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19.1 INTRODUCTION

19.1.1 Purpose

This chapter presents the summary of how Mechanical Engineering has contributed to the design of the standard Small Modular Reactor (SMR)-300 plant. In context of the broader safety case, the application of Mechanical Engineering is in support of delivering Safety Functions (SFs) and minimising risks of and arising from mechanical equipment failure.

Plant-level systems have Safety Functional Requirements (SFRs) that protect against faults and identify operational functions, and these are identified as part of the following Preliminary Safety Report (PSR) chapters:

- PSR Part B Chapter 1, Reactor Design and Engineering Aspects [1].
- PSR Part B Chapter 2, Fuel and Core [2].
- PSR Part B Chapter 5, Reactor Supporting Facilities [3].
- PSR Part B Chapter 10, Radiological Protection [4].
- PSR Part B Chapter 13, Radioactive Waste Management [5].
- PSR Part B Chapter 24, Fuel Route and Storage [6].

These PSR chapters present safety functions and the systems directly providing these functions. The Mechanical Engineering chapter discusses both the Mechanical Structures, Systems and Components (SSCs) and the application of Mechanical Engineering that has been used to develop the SSCs to ensure they deliver their SFs.

19.1.2 Scope

To meet the purpose stated in Section 19.1.1, the Mechanical Engineering chapter has many SSCs in scope. There are two main categories of SSCs:

- Sub-systems and components for plant-level systems delivering SFRs to ensure plant safety:
    - These SSCs are identified in systems chapters and a breakdown of these plant-level SSCs.
    - Where plant-level SSCs include a mixture of Mechanical and other SSCs, only the Mechanical SSCs will be explored in this chapter.
- SSCs whose failure could challenge the safety of the plant:
    - These SSCs are identified through Fault Studies and Internal Hazards.

As the SSCs that meet these definitions are broad, the Mechanical Engineering topic has been divided into 6 sub-disciplines:

1. Cooling systems.
2. Reactor support systems.
3. Heating, Ventilation, and Air Conditioning (HVAC) systems.
4. Radioactive Waste systems.
5. Mechanical Handling systems.
6. Barriers, hatches, seals, and doors – referred to as *Thresholds* throughout.

The SSCs in scope for this PSR chapter are shown in Appendix A.

19.1.3 Interfacing Disciplines

As Mechanical Engineering is a broad topic that is applied across the plant, there are many important interfaces. The primary interfaces are driven by the safety claims and associated safety functional requirements.

19.1.3.1 Mechanical SSCs

Mechanical SSCs contribute to operational and safety functions. Functions are provided by plant-level systems identified in other Chapters of the Holtec SMR-300 Generic Design Assessment (GDA) Preliminary Safety Report (PSR). These chapters are presented below.

B1 Description of the Reactor Coolant System and Engineered Safety Features [1] identifies the systems delivering the primary engineered safety features of the SMR-300, including the Pressurizer, Automatic Depressurization System, and others. These systems include Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

B2 Reactor Fuel and Core [2] identifies the systems delivering the safety features of the design of the fuel and core systems, including the Fuel System, Control Rod Drive Systems, and others. These systems include Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

B5 Description of the Reactor Supporting Facilities [3] identifies the systems supporting the reactor and their operational and safety functions, including the Overhead Heavy Load Handling System, the Residual Heat Removal System, the Chemical and Volume Control System, and others. These systems include Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

B10 Radiological Protection [4] identifies the approaches to radiological protection in the SMR-300 facility, including radiation zoning, systems providing radiation protection, systems that contribute to the boundaries of radiation zones, and other aspects of radiation protection. This relies on Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

B13 Radioactive Waste Management [5] identifies the approaches used for managing, measuring, and handling different types of radioactive waste in the SMR-300. This relies on Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

B24 Fuel Transport and Storage [6] is a cross-cutting chapter that describes the fuel handling routes across the SMR-300 and the systems which are involved in this. This relies on Mechanical SSCs which are presented in this PSR Chapter and supporting documents.

19.1.3.2 Mechanical Engineering Input

Mechanical engineering processes and procedures have been used to develop the safety case of the SMR-300. The broader interfaces extend to engineering procedures and the development of procedures, cross-cutting information and systems, as discussed below.

Mechanical SSCs are part of systems that respond to and mitigate Internal and External Hazards, discussed in chapters B21 [7] and B22 [8] respectively.

Plant-level systems are the result of interdisciplinary work with input from different engineering teams, and are composed of SSCs that are described in several PSR chapters outlining the engineering practices and procedures, including B4 Instrumentation and Control [9], B6 Electrical Engineering [10], B18 Structural Integrity [11], and B20 Civil Engineering [12].

Accident analysis, as outlined in B14 Design Basis Accident Analysis [13], B15 Beyond Design Basis Analysis, Severe Accidents Analysis and Emergency Preparedness [14], and B16 Probabilistic Safety Analysis [15] considers the failure and response of plant systems, including their mechanical SSCs.

Plant operations are an integral part of Mechanical SSCs. The design of Mechanical SSCs must incorporate aspects of many operations through the lifecycle of the SMR-300. B9 Description of Operational Aspects/Conduct of Operations [16] outlines the operations of the plant, which includes many mechanical SSCs.

Environmental protection as outline in B11 Environmental Protection [17] is provided by specialised systems, with reliance on mechanical systems and components. Mechanical SSCs used in environmental protection include ventilation systems, seals, doors, and others.

19.2 CLAIMS AND ARGUMENTS

The primary purpose of a Claims, Arguments, Evidence (CAE) approach is to capture the golden thread of a safety case narrative demonstrating how plant and operational evidence is brought together to justify that a high-level or fundamental claim is true. In the context of the generic SMR-300, that is how the Fundamental Purpose of the Safety, Security and Environmental Cases (SSEC), presented in PSR Part A Chapter 1 Introduction [18], is achieved.

