Form10/00

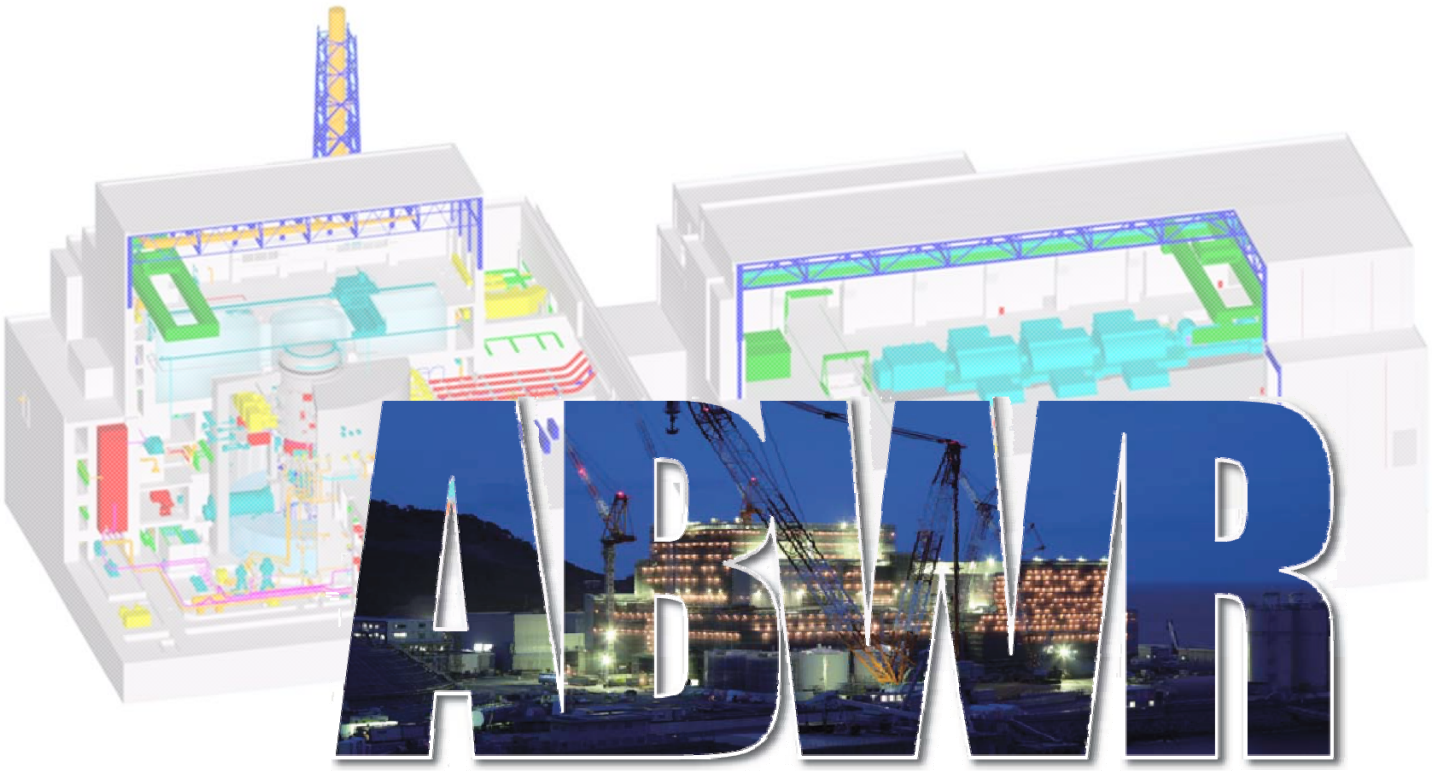
HITACHI

UK ABWR

Document ID	:	GA91-9101-0101-29000
Document Number	:	QGI-GD-0011
Revision Number	:	C

UK ABWR Generic Design Assessment

Generic PCSR Chapter 29 : Commissioning



Hitachi-GE Nuclear Energy, Ltd.

DISCLAIMERS

Proprietary Information

This document contains proprietary information of Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE), its suppliers and subcontractors. This document and the information it contains shall not, in whole or in part, be used for any purpose other than for the Generic Design Assessment (GDA) of Hitachi-GE's UK ABWR. This notice shall be included on any complete or partial reproduction of this document or the information it contains.

Copyright

Table of Contents

Executive Summary

This chapter describes the generic arrangements and processes for commissioning that are expected to be followed by a future UK ABWR licensee. It demonstrates, for the purposes of the Generic Design Assessment (GDA), that the UK ABWR can be safely commissioned, and shows how the commissioning activities support the subsequent safe operation of the facility during normal operation and fault conditions.

The chapter outlines the generic concept of commissioning (principles and strategy), together with the required generic framework (processes, organisation, roles, responsibilities, etc.). It presents the generic plan for commissioning and explains how the hazards and risks in different stages of commissioning will be controlled and reduced to levels that are As Low As Reasonably Practicable (ALARP). It discusses how the future licensee's responsibility for safe commissioning can be delivered whilst multiple activities on the site are undertaken by contractor personnel. The relevance of the safety case assumptions and Limits and Conditions for Operation that are specified in other PCSR chapters to commissioning activities is explained.

Commissioning is shown to be an essential process for the subsequent safe operation of a new nuclear power plant, using a structured programme of inspection and testing to verify the functionality of the plant and equipment and to validate that it meets the design intent. In particular, the commissioning process will demonstrate that safety requirements (for example Safety Functional Claims) for Structures, Systems and Components and Human-Based Safety Claims that are identified in other PCSR chapters have been met by the constructed and installed plant when tested against the design basis.

The chapter also explains how previous commissioning experience is expected to inform commissioning activities of the UK ABWR. In addition, commissioning will provide an opportunity to train operating staff, to validate the operating technical specifications, procedures and instructions, and to capture testing data which can be collated to provide confidence that the plant can be operated safely.

It is concluded that the commissioning arrangements have been developed to a level of detail that is appropriate for GDA, and that completion of commissioning will contribute towards ensuring the safe operation of UK ABWR and contribute to reducing risks ALARP.

It is acknowledged that further work will be required post GDA to develop a complete suite of commissioning arrangements which fully incorporate future licensee and site specific aspects. This work should be the responsibility of any future licensee.

29.1 Introduction

Commissioning is an essential process for the subsequent safe operation of a nuclear power plant and it should be carefully developed, planned, and executed.

The main objective of this chapter is to outline the arrangements and processes that are expected to be followed by a future UK ABWR operator in order to demonstrate, within the GDA process, that the UK ABWR can be safely commissioned. These include a strategy for commissioning, principles for commissioning and a generic plan for commissioning. This chapter shows how the hazards and risks in different stages of commissioning can be identified, controlled and reduced ALARP.

