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Operating Performance

Conduct of Licensed Activities: Construction and Commissioning Programs

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Conduct of Licensed Activities: Construction and Commissioning Programs
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Preface

This regulatory document is part of the CNSC's Operating Performance series of regulatory documents, which also covers accident management and periodic safety reviews. The full list of regulatory document series is included at the end of this document and can be found on the CNSC's website.

REGDOC-2.3.1, *Conduct of Licensed Activities: Construction and Commissioning Programs*, sets out requirements and guidance for the construction and commissioning of facilities in Canada that use nuclear reactors. These facilities (referred to as "reactor facilities" in this document) include:

- nuclear power plants (NPPs) or small reactors for the generation of power or heat for industrial process
- small reactors for non-power-generation uses (e.g., isotope production, and research and development activities)

The requirements and guidance in this document apply primarily to NPPs. However, the principles behind the requirements and guidance are equally applicable to smaller facilities in a risk-informed (graded) manner, and should be considered in the overall safety case for any reactor facility.

This document is intended to form part of the licensing basis for a regulated facility or activity. It is intended for inclusion in licences as either part of the conditions and safety and control measures in a licence, or as part of the safety and control measures to be described in a licence application and the documents needed to support that application.

For proposed new facilities: This document will be used to assess new licence applications for reactor facilities.

Guidance contained in this document exists to inform the applicant, to elaborate further on requirements or to provide direction to licensees and applicants on how to meet requirements. It also provides more information about how CNSC staff evaluate specific problems or data during their review of licence applications. Licensees are expected to review and consider guidance; should they choose not to follow it, they should explain how their chosen alternate approach meets regulatory requirements.

For existing facilities: The requirements contained in this document do not apply unless they have been included, in whole or in part, in the licence or licensing basis.

A graded approach, commensurate with risk, may be defined and used when applying the requirements and guidance contained in this regulatory document. The use of a graded approach is not a relaxation of requirements. With a graded approach, the application of requirements is commensurate with the risks and particular characteristics of the facility or activity.

An applicant or licensee may put forward a case to demonstrate that the intent of a requirement is addressed by other means and demonstrated with supportable evidence.

Important note: Where referenced in a licence either directly or indirectly (such as through licensee-referenced documents), this document is part of the licensing basis for a regulated facility or activity.

The licensing basis sets the boundary conditions for acceptable performance at a regulated facility or activity, and establishes the basis for the CNSC's compliance program for that regulated facility or activity.

Where this document is part of the licensing basis, the word "shall" is used to express a requirement to be satisfied by the licensee or licence applicant. "Should" is used to express guidance or that which is advised. "May" is used to express an option or that which is advised or permissible within the limits of this regulatory document. "Can" is used to express possibility or capability.

Nothing contained in this document is to be construed as relieving any licensee from any other pertinent requirements. It is the licensee's responsibility to identify and comply with all applicable regulations and licence conditions.

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Conduct of Licensed Activities: Construction and Commissioning Programs

1. Introduction

This document provides a framework within which the requirements and guidance in other regulatory documents, codes, and standards may be used in construction and commissioning activities. This framework contributes to ensuring that the construction and commissioning of the plant is effectively managed and consistent with design requirements.

1.1 Purpose

REGDOC-2.3.1, *Conduct of Licensed Activities: Construction and Commissioning Programs*, sets out the requirements and guidance of the Canadian Nuclear Safety Commission (CNSC) for the construction and commissioning of facilities in Canada that use nuclear reactors. These facilities (hereafter called “reactor facilities” in this document) include:

- nuclear power plants or small reactors for the generation of power or heat for industrial processes
- small reactors for non-power generation uses (e.g., isotope production, and research and development activities)

1.2 Scope

Part A of this regulatory document applies to the construction of a new reactor facility, and is focused primarily on the structures, systems and components (SSCs) that are important to safety. Part B applies to the commissioning of a new reactor facility.

The principles set out in this document also apply in a graded manner to activities related to the life extension, refurbishment and modification of an existing reactor facility.

Design activities are not addressed in this regulatory document. See CNSC regulatory document REGDOC-2.5.2, *Design of New Reactor Facilities* [1], for the CNSC’s requirements and guidance on this related activity.

Note that, where necessary or deemed important, CANDU-specific experience, requirements and expectations are cited in the guidance material in this document.

1.3 Relevant regulations

The sections of the regulations made under the *Nuclear Safety and Control Act* (NSCA) relevant to this document include:

- subsection 24(4) of the NSCA, which provides that “No licence shall be issued, renewed, amended or replaced – and no authorization to transfer one given – unless, in the opinion of the Commission, the applicant or, in the case of an application for an authorization to transfer the licence, the transferee (a) is qualified to carry on the activity that the licence will authorize the licensee to carry on; and (b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.”

- subsection 24(5) of the NSCA, which provides that “A licence may contain any term or condition that the Commission considers necessary for the purposes of this Act…”
- section 3 of the *General Nuclear Safety and Control Regulations*, which states the general licence application requirements
- paragraphs 12(1)(*a*), (*b*) and (*c*) of the *General Nuclear Safety and Control Regulations* stipulate that a “licensee shall:
- (*a*) ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely and in accordance with the Act, the regulations made under the Act and the licence;
- (*b*) train the workers to carry on the licensed activity in accordance with the Act, the regulations made under the Act and the licence;
- (*c*) take all reasonable precautions to protect the environment and the health and safety of persons and to maintain the security of nuclear facilities and of nuclear substances;”
- section 3 of the *Class I Nuclear Facilities Regulations*, which states the general licence application requirements for Class I facilities
- Paragraphs 5(*c*) and (*i*) of the *Class I Nuclear Facilities Regulations* state that “an application for a licence to construct a Class I nuclear facility shall contain the following information:
  (*c*)the proposed construction program, including its schedule;
  (*i*) the effects on the environment and the health and safety of persons that may result from the construction, operation and decommissioning of the nuclear facility, and the measures that will be taken to prevent or mitigate those effects;”
- section 6 of the *Class I Nuclear Facilities Regulations*, which states the licence application requirements for a licence to operate under subsection 24(4) of the NSCA
- paragraph 6(*g*) of the *Class I Nuclear Facilities Regulations*, which provides that an application for a licence to operate a Class I nuclear facility shall contain, in addition to other information, “the proposed commissioning program for the systems and equipment that will be used at the nuclear facility;”
- paragraph 14(2)(*b*) of the *Class I Nuclear Facilities Regulations*, which provides that “Every licensee who operates a Class I facility shall keep a record of the results of the commissioning program referred to in the licence;”

2. Management System

Licensees shall manage construction and commissioning activities in accordance with their management system as defined in the licensing basis. This document further clarifies how the management system’s generic requirements apply specifically to construction and commissioning activities.

Guidance

All construction, commissioning and related activities should be developed and implemented under the control of the licensee using a management system meeting the requirements of CSA N286, *Management system requirements for nuclear facilities* [2].

Part A: Construction of Reactor Facilities

3. Management and Organization

3.1 Role of the licensee

The licensee shall have the primary responsibility for safety and security of all construction activities, including work carried out on its behalf by contractors. The licensee shall also have within its organization the knowledge, expertise and resources to maintain control and oversight of safety at all times.

Guidance

The licensee’s responsibilities cover all aspects related to the construction of the facility. Some examples of the licensee’s responsibilities are:

- confirming the facility is being built in accordance with the design basis, regulatory requirements, and applicable codes and standards
- maintaining ownership of the safety case, including the information provided by the design and construction organizations and contractors
- providing a point of contact for communicating with the CNSC on all matters related to the facility’s construction
- ensuring construction program documents are prepared and updated
- ensuring construction instructions and procedures are established
- ensuring inspections, tests and verification of SSCs important to safety are performed
- ensuring safety-significant inspection findings are evaluated and reporting the evaluation results to the CNSC
- identifying jurisdictional boundaries and responsibilities where there is more than one regulatory body governing a particular area

Construction and commissioning are an integral part of design assurance for the nuclear facility. For activities important to design assurance where commissioning is not practicable, special attention should be placed on assurance of construction.

Reactor facilities will likely be constructed by contractors and subcontractors with the licensee undertaking primarily an oversight role. Nonetheless the licensee has the primary responsibility for safety, and must ensure directly, or indirectly, that adequate provisions have been made for the safety of the public, workers and the environment for all construction activities. Effective oversight of construction activities is essential to maintain the construction safety case and to support the operations safety case.

As the licensee is directly responsible for managing its contractors, this should be reflected in contractual arrangements between the parties. Relevant arrangements between the licensee and major contractors should then cascade down into the contracts throughout the supply chain of SSCs important to safety.

It is the responsibility of the licensee and those involved in the supply chain to understand the applicable requirements set out in the NSCA and the regulations for the contract they are seeking to place. The contracting party should document all relevant requirements without an over reliance on referencing other documents. This will ensure that there is clear understanding between all parties on how to implement all relevant requirements.

Although it is the responsibility of the licensee to ensure compliance with applicable requirements, all parties within the supply chain should understand the nuclear safety significance of the contracted work, and be able to demonstrate that arrangements have been made to comply with the contract's specifications. Each link in the supply chain should therefore ensure that its staff, and any subcontractors, are suitably trained and briefed on their responsibilities under the relevant requirements, and that suitable measures are implemented to assure compliance with contract specifications.

The licensee should have the capability to understand the nuclear safety significance of any purchased expertise or equipment, specify requirements, supervise the work, and technically review the output before, during and after implementation. This is known as the intelligent customer capability.

Contractors at all levels in the supply chain should expect to be audited on a regular basis as part of contractual arrangements. Contractors could also be visited by the CNSC as part of regulatory oversight, particularly if the equipment they are manufacturing has high nuclear safety significance.

3.2 Construction management

3.2.1 Regulatory and other requirements

The licensee shall identify health and safety, environmental, and other requirements applicable to construction activities. Relevant requirements shall be communicated to all parties and taken into account when establishing, implementing and maintaining management practices and controls. Conflicting requirements shall be identified and resolved.

3.2.2 Interface arrangements

Before construction starts, interfaces between the licensee and the CNSC, as well as the licensee and other regulatory authorities, shall be defined, agreed upon and understood such that the CNSC and other regulatory authorities are provided with relevant performance issues that have affected, or have the potential to affect, the quality of construction and future operational safety of SSCs. The interface arrangements shall be specified in management system documentation and in appropriate contracts.

3.2.3 Oversight of contractors

The licensee shall develop measures to ensure that contractors and subcontractors meet their respective contractual obligations in accordance with an appropriate safety management system.

The licensee shall maintain records of its oversight activities and report to the CNSC relevant contractor performance that has affected, or has the potential to affect, the quality of construction and future operational safety.

Guidance

As part of contractor oversight, the licensee should:

- take both qualitative and quantitative measures, appropriate to the safety significance of the SSCs, to monitor conformance and enable trends
- take proactive measures of performance that monitor conformance
- take reactive measures of performance which enables trends to be monitored
- monitor the effectiveness of controls for the management systems/quality assurance programs
- retain relevant information as evidence of the results and report to the CNSC relevant contractor performance that has affected, or has the potential to affect, the quality of construction and future operational safety

Examples of proactive measures include:

- assessments of compliance with regulatory and other requirements
- the effective use of the results of workplace safety tours or inspections
- evaluation of the effectiveness of training
- use of behaviour observations
- use of perception surveys to evaluate safety culture and related worker satisfaction
- the effective use of internal and external audits
- completion of regulatory commitments as scheduled
- the extent to which management system / quality assurance programs have been implemented
- the effectiveness of worker participation process
- benchmarking of good construction practices
- work activity assessments

The following should be considered for contractor performance when it has the potential to affect the quality of construction and future operational safety performance:

- for selection of contractors:
  - confirmation that the contractors have the ability to supply the goods or services
  - acceptance of the contractor’s management system through review of documentation and audit
  - confirmation that the contractor understands all regulatory requirements
  - resolution of any exceptions the contractor has to the licensee’s requirements
  - reviews of contractor submissions against requirements
- for contract management:
  - evidence of a positive safety culture
  - evidence that the contractor satisfies all contractual requirements related to health and safety, environment, security, control of materials and quality
  - problem identification and resolution, and effective corrective action programs
- for contractor supply chain (manufacturing and construction) activities:
  - pre-screening of subcontractors used by the contractor, to ensure the subcontractors are acceptable and to incorporate them into the licensee’s supply chain program
  - verification that the specification used for purchasing equipment, materials and components have been met
  - review of contractor manufacturing or construction documentation, including quality plans/manufacturing and inspection and test plans, and special process procedures

- source verification and audits, during manufacturing and construction, to verify compliance of the contractor or its subcontractors
- review and disposition of any contractor non-conformances to requirements

The above guidance should also extend to the contractor's measures to ensure its subcontractors meet their respective obligations.