The Fundamental Purpose follows a golden thread throughout the SSEC to CAE via the objectives of the PSR, the Preliminary Environmental Report (PER) and the generic Security Report (GSR). The overarching SSEC claims are presented in PSR Part A Chapter 3 Claims, Arguments and Evidence [19] and this chapter links to the overarching claims through Claim 2.2.

Claim 2.2: The design of the systems and associated processes have been developed taking cognisance of relevant good practice and substantiated to achieve their safety and non-safety functional requirements.

As set out in Chapter A3 [19], Claim 2.2 is further decomposed across several engineering disciplines which are responsible for development of the design of relevant SSCs.

This chapter presents the Mechanical Engineering topic for the generic SMR-300 to support claim 2.2.10.

Claim 2.2.10: The overall design and architecture of Mechanical SSCs ensures that safety functions and non-safety functions are delivered and faults arising from failures of the SSCs are minimised.

Claim 2.2.10 has been further decomposed within PSR Part B Chapter 19 Mechanical Engineering, across the design lifecycle, to provide confidence that the relevant requirements on mechanical SSCs will be met during all lifecycle phases.

This has been done by breaking down Claim 2.2.10 into four further sub-claims.

Claim 2.2.10.1 is an enabling claim across the design lifecycle, to demonstrate the processes applied to the design and substantiation of mechanical components will ensure the SSCs can achieve their requirements.

Claim 2.2.10.2 focuses on the design phase and demonstration that the codes and standards applied to the mechanical design are appropriate.

Claim 2.2.10.3 then ensures mechanical SSCs achieve their design intent through quality *Manufacturing* and *Installation* processes, noting that the maturity of evidence for this claim will be limited at a PSR stage. Claim 2.2.10.3 also covers through-life *Operational* maintenance aspects for civil structures noting the overall approach to Examination, Inspection, Maintenance and Testing (EIMT) is provided in PSR Part B Chapter 9 Conduct of Operations [16].

Claim 2.2.10.4 sets out how redundancy and diversity (i.e., Defence in Depth (DiD)) is achieved across the mechanical design process to ensure delivery of safety functions with appropriate reliability.

Table 1 shows in which subchapter of this PSR chapter these claims are demonstrated.

Table 1: Mechanical Engineering Level 4 Safety Claims

Claim No.	Claim	Sections
2.2.10.1	Processes have been established to ensure mechanical specific safety requirements, functional requirements and architecture requirements are captured in the design, procurement and manufacturing steps.	19.3
2.2.10.2	Mechanical SSCs are designed using appropriate Codes and Standards, taking cognisance of Relevant Good Practice (RGP) and Operating Experience (OPEX).	19.4
2.2.10.3	Mechanical SSCs achieve the design intent through quality manufacturing and installation process.	19.5
2.2.10.4	Mechanical SSC design incorporates Defence in Depth to protect against anticipated operational occurrences and accident conditions	19.3.3

A summary of the current CAE route map for Chapter B19 is provided in Appendix B and a further update on claim decomposition, argument development and evidence maturity will be provided in the subsequent update of the Chapter.

19.3 MECHANICAL ENGINEERING DESIGN

Claim 2.2.10.1: Processes have been established to ensure mechanical specific safety requirements, functional requirements and architecture requirements are captured in the design, procurement and manufacturing steps.

Claim 2.2.10.4: Mechanical SSC design incorporates Defence in Depth to protect against anticipated operational occurrences and accident conditions

This section presents the mechanical engineering design practices and how these are applied to achieve the design of mechanical SSCs to meet safety, functional and architecture requirements. This section relies on the Mechanical Engineering Design Basis Report [20], to be delivered in GDA.

The Mechanical Engineering Design Basis Report outlines the mechanical SSCs that support Safety Functions and higher-level systems, demonstrates how the mechanical SSCs contribute to SFs, the design methodologies that have been used, and what safety requirements are incorporated into the design of these mechanical SSCs.

19.3.1 Component Design Practices

Many Mechanical Engineering design practices are used across the SMR-300, both due to the number of sub-disciplines and the variation in SSC classification. These are presented on a case-by-case basis in the Mechanical Engineering Design Basis Report [20], which presents mechanical SSCs, their functional performance requirements, safety requirements, and the design processes used.

The primary means for controlling component design procedures is establishing robust component requirement specifications. These establish key requirements across multiple areas (below). As the systems are produced with input across many engineering disciplines, only the **highlighted requirements** will be documented within this Chapter.

- **Safety.**
- System functions, covered in PSR Part B Chapter 14 Design Basis Accident Analysis [13].
- **System performance.**
- **Layout.**
- Human factors, covered in PSR Part B Chapter 17 Human Factors [21].
- Classification, covered in Chapter B14 [13].
- **Reliability:**
    - High and Very High Reliability components are discussed in PSR Part B Chapter 18 Structural Integrity [11].
- **EIMT.**
- **Seismic.**
- **Environmental qualification**.
- **Grouping and separation.**
- **Containment isolation.**
- **Radiation protection:**
    - Some radiation protection requirements are achieved with methods other than Mechanical Engineering.

    - Other aspects are explored in Chapter B10 [4].
- **External events:**
    - As there are many external events (or external hazards), Mechanical Engineering is not used to protect against all.
    - Mechanical Engineering will be relevant for Ventilation systems, particularly related to external temperature loads.
    - External hazards are presented in more detail in PSR Part B Chapter 21 External Hazards [7].
- Severe Accident, covered in PSR Part B Chapter 15 Beyond Design Basis Analysis and Severe Accident Analysis, and Emergency Preparedness [14].
- Post-accident monitoring, covered in PSR Part B Chapter 4 Control and Instrumentation Systems [9].
- Instrumentation and control, covered in Chapter B4 [9].

Within individual sub-disciplines (or for the design of individual SSCs), varying workflows have been used to achieve SSC designs that meet these requirements.

This is explored in more depth in the Mechanical Engineering Design Basis Report [20], which identifies the design practices for individual SSCs and identifies design documentation demonstrating this for Mechanical SSCs.

