DS 446: Draft no.1
Date: xxx

IAEA SAFETY STANDARDS
for protecting people and the environment

Status: For MS consultations
Deadline 29 February 2012

Title
Commissioning for Nuclear Power Plants

DRAFT SAFETY GUIDE
DS446

Revision of NS-G-2.9 “Commissioning for Nuclear Power Plants”

IAEA

International Atomic Energy Agency

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SAFETY

STANDARDS

SERIES

Commissioning for Nuclear Power Plants

SAFETY GUIDE

DS446

INTERNATIONAL

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1. INTRODUCTION

BACKGROUND

1.1 This Safety Guide was prepared under the IAEA programme for safety standards for nuclear power plants. It supplements and elaborates on Section 6 “Plant commissioning” of Safety of Nuclear Power Plants: Commissioning and operation [1] on specific safety requirements for the commissioning programme of nuclear power plants. This Safety Guide is a revision of the IAEA Safety Guide on Commissioning for Nuclear Power Plants which was issued in 2003 as Safety Series No. NS-G-2.9;

1.2 The revision of the Safety Series publication No. NS-G-2.9 was conducted according to the following:

- the technical content of the original Safety Guide was kept largely unchanged and updated where necessary;
- additional material resulting from the development of other IAEA standards and guides and from recent experience in the area of commissioning was included;
- the text was restructured to be in accordance with the logic of organizing, managing and implementing commissioning of a nuclear power plant;
- the content was giving more explicit attention to the role and authorization process of the regulatory body and the operating organization

OBJECTIVE

1.3 The objective of this Safety Guide is to give recommendations based on international good practices in the commissioning of nuclear power plants, as currently followed in Member States, which will enable commissioning to proceed safely and to a high quality. It will also enable the necessary assurances to be provided that the plant has been constructed in accordance with the design intent and can be operated safely.

1.4 Some or all of this Safety Guide may be relevant when a nuclear power plant is to be restarted after an extended shutdown period. Where extensive modifications have been made to an existing nuclear power plant, the commissioning of these modifications and their integration into the plant may require comprehensive tests to demonstrate that the plant meets the original or modified design requirements. The commissioning of modifications is covered in Ref. [2]; however, all or part of this Safety Guide may be used.

SCOPE

1.5 This Safety Guide deals with the commissioning of land-based stationary thermal nuclear power plants of all types. It covers how to meet the requirements of the commissioning programme, organization and management, test and review procedures, and the interfaces between organizations involved in the commissioning activities including the regulatory body. It also deals with the control of changes in the commissioning programme and with the documentation required and produced in commissioning.

STRUCTURE

1.6 Section 2 relates to the entire commissioning process. The commissioning objectives are described as well as recommendations for the preparation and approval of the commissioning programme. The different stages of commissioning are covered in accordance with the practices commonly adopted by Member States. The regulatory role and the operating organization role during commissioning for approval, authorization and supervision are presented.

1.7 Section 3 describes the organizational matters of the commissioning process including the functions and responsibilities of the parties involved and the interfaces between them. It covers the characteristics of the management system of particular relevance to commissioning, and includes management for safety, quality management and qualification of the commissioning personnel. The organizational interfaces among construction, commissioning and operation are presented as well as the management of plant handover.

1.8 Section 4 presents practical issues relating to the implementation of the commissioning programme. The commissioning stages and the different aspects of the testing which forms the core of the commissioning programme are presented and discussed. Initial fuel loading as well as the achieving of initial criticality is dealt with. Regulatory approval during commissioning and authorization for subsequent stages are dealt with.

1.9 Section 5 deals with the documentation to be prepared and produced during commissioning, and the requirements for the lifetime records.

1.10 The Appendix identifies the pre-requisites for fuel loading and presents specific items to be included in the fuel loading procedures. The Annexe lists examples of typical commissioning tests.

2. COMMISSIONING PROCESS

2.1 Commissioning is an essential process for the subsequent safe operation of the plant and should be carefully developed, planned, executed and regulated. The commissioning should be considered as a progressive transition between construction and operation of the plant.

2.2 Good coordination and communications should be established among all participants to the commissioning process (designers, construction group, license holder, commissioning and operating groups) keeping all the involved parties informed of all pertinent decisions.

COMMISSIONING OBJECTIVES

2.3 The commissioning has the objective to demonstrate that the NPP as constructed meets the design requirements and the safety requirements as described in the safety analysis report and the license conditions. For the achievement of future safe and reliable operation of the plant, the commissioning process should:

- to validate those operating and surveillance procedures for which the commissioning tests provide representative activities and conditions;
- to validate by trial use, to the extent practical, that the facility operating procedures and the emergency procedures are adequate;
- to familiarise the NPP's operating, maintenance and technical staff with the operation of the power plant;

COMMISSIONING PROGRAMME

2.4 The commissioning programme should cover all the activities to be performed on structures, systems and components to bring them to an operating mode and should cover the widest range of plant conditions considered in the safety analysis report and in the license conditions. It should allow verifying, while remaining in a safe domain, the assumptions made in the safety analysis report and the existence of adequate margins between design and safety requirements and actual performance.

2.5 The commissioning programme to be performed on site should take into account, to the extent possible, tests performed off site if adequately justified for their application to structures, systems and components (SSC) as installed and integrated with their physical and functional interfaces in the NPP onsite.

2.6 As part of the commissioning program a detailed list of commissioning activities should be prepared. Responsibilities for implementing and reporting on the various parts of the commissioning programme should be clearly defined. In planning commissioning, all activities and organizations involved should be taken into consideration.

2.7 Adequate provision should be made for the allocation of responsibilities for safety at different milestones of the commissioning programme, especially with reference to the:

— arrival of fuel at the site enacting the safety and security link with fuel storage, including control of building access and relevant systems operation and monitoring;

— first fuel loading enacting the safety link with nuclear plant operation;

2.8 The commissioning programme should be structured so as to ensure that:

— all the tests necessary to demonstrate that the plant meets the design intent stated in the safety analysis report are performed;
— the tests are performed in a logical sequence: in particular, tests should be arranged to be progressive, so that the plant is exposed to less onerous conditions before more onerous ones;
— the tests are grouped in commissioning stages in a logic sequence from non-nuclear testing stages to nuclear testing stages and from individual components and systems tests to overall integrated systems tests stages, with at the end overall plant tests stages;
— the programme provides means of identifying hold points in the commissioning process;
— operating personnel are trained and procedures are validated;
— milestones including whose where the regulatory body authorization is required to proceed in the process of commissioning are identified;

2.9 Whatever the organizational arrangements for commissioning of the nuclear power plant, the operating organization should review and approve the commissioning programme.

2.10 The commissioning programme should include:

— the points at which reviews and hold points are required to check the compliance to safety requirements and receive authorization for proceeding from the regulatory body;
— any applicable requirements of the regulatory body, including the witnessing of specified tests;
— the title of each test together with a unique identification;
— cross-references to other documents relevant to commissioning; and
— provision for data collection for further use;

2.11 During commissioning, normal operating procedures, including those for operational periodic tests should be widely used to validate their applicability. The emergency operating procedures should also be validated in the commissioning programme, to the extent possible.

2.12 The commissioning programme should include provisions to ensure that operating and maintenance personnel in all disciplines participate to the extent possible in commissioning activities and that the operating procedures are validated to the extent practicable with the participation of plant staff. Designers and other specialists should be involved in the development and review process of commissioning and tests programmes and procedures.

2.13 The programme should provide a framework for the scheduling of tests and related activities, and for suitable personnel and equipment to be available at the proper time. The programme should also provide for the timely production of all documentation.

2.14 The commissioning programme should be written in such a form as to enable the objectives and methods of testing to be readily understood by all concerned and to allow control and co-ordination by management.

2.15 The commissioning programme should be prepared in the frame of the existing management system giving proper consideration to all management aspects.

STAGES OF COMMISSIONING

2.16 The commissioning programme of a nuclear power plant should be divided into stages whose number and size will depend upon safety requirements and technical and administrative requirements. A review of the stage test results should be completed before continuing to the next stage. The review should enable a judgement to be made on whether the commissioning programme should continue to the next stage, and whether the succeeding stages should be modified as a consequence of the test results or because some tests in the stage had not been undertaken or had not been completed. (The Annex provides a typical list of tests to be considered in developing the commissioning programme.)

2.17 In addition, if the sequence of tests in a stage of commissioning is significant for safety, sub stages may be required by the operating organization or regulatory body. Each stage and sub stage should be followed by a review before the next stage is started. Before the start of initial criticality tests, low power tests and power ascension tests, all the tests at the previous stages should be completed and open issues, if any, accepted as to be cleared before or at next stage.

2.18 On the basis of the broad range of commissioning practices in States, the commissioning process can be divided into the following stages and sub - stages:

— Non-nuclear testing, which include:
  - individual pre-operational tests of components and systems;
  - overall pre-operational systems tests;
— Nuclear testing, which include:
  - initial fuel loading;
  - subcritical tests;
  - initial criticality;
  - low power tests;
  - power ascension tests;

2.19 The sequence of tests within each sub stage should be given in the order in which they are expected to be performed. Adjustment in the test sequence can be performed according to test progress, test results or external conditions such as grid availability, need of periodic tests or maintenance activities performance. These adjustments require respect of safety conditions and a common agreement of commissioning and operation organizations.

2.20 Each stage/sub stage should include the tasks necessary for the preparation of the succeeding stage/sub stage and in particular the availability requirements of the systems for the succeeding stage.

2.21 The relevant safety system settings and alarm settings, including those of radiological protection instruments, should be specified at the appropriate commissioning stages or sub stages.

EXECUTION OF THE COMMISSIONING PROGRAM

2.22 Testing, as the core of the commissioning programme, should be sufficiently comprehensive to demonstrate that the plant can operate in all modes for which it has been designed to operate. However, tests should not be conducted and operating modes or plant configurations should not be established if:

— they have not been analysed and found safe;
— they fall outside the range of assumptions made in the safety analysis report; or
— they might damage the plant or jeopardize safety;

2.23 Appropriate and extensive tests of the NPP safety functions and related structures systems and components should be identified and executed.

2.24 In determining the sequence of testing, the following points should be carefully considered:

— certain systems should have prior testing so that they are available for the proper testing of other systems;
— certain systems should be operational to ensure that other systems can be tested without jeopardizing personnel, the plant or safety;
— relevant tests should be grouped together in an integrated systems test stage (or sub-stage);

2.25 Specific programmes and procedures should be written in support of the commissioning programme and should describe the principles, objectives and nature of the tests. They should include the criteria for judging the validity of the results and the acceptance criteria. These procedures for systems important for safety should contain checks that all performance levels and operating parameters have been demonstrated for all the operating configurations (normal, transient and accident conditions) to the extent possible.

2.26 The commissioning programme should be comprehensive, including statutory non-nuclear tests according to national practice, and should have sufficient scope to ensure that there have been no omissions in testing complex systems.

2.27 For multiunit sites the following provision should be taken:

a. Separate commissioning programme should be produced for each unit;
b. If some of the structures, systems and components are common to more than one unit, tests should be conducted to provide assurance that the specified performance requirements of these structures, systems and components can be met for the design intent of each unit;
c. Special provision should be made to ensure that the safety of a unit already in operation is not jeopardized in the commissioning tests of another unit. Such provisions should include conducting a hazard assessment and may require obtaining the prior approval of the regulatory body, in accordance with national practices, or specific written approval from the manager responsible for the operating unit;

REGULATORY BODY ROLE

2.28 The commissioning programme, together with other relevant documentation, should be submitted for review and approval to the regulatory body, in accordance with national practice.

2.29 Close liaison should be maintained between the regulatory body and the operating organization throughout the implementation of the whole commissioning programme.

2.30 The regulatory body during the implementation commissioning program at predefined hold points or milestones, based on the evaluation of test results, appropriate reports prepared by the licensee and onsite inspection activity, should decide whether the licensee may proceed to subsequent stage/sub stage of the commissioning program.

OPERATING ORGANIZATION ROLE

2.31 The operating organization, as the license holder to operate the plant, bears the overall responsibility for nuclear and radiation safety and should ensure the correct and satisfactory organization, planning, execution and assessment of commissioning process.

2.32 Appropriate organizational arrangements should be established to ensure that the operating organization can correctly and effectively discharge its responsibility, 2.33 The operating organization should take appropriate actions during the commissioning phase to promote and foster the development of safety culture at the plant and to ensure the involvement in the commissioning activity of the operating personnel as earlier as possible.