3.3 Programs supporting construction activities

3.3.1 Security

Security measures shall include the prevention of, detection of, and response to, criminal or intentional, unauthorized acts involving or directed at construction activities, and other intentional acts that could directly or indirectly produce harmful consequences. Security measures shall extend to:

1. physical security of the site
2. personal security
3. protection of information
4. document security
5. cyber security

Guidance

The security program should include the actions to be taken to protect SSCs under construction and to detect and deter conditions that would otherwise impair site security.

It is understood that as construction proceeds, the focus and requirements of the security program will evolve. The following key elements should be reviewed to ensure that the necessary provisions are made for security:

- security measures in place are commensurate with onsite conditions such as commercial 'loss control', whether there is nuclear material on site, and turnover to operations
- access control of personnel, materials and vehicles
- scheduled and random patrols and inspections
- screening (pre-employment and gate clearance) for access to work areas
- physical barriers, fencing, surveillance and monitoring capability
- cyber security controls to protect computer-based systems
- response capability

The following regulatory documents provide specific requirements and guidance for security programs: RD-321, RD-361, REGDOC-2.12.1-3, G-205, G-208 (only if fuel onsite under the licence to construct).

3.3.2 Safeguards

The International Atomic Energy Agency (IAEA) shall have access to the site and information about site buildings and structures, operational parameters, flow and storage of nuclear material, and installation of safeguards surveillance and monitoring equipment consistent with the Canada-IAEA safeguards agreements.

3.3.3 Personnel training and qualification

Personnel engaged in construction activities shall have appropriate training, qualifications and competence to perform their assigned tasks effectively and safely.

Guidance

REGDOC-2.2.2, *Human Performance Management: Personnel Training*, [3] provides specific requirements and guidance for training programs.

The training programs should emphasize the importance of adhering to established programs, processes and procedures in assuring nuclear safety in future phases of the project (e.g., commissioning and operation). Training programs should further emphasize that everyone working at the site is responsible for safety in all construction activities.

Operational phase training and personnel certification approaches, such as for those who will be involved in commissioning, operation, maintenance and technical support activities should be considered. It is understood that training program provisions evolve as construction progresses.

3.3.4 Effect on and from existing facilities

As part of its assessment of safety and security during construction, the licensee shall consider all hazards to or from nearby site facilities and any interdependence of safety systems. The consequences of potential contamination (nuclear and hazardous substances) from a construction site to operating units, as well as from operating site to construction site, shall be assessed and any contamination monitored as necessary. All other potential risks shall also be assessed (e.g., excavation, accidental fall of cranes, use of explosives). Such consideration shall also include an impact assessment of cumulative environmental discharges for all facilities on the site.

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

For adjacent installations or those with common buildings or services, the boundaries of the following shall be identified:

1. physical
1. system
2. controlled areas
3. security access
4. clean zones

When using the resources of existing nuclear installations (e.g., water, electric power or security), clear interfaces shall be defined so as not to jeopardize operating installations.

Emergency plans shall take full account of the presence of other parties in the area. Procedures shall be implemented to ensure the licensee of an existing facility or facilities endorses a change of status for those common buildings or services before the construction organization puts such plans in place.

3.3.5 Emergency management and fire protection

The licensee shall ensure an appropriate plan is in place for managing emergencies during construction.

Fire protection controls (i.e., temporary measures to mitigate potential fires) shall be available until final systems for plant fire detection, protection and suppression are installed and operational. Details of these controls shall be included in the emergency preparedness arrangements.

Guidance

REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response*, [5] provides specific requirements and guidance on emergency preparedness.

For construction sites at existing nuclear facilities, emergency measures should include a risk and threat assessment to identify any increased risks to the site. Preventive measures should include managing risk to the existing facility, by construction activities such as dredging, quarrying and blasting, and the creation of connections between the site and the facility.

The proximity of other nuclear facilities should be considered so that mutual aid agreements may be put in place to support emergency response. As construction proceeds the licensee should ensure that emergency measures in place are commensurate with onsite hazards.

4. Readiness Review

In preparation for construction, the applicant/licensee shall ensure the contractors are ready to proceed with construction by verifying that:

1. management systems are in place
2. adequate planning has been conducted
3. procedures and training are complete
4. construction hazards are adequately evaluated and control measures identified

These activities shall be accomplished through a construction readiness review.

Guidance

The following areas should be assessed in a construction readiness review:

- **Regulatory requirements:** Focus on confirming all regulatory requirements have been satisfied. This includes obtaining all required licences and permits from federal, provincial and municipal agencies.
- **Management system:** Focus on aspects of the management system, organization and staffing for the execution of the construction project. It is expected that key construction positions are established, related organizational roles and responsibilities are clear, and project staff are sufficiently staffed to oversee construction activities. Additionally, management systems should be in place to monitor performance against the project baseline.
- **Design completion:** Confirm that the design is sufficiently complete, as agreed between the licensee and the contractor, to allow the four steps listed above to be undertaken.

Additionally, confirm that any incomplete areas have been identified and schedules have been prepared for their completion.

- **Information technology:** Assesses the alignment and interoperability of hardware, software, information communications, and the information technology environment between the applicant/licensee and contractors to ensure timely creation and delivery of quality information between all parties, in the proper form and format to facilitate the reactor facility's information strategy over the facility's lifecycle.
- **Construction procedures:** Focus on the contractor and key subcontractor procedures used for the completion of the facility construction. It is expected that the procedures address the key elements and requirements to safely complete construction activities in accordance with applicable regulations, design requirements and contract requirements.
- **Materials management:** Focus on the materials management process for the construction activities, including the acquisition of materials, their delivery, packaging, and waste management from materials receipt.
- **Safety assurance:** Confirm that the construction contractor is capable of managing a safe project. Key requirements related to integrated safety management systems, and specific plans and procedures related to industrial health and safety, and industrial hygiene along with environmental controls should be evaluated. The applicant/licensee should also verify that contractors have completed a project safety and health plan, and environmental management plan.
- **Project control:** Focus on the adequacy of project controls relied on to ensure adherence to the performance baseline and the systems or processes relied on for controlling any field changes to procedures or other project documents.
- **Construction execution plan:** Address specific construction activities and practices, as well as the personnel and procedures in place to accomplish the work. Included are criteria related to general construction topics such as preparedness of the site and work sequencing.
- **Training and qualification:** Focus on the training and qualification of personnel responsible for construction activities. This review encompasses both the general training required for site access and the specific training and qualifications necessary for performing the planned construction activities.
- **Work planning:** Assess the work planning to ensure that work processes are controlled by approved instructions, procedures, design documents, technical standards or hazard controls as appropriate for the task to be performed. The organization of work and whether systems are in place and mature to support development of work packages or processes should also be evaluated.
- **Constructability:** Focus on the project's constructability. The key elements include the design specifications, drawings, site conditions and the construction schedule including the order of construction elements and potential impacts.
- **Field engineering:** Assess the readiness of activities explicit to construction of specific facility systems in accordance with their approved design, as well as taking into account feedback from field observations that may impact design.
- **Infrastructure:** Focus on support systems, including required electricity, gas and water supply, fire protection, protection or coverage of SSCs after work installation (including maintaining environmental qualification), and ensure they are in place at a level commensurate with the progress of construction activities.
- **Quality assurance:** Verify that an approved quality assurance plan or equivalent is in place and is up to date to address quality assurance requirements pertinent to construction activities. Quality assurance during procurement should also be addressed to ensure the final products meet design criteria.

- **Labour management:** Focus on aspects of labor management necessary to ensure that the project can be successfully executed with the overall objective being to ensure the adequacy of the local labor force to support the project.
- **Construction tools and equipment:** Focus on the availability and operability of the tools and equipment necessary to support the construction activities. The review should confirm that the equipment meets jurisdictional requirements.

5. Construction Program

5.1 Planning, scheduling and construction sequencing

The licensee's planning, scheduling and construction sequencing shall identify and include provisions for hold and witness points by various parties, such as architects/engineers, authorized inspection agencies and the CNSC.

Guidance

To ensure construction sequencing will not be adversely affected by later construction activities, planning, scheduling and work sequencing should identify and include provisions for:

- items with long lead times (long-lead items)
- onsite manufacturing, modular assembly and testing activities

Consideration should be given to the design of components and plant fixtures; e.g., the form of cast-in components, so that post-drilling of concrete is kept to a minimum.

5.2 Long-lead items

Any differences between the original purchasing requirements, the licence-to-construct design basis and the as-built items shall be evaluated, reconciled and reported to authorized inspection agencies and the CNSC.

Guidance

The procurement of long-lead items is entirely at the licensee's risk. Submissions for procurement of items for which the licensee seeks CNSC acceptance, prior to the application for a licence to construct, will be reviewed on a case-by-case basis.

When the licensee/applicant proceeds with the procurement of long-lead items, submissions should include the following information:

- item description and quantity
- codes and standards
- safety classification
- code classification
- code-effective date
- technical performance requirements
- quality assurance requirements
- documentation requirements and timing of submission

5.3 Manufacture and assembly

The licensee shall ensure right of access to facilities and records for witness points or audit by the CNSC.

5.4 Receipt of components important to safety

Guidance

An initial check should be carried out when components important to safety are received at the construction site to ensure:

- the components are as ordered
- have not been obviously damaged during transport
- that counterfeit, fraudulent and suspect items have not entered the construction site

Before the component is accepted and used, an inspection should be carried out to confirm that:

- components are configured correctly
- identification and marking are correct
- manufacturing and assembly documentation, including approved deviations, is available where required
- inspection records and/or certificates are traceable to the inspected item for confirmation of acceptance
- source verification release notes – for both components and documentation – are available where required
- protective covers and seals are intact
- coatings and preservatives have not been damaged
- no physical damage has been sustained
- cleanliness meets applicable codes and standards and design requirements
- inert gas blankets and the condition of desiccants, where relevant, have not been compromised
- non-conformance identified by receipt inspections, or detected during manufacturing but to be corrected onsite, are recorded

Controls should be in place to prevent inadvertent installation or use of components.

5.5 Protection of systems, structures, and components important to safety

The licensee shall ensure that SSCs important to safety are protected from construction activities. Such measures shall include:

1. conducting preventative and corrective maintenance to maintain the functionality of SSCs important to safety, as required by the design, until operational maintenance programs are initiated
2. ensuring that fabrication/manufacturing, construction and installation processes do not adversely affect aging performance of SSCs important to safety or adjacent reactor units
3. performing periodic monitoring of environmental conditions to confirm that they remain within allowable limits throughout construction

4. implementing housekeeping, cleanliness and foreign material exclusion measures as necessary to protect sensitive mechanical, electrical and control equipment from internal and external contamination

Temporary use of SSCs important to safety that are to become part of the completed facility shall be authorized by the responsible organization. Such temporary use shall not subject the SSCs important to safety to conditions for which they were not designed.