19.3.2 Functional Capability and Engineering Schedule

This section outlines the approach to defining performance requirements that assure functional capability is met. Holtec plan to develop an SMR-300 engineering schedule, alongside the development of the Preliminary Fault and Protection schedule within GDA Step 2, focused on those SSCs within scope of the GDA process. The engineering schedule will continue to develop to cover all SSCs during site specific development of the Pre-Constuction Safety Report (PCSR) and to support later project lifecycles. The engineering schedule specifies the SFRs that SSCs satisfy and is developed iteratively throughout design development and GDA.

The performance requirements outlined here are inputs to the engineering schedule, identifying SSC loads in support of plant safety functions.

At Fundamental Assessment/PSR stage, this is presented as part of the approach used to demonstrate safety of the GDA Reference SMR-300, although Mechanical SSC performance requirements are not fully defined across the plant.

An example of how Functional Capability of Mechanical SSCs contributes to the Engineering Schedule is shown in Table 2, below. This example is for demonstration purposes, while a full engineering schedule will also include clear references for SFRs.

Table 2: (REDACTED)

REDACTED

19.3.3 Defence in Depth

Mechanical SSCs have significant contribution to DiD safety requirements across the SMR-300. DiD is a broader safety feature applied across the SMR-300 plant. Mechanical SSCs contribute to DiD through specific design redundancy and diversity measures. Table 3 provides a summary of the Redundancy and Diversity requirements applied in each Mechanical sub-discipline.

Table 3: Mechanical SSCs Redundancy and Diversity Features

Sub-discipline	SSC	Redundancy/Diversity features
Mechanical Handling Systems	CSH	Single-Failure Proof crane, meeting American Society of Mechanical Engineers (ASME) NOG-1 and NUREG 0554.
Cooling Systems	PDH	Redundant Isolation Valves
Cooling Systems	PDH	Diverse valve actuation
Cooling Systems	RHR	Components with safety functions are designed with redundancy (2x100% capacity pumps, 2x100% capacity heat exchangers)
HVAC Systems	CBV	Redundant reactor cavity cooling fans, 2x100% capacity Redundant Containment Cooling Fans, 3x50% capacity
HVAC Systems	CBV	Grouping and Separation requirements from the SMR-300 Design Standard for Grouping and Separation

This is explored in greater depth in the Mechanical Engineering Design Basis Report [20].

19.3.4 CAE Summary

The SMR-300 design procedures for mechanical SSCs cover a broad scope of safety and operational related requirements. These design procedures ensure that mechanical SSCs deliver their safety functions and meet their safety requirements. Mechanical SSCs and their functional performance is recorded in an Engineering Schedule, which demonstrates that mechanical SSCs have been appropriately designed to deliver their safety functions. The general approaches used have been discussed within this chapter, with more detail on how these have been implemented in the Mechanical Engineering Design Basis Report [20]. This supports Claim 2.2.10.1.

Mechanical SSCs support the DiD protections of the SMR-300 plant, with mechanical SSCs being designed with redundancy and diversity features. Examples of redundancy and diversity features have been given in this chapter, with a breakdown of the redundancy approach given per-SSC given in the Mechanical Engineering Design Basis Report [20]. This supports Claim 2.2.10.4.

19.4 CODES, STANDARDS AND METHODOLOGY

Claim 2.2.10.2: Mechanical SSCs are designed using appropriate Codes and Standards, taking cognisance of Relevant Good Practice (RGP) and Operating Experience (OPEX).

This section presents the design methodologies used in mechanical engineering across the SMR-300 and presents these against the UK context. This is a precursor to demonstrating that the systems as designed provide the necessary protections and do reduce risks to As Low As Reasonably Practicable (ALARP), which will be provided in a more detailed assessment stage of the SMR-300.

19.4.1 Design Codes and Standards

This section explores the Codes and Standards (C&S) used in the design of Mechanical SSCs, with summary information of whether the C&S constitute RGP given in Appendix C. More detail is provided against each Mechanical sub-discipline in the SMR-300 Mechanical Engineering Codes and Standards report [22].

19.4.1.1 Primary Design Codes

Mechanical SSCs are designed to meet the following Design Codes:

- ASME Boiler and Pressure Vessel Code:
    - Section II – Materials.
    - Section III – Rules for Construction of Nuclear Facility Components.
    - Section V – Non-destructive Examination.
    - Section IX – Qualification Standard for Welding, Brazing, and Fusing Procedures.
    - Section XI – Rules for In-Service Inspection.
- ASME B31.1 Pressure Piping Code.
- ASME AG-1, Code on Nuclear Air and Gas Treatment.
- US Code of Federal Regulations:
    - 10 CFR 21.
    - 10 CFR 50, including appendices A and B.

19.4.1.2 Primary Design Standards

Mechanical SSCs are designed using the following Design Standards:

- ASME NOG-1, Rules for Construction of Overhead and Gantry Cranes.
- NUREG-0554, Single Failure Proof Cranes.
- ANSI/ASME B1.1, Unified Screw Threads.
- ASME N509, Nuclear Power Plant Air-Cleaning Units and Components.
- ASME N510, Testing of Nuclear Air Treatment Systems.
- ASME B16.11, Forged Fittings, Socket Welding and Threading.
- ASME NQA-1, Nuclear Quality Assurance.
- ASME QME-1, Qualification of Active Mechanical Equipment Used in Nuclear Facilities.
- ASME TDP-2, Prevention of water damage to Steam Turbines Used for Electric Power Generation: Nuclear-Fuelled Plants.
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA):

    - Round and Industrial Duct Construction standards.
    - HVAC Duct Construction Standards – Metal and Flexible.
- ANSI N14.6, Special Lifting Devices for Shipping Containers.
- Tubular Exchanger Manufacturers Association:
    - Standards of the Tubular Manufacturer Exchanger Manufacturer Association.