3. COMMISSIONING ORGANIZATION & MANAGEMENT

MANAGEMENT SYSTEM FOR COMMISSIONING

3.1 For the commissioning phase, the operating organization should develop and implement a management system that:

a. Meets the requirements established in Ref. [GS-R-3];
b. Takes into account the generic recommendations provided in Ref. [GS-G-3.1] and Ref. [GS-G-3.5].

3.2 The following recommendations have been developed to provide a means of meeting the requirements in Ref. [GS-R-3] for the commissioning of nuclear power plants. They are supplementary to, and should be read in conjunction with, the recommendations provided in Ref. [GS-G-3.1] and Ref. [GS-G-3.5]. A successful management system during commissioning ensures that nuclear safety matters are not dealt with in isolation but are considered within the context of all commissioning activities.

3.3 Organization responsible for commissioning (Licensee) should develop and implement a management system that describes the overall arrangements for the management, performance and assessment of the nuclear power plants during commissioning. The management system should cover all the activities that are carried out in the commissioning phase.

3.4 For a new reactor project, the management system for commissioning should be established early before the start of commissioning. The system should cover all items, services and processes related to commissioning, including those important to safety. In establishing and implementing the management system for commissioning a graded approach based on the relative importance to safety of each item or process should be used.

3.5 Systems, structures and components are classified during design phase based on their importance to safety. The classification can provide a basis for determining commissioning requirements, methods, testing, inspections, reviews, qualification of personnel and record requirements.

3.6 The objective of the management system during commissioning is to ensure that the nuclear power plant meets the requirements for safety as derived from:

—the requirements of the regulatory body;

—design requirements and assumptions;

—the safety analysis report;

—operational limits and conditions;

—the administrative requirements established by the licensee’s management;

3.7 The management system should support the development, implementation and enhancement of a strong safety culture in all commissioning activities. The commissioning phase should foster a safety culture which should be maintained throughout the operating phase.

3.8 Specific consideration should be given to the arrangements used by organizations participating in the commissioning process to enhance safety culture and achieve good performance.

3.9 The licensee should establish and implement in the frame of the management system arrangements to ensure quality for commissioning that is effective and in accordance with national and international standards. Provision should be taken to ensure that the quality requirements for commissioning are met by all participating organization in the commissioning activity including subcontractors.

3.10 Appropriate procedures should be established by the organization responsible for performance and the control of commissioning activities at the site to ensure that the commissioning of the plant fulfils the quality provisions of commissioning programme. Arrangements should be made to ensure that these procedures are reviewed and approved before issue and that their subsequent amendment is controlled.

3.11 Independent oversight and control of quality of on-going works should be provided by competent organization.

Organizational arrangements

3.12 Organizational arrangements should be in place to achieve the safety objectives of commissioning in accordance with the commissioning programme. They should represent a convenient and practical working scheme which allows optimum use of available personnel, materials and methods, and which enables assurances on safety to be obtained.

3.13 The principal activities performed in commissioning may be divided into the following categories:

(a) those associated with the final stage of construction and installation of the plant;

(b) those specific to commissioning, including testing activity and safety review activity;

(c) those associated with the operation and maintenance of the plant;

Accordingly, personnel performing the above activities may belong to the following groups:

— construction group;
— commissioning group;
— operating group;

There may be other representatives participating in commissioning activities, such as designers, manufacturers, and technical support organizations. These representatives should collaborate with the aforementioned groups as appropriate. In particular, designers and manufacturers should provide adequate and complete information to the groups. The designers should also review the commissioning data, and be involved in the resolving of problems and defects detected during commissioning stage.

3.14 There may be many ways in which the construction, commissioning and operating groups could be formed. This may depend upon industrial practice and experience of nuclear power in the State, upon contractual arrangements, as well as upon the physical size and design of the plant. The composition of the groups may also be influenced by the availability and experience of personnel performing specialized functions. If the operating organization 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 operating organization.

3.15 The working arrangements should, as far as practicable, make use of the operating personnel so that they become familiar with the plant and the facilities during commissioning. In addition, the operating group should participate in the commissioning activities from start of the commissioning process in order to ensure that as many operating personnel as possible gain field experience and to establish an 'institutional memory' of the plant.

3.16 Since construction, commissioning and operating activities overlap, in the arrangements made in respect of utilization of personnel between the construction, commissioning and operating groups, it should be ensured that responsibilities remain clear at all times.

3.17 In all the cases, under the overall direction of the operating organization as license holder:

- the commissioning group should ensure that structures, systems and components are tested to provide assurance that the plant has been properly designed and constructed and is ready for safe operation;

- the operating group should operate systems and plant in accordance with the assumptions and intent of the commissioning programme, respecting the operating limits and conditions, and since the start of nuclear testing respecting the operating technical specifications;

Operating organization

3.18 The operating organization, as the organization authorized by the regulatory body to operate the plant, should be the overall controlling and co-ordinating authority for overseeing the safe and satisfactory completion of all construction and commissioning work.

3.19. When commissioning activities are conducted by contractors, the operating organization should make the necessary arrangements to review and approve these activities at all stages establishing appropriate hold points and milestones.

3.20 Appropriate actions should be taken by the operating organization during the commissioning phase to promote and foster the development of safety culture at the plant. Attributes such as personal dedication, safety consciousness and a questioning attitude should be fostered at the pre-operational phase so as to become habitual in the subsequent operation phase

3.21 The responsibilities of the operating organization should include:

— to control, review and co-ordinate the activities of the construction, commissioning and operating groups in an effective manner;
— to ensure that the commissioning procedures are prepared, reviewed and approved;
— to arrange for the required submissions to the regulatory body in accordance with national practices;
— to ensure that agreed procedures are established for co-ordination and management of activities during the commissioning phase including the definition, interface and transfer of responsibilities at given milestones. These procedures should take into account the views and experience of members of the construction, commissioning and operating groups as well as other participants;

— to ensure that construction, commissioning and operating groups maintain adequate numbers of properly trained, experienced, qualified and, where required, authorized personnel;
— to receive and disseminate the requirements of and information from the regulatory body;

3.22 In discharging these responsibilities, various methods may be adopted by the management of the operating organization. The essential tasks in achieving the necessary co-ordination are as follows:

— to review and approve the commissioning programme;
— to ensure that adequate provisions are taken enabling the availability of necessary resources (personnel and materials) for commissioning;
— to make available, from the start of commissioning phase, operating, maintenance and technical staff for their familiarization with the operation and management of the NPP;
— to identify and monitor the transfers of responsibilities;
— to monitor the implementation of the commissioning programme;
— to resolve problems between groups and interface problems;
— to review and approve test procedures;
— to consider the safety aspects of commissioning procedures and their proposed changes;
— to determine whether tests and stages have been properly completed;
— to monitor the resolution of those defects or deviations detected during commissioning phase ;
— to maintain liaison with the regulatory body according to national regulations and practice;

Organization of the Commissioning Group

3.23 The commissioning group and the special arrangements made to ensure proper co-ordination and performance of commissioning activities during commissioning should be established early enough to allow all these activities to be identified and adequate preparations to be made.

3.24 The commissioning group should be headed by a commissioning manager who has had relevant experience and qualification. The commissioning manager should be appointed well in advance of the actual commissioning work so as to be able to make the necessary arrangements for scheduling and organizing work units, work plans and other resources.

3.25 Specific test teams should be established to perform commissioning tests. The number and composition of these teams should be dependent on aspects such as:

- the number and complexity of the systems to be tested;
- the scheduled target dates;
- the workload;
- the skills necessary to perform the tests;
- the staff available;

3.26 Effective co-ordination of work should be ensured between test teams.

3.27 In addition to the overall commissioning and scheduling the detailed planning and scheduling function should be managed in the commissioning group.

FUNCTIONS AND RESPONSIBILITIES

General

3.28 Commissioning activities may be assigned to a contractor, the construction organization or the operating organization. In some cases responsibility may be transferred from one organization to another at the time of fuel delivery and fuel loading or at some other appropriate milestone hold point. Whatever the arrangement, the organization or individual performing commissioning should be accountable to the organization or individual responsible for compliance with the licence for the following:

- demonstrating that the plant behaves in accordance with the design intent;
- confirming that the plant has been tested within the design limits;
- ensuring that the commissioning process is conducted in observance of safety requirements;

3.29 A gradual handover of systems and components of the plant from construction group to operation group should be set-up with clear definition of the associated transfer of responsibilities

3.30 The detailed listing of the functions and responsibilities should be viewed as illustrative only; actual functional responsibilities may be assigned according to the national regulations and practice.

Construction group

3.31 The responsibilities of the construction group in relation to the commissioning process should generally include the following:

- to ensure that the construction and installation of structures, systems and components has been completed in accordance with design requirements and specifications;

— to make suitable arrangements for surveillance and maintenance to prevent deterioration after the completion of installation (construction) and before the handover;
— to provide, for use as baseline data, as-built documentation of installation construction and test reports, highlighting design changes and concessions;
— to ensure that configuration control is maintained and that the effected systems design basis documentation, including the FSAR, as required, has been updated to reflect any design changes and/or concessions;
— to transfer the installed systems to the commissioning group using a system of plant hand over documents;
— to ensure the clearance of remaining open points conditioning the acceptance of the transfer, and
— to correct deficiencies in construction and installation detected in commissioning;
— to assist the commissioning group for construction relevant issues;

Commissioning group

3.32 The responsibilities of the commissioning group generally should include the following:
— to plan in advance the development of the commissioning programme with detailed test sequences, time schedules and staffing requirements;
— to update the commissioning programme in the light of experience in commissioning and as a result of design modifications;
— to establish a procedure for the preparation, review and approval of test procedures and other procedures;
— to ensure that operational flow sheets, operating and maintenance instructions, commissioning procedures, formats for commissioning reports and test reports, plant handover documents and submissions to the regulatory body are available;
— to establish a procedure for the systematic recording of plant data for future use;
— to establish a procedure for ensuring that incidents and unexpected events during commissioning are handled and analysed so that the experience can be fed back to the designers or the operating group;
— to verify that the installation of structures, systems and components has been satisfactorily completed and codified for proper identification;
— to ensure that the prerequisites for the commissioning programme have been satisfied and that pre-operational tests such as functional checks, logic checks, interlock checks and system integrity checks have been completed;

— to ensure that the commissioning procedures comply with the appropriate rules and regulations for safety (including radiological protection, nuclear safety and protection of environment);
— to ensure that the systems are commissioned safely and to confirm that the written operating procedures are adequate;
— to implement all tests in the commissioning programme, including repeat testing of the systems that have been commissioned initially as partially installed;
— to make suitable arrangements for testing and maintaining systems (particularly safety related items) for which responsibility has been accepted;
— to direct the operation of systems in the commissioning programme and to provide inputs for updating operational flow sheets, operating and maintenance instructions and procedures based on the commissioning experience;
— to issue commissioning reports on tests;
— to ensure that a procedure is in place to control the calibration of test and measurement equipment;
— to establish a procedure to ensure that all participants in the commissioning process are suitably qualified and experienced;
— to ensure the configuration management, maintaining the consistency between as-built drawings and procedures and physical configuration and the design requirements;
— to ensure that design changes are requested, reviewed, implemented and re-tested when design criteria are not met or when they fall short;
— to establish a procedure for controlling temporary changes to plant and equipment;
— to issue test certificates and stage completion certificates or their equivalent;
— to provide up to date baseline information to the operating group and the operating organization;
— to report to the operating organization any deficiency detected in commissioning tests in order that corrective actions can be taken;
— to maintain a record of limiting conditions in commissioning;
— to ensure that plant performance is in accordance with the design intent, including all aspects of radiological protection and safety and environment;
— to document that the commissioning programme has been satisfactorily completed;
— to transfer the responsibility for operation of the commissioned systems and/or plant to the operating group using a system of relevant documents;

— to establish and implement procedures that ensure the orderly transfer of responsibilities for structures, systems and components from the construction group to the commissioning group and from the commissioning group to the operating group;
— to ensure that an opportunity is provided for operating personnel to gain plant experience, typically by utilizing the appropriate personnel, as necessary, for commissioning activities;
— to establish procedures for analysing the results of tests; and
— to resolve any deviation detected and producing test reports;

Operating group

3.33 The responsibilities of the operating group in relation to commissioning should generally be as follows:

— to participate as earlier as possible in the commissioning activities;
— to satisfy themselves that the systems which are transferred comply with specified performance requirements, the design intent and safety requirements;
— to accept responsibility (operational, maintenance and safety) for the transferred systems;
— to increase competent in the methods of operation of the plant;
— to carry out operation and maintenance with competent staff using approved techniques to meet the needs of the commissioning programme;
— to establish and implement a procedure for the systematic recording of plant data as results of commissioning tests;
— to establish and implement a procedure including organizational responsibility to maintain plant design and configuration control over the operating life of the plant. This includes maintaining the safety analysis report current and up to date;

Other participants in the commissioning activities

3.34 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:

— to co-operate with the commissioning group by means of active participation when required;
— to provide specialist knowledge, expertise and relevant experience from plants already commissioned;
— to provide support for evaluation and assessment of tests results including any deviation;

— to provide baseline data and all necessary information;
— to provide a safety assessment when necessary;
— to participate in the analysis of discrepancies and unexpected events;
— to design modifications in order to rectify design deficiencies and to provide complete documentation of the modification, including requalification tests;

INTERFACES

3.35 Many activities are to be performed in parallel with the commissioning of the plant, such as activities relating to construction, operation and maintenance.