Guidance

See RD/GD-210, *Maintenance Programs for Nuclear Power Plants*, [6] and REGDOC-2.6.3, *Fitness for Service: Aging Management*, [7] for more information.

Examples of environmental conditions where allowable limits should be specified during construction work include temperature, pressure, humidity, dust, dirt, airborne salt, wind, and electromagnetic conditions.

Foreign material exclusion measures should include provisions for preventing the introduction of outside materials, debris, tools, and components into the systems and components, and areas where they pose a health and safety hazard or environmental impact.

Installed SSCs should be protected from personnel traffic, temporary structures, weather, and adjacent construction activities (such as sandblasting, acid cleaning, welding, jackhammering, chipping, burning, and stress relieving) that would adversely affect the quality of the SSCs or any test results. The protection may be provided through good cleanliness and housekeeping practices, temporary packaging, erection of barriers, protective covers, and walkways as required.

Specific requirements and cleaning methods should be implemented for systems such as hydraulic and instrumentation control systems and lubrication lines, as well as for those where interior surfaces are generally not accessible for visual inspection.

The compatibility of cleaning methods and materials with the components being cleaned and cleanliness of components after cleaning should be confirmed. The latter includes any remnants of preservatives or cleaning agents on components before installation

Fluid and gas piping systems, and associated components should be laid up, cleaned, flushed and conditioned according to applicable chemistry requirements. Chemistry staff, facilities and procedures should be available to support system flushing and hydrostatic testing to ensure requirements are met.

Waste materials and remaining consumables used or generated onsite during construction should be removed after work is complete.

5.6 Storage

To protect components important to safety prior to their installation, storage shall be provided as specified by the designers and manufacturers.

Guidance

When establishing storage areas, the following should be taken into account:

- cleanliness and housekeeping practices
- requirements for fire protection
- protective requirements related to coatings, preservatives, covers and sleeves
- prevention of physical damage
- environmental controls: airborne matter, static electricity, temperature and humidity
- preventive maintenance
- security against theft, vandalism and unauthorized use
- shelf life due to physical and chemical characteristics
- identification of components

5.7 Onsite manufacturing and testing

Onsite manufacturing shall be located where it will not affect SSCs important to safety or construction activities. The licensee shall ensure that rules and procedures are established for onsite testing facilities to ensure that industry codes and standards are met.

Guidance

Examples of onsite manufacturing include:

- core extraction and testing for the entire concrete and backfill program in accordance with the technical specifications covering the supply of concrete and backfill
- rebar assembly
- pipe spool fabrication
- modular assembly, such as:
    - mechanical modules: structural equipment on a common structural frame, along with interconnecting piping, valves, instruments and wiring
    - structural modules: liner, wall, floor, heat sink floor, turbine pedestal form, stairs, platform, structural steel, and space frame modules; some structural modules may include leave-in-place formwork for concrete
    - piping modules: pipe, valves, valve tree, pumps and associated instrumentation and wiring on a common structural frames
    - electrical modules: electrical modules on a common structural frame
- other onsite activities to facilitate construction

When specialty construction equipment is required (e.g., very heavy lift cranes, automated rebar assembly machines) the set-up, use and disassembly should be controlled as required by the manufacturers.

Testing facilities include those for:

- concrete mix, and core extraction and testing
- process instrumentation and set point calibration
- pressure relief valve setting

- pressure gauge calibration

6. Turnover of Work

6.1 Turnovers during construction

The licensee shall ensure that a process for turnover of SSCs important to safety is established.

Guidance

Process and procedures should be established to control and coordinate the turnover of completed work and associated facility configuration information from one party to another (e.g., from civil to mechanical, piping and electrical) to maintain completed work integrity. Access control for SSCs important to safety and work areas should also be established and implemented for the transfer. Transfer requirements and responsibilities should be documented.

When SSCs and work areas are to be transferred between parties within the construction organization or contractors, both parties should jointly check the SSCs and work areas as well as the facility configuration information. Both parties should agree on the configuration of the SSCs and work areas and how to address any identified deficiencies.

After turnover, further work or corrective actions by the previous party should only be done with appropriate authorization by the party who has received the work and the licensee.

6.2 Turnover of work to operations/commissioning

Guidance

Process and procedures established to control and coordinate the turnover of work should include the following activities:

- review of the facility configuration information relating to SSCs, and areas by the party turning over the work and the party receiving it for completeness and accuracy
- performance of tests to ensure the SSCs have been manufactured, constructed and installed according to design specifications
- identification and assessment of any remaining non-conformances or incomplete components, to ensure there is no safety implication during commissioning activities
- development of inaugural or baseline inspection data for systems or components for comparative purposes for in-service inspection
- agreement upon, planning and scheduling of any outstanding work
- identification of termination points of the boundaries of turned over SSCs (or parts thereof) in turnover documentation with associated required configuration
- inspection of turned over components and associated records and documents
- assessment of compatibility of information and communication technology systems when turning over electronic documents and records
- documentation of the turnover of responsibilities
- establishment and turnover of approved as-built plans together with adequate and precise plant configuration details
- marking and tagging of all SSCs turned over

Turnover requirements and responsibilities should be documented. The level of technical detail in turnover documentation should be sufficient to allow the recipient to identify parts and order replacements for maintenance. All relevant information should be copied to the parties who will be responsible for aging management.

7. Configuration Control

7.1 Facility configuration information

Recorded information that describes, specifies, certifies, or provides data or results created during construction, as part of the facility configuration information, shall be agreed to, planned and processed so as to facilitate its turnover to commissioning and operations in the agreed form, format and required quality.

Guidance

To enable successful turnover of facility configuration information created during construction, the following should be considered:

- What information is required for turnover?
- Who will produce the required information?
- How will the information be delivered (i.e., electronically or paper copies)?
- When will the information be delivered (i.e., timing and frequency)?
- Who will receive the information turned over?
- Where will the information be stored?
- Who is responsible for the information’s management and integrity?

The control of construction records should be established at the beginning of the construction program for input into the schedule for accomplishing construction activities.

Visual construction records of as-built conditions should be compiled, particularly in inaccessible areas or areas that will be subject to intense radiation, to facilitate the planning of work in these areas during commissioning, operation and decommissioning. These records should show identification marks and should be 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 work preparation.

7.2 Changes to facility configuration information

Changes that occur in the course of construction shall be processed to maintain conformance among the design requirements, the physical configuration and the facility configuration information. The CNSC shall be notified where configuration changes have an impact on the submitted design and licensing basis information.

Guidance

All mechanisms that can lead to a temporary or permanent change in the design requirements, physical configuration and facility configuration information should be identified as configuration management related change mechanisms. Examples of change mechanisms include:

- design changes
- field changes
- non-conformances
- changes to as-built condition
- changes to as-built test documentation
- changes to inaugural inspection records
- computer software changes
- changes to records of maintenance history
- temporary modifications and alterations

Part B: Commissioning of Reactor Facilities

8. Management and Organization

8.1 Organizational responsibilities

The licensee shall have the primary responsibility for safety and security and shall oversee the organization, planning, execution and assessment of the commissioning program.

The licensee shall be responsible for the construction, commissioning and operating organizations, which may be part of the licensee's organization or from a contracted organization responsible for their scope of work.

The licensee shall ensure that necessary resources are available to carry out the commissioning activities and to establish, implement, assess and continually improve commissioning activities.

During and following commissioning, under the overall direction of the licensee:

1. the construction organization shall ensure that SSCs have been constructed as per design and that quality assurance requirements have been satisfied
2. the commissioning organization shall ensure that SSCs are tested to provide assurance that the reactor facility has been properly designed and constructed and is ready for safe operation
3. the operating organization shall:
    a. carry out operation and maintenance
    b. satisfy itself that the systems transferred comply with the specified performance, design intent and safety case
    c. satisfy itself through integrated system validation exercises that the human-machine system design and supporting mechanisms facilitate human performance in achieving safety and operational goals
    d. accept responsibility for the transferred systems
    e. become competent in the management and operations of the reactor facility
    f. ensure that there will be a sufficient number of qualified workers to operate the facility
4. SSCs shall be operated in accordance with the assumptions and intent of the commissioning program, respecting the relevant operating limits and conditions that apply to each testing stage
5. the responsibilities of other participants, such as designers, manufacturers and supporting technical organizations, shall be specified in appropriate documents

Interface arrangements shall be identified and agreed upon between the licensee, commissioning organization, operating organization, construction organization and any other organizational units performing the work. The interface arrangements shall be specified in management system documentation and in appropriate contracts.

Interface control shall include the assignment of responsibilities and the establishment of procedures for the identification, review, approval, release, distribution and release of documents that cross organizational boundaries.

Guidance

Responsibilities of each organization should remain clear at all times, even if activities overlap in respect to the use of personnel. The participating organizations may adopt various arrangements in discharging their responsibilities. Appendix E provides examples of typical responsibilities, and appendix F gives further guidance on recommended interface arrangements.

Commissioning activities should be aligned with the regulatory licensing process. The principal activities performed in commissioning may be divided into the following categories:

- those associated with the final stage of construction and installation of the reactor facility
- those specific to commissioning, including testing and safety review activities
- those associated with the operation, security and maintenance of the reactor facility

Accordingly, personnel performing the above activities may belong to the construction, commissioning or operating organizations, depending on industrial practice and contractual arrangements, as well as on the physical size and design of the reactor facility. The composition of these organizations may also be influenced by the availability and experience of personnel performing specialized functions. If the licensee decides to contract the commissioning activities to another organization, it should be made clear that the ultimate responsibility for commissioning and safety remains with the licensee.

8.2 Personnel training and qualification

Personnel engaged in commissioning activities shall have appropriate training, qualifications and competence to perform their assigned tasks effectively.

Guidance

REGDOC-2.2.2, *Human Performance Management: Personnel Training*, [3] and RD-204, *Certification of Persons Working at Nuclear Power Plants*, [4] provide specific requirements and guidance for training and personnel certification programs respectively.

Training program subjects relevant to the commissioning program should include, but are not limited to:

- commissioning organization and structure
- commissioning procedures
- reactor facility systems
- conduct of testing and maintaining the reactor facility in safe conditions
- procedural and design changes
- permanent and temporary modifications
- work control and equipment isolation
- interfaces of construction, design and operation with commissioning
- test limitation boundaries in mechanical and electrical systems
- the criteria for, and importance of, reporting incidents and deviations
- commissioning methods and techniques
- safety culture

- nuclear safety, industrial safety, fire protection, emergency preparedness, radiation protection and security
- design criteria, technology and operational limits and conditions (or the equivalent) for the reactor facility
- environmental protection and waste management of spent fuel and radioactive waste
- full-scope simulator training of operators for reactor start-up, regular operations, reactor shutdown and cool down and handling of various transients, including accidents

8.3 Problem identification, resolution, and continual improvement

The operating organization shall be responsible for problem identification, resolution, and continual improvement during commissioning.

Guidance

Personnel should be made aware that they are expected to identify and report non-conformances.

A system should be in place to define non-conformances and specify the roles and responsibilities of the licensee, commissioning organization, and other involved organizations for reporting and correcting non-conformances. In addition, this system should incorporate the regulatory approval process for handling problems and non-conformances when required.

The commissioning stage yields much information that should be taken into account in the subsequent operation of the reactor facility. Systematic processes and procedures should be established for reporting on and analyzing abnormal events, human errors and "near misses". Experience gained at this stage should be fed back into the training program for commissioning and operating personnel. Available information on operating experience, including reportable occurrences at the operating power reactor, should be used appropriately in developing and executing procedures. Consideration should also be given to the need for any changes in the design and related documents.