19.4.1.3 Regulatory Guidance

The following Regulatory documents have been used to guide the development of the SMR-300 and Mechanical SSCs:

- US NRC Regulatory Guides:
    - 1.28, Quality Assurance Program Criteria (Design and Construction).
    - 1.43, Control of Stainless Steel Weld Cladding of Low-Alloy Steel Components.
    - 1.44, Control of the Processing and Use of Stainless Steel.
    - 1.52, Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants.
    - 1.60 (July 2014), Design Response Spectra for Seismic Design of Nuclear Power Plants.
    - 1.61 (2007), Damping Values for Seismic Design of Nuclear Power Plants.
    - 1.65R, Materials and Inspections for Reactor Vessel Closure Studs.
    - 1.78, Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release.
    - 1.140, Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants.
    - 1.196, Control Room Habitability at Light-Water Nuclear Power Reactors.
    - 1.197, Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors.
- CNSC REGDOC-2.5.2 Design of Reactor Facilities: Nuclear Power Plants.

19.4.2 UK Legislation and ACoPs

As part of the development of a GDA Reference SMR-300, UK legislation has been identified throughout the Mechanical Engineering discipline. The principal legislation identified to Mechanical Engineering chapter is as follows:

- The Provision and Use of Work Equipment Regulations 1998.
- The Lifting Operations and Lifting Equipment Regulations 1998.
- The Pressure Systems Safety Regulations 2000.

The principal legislation identified above is in addition to legislation that underpins the broader safety requirements. The legislation relevant to Mechanical Engineering includes conventional Health and Safety as well as radiation and nuclear safety legislation. The broader safety case is subject to these safety requirements as presented in the following legislation:

- The Ionising Radiation Regulations 2017.
- Pressure Equipment (Safety) Regulations 2016.

- The Management of Health and Safety at Work Regulations 1999.
- The Construction and Design Management Regulations 2015.
- The Work at Height Regulations 2005.

The relevant legislation to individual SSCs will be explored via each sub-discipline of Mechanical Engineering. Alongside the legislation, the RP will also identify the Approved Codes of Practice (ACoPs) and identify where these can be adopted into the SMR-300 design. This is presented in more detail in the SMR-300 Mechanical Engineering Codes and Standards report.

Where the US SMR-300 design is found not to comply with UK legislation, this will trigger a Prospective Design Change for the SMR-300 GDA Reference Design [23].

19.4.3 CAE Summary

The SMR-300 mechanical design has been undertaken using best practice nuclear industry codes and standards by use of the ASME BPVC, AISC, ACI, ASCE/SEI design codes. These have been assessed against several criteria to determine if they are relevant and appropriate for developing mechanical SSCs.

Relevant UK legislation has been identified for Mechanical SSCs. Prospective Design Changes will be raised for mechanical SSCs that are found to not comply with UK legislation.

This supports Claim 2.2.10.2.

19.5 QUALITY MANUFACTURING AND INSTALLATION

Claim 2.2.10.3: Mechanical SSCs achieve the design intent through quality manufacturing and installation process.

19.5.1 Quality Assurance and Classification

Mechanical SSCs are classified in accordance with their safety significance, including quality and seismic classification, and are designed in accordance with the codes and standards appropriate to their identified classification.

The SSC classification methodology is defined in Chapter B14 [13] and assigns safety requirements and design standards to Mechanical SSCs. The design codes used for Mechanical SSCs are defined in section 19.4.1, and are explored in greater detail in a supporting document: Mechanical Engineering C&S Report [22]. The C&S used have been assessed for either precedence in UK GDA or assessed the relative strengths or weaknesses of the C&S selected. This assessment is documented in the Mechanical Engineering C&S Report [22], with an excerpt presented in Appendix C.

The SSC Classification methodology is discussed in SMR-160 Systems, Structures, and Components Classification Standard [24], and the C&S are evaluated as to whether they constitute RGP in Appendix C. This approach complies with NUREG 0800, and the Construction Codes and Standards defined in the NRC Quality Classification System, as shown in Table 4.

Table 4: Summary of Construction Codes and Standards for Components of Water-Cooled Nuclear Power Plants by NRC Quality Classification System [25]

Component	Quality Group A	Quality Group B	Quality Group C	Quality Group D
Pressure Vessels	ASME BPV Code, Section III, Division 1, Subsection NB: Class 1, Nuclear Power Plant Components	ASME BPV, Section III, Division 1, Subsection NC Class 2, Nuclear Power Plant Components	ASME BPV Code, Section III, Division 1, Subsection ND: Class 3, Nuclear Power Plant Components	ASME Boiler and Pressure Vessel Code, Section VIII, Division 1
Piping	Class 1 (NB)	Class 2 (NC)	Class 3 (ND)	ANSI B31.1 Power Piping
Pumps	Class 1 (NB)	Class 2 (NC)	Class 3 (ND)	Manufacturer's standards
Valves	Class 1 (NB)	Class 2 (NC)	Class 3 (ND)	ANSI B31.1 Power Piping and ANSI B16.34
Atmospheric Storage Tanks	Not Applicable	Class 2 (NC)	Class 3 (ND)	API-650, AWWA D100, or ANSI B96.1
0-15 psig Storage Tanks	Not applicable	Class 2 (NC)	Class 3 (ND)	API-620
Supports	Subsection NF provisions for Class 1 supports	Subsection NF provisions for Class 2 supports	Subsection NF provisions for Class 3 supports	Manufacturers standards
Metal Containment Components	Not applicable	Subsection NE provisions for Class MC components	Not applicable	Not applicable
Core Support Structures	Not applicable	Subsection NG provisions for Class CS components	Not applicable	Not applicable

19.5.2 Manufacturing and Fabrication

The generic SMR-300 design utilises modular construction techniques where possible for the twin unit site. Mechanical SSCs include bespoke components fabricated by Holtec International and their supply chain, and Commercial-Off-The-Shelf (COTS) items. These SSCs are subject to the SMR-300 Project Quality Plan [26], which includes procedures to select and maintain suppliers, conformance testing, quality assurance (QA) records, and audits, among other Holtec Quality Procedures.

