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SUB-CHAPTER 5.0 - SAFETY REQUIREMENTS

1. SAFETY FUNCTIONS

This sub-chapter describes the safety requirements and functional criteria used in the design of the reactor coolant system, together with a brief outline of testing requirements.

1.1. REACTIVITY CONTROL

The core cooling water of the Reactor Coolant System (RCP [RCS]), which is also used as a neutron moderator, neutron reflector and solvent for concentrated boric acid solutions, must contribute to the reactivity control independently from the Rod Cluster Control Assemblies (RCCAs).

1.2. RESIDUAL HEAT REMOVAL

The RCP [RCS] must provide heat removal under the following operating conditions:

- PCC-1 and PCC-2: transfer of thermal energy from the reactor core to the secondary cooling system or to the Residual Heat Removal System (RRA [RHRS]). In the event of loss of off-site power (LOOP), residual heat is removed by natural circulation in the reactor coolant system loops.
- PCC-3, PCC-4 and RRC-A: contribution to the removal of residual heat to the secondary cooling system, the RRA [RHRS], or engineered safeguard systems.
- In the event of both normal cooling systems (secondary cooling system and the RRA [RHRS]) being unavailable, core cooling is maintained by the use of feed and bleed operation (RRC-A).

1.3. CONTAINMENT OF RADIOACTIVE MATERIALS

The reactor coolant system (RCP [RCS]) and its connected pipework must provide containment of:

- radioactive products in the event of fuel cladding failures, since the Reactor Coolant Pressure Boundary (CPP [RCPB], which consists of the major RCP [RCS] components and the RCP [RCS] main coolant lines) forms the second barrier to the release of activity into the containment.
- activated products in solution or in suspension in the primary coolant.

The main reactor coolant system must be depressurised in the event of a severe accident (RRC-B conditions), in order to protect the integrity of the containment (third barrier).

2. FUNCTIONAL CRITERIA

2.1. REACTIVITY CONTROL

The requirements and criteria related to the control of reactivity are given in the chapters on Nuclear Design (see Sub-chapter 4.3), on the Extra Boration System (RBS [EBS]) (see Sub-chapter 6.7) and the Chemical and Volume Control System (RCV [CVCS]) (see Sub-chapter 9.3, section 2)

2.2. RESIDUAL HEAT REMOVAL

The reactor core, associated cooling systems and protection and control systems, must be designed with sufficient margin to ensure that acceptable fuel limits are not exceeded under normal or abnormal operation (PCC and RRC-A situations).

Instrumentation is provided to monitor the reactor coolant parameters under both normal operation and during/post incident and accident conditions. This instrumentation is connected to control devices which maintain the parameters within acceptable limits.

The reactor coolant system and associated auxiliary systems are designed to control the following main coolant parameters:

- the water inventory (coolant water level in the vessel and pressuriser). All conditions are considered, normal (in particular when the RCP [RCS] level is at the "lower working range of the RRA [RHRS]") and abnormal.

- the margin to saturation (sub-cooling margin).

The integrity of the fuel cladding must be maintained after a total loss of off-site power. This is achieved by the inertia of the Reactor Coolant Pumps during run-down and, if necessary, the use of the protection systems.

The layout of the reactor coolant system enables heat removal via natural circulation after loss of Reactor Coolant Pumps forced flow.

2.3. CONTAINMENT OF RADIOACTIVE MATERIALS

2.3.1. Isolation of the reactor coolant system

Two isolation devices in series must be installed between the Reactor Coolant Pressure Boundary (CPP [RCPB]) and any connected system where failure of the connecting line would lead to a leak that could not be compensated by the RCV [CVCS].

2.3.2. Reactor coolant system (RCP [RCS]) integrity

The temperature and pressure in the Reactor Coolant System must not exceed the maximum operating temperature and pressure during normal operating and upset conditions. For each PCC or RRC-A which is not a LOCA, the RCP [RCS] must remain intact.

The integrity requirement of the Reactor Coolant Pressure Boundary (CPP [RCPB]) requires the application of specific high quality measures. High quality levels have to be achieved for its components, through the choice of materials, of manufacturing processes and associated inspections, of calculation rules with appropriate assumptions in systems and accident analyses.

The Reactor Coolant System is protected against over pressurisation by appropriate safety devices (see Sub-chapter 3.4).

In the event of PCCs including accidents in states C and D, the integrity of the system is ensured by the pressuriser safety relief valves (PSRVs) in addition to the reactor trip.

This over pressure protection is also provided under RRC-A conditions, in particular in the event of an Anticipated Transient Without Scram (ATWS).

To avoid contamination of the containment during normal operation (small leaks or discharge from tests of the PSRVs) the PSRVs discharge is routed to the Pressuriser Relief Tank (PRT) which condenses discharged steam and collects incondensable gases before recovery by the Nuclear Vents and Drains System (RPE [NVDS]).