9. Commissioning Program

The licensee shall establish and implement a program for the commissioning of a reactor facility that:

1. defines clear responsibilities for commissioning activities and oversight, specifying interfaces between design, construction, commissioning and operating organizations
2. is structured to enable the objectives and methods of testing to be understood and to allow management control and coordination
3. outlines the testing that must be performed to ensure that SSCs important to safety are built as designed and meet the requirements of the facility design and safety analysis
4. verifies safety analysis assumptions and the presence of adequate safety and operating margins between design, safety requirements and normal operating conditions
5. ensures tests are only conducted if the reactor facility falls within the range of assumptions made in the safety analysis and the licensing basis remains valid
6. includes provision of temporary utilities (i.e., power, HVAC, demineralized water, fire protection, lightning, communications, compressed air, waste water processing and discharge)

7. identifies the security systems to be commissioned before nuclear fuel or material is brought onsite
8. documents the testing results and identifies any impacts on or changes to the facility design basis
9. validates operating and surveillance procedures for which the commissioning tests provide representative activities and conditions
10. verifies operating and emergency procedures by trial use
11. ensures integrated system validation of control rooms and control areas
12. ensures a schedule, including milestones and regulatory hold points, and test results to be submitted for review are identified and communicated to the CNSC

The licensee shall submit the commissioning program in advance of commissioning activities within an agreed-upon lead time to ensure sufficient time for regulatory reviews and for any concerns raised during the review process to be adequately addressed. The lead time will be related to the size of the facility and the extent of the commissioning proposed. For a new build power reactor the lead time will typically be in the order of one year.

For sites that will contain multiple reactor facilities, the commissioning program shall clearly identify and track commissioning activities for each individual unit or module.

The content of the final safety analysis report shall be updated according to commissioning results.

Guidance

IAEA documents SSG-28, *Commissioning for Nuclear Power Plants*, [8] and NS-G-2.3, *Modifications to Nuclear Power Plants*, [9] define recommended commissioning programs for new facilities and modifications to existing facilities, respectively. The commissioning program for a new facility should cover the integrated plant and all the SSCs, including any interfaces with existing operating facilities onsite. For the life extension, refurbishment and modification of an existing reactor facility, the extent of commissioning activities is recognized to be different. In these cases, the commissioning program should address the impact of design modifications (both hardware and software), as well as the work done on the SSCs that were dismantled or laid-up during the extended outage. Once these SSCs are satisfactorily checked and tested for readiness to load fuel, the commissioning program – from fuel load to full power – should be similar, if not identical to a new facility commissioning program.

To assist in developing the applicable commissioning program, the licensee should categorize the SSCs as defined below, to reflect their status and scope of work performed.

Category A: Systems that remain in normal operation with continued health monitoring and routine maintenance program activities

Temporary changes may have been implemented on some of these systems, to enable them to provide necessary service throughout the outage. No formal commissioning is required to return these systems to normal service. However, any temporary changes should be carefully removed and normal operation restored, in accordance with the operating procedures.

Category B: Systems that are shut down and placed in a laid-up state

This includes systems that may have been disconnected or dismantled to provide proper access to perform work. Depending on the nature of the work involved, some commissioning activities may be required to confirm that the system has been reinstalled correctly and performs in accordance with the design specifications.

Category C: New installed systems or existing systems that have had portions of systems or components modified.

Commissioning would be required to confirm that the modified system – and the integrated plant – performs in accordance with the design specifications.

The extent and depth of the commissioning program is dependent on various factors. In situations where a commissioning requirement may not be applicable, the licensee may make a justification for not meeting the requirement, or propose an alternate method of compliance (which will be reviewed by CNSC staff).

10. Commissioning Tests

10.1 Test objectives

Testing is the core activity of the commissioning program. It shall be sufficiently comprehensive to demonstrate that the reactor facility can operate in the modes for which it has been designed.

In developing test objectives, the safety functions of the SSCs important to safety shall be systematically reviewed to ensure that all safety requirements are met.

Where it is deemed impractical to fully test the functionality of SSCs important to safety for all design-basis events, gaps in testing shall be identified and documented. Additional compensatory measures (such as computer simulation, additional verification or third-party review) shall be documented to compensate for the gaps in the commissioning assurance provided by testing.

10.2 Test scope and methods

Tests necessary to demonstrate operability, safety and safety-related functions shall be fully performed. For tests that cannot be performed to their fullest extent, it shall be documented how the safety and design intent is met.

Functional and performance requirements and parameters that clearly identify the approach used for each testing aspect shall be defined.

The commissioning program shall have provisions to ensure there have been no omissions in testing complex systems. The combination of testing and other means of assurance (where testing is impractical) shall be such that risk to the public and environment is assured to be within the licensing envelope of the facility.

Tests shall be performed under the most realistic operating conditions practicable and shall confirm analytical tool validation.

Facility-level integrated tests shall be performed for every reactor facility, irrespective of the availability of similar or identical tests from other single- or multi-unit reactor facilities. Where integrated testing cannot be performed for safety reasons, the licensee shall provide a technical argument that includes acceptable testing alternatives to meet the objectives of the commissioning program.

For any offsite tests, their applicability at the component level shall be documented. Their applicability shall also be documented when integrated at system and facility levels.

For multi-unit reactor facilities:

1. component- and system-level integration tests shall be done onsite for every unit in the reactor facility
2. special provisions shall be made to ensure that the commissioning tests of a unit do not jeopardize the safety of another unit; such provisions shall include safety analysis (of the operating unit), conducting a hazard assessment, and obtaining specific written approval from the manager responsible for the operating unit
3. that have SSCs important to safety common to more than one unit, tests shall be conducted on each unit to provide assurance that the specified performance requirements meet the design intent of each unit

Guidance

If the testing procedure uses SSC test results from offsite tests, this should be defined and justified, showing the validity and applicability of performed offsite tests to:

- the onsite physical and functional condition of SSCs important to safety
- their interfaces with the rest of the reactor facility

For some reactor technologies and construction processes, some tests on SSCs important to safety performed offsite may need to be considered as part of the commissioning process. In such cases, specific justification should be provided showing the validity of the performed tests for the current installed conditions of the SSCs important to safety and related functional and physical interfaces.

10.3 Acceptance criteria

Acceptance criteria for the commissioning tests, against which the acceptability of the test results will be evaluated, shall be defined by the test procedures.

The technical basis of the acceptance criteria, which is consistent with the safety, design and performance requirements, shall be documented in preparation for and prior to conducting the tests.

When using analytical tools, CSA N286.7, *Quality Assurance of Analytical, Scientific, and Design Computer Programs for Nuclear Power Plants*, [10] shall apply.

Guidance

CNSC acceptance of the acceptance criteria may be needed before performing the commissioning tests. This will depend on the facility-specific commissioning program. Any criteria requiring

CNSC acceptance will be identified by the CNSC at the time of review of the overall commissioning program and prior to testing.

Parameters measured during the test should directly relate to, or correlate with, the design requirements important to safety while recognizing the safety limits and integrity of the structure, system or component. In cases where measured parameters do not directly relate to the acceptance criteria, analytical tools may be used to demonstrate that the safety objectives are met.

Acceptance criteria, especially those directly or indirectly linked to safety, should not change during the execution of a test.

After completion of a test, there may be a discrepancy between the results and acceptance criteria. Observed discrepancies and their resolution should be documented; impact assessment of the discrepancies on the past and pending tests should also be performed and approvals should be secured before proceeding with further tests.

10.4 Test procedures

All commissioning tests shall be performed in accordance with the commissioning program using procedures reviewed, verified and approved by the licensee.

Test procedures shall establish actions for deviations from procedures, where test results fall outside the acceptance criteria or if unexpected events occur. Tests shall only resume after any existing issue is dispositioned (e.g., through design change, change in operating requirements, or change in operating modes,) by the commissioning organization and approved by the relevant parties.

Guidance

For some tests, the test procedures may require SSCs important to safety to be placed in a different configuration than the normal operating configuration. Such deviations or changes may involve temporary interlock bypasses, temporary additional interlocks, temporary system bypasses, valve configurations and instrument settings. Consideration should be given to minimize such arrangements, and to ensure that any deviations from the normal functioning of the as-built systems do not invalidate the test objectives. In such instances, the test procedures should:

- specify the deviations/changes for the SSCs important to safety from the normal operating configurations
- specify back-out provisions and anticipate response to events that could arise from the test
- provide supporting evidence with reference to safety analysis
- include all the necessary steps for the restoration of the SSCs important to safety to their normal configuration after the test is completed
- include a list of all necessary checks that are needed to ensure that:
  - the deviations/changes are made safely and correctly
  - the SSCs important to safety are returned to their normal configuration safely and correctly

Test procedures should use normal operating procedures to ease their verification. Where improvements to operating procedures are identified during commissioning, commissioning personnel should consider, in consultation with the operating organization, amending the procedures to permit operating personnel to become familiar with them. Where operating procedures have not yet been developed, the operating organization should have processes in place to manage commissioning records for use in developing operating procedures.

The development, verification and validation of commissioning test procedures may benefit from the use of validated simulator and computer codes. The use of the facility simulator should be considered in training and preparing commissioning teams, particularly for complex commissioning tests or for investigating possible adverse conditions that may occur during the test.

The process for preparing test procedures should allow for sufficient time to:

- conduct various levels of review, including responding to potential review requests from the CNSC; the design organization should review the procedures – in particular, the validity of the acceptance criteria (scope and depth of reviews should be commensurate with the nature of the test, regardless of whether a test requires SSCs to be placed in a different configuration from the normal operating configuration, and the impact on system safety)
- report test results
- enable review of the test results to proceed safely and efficiently

Examples of deviations from approved test procedures to be addressed according to the operating organization's control change procedures include:

- a test acceptance criterion that is not met
- inability to demonstrate compliance with the acceptance criterion because of at least one of the test conditions not being fulfilled
- the determination of an inadvertent change to the test procedure steps that impacts the acceptance criterion
- inability to implement the test completely, as developed in the test procedure

Should a deviation occur, a review that includes the following should be carried out:

- immediate corrective actions to ensure facility and personnel safety
- safety implications of the deviation
- root-causes of the deviation
- an assessment of whether the deviation prevents continuation of the commissioning activities
- violations of safety and regulatory requirements
- appropriate corrective actions, such as:
    - re-performing the test as per procedures
    - modifying the design
    - updating the safety analysis
    - updating/correcting test procedures
    - updating operational documentation

The deviation review process should not be finalized until all corrective actions are completed and the commissioning procedures are updated and approved. For any deviations requiring a design change, the affected test(s) should be repeated to confirm conformance after the design change modifications have been implemented.

For unexpected events, consideration should be given to any fault responses and emergency actions required for each test procedure. In some cases it may be the same response to alarms as would be necessary for planned operation, whereas other cases may require specific actions because of the configuration of the reactor facility during testing. The test procedures should identify the specific limits and conditions applicable to the test and the actions to be taken if the limits are approached.

Although the format of procedures may vary from facility to facility, the contents of test procedures should include the following:

- **Introduction:** Summarize the main test objectives and the safety aspects to be demonstrated. The system to be tested should be identified and the anticipated test results should be indicated. The relationship of the test being carried out to the main phases of the commissioning program should be highlighted.
- **Test objectives and methods:** Set out the objectives of the test and the means by which they are to be achieved, including step-by-step actions.
- **Limiting criteria:** Applicable operational limits and conditions, including temporary ones. Limits and conditions that must be adhered to in order to prevent damage to the reactor facility should also be included.
- **Prerequisites and initial conditions:** The state of all relevant SSCs and other pertinent conditions that might affect the operation of the system to be tested (including coordinating construction, commissioning, operations, verification and validation activities, and hold points), particularly if different from normal. This information should include, where appropriate, the precautions necessary to maintain the desired system configuration.
- **Test conditions and procedures:** The way in which the system to be tested is required to be brought up to test conditions and details of the test procedures, preferably in a step-by-step format. This information should include any temporary changes or abnormal alignments of the system or of adjacent systems, and be supported by safety analysis.
- **Acceptance criteria:** The stated acceptance criteria. Wherever possible, this statement should be quantitative as well as qualitative (e.g., for fuel loading).
- **List of instrumentation and special test equipment:** List all special equipment and calibrations necessary to perform the test. The equipment should have appropriate accuracy and should be clearly identifiable.
- **Staffing, qualification and responsibilities:** Staffing needs, qualification requirements and assignment of duties and responsibilities for conducting tests, including personnel required to oversee and/or witness.
- **Special precautions:** Measures and actions necessary for the safety of personnel and the security of equipment.
- **Completion of test:** Indication by the responsible personnel that the test has been completed and the systems have been returned to normal conditions. The removal of temporary changes or of any abnormal lineup should be individually specified (i.e., as steps in the test procedure).
- **Permanent records:** Information necessary for permanent records, including baseline data.
- **Identification, cross-referencing and distribution:** a unique identification system (such as one using reference numbering), including comprehensive cross-references to associated documents and a distribution list of those persons who should receive it.

