals engaged in construction should be made aware by the licensee that they are expected to identify and report non-conformances. The system should define what a non-conformance is and specify the roles and responsibilities of the licensee, the construction organization and contractors in reporting non-conformances and correcting them. The system should cover the investigation

of any non-conformances identified, and should establish why they arose with the aim of preventing recurrences.

4.57 Non-conformances of safety significance should be treated as events by the licensee, and should be resolved by means of a corrective and preventative action programme in a graded manner. The process of determining the safety significance of the non-conformance and the necessary corrective and preventative actions should involve appropriate experts, including the design organization, if necessary. Care should be taken to ensure that the aggregation of a number of more minor non-conformances does not lead to unforeseen consequential safety significant changes. A process should be put in place for obtaining, as required, regulatory approval of safety significant corrective and preventative actions.

4.58 The licensee should maintain records of the corrective and preventative actions taken to resolve non-conformances. The effectiveness of the process for resolving non-conformances should be monitored.

4.59 Owing to the challenging nature of construction projects (which can involve tight schedules, new technology or limited availability of resources), extended time scales may be required to correct non-conformances and non-conformances may remain as pending issues even after the handover of responsibilities from one party to another. The implementation of preventive actions should not be delayed unnecessarily if corrective actions require an extended time period. Any pending issues relating to non-conformances and corrective actions should be tracked to completion by the licensee. Records should be maintained and relevant parties should be informed.

Feedback on experience from construction

4.60 Experience in construction and examples of good practices, not only from the nuclear installation at hand but also from the construction of other nuclear and non-nuclear installations, should be collected by the licensee and any lessons that are learned should be disseminated for the enhancement of quality and safety within the industry. Criteria should be established for reporting of construction related experience and measures should be put in place to ensure the dissemination of such information to relevant parties in the nuclear industry as a whole. Mechanisms should be put in place to enable the sharing of construction experience in a systematic and timely manner.

4.61 The licensee should be pro-active in sharing safety relevant experiences to relevant parties in the State and at an international level.

5. MANAGEMENT OF CONSTRUCTION ACTIVITIES

GENERAL CONSIDERATIONS

Planning, scheduling and the sequencing of work

5.1 Construction activities should be planned. The plan should specify, for instance:

- The activities to be performed, in manageable units. Complex activities, such as verification and validation for digital instrumentation and control systems and environmental and seismic qualification of items important to safety, should be planned carefully;
- The planned sequential order (taking into account pre-requisites) and the 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 should be communicated to relevant parties. The construction project should be fully integrated with a procurement programme in which emphasis is placed on items with a long lead time. In the case where the procurement of items with a long lead time starts before the construction licence is issued, and possibly the construction organization is not yet in place, the licensee should ensure that procured items important to safety achieve the design specification and the required level of safety. The regulatory body should be provided with regular and timely updates of the construction schedule.

5.3 The planning, scheduling and sequencing of work should include hold points as necessary. These may be specified by the licensee and/or the regulatory body.

5.4 The planning, scheduling and sequencing of work should include requirements for off-site manufacturing and assembly under an adequate management system including a quality assurance programme. All contractors should have in place a quality assurance programme, which should be consistent with that of the licensee.

5.5 Specifications, documents, drawings, plans and schedules should identify which manufacturing, assembly, installation, inspection and testing activities should be performed on the site and the provisions to be made to carry them out adequately.

5.6 The construction organization should ensure that on-site manufacturing and assembly of items important to safety are capable of producing an acceptable product that meets safety and design requirements and also applicable codes and standards.

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

5.8 The design organization should ensure that the design can be constructed using established processes (see Requirement 11 of Ref. [5]). The construction organization should verify the adequacy of construction methods with reference to the design organization where necessary. Early involvement of contractors can influence design options at the appropriate stage by enabling the construction methods of constructors to be taken into account. There should be regular meetings at which the contractor's construction methods are discussed with the design team, as there is a potential for the contractor's construction methods to undermine design assumptions. Assessment of the risks associated with construction and the reduction of such risks by suitable choices in design is a statutory requirement in some States.

5.9 The sequencing of construction activities should ensure that prior construction work (such as items embedded in walls or in the ground) will not be adversely affected by later construction works. Special consideration should be given to the form of cast-in items and installation fixings, as the post-drilling of concrete for the installation of fixings may be unacceptable and may undermine safety; this should be done only in exceptional cases and after due consideration.