3.36 The interface between these activities should be adequately managed to ensure the protection and safety of the plant and personnel and to allow for adequate commissioning programme.

3.37 The interrelationships between tests, between systems and between units on the same site should also be considered.

3.38 The appropriate work control processes should be established to co-ordinate the activities of all groups involved in commissioning and to cover the major work activities, including post-work testing. This process should provide for the proper channelling of the work to the person responsible for the system and for ensuring notification and awareness in the control room of all the work activities that are in progress.

3.39 All the organizations involved in the commissioning process should develop an appropriate safety culture, commensurate with the task they perform.

Interface between construction activities and commissioning activities

3.40 Clear and well understood lines of authorization and communication between construction and commissioning activities should be established and documented. The lines of communication should support the commissioning schedule and should comply with the agreement on the scope of activities in both organizations, in particular at the interfaces.

3.41 The construction group may be the lead group for some activities during the commissioning programme. This should be defined well in advance of commencement of this programme in order to prevent misunderstandings.

3.42 The following particular areas of consideration are appropriate to the interface between construction and commissioning:

— procedures for transferring structures, systems and components from construction to commissioning;
— procedures for isolation of plant portions transferred to the commissioning from the part remaining under construction;

— prerequisites for the start of the commissioning programme and the start of system commissioning;
— special precautions necessary for the commissioning of partly installed systems;
— procedures for performance of works on systems under commissioning;

3.43 Specific attention should be paid to systems which have been partially installed and, as a consequence, have only been partially commissioned. Commissioning tests should be designed and implemented to allow for adequate commissioning of the full system.

Interface between commissioning activities and operating activities

3.44 The following particular aspects should be considered in relation to the interface between commissioning and operating activities:

— provisions in the definition of role, functions and delineation of responsibilities of operating group and commissioning group before transfer of structures, systems and components for operation;
— procedures for transferring structures, systems and components 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 commission milestones and performed transfers to operation, including the nomination of responsible persons;
— modifications to the plant and to the procedures;
— availability of as-built drawings, instructions and procedures for operating and maintaining the systems and the plant;
— conditions for access of personnel, with account taken of 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; for example, 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 structures, systems and components as each system is transferred to the operating group;
— provision of sufficient opportunity for the operating personnel to become both trained in and familiar with operating and maintenance techniques for the plant;

— procedures for radiological monitoring and protection for site personnel and keeping records of occupational exposures deriving from the commissioning in accordance with national regulations;
— 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 the light of experience gained in commissioning;
— development of arrangements and instructions for emergency preparedness;
— keeping records during commissioning of information that could have implications for decommissioning and subsequent handover of these records to the operating organization (examples could be records of spills or other unusual occurrences that could have long term effects);

3.45 There should be plans to include operating personnel in commissioning activities at the plant at all levels, thus providing the operating staff with an opportunity to become familiar with and gain experience valuable for the operation of the plant.

3.46 Procedures for operating and periodic testing should be used as far as the conditions of the plant will allow in the commissioning phase so as to validate them eventually with success criteria more numerous or more challenging that the ones to be used during operation. Inter-organizational arrangements should be made to schedule this activity so as to ensure that procedures, including operating, maintenance and surveillance procedures, are adequately validated.

3.47 Personnel should adhere to normal operating rules such as those relating to access to the control room, control of information, control cabinets and switchboards, communications with the control room about abnormalities and changes in plant configuration.

Interface with the Regulatory Body

3.48 The regulatory body should prepare a programme of review and assessment of the commissioning process. Before the start of commissioning, the regulatory body should review and approve the commissioning programme as required by national practice. Where appropriate, hold points should be established in order to assess test results before regulatory authorization may be given to proceed as required by national practice. During commissioning the regulatory body should perform inspections to verify that the commissioning activities conform to applicable requirements.

3.49 Before authorizing the loading of nuclear fuel or initial criticality, the regulatory body should complete as appropriate the review and assessment of such aspects as:

— preliminary final safety analysis report;
— the as-built design of the plant;
— the results of pre-operational tests;
— the operational limits and conditions (OLCs);
— the specific limits and conditions for operation during the commissioning of the plant from first criticality to full power;
— the adequacy of safety significant operating procedures and instructions, including emergency operating procedures and accident management procedures;
— the staffing and management structure of the plant and arrangements for ensuring that qualification and training are performed;
— the arrangements to ensure quality for all commissioning, operation and maintenance activities;
— the records and reporting system;
— the radiation protection programme;
— onsite emergency preparedness;
— the arrangements for commissioning and operation activities (including periodic testing, maintenance, inspection and surveillance);
— the arrangements for configuration control, especially control of plant modifications;
— the adequacy of the arrangements for security;
— the fulfilment of the applicable requirements in respect of safeguards and accounting for fissile and radioactive materials;

3.50 Before licensing and/or authorizing routine operation at full power, the regulatory body should complete the review and assessment of:

— the results of commissioning tests and their analysis;
— the updated final safety analysis report and updated operational limits and conditions;

SYSTEMS TRANSFER & PLANT HANDOVER

3.51 Plant handover is the transfer of responsibilities for the plant. This should include structures, systems, and components, items of equipment, and documentation and may include personnel. Depending on the plant organization and the framework for handover, two separate types of transfers may be found: one from the construction group to the operating group directly, and the other from the construction group to the commissioning group and finally to the operating group. All of these activities should be documented.

3.52 The operating organization should ensure that an appropriate procedure for the handover of the plant is in place. The provisions describing detailed steps in the handover process, including responsibilities and authorities of the parties involved, should be presented in this procedure.

3.53 Responsibility for systems should be transferred gradually to the operating group as soon as the testing before the introduction of fissile and radioactive material (pre-nuclear) tests have been performed and the results approved.

3.54 The transfer of documentation is a key feature in the handover process. Documentation should be transferred in system packages and over a reasonable period of time.

3.55 The following documentation should be included in the acceptance package for each system:

— general correspondence and system records;
— results of load tests, pressure tests and flushing and cleaning records: a master strainer logbook used for equipment testing and piping flushing;
— acceptance packages from construction (including welding inspection records);
— as-built diagrams, electrical diagrams, instrumentation and control diagrams, flow diagrams;
— documentation of pre-nuclear test procedures and report data sheets;
— failure reports and incident reports;
— documentation on temporary modifications, lifted leads and jumpers, and software modifications records;
— equipment isolation records and work permit records;
— records of preventive and corrective maintenance;
— surveillance records;
— records of field changes and design changes;
— pending item lists, including defects, omissions and weaknesses carried forward from the previous handover;
— vendors' manuals and set point books;

3.56 Suitably qualified personnel should be designated to conduct the review to be carried out by the operating organization receiving the handover package. In performing the review, meetings should be held and plant walk downs should be carried out by representatives of the organizations involved in the handover process.

RESOURCES

Provision of Resources

3.57 Ref. [1] states in para.4.1 and 4.2 that:

“Senior management shall determine the amount of resources necessary and shall provide the resources to carry out the activities of the organization and to establish, implement, assess and continually improve the management system.”

The information and knowledge of the organization should be managed as a resource.

3.58 A licensee should have human resource planning process in place to ensure adequacy of organization during commissioning. This includes the planning of the organization and raising the competency of the staff during the commissioning. Adequacy of organization and staff competency should be assessed on a continuous base.

3.59 The Licensee should have a systematic approach to monitor and supervise the adequacy of contractors’ resources and their competency.

3.60 Resources necessary to carry out the commissioning activities such as tools, utilities and logistics should be planned for. For example, the amount of desalinated water for using flushing of installed components, stable electric power source should be estimated and secured for the commissioning of SSCs important to safety.

Qualification and training

3.61 Personnel engaged in commissioning activities should be suitably qualified and experienced for the level of responsibility and importance to safety of their work. The necessary level of qualification and experience should be specified for each position in the organization. Training of personnel who participate in the commissioning process should include relevant aspects of the plant site and methods of working.

3.62 A training programme should be developed to cover these aspects. The subjects that should be considered are:

— conduct of testing and maintaining the plant in safe conditions;
— procedural changes 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;
— methods of and techniques for commissioning;
— safety culture;
— nuclear safety, industrial safety, fire protection , radiation protection and security
— design criteria, technology and operational limits and conditions (or the equivalent) for the plant;

— environmental protection and waste management;

3.63 The training programme and trainees should be subject to periodic assessment, the results of which should be passed on to the commissioning manager and supervisors.

3.64 As for safety culture, construction and commissioning personnel should understand their functions in establishing a sound basis for the subsequent operation and eventual decommissioning of a plant.

3.65 If any major incidents occur during commissioning, training should be systematically reassessed. Experience gained in commissioning should be appropriately incorporated into the training material. Objectives of quality and safety should be emphasized.

3.66 Recommendations and guidance on the qualification and training of commissioning personnel, particularly those involved in the commissioning of safety related systems, are presented in Ref. [7].

PROCESS IMPLEMENTATION

3.67 The management systems should include the requirements for generic management system processes in accordance with GS-R-3, GS-G-3.1 and GS-G-3.5, which covers following processes applicable to commissioning.

— Control of documents
— Control of products
— Measuring and testing equipment
— Control of records
— Purchasing
— Communication
— Managing organizational change
— Project management
— Work planning and control
— Assessment of work place risk
— Safety of personnel
— Control and supervision of contractors
— Design
— Configuration management
— Plant modification
— Maintenance
— Housekeeping and cleanliness
— Handling and storage

- Inventory management
- Identification and labelling of SSCs
- Radiation waste management
- Protection against environment
- Regulatory interface
- Information technology
- Protection against fires
- Accounting for, and control of, nuclear material and radioactive material
- Security

MEASUREMENT, ASSESSMENT and IMPROVEMENT

3.68 The commissioning activity should be performed according to a well-defined management system which involves main responsible organizations and subcontractors.

3.69 The system should be developed and implemented to monitor and measure the effectiveness of the management system.

Management of Non-Conformances

3.70 The provision of a consistent process for the management of non-conformances is a requirement of all safety management systems, and the process applies to the failure of components to meet their specified performance requirements and for larger systems to meet their requirements from the safety analysis or other performance specifications. A robust system for recording and resolving non-conformance and for approving concessions, corrective and preventative actions should be in place. Refer to [GS-R-3] and [GS-G-3.1] for further information.

Experience Feedback from Commissioning

3.71 The commissioning phase yields much information that should be taken into account in the subsequent operation of the plant. Proper systems should be established for reporting on and analysing abnormal events, human errors and ‘near misses’ in the commissioning phase. Experience gained at this stage should be fed back into the training programme for operating and commissioning personnel. The lessons learned should be used in the improvement and development of the commissioning programme, operating procedures and instructions. Available information on operating experience, including reportable occurrences at operating power reactor, should be used appropriately in developing and executing the test procedure. Consideration should also be given to the need for any changes in the design.

3.72 In the preparation of the commissioning programme, consideration should be given to experience gained around the world and on which information is available through industrial bodies.

MAINTENANCE DURING COMMISSIONING

3.73 From construction to commissioning and finally to operation, the plant should be adequately monitored and maintained. It should be subject to the required periodic tests and inspections in order to protect equipment, to support the testing stage and to continue to comply with the safety analysis report. Historical records of operation and maintenance should be kept from the time of initial energization and operation of each plant system, and provision should be made to transfer them eventually to the operating organization.

3.74 The organization for maintenance during commissioning should be adequately described and documented so as to be clear to all parties involved. Recommendations and guidance on maintenance activities can be found in Ref [8].

EMERGENCY ARRANGEMENTS

3.75 The operating organization should be responsible for ensuring that an appropriate organizational plan is in place for managing emergencies in the commissioning phase. Appropriate emergency arrangements should be established from the time that nuclear fuel is brought to the site and complete emergency preparedness arrangements should be in place and should be tested before the commencement of fuel loading.

3.76 In preparing emergency arrangements for the commissioning phase, account should be taken of the fact that construction related hazards may still exist.