- **Data collection and processing:** Make arrangements for tabulating data and test results. Test sheets should have standardized forms and each sheet should be signed by the data collector. Chronological recording is desirable (test data, date and time). Data pre-processing by the data acquisition system and post-processing, if any, should be validated and verified.
- **Non-conformities:** Make arrangements to manage any non-conformities identified as a result of the tests.
- **Provisions for the techniques and methods of data analysis, including the analysis of measurement results:** Verify and validate the software used for data collection, storage and analysis prior to the test. The repeatability, accuracy and measurement uncertainty should be documented.

10.5 Review, evaluation and reporting of test results

Test results shall be reviewed by the commissioning organization to ensure that all deviations are resolved and that operating constraints, if any, are identified and documented.

Interpretation of test data shall be reviewed by persons who have the technical expertise to determine that the operational characteristics of the structure, system or component and/or process are captured.

Formal reports for each test shall be prepared by individuals responsible for the tests, and approved by the commissioning and design organizations.

The reactor facility design, operational and safety documentation shall be updated to reflect test results and resolution of deviations.

If test results indicate that a change to the scope of subsequent tests is required, a documented assessment shall be performed prior to proceeding with the remaining tests to ensure that:

1. the proposed changes do not fall outside the range of assumptions made in the safety analysis and do not invalidate the licensing basis
2. the proposed changes do not invalidate the results of the previous tests
3. the proposed changes do not adversely impact future tests in terms of scope, objectives and sequence
4. the commissioning documents are updated with the nature of, and justification for, the proposed changes as per management system requirements

The commissioning organization shall report the test results to the operating organization and to other participants in the commissioning program, as required.

Guidance

Although it may be expedient to prepare summary reports as an interim measure for a quick assessment of the test results, a formal comprehensive report that includes a final evaluation of the test results should be prepared.

The format of a report may vary, but should typically include:

- an introduction, which includes a summary of test objectives with evidence of safety objectives, a description of the test method and acceptance criteria

- references to appropriate test procedures
- the conduct of the test, including the duration, the initial and final states of the reactor facility, the actual limitations experienced and the problems encountered and actions taken to overcome them (including modifications to the facility or procedures)
- a concise description of any special test equipment used
- a summary of data collected and analysis of the data
- an evaluation of results, including both qualitative observations (e.g., visual observations) and a comparison of applicable test data with the acceptance criteria
- conclusions regarding system or component adequacy
- deficiencies relating to design and construction found during conduct of the tests, as well as system modifications and corrective actions required to correct these deficiencies
- cross-references and a distribution list

Formal reports may serve as valid test/phase completion certificates, as long as they contain all the required information. In addition to individual test reports, phase test reports and a final station commissioning report should be prepared.

The licensee should establish clear objectives for the state of design, operational and safety documentation at the time of turnover to operations. Documentation should be updated in a timely manner to reflect test results and resolution of deviations, in order to minimize the risk of human error. The CNSC will monitor the status of documentation as a part of ongoing compliance verification.

10.6 Modifications

Modifications to test procedures and other related documents shall be authorized by means of a formal licensee-approved process to control changes in documentation.

For modifications to the sequence of a test within a hold point or across hold points, reviews shall be performed and approvals obtained from the appropriate organizations. The reviews shall ensure that prerequisites for the out-of-sequence test are met in order to ensure the test is performed safely.

Temporary modifications to an approved design configuration for the purposes of commissioning testing shall be controlled by the commissioning organization, with licensee oversight. A review shall be performed to ensure that safety implications are considered.

Guidance

Modifications to the test sequence may be made because of:

- changes in external conditions (e.g., availability of the grid)
- progress in other tests
- status of periodic tests or maintenance activities

Proposals for design modifications to address a deviation should consider regulatory requirements and the stipulations of the operating organization, including the impact on other systems as well as safety implications for the commissioning program or individual tests.

11. Testing Phases

Tests shall be performed in phases and in a logical progressive sequence. There shall be a minimum of four phases:

1. Phase A: prior to fuel load
2. Phase B: prior to leaving reactor guaranteed shutdown state
3. Phase C: approach to critical and low-power tests
4. Phase D: high-power tests

Before proceeding to the next phase, it shall be confirmed that all prerequisites established between the licensee and the CNSC necessary for proceeding beyond the current phase are met.

Before transitioning from one phase of the commissioning process to the subsequent phase, the licensee shall assure that SSCs credited in the safety case for that phase have been installed and confirmed to the extent practicable to meet their designed safety function.

The CNSC may choose to witness some commissioning tests. In such cases, the licensee shall inform the CNSC so that staff can attend.

Guidance

Testing of a specific structure, system or component may require changes to the reactor facility configuration and modes of operation. Such testing may also place demands on appropriate functioning of other SSCs and the availability of various safety functions. Therefore, the sequence of testing is important to the overall safety of the reactor facility.

Tests should be planned in chronological order. Before nuclear material is brought onsite, applicable security systems should be commissioned and operational. Safety systems and safety-related systems (e.g., fire protection system, radiation protection system, emergency power system) should be operational before other systems are tested, for the protection of personnel, public and the environment, and facility or nuclear safety. Tasks necessary for the preparation of the next sequence of tests, in particular the availability requirements of the systems that are necessary, should be identified. Relevant safety system(s) and alarm settings, including those of radiological protection instruments, should be specified at appropriate stages during commissioning.

A system/component-level functional dependency matrix (within a system, across systems, at system interfaces, and across units for multi-unit sites) may help identify and plan the chronology and sequence of tests. Some tests across systems may need to be grouped and performed at the same time to ensure appropriate interfacing of such systems. Support systems (e.g., compressed air system, electrical system, service water system, demineralized water supply system) should be tested prior to the testing of other systems that depend on their availability.

Within the overall fuel-out (phase A) or fuel-in (phase B and up) (see sections 11.1 and 11.2, respectively) commissioning program, activities are usually further divided into cold and hot performance tests.

Cold performance tests are thermal hydraulic tests under cold conditions and involve:

- pressure and pressure drop

- flow
- pump-head/pump-flow characteristics
- equipment and instrument performance tests of the nuclear steam plant and balance of plant

Cold performance testing includes the initial starting of fluid and support systems. The objectives of these tests are to obtain initial operational data on equipment, determine operational compatibility with interfacing systems, and verify the functional performance of these systems.

Hot performance tests are thermal hydraulic tests under hot conditions and involve:

- pressure, and pressure drop
- flow
- equipment and instrument performance tests of the primary and secondary side systems

Hot performance testing should be undertaken to verify the conformance of systems with specified requirements. Where possible, these tests should follow cold performance tests under operating conditions that simulate typical temperatures, pressures and flow rates for anticipated operational occurrences (AOOs) and design-basis accidents (DBAs).

The tests should verify the effectiveness of heat insulation and heat removal systems. Initial flow rates, pump-head/pump-flow characteristics, pressure drop and temperature measurements at various locations around the reactor facility should be checked and confirmed against design calculations. The vibration levels, clearances and other provisions that were made to accommodate thermal expansion of SSCs should be checked and confirmed.

Phases are imposed to ensure proper assessment of available commissioning results against pre-defined acceptance criteria. Licensees may incorporate as many phases or hold points as they see fit. Depending on the situation, the CNSC may request regulatory hold points. The selection of regulatory hold points will generally be agreed upon between the licensee and the CNSC and incorporated into the licence.

For each phase, the test results and the general condition of the reactor facility should be reviewed and approved by the commissioning and operating organizations. It is recommended that the licensee develop detailed matrices of the prerequisites to be formally demonstrated for each phase and hold point within the phase. These matrices should be developed in agreement with all stakeholders.

The following steps should be undertaken at the end of each phase:

- documents to certify the performance of tests and provide phase clearances for the continuation of the commissioning program should be prepared and issued
- test certificates should be issued by the commissioning organization to certify that the tests have been completed in accordance with authorized procedures, stating any reservations about departures from or limitations of the procedures
- phase completion certificates should be issued by the commissioning organization to certify that all the tests in the respective commissioning phase have been satisfactorily completed (listing all deficiencies and non-conformances, if any); phase completion certificates should also list associated test certificates
- it should be ensured that succeeding phases can be conducted safely and that the safety of the reactor facility is never dependent on the performance of untested SSCs

The written request to the CNSC for approval to proceed beyond a commissioning phase should confirm that:

- all related project commitments tied to the phase have been completed
- all systems required for safe operation beyond the phase are available
- all specified operating procedures have been formally verified and validated
- specified training has been completed and staff are qualified
- all non-conformances and unexpected results identified leading up to the next phase have been addressed

11.1 Phase A: prior to fuel load

Before fuel is loaded into the core, the operability, availability and performance of the SSCs that will ensure safety with fuel in the core shall be tested, and appropriate tests of fuel handling equipment shall be completed.

Guidance

Satisfactory pre-operational tests (see appendix A for recommended tests) should take into account the proper sequence of tests of electrical systems, instrumentation systems and other service systems (such as cooling water and fire protection systems). This is to ensure the availability of the services required to implement the entire commissioning program. Special instrumentation and control required for the first fuel load and start-up should be installed and checked during this phase.

During this phase, operations personnel should take the opportunity to use, verify and validate operating procedures.

Some critical elements of heat sinks (flow rates, pressures, etc.) may be tested with fuel imitators in the core. These tests provide early assurances that safety will be maintained once fuel is loaded. Typically, testing of these systems will continue after fuel load.

Emergency management arrangements should be in place and tested before the commencement of fuel loading begins and take into account the fact that non-nuclear hazards, such as fire, could arise while the nuclear fuel is on the site.

11.2 Phase B: prior to leaving reactor guaranteed shutdown state

This phase focuses on ensuring the fuel is loaded into the reactor safely, and on confirming that the reactor is in a suitable condition to be started up and that all prerequisites for permitting the reactor to go critical have been met. This phase shall be successfully completed before approaching criticality.

During this phase:

1. the reactivity control mechanism shall be available and in service and the reactor shall be maintained subcritical at all times
2. availability of the automatic shutdown systems shall be confirmed
3. the availability of the reactor trip system against neutronic and process-related upsets shall be confirmed

4. subcriticality checks shall be performed at regular steps during fuel loading to determine safe loading increments for subsequent loading
5. predictions of the behaviour of the core in terms of its reactivity shall be available for the evaluation of subcriticality margin
6. acceptance criteria for the maximum permissible deviation of predicted values from measurements shall be defined
7. tests on coolant flow, pressure, temperature and the performance of associated instrumentation and control mechanisms shall be conducted
8. fuel loading shall be supervised by certified personnel from the operating organization

Guidance

This phase involves initial fuel loading and subcriticality tests (see appendix B for recommended tests).