Procurement specifications

5.10 Procurement specifications should be developed with sufficient lead time to ensure that items important to safety will be provided in such a way that the achievement of the design specifications and required level of safety can be assured. More information on the

preparation of procurement requirements is provided in Ref. [2].

5.11 The procurement specifications relevant to items important to safety should emphasize the safety requirements relevant to the technical characteristics of the items, safety culture and quality management.

5.12 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), where these have not been specified by the design organization. If the supplier determines codes and standards, this should be made subject to formal agreement of the design organization or the licensee. Any change in the safety classification should be notified to the supplier and the impact on equipment that has already been manufactured should be assessed.

5.13 Procurement documents for items important to safety should specify the requirement for an 'end of manufacturing report' (or an 'end of assembly report' if appropriate). This should include:

- A compliance certificate;
- Inspection and test results;
- Non-conformance reports;
- Procurement records;
- Instructions for storage, installation, testing and preservation;
- Operation and maintenance manuals;
- Operational limits and conditions;
- Training requirements for personnel;

- As-built drawings;
- A bill of materials with a list of raw materials, sub-components, components and parts and the quantities of each.

5.14 Particular consideration should be given to the procurement of commercial grade components or products that are proposed for any safety function. The suitability of commercial grade products or components should be verified as described in paras 5.35 – 5.37 of Ref. [3].

MANUFACTURING AND ASSEMBLY

5.15 The licensee's management system, covering the quality assurance programme for manufacturing and assembly activities, should provide for the review of procurement documents for the item to be manufactured or assembled, in order to determine which regulations, codes, standards and other requirements are applicable during manufacturing and assembly. The regulatory requirements, design requirements and other requirements set out in procurement documents should be met, as appropriate, in manufacturing drawings, specifications, inspection and test plans, procedures and work instructions.

5.16 During the planning phase for manufacturing and assembly, consideration should be given to such factors as:

- (a) Understanding the manufacturing implications of the design;
- (b) The procurement of items on construction critical path and items with a long lead time;

- (c) Clean conditions and other environmental controls to meet requirements and to achieve the required quality. Such conditions and controls may include dust-free or inert atmospheres, humidity controls, temperature controls and control of the chemical composition of water;
- (d) The location of assembly of the equipment;
- (e) Handling, storing, packaging and delivery requirements;
- (f) The application of new techniques in manufacturing, assembly, inspection and testing;
- (g) Equipment qualification tests and associated tests;
- (h) The need for inspections and tests specified by the design organization and the regulatory body, and those deemed necessary by the manufacturer to control quality and to ensure the process has been followed;
- (i) The need to develop, qualify and control any new manufacturing or assembly processes;
- (j) Processes that are complex or sensitive, or which require extensive set-up, special equipment or special training;
- (k) Compatibility of cleaning methods and materials with the items to be cleaned.

5.17 The licensee should ensure that each manufacturer's management system includes the identification and control of processes where the results cannot be fully verified by subsequent inspection and testing and processing non-conformances may become apparent only after the item is in use or in operation.

5.18 Special equipment, such as tooling, jigs, fixtures, unique inspection gauges, computers and computer software used in the manufacturing or assembly process should be properly qualified or validated. Personnel using the equipment should be trained and should be aware of any limitations in its use.

5.19 The licensee and the construction organization should establish and implement requirements and procedures for the verification of the quality of manufacturing and/or assembly (including the quality of materials and procedures) of items important to safety.

5.20 The technological expertise of the contractors should be verified by the licensee and/or the construction organization, before the procurement requirements are specified. Augmented monitoring and inspections, if necessary, should be employed to verify that new manufacturing techniques and new types of equipment meet relevant design requirements.

5.21 All items important to safety should be inspected and tested by the manufacturer in accordance with the requirements established in the procurement specifications. The traceability of individual items important for safety or the identification of batches of such items, as appropriate, should be highlighted in the inspection and test plan.

5.22 If appropriate, before components are transported to the site, they should be pre-assembled and match-marked, to ensure their proper re-assembly at the site.