Procurement of safety significant scope of work from a supplier requires that either the supplier is on the Approved Vendors List (AVL), or the company performs dedication/upgrades to their control to qualify the products within a scope of work. Suppliers are approved based upon recommendations, certifications and experiments, qualification of suppliers within Holtec's QA program through auditing, or extension of Holtec's QA program for performance of supplier scope.

The QA procedures used throughout the SMR-300 program are an implementation of a QA program successfully applied across Holtec International projects and programs. These processes ensure that SMR-300 SSCs will be manufactured and fabricated to high standards, which ensures that the SSCs will deliver the design intent. This supports Claim 2.2.10.3.

19.5.3 Examination, Inspection, Maintenance, and Testing

Many mechanical SSCs are designed with planned replacement within the 80 year lifetime of the generic SMR-300. These SSCs are designed such that sufficient space and equipment will be available for personnel to perform maintenance of system equipment and components, as needed.

An effective EIMT program shall be in place throughout the lifetime of the facility. Further information on the EIMT program is provided in Chapter B9 [16] of the PSR.

The EIMT procedures ensure that mechanical SSCs will continue to meet their design intent throughout the life of an SMR-300 plant, supporting Claim 2.2.10.3.

19.5.4 CAE Summary

The QA requirements for mechanical SSCs are defined in their design specifications. These QA requirements must be satisfied in manufacturing/fabrication, as well as through life by using EIMT. Claim 2.2.10.3 is supported by the Requesting Party (RP) establishing processes to ensure mechanical SSCs to meet high quality standards, including rigorous QA processes.

19.6 CHAPTER SUMMARY AND CONTRIBUTION TO ALARP

19.6.1 Technical Summary

PSR Chapter B Part 19, Revision 0 demonstrates that the Mechanical Engineering SSCs within the scope of this report meet the high-level Claims of the SSEC and that the SSCs can be substantiated at PCSR stage. This is demonstrated through the following sub-claim:

Claim 2.2.10: The overall design and architecture of Mechanical SSCs ensures that safety functions and non-safety functions are delivered and faults arising from failures of the SSCs are minimised.

The high-level safety functions of the SMR-300 GDA reference plant protect against failures and hazards. Mechanical SSCs enable these safety functions, with appropriately designed SSCs delivering the necessary functionality. This information about mechanical SSCs is captured in the Engineering Schedule, which details the individual components contributing to plant safety functions.

The Mechanical Engineering Design Basis Report [20] will provide a clear demonstration of how these SSCs contribute to safety functions, as well as safety features included in the design of Mechanical SSCs.

Mechanical SSCs support DiD across the SMR-300, with mechanical SSCs having levels of redundancy and diversity throughout, and contributing to multiple, independent trains of protection in the SMR-300.

Grouping and separation criteria have been established for the SMR-300. The Grouping and Separation Design Standard identifies these design criteria and design and requirements, as well as the project approach to addressing grouping and separation in the design process.

The design of mechanical SSCs in the SMR-300 has been undertaking best practice nuclear industry codes and standards. These include ASME BPVC, ASME B31 and ANSI design codes.

The QA requirements for mechanical SSCs are appropriate to the SSCs safety and seismic classifications.

PSR Revision 1 will define the hazards considered in the design and their magnitude by reference to Chapter B21, [7] and PSR Part B Chapter 22, Internal Hazards [8]. It will present a description of mechanical SSC designs and design processes used to deliver a safe SMR-300.

19.6.2 ALARP Summary

This section provides a summary of how Mechanical Engineering has been used to reduce risks across the SMR-300 plant. This section is informed from supporting GDA documents, primarily the Mechanical Engineering *Design Basis* [20] and *C&S* [22] reports.

19.6.2.1 Demonstration of RGP

This sub-section discusses the C&S used and identifies whether these meet the standard of RGP.

C&S have been assessed as meeting RGP by reviewing three sources:

- Codes, standards or methodologies used in prior technologies receiving a GDA Design Acceptance Confirmation/Statement of Design Acceptability.
- Codes or standards identified in international regulatory guidance.
- Codes or standards identified in UK regulatory guidance (specifically Technical Assessment Guidance).

Appendix C shows examples of this comparison between the C&S used and RGP and is an excerpt from the Mechanical Engineering C&S Report [22].

The Mechanical Engineering C&S Report [22] also compares the C&S used with comparable C&S to evaluate whether the choice of C&S has reduced risks.

19.6.2.2 Design Methodologies

The Mechanical Engineering discipline implements common design practices used across the SMR-300 project which have clear direction to reduce or eliminate risk in SSC designs. By establishing common design methodologies that reduce risk, the SSCs developed using these methodologies have reduced risks in their design and in the arrangement of SSCs in the plant.

These methods include the following high-level methodologies:

- SMR Procedure for Evaluating and Performing Design Decisions [27]:
    - This establishes a process to manage design changes across the SMR-300 project.
- UK Specific process: Proposed GDA Design Change Process.
- SMR-300 DiD Strategy:
    - This document defines the DiD strategy for the plant, and the requirements placed on Mechanical SSCs to support this through Redundancy and Diversity requirements.
- SMR-300 Design Standards establishing requirements for:
    - Human Factors.
    - Radiation Protection.
    - Severe Accident Design and Analysis.
    - Application of Single Failure Criterion.
    - Grouping and Separation.

As SSCs are developed, the designs for these SSCs are verified appropriate to the level of maturity.

As outlined in Section 19.6.2.3, the design decision process is used to manage and guide design decisions. This process balances multiple aspects of power plant design, balancing risk reduction and practicability.

19.6.2.3 Design Decisions and Risk Reduction

Risk reduction is core to SMR-300 development. Holtec maintains a design decision register as part of the SMR-300 project, as well as a separate process for the GDA Reference SMR-300 design: Prospective Design Change Procedure [23].

Design decisions are managed in accordance with the Design Decision Process [27]. This procedure outlines decision category criteria, how the decision must be presented and recorded, and the relevant level of authority for the decision.