3.77 A potential nuclear hazard could arise if an operating plant is adjacent to a construction site or a commissioning site. If this is the case, emergency arrangements should be made for the protection of construction personnel and commissioning personnel. Emergency arrangements should take into account any other local hazards.

3.78 All the parties involved in the commissioning programme should be trained appropriately to cope with any anticipated emergency at the plant during commissioning.

3.79 Recommendations and guidance on detailed instructions and procedures for actions to be taken in the event of a nuclear or radiological emergency are given in Ref. [9].

3.80 Management of unexpected events

Commissioning activities including the commissioning tests should be planned and performed within the limits and conditions of the safety analysis report. However, faults may occur, and for each test procedure consideration should be given to any fault responses and emergency actions required. In some cases these may be the same response to alarms as will be necessary for planned operation, but in some cases specific actions will be required, due to the configuration of the plant 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.

SECURITY ARRANGEMENTS

3.81 Recommendations on security arrangements can be found in Ref [GS-G-3.5], paras 5.182-5.183.

4. IMPLEMENTATION OF COMMISSIONING PROGRAMME

4.1 For implementation of commissioning activities personnel may need to be licensed by the nuclear regulatory authority according to national regulations.

4.2 The commissioning program should be implemented in stages/sub-stages so that at the end of each stage a review of the results can be performed to support the decision whether the commissioning program shall continue to the next stage, or whether the succeeding stages need to be modified as a consequence of results obtained or because some activities in the stage have not been undertaken or have not been completed.

4.3 The commissioning program should be implemented consistent with requirements of the management system. To this end, all contractors and subcontractors, involved in the commissioning process should ensure that their own arrangements meet the requirements of the management system.

4.4 There could be tests performed off-site on SSC which 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 to the current installed conditions of the SSC and related functional and physical interfaces.

4.5 The commissioning process should be documented in compliance with the licensee management system. The documentation showing the testing and results, analysis, deviations and dispositions should be kept for the lifecycle of the NPP.

4.6 The NPP design, operational and safety documentation should be updated during the commissioning process according to the test results and resolution of deviations.

COMMISSIONING TESTS

Test purpose and objectives

4.7 Preparatory process for testing should clearly identify the test purpose and test objectives from the commissioning test program, with particular focus on the safety objectives. The safety objectives should be clearly put in evidence in order to facilitate the regulatory review. The safety objectives should be linked with safety criteria and characteristics mentioned in (preliminary) safety analysis report.

Test scope and methods

4.8 The scope of the test in terms of functions, parameters and requirements to be tested should be defined with indication of approach and methods applied for each relevant aspect. If the testing procedure will make use of results of already performed in-factory tests this should be defined and justified showing the validity and applicability of performed factory tests to the onsite physical and functional status of equipment or system subject to the test and its interfaces with the rest of NPP.

Acceptance criteria

4.9 The acceptance criteria (against which the test results will be evaluated), their acceptability or the evidence of potential non-conformity should be clearly defined in the preparatory activity. The technical basis of the acceptance criteria should be consistent with the safety objectives and requirements.

4.10 The acceptance criteria should be linked to safety and/or design expectations, performance and requirements. Acceptance criteria should be organized into families regarding their importance to safety. At least two families should be defined:

— acceptance criteria for safety requirements;
— acceptance criteria for non-safety aspects;

4.11 The acceptance criteria should be defined and justified in order to ensure that they do demonstrate the achievement of test safety objectives. This definition and justification should taking into account the limitation of achieving site specific conditions without impairing the plant, structure or equipment integrity. The acceptance criteria definition and justification should establish a link between the safety requirements to be demonstrated and the parameters measured during the test.

The adequacy of the acceptance criteria should be documented in the test documentation, at least for the acceptance criteria linked to safety.

In cases, where safety requirements are verified by calculation, the computer code or simulation tools should be validated.

4.12 A list of the acceptance criteria that are be verified should be available at the end of each commissioning stage or sub-stage, notably the acceptance criteria linked to safety concerns. This represents one of the main inputs to assess the ability to proceed to further commissioning stages.

REPARATION FOR TESTING

Test procedures

4.13 All commissioning tests should be performed in accordance with written procedures. The preparation of test procedures, including their verification and approval, should be implemented according to the management system. The level of review should reflect the importance to safety of the system and the nature of the test. The procedures that are established should allow commissioning to proceed safely and efficiently.

4.14 The test procedures should define in detail how each item of equipment or system or component will be commissioned and they will thus form the core of the commissioning process. Competent personnel and adequate controls should therefore be in place to ensure that the test procedures are of a high standard.

4.15. The test procedures should be subject to a thorough verification involving the operating organization. The designers should also participate in the approval process, in particular in reviewing the validity of the acceptance criteria.

4.16 The test procedures should follow normal plant operating procedures to the extent practicable so as to verify them. If necessary, the normal operating procedures should be amended for use during commissioning.

4.17 The development, verification and validation of commissioning test procedures should benefit from the use of simulator or computer codes. The use of simulator should contribute also to the preparation on specific relevant aspects of the team implementing the commissioning test.

4.18 The test procedures should state any necessary deviations/changes from the normal plant operating configurations. Examples of such deviations/changes may be temporary interlock bypasses, temporary additional interlocks, temporary system bypasses, valve configurations and instrument settings. The test procedures should also include all necessary checks that are needed to ensure that these deviations are made correctly. They should also include all necessary steps for the restoration of the systems and components to their normal status once the testing is completed. Consistent with safety requirements, consideration should be given to minimizing such arrangements and to ensuring that any deviations from the normal functioning of the as-built systems do not invalidate the test objectives.

4.19 Although the format of procedures may vary from plant to plant, the contents of test procedures should include, but are not limited to, the following:

a. *Introduction* - A summary should be given of the main test objectives and of 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 stages of the commissioning programme should be highlighted.

b. *Test objectives and methods*- The objectives of the test and the methods by which they are to be achieved should be stated.

c. *Limiting and conditions*- Applicable operational limits and conditions, including appropriate temporary operational limits and conditions, should be stated. In addition those plant limits and conditions which must be observed to prevent damage to plant should also be included.

d. *Prerequisites and initial conditions*- The state of all relevant systems and components and other pertinent conditions that might affect the operation of the system to be tested should be stated, particularly if different from normal. This information should include, where appropriate, the precautions necessary to maintain the desired system configuration.

e. *Test conditions and procedures*- The way in which the system to be tested is required to be brought up to test conditions should be specified and details of the test procedures should be provided, preferably in a step by step format. This should include any temporary changes or abnormal alignments of the system or the adjacent systems.

f. *Acceptance criteria*- The acceptance criteria should be stated and this statement should wherever possible be quantitative as well as qualitative (for fuel loading, for example). Origin of the criteria should be mentioned.

g. *List of instrumentation and special test equipment*- Any special equipment and calibrations necessary to perform the test should be specified. Attention should be paid to ensuring that such equipment is clearly identifiable and of appropriate accuracy.

h. *Staffing, qualification and responsibilities*- Staffing needs, qualification requirements and assignment of duties and responsibilities for conducting tests should be specified as necessary.

i. *Special precautions*- Special precautions necessary for the safety of personnel and the security of equipment should be clearly described in the test procedure. In addition, any special precautions necessary to ensure safety should be stated.

j. *Completion of test*- Provision should be made for a statement by the individuals responsible to indicate that the test has been satisfactorily completed and that the systems have been returned to normal conditions. The removal of temporary changes or of any abnormal line-up should be individually specified; for example, as steps in the test procedure.

k. *Permanent records*- A list of information necessary for permanent records should be provided, including baseline data to be collected in the test.

l. *Identification, cross-referencing and distribution*- Each authorized test procedure should incorporate a unique identification (such as by reference numbering), including comprehensive cross-references to associated documents, and a distribution list of those persons who should receive it.

m. *Data collection and processing*- The test procedures should include arrangements for tabulating data and test results. Test sheets should have standardized forms and each sheet should be signed by the collector of the data. 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.

n. *Non-conformity management*- The test procedure should describe the procedure to manage the non–conformities identified as results of the test.

4.20 Techniques and methods of data analysis including the analysis of measurement results should be presented in the Test procedure. The quality of the measurement instruments and the software for data analysis should be verified before beginning of the test.

Equipment and measurement tool for testing

4.21 In order to comply with the requirements prescribed in testing procedures, various precision, calibrated tools, measuring and test equipment should be used to ensure the component; system and structure conform to the manufacturer's specification. These measuring and test equipment should be periodically calibrated in order to achieve and maintain the precision adequate to the testing requirements. Where a testing process, or sequence of testing processes, requires calibrated tools or equipment to be used to determine conformance to specification of the systems, structures and components for certification for release-to-service then calibrated equipment should be used at each step in the process.

4.22 The register of the measuring and test equipment should be established for the equipment currently in use by the commissioning organization. The Register should identify the equipment by means that can be related to actual marking on the equipment itself.

4.23 The management system should provide guidance to the commissioning personnel, regarding the maintenance and calibration of measuring and test equipment.

4.24 The management system should ensure that the calibration intervals are not exceeded for the testing equipment and measurement tools and ensuring that any new such equipment and tools are obtained with the appropriate calibration certificate. All the individual instrument users should be also responsible for ensuring that the measuring or testing equipment is in good conditions and the calibration status is known.

TESTING PREREQUISITES

4.25 The start of a test of a SSC should require that certain other activities have been performed first, e.g., completion of construction, and/or preliminary tests, inspections, and certain other preoperational tests or operations. The typical prerequisites of the testing are as following:

- construction and installation activities associated with the system to be tested have been completed and documented;
- tests of individual components or subsystems to demonstrate that they meet their functional requirements have been completed;
- checkout of wiring continuity and electrical protective devices; adjustment of settings on torque-limiting devices and calibration of instruments;
- all special conditions for the plant or system or status of equipment necessary prior to the commencement of testing using the procedure are implemented;
- all necessary jumpers, interlocks are installed for the certain testing configuration;
- required personnel are available and briefing is complete;
- testing and measuring devices are adjusted, calibrated and checked;
- field inspections have been made to ensure that the equipment is ready for testing, including inspection for proper fabrication and cleanness;
- communication tools are available and checked for operability;
- written authorization, as required, should be issued prior to the commencement of the performance of the test or commissioning stage;
- necessary documentation (state that all documentation showing the readiness for the test to be performed should be issued and approved) is available;

- safety analysis (safety analysis of the NPP conditions during the test to be performed should be carried out in advance and should show the existence of acceptable safety conditions during the performance of the test);

- compliance with regulatory authorization corresponding to what was envisaged in the commissioning program, to the hold points established by the regulatory body and also to specific conditions and request issued by the regulator in accordance with national practices;

4.26 The starting of a commissioning stage or sub stage, as described in the commissioning program, should be based on the completion of the previous stage and fulfilment of pre-defined conditions. For instance the preoperational tests should be completed and the results of such tests evaluated and approved before proceeding to fuel loading and subcritical tests.

4.27 Administrative controls should be established to ensure that activities are started or performed as required on the basis of the programs, pre-defined sequence and according to requests or constraints imposed by involved parties (commissioning organization, operating organization, regulatory authority and other parties as envisaged).

TESTING STAGES AND SEQUENCE

4.28 In determining the sequence of testing, the following points should be carefully considered:

(1) Sequence of commissioning tests should be planned in a chronological order in which they are expected to be performed and that the systems required to ensure the nuclear safety of a commissioning stage should be adequately tested prior to integrated system testing;

(2) certain support systems (e.g. compressed air system, electrical system, service water system, de-mineralized water supply system) should be commissioned prior to other systems so that they are available for the proper testing of other systems;

(3) certain systems should be operational to ensure that other systems can be tested without jeopardizing personnel, plant or nuclear safety(e.g. Fire Protection System, Radiation Protection System, Emergency power system);

(4) at any given stage, the corresponding tests to be performed should be grouped together and completed before the commissioning programme can safely continue;

Preoperational tests

4.29 Before the commencement of the initial testing of any structure, system or component:

(1) construction activities associated with the system, including quality assurance checks and documentation, should be completed and documented and reviewed;

(2) it should be ensured that the equipment is ready for commissioning as per prerequisites mentioned in the applicable commissioning procedure;

(3) it should be ensured that test equipment and instruments to be used during commissioning are appropriate and operable, properly calibrated and that response times are within acceptable limits;

4.30 A review should therefore be undertaken before the commencement of this stage to ensure that the tests have been carried out on those systems and components required for this stage. The tests should ensure that the construction is of the appropriate quality and that the equipment is in a fit state for commissioning to be started.

4.31 A satisfactory preoperational test should take into account the proper sequence of tests of electrical systems, instrumentation systems and other service systems such as cooling water systems and fire protection systems in order to ensure the availability of the necessary services for the implementation of the entire commissioning programme.