Prerequisites for construction works

5.23 If the final design is not available at the start of construction work, the action plan developed by the design organization (see para. 2.10) should ensure that the outstanding design documentation is completed with sufficient time in advance to ensure the quality of

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

5.24 Contractors should obtain the approval of the licensee and/or the construction organization before beginning work. Contractors should ensure they have relevant, up to date information, including the work schedule, instructions with drawings and compatible consumables prior to performing each construction activity.

Work and environmental conditions

5.25 The construction work and the environmental conditions should be monitored by the construction organization, to ensure that safety significant mechanical, electrical, instrumentation and control equipment, and structures are protected from internal and external damage or contamination by dirt, dust and foreign material.

5.26 The licensee should specify the allowable environmental conditions, such as temperature, pressure, humidity, rain, snow, dust, dirt, airborne salt, wind and electromagnetic conditions, for construction work including for manufacturing, assembly and transport. The construction organization should periodically monitor the environmental conditions to confirm that they are within allowable limits. Such limits should be developed only for conditions applicable to the specific work location and the specific construction activity.

Cleanliness and foreign material control

5.27 When procuring items for installation, it should be ensured by the licensee or the construction organization that requirements for cleanliness are included in the procurement documentation, so that the items arrive on the site with an acceptable standard of cleanliness.

5.28 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. Such measures include the following:

- (a) Methods and techniques for control of the site area, individual structures and systems, the facilities on the site, and the material and equipment being incorporated into the installation;
- (b) Methods for the control of environmental conditions;
- (c) Control of personnel access. 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;
- (e) Contingency plans, if the protection measures and controls fail.

5.29 Specific procedures and cleaning methods should be implemented for systems such as hydraulics, instrument control and lubrication lines and systems where interior surfaces are generally not accessible for visual inspection.

5.30 Specific procedures should be developed and implemented for cleaning by flushing or rinsing. Such procedures should include:

- Checking of the actual flow paths, in order to satisfy specified requirements with regard to the location, position and status of all components;
- Tagging and locking as appropriate of critical components to prevent inadvertent actuation;

- Inspection of the interior of all accessible components and piping for cleanness;
- Isolation or protection of components such as demineralizers, filters, instruments and any other components that may be damaged by cleaning;
- Sealing of the openings of the cleaned system(s);
- Checking the installation and subsequent removal of temporary devices (for example, temporary caps in piping).

Receipt, handling, transport, storage, preservation and maintenance

Control of items and consumables

5.31 Items and consumables should be controlled through the proper packaging, shipping, handling, receipt and storage at any location, including at off-site manufacturing facilities, to prevent their abuse, misuse, damage, deterioration or loss of identification. Items and consumables that could represent a security concern if misused should be controlled in accordance with the level of risk.

Handling

5.32 The use of equipment 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 items important to safety. Operators and handlers of all such equipment should be competent in carrying out their tasks. Equipment for handling items should be used and maintained in accordance with national regulations and standards. Handling devices should be included in the scope of the supervision performed by the construction organization to ensure the safety of the items handled.

Transport

5.33 All transport routes both off the site and on the site should be planned with appropriate protection measures for items important to safety. For the transport of large or heavy components, all aspects of the route should be appropriately assessed to ensure that transport is possible without causing hazards, damage or injury to people, the items themselves or anything else along the route.

Storage

5.34 Suitable storage should be provided as specified by the design organization and the manufacturer to protect items important to safety prior to their installation and use.

5.35 Storage areas should be established 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) The physical and chemical characteristics of the items to be stored;
- (i) Radiation protection and appropriate markings on any sources of radiation.

5.36 Inspections should be performed by the construction organization, as necessary, to ensure that the specified conditions are maintained and that any non-conformances are appropriately dealt with. Such inspections may need to be continued into the commissioning and operation stages, in which case suitable handover arrangements should be established (see para. 4.59).

5.37 Items important to safety and their components should be clearly identified by using appropriate marks. The marking materials used should be compatible with the item, to ensure material preservation. The construction organization should implement on-site physical protection against the unauthorized removal of items important to safety in use and storage [11].

5.38 Before the installation of any items important to safety, the construction organization or the contractor should inspect them against the specified requirements and if necessary should take remedial action.

Preservation of installed items

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

5.40 The contractor or the construction organization should ensure that the use of temporary structures does not adversely affect items important to safety.

5.41 During on-site or off-site tests, other items important to safety should be isolated or protected to avoid inadvertent effects.