Design Decisions relating to Mechanical SSCs are presented to demonstrate how risk has been managed across the SMR-300 design.

19.6.2.4 GDA Commitments and Forward Action Plan

Gaps identified in developing this PSR chapter have been captured in a GDA Forward Actions and Gaps Tracker, which is used across the SMR-300 GDA project. The Forward Action Plan presents the actions that Holtec commits to beyond GDA. These actions are to develop this safety case from a PSR to a PCSR, and to close the gaps identified throughout GDA.

19.6.3 Conclusion

This chapter supports an overarching safety Claim with 4 additional, lower-level Claims specific to Mechanical Engineering. These claims are supported with three supporting documents:

- Mechanical Engineering Design Basis Report [20]:
    - This referenced report demonstrates that Mechanical SSCs support delivery of established Safety Functional Requirements.
- Mechanical Engineering C&S Report [22]:
    - This referenced report establishes the C&S used within the Mechanical Engineering topic area that have been used to develop Mechanical SSCs.
    - This report contributes to risk reduction, as the C&S used have been assessed against UK RGP.
- ALARP Summary Report [28]:
    - This referenced report summarises the risk reduction measures across development in Mechanical Engineering and Mechanical SSCs of the SMR-300, specifically including the risk reduction defined in the *Design Basis* [20] and *C&S* [22] reports.
    - These measures are given alongside design decisions that have considered the practicability of different design decisions and balancing different hazards.

Excerpts from these documents are provided in the appendices for this chapter to demonstrate the SSCs in scope, design decisions establishing risk reduction and practicability concerns, C&S Review, and gaps identified within the Mechanical Engineering design of SSCs and project.

This chapter has been assessed for gaps against UK nuclear regulatory requirements, which have been used to produce a Forward Action Plan that Holtec will action beyond GDA.

Forward Actions have been collated and are managed via the process described in PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [29]. PSR Part A Chapter 5 ALARP Summary [30] describes the contribution of the forward actions to the ALARP argument.

19.7 REFERENCES

[1] Holtec Britain, "HI-2240337, Holtec SMR GDA PSR Part B Chapter 1 Reactor Coolant System and Engineered Safety Features," Revision 0, August 2024.

[2] Holtec Britain, "HI-2240776, Holtec SMR GDA PSR Part B Chapter 2 Reactor Fuel and Core," Revision 0, August 2024.

[3] Holtec Britain, "HI-2240777, Holtec SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities," Revision 0, August 2024.

[4] Holtec Britain, "HI-2240341, Holtec SMR GDA PSR Part B Chapter 10 Radiological Protection," Revision 0, August 2024.

[5] Holtec Britain, "HI-2240344, Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management," Revision 0, August 2024.

[6] Holtec Britain, "HI-2240353, Holtec SMR GDA PSR Part B Chapter 24 Fuel Transport and Storage," Revision 0, August 2024.

[7] Holtec Britain, "HI-2240350, Holtec SMR GDA PSR Part B Chapter 21 External Hazards," Revision 0, August 2024.

[8] Holtec Britain, "HI-2240351, Holtec SMR GDA PSR Part B Chapter 22 Internal Hazards," Revision 0, August 2024.

[9] Holtec Britain, "HI-2240338, Holtec SMR GDA PSR Part B Chapter 4 Control and Instrumentation Systems," Revision 0, August 2024.

[10] Holtec Britain, HI-2240339, Holtec SMR GDA PSR Part B Chapter 6 Electrical Engineering, Revision 0, August 2024.

[11] Holtec Britain, "HI-2240349, Holtec SMR GDA PSR Part B Chapter 18 Structural Integrity," Revision 0, August 2024.

[12] Holtec Britain, "HI-2240356, Holtec SMR GDA PSR Part B Chapter 19 Mechanical Engineering," Revision 0, August 2024.

[13] Holtec Britain, "HI-2240345, Holtec SMR GDA PSR Part B Chapter 14 Design Basis Accident Analysis," Revision 0, August 2024.

[14] Holtec Britain, "HI-2240346, Holtec SMR GDA PSR Part B Chapter 15 BDBA, Severe Accidents Analysis and Emergency Preparedness," Revision 0, August 2024.

[15] Holtec Britain, "HI-2240347, Holtec SMR GDA PSR Part B Chapter 16 Probabilistic Safety Assessment," Revision 0, August 2024.

[16] Holtec Britain, "HI-2240340, Holtec SMR GDA PSR Part B Chapter 9 Conduct of Operations," Revision 0, August 2024.

[17] Holtec Britain, "HI-2240342, Holtec SMR GDA PSR Part B Chapter 11 Environmental Protection," Revision 0, August 2024.

[18] Holtec Britain, "HI-2240332, Holtec SMR GDA PSR Part A Chapter 1 Introduction," Revision 0, August 2024.

[19] Holtec Britain, "HI-2240334, Holtec SMR GDA PSR Part A Chapter 3 Claims, Arguments and Evidence," Revision 0, August 2024.

[20] Holtec Britain, "SMR-300 Mechanical Engineering Design Basis Report," 2024.

[21] Holtec Britain, "HI-2240348, Holtec SMR GDA PSR Part B Chapter 17 Human Factors," Revision 0, August 2024.

[22] Holtec Britain, "Mechanical Engineering Codes and Standards," 2024.

[23] Holtec International, "HPP-3295-0017, Holtec SMR-300 Generic Design Assessment Reference Design Process and GDA Prospective Design Change Register," 2024.

[24] Holtec International, "HPP-160-3004, SMR-160 Systems, Structures, and Components Classification Standard," February 2022.

[25] US Nuclear Regulatory Commission, "NUREG 0800, Chapter 3.2.2: System Quality Group Classification," US NRC, 2016.

[26] Holtec International, "SMR-300 Project Quality Plan," Holtec, 2024.

[27] Holtec International, "HPP-160-3008, SMR-160, Procedure for Evaluating and Performing Design Decisions," Revision 0, October 2017.