4.32 Stages of the preoperational tests may be divided into the following sub stages:

– cold performance tests; and

– hot performance tests;

Any required pre-service inspections should be performed during or at the end of these stages.

Cold performance tests

4.33 Cold performance testing includes the initial starting of fluid systems and support systems. The objective of this stage is to obtain initial operational data on equipment, compatibility of operation with interfacing systems and verification of the functional performance of these systems. The tests usually include the pressure test of the primary and secondary systems.

4.34 Where a pressure test required by regulations is not carried out before transfer of the system to the commissioning group, it should be carried out as part of the commissioning programme in this sub stage.

Hot performance tests

4.35 Hot performance tests should be undertaken to verify the conformance of systems with specified requirements. Where possible, these tests should follow cold performance tests, simulating as far as practicable plant operating conditions, including anticipated operational occurrences at typical temperatures, pressures and flow rates.

4.36 The tests should, to the extent possible, verify the effectiveness of heat insulation and heat removal systems. They will enable initial checking of flow rates, of vibration, of clearances and of other provisions made for accommodating the thermal expansion of components or systems. The operation of instruments and other equipment at high temperature should be verified and the relevant operating techniques should be confirmed.

4.37 The duration of hot performance testing should be such that a steady state operating condition is achieved, in order to determine whether the structures, systems and components are operating according to specifications.

4.38 The operating personnel should take the opportunity at this sub stage to use and validate operating procedures.

Initial fuel loading and subcritical tests

4.39 The purpose of the stage of fuel loading and subcritical tests is to ensure that the fuel is loaded into the reactor safely in accordance with the loading pattern calculated in the design. In addition, at this stage it should be confirmed that the reactor is in a suitable condition to be started up and that all prerequisites for the reactor to receive fuel in the vessel and to go critical have been met (see also the Appendix).

4.40 With the core loaded and the reactor maintained in a subcritical condition, a series of performance tests should be done. These should include checks on coolant flow rates, instrumentation, rod control mechanisms, automatic rod insertion and other important features of the primary circuit.

4.41 The plant should be prepared well in advance for the initial fuel loading. The prerequisites regarding testing, systems, equipment, documentation and personnel should be established (see Appendix). These prerequisites, including satisfactory performance of the integrated plant systems and containment, should be clearly described and documented on the basis of the safety analysis report and the existing regulatory requirements. These prerequisites should be satisfied well in advance of the initiation of fuel loading.

4.42 The requirements and procedures should be in place to test the fuel loading machine and/or any other tool or systems necessary before the commencement of fuel loading. The personnel responsible for fuel loading should be qualified and trained in advance. Proper training should be carried out on the fuel machine, including operations in the reactor cavity and spent fuel pit, using dummy fuel assemblies.

4.43 Fuel should be loaded in accordance with a written procedure to ensure safe and correct loading. Attention should be paid to adequate monitoring of neutron flux to prevent inadvertent criticality and if prevention fails for timely identification of such criticality. An adequate means should be available to restore shutdown margin in the event of an approach to inadvertent criticality.

4.44 Initial fuel loading should not be authorized unless all preoperational tests deemed necessary by the operating organization and the regulatory body have been performed and the results obtained are acceptable to both parties.

4.45 Initial fuel loading should be supervised by duly authorized personnel and any changes occurring in the reactor should be reported immediately to the control room personnel.

4.46 The fuel loading procedure should require, as appropriate: periodic data recording; audible indication of flux increases; and monitoring of neutron count rate instruments when fuel is being inserted and/or when other operations are performed that could affect core reactivity. In addition, sub criticality checks should be performed at regular steps in the loading procedure to determine safe loading increments for subsequent loading. Predictions of the behaviour of the core in terms of its reactivity should be available for evaluation of the sub criticality margin. If actual measurements deviate from the predicted values, procedures should require further fuel loading to be stopped until the circumstances have been analysed, the reasons for the deviations have been determined, and any appropriate corrective action has been taken. (The Appendix contains further guidance on the details to be included in the procedures for fuel loading.)

4.47 During the fuel loading operations, the exact position of each core element should be clearly indicated in the loading procedures or loading plan and documented. By the end of fuel loading, the position of each core element should be independently confirmed and documented.

4.48 In heavy water reactor systems, where criticality may be achieved by either the introduction of the moderator or by controlled reduction of dissolved neutron absorber in the moderator after initial fuel loading, the precautions for preventing inadvertent criticality during this sub stage should be specified accordingly. For example, the moderator introduced should have an adequate quantity of dissolved absorbers (such as boron or gadolinium).

4.49 After fuel loading, performance tests should be undertaken to check the characteristics of coolant flow and the effects on components, as well as the mechanical operability of reactor control equipment. During these tests sub criticality is required to be ensured.

Initial criticality

4.50 Before reactivity is increased ('inserted') to approach initial criticality, the necessary prerequisites should be met to ensure that the reactor is in the proper condition for start-up in terms of the availability and readiness of qualified personnel and systems important to safety. It should be adequately documented that these prerequisites have been met and the reactor is in the proper condition for start-up, and the appropriate approvals to proceed to this stage of commissioning have been obtained.

4.51 Before the approach to criticality is started, operability of the automatic reactivity shutdown devices is required to be ensured and appropriate start up monitoring instrumentation to be available to initiate shutdown devices when necessary.

4.52 Measures should be taken to ensure that the start-up proceeds in a safe and orderly manner. For this purpose, changes in reactivity should be continuously monitored and evaluated so that the prediction of the point of criticality is continually checked. The sequence and magnitude of changes in reactivity, made by means of removal of the absorber and/or adjustment of the moderator level, should be defined in the procedures.

4.53 Instruments for neutron monitoring at start-up should be calibrated before the approach to criticality and the required minimum neutron count rate should be obtained, using in-core neutron sources if necessary. Trip set points should be reduced to a minimum level compatible with the demands of the tests scheduled in this sub stage.

4.54 The procedures for achieving criticality after significant subcritical multiplication has been experienced require a very cautious approach, i.e. through continuous monitoring of the neutron flux and predictions of the point of criticality and successively smaller adjustments in positive reactivity. The objective of above actions is to avoid passing through the point of criticality with a high rate of change in neutron flux (that is, with a short period of multiplication). After criticality has been achieved, a conservative start-up rate of flux increase should be used in attaining low power.

Low power testing

4.55 At the stage of initial criticality and low power tests, the initial criticality of the loaded core is achieved for the first time. The subsequent low power tests should be made to confirm that:

— the performance of the reactor core is commensurate with predictions made in the core design;
— the reactor core is in a proper condition for operation at higher power levels and the characteristics of the reactor core coolant, reactivity control systems and shielding (as appropriate) and reactor physics parameters are in accordance with predictions made in the core design;

In order to permit power testing, assurance should first be obtained on the basis of the information gained from these tests that there is no serious discrepancy between measured values of reactor physics parameters and other parameters and values used in the safety analysis report. The power levels for low power testing should be the lowest power that gives reliable and stable measurements and enable the required conditions necessary to perform the specified tests. Special start-up instrumentation should be provided if necessary.

4.56 Where necessitated by the reactor design, system flow tests and cold and hot tests of appropriate duration should be made with the loaded core.

4.57 In these tests the trip limits of the nuclear flux channel for the reactor protection system should be set down to a conservative level.

Power ascension tests

4.58 This stage of commissioning consists of a step by step approach to full power and full power tests. At each sub stage a series of tests will be carried out at specified power levels. Typical steps may be 10%, 25%, 50%, 75%, 90% and 100% of full power.

4.59 A comprehensive range of power tests should be made to confirm that the plant can be operated in accordance with the design intent and that the plant can continue to be operated in a safe manner. Those tests that are necessary to demonstrate safe operability should be completed without delay. This stage should in general be limited to those tests which can only be carried out at power.

4.60 Tests should be made to demonstrate to the extent practicable that the plant operates in accordance with the design both in steady state conditions and during and after anticipated operational occurrences, including reactor trips and load rejections initiated at appropriate power levels.

4.61 A review should be carried out at the end of the stage to confirm whether the operational limits and conditions are adequate (see Ref. [3]), and to identify any constraints on the operation of the plant which the commissioning tests have shown to be necessary.

REVIEW, EVALUATION AND REPORTING OF TEST RESULTS

Review and evaluation of test results

4.62 After each test completion the test results should be reviewed to provide assurances that the test was performed as intended and that results demonstrate that the performance of the systems considered is in accordance with the plant design intent, and that any operating constraints have been identified. It should ensure that all necessary data have been obtained and analysed, and that a technical evaluation and report have been completed. It should also provide assurances that the succeeding stages can be conducted safely and that the safety of the plant is never dependent on the performance of untested structures, systems or components.

4.63 The evaluation process should assure that the interpretation of test data is appropriately reviewed by competent persons who have the technical expertise to determine that the operational characteristics of SSCs and/or process is performing satisfactorily. The evaluation of the test results should include a comparison with the acceptance criteria and an analysis of any deviation detected.

Review of the stage completion

4.64 At the end of a stage, the results of the tests in that stage and the general condition of the plant should be reviewed by the representatives of the commissioning group and the operating organization prior to approval being granted to begin the next stage. Depending on the national regulatory practices, the regulatory body may be involved in the review and approval of the results of the specific stage.

4.65 Reviews should ensure that all systems and special testing equipment for the tests in the next stage will be available before proceeding to that stage, and that all relevant administrative and control procedures will be complied with, as documented.

4.66 To ensure that the commissioning programme proceeds in an orderly manner, suitable preparations should be made so that the stage completion and approval documents can be produced expeditiously. To this end, reviews of test results should be undertaken and test results should be accepted at suitable times during the progress of testing within each stage. The end of each stage should include preparations for the start of the succeeding stage and a means should be arranged for the continual updating the documentation (see Section 5). In addition, close liaison should be maintained with all participants in the commissioning programme, including personnel at the headquarters of the operating organization and personnel of the regulatory body.

4.67 Progress to the next stage should only be permitted by the operating organization when the completed review of the current stage has been approved by the operating organization and where relevant in accordance with the requirements of the regulatory body.

Approvals and Issue of Test reports

4.68 Documents should be prepared and issued during the progress of the commissioning activities to document the performance of the tests and provide stage clearances for the continuation of commissioning programme. Regulator's approval should be obtained when necessary.

Reporting of test results

4.69 The commissioning group should report the test results to the relevant participants in the commissioning programme. Although it may be expedient to prepare summary reports for a quick assessment of the test results, a formal comprehensive report should nevertheless be established containing all the required information, including a collation and final evaluation of the test results. These formal reports should be retained for record purposes. In addition to individual tests, stage test reports and a final station commissioning report should be prepared.

HANDLING OF DEVIATIONS

4.70 During commissioning, changes to plant design, programmes or tests may be necessary, unexpected results may be obtained and incidents may occur. The operating organization should establish procedures for dealing with these situations within the frame of its management system.

Modifications

4.71 In making proposals for modifications, account should be taken of: regulatory requirements; the stipulations of the operating organization; the effects of the proposed modification on any other system; and the safety implications of the proposed modification for the commissioning programme or the individual test.

4.72 Where safety is a factor, modifications to plant components and systems should be made as recommended in Ref. [2]. The procedures for making modifications should cover design, safety reassessment and methods of implementation and testing. The scope of the assessment should correspond to the safety significance of the proposed modification.

4.73 As a result of modifications to plant components or systems, the issuing of new procedures or the revision of previously issued documents may be necessary. These changes to the procedures or documents should be performed according to the management system.

4.74 If there is a need to change the sequence of a test, an appropriate review should be performed prior to varying the sequence of the test from the intended programme. The review should ensure that all the prerequisites for the out of sequence test are met in order to ensure the safe performance of the test.

4.75 Any changes to the approved test procedures should be controlled according to the management system.

4.76 Unavoidable temporary modifications that interfere with the intended design configuration should be properly controlled. An appropriate review should be performed to ensure that safety implications are properly considered.

4.77 Additional guidance on arrangements in connection with anticipated plant modifications during the commissioning stage can be found in Ref. [2].

Unexpected test results and occurrences

4.78 In spite of adherence to appropriate design, construction and commissioning procedures and work methods, unexpected test results or occurrences may arise during commissioning. To ensure that adequate consideration is given to such events, the following procedure should be adopted:

- Commissioning documents should be compiled, containing, where appropriate, instructions for the immediate actions to be taken if the results obtained in the course of the test fall outside the specified limits or if unexpected events occur.
- A review should be carried out to understand the cause(s) of event and to decide on the corrective actions to be taken.