29.1.1 Background

The GDA process involves regulatory assessment of the safety, environmental and security safety case for the UK ABWR. Primarily this is an assessment of the deterministic and probabilistic safety analysis plus consideration of hazards etc.

In effect the GDA safety case (as presented in other chapters of this PCSR) sets out the basis of a 'specification and plant description' for construction of the UK ABWR together with a safety analysis to show that operation of the proposed design will be safe and will meet UK regulatory expectations. The proof that these safety claims have been achieved can only be provided through testing after the plant has been constructed and installed. These safety tests form the subject of commissioning and it is appropriate during GDA to identify how those tests should be undertaken to verify and validate the design and safety case.

The UK ABWR is a complex plant and the objective of commissioning is to demonstrate that it has been correctly constructed and that equipment has been correctly installed and connected to interfacing and supporting systems. Therefore the commissioning programme should include all the tests necessary to demonstrate that the plant as built and as installed meets the requirements of the safety case and satisfies the design intent and, consequently, to ensure that the plant can be safely operated in accordance with the operational limits and conditions.

It is not appropriate during GDA to identify every test that needs to be undertaken, but the arrangements to identify those tests that are important to prove that the as-built plant has been correctly constructed/installed should be considered.

The commissioning phase sees the transition of the plant from construction to operation and significantly it sees the introduction of hazards into the plant for the first time. The hazards include live electrical systems, pressurised pipes and vessels, gases and also include bringing nuclear fuel onto the site for the first time, which changes the status of the site from a construction to a nuclear site. All these hazards need to be appropriately identified and controlled and therefore an important

element of commissioning is the management arrangements that will ensure safety. These management arrangements will be the responsibility of the future licensee through appropriate arrangements under the Nuclear Site Licence. As commissioning is a matter for the future licensee and detailed information is generally not included within GDA then there are no formal claims made in this chapter and there is no directly supporting topic report (as would be expected in strict compliance with the safety case development manual [Ref-8]). The supporting documents for commissioning will be prepared in the post GDA phase. However in GDA, it is appropriate for the requesting party (designer), Hitachi-GE, to identify its expectations for safe management of commissioning.

Given this background, it is therefore the intention of this PCSR chapter to describe the expectations for commissioning, so far as appropriate for the GDA stage.

29.1.2 Document Structure

The following sections of PCSR Chapter 29 outline the commissioning strategy which is being considered for GDA of the UK ABWR.

Section 29.2 Purpose and Scope: This section sets out the purpose and scope of the commissioning PCSR chapter for GDA and identifies what is not included. It also identifies links to other PCSR chapters.

Section 29.3 Commissioning Programme Principles: This section sets out the principles, expectations, and requirements for a comprehensive commissioning programme, which includes Construction Testing, Pre-Operational Testing, and Start-up Testing. This section identifies the need for commissioning to be split into phases with a logical sequence between them and with hold points at appropriate places to verify the acceptability of results before proceeding to the next phase.

Section 29.4 Commissioning Programme Objectives: This section describes the main objectives of the commissioning programme, which include ensuring that the systems, structures, and components (SSCs) have been constructed, manufactured, and installed correctly and demonstrate that they function as designed.

Section 29.5 Commissioning Programme Organisation: This section describes the basic organisational arrangements that are required to ensure that commissioning is completed comprehensively and safely.

Section 29.6 Conduct of Commissioning: This section outlines the management arrangements and procedures that will be required for development and control of test procedures, review and approval of test results, resolution of failures to meet acceptance criteria, test records, requirements for

progressing from one testing hold point to the next, and system handover processes for moving from commissioning to operational states.

Section 29.7 Commissioning Programme: This section gives an overview of the main phases of the plant commissioning programme and what kind of testing is included within each phase.

Section 29.8 Managing Safety during Commissioning: This section provides an overview of the safety management arrangements that are expected to be required for ensuring safety during commissioning.

Section 29.9 Assumptions, Limits and Conditions for Operation: This section describes utilisation and verification of Assumptions, Limits and Conditions for Operation (LCOs) for testing and operation during commissioning. In addition, the general principles for the identification of Assumptions, Limits and Conditions for Operation within other chapters of GDA PCSR, are described in Generic PCSR Chapter 4: Safety Management throughout Plant Lifecycle, section 4.12.

Section 29.10 Summary of ALARP Justification: This section describes ALARP from two aspects: firstly the way that commissioning contributes to the overall ALARP justification through thorough testing of all plant; secondly the way that the management arrangements for commissioning aim to ensure that risks to nuclear safety are reduced ALARP.

Section 29.11 Conclusions: This section provides a summary of the main aspects of this chapter.

Section 29.12 References: This section lists documents referenced within this chapter.

This chapter does not cover the following topics:

- the definition and description of the operating modes (see Chapter 5: General Design Aspects)
- the approach to compliance with NSEDPs (see Chapter 5)
- emergency arrangements (see Chapter 22: Emergency Preparedness)
- security requirements for the commissioning phase
- commissioning of environmental or security related structures/equipment
- the environmental impact of the commissioning activities
- identification and assessment of conventional health and safety related hazards for the commissioning activities.

- human factors actions related to commissioning activities (but appropriate references are included to Chapter 27: Human Factors).
- chemistry control (Chapter 23: Reactor Chemistry)
- radiation protection (Chapter 20: Radiation Protection)

Environmental and security aspects of the UK ABWR design. For generic links to GEP, and CSA documentation, please refer to Generic PCSR Chapter 1: Introduction. For GEP, where specific references are required, for example in Radioactive Waste Management, Radiation Protection, Decommissioning, these will be included in the specific sections within the relevant chapter.

Chapter 29 has links with a number of other PCSR chapters, particularly in respect of how commissioning aims to validate relevant claims from the other PCSR chapters covering SSCs, DBA (Design Basis Accident), PSA (Probabilistic Safety Analysis), Human Factors etc. This means that there is an implicit link with almost all of the other PCSR chapters. In addition, chapter 29 discusses specific links with the following chapters:

- Chapter 4: Safety Management throughout Plant Lifecycle – Reference for safety management and technology transfer to the future licensee
- Chapter 5: General Design Aspects - Input to graded approach (safety class and category), and reference for operating modes at start-up testing.
- Chapter 22: Emergency Preparedness - Input to emergency planning
- Chapter 23: Reactor Chemistry - Input to chemistry control for SSCs during commissioning phase and link as source of commissioning requirements
- Chapter 24: Design Basis Analysis - Link as source of commissioning requirements
- Chapter 27: Human Factors - Link as source of commissioning requirements, and human factors actions related to commissioning
- Chapter 28: ALARP Evaluation - Link to ALARP evaluation
- Chapter 31: Decommissioning - To recognise the importance of good record management during the commissioning phase on future decommissioning planning.