Maintenance

5.42 During the entire construction stage, the licensee and/or the construction organization should ensure that items important for safety are made subject to an appropriate preventive or corrective maintenance plan to maintain their functionality as required by the design. This plan should be continued into commissioning until maintenance programmes for operation are initiated.

Verification and testing of construction activities

5.43 The licensee and the construction organization should develop and agree a process to verify the completion of construction activities and the transfer of completed work. The test plan and the acceptance criteria should be documented by the construction organization such that they can be independently assessed. The results of the tests (their coverage, content, results and timing) should be compared with the specified acceptance criteria. Testing and verification should be performed by a qualified independent party for items important to safety. This verification should be formally documented to confirm that the items important to safety have been constructed to the specified requirements and that they comply with the acceptance criteria, including those detailed in the licensing documentation.

5.44 A typical verification record should include the following:

- (a) Identification of the structure, system or component;
- (b) A description of how the results were verified;

- (c) The date and time of verification;
- (d) The name and organization of the verifier;
- (e) Any special tools or calibrated equipment used;
- (f) The test results and a comparison with acceptance criteria;
- (g) A list of remaining deficiencies and the plan for their resolution;
- (h) A list of outstanding items of work and the action plan for completing this work;
- (i) Confirmation that specified documentation and records are available and complete;

5.45 Any use of radioactive sealed sources and radiation devices during activities such as radiographic examinations, gauging (density, thickness, moisture, etc.) or material analysis should meet the requirements for protection of workers, as established in Ref. [32].

ON-SITE CONSTRUCTION PROCESSES

Receipt

5.46 As items are received at the construction site, an initial check should be carried out to ensure that the items are as ordered and have suffered no obvious damage during transport.

5.47 After the 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 of the items in construction. Such inspections should include checks for the following:

- (a) The item is configured correctly;

- (b) The identification of the item and the markings on the item are adequate;
- (c) Manufacturing and assembly documentation is available as required;
- (d) The inspection record and/or certificate is 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) Cleanness of the item meets applicable codes and standards and design requirements;
- (i) Inert gas blankets and the condition of desiccants, where relevant, have not been compromised;
- (j) Non-conformances identified by inspections on receipt or detected during manufacturing but to be corrected on the site are recorded;
- (k) Necessary tests of hardware characteristics have been performed;
- (l) Storage has been controlled to prevent inadvertent installation or use of the item.

Effect on and from existing operating nuclear installations

5.48 A construction site may already have operating nuclear installations on the site,

which may share safety systems 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. An assessment of safety and security during construction should be performed by the appropriate licensee(s) and should take into account all hazards from, or to, nearby facilities on the site and any interdependence of their safety systems. For instance, the consequences of potential contamination by dust, dirt and foreign materials from a construction site on operating nuclear installations as well as from an operating nuclear installation to the construction site should be assessed and such contamination by dust, dirt and foreign materials should be monitored, if necessary. Potential impact of radioactive contamination from existing operating nuclear installations to the construction site should be assessed and monitored as well. All other risks should also be assessed (for example, from digging, excavation, accidental fall of cranes, collapse of items, and use of explosives). Such consideration should also include an assessment of the impact of cumulative discharges to the environment from all facilities on a site.

5.49 The responsibilities of the relevant licensee(s) and the construction organization for safety and nuclear security should be agreed before the start of construction activities at the site. Close communication and cooperation between the parties should be established. All steps should be taken to ensure that existing operating nuclear installations can be operated safely and securely during construction activities.

5.50 For the construction of a nuclear installation adjacent to an existing operating nuclear installation or for which sharing of common buildings or services is envisaged, the following boundaries should be identified: radiation protection boundaries, physical boundaries, system

boundaries, security boundaries, access boundaries and boundaries to clean zones. In utilizing the services of an existing operating nuclear installation, such as water, electric power, compressed air, fire protection, emergency medical services and security, clear interfaces should be defined and understood by the construction organization so as not to jeopardize the safety of the existing operating nuclear installations. Emergency plans should be adapted if necessary to take full account of the presence of other parties in the area. Procedures should be put in place to ensure that the licensee(s) of an existing operating nuclear installation(s) endorse(s) a proposed change of status for those common buildings or services before implementation of the change by the construction organization.