5. DOCUMENTATION

THE COMMISSIONING DOCUMENTATION ARRANGEMENTS

5.1 The commissioning documentation is important for the subsequent safe operation of the plant. The structure, content, extent and control of commissioning documents should therefore be described in the management system of the operating organization.

5.2 Arrangements for documentation for commissioning should provide the following:

— continuity in the commissioning activity and a means for the continual updating of documents to facilitate the execution of stage reviews;

— evidence to the various participants that the design intent has been met and deviations if any have been assessed and that appropriate modifications have been made;

— assurance to the operating organization that commissioning is proceeding safely

— records that need to be available throughout the lifetime of the plant;

— assurance to the regulatory body that its requirements are being met;

5.3 The preparation, review, approval and control of commissioning documentation should be in accordance with the management system. [Ref. GS-R-3]. All commissioning documentation including latest approved issues, completed test documents and test reports should be retained in an appropriate location for both control and archival purposes.

5.4 Methods for the preparation, safe keeping, retrieval and review of documents are specified. Document control procedures should be in place to ensure that those persons participating in a commissioning activity are provided with approved procedures.

THE SCOPE AND STRUCTURE OF COMMISSIONING DOCUMENTATION

5.5 The commissioning documentation should comprise the commissioning organization and management documents, the commissioning procedures and the commissioning reporting documentation.

Commissioning Management System Manual

5.6 The Commissioning Management System Manual (MSM) (sometimes referred to as the Commissioning Manual) should form the part of the suite of commissioning documentation, set out the management organisation and documentation processes. The Commissioning MSM should detail the commissioning management structure to permit commissioning activities to be logically planned and safely executed.

5.7 The purpose of the Commissioning MSM is to define the organisational structure and responsibilities for the management and control of testing and commissioning to meet the requirements for quality, established requirements, statutory obligations and the License provisions. The Commissioning MSM should define the extent, nature and approval process of the documentation including procedures and certificates to be used during the commissioning.

The Commissioning MSM should provide the basis for the planning and execution of the testing and proving of plant items and systems, as a coordinated activity within the operating organization and between the operating organisation and its relevant contractors.

5.8 The Commissioning MSM referring as appropriate to the management system should comprise the following items of the commissioning process:

- the commissioning objectives
- the management policy of the Operating organisation (Licensee)
- responsibilities of the participating organisations in relation to commissioning of power plant

- commissioning organisational structure
- commissioning management
- the commissioning programme
- safety aspects
- management of deviations detected during commissioning
- commissioning documentation arrangements

Baseline documentation

5.9 The commissioning documentation should include the basic information on the principles and objectives of the plant commissioning tests as well as details of the testing to be carried out on the plant. Such documentation should contain sufficient information about the design, function and expected performance of the plant systems to adequately characterise the system for subsequent proposed tests definition. This documentation may also include the vendor specifications, design basis and safety analysis report and records of subsequent changes to any of these documents, requirements of the regulatory body, licences and other relevant statutory documents. Such information should also substantiate the proposed commissioning tests and clearly address any specific precautions or measures required during the tests in order to protect personnel and plant. The testing substantiations may be presented as the separate document or included in the testing procedures.

Programmes and schedules

5.10 The Overall Plant Commissioning Programme (OPCP) gives a general presentation of the Commissioning Program for the whole plant, a description of the different commissioning stages and associated commissioning activities, and the overall plant commissioning stages schedule.

5.11 System Commissioning programmes (SCP) are related to a System (or group of Systems or particular commissioning scope). Each SCP gives a brief description of the objectives, principles, test conditions and acceptance criteria for all the tests to be performed within the test stages for the concerned system (s), including the reference to documents to be used for test performance (test guidelines, test procedures), the stages during which they are performed and their logical sequence.

5.12 Stage Commissioning Programs (StgCP) are related to a Commissioning Stage (or sub-stage)

The StgCP defines the prior conditions to start the stage as well as waivers with respect to the Technical Specifications after fuel loading, gives the chronology of all the tests and activities to be carried out during the related stage and includes the list of Test Procedures to be performed during the stage and the list of operating procedures and periodic testing procedures to be applied / validated during the phase.

Procedures

Administrative procedures

5.13 Procedures should be established by the responsible organization for the control of commissioning activities at the site to ensure that commissioning of the plant fulfils the provisions of the commissioning programme. These controls will usually be in the form of administrative procedures, which will include all administrative controls and requirements for carrying out commissioning activities. Arrangements should be made within the frame of management system to ensure that these procedures are reviewed and approved before issue, and that their subsequent amendment is controlled.

Testing procedures

5.14 All commissioning activities should be performed in accordance with authorized written procedures. The preparation of test procedures, including their verification and approval, should be defined within the management system. The level of review should reflect the importance to safety of the system and the nature of the test. The procedures that are established should provide for timely reporting to allow commissioning to proceed safely and efficiently.

5.15 Based on the tests scheduled in the commissioning programme the procedures should be prepared for each of the individual plant item and system tests. Each procedure should detail the objectives of the testing proposals and should contain the detailed instructions to members of the test team carrying out the work. In addition to the detailed step-by-step procedure they should contain specific information about safety requirements, emergency procedures, programmes and test data collection. The detailed content of the test procedures are in paragraphs

Records

Test reports

5.16 A report should be drawn up on the results of all tests included in the testing programme. Formal reports for each test should be prepared and approved according to the management system processes. The format of a report may vary but normally it should include:

— introduction;
— references to appropriate test procedures;
— description of the test method and objectives for each test;
— conduct of the test, including initial and final state of the plant, the actual limitations experienced, and problems encountered and the actions taken to overcome them, including any modifications to the plant or to procedures;
— concise description of any special test equipment used;
— summary of data collected and analyses of the data;
— evaluation of results, including statements that the acceptance criteria have been met;
— conclusions;
— identification, cross-references and a distribution list;

Stage reports

5.17 A summary report shall be drawn up on each stage (sub-stage) of the testing. Besides essential results of the test stage concerned, the report shall contain a summary of the observations made during the testing as well as an assessment of the appropriateness of the testing performed in the stage concerned and of any necessary changes to the testing programme or the plant use.

Records of deficiencies and reservations during commissioning

5.18 The commissioning documentation should also include the defect reports that should be created and updated throughout the commissioning phase. All test reservations which have not been fully implemented/closed-out at time of endorsement of the test report should be presented in these reports.

Certificates

5.19 Documents should be prepared and issued during the progress of the commissioning activities in order to report on the performance of the tests and to provide the required inputs for the continuation of the programme, in accordance with the procedures established by the operating organization. The following types of documents may be used to certify the completion the test or the group of the tests within the commissioning stage.

Plant/system handover documents

5.20 Documents should be prepared and issued for the handover of plant systems in order to formalize that the plant system was installed and tested as required by the commissioning programme and the system is functioning in accordance with design provisions. The handover certificate should be supplemented by the handover acceptance package.

5.21 The transfer of documentation is a key feature in the handover process. Documentation should be transferred in system packages and over a reasonable period of time in order for the plant personnel to be able to make a comprehensive review of every package. These transfers should also depend on how the responsibilities for the testing after fuel loading, at initial criticality, at low power and at power escalation are assigned.

Supporting documentation

5.22 The commissioning documentation should also include supporting information presented in the form of guides or procedures that are needed to support the commissioning process activities. The examples of such documents are records relating to location of fuel assemblies and other nuclear materials, procedures for the safety of personnel, procedures for radiological protection and associated records. Where relevant, all supporting test information which is not contained within the test procedure as well as any documentation used to evaluate and judge the performance of the test should be referenced in the appropriate section of test report.

Appendix

FUEL LOADING

A.1. For safely accomplishing initial fuel loading into the reactor and ensuring that inadvertent criticality does not occur during the loading process, account should be taken of the items listed in this Appendix. The list should apply in detail in all commissioning stages.

Prerequisites

A.2. The following activities and checks should be considered for completion before fuel loading:

— verification of the configuration of all relevant systems as specified in the design documentation;

— inspections of fuel assemblies, reactivity control devices and other absorbers, and the identification of fuel (careful distinction should be made between different types of fuel and different grades of enrichment, and note taken of which of the elements are 'poison' elements);

— operability of nuclear start up instrumentation, in terms of proper calibration, location (source–fuel–detector geometry) and functionality, including audible and visual alarm indications in the control room as well as the response of the instrumentation to a neutron source;

— status of the containment and of the primary circuit as specified, with components correctly placed or removed as specified;

— status of the coolant and coolant circulation, such as fluid quality and level, as specified in the loading procedures, with systems and components arranged and secured to prevent changes to their status; examples are valves, pumps and other equipment lockouts;

— operability of appropriate reactivity controls and readiness for reactor shutdown by the 'insertion' of negative reactivity;

— conformity of the reactivity condition of the reactor core with specifications, and ensuring the shutdown margin by making conservative assumptions about conditions and by locking off power supplies to prevent the inadvertent 'removal' (reduction) of negative reactivity;

— operability of fuel handling equipment, including on-site trials of fuel handling equipment using dummy fuel assemblies;

— status of protection systems, interlocks, mode switches, alarms and radiation protection equipment is as prescribed; high flux trip points set for a relatively low power level (approximately 1% of full power) for operability of control rods during fuel loading, and the alarm and trip settings of other protection channels set to low values;

— availability of criticality precautions;

— composition of the fuel handling crew, and their duties and responsibilities in the event of emergencies;

— operability of radiation monitors, nuclear instrumentation, and manual and automatic devices for actuating building evacuation alarms and ventilation controls;

— approval of fuel loading by the regulatory body.

Test conditions and procedures

A.3. The following items should be considered for inclusion in the conditions and procedures for the fuel loading test:

— fuel handling, including the precautions to prevent criticality and physical damage;

— loading sequences and patterns for the different types of fuel (in terms of grades of enrichment and poisons), control rods, and other absorbers and components;

— guidance on fuel addition increments with fuel loading arranged so that the reactivity worth of the individual fuel elements inserted decreases as the core is assembled;

— details of the information that should be maintained on the fuel inventory and control rod inventory in the core and in storage and details of appropriate records of core loading;

— information on proper seating and orientation of fuel and components and checking of fuel identification;

— a functional test of the associated control rod (for boiling water reactors) as the installation of each fuel cell is completed;

— requirements for nuclear instrumentation and neutron sources for monitoring subcritical multiplication, including methods for relocation of sources or detectors and normalization of count rate after relocation (a minimum of source range monitors should be required to be operable whenever operations are performed that could affect the reactivity of the core);

— flux monitoring information, including counting times and frequencies, and rules, as necessary, for plotting a curve for inverse multiplication and interpreting plots using at least two channels;

— limits on fuel loading increments, if applicable, on the basis of an extrapolation and conservative interpretation of these plots (see the item on flux monitoring information) above), and other predetermined limits on loading increments as specified in advance;

— expected subcritical multiplication behaviour;

— confirmation of the minimum shutdown margin and performance of tests of rod reactivity worth in unborated reactors, and the frequency of confirmation during loading and on completion (for borated reactors, this necessitates the determination of the boron concentration at a frequency commensurate with the worst case dilution capability, with account taken of the piping systems attached to the reactor coolant system);

— actions for periods when fuel loading is interrupted, especially those pertaining to flux monitoring;

— a method of maintaining adequate communication between the control room and the loading station;

— the minimum number of personnel necessary to load fuel;

— identification of the permitted working time of the personnel;

— establishment of criteria for stopping fuel loading, such as unexpected subcritical multiplication behaviour, loss of communication between the control room and the fuel loading machine, inoperability of a source range monitor or inoperability of the emergency shutdown system;

— specified limits of the counting period for count rates;

— establishment of criteria for reducing the fuel loading increment, if applicable (if this increment is reduced because of excessive subcritical multiplication, it shall not be increased again);

— establishment of criteria for emergency injection of fuel poison (or tripping of the shutdown control rod groups);

— specified limits for the quality of the reactor coolant;

— establishment of criteria for containment evacuation;

— actions to be taken in the event of fuel damage;

— if any stated limits have been reached or exceeded, actions to be taken or approvals to be obtained before routine loading may resume.

Annex

TYPICAL LISTING OF COMMISSIONING TESTS

INTRODUCTION

A.1. This Annex provides detailed lists of tests to be considered in the development of a commissioning programme. These lists of tests are neither complete nor applicable to all reactor types. These lists of tests are mainly based on water reactor technology, and they are illustrative only and certainly not exhaustive. Reactors are now being designed which include many passive safety features or which do not include some parts of the systems mentioned here. Clearly the commissioning for such reactors will differ in many respects.

PREREQUISITES FOR PRE-OPERATIONAL TESTS

Functional tests of individual subsystems or components

A.2. Typical tests to be considered are as follows:

(a) Valves: leakage, opening and closing times, valve stroke, position indication, torque and travel limiting settings, operability at differential pressures, correct settings and functioning of relief and safety valves.