29.2 Purpose and Scope

29.2.1 Purpose

The objective of this chapter is to describe the arrangements and processes that are expected to be followed by a future UK ABWR operator in order that the UK ABWR can be safely commissioned. These include a description of the commissioning principles and strategy, the programme and the related management arrangements that demonstrate, to the extent appropriate for GDA, that the plant components and systems, as constructed and installed, are capable of safe and reliable operation in accordance with their design specifications, their performance objectives, their safety requirements and reliability requirements as claimed in the safety case.

Specific objectives of this PCSR chapter are to describe:

- the generic concept of commissioning (principles and strategy)
- the required generic framework (processes, organisation, roles, responsibilities, etc.) and the generic plan for commissioning.
- how the hazards and risks in different stages of commissioning will be controlled and reduced ALARP.
- identify links to relevant content of other GDA PCSR chapters, to ensure consistency across the whole safety case, and to ensure the overall safety case presented is complete.
- describe where additional supporting information can be found.

29.2.2 Scope

The UK ABWR GDA PCSR Commissioning chapter covers commissioning activities from the beginning of Construction testing, Pre-Operational Testing to the end of the Start-up Testing phase.

This chapter describes, at a generic level, the:

- Commissioning Basis and Framework
- Commissioning Objectives
- Commissioning Testing Programme
- Organisational structure required for commissioning
- Processes, procedures and other documentation required to support commissioning.

- Risks involved during the commissioning activities and the mitigating measures required.
- Requirement for handover processes from construction to commissioning and to the Operating organisation(s).
- Requirement for a hold point process.

This chapter aims to:

- Identify links to other chapters of the PCSR to ensure consistency across the whole safety case.
- Identify the linkage, or provide a reference, between the safety case functional requirements, SSCs, and commissioning test requirements.
- Provide or identify references to information required to demonstrate that the risks associated with commissioning the UK ABWR will be ALARP.
- Emphasise that although the chapter sets out the expectations for commissioning at the GDA stage, the future licensee has prime responsibility for all site activities that may affect safety, including commissioning undertaken by contractors, and that this cannot be delegated.

29.3 Commissioning Programme Principles

The commissioning programme aims to demonstrate that the plant SSCs, as constructed/erected and installed are capable of safe and reliable operation in accordance with their design specifications, performance objectives, safety and reliability requirements as documented in the safety case. Commissioning seeks to verify and validate the identified SSCs' Safety Functional Claims (SFCs) and their design through testing. These design and safety requirements may be modified during the detailed design phases but need to remain linked to the commissioning tests.

The UK ABWR has been designed to allow safe commissioning. The expectation is that the testing and management arrangements put in place by the future licensee during the commissioning stage will ensure that commissioning is completed effectively. Importantly, commissioning is expected to demonstrate, through a suitable and sufficient plan of verification and validation (V&V), the practicality of implementation of the conditions, constraints, and assumptions that underpin the Human Based Safety Claims (HBSCs) and SPCs (primarily SPCs relating to testability and maintainability) made within the safety case. HBSCs are discussed in Chapter 27: Human Factors and are known as; the systematic and thorough identification and understanding of all human actions that are mainly important to achieving safety and resilience in response to abnormal events. All of the claims made on human actions within the UK ABWR safety case are captured in "Human-Based Safety Claims Report" [Ref-12]. The commissioning stage is therefore a key element of demonstrating that the plant meets the requirements of the safety case.

Regarding maintaining soundness of SSCs, installed SSCs are maintained and protected in accordance with preservation controls, i.e. administrative control for maintaining SSCs' soundness which specifies rust proof, moisture-proof, damage prevention, etc, throughout the construction and commissioning phase. The future licensee is expected to have oversight of the preservation controls during all phases. In addition, chemistry control during commissioning is discussed in Chapter 23: Reactor Chemistry and the topic report "Topic Report on Commissioning Chemistry" [Ref-5]. The commissioning programme is formed around international guidance of [Ref-1], [Ref-2], [Ref-3], and [Ref-4].

A comprehensive commissioning programme, including Construction Testing, Pre-Operational Testing, and Start-up Testing, is expected to be prepared by the future licensee for implementation on site. A graded approach is envisaged to be applied to commissioning based on the classification of the SSCs. It is expected that the future licensee is able to benefit from Operational Experience (OPEX) from recent new build projects and relevant commissioning experience to help in development of this comprehensive commissioning.

This programme will be expected to include hold points at key milestones, at which the acceptability of the commissioning tests results will be verified (with particular focus on demonstrating that the

plant meets the appropriate design safety requirements) before entering into the next phase of commissioning.

The commissioning programme will consider the plant configurations considered in the safety case and perform the V&V of the claimed SSCs performances. The tests will be grouped into commissioning phases in a logical sequence from non-nuclear testing phases to nuclear testing phases, and from testing for individual components and systems to overall testing for integrated systems, with overall testing for the plant at the end of commissioning. The sequence of tests will be such that plant safety is never dependent on the performance or availability of SSCs that have not yet been tested. Where appropriate there will be a progressive sequence of tests so that the plant is exposed to less onerous test conditions before it is exposed to more onerous conditions.

The conduct of commissioning in accordance with the principles contributes to the overall demonstration that risks from UK ABWR have been reduced ALARP. There are five elements to this:

- Completion of commissioning safety demonstration tests to show compliance with the safety case,
- Demonstration that the plant has been correctly constructed and installed before operation commences,
- Minimising nuclear safety risks before and during testing;,
- Learning from experience, using current good practice, and considering the potential for improvements, and
- Other aspects of verification and validation conducted in commissioning.

Further information on the relationship between commissioning and the demonstration that risks from UK ABWR are ALARP is given in section 29.10.

In addition, records in commissioning phase will be all important for the decommissioning safety case as the design information alone will not provide an adequate level of accuracy for the as-built plant. This is described in Chapter 31: Decommissioning, section 31.9.1.2 Commissioning and Handover Information.

29.4 Commissioning Programme Objectives

The objectives of the commissioning programme are to:

(1) Ensure that the structures, systems, and components have been constructed, manufactured, and installed correctly and that they function as required by the design specification.

(2) Demonstrate the systems, structures, and components operate in accordance with their design bases, specifically with regard to safety requirements. This demonstration primarily implies verifying and validating whether SSCs meet their Safety Claims (HBSCs included) identified in the safety case:

- That the unit operates correctly under steady state and transient conditions,
- That plant performance complies with safety criteria,
- That assumptions considered in safety analysis are suitably conservative,
- That operating technical specifications are suitably derived from the safety case and reflecting the plant design.

(3) Complete fuel loading in a safe manner.

(4) Demonstrate, where practical, that the plant is capable of withstanding anticipated transients and postulated accidents.

(5) Verify and validate, to the extent possible, that the plant operating instructions reflect the installed SSCs and contain the correct information to ensure that the plant can be operated in a safe manner.