[28] Holtec Britain, "SMR-300 Mechanical Engineering ALARP Summary Report," 2024.

[29] Holtec Britain, "HI-2240335, Holtec SMR GDA PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance," Revision 0, August 2024.

[30] Holtec Britain, "HI-2240336, Holtec SMR GDA PSR Part A Chapter 5 Summary of ALARP," Revision 0, August 2024.

19.8 LIST OF APPENDICES

Appendix A (REDACTED)

Appendix B Mechanical Engineering CAE Route Map

Overarching SSEC Claim	Chapter Claim/s	Chapter Sub Claim/s	Chapter Section
Claim 2.2 – System/Process Design and Substantiation The design of the systems and associated processes have been developed taking cognisance of relevant good practice and substantiated to achieve their safety and non-safety functional requirements.	**Claim 2.2.10 – Construction, Commissioning and Operation** The overall design and architecture of Mechanical SSCs ensures that safety functions and non-safety functions are delivered and faults arising from failures of the SSCs are minimised.	**Claim 2.2.10.1 –** Processes have been established to ensure mechanical specific safety requirements, functional requirements and architecture requirements are captured in the design, procurement and manufacturing steps.	19.3 Mechanical Engineering Design
		Claim 2.2.10.2 – Mechanical SSCs are designed using appropriate Codes and Standards, taking cognisance of Relevant Good Practice (RGP) and Operating Experience (OPEX).	19.4 Codes, Standards and Methodology
		Claim 2.2.10.3 – Mechanical SSCs achieve the design intent through quality manufacturing and installation process.	19.5 Quality Manufacturing and Installation
		Claim 2.2.10.4 – Mechanical SSC design incorporates Defence in Depth to protect against anticipated operational occurrences and accident conditions	19.3 Mechanical Engineering Design

Appendix C RGP Comparison with SMR-300 Codes and Standards

Code / Standard ID	Code / Standard Name	Related Sub-discipline(s)	RGP Identification
ANSI/ASME B1.1	Unified Inch Screw Threads (UN, UNR, and UNJ Thread forms)	Core Support Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards.
ANSI/ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications	Cooling Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. This standard has been used extensively in operating reactors, such as AP1000 and ABWR.
ANSI/ASME N509	Nuclear Power Plant Air-Cleaning Units and Components	HVAC & Ventilation Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. Utilized as the principal design code for various HVAC & ventilation systems within AP1000.
ANSI/ASME N510	Testing of Nuclear Air Treatment Systems	HVAC & Ventilation Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. The ductwork and filtration components from AP1000 were designed and tested in accordance with ANSI/ASME N510.
ANSI/SMACNA	"Round Industrial Duct Construction Standards," Second Edition, 1999.	HVAC & Ventilation Systems	Standard organization ANSI have developed mature, established and internationally recognized standards. The AP1000 ductwork was designed, tested and constructed in accordance with SMACNA, the principal design code for: fans, ductwork.
	"Rectangular Industrial Duct Construction Standards," Second Edition, 2004.		
	"HVAC Duct Construction Standards-Metal & Flexible," Third Edition, 2005.		
ANSI/ASME B16.11	Forged Fittings, Socket-Welding and Threaded	Cooling Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. This standard was used in the design of the AP1000 PZR.
ASME TDP-2	Prevention of Water Damage to Steam Turbines Used for Electric Power Generation: Nuclear-Fueled Plants		Standard organization ASME have developed mature, established and internationally recognized standards.
ANSI N14.6	Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10000 pounds (4500kg) or more	Core Support Systems	Standard organization ANSI have developed mature, established and internationally recognized standards.

Code / Standard ID	Code / Standard Name	Related Sub-discipline(s)	RGP Identification
		Mechanical Handling Systems	As part of the AP1000 the PZR and lifting lugs of the core makeup tank and accumulator were designed in accordance with the criteria specified in ANSI N14.6.
TEMA	Standards of the Tubular Exchanger Manufacturers Association	Cooling Systems	Principal design code for AP1000 heat exchangers along with ASME BPVC Section VIII.
US NRC 1.28	Quality Assurance Program Criteria (Design and Construction)	Cooling Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.43	Control of Stainless-Steel Weld Cladding of Low-Alloy Steel Components	Cooling Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.44	Control of the Processing and Use of Stainless Steel	Cooling Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.52	Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post Accident Engineered Safety Feature Atmosphere Cleanup Systems in Light Water-Cooled Nuclear Power Plants	HVAC & Ventilation Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.60	Design Response Spectra for Seismic Design of Nuclear Power Plants	Cooling Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.61	Damping Values for Seismic Design of Nuclear Power Plants	Cooling Systems	This regulatory guide has been used in operating reactors, such as ABWR.
US NRC 1.65R	Materials and Inspections for Reactor Vessel Closure Studs	Cooling Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.78	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release	HVAC & Ventilation Systems	This regulatory guide has been used in operating PWRs, such as AP1000
US NRC 1.140	Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants	HVAC & Ventilation Systems	This regulatory guide has been used in operating PWRs, such as AP1000 for the design, construction and testing of the charcoal absorbers.
US NRC 1.196	Control Room Habitability at Light-Water Nuclear Power Reactors	HVAC & Ventilation Systems	This RG has been used alongside RG 1.78 and 1.197, guiding the overall design for the Main Control Room Habitability System. Holtec will consider ISO 26802:2010 as an alternative for input to ventilation