(b) Motors and generators: direction of rotation, vibration, overload and short circuit protection, margins between set points and full load running current, lubrication, insulation tests, supply voltage, phase to phase checks, neutral current, acceleration under load, temperature rise under specified cold and hot starting conditions, phase currents, and load acceptance capability versus both time and load (for generators).

(c) Pumps, fans or gas circulators: vibration, motor load versus time, seal or gland leakage, seal cooling, flow and pressure characteristics, lubrication, acceleration and coast down.

(d) Piping and vessels: pressure tests; leak tightness, cleaning and flushing; clearance of obstructions; support adjustments; proper gasketing; bolt torque; insulation; filling and venting.

(e) Instrumentation and control: voltage, frequency, current, circuit breaker operation, busbar transfers, trip settings, operation of prohibiting and permissive interlocks, calibration.

PRE-OPERATIONAL TESTS

Reactor coolant system

A.3. The reactor coolant system includes all pressurized components such as pressure vessels, pressure tubes, piping, ducting, pump and circulator casings and valve bodies forming the pressure boundary of the primary coolant for the reactor, together with such items as the associated pumps, valves and instrumentation.

(a) System tests: expansion and restraint tests to confirm acceptability of clearances and displacements of vessels, piping, ducting, piping hangers, hold-down support, or restraining devices such as for seismic protection in the as-built system; hot performance and/or cold testing of the system with simultaneous operation of auxiliary systems, including chemical control aspects.

(b) Component tests: appropriate tests and measurements of reactor coolant system components, including:

— pressurizer;
— pumps, fans or gas circulators with associated motors;
— steam generators;
— pressure relief valves (and associated dump tanks and cooling circuits, if any) and supports and restraints for discharge piping;
— safety valves;
— other valves;
— instrumentation used for monitoring system performance or performing prohibiting and permissive interlock functions;
— reactor vessel and internals, including checks of prestressed concrete tendons;
— jet pumps or internal recirculation pumps;
— reactor gas plant.

(c) Vibration tests: vibration monitoring of reactor internals and other components such as piping systems, heat exchangers, steam generator tubing and rotating machinery.

(d) Pressure boundary integrity tests: baseline data for subsequent in-service testing.

Moderator system

A.4. Tests on the moderator system include:

(a) System tests: cold performance test of the moderator channel system, including cover gas system and auxiliary systems for chemical control, moderator and/or fuel channel alignment checks.

(b) Component tests: appropriate tests of system components, including:

— cover gas pressurizer;
— pumps, compressors and motors;
— gas recombination units;
— pressure relief devices;
— devices for injection of chemical absorbers.

Reactivity control systems

A.5. Tests on the reactivity control systems include:

(a) Tests of the chemical control system: proper blending of boric acid solution and moderator, uniform mixing and adequacy of sampling and analytical techniques, operation of heaters and trace heating; operation of instrumentation, controls, interlocks, alarms; rate of injection into and dilution from the bulk system; redundancy, electrical independence and operability of system components; correctness of failure mode on loss of power to system components.

(b) Tests of the liquid poison system: operation of the system with demineralized water; mixing of moderator solution and adequacy of the sampling system; operability of instrumentation, controls, interlocks and alarms; operability of trace heating; operation of quick acting valves including test firings of squib actuated valves; redundancy and electrical independence.

(c) Control system and shut-off system tests: normal operation and shutdown capability including cooling requirements; scram times and, where applicable, friction tests; appropriate performance of inhibiting and other functions in the system logic (such as rod selection, insertion, withdrawal and runback features, sequence control devices, rod worth minimizers); instrumentation for rod position and interaction of the control and shut-off drive systems with other systems such as automatic reactor power control systems and refuelling equipment; correct failure mode on loss of power for the rod drive systems; and appropriate operation of system alarms.

Reactor protection systems

A.6. Tests on the reactor protection systems include: response time of protection channels, including sensors and associated hardware between the measured variable and the input to the sensor (such as snubbers); operation in all combinations of logic, calibration and operability of primary sensors, trip and alarm settings, operation of prohibiting, permissive and bypass functions, and operability of bypass switches; operability in conjunction with other systems, redundancy, coincidence, electrical independence and safe failure on loss of power; operability of any devices provided to protect the plant from anticipated operational occurrences in conjunction with failure to trip automatically. Any defensive measure to ensure the integrity of the protection system should also be tested (such as key interlock systems or electromagnetic converter protection etc.).

Power conversion system

A.7. The power conversion system includes all components provided to transfer the reactor’s thermal energy in normal operation from the boundaries of the reactor coolant system to the main condenser, and those systems and components provided for the return of condensate and feed water from the main condenser to complete the cycle. System expansion, restraint and operability tests and other appropriate tests are to be carried out on the following components and systems:

— steam generators;
— steam and feed water process lines;
— auxiliary coolant systems;
— relief and safety valves for steam generator pressure;
— emergency feed water pump;
— stop, control, intercept and bypass valves for the turbine;
— feed water system;
— condenser circulating water system;
— make-up water and chemical treatment systems;
— steam extraction system;
— control system for the hot well level of the main condenser;
— feed water heaters and drainage systems;
— main condenser auxiliaries used for maintaining condenser vacuum;
— condenser off-gas system.

Auxiliary and miscellaneous systems

A.8. Appropriate tests are conducted to demonstrate the operability of auxiliary and miscellaneous systems and, where appropriate, to verify redundancy and electrical independence. The following list is illustrative of the types of systems whose performance is demonstrated by testing:

— reactor coolant make-up system: capability during all operational states and accident conditions;
— seal fluid system;
— system for seal and pump cooling fluid;
— vent and drainage systems;
— fire protection systems, including manual and automatic operation of fire detection, alarm and suppression systems;
— service water and raw water systems;

— heating, cooling and ventilation systems, including control room habitability systems, detection systems for smoke and toxic chemicals, ventilation shutdown devices, and systems for leak tightness of ducts and flow rates, direction of airflows and control of space temperatures;

— compressed gas systems, including instrument air system and other compressed gas systems used for safety related functions;

— emergency condenser system, residual heat removal system or system for post-trip shutdown logic;

— cooling system for reactor core isolation;

— cooling system for reactor vessel head;

— shield cooling system;

— leak detection system: sensitivity and accuracy to detect leakage of primary fluid through the boundaries of the reactor coolant system, moderator system, auxiliary system or emergency cooling system, or leakage of secondary coolant into the primary coolant;

— primary pressure relief system;

— boron recovery system;

— communication systems: operation of evacuation and other alarms, public address system within the plant, systems that may be used if the plant is required to be shut down from outside the control room, and communication systems required by the facility emergency plan;

— chemistry control systems for the reactor coolant system and secondary coolant systems;

— cooling and heating systems associated with spent fuel storage if necessary;

— equipment and controls for establishing and maintaining sub atmospheric pressure in sub atmospheric containments;

— component cooling water systems;

— reactor coolant and secondary sampling systems;

— closed loop cooling water systems;

— purification and clean-up systems.

Electrical systems

A.9. The plant electrical systems include the normal AC power distribution system, the emergency AC power distribution system, the emergency AC power supplies, and the DC supply and distribution system.

(a) Normal AC power distribution system: operation of protection devices, initiating devices, relaying and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, redundancy and electrical independence, integrated system performance with simulated partial and full loss of off-site power under worst case conditions, capability to transfer from on-site to off-site power sources.

(b) Vital bus bar and associated AC power supplies: a load test that uses all and minimum sources of power supplies to bus bars.

(c) DC system: calibration and trip settings of protective devices, including relaying devices, operation of breakers, prohibiting and permissive interlocks; capability of battery chargers, transfer devices, inverters, instrumentation and alarms used to monitor system availability including under voltage alarms and ground detection instrumentation; redundancy, electrical independence and actual total system loads, a discharge test of each battery bank at full load and for the design duration of load, adequacy of emergency lighting.

(d) Emergency AC power distribution system: includes operation of protection devices, relaying and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, capability of emergency and vital loads to start in the proper sequence and to operate under simulated accident conditions with both the normal (preferred) AC power sources and/or emergency (standby) power source in accordance with design requirements for voltage and frequency; duration tests of diesel generators or equivalent machines, capability to start and operate with maximum and minimum design voltage available; (to the extent practicable) testing of emergency or vital loads conducted for a sufficient period of time to provide assurance that equilibrium conditions are attained; verification of system redundancy and electrical independence; testing of loads supplied from the system such as motor generator sets with flywheels designed to provide non-interruptible power to vital plant loads, to demonstrate proper operation; load tests for vital bus bars using normal and emergency sources of power supplies to the bus bar; operation of indicating and alarm devices used to monitor the availability of the emergency power system in the control room; adequacy of the plant’s emergency lighting system.

(e) Emergency or standby AC power supplies: redundancy, electrical independence, and proper voltage and frequency regulation under transient and steady state conditions; performance of auxiliary systems such as those used for starting, cooling, heating, ventilating, lubricating and fuelling, duration of test to ensure that equilibrium conditions are attained;

logic, correct set points for trip devices and proper operation of initiating devices, prohibiting and permissive interlocks, redundancy and electrical independence.

Containment systems

A.10. In tests on the primary and secondary containment systems, account should be taken of the functional requirements during normal operation such as those for heating, ventilation and air conditioning, as well as isolation and integrity requirements under simulated accident conditions. Particular attention should be paid to:

— integrated and partial (penetration air lock, valve) leakage testing of containment and overpressure (or vacuum) structural test;

— functional test on isolation valves and on initiation logic;

— containment vacuum breaker testing;

— functional testing of the auxiliary containment system, such as purge system and systems for air purification, gas treatment and inerting;

— primary and secondary ventilation system tests; leak collection and exhaust system tests; dousing or spray water system tests.

Systems for disposal of radioactive waste

A.11. Tests on radioactive waste disposal systems include those designed to demonstrate the operability and to verify the performance of systems and components used to process, store and release, or to control the release of, liquid, gaseous and solid radioactive wastes, and of pumps, tanks, controls, valves and other equipment, including automatic isolation and protective features and instrumentation and alarms; and systems designed to verify tank volumes, capacities, holdup times and proper operation and calibration of associated instrumentation.

Fuel storage and handling systems

A.12. Tests on fuel storage and handling systems are to demonstrate operability in accordance with the design intent of equipment and components used to handle or cool irradiated fuel and to handle non-irradiated fuel. These may include:

— integrity testing or inspection of spent fuel storage and its liner;

— tests on cooling and purification systems for spent fuel facilities (including the testing of antisiphon devices, high radiation alarms and low water level alarms);

— tests on refuelling equipment (including hand tools, power equipment, bridge and overhead cranes and grapples) and operability of protective interlocks and devices;

— tests on containment devices, and for leakage and ventilation in the fuel discharge route;

— tests on fuelling machines, control and hydraulic systems, and pressurizing and cooling equipment;

— appropriate tests or inspections of storage facilities for ensuring sub criticality;

— handling test on fuel transfer flasks.

Handling systems for reactor components

A.13. Tests on the handling systems for reactor components cover equipment handling, hoists used for reactor components that need to be moved (for example, for refuelling or for reactor vessel inspection), and protective interlocks on cranes and hoists.

Radiation protection systems

A.14. Appropriate tests on systems and components used to monitor or measure radiation levels to provide for personnel protection or to control or limit the release of radioactive material include the following:

— process tests, effluent tests and area radiation monitor tests;

— tests on personnel monitors and radiation survey instruments;

— tests on laboratory equipment used to analyse or measure radiation levels and activity concentrations; and

— in situ efficiency tests of high efficiency particulate air filters and adsorption filters.

Instrumentation and control systems

A.15. Tests on instrumentation and control systems cover control functions for normal operation and instrumentation to provide alarms for off-normal conditions in order to initiate corrective action and to monitor events. Instrumentation and control systems should be tested over the design operating range, and limiting malfunctions and failures should be tested by simulation. Any defensive measure to ensure the integrity of the instrumentation and control system should also be tested (such as electromagnetic converter protection).

A.16 A listing of instrumentation parameters and factors for testing (some of this equipment may be tested in conjunction with the control system) should typically include the following:

— pressurizer pressure and level;

— reactor vessel level;

— reactor coolant flow;

— feed water control;

— automatic control of reactor temperature and power;

— steam pressure in the secondary system;

— leak detection in the reactor coolant system;

— reactor and primary circuit diagnostic systems;

— instrumentation initiating the emergency core cooling system and containment spray;
— annunciators for reactor control and engineered safety features;
— equipment to measure chemical parameters;
— reactor start up instrumentation;
— instrumentation and controls used for shutdown from outside the control room;
— in-core and ex-core neutron instrumentation;
— detection of failed fuel;
— traversing in-core probe;
— monitoring of loose parts;
— pressure control to maintain design differential pressures;
— seismic instrumentation;
— detection of external and internal flooding conditions;
— instrumentation monitoring the course of postulated accident conditions;
— post-accident hydrogen monitors and analysers used in the control system for combustible gas;
— computer control, monitoring and logging systems.