(6) Provide measured data for use as a reference in subsequent plant operation and testing during plant-life.

(7) Bring the plant to rated capacity and sustained power operation and confirm that the plant is capable of generating the power required under the specified operating conditions.

(8) Familiarise the future licensee's staff (including Operators) with the operation of the facility.

29.5 Commissioning Programme Organisation

An organisation for implementing the commissioning programme will be defined and is expected to consist of the future licensee, contractors (including Hitachi-GE), the architect engineer, and other vendor personnel. It is expected that the future licensee is involved in the preparation, performance, and analysis of the tests, as well as in the application of improvements to plant operations which may result from any lessons learned during commissioning tests.

The organisational arrangements must address the conduct of the construction work, commissioning, and operation, and take into account that these activities are likely to overlap each other. The arrangements should identify the roles and responsibilities of the groups involved. There are many ways in which the construction, commissioning, and operating groups may be formed by different organisations. This may depend, in part, on industrial practices and contractual arrangements. However, Hitachi-GE expectation is that the operating organisation will develop and implement a management system organisation for commissioning that will follow international good practice and guidance such as described in IAEA SSG-28 [Ref-1], including arrangements for the safe management, performance and assessment of all activities at the nuclear power plant during commissioning. The details of the organisational arrangements will be provided during the site specific stage.

Qualification of commissioning personnel should aim to be consistent with international standards and best practices, and is expected to be embedded within the future licensee's and contractors' procedures.

29.6 Conduct of Commissioning

29.6.1 Overview

The commissioning programme will be conducted in accordance with arrangements set forth by the future licensee. The commissioning management arrangements will be established consistent with the site license required arrangements. Contractors' management arrangements must be consistent with the future licensee's arrangements and the interface with the licensee's management system should be transparent. These arrangements are based on extensive BWR & ABWR commissioning experiences which have been used for commissioning of many BWR and ABWR stations. They will enable knowledge transfer to the future licensee, and will be summarised in the administrative procedures for site commissioning that underpin the commissioning programme. These administrative procedures address development and control of test procedures, review, and approval of test results, resolution of failures to meet acceptance criteria, test records, requirements for progressing from one testing hold point to the next, conduct of maintenance, and system turnover processes. The administrative procedures are intended to supplement normal plant administrative procedures by addressing those concerns that are unique to the commissioning programme or that are best approached in a different manner.

Commissioning tests serve as a progressive transition between the erection, installation and the start of normal operation of the various plant systems. These tests may take place in-factory, on specific test facilities or on-site. The choice depends on the type of equipment, on the level of a system's integration that can be simulated off-site (e.g. Control & Instrumentation systems (C&I)), and on the ability to obtain specific conditions on-site (e.g. for accident transients).

29.6.2 Test Procedure Development

It is expected that the future licensee arrangements is established to develop, check, and approve test procedures.

The majority of commissioning tests are undertaken using step-by-step procedures to control the conduct of each test. Such test procedures typically specify testing prerequisites, describe desired initial conditions, include appropriate methods to direct and control test performance (including the sequencing of testing), specify acceptance criteria by which the test is to be evaluated, and provide for or specify the format by which data or observations are to be recorded. The commissioning procedures will be developed and reviewed by personnel with appropriate technical backgrounds and experience. This includes the participation of principal design organisations in the establishment of test performance requirements and acceptance criteria.

29.6.3 Evaluation, Review and Approval of Test Results

It is expected that the future licensee's arrangements is established to evaluate, review, and approve test results. Individual test results will be evaluated and reviewed by suitably qualified and experienced personnel of the commissioning group. Test exceptions or acceptance criteria violations are communicated to the affected and responsible organisations that will help resolve the issues by suggesting corrective actions, design modifications, and retests. Test results, including final resolutions, are then reviewed and approved by future licensee and contractor personnel who will also have responsibility for final review and approval of overall test phase results and for selected milestones or hold-points within the testing phases.

29.6.4 Use of Operating Experience

The Advanced Boiling Water Reactor design is an evolutionary development of the previous BWR plants. The ABWR plants have the benefits of experience acquired with the successful and safe start-up of more than 30 previous BWR/1–6 and ABWR plants. The operational experience and knowledge gained from these plants and other reactor types has been factored into the design and test specifications of the Hitachi-GE supplied systems and equipment that will be demonstrated during the pre-operational and start-up test phases. Additionally, reactor operating and testing experience of similar nuclear power plants obtained from other industry sources will be utilised in developing and carrying out the commissioning programme.

29.6.5 Validation of Operating Instructions

It is expected that the future licensee's arrangements is established to ensure test procedures, to the extent practicable, use existing operating, emergency and abnormal instructions in the performance of tests. These instructions should be developed by the future licensee with contractor input. The use of these operating, emergency, and abnormal instructions is intended to do the following:

- Prove the specific instruction or illustrate changes which may be required.
- Supplement training of plant personnel in the use of these instructions.
- Increase the level of knowledge of plant personnel on the systems being tested.

Arrangements will be in place to ensure that the lessons learned during use of the operating instructions are captured and the instructions updated as applicable.

29.6.6 Turnover Principles

Turnover of a system which is planned implementation of Pre-Operational Testing will occur in phases from Construction Testing/Work to Pre-Operational Testing and Pre-Operational Testing to the future licensee. Turnover is the transfer of authority for managing a SSC which may occur between the different phases of commissioning, and clarify which organisation has management responsibility for equipment of a system. Turnovers will be performed on systems and structures (areas). The future licensee has prime responsibility for the turnovers.

Turnover of systems, i.e. SSCs and their management authority by contractors, from fabrication to assembly and Construction Testing/Work to Pre-Operational Test is implemented under the future licensee's oversight. Thereafter implementation of pre-operational test by the commissioning organisation may begin. In addition, it is expected that controlling processes are in place and suitably qualified and experienced personnel are in place ready to accept the turnover. The Construction Testing/Work to Pre-operational Testing turnover of a system shall typically involve the following: Clearly defined scope of the system being turned over, review and acceptance of system deficiencies or open items, review and acceptance of completed test results and records performed by construction, and review and acceptance of completed maintenance and calibration records performed by construction.

This turnover is implemented according to construction work progress and planned test schedule. For example:

- System level turnover (entire system), and
- Partial level turnover: If a system is expanding to an entire building or outside of a building and so on, turnover may be able to be implemented on each floor/area/room according to progress of construction work and test. i.e. specific scope on the Piping & Instrumentation Diagram (P&ID).

The expectation at turnover from Pre-Operational Testing and/or Construction Work/Testing to the future licensee is that a system will be ready to operate and support Unit start-up. In addition, it is expected that controlling processes and procedures are in place and suitably qualified and experienced personnel are available to operate and maintain the system. The turnover of a system from Pre-Operational Testing to the future licensee should typically involve the following: a clearly defined scope of the system being turned over, review and acceptance of system deficiencies or open items, review and acceptance of baseline testing data collected for future use and comparison, review and acceptance of records showing validation of operating and surveillance test procedures.