The processes for loading fuel must provide assurance that fuel and structures are not damaged in the process of fuel load and that the nuclear material in the core is in the specific configuration established by design. For applicable reactor designs, the core should be fuelled in accordance with a predetermined loading pattern. Fuel loading procedures should include, as appropriate:

- periodic data recording
- audible indication of flux increase
- monitoring of neutron count rate when reactivity is being inserted or removed and during any other operations that could potentially affect core reactivity

Availability of the shutdown systems should be assured before a reactor state is entered that may require the system to actuate to prevent damage to the fuel and/or the facility. Where full testing of the functional part of the system and credited trips is not possible before entering a specific reactor state, the gap in assurance normally provided by a full testing program should be compensated by other means such as partial testing, wire by wire checking, additional analysis and modelling additional verification. Testing to fill the gaps should be scheduled at the first opportunity when plant systems enable conditions to allow testing.

Any changes occurring in the reactor should be reported immediately to the control room personnel. Fuel loading should be stopped if measurements deviate from predicted values and commence only after the root causes are determined and appropriate corrective actions are taken. If required by the safety analysis, the position of each core element should be independently confirmed and documented.

11.3 Phase C: approach to critical and low-power tests

This phase focuses on confirming reactor behaviour at the stage of initial criticality and subsequent low-power tests. It includes activities that cannot be performed with the reactor held in a subcritical state (shutdown state).

During this phase:

1. trip set points shall be verified to ensure that they are compatible with the demands of the tests scheduled in this phase
2. the availability of the automatic shutdown systems shall be confirmed for low-power shutdown

3. radiological surveys and functional tests of radiation protection equipment shall be made
4. changes in reactivity shall be continuously monitored and evaluated so that the prediction of the point of criticality is continually checked
5. the sequence and magnitude of the reactivity changes shall be performed in accordance with defined procedures
6. the performance of the reactor core shall be commensurate with design assumptions and predictions, and comply fully with the safety analysis report
7. it shall be confirmed that the reactor core is in proper condition to operate at higher power levels
8. characteristics of the reactivity control systems and shielding shall be commensurate with design assumptions and predictions, and shall comply fully with the safety analysis report
9. integrated system validation shall be completed if it has not been conducted during earlier phases of commissioning

Guidance

During this phase, criticality of the fuel in the reactor core is achieved for the first time (see appendix C for recommended tests). The power levels of this phase will be the lowest that give reliable and stable measurements and that enable the required conditions to perform the specified tests. Special very-low-power (start-up) instrumentation may be used if necessary and may need to be connected into the shutdown logic where trip coverage is not available from the normal shutdown means (detectors out of range).

Reactivity changes are controlled using reactivity devices such as mechanical control rods (and rods of other types), adjustable reflectors, liquid poison, and adjustment of process fluids such as coolant flow, liquid zone controls or moderator level. In these tests, reactor trip set points for different shutdown means should be set to conservative values.

Achieving criticality requires a cautious approach and continuous monitoring of the neutron flux. After the subcritical multiplication factor has been determined, predictions for the point of criticality should be performed while making smaller, successive adjustments to positive reactivity. The objective of these actions is to avoid passing through the point of criticality with a high rate of change in neutron flux (short period of multiplication). After criticality has been achieved, a conservative start-up rate of flux increase should be used in attaining low power.

11.4 Phase D: high-power tests

This phase focuses on demonstrating reactor and systems behaviour at higher power levels, including activities that could not be carried out at the power levels in Phase C.

During this phase:

1. high-power tests shall be performed at various bulk power intervals, and these intervals shall be approved by the CNSC
2. in accordance with the design, tests shall be made to demonstrate that the reactor facility is able to:
    a. safely operate at steady state under normal operating conditions
    b. mitigate or prevent AOOs escalating to more severe events
    c. safely cope with DBAs (note that the facility need not be put into a DBA condition, but rather the function of mitigating systems verified)

3. a documented review shall be carried out at the end of each high-power test to confirm that the operational limits and conditions are adequate and practicable and identify any constraints on the operation of the reactor facility

Guidance

This phase should generally be limited to those tests that can only be carried out at high power (see appendix D for recommended tests).

This phase of commissioning tests consists of incremental approach to full power. A comprehensive range of power tests should be made to confirm that the reactor facility can be operated in accordance with the design intent and that the reactor facility can continue to operate safely. Typically, power is increased in increments until full power is reached. At each increment, a series of prerequisite tests are performed that must be met before proceeding to the next power level. The CNSC may stipulate more than one regulatory hold point as power increases, based on the specifics of the testing program and the relevance to demonstrating the safe operation of the facility.

During testing, in order to minimize time at risk, tests that are necessary to demonstrate safe operability should be completed without delay.

12. Transfer of Structures, Systems and Components and the Reactor Facility

Appropriate procedures shall be in place for the transfer and ownership of SSCs and the reactor facility from the construction organization and non-licensee commissioning staff to the licensee's operating organization. These procedures shall describe the detailed process steps, including responsibilities and authorities of the parties involved.

Prior to fuel-in-core testing, all SSCs important to safety shall be under the control of the operating organization.

Before the transfer takes place, representatives of the organizations involved in the turnover process shall carry out facility walk downs of all systems.

The licensee shall maintain responsibility for safety and security at all times during the transfer.

The transfer of SSCs shall be documented. All commissioning records shall be turned over to the operating organization's records-management program and retained for the life of the reactor facility.

Guidance

Turnover includes the transfer of SSCs and documentation, and may also include the transfer of personnel. The transfer of documentation (paper and electronic) is a key feature in the turnover process. Documentation should be transferred in system packages and over a reasonable period of time, to enable reactor facility personnel to perform a comprehensive review of every package. Document transfers should also depend on how responsibilities for testing after fuel loading, at initial criticality, at low power and at power escalation are assigned.

Appendix A: Recommended Phase A Commissioning Tests

The following tests, as applicable to the facility should be performed prior to fuel loading:

- testing of relevant systems in main and secondary control rooms in service to support phase A testing
- confirmation that reactor coolant and connected systems meet cleanliness requirements
- confirmation of the availability and functionality of the reactor control system
- testing of neutron detectors
- service tests:
  - compressed air systems used for safety-related functions in service
  - fire protection systems in service throughout facility
  - safety-important process cooling systems in service (e.g., heat sink systems important to reactor cooling and emergency sources of water)
  - facility heating, ventilating and air conditioning systems (fans, ducts, dampers, chiller units, piping, tanks, instrumentation and control)
  - facility communication system (annunciating system, telephones and wireless)
  - nuclear security systems
- CANDU – moderator system tests:
  - leak test
  - pumps and motors
  - cover gas recombination units
  - relief valves in cover gas system
  - purification columns
  - liquid poison addition system
  - leakage collection system
  - heavy water addition and transfer system
  - vibration
  - water quality
- electrical system tests (as needed to support safe reactor operation):
  - AC power (normal, emergency and standby)
  - DC power (normal, emergency and standby)
  - back-up, emergency diesel, black-out diesel load sequencing tests
  - preliminary loss of offsite and house load power tests
- safety systems tests:
  - made operational to the extent possible
  - check insertion and withdrawal speeds for control absorbers/shut-off rods/adjustable reflectors
  - check insertion speeds for second shutdown system (if applicable)
  - logic/interlocks
- fuel storage and handling tests:
  - test and calibration of fuelling machines (CANDU)
  - fuel transfer systems
  - spent fuel storage bay cooling and purification systems (including alarms)
  - decontamination facilities

- radiation protection system tests:
  - area radiation monitors
  - personnel monitors and radiation survey instruments
  - laboratory equipment
  - *in situ* efficiency tests of air and absorption filters
- other generic commissioning for systems to support fuel load
- other prerequisites that could be considered for this phase include:
  - automatic shutdown systems poised
  - start-up monitoring instrumentation verified and made available to initiate automatic and manual reactor shutdown when necessary
  - wiring continuity and electrical protective devices checked
  - software verification and validation
  - settings on torque-limiting devices and calibration adjusted (CANDU)
  - all necessary “jumpers” and interlocks installed for the specific testing configuration
  - requirements and procedures ready to test the fuel handling and fuelling machine (CANDU) and/or any other tool or system as necessary
  - the means to prevent inadvertent criticality specified
  - the readiness of the neutron flux monitoring system
  - availability of qualified personnel and SSCs important to safety

Appendix B: Recommended Phase B Commissioning Tests

The following tests, as applicable to the facility, should be performed prior to leaving the shutdown state:

- reactor coolant system (RCS) pressure boundary integrity before filling
- testing of neutron detectors
- RCS tests:
  - flow verification (confirm flow distribution and absence of flow blockage)
  - pressurizer heaters available and feed/bleed paths open
  - RCS inventory control systems in service
  - pumps and motors
  - pressure control and relief valves
  - strainers/filters, purification columns, tanks, etc.
  - instrumentation used for monitoring system performance and logic functions
  - coolant water addition and transfer system available to supply make-up water on demand
  - vibration
  - water quality within specifications
  - boration systems
- containment integrity tests:
  - containment leak-rate test
  - functional tests on containment isolation valves, dampers, air locks and associated logic and instrumentation
  - leak detection and associated filtration and vent paths systems calibrated and functional
  - containment button-up logic to be fully tested and available for service
- RCS hot performance, including:
  - garter spring location check (CANDU)
  - baseline data for creep measurement
- check reactor trip logic available
- reactivity control system tests:
  - check control rod withdrawal and insert speeds
  - rod position indication
  - protective interlocks and circuitry
  - liquid zone control function (CANDU)
  - ion or fission chambers in service
  - chemical control of liquid poison addition within specifications
- reactor auxiliary systems (CANDU):
  - ventilation and heavy water vapor recovery system (fans, dampers, air coolers, dryers, temperature control, control logic, air flows and flow balancing, etc.)
  - end shield cooling system (flow, pumps and valves, venting, make-up system, chemical control, instrumentation, etc.)
  - calandria vault cooling system (pumps and valves, make-up system, chemical control, instrumentation, etc.)
  - annulus gas monitoring system (gas addition, piping, valves and associated instrumentation)

- power conversion system:
  - steam generators
  - steam expansion, restraint and operability tests
  - steam and feed water process lines
  - condensate and auxiliary feed water system
  - chemical treatment systems
  - turbine stop, control and intercept valves
  - steam dump, discharge and safety relief valves
  - steam extraction system
  - auxiliary feedwater flow measurement
  - condenser cooling water system
  - turbo generator and its auxiliaries (hydrogen cooling, seal and oil systems)
  - hydrogen leak detection system
  - turbine governing system
  - datum block readings
- radioactive waste capture, treatment and disposal systems:
  - liquid waste drainage systems available and activity/level monitoring in service
  - decontamination centre
  - liquid effluent segregation and storage system, treatment and disposal in service
  - solid waste handling and storage facilities in service for the level of waste anticipated
  - sampling and surveillance systems
- instrumentation and control systems in service:
  - main and secondary control rooms in service
  - emergency response center in service
  - pressurizer pressure and level control
  - bleed condenser pressure, temperature and level control (CANDU)
  - feed water flow control
  - steam generator pressure and level control
  - RCS pressure control, and flow and temperature monitoring
  - regulation and protection system
  - seismic instrumentation
  - failed fuel detection system
  - in-core flux monitoring and ion chamber instrumentation
  - calibration and neutron response check
  - detection of internal and external flooding conditions (CANDU)
  - control operator information system, programmable digital comparator system, radiation data acquisition system, fuel handling control system, etc.
  - sampling systems (light water, heavy water, steam, air)
- secondary control room tests:
  - verification of independent protection, control and monitoring
  - check of habitability and emergency procedures
- pressure testing of SSCs and overpressure protection devices
- integrated testing of fuel handling and transfer system (CANDU)
- verification of proper operation of associated alarms and protective functions

- generic commissioning for systems to support first criticality
- other prerequisites that could be considered for this phase include:
  - availability and readiness of qualified personnel and SSCs important to safety, to ensure the reactor is ready for start-up
  - surveillance necessary to demonstrate proper operation of interlocks, set-points and other protective features
  - appropriate start-up monitoring instrumentation available to initiate automatic and manual reactor shutdown when necessary
  - field inspections made to ensure that the equipment is ready for testing, including inspection for proper fabrication and cleanliness
  - availability of communication tools and verification of their operability