Code / Standard ID	Code / Standard Name	Related Sub-discipline(s)	RGP Identification
US NRC 1.197	Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors	HVAC & Ventilation Systems	This regulatory guide involves broad testing requirements. This is in addition to the design guidance in RG 1.196 and the evaluation guidance in RG 1.78. These provide comprehensive guidance on the development of the MCH system, which meets the standards that have been achieved with operating reactors, such as ABWR.
ASME NOG-1	Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)	Mechanical Handling Systems	Standard organization ASME have developed mature, established and internationally recognized standards. The "one fault safe" approach incorporated into the standard is referenced within ONR's TAG, NS-TAST-GD-056, as a safety measure. Relating to shut down and refueling lifting operations associated with PWRs and BWRs. This TAG identifies that ASME NOG-1 has shortfalls, and the RP will evaluate this further beyond GDA Mechanical handling systems from other operating reactors, such as AP1000, ABWR & HPR1000, were designed in accordance with this standard.
NUREG-0554	Single Failure Proof Cranes For Nuclear Power Plants	Mechanical Handling Systems	Recognized within ONR's TAG, NS-TAST-GD-056, as a method of reducing the risk of uncontrolled lowering through the "single failure proof" hoist system. Mechanical handling systems from AP1000 were designed in accordance with this standard.
ASME BPVC	ASME Boiler and Pressure Vessel Code		Standard organization ASME have developed mature, established and internationally recognized standards.
• Section II	Materials	Cooling Systems Core Support Systems	This standard has been used as part of AP1000 & ABWR, to ensure that well-proven materials are chosen, and that the materials have good resistance to fracture and are of suitable chemical composition to limit the effect of through-life degradation mechanisms.
• Section III	Rules for Construction of Nuclear Facility Components	Cooling Systems Core Support Systems HVAC & Ventilation Systems Radioactive Waste Systems Thresholds	ONRs TAG, NS-TAST-GD-020, mentions this standard was used for the Sizewell B PWR containment proof pressure test. Also stating that this standard should be satisfied when producing a surveillance program during the construction phase. ASME BPVC Section III has been used extensively in the design of other operating reactors, such as AP1000 and ABWR.

Code / Standard ID	Code / Standard Name	Related Sub-discipline(s)	RGP Identification
• Section V	Non Destructive Examination	Core Support Systems	BPVC Section V has been used in the design of operating reactors, such as AP1000 and ABWR.
• Section IX	Welding, Brazing and Fusing Qualifications	Core Support Systems	Section IX has been used in operating reactors such as AP1000 & ABWR, providing welding procedures, welder qualifications and weld inspection requirements.
• Section XI	Rules for Inservice Inspection of Nuclear Power Plant Components	Cooling Systems Core Support Systems HVAC & Ventilation Systems Radioactive Waste Systems Thresholds	ONRs TAG, NS-TAST-GD-020, references section XI for detailed guidance on the frequency and content of inspection of pre-stressed and reinforced concrete containments. Noting how the visual inspection of Sizewell B PWRs mild steel liner was based on section XI. AP1000 & ABWR ISI will be specified in accordance with Section XI.
• Section VIII	Rules for Construction of Pressure Vessels	Core Support Systems	ASME BPVC Section VIII has been used extensively in the design of other operating reactors, such as AP1000 and ABWR.
ANSI/ASME B31.1	Power Piping	HVAC & Ventilation Systems Cooling Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. Pipework systems associated with SSC’s from operating reactors, such as AP1000 & ABWR, have been designed and constructed to ANSI/ASME B31.1.
ANSI/ASME AG-1	Code on Nuclear Air and Gas Treatment	HVAC & Ventilation Systems	Standard organizations ASME and ANSI have developed mature, established and internationally recognized standards. Ductwork and filtration systems of the AP1000 and ABWR were designed, constructed, qualified and tested in accordance with ANSI/ASME AG-1.
10 CFR 21	Reporting of Defects and Noncompliance	Cooling Systems Core Support Systems	Used in operating PWRs, such as AP1000
10 CFR 50	Domestic Licensing of Production and Utilization Facilities	Cooling Systems Core Support Systems HVAC & Ventilation Systems	ONRs TAG, NS-TAST-GD-020, mentions a containment leak test that should be undertaken in accordance with 10 CFR 50. A given example of this is the leak rate test at Sizewell B which was in accordance with appendix J of 10 CFR 50. Other instances, where 10 CFR 50 have been used, include AP1000 and ABWR.
NEMA MG-1	Motors & Generators	Mechanical Handling	This standard has been used in operating PWRs such as AP1000

Code / Standard ID	Code / Standard Name	Related Sub-discipline(s)	RGP Identification
ACI 349-13	Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary	Cooling Systems	ACI is a leading authority and resource worldwide for the development of standards related to concrete design, construction and materials. Within ONRs TAG, NS-TAST-GD-014, ACI 349 is referenced as a relevant design code when setting criteria during analysis. Reinforced concrete walls, slabs and structures from AP1000 & ABWR have been designed to ACI-349.
ANSI/ANS-58.14	Safety and Pressure Integrity Classification Criteria for Light Water Reactors	Cooling Systems HVAC & Ventilation	ANS is an international organization of scientists, engineers and industry professionals that have developed industry standards approved by ANSI.
API Standard 650	Welded Tanks for Oil Storage	Radioactive Waste Systems	Principal design code for various storage tanks within operating reactors such as AP1000 & ABWR.
ANSI/ANS-56.2	Containment Isolation Provisions for Fluid Systems After a LOCA	Cooling Systems Radioactive Waste Systems	ANS is an international organization of scientists, engineers and industry professionals that have developed industry standards approved by ANSI.
REGDOC 2.5.2	Canadian Nuclear Safety Commission – Design of Reactor Facilities: Nuclear Power Plants	HVAC & Ventilation Thresholds Radioactive Waste Systems	This regulatory document sets out requirements and guidance for the design of water cooled nuclear power plants, and is an adoption of principles set by the International Atomic Energy Authority (IAEA). The SMR-300 will be designed to Sections 7.21, 8.6, 8.11, and 10.2, and these have been used across the relevant sub-disciplines, particularly for requirements of radioactive containment. REGDOC 2.5.2 contributes to a robust set of requirements for the SSCs it has been used for, by establishing high- and low-level requirements on containment isolation, ventilation, and radiation protection.
ANSI/AISC N690	Specification for Safety-Related Steel Structures for Nuclear Facilities	Cooling Systems	This standard has been used in operating reactors such as AP1000 & ABWR