29.7 Commissioning Programme

29.7.1 Commissioning Programme Test Overview

The following description gives a preliminary overview of the plant commissioning programme schedule. Only the main test phases are listed. The detailed and comprehensive programme schedule will be developed during later programme stages.

The project commissioning phase starts during the later parts of the construction phase (when the construction testing is performed on a component basis) and ends at the start of the commercial operation phase. The commissioning phase is broken into three parts:

- Construction Testing,
- Pre-Operational Testing, and
- Start-up Testing.

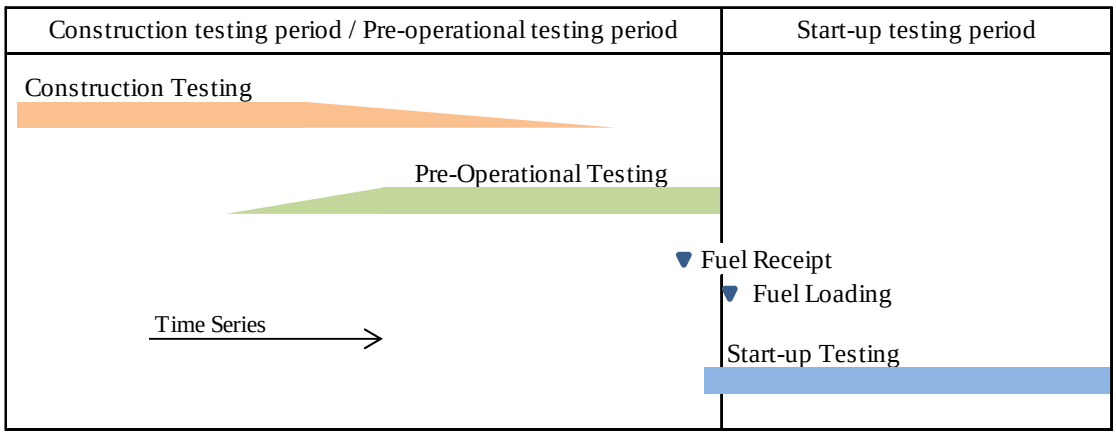


Figure 29.7-1 Commissioning Schedule Overview

Construction testing determines correct installation and functionality of equipment. Pre-Operational Tests are those tests normally conducted prior to fuel loading to demonstrate the capability of plant systems to meet performance requirements. Start-up tests begin with fuel loading and demonstrate the capability of the integrated plant to meet performance requirements.

The commissioning organisation will have hold points before systems are turned over from Construction Testing/Work to Pre-Operational Testing and Pre-Operational Testing to the future licensee and prior to each Start-Up testing plateau to review adequacy of testing in the previous plateau.

Testing requirements that are identified in GDA safety case documents are defined as Commissioning Requirements in "Standard Control Procedure for Identification and Registration of Assumptions, Limiting Condition for Operation" [Ref-10]. This document describes how these requirements and assumptions are identified in the safety case. This ensures that they should be captured in construction, commissioning or operational documentation and allows the future licensee to demonstrate that the requirements and assumptions in the safety case have been fulfilled. Identified requirements are transferred to the future licensee in accordance with "Technology Transfer to Licensee and Operating Regime" [Ref-11] that defines the whole process to ensure that the requirements & assumptions will be appropriately extracted from the Safety Case and will be eventually transferred to the future licensee. Testing requirements other than safety case related items will be identified based on actual SSCs design and specification of requirements, post GDA phase.

As part of the start-up testing phase, transient plant conditions will be tested, which are mainly derived from the Fault Schedule and are discussed in Chapter 24: Design Basis Analysis and "Topic Report on Fault Assessment" [Ref-6]. Such tests will be performed to verify that the interlocks work properly in the required operating conditions, that major parameters do not exceed safety margins and that the plant operates as expected, etc. Transient tests should be specified based upon reasonably testable events in the Fault Schedule. Because extreme transient tests carry a greater risk of harm to the SSCs, workers, and potentially the public, the selection of the tests must take full consideration of the safety implications for both plant and people. Safety should be the main priority when conducting commissioning activities, as was emphasised by the lessons learned from the Chernobyl event. For example, tests such as the following should be avoided after fuel is loaded:

- LOCA (Loss of Coolant Accident) events, SBO (Station Blackout) events, inadvertent events, misloading of fuel bundle(s), drain down events, leakage events, Internal Hazard events, External Hazard events, and dropping load events,

- tests that involve substantial risk, e.g. controller/regulator failure events, malfunction of the Control Rod System & malfunction of Reactor Protection System (including withdrawal error), medium term and long term LOOP (Loss of Off-site Power) events, CCF (Common Cause Failure) events, and ATWS (Anticipated Transients Without Scram) events,

- tests that require automatic initiation of ECCS and/or Severe Accident Mechanical Systems, e.g. loss of all feedwater flow event,

- tests that lead to deviation from the safe operating envelope (e.g. operation outside the Operating Power-Flow Map), or introduce a deviated condition, e.g. all Reactor Internal Pumps trip event, loss of feedwater heating, loss of operating Residual Heat Removal System (cooling) events, and

- tests that directly affect radioactive discharges from the plant, e.g. Off-gas system failure event, Radwaste system failure events, etc.

Even if the selected transient tests are reasonably practicable, appropriate additional safety measures to conduct safe testing should be considered. Approaches to manage safety during commissioning are discussed in sections 29.8 and 29.10.

29.7.2 Construction Testing

The construction tests are those carried out to ensure that the structures and components have been constructed, manufactured, and installed in accordance with the design specifications. A graded approach will be applied to the construction tests based on the categorisation and classification of the SSCs.

The construction testing occurs during the later portions of the construction phase. The construction testing part ensures system construction is sufficiently complete to support safe performance of Pre-Operational Testing. Construction tests consist of activities such as initial instrument calibration, wiring continuity and separation checks, hydrostatic pressure tests, electric power distribution facilities tests, functional tests of components (e.g., valve testing), factory acceptance tests of digital equipment and initial energisation and operation of components and systems. In some cases, it may also include final calibration of digital interfaces.

29.7.3 Pre-Operational Testing

Pre-Operational Testing is the second part of the commissioning programme. The Pre-Operational Testing part ensures that plant systems are capable of operating in a safe and efficient manner compatible with the system design bases and safety case. Completion of Pre-Operational Testing will demonstrate that systems and safety equipment are operational and that it is possible to proceed to fuel loading and Start-up Testing.