Appendix C: Recommended Phase C Commissioning Tests

The following approach to critical and low-power tests, as applicable to the facility, should be used:

- testing of neutron detectors
- achievement of first criticality in a safe, controlled, predictable manner
- check of the regulating system's automatic control function
- confirmation of temperature coefficient of reactivity for reactor coolant systems (all reactor types) and moderator (CANDU)
- measurement of the combined reactivity worth of the zone control units (CANDU)
- determination of the reactivity worth of each mechanical absorber rod
- measurement of axial and radial flux distribution for defined configurations of reactivity mechanisms
- testing of reactor shutdown and control systems
- neutron and gamma radiation surveys
- confirmation of performance of the low-power neutronic instrumentation
- commissioning of emergency core cooling systems to the extent possible
- confirmation of critical poison concentration (if applicable)
- verification of efficiency of reactivity control and shut-off means
- verification that auxiliary feedwater/cooling pumps are available

Appendix D: Recommended Phase D Commissioning Tests

The following tests, as applicable to the facility, should be performed in the approach to full power:

- testing of neutron detectors
- performance of the following, at various power levels:
  - power manoeuvre tests as would be required during normal operation
  - reactor setback and stepback tests as would be required during normal operation (CANDU)
  - verification of channel flow (CANDU)
  - calibration of flux mapping detectors (CANDU)
  - calibration of neutron power versus thermal power
  - calibration of ion chambers and in-core flux detectors
  - dynamic response to load rejections, including turbine trip
  - verification of chemical and radiochemical control systems and sampling yield results within specification
  - verification that piping and component movement, vibrations and expansions are acceptable for safety systems
  - verification of performance of main plant control, reactor coolant system pressure control, steam generator level control, generator speed, steam pressure control, etc.
  - verification of performance of control room instrumentation and control systems (comparison of measured to monitored values, validate analogue and digital safety functions)
  - radiation surveys to verify shielding effectiveness
  - verification of performance of heating, ventilating and air conditioning systems
  - verification of shutdown capability of secondary control room
- performance of the following, at lower power levels:
  - thermal and control performance tests of nuclear steam plant and balance of plant systems
  - gaseous fission product / delayed neutron scan
  - atmospheric steam discharge valve capacity test (CANDU); power-operated relief valve and safety valve tests (all)
  - condenser vacuum test
  - digital control computers or distributed control systems (DCS) transfer of control tests (CANDU)
  - generator run-up and overspeed tests
  - turbine stop valve / governor valve leak test
  - generator open- / short-circuit tests
  - generator voltage adjustment and reactive capability checks
  - automatic voltage regulation limit checks
  - generator synchronization to grid
  - dynamic response to single and multiple reactor coolant pump trips
  - steam generator moisture carry-over test
  - dual computer failure test or failure of relevant DCS partitions (CANDU)

- performance of the following, at higher power levels:
  - reactor coolant system boiling check (CANDU)
  - crash cool rundown test
  - testing of reactor shutdown and control systems
  - duty changeover tests (condensate extraction pump, boiler feed pump, steam generator, de-aerator and condenser level control valves)
  - test for loss of offsite / house power

Appendix E: Recommended Organizational Responsibilities

Commissioning organization

The responsibilities of the commissioning organization should include, but are not limited to, the following:

- planning the development of the commissioning program in advance, including detailed test sequences, time schedules and staffing requirements
- updating the commissioning program in light of experience in commissioning and as a result of design modifications
- establishing a procedure for the preparation, review and approval of test and other procedures
- ensuring that field visual aids (e.g., drawings, flow sheets), operating and maintenance instructions, commissioning procedures, formats for commissioning and test reports, reactor facility turnover documents and submissions to the CNSC are available
- establishing a procedure for the systematic recording of reactor facility data for future use
- establishing a procedure to ensure that incidents and unexpected events during commissioning are handled and analyzed, so that the experience can be fed back to the designers and the operating organization
- verifying that SSCs have been satisfactorily installed and codified for proper identification
- ensuring that the prerequisites for the commissioning program have been satisfied and that pre-operational tests (such as system flushing, functional checks, logic checks, interlock checks and system integrity checks) have been completed
- ensuring that commissioning procedures comply with appropriate rules and regulations for security and safety, including radiological and environmental protection and nuclear, industrial and fire safety
- ensuring that systems are commissioned safely, and confirming that procedures are adequate
- implementing all tests in the commissioning program, including repeat testing of the systems that have been commissioned initially as partially installed
- making suitable arrangements for testing and maintaining systems (particularly safety-related items) for which responsibility has been accepted
- directing the operation of systems in the commissioning program and providing input for updating operational flow sheets, operating and maintenance instructions and procedures based on commissioning experience
- issuing commissioning test reports
- ensuring the CNSC has approved safety-related test results as necessary
- ensuring a process is in place to control the calibration of test and measurement equipment
- establishing a procedure to ensure that all participants in the commissioning process are suitably qualified and experienced
- ensuring the configuration control maintains consistency between the physical state of the installation and the test procedures and design requirements, and reporting any discrepancies to the relevant parties
- ensuring that design changes are requested, reviewed, implemented and re-tested when design criteria are not met or when they fall short
- establishing and implementing a system for controlling, recording and communicating temporary changes to reactor facility and equipment
- issuing test and completion certificates or their equivalent

- providing up-to-date baseline information to the operating organization
- informing the operating organization of any deficiency detected in commissioning tests, so corrective actions can be taken
- maintaining a record of limiting conditions in commissioning, and ensuring tests to be performed do not exceed these conditions
- ensuring that reactor facility performance is in accordance with the design intent, including all aspects of radiological and environmental protection, and nuclear, industrial and fire safety
- documenting that the commissioning program has been satisfactorily completed
- transferring the responsibility for operation and maintenance of commissioned systems and the reactor facility to the operating organization, using a system of relevant documents
- establishing and implementing procedures that ensure the orderly transfer of responsibilities for structures, systems and components from the construction organization to the commissioning organization, and from the commissioning organization to the operating organization
- establishing procedures for analyzing test results
- ensuring that any detected deviations are recorded, resolved and documented
- recording all commissioning feedback experience
- establishing a procedure in order to compile the lessons learned from commissioning activities and related corrective actions

Operating organization

The responsibilities of the operating organization should include, but are not limited to, the following:

- overseeing the commissioning program (including compliance monitoring activities)
- being qualified to participate as early as possible in the commissioning activities
- satisfying itself that the transferred systems comply with specified performance requirements, the design intent and safety and regulatory requirements
- accept responsibility (operational, maintenance and safety as per operating limits and conditions) for the transferred systems
- increasing competency in the methods of operation of the reactor facility
- carrying out operation and maintenance with competent and duly authorized personnel using approved techniques to meet the needs of the commissioning program (RD/GD-210, *Maintenance Programs for Nuclear Power Plants*, provides more detailed requirements for maintenance programs)
- establishing and implementing a procedure for the systematic recording of reactor facility data generated by the commissioning tests
- maintaining reactor facility design and configuration control over the commissioning phase up to the start of operating life of the facility; this also includes maintaining the safety analysis report current
- participating in a safety assessment when necessary
- assisting with design modifications to rectify design deficiencies and produce complete documentation of the modification, including requalification tests
- recording all operating experience feedback and associated lessons learned
- establishing and implementing appropriate emergency arrangements

Construction organization

The responsibilities of the construction organization should include, but are not limited to, the following:

- ensuring that structures, systems and components have been built and installed in accordance with design requirements and specifications
- making suitable arrangements for surveillance, preservation and maintenance to prevent deterioration after installation (construction) is complete, and before the turnover
- providing, for use as baseline data, as-built documentation of installation construction and test reports, highlighting design changes and concessions
- transferring the installed systems to the commissioning organization using a system of reactor facility turnover documents
- ensuring the clearance of remaining open points conditioning the acceptance of the transfer
- correcting deficiencies in construction and installation that were detected during commissioning
- assisting the commissioning organization in resolving construction-related issues

Other participants in commissioning activities

The responsibilities of the other participants, such as designers, manufacturers and supporting technical organizations in the commissioning activities, should be specified in the appropriate contracts. The following responsibilities should be considered:

- co-operating with relevant parties engaged in commissioning activities by means of active participation when required
- providing specialist knowledge, expertise and relevant experience from reactor facilities already commissioned
- providing support for evaluation and assessment of tests results including any deviations
- providing baseline data and all necessary information
- providing a safety assessment when necessary
- participating in the analysis of discrepancies and unexpected events
- ensuring that configuration control is maintained and that the affected systems' design basis documentation – including the final safety analysis report – has been updated to reflect any design changes and concessions
- devising modifications in order to rectify design deficiencies, and providing complete documentation (including requalification tests) of the modifications

Appendix F: Recommended Interface Arrangements

Interfaces between construction and commissioning organizations:

- procedures for transferring structures, systems and components (SSCs) from construction to commissioning
- procedures for isolating reactor facility portions transferred to commissioning from the part remaining under construction
- prerequisites for the start of the commissioning program and the start of system commissioning
- special precautions necessary for the commissioning of partly installed systems
- procedures for performing work on systems under commissioning

Interfaces between commissioning and operating organizations:

- provisions in the definition of role, functions and delineation of responsibilities of operating and commissioning organizations before transfer of SSCs for operation
- procedures for transferring SSCs, the unit and the facility for operation
- methods of identifying special technical, operational or staffing restrictions necessary as a result of partial completion of a construction or commissioning activity
- baseline data derived from commissioning, such as the issuing of formal test reports and a statement of the existing radiological conditions
- changes in responsibility for safety, depending on considered commissioning milestones and performed transfers to operation, including the nomination of responsible persons
- modifications to the reactor facility and to the procedures
- availability of as-built drawings, instructions and procedures for operating and maintaining the systems and the reactor facility
- conditions for access of personnel, with consideration given to delineation between systems already in operation and those being tested
- control of temporary procedures and equipment available during commissioning but not appropriate to normal operation; e.g., special start-up instrumentation or duplicate safety keys and authorization for the use of jumpers and vetoes
- the implementation of operating and maintenance requirements for SSCs as each system is transferred to the operating organization
- provision of sufficient opportunity for the operating personnel to become trained in, and familiar with, operating and maintenance techniques for the reactor facility
- procedures for radiological zone mapping, monitoring (including personal dose recording) and radiation protection
- training in radiological safety and authorization of commissioning personnel to work in the controlled area
- reassessment of routine operating and maintenance instructions and procedures in light of experience gained in commissioning
- development and implementation of measures for emergency preparedness and response
- training in required areas for nuclear security
- development and implementation of procedures for nuclear security, including access control, alarm assessment and response

- during commissioning, the recording of information that could have implications for decommissioning, and subsequent turnover of these records to the operating organization (this information could include records of spills or other unusual occurrences with potential long-term effects)

Glossary

anticipated operational occurrence (AOO)
An operational process deviating from normal operation that is expected to occur at least once during the operating lifetime of a reactor facility but, because of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions. AOO is a plant state.

authorized inspection agency
An organization designated by the regulatory authority as authorized to register designs and procedures, perform inspections, and perform other defined functions.

commissioning
A process intended to demonstrate that installed structures, systems and components perform in accordance with their specifications before they are put into service.

commissioning documentation
The plans, instructions, procedures, drawings, reviews, records, reports and the like, which together describe the commissioning of a system or the integrated reactor facility.

commissioning report
A report written on completion of a logical group of commissioning activities to record results, assess compliance with the acceptance criteria, record actions taken to rectify any deficiencies.

commissioning tests
Testing to demonstrate that structures, systems and components perform within their design specifications.