Engineered safety features

A.17. Engineered safety features prevent or mitigate the consequences of postulated accidents. Since they vary for different plant designs, the following list is only illustrative of those commonly provided:

— emergency core cooling systems and essential auxiliary systems for equipment operability using normal and emergency power and cooling supplies, design pump run out conditions and injection at required flow rate and pressure; operability of overpressure protection for low pressure cooling systems;
— auto depressurization system;
— systems for post-accident removal of heat from the containment, spray systems and recirculation fans;
— control system for combustible gases in the containment;
— cold water injection interlocks;
— emergency water supply system;
— emergency feed water system.

A.18. Tests on the engineered safety features include: tests for satisfactory performance and response time in all expected operating configurations or modes, operation of initiating devices, correct logic and set points, operation of bypasses, prohibiting and permissive interlocks and protective devices for equipment that could shut down or defeat the operation or functioning of engineered safety features. Concurrent testing of systems or components provided to ensure or support the operation of engineered safety features should also be conducted using the minimum number of operable components available with which these systems are designed to function. These include systems and components such as systems for heating, ventilation and air conditioning, cooling water and seal injection systems and protected compressed gas supplies; protective devices, such as leaktight covers or housings provided to protect engineered safety features from flooding, or devices used to prevent 'water hammer' and possible damage to fluid systems.

FUEL LOADING, INITIAL CRITICALITY AND LOW POWER TESTS

Tests during fuel loading and initial criticality period

A.19. Before reactivity is increased ('inserted') to approach initial criticality, the prerequisites for fuel loading (see paras 5.34–5.47 and Appendix for details), open vessel tests and final checks are to be completed to ensure that the reactor is in proper condition for start-up. The following list is illustrative of the types of tests and verifications that are conducted during or after initial fuel loading:

— tests of withdrawal and insertion speeds for reactivity control rods, sequences, rod position indication, protective interlocks and circuitry, and scram timing of reactivity control and shutoff devices after the core is fully loaded; to the extent practicable, testing should demonstrate scram times for reactivity control rods at the extreme temperatures and flow ranges for the reactor coolant system;

— local criticality tests;

— testing of the reactor protection system: trip point, logic and operability of scram breakers and valves, and manual scram functions;

— rod drop time measurements: each rod, cold and hot, at rated recirculation flow and with no recirculation flow plus additional measurements for each of the fastest and slowest rods;

— testing of leak rates for the reactor coolant system;

— testing of moderator cooling;

— chemical tests: water quality and boron concentration of the reactor coolant and/or moderator system;

— calibration and neutron response check of source range monitors; calibration of intermediate range neutron flux measuring instrumentation; verification of proper operation of associated alarms and protective functions;

— mechanical and electrical in-core monitors, including traversing in-core probes, if installed;

— flow tests for the reactor coolant system: verification of vibration levels, of differential pressures across the fully loaded core and across major components in the reactor coolant system; verification of the piping reactions to transient conditions (such as pump starting and stopping) and flows for all allowable combinations of pumps in operation; loss of flow tests conducted to measure flow coast down;

— test of the effectiveness of the pressurizer (hot shutdown);

— vibration checks or monitoring;

— shutdown margin verification for partially and fully loaded core.

Low power tests

A.20. After achieving initial criticality, tests are performed as necessary to verify that the behaviour and characteristics of the core, the cooling system, reactivity control systems, reactor physics parameters and shielding are as expected, and that the reactivity coefficients are as assumed in the safety analysis report; and to confirm the operability of plant systems and design features that could not be completely tested during the pre-operational test phase owing to the lack of an adequate heat source for the reactor coolant system and the main steam system. The following list is illustrative of the tests to be conducted, as applicable, if they were not completed previously during pre-operational, hot functional testing:

— neutron and gamma radiation surveys;

— determination that there is an adequate overlap of source range and intermediate range neutron instrumentation and verification of alarms and protective functions intended for operation in the low power test range; checks on detector sensitivity as a result of changes in temperatures of coolant and shielding;

— radiation monitors: verification of proper response to a known source;

— measurement of temperature reactivity coefficient for poison and moderator and/or coolant over the temperature range and poison concentration range in which the reactor may become critical;

— determination of reactivity worth for control rods and the control rod bank, including verification of rod insertion limits to ensure an adequate shutdown margin, consistent with the assumptions for accidents (for example, with the control rod of greatest reactivity worth failing to enter the core);

— measurements of absorber reactivity worth;

— determination of absorber concentration at initial allocation of criticality and reactivity;

— flux distribution measurement with normal rod patterns (this may be performed at a higher power, consistent with sensitivity of in-core flux instrumentation);

— chemical and radiochemical measurements to demonstrate the design capability of the chemical control systems and installed analysis and alarm systems to maintain water quality within limits in the moderator, the reactor coolant and secondary coolant systems;

— determination of reactivity worth of the most reactive rod;

— operability of control rod withdrawal and insertion sequencers and of the inhibit or block functions associated with control rod withdrawal up to the reactor power level at which such features must be operable;

— chemical tests of control fluid quality;

— comparison of actual critical configuration with predicted configuration;

— leak test of reactor coolant system;

— confirmation of calibrations of reactivity control devices as predicted for standard rod patterns (for non-standard patterns, differential and integral reactivity worths are to be determined);

— functional test of cooling system for the reactor vessel head;

— capability of the primary containment ventilation system to maintain environmental parameters in the containment and to maintain important components in the containment within design limits, with the reactor coolant system at rated temperature and with the minimum availability of ventilation system components for which the system is designed to operate;

— demonstration of the operability of steam driven engineered safety features and steam driven plant auxiliary equipment and power conversion equipment;

— verification of piping and component movements, vibrations and expansions for the acceptability of safety systems; operability, including stroke times, of isolation valves and bypass valves for the main steam line and branch steam line at rated temperature and pressure conditions; operability of the leakage control system for the main steam isolation valve;

— operability of computer system for process control;

— scram time for control rods and shutdown rods at rated temperature in the reactor coolant system;

— operability of pressurizer relief valves and main steam system relief valves at rated temperature;

— operability of residual heat removal systems or decay heat removal systems, including atmospheric steam dump valves and turbine bypass valves;

— operability of purification and clean-up systems for the reactor coolant system;

— measurements or checks of reactor vessel internals and of the vibration of components of reactor coolant systems.

POWER TESTS

A.21. The following list is illustrative of the types of performance demonstrations, measurements and tests in the power tests stage.

— natural circulation tests of the reactor coolant system;

— tests of power reactivity coefficients or power versus flow characteristics;

— tests of dynamic plant response to the design load swings, including step and ramp changes, and response to automatic control;

— chemical analyses (at frequent intervals);

— functioning of chemical and radiochemical control systems and sampling to verify that characteristics of the reactor coolant system and secondary coolant system are within specified limits;

— effluent monitoring systems: verification of calibration by laboratory analysis of samples (as early in power ascension as possible and repeated at defined power steps);

— process radiation monitoring systems and effluent radiation monitoring systems: correctness of response;

— evaluation of core performance: reactor power measurements, verification of calibration of flux and temperature instrumentation, with sufficient measurements and evaluations conducted to establish flux distributions, local surface heat flux, linear heat rate, departure from nucleate boiling ratio, radial and axial power peaking factors, maximum average planar linear rate of generation of heat, minimum critical power ratio and quadrant power tilt throughout the permissible range of power to flow conditions;

— turbine trip;

— trip of generator main breaker: with the method used for opening the generator output breakers (by simulating an automatic trip) selected such that the turbine generators will be subjected to the maximum credible over speed condition they could encounter during plant operations;

— loss of off-site power (>10% generator power output);

— radiation surveys to determine the effectiveness of shielding;

— on-power refuelling tests;

— dropped rod: effectiveness of instrumentation in detecting a dropped rod and verification of associated automatic actions;

— evaluation of flux asymmetry with single rod assembly fully inserted and partially inserted below the control bank, and evaluation of its effects;

— vibration monitoring of reactor internals in steady state and transient operation, if this testing has not been completed previously;

— determination of the reactivity worth of the most effective rod;

— process computer: comparison of safety related predicted values with measured values; verification of inputs to control room computers or process computers from process variables, data printouts and validation of performance calculations performed by the computer; validation of all computer safety functions;

— verification of scram times after plant transients that result in scrams;

— functional tests of relief valves; verification of operability, response times, set points and reset pressures, as appropriate, for pressurizer relief valves, main steam line relief valves and atmospheric steam dump valves;

— verification of operability and response times of isolation valves for the main steam line and branch steam line;

— evaluation of performance of shutdown cooling system; capability of all systems and components provided to remove residual heat or decay heat from the reactor coolant system, including condenser steam dump valves or atmospheric steam dump valves, residual heat removal system in steam condensing mode, reactor core isolation cooling system, and testing of the auxiliary feed water system to include provisions that will provide reasonable assurance that excessive flow instabilities (such as ‘water hammer’) will not occur during subsequent normal system start up and operation (before exceeding 25% power);

— measurement of power control by flow variation and demonstration of flow control;

— calibration and tests of the pressure regulator, including response to operation of a bypass valve;

— emergency condenser performance (after shutdown from >25% power);

— performance of reactor core isolation cooling system (after shutdown from >25% power);

— calibration of reactivity control devices, as necessary, and verification of performance of major or principal plant control systems such as average temperature controller, automatic reactor control systems, integrated control system; pressurizer control system, reactor coolant flow control system, and main, auxiliary and emergency feed water control systems; hot well level control systems; steam pressure control systems; and reactor coolant make-up and let-down control systems;

— rod pattern exchange demonstration (at the maximum power that rod exchange will be permitted during operation);

— dynamic response of the plant and subsequent steady state of the plant for single and credible multiple trips of the reactor coolant pump or the circulator and/or failure of flow control valves of the reactor coolant system;

— trip-out of feed water pump and restart of standby pump;

— control rod sequencers, reactivity worth minimizers for control rods, rod withdrawal block functions, rod runback, partial scram, operability of the 'select rod insert' features;

— reactivity control systems, including functioning of control and shutdown rods and poison addition systems;

— operation of the reactor coolant system with the plant in steady state conditions to establish flow rates, reverse flows through idle loops or jet pumps, core and channel flow, differential pressures across the core and major components in the reactor coolant system, and vibration levels of other components;

— baseline data for the monitoring system for loose parts of the reactor coolant system;

— effectiveness of leak detection systems for reactor coolant, if not previously demonstrated;

— operation of failed fuel detection systems in accordance with predictions;

— shielding and penetration cooling systems: maintenance of temperatures of cooled components with the minimum design capability of cooling available;

— performance of the auxiliary systems for the operation of engineered safety features with the minimum design capability of operable components in these auxiliary systems;

— operation of processing, storage and release systems for gaseous and liquid radioactive waste;

— dynamic response of the plant for a simulated condition of loss of turbine generator coincident with loss of off-site power;

— dynamic response of the plant to load rejections including turbine trip (this test may be combined with the turbine trip test if a turbine trip is initiated directly by all remote manual openings or automatic trips of the generator main breaker; that is, a direct electrical signal, not a secondary effect such as turbine over speed);

— dynamic response of the plant for the case of automatic closure of all main steam line isolation valves (for pressurized water reactors the test may be made at a lower power level to demonstrate proper plant response to this transient);

— observations and measurements, as appropriate, to ensure that piping and component movements, vibrations and expansions are acceptable for safety systems (tests performed in low power testing need not be repeated);

— dynamic response of the core and plant to fast load changes initiated by the load control;

— capability of plant systems to control oscillations in xenon levels in the core;

— performance of ventilation systems and air conditioning systems;

— dynamic response of the plant to loss of or bypassing of the feed water heater(s) due to a credible single failure or operator error that results in the most severe case of reduction in feed water temperature;

— load carrying capability of systems, components and cables;

— shutdown from outside the control room.

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GS-R-3 THE MANAGEMENT SYSTEMS FOR FACILITIES AND ACTIVITIES

GS-G-3.1 APPLICATION OF THE MANAGEMENT SYSTEMS FOR FACILITIES AND ACTIVITIES

GS-G-3.5 THE MANAGEMENT SYSTEMS FOR NUCLEAR INSTALLATIONS