During the Pre-Operational Testing phase, testing should be performed as system turnover from construction testing/work allows. Further, the system turnover from the construction testing/work is conducted one after another along with progress of each system's construction/installation work. Therefore, not only Pre-Operational tests but also construction tests/inspections/works are expected to carry out in various places at the same time. However, the interdependence of systems will be considered so that common support systems, such as service and instrument air, various makeup water and cooling water systems, are tested as early as possible. The majority of pre-operational testing will be performed on an individual system bases under cold state. i.e., interlock testing, pump/fan/blower testing, system operation testing. However, integrated systems testing will also be performed, e.g, condenser vacuum up test, integrated leak rate tests, and integrated interlock test (including LOOP/LOCA test).

The tests will use appropriate sequencing so that the satisfactory completion of one test ensures the safe performance of subsequent tests. Some steps could therefore necessitate the simulation of some operating situations that could not otherwise be achieved. Many of the above tests are repeated when plant conditions can be obtained which are representative of those required in the safety case.

Test descriptions will be prepared which include purpose, prerequisites, general test methods, and acceptance criteria. The list and details of these pre-operational tests will be defined during later stages of the licensing process, post GDA phase.

All pre-operational tests are normally completed before the initial core is loaded. Moreover, when a pre-operational test cannot normally be completed before initial core loading, due to unavailability of associated equipment and/or systems or when its results are deemed unsatisfactory then, with rare exception and appropriately justified, the test may be carried out or repeated after fuel loading has taken place. However, neither test performance nor lack of test results may in any way conflict with the safety requirements.

29.7.4 Start-up Testing

Start-up Testing is the third part of the commissioning programme. This part begins after all systems have been turned over from Pre-operational Testing to the future licensee. This part ends with completion of the Warranty Run. The tests conducted during the start-up phase consist of major and minor plant transients, steady-state tests, and process control system tests all of which are directed towards demonstrating correct performance of the nuclear boiler and the various plant systems whilst at power. The testing in this part is performed in various test plateaus (for example, Open Vessel, Nuclear Heat-up, Low Power, Mid Power and High Power) which are defined by plant operational conditions. The aim of this process of start-up testing is the grouping of testing into phases that are separated by hold points which allow for clear review and verification of the test results before proceeding to the next stage. Operating Technical Specifications will be applied in this period which contributes towards the plant safe operation during start-up testing.

Although the order of testing within a given plateau is somewhat flexible, the normal recommended sequence of tests would be: (1) core performance analysis; (2) steady state tests; (3) control system tuning; (4) system transient tests (including pump trips); and (5) major plant transients (including plant trips). Also, for a given testing plateau, testing at lower power and flow levels should generally be performed prior to higher power and flow levels.

The types of start-up tests anticipated for the UK ABWR are presented in this section. These general test descriptions will be prepared which provide a test purpose, test prerequisites, test description and test acceptance criteria, where applicable. The list and details of these Start-up tests will be defined during later stages of the licensing process, post GDA phase.

Start-up tests types are defined as:

- *Standard start-up tests*, which are designed to verify the proper operation of the installation and its compliance with the associated performance objectives;
- *Tests, which are repeated at different power levels* during power escalation (core physics and control systems tests) for the purpose of confirming, for each power level, the validity of the hypotheses used in the plant operation and safety analyses and during the design of protection systems;
- *"First-of-a-kind" tests* are performed in order to verify an innovative concept, which has not yet been validated. Such tests may require specific instrumentation capable of confirming theoretical data.

29.8 Managing Safety during Commissioning

Safety management arrangements in the commissioning phase are set by the future licensee and contractors' safety management arrangements should align with the future licensee's arrangements. Details of the arrangements are discussed in the Chapter 4: Safety Management throughout Plant Lifecycle, section 4.9 Safety in the Commissioning Phase.

The arrangements in the commissioning phase consider both Industrial Safety and Nuclear Safety and they address issues such as receiving new nuclear fuel, setting Radiation Control Areas and the protection of safety related structures against latent induced defects. Additionally, appropriate emergency planning is put in place for preparedness for, and response to, any emergency in the commissioning stage. The emergency plan is also established before receiving new nuclear fuel – this is separately considered in Chapter 22: Emergency Preparedness.

All of the tests, especially the systems which are handed over to testing, should apply the permit system in order to prevent unexpected events (incidents and accidents) which may adversely affect testing staff, field workers, the public, and SSCs. The arrangements include rules and generic precautions to conduct safe testing and are instituted post GDA phase. These conventional safety aspects will not form a part of the nuclear safety case but will be considered in separate submissions.

Around the time when almost all pre-operational tests and preparation work for fuel loading are finished, confirmation and adoption of the safety case is carried out to ensure safety of the nuclear power plant. In start-up testing, the plant is operated by the operating organisation, and the normal operational safety management arrangements and Operating Technical Specifications (OTS) are applied to ensure so that the plant maintains safe operation.

Start-up testing includes non-routine operational activities to verify functions, interlocks, etc and it is necessary to address potential risks associated with harmful effects of ionizing radiation and plant damage. All testing important to nuclear safety in start-up testing is carried out in accordance with written testing procedures to ensure that the plant is operated within the safe operating envelope. Therefore, the procedures will incorporate temporary safety measures and configurations such as:

- pre-requisites and initial conditions to keep away from known harmful risks and to start safe testing (e.g. area/room access control to avoid harmful risks for field worker/engineer, required plant initial conditions for the testing, surveillance test requests, etc),

- appropriate temporary plant isolations (valves; electrical; software) to limit the potential for widespread undesirable impact from start-up tests, such as measures to avoid consequences from unnecessary actuation during testing (especially where tests are initiated using a simulation signal).

- management arrangements to clarify the expected role of testing staff and operators to ensure safe and smooth testing. (e.g. deployment of supporting/additional operator and testing staff in specific required locations, based on their expected role, etc),

- precautions for operator/testing staff to make them recognise and keep away from risks (as prevention measures),

- response measures for anticipated abnormal situations in the testing (e.g. recovery procedure, referring to appropriate section of Abnormal Operating Procedures, as mitigation/recovery measures), and

- relevant LCOs which are listed in the OTS to make operator/test staff recognise them to pay more special attention, if necessary. It will be utilised the plant monitoring during testing.

These measures take account of the anticipated risks which may be identified from the contents of the testing (procedure, anticipated plant behaviour and its associated interlocks, required operator/testing staff action, etc), and are included in the test procedure. Hazard identification and risk mitigation will be implemented for each phase in the testing. Known risks identified from past BWR/ABWR commissioning experience are expected to be taken into account when considering risk reduction measures.

In addition, plant isolations for commissioning activities are also applied using the permit system in line with the site specific work management process.

These safety measures are briefed to the testing personnel including the operating organisation prior to the testing at pre-job briefings and/or any other appropriate meetings to ensure implementation of safe testing.