construction
The process of procuring, manufacturing and assembling the components, carrying out civil work, installing and maintaining components and systems, and performing associated tests.

construction organization
The entity managing the procurement, manufacture and assembly of components, carrying out of civil work, installment and maintenance of components and systems, and performance of associated tests. They may be part of the licensee's organization or a contracted entity.

construction safety case
The information provided with the licence application for a licence to construct, including the documents to which the application makes reference, once approved by the CNSC.

design
In the context of a review of a reactor design, the overall planning and philosophies that go into ensuring that every aspect of the physical design will consider safety, security and safeguards under all scenarios it may encounter during its lifecycle.

design basis
The range of conditions and events taken explicitly into account in the design of a nuclear facility, according to established criteria, such that the facility can withstand this range without exceeding authorized limits. **Note:** For Class IA facilities, this is achieved by the planned operation of safety systems.

design-basis accident (DBA)
Accident conditions for which a nuclear facility is designed according to established design criteria, and for which damage to the fuel and the release of radioactive material are kept within authorized limits. DBA is a plant state.

facility configuration information
Recorded information that describes, specifies reports, certifies, or provides data or results regarding the design requirements or design basis, or that pertains to other information attributes associated with the facility and its structures, systems and components.

graded approach
A method or process by which elements such as the level of analysis, the depth of documentation and the scope of actions necessary to comply with requirements are commensurate with:

- the relative risks to health, safety, security, the environment, and the implementation of international obligations to which Canada has agreed
- the particular characteristics of a facility or activity

hold point
A commissioning activity that requires approval of the designated authority in order for commissioning to proceed.

integrated system validation
An evaluation, using performance-based tests, to determine whether an integrated system's design (i.e. hardware, software and personnel elements) meets performance requirements and supports the facility's safe operation.

interoperability
The capacity to manage and communicate electronic product and project detail between collaborating firms and within individual companies' design, construction, operations, maintenance, and business process systems.

licensee
The organization authorized by a licence from the Canadian Nuclear Safety Commission to build and operate a reactor facility in accordance with specified requirements. The licensee has the overall responsibility and controlling authority to oversee the safe and satisfactory completion of the reactor facility design, procurement, manufacturing, construction, commissioning and operation, and decommissioning.

licensing basis
A set of requirements and documents for a regulated facility or activity comprising:

- the regulatory requirements set out in the applicable laws and regulations
- the conditions and safety and control measures described in the facility‘s or activity's licence and the documents directly referenced in that licence

- the safety and control measures described in the licence application and the documents needed to support that licence application

management system
A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective way. **Note:** The management system integrates all elements of an organization into one coherent system to enable all of the organization's objectives to be achieved. These elements include the structure, resources, and processes. Personnel, equipment and organizational culture as well as the documented policies and processes are parts of the management system.

nuclear power plant (NPP)
A nuclear facility consisting of any fission-reactor installation that has been constructed to generate electricity on a commercial scale. **Note:** An NPP may include more than one nuclear reactor.

operation
All activities performed to achieve the purpose for which a nuclear facility was constructed. For example, at reactor facilities, operation includes maintenance, refuelling, in-service inspection and other associated activities.

reactor facility
Any fission reactor as described in the *Class I Nuclear Facilities Regulations*, including structures, systems and components:

- that are necessary for shutting down the reactor, ensuring that it can be kept in a safe shutdown state
- that may contain radioactive material and that cannot be reliability isolated from the reactor
- whose failure can lead to a limiting accident for the reactor
- that are tightly integrated into the operation of the nuclear facility
- that are needed to maintain security and safeguards

regulatory hold point
A commissioning activity that requires approval of the Canadian Nuclear Safety Commission in order for commissioning to proceed.

safety analysis
With respect to deterministic safety analysis, analysis by means of appropriate analytical tools that confirms the design basis for the items important to safety and ensures that the overall nuclear facility design is capable of meeting specified acceptance criteria.

safety assessment
An assessment of all aspects relevant to safety of the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility.

safety case
An integrated collection of arguments and evidence to demonstrate the safety of a facility and the meeting of all applicable regulatory requirements. A safety case will normally include a safety assessment, but could also typically include information (such as supporting evidence and reasoning) on the robustness and reliability of the safety assessment and the assumptions made therein.

small reactor
A reactor with a power level of less than approximately 200 megawatts thermal that is used for research, isotope production, steam generation, electricity production or other applications.

structures, systems and components (SSCs)
A general term encompassing all of the elements of a facility or activity that contribute to protection and safety. Structures are the passive elements: buildings, vessels, shielding, etc. A system comprises several components, assembled in such a way as to perform a specific (active) function. A component is a discrete element of a system. Some examples are wires, transistors, integrated circuits, motors, relays, solenoids, pipes, fittings, pumps, tanks and valves.

structures, systems and components important to safety
Structures, systems and components of the nuclear power plant associated with the initiation, prevention, detection or mitigation of any failure sequence and that have an impact in reducing the possibility of damage to fuel, associated release of radionuclides or both.

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Additional Information

Codes, standards and guides:
The following national and international codes, standards and guides, which are the most widely accepted and used internationally, provide detailed information on how to meet the requirements of this regulatory document:

- American Concrete Institute, ACI 349, *Code requirements for Nuclear Safety Related Concrete structures*, Farmington Hills, Michigan, 2007.
- American National Standards Institute (ANSI) and Nuclear Information and Records Management Association, ANSI/NIRMA CM 1.0-2007, *American National Standard for Guidelines for Configuration Management of Nuclear Facilities*, New York, 2007.
- ANSI and American Nuclear Society, ANSI/ANS-56-8, *Containment System Leakage Testing Requirements*, New York, 2002.
- American Society of Mechanical Engineers (ASME), *Rules for Construction of Nuclear Facility Components ASME Boiler and Pressure Vessel Code, Section III, Division I,* New York, 2010.
- ASME, *Rules for Construction of Nuclear Facility Components, ASME Boiler and Pressure Vessel Code, Section III, Division 2,* New York, 2010.
- ASME, NQA-1-2008, *Quality Assurance Requirements for Nuclear Facility Applications*, 2008.
- ASME, NQA-1a-2009, *Addenda to ASME NQA-1-2008: Quality Assurance Requirements for Nuclear Facility Applications*, 2009.
- British Standards Institution, OHSAS 18001:2007, *Occupational Health and Safety Management Systems – Requirements*, 2007.
- CNSC, RD-360, *Life Extension for Nuclear Power Plants*, 2008.
- CNSC, G-278, *Human Factors Verification and Validation Plans,* 2003.
- CNSC, G-323, *Ensuring the Presence of Sufficient Qualified Staff at Class I Nuclear Facilities – Minimum Shift Complement*, 2007.
- CNSC, RD/GD-98, *Reliability Programs for Nuclear Power Plants*, Ottawa, 2012
- CNSC, S-296, *Environmental Protection Policies, Programs and Procedures at Class I Nuclear Plants and Uranium Mines and Mills*, 2006.
- CNSC, G-225, *Emergency Planning at Class I Nuclear Facilities and Uranium Mines and Mills*, 2001.

CSA Group standards:

- CSA N285.0, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Plants*, Mississauga, 2012.
- CSA N285.4-10, *Periodic Inspection of CANDU Nuclear Power Plant Components*, Mississauga, 2010.
- CSA N285.5, *Periodic Inspection of CANDU Nuclear Power Plant Containment Components*, Mississauga, 2013.

- CSA N286, *Management System Requirements for Nuclear Facilities, Mississauga*, 2012.
- CSA Group, CSA N287.1, *General Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants*, Mississauga, 1993, reaffirmed 2009.
- CSA, N287.4, *Construction, Fabrication, and Plant Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants*, Mississauga, 2009.
- CSA N287.5, *Examination and Testing Requirements for Concrete Containment Structures for Nuclear Power Plants*, Mississauga, 2011.
- CSA N287.6, *Pre-operational Proof and Leakage Testing Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants*, Mississauga, 2011.
- CSA Group, CSA N287.7, *In-service examination and testing requirements for concrete containment structures for CANDU nuclear power plants*, 2008.
- CSA N288.4-10, *Environmental Monitoring*, Mississauga, 2010.
- CSA N289.4, *Testing procedures for seismic qualification of nuclear power plant structures, systems and components*, Mississauga, 2012.
- CSA N290.7, *Cyber security for nuclear power plants and small reactor facilities* (draft).
- CSA N291-08, *Requirements for safety-related structures for CANDU Nuclear Power Plants, Mississauga*, 2008.
- CSA, N293-12, *Fire Protection for CANDU Nuclear Power Plants*, Mississauga, 2012
- CSA, N393-13, *Fire protection for facilities that process, handle or store nuclear substances*, Mississauga, 2013.
- CSA, Z1000-06, *Occupational Health and Safety*, Mississauga, 2012.

IAEA Safety Standards:

- International Atomic Energy Agency, draft standard, DS441, *Construction for Nuclear Power Plants Safety Guide*, Vienna.
- IAEA, SSR-2/2, *Safety of Nuclear Power Plants: Commissioning and Operation*, 2011.
- IAEA, GS-R-3, *The Management System for Facilities and Activities*, 2006.
- IAEA, GS-G-3.1, *Application of the Management System for Facilities and Activities*, 2006.
- IAEA, GS-G-3.5, *The Management System for Nuclear Installations*, 2009.
- IAEA, NS-G-2.2, *Operating Limits and Conditions and Operating Procedures for Nuclear Power Plants*, 2000.
- IAEA, GS-R-2, *Preparedness and Response for a Nuclear or Radiological Emergency*, 2002.
- IAEA, GS-G-2.1, *Arrangements for Preparedness for a Nuclear or Radiological Emergency*, 2007.

Safeguards agreements:

- Agreement Between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons Article iaea.org/Publications/Documents/Infcircs/Others/infcirc164.shtml
- Protocol Additional to the Agreement Between Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non- Proliferation of Nuclear Weapons iaea.org/Publications/Documents/Infcircs/2000/infcirc164a1.pdf

Nuclear industry organizations:

- Institute of Nuclear Power Operations (INPO) inpo.org
- World Association of Nuclear Operators (WANO) wano.info
- Electric Power Research Institute (EPRI) epri.com
- Nuclear Energy Institute (NEI) nei.org
- Institute of Electrical and Electronics Engineers (IEEE) ieee.org
- Organisation for Economic Co-operation and Development – Nuclear Energy Agency (OECD-NEA) oecd-nea.org
- International Atomic Energy Agency (IAEA) iaea.org
  Safety Series, Nuclear Energy Series, Safety Report Series, Nuclear Security Series and Technical Documents
- Project Management Institute (PMI), PMBOK® Guides and Standards pmi.org

Other nuclear regulatory organizations:

- United States Nuclear Regulatory Commission (NRC) nrc.gov
- United States Department of Energy (DOE) energy.gov
- United Kingdom's Office for Nuclear Regulation onr.org.uk/
- Finland's Radiation and Nuclear Safety Authority (STUK) stuk.fi/en_GB/
- French Safety Authority (ASN) french-nuclear-safety.fr

CNSC Regulatory Document Series

Facilities and activities within the nuclear sector in Canada are regulated by the Canadian Nuclear Safety Commission (CNSC). In addition to the *Nuclear Safety and Control Act* and associated regulations, these facilities and activities may also be required to comply with other regulatory instruments such as regulatory documents or standards.

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1.4 Class II facilities
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2.0 Safety and control areas

Series 2.1 Management system
2.2 Human performance management
2.3 Operating performance
2.4 Safety analysis
2.5 Physical design
2.6 Fitness for service
2.7 Radiation protection
2.8 Conventional health and safety
2.9 Environmental protection
2.10 Emergency management and fire protection
2.11 Waste management
2.12 Security
2.13 Safeguards and non-proliferation
2.14 Packaging and transport

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3.2 Public and Aboriginal engagement
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3.5 CNSC processes and practices

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