On-site manufacturing and assembly

5.51 Temporary devices and equipment used during manufacturing, installation, inspection and testing should be controlled and documented.

5.52 Waste materials and remaining consumables used or generated on the site during construction work should be removed and disposed in an appropriate way by the contractors after the work is complete.

REFERENCES

- [1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006).
- [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).
- [3] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2009).
- [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Modifications to Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.3, IAEA, Vienna (2001).
- [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012).
- [6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Commissioning and Operation, IAEA Safety Standards Series No. SSR-2/2, IAEA, Vienna (2011).
- [7] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Research Reactors, IAEA Safety Standards Series No. NS-R-4, IAEA, Vienna (2005).
- [8] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. NS-R-5, IAEA, Vienna (2008).

- [9] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).
- [10] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards Series No. GSR Part 1, IAEA, Vienna (2010).
- [11] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).
- [12] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Culture, IAEA Nuclear Security Series No. 7, IAEA, Vienna (2008).
- [13] INTERNATIONAL ATOMIC ENERGY AGENCY, Preventive and Protective Measures against Insider Threats, IAEA Nuclear Security Series No. 8, IAEA, Vienna (2008).
- [14] INTERNATIONAL ATOMIC ENERGY AGENCY, Development, Use and Maintenance of the Design Basis Threat, IAEA Nuclear Security Series No. 10, IAEA, Vienna (2008).
- [15] INTERNATIONAL ATOMIC ENERGY AGENCY, Computer Security at Nuclear Facilities, IAEA Nuclear Security Series No. 17, IAEA, Vienna (2011).
- [16] INTERNATIONAL ATOMIC ENERGY AGENCY, Engineering Safety Aspect of the Protection of Nuclear Power Plants against Sabotage, IAEA Nuclear Security Series No. 4, IAEA, Vienna (2007).

- [17] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary, Terminology Used in Nuclear Safety and Radiation Protection, 2007 Edition, IAEA, Vienna (2007).
- [18] INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.9, IAEA, Vienna (2003).
- [19] INTERNATIONAL ATOMIC ENERGY AGENCY, Licensing Process for Nuclear Installations, IAEA Safety Standards Series No. SSG-12, IAEA, Vienna (2011).
- [20] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles: Safety Fundamentals, IAEA Safety Standards Series No. SF-1, Vienna (2006).
- [21] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).

- [22] INTERNATIONAL ATOMIC ENERGY AGENCY, Format and Content of the Safety Analysis Report for Nuclear Power Plants, IAEA Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004).
- [23] INTERNATIONAL ATOMIC ENERGY AGENCY, External Human Induced Events in Site Evaluation for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-3.1, IAEA, Vienna (2002).
- [24] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Delayed Nuclear Power Plant Projects, IAEA TECDOC-1110, IAEA, Vienna (1999).
- [25] INTERNATIONAL ATOMIC ENERGY AGENCY, Restarting Delayed Nuclear Power Plant Projects, IAEA Nuclear Energy Series No. NP-T-3.4, IAEA, Vienna (2008).
- [26] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization and Staffing of the Regulatory Body for Nuclear Facilities, IAEA Safety Standards Series No. GS-G-1.1, IAEA, Vienna (2002).
- [27] INTERNATIONAL ATOMIC ENERGY AGENCY, Review and Assessment of Nuclear Facilities by the Regulatory Body, IAEA Safety Standards Series No. GS-G-1.2, IAEA, Vienna (2002).
- [28] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body, IAEA Safety Standards Series No. GS-G-1.3, IAEA, Vienna (2002).
- [29] INTERNATIONAL ATOMIC ENERGY AGENCY, Documentation for Use in Regulating Nuclear Facilities, IAEA Safety Standards Series No. GS-G-1.4, IAEA, Vienna (2002).

- [30] INTERNATIONAL ATOMIC ENERGY AGENCY, Use of External Experts by the Regulatory Body, IAEA Safety Standards Series No. GSG-4, IAEA, Vienna (2013).
- [31] INTERNATIONAL ATOMIC ENERGY AGENCY Project Management in Nuclear Power Plant Construction: Guidelines and Experience IAEA Nuclear Energy Series No. NP-T-2.7, IAEA, Vienna (2012).
- [32] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards – Interim Edition, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2011).

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