29.9 Assumptions, Limits and Conditions for Operation

29.9.1 Purpose

One purpose of this generic PCSR is to identify constraints that must be applied by a future licensee of a UK ABWR plant to ensure safety during normal operation, fault, and accident conditions. Some of these constraints are maximum or minimum limits on the values of system parameters, such as pressure or temperature, whilst others are conditional, such as prohibiting certain operating modes or requiring a minimum level of availability of specified SSCs. The purpose of this section within other chapters of GDA PCSR is to describe these LCOs. The definition and context of Assumptions, LCOs in GDA is described in PCSR Chapter 4: Safety Management throughout Plant Lifecycle,, section 4.12.

In commissioning, the assumptions and LCOs made in the safety case are verified and validated, as the commissioning phase provides the first practical opportunity to operate the plant. As such, during and after commissioning, the LCOs and relevant safety analysis will be reviewed and amended where necessary on the basis of the results of testing.

29.9.2 Limits and Conditions for Commissioning

It is assumed that the future licensee will ensure that the plant is operated in accordance with their Operating Technical Specifications and appropriate operating instructions and procedures and this will include ensuring that commissioning is performed so that it does not exceed LCOs. However, plant operation during commissioning may require different limits and conditions than the LCOs developed in the PCSR.

Specifically, it is expected that, in order to perform the testing necessary during commissioning, there will be a need to put the plant in special configurations that are different to those expected in normal operations. As such, there will likely be a requirement during certain commissioning activities to temporarily change LCOs or create new limits and conditions specific to commissioning. In such cases, these are expected to be developed from the future licensees' safety case on commissioning. It is further assumed that these specific activities will be planned and performed within appropriate management arrangements, including suitable and sufficient documentation that details the safety justification and risk reduction measures for the situation.

In addition, if during any commissioning activities an unexpected deviation from an LCO actually occurs, then it is expected that the plant will be returned to a safe operational state as soon as possible, the event will be investigated and any appropriate corrective actions undertaken.

29.9.3 Assumptions for Commissioning

Plant commissioning will help demonstrate that safety claims and safety analysis assumptions made in the safety case are met, including those that were used to derive the LCOs, which are defining the unit safe operating envelope and are listed in "Generic Technical Specifications" [Ref-9]. The commissioning provides a practical demonstration of compliance with the safety case and LCOs and shows that they are valid for actual operation. This helps demonstrate that the plant can be operated safely within its defined safety case at all times.

In commissioning, assumptions and other factors which are to ensure safe operating envelope such as C&I set values, operating instructions/manuals, new design items, and design change items are verified directly and/or indirectly along with progressing the testing and plant operation during commissioning. The test results are transferred to the responsible organisation and reflected in its design, operating instructions, etc. The commissioning tests results will feed into updating the plant design and operating documentation and will constitute the baseline for the operation phase. Generally, the following feedback items are expected in commissioning phase:

- operation data of the plant, systems, and equipment,
- control parameters and set values for each C&I controller which were tuned, verified, and finalised by commissioning,
- valve position information of manual operated valves which were set to the prescribed flowrate or pressure,
- feedback on operating instructions, and
- identified non-conformities which requirement management action, for example design changes.

29.10 Summary of ALARP Justification

This section presents a high level overview of how the ALARP principle has been applied for Chapter 29 and how commissioning will contribute to the overall ALARP argument for the UK ABWR.

Generic PCSR Chapter 28: ALARP Evaluation presents the high level approach taken for demonstrating ALARP across all aspects of the design and operation. It presents an overview of how the UK ABWR design has evolved, the further options that have been considered across all technical areas resulting in a number of design changes and how these contribute to the overall ALARP case. The approach to undertaking ALARP Assessment during GDA is described in the GDA ALARP Methodology [Ref-7] and Safety Case Development Manual [Ref-8].

This section describes the relationship between commissioning and the demonstration that risks from UK ABWR are ALARP. There are five elements to this:

(1) Completion of commissioning safety demonstration tests,

(2) Demonstration of correct construction and installation,

(3) Minimising nuclear safety risks during testing,

(4) Learning from experience and seeking improvement,and

(5) Other aspects of verification and validation conducted in commissioning.

Through successful management of these five elements it is possible to demonstrate that commissioning will contribute to the overall demonstration that risks from UK ABWR have been reduced ALARP.

(1) Completion of commissioning safety tests

The GDA safety case as presented in other chapters of this PCSR sets out the basis of a ‘specification and plant description’ for construction of the UK ABWR to show that the proposed design will meet UK regulatory requirements. However, for some of these safety claims, proof that they have been achieved can only be provided through demonstration tests after the plant has been constructed and installed. Therefore, demonstration that risks from UK ABWR are ALARP requires these commissioning safety tests to be completed during commissioning.

This PCSR chapter therefore describes the approach to testing that should be undertaken to verify and validate the design and safety case and to reduce risks ALARP by showing that SSCs perform as required. This PCSR chapter also describes the requirement for the future licensee to have appropriate management arrangements to verify that these commissioning safety demonstration tests are completed appropriately.

(2) Demonstration of correct construction and Installation.

The UK ABWR is a complex plant and incorrect construction or incorrect installation of SSCs could lead to in-built faults that may only be revealed at a critical point of operation. To avoid this and to ensure the risks from operation of UK ABWR are ALARP a key objective of commissioning is to demonstrate that the plant has been correctly constructed and that SSCs have been correctly installed.

This PCSR chapter therefore describes the requirement for the future licensee to have commissioning management arrangements that ensure that the risk of incorrect construction or installation have been reduced ALARP. These arrangements will ensure the commissioning programme includes all the tests necessary to demonstrate that the plant as-built and as-installed meets the design intent; as well as ensuring there is an acceptance and review process to verify that that all tests were conducted and met performance requirements. In this manner it can be demonstrated that the risk of any in-built construction faults remaining has been reduced ALARP.

(3) Minimising nuclear safety risks during testing

The commissioning phase sees the transition of the plant from construction to operation and significantly it sees the introduction of operational hazards into the plant for the first time. The hazards include nuclear risks from bringing nuclear fuel onto the site for the first time, installing it into the reactor and starting physics and initial operation tests.

These hazards present risks that need to be appropriately controlled to ensure that they have been reduced ALARP. An important element of commissioning is therefore the practical achievement of ALARP by introducing management arrangements that will ensure safety. Although these management arrangements should be the responsibility of the future licensee under the Nuclear Site Licence, this PCSR chapter has identified the key expectations for safe management of commissioning in order to reduce such risks ALARP.

A key element of these arrangements is the grouping of testing into stages that are separated by hold points which allow for clear review and verification of the test results before proceeding to the next stage. This sequencing will ensure that plant safety is never dependent on systems or equipment that have not been tested.

A further element of the commissioning arrangements for minimising nuclear safety risks during testing will be the use of the Operating Technical Specifications and appropriate operating instructions and procedures. This will ensure that plant operation during start-up testing is operated within operational limits and conditions, which will prevent situations arising that could lead to anticipated operational occurrence or accident conditions, and will help minimise the consequence of such events if they do occur. (See section 29.9)

(4) Learning from experience and seeking improvement

Commissioning is a standard activity for any nuclear power plant and there has been much learning from past experience to help reduce associated risks ALARP, much of which has been captured in IAEA document [Ref-2]. As well as benefitting from past BWR experience, the commissioning planning for UK ABWR benefits from the relatively recent experience of ABWR commissioning in Japan that sets a benchmark for what can be considered current good practice.

An example of reducing risks based on learning from experience is minimising those tests that can significantly challenge the reactor plant. For example:

- SCRAM test (which create a large transient). Reactor SCRAM can be initiated by many signals and these all need to be tested. However, the behaviour at/after SCRAM is almost the same in each case. Therefore, application of representative tests can sufficiently verify the SCRAM function, allowing the majority of such tests to be replicated with signal only.,
- LOOP tests at power can be undertaken at low power rather than at 100% power in order to limit the plant transients, and
- Plant isolations (valves; electrical; software) can be applied to limit the potential for widespread impact of tests.

As well as adopting this good practice for UK ABWR, the potential for further risk reduction during commissioning has been considered during GDA. For example, options for the chemistry regime during the commissioning have been considered to see if there could be advantages for through life dose reduction. (This is explained further in PCSR Chapter 23: Reactor Chemistry.)

This combination of use of current good practice plus consideration of potential improvements contributes to asserting that the risks from commissioning will be reduced ALARP.

(5) Other aspects of verification and validation

As well as the aspects covered above such as safety demonstration tests and verification of correct construction and installation, there are a number of other aspects related to commissioning that further contribute to the overall demonstration of ALARP. These include:

- verification and validation of the operating documentation (OTS, procedures, instructions, maintenance, testing, etc.) that are utilised as part of the commissioning process (see section 29.6.5),

- verification of the HBSCs that are stated in PCSR Chapter 27: Human Factors and supporting reports [Ref-12],
- demonstration of the practicability of the through-life SSC maintenance and inspection activities that are first conducted during commissioning, and
- verification and validation of the operators' training programme.

Overall therefore, through appropriate management of the five elements discussed above it is possible to demonstrate that successful commissioning will contribute to the overall demonstration that risks from UK ABWR have been reduced ALARP.

29.11 Conclusions

This PCSR chapter has identified that commissioning is an essential process for the subsequent safe operation of a nuclear power plant and it should be carefully developed, planned, and executed. This chapter has therefore described the processes that will be followed to ensure that the UK ABWR will be safely commissioned.

This chapter has described that the objective of commissioning is to demonstrate that the plant has been correctly constructed and that equipment has been correctly installed and connected to interfacing and supporting systems. In the context of the safety case, the principal goal of commissioning is to demonstrate that the safety requirements placed on SSCs have been met by the constructed and installed plant when tested against the design basis.

It has been identified that during GDA it is not appropriate to identify every test that needs to be undertaken, but the key elements of arrangements for safe management of commissioning are identified. This chapter therefore includes a description of the commissioning principles and strategy, the required generic framework (processes, organisation, roles, responsibilities, etc.), the generic programme and the related management arrangements. It describes how the hazards and risks in different stages of commissioning will be identified, controlled and reduced ALARP. Through these arrangements it will be demonstrated that the plant components and systems, as constructed and installed are capable of safe and reliable operation in accordance with their design specifications and safety requirements as claimed in the safety case.

The commissioning phase sees the transition of the plant from construction to operation and significantly it sees the introduction of hazards into the plant for the first time. This chapter therefore has identified that all these hazards need to be identified and controlled through appropriate management arrangements to ensure safety.

Additionally this chapter has described how commissioning provides the opportunity to train operating staff, to validate the operating technical specifications, procedures, instructions and human based safety claims, and to capture testing data (baseline) which will be collated to provide confidence that the plant can be operated safely.

This chapter has also presented a high level overview of how the ALARP principle has been applied for Chapter 29 Commissioning and how this contributes to the overall ALARP argument for the UK ABWR.

Therefore, in this PCSR chapter Hitachi-GE has comprehensively identified its expectations for safe management of commissioning, so far as appropriate for GDA. The future licensee should have prime responsibility for all site activities that may affect safety and should take account of the expectations described here within its management arrangements to ensure the safe conduct of

commissioning. This GDA commissioning PCSR chapter will therefore contribute towards ensuring safe operation of the UK ABWR.

29.12 References

[Ref-1] International Atomic Energy Agency, “Commissioning for Nuclear Power Plants”, IAEA Safety Standards Series No. SSG-28, Vienna, June 2014

[Ref-2] International Atomic Energy Agency, “Safety of Nuclear Power Plants: Commissioning and Operation”, IAEA Safety Standards Series No. SSR-2/2, Revision 1, Vienna, February 2016

[Ref-3] UK Office for Nuclear Regulation, “Safety Assessment Principles for Nuclear Facilities: 2014 Edition”, Rev. 0, November 2014

[Ref-4] US Nuclear Regulatory Commission, “Initial Test Programs For Water-Cooled Nuclear Power Plants”, Regulatory Guide 1.68, Revision 4, June 2013

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Commissioning Chemistry", GA91-9201-0001-00209 (WPE-GD-0276), Revision 2, June 2017

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Fault Assessment", GA91-9201-0001-00022 (UE-GD-0071), Revision 6, July 2017

[Ref-7] Hitachi-GE Nuclear Energy, Ltd., "GDA ALARP Methodology", GA10-0511-0004-00001 (XD-GD-0037), Revision 1, November 2015

[Ref-8] Hitachi-GE Nuclear Energy, Ltd., "GDA Safety Case Development Manual", GA10-0511-0006-00001 (XD-GD-0036), Revision 3, June 2017

[Ref-9] Hitachi-GE Nuclear Energy, Ltd., "Generic Technical Specifications", GA80-1502-0002-00001 (SE-GD-0378), Revision 3, August 2017

[Ref-10] Hitachi-GE Nuclear Energy, Ltd., "Standard Control Procedure for Identification and Registration of Assumptions, Limits and Conditions for Operation", GA91-0512-0010-00001 (XD-GD-0042), Revision 2, March 2017

[Ref-11] Hitachi-GE Nuclear Energy, Ltd., "Technology Transfer to Licensee and Operating Regime", GA70-1502-0001-00001 (QGG-GD-0001), Revision 0, August 2016

[Ref-12] Hitachi-GE Nuclear Energy, Ltd., "Human-Based Safety Claims Report, GA91-9201-0001-00043 (HFE-GD-0064), Revision E, August 2017