Support structures for the large primary circuit equipment are provided to limit the stress imposed on the main coolant lines during normal operation or in the event of an incident or accident.

In order to avoid long-term corrosion of components which constitute the RCP [RCS], sampling of the coolant is implemented and its chemical characteristics checked periodically (see Sub-chapter 9.3).

2.3.3. Reactor Coolant System pipe break assumptions

The break preclusion concept applies to the main coolant lines. Connected pipework is excluded from this approach. Safety requirements relating to break preclusion are detailed in Sub-chapter 5.2. As a consequence of the break preclusion concept, main coolant lines guillotine breaks are not considered as part of PCC-4 design basis accidents. However, breaks of connected branch pipework must be considered. Such breaks apply, in particular to:

- the pressuriser surge line (largest connected branch pipework)
- the RRA [RHRS] nozzle on the hot leg
- the RIS [SIS] nozzle on the cold leg.

Analyses using the assumptions specific to PCC-4 accidents must confirm that, beyond the core safeguard:

- the break does not result in failure of the RCP [RCS] main coolant lines, or other connected branch pipework,
- the physical performance of the vessel internal components is acceptable, enabling core cooling to be maintained and shutdown carried out (possible rod drop, coolable core geometry, etc.),
- the integrity of the primary system component supports is ensured,

- the integrity of the pressure boundary of large components (Reactor Coolant Pumps, Steam Generators, etc.) and their internals when they are part of the pressure boundary is ensured.

A 2A equivalent section break in the main coolant lines must also be considered as part of the additional measures identified within the Break Preclusion concept. The objective is to reduce the severity of beyond design basis accidents, especially those that could occur despite the implementation of the Break Preclusion concept.

This analysis must allow:

- the definition, using realistic assumptions, of:
  - the Safety Injection Systems (RIS [SIS]) capacity,
  - the resulting pressure and temperature and the verification of containment building resistance,
  - the post accident conditions to be used for equipment qualification.
- the application of installation measures which ensure that any damage is confined to a single loop,
- the verification of the large components stability under the effect of a “2pA” static load.

2.3.4. RCP [RCS] leaks

As part of the defence-in-depth, and despite the implementation of the Break Preclusion concept on the RCP [RCS] main coolant lines, efficient leak detection features must be available to identify and measure reactor coolant leakage. Detection times must be consistent with the potential propagation time of a detectable defect.

2.3.5. Severe accident

In order to avoid the risk of high pressure rupture of the reactor vessel after core melt, when such a rupture could impact the integrity of the containment, the three PSRVs must be supplemented by further diverse means of safety relief. These diverse means of relief are redundant and qualified in accordance with the high temperatures reached under these conditions (See Sub-chapter 5.4).

3. DESIGN REQUIREMENTS

3.1. SAFETY CLASSIFICATION REQUIREMENTS

3.1.1. Safety classification

The Reactor Coolant System (RCP [RCS]) must be safety classified, in accordance with the classification described in Sub-chapter 3.2.

3.1.2. Single failure criterion (active and passive)

The single failure criterion applies to components providing F1 functions.

The functional redundancy of the F1B classified standstill seal systems (DEA [SSSS]) must be ensured by adequate cooling of the F1B classified thermal barrier.

3.1.3. Emergency power supply

The power supply to redundant components must be backed-up by diesel generators so that their safety function can be ensured following a loss of off-site power.

3.1.4. Qualification under operating conditions

RCP [RCS] components providing F1 or F2 functions must be qualified to remain operational under normal and post-accident operating conditions.

The resulting component requirements (integrity, operability, functional capacity, etc.) are shown in Sub-chapters 3.1, 3.4 and 3.6.

3.1.5. Mechanical, electrical and instrumentation and control equipment classification

Mechanical, electrical and instrumentation and control equipment are classified in accordance with the rules given in Sub-chapter 3.2.

Pipework with a nominal diameter less than or equal to 50 mm is designed and manufactured in accordance with the rules of the RCC-M A 4000.

3.1.6. Seismic classification

The RCP [RCS] must be seismically classified in accordance with the classification described in Sub-chapter 3.2.

3.1.7. High Integrity Component classification

As stated in Sub-chapter 3.1 the Main Coolant Lines are High Integrity Components for which the specific measures described in section 0.3.6 of Sub-chapter 3.4 concerning prevention, surveillance and mitigation contribute to their high integrity demonstration.

3.2. OTHER REGULATORY REQUIREMENTS

3.2.1. Official Documentation

The official documentation applicable to the RCP [RCS] is defined in Sub-chapter 1.4.

3.2.2. Basic Safety Rules

The application of these rules is given in Sub-chapter 1.4.

3.2.3. Technical Guidelines

RCP [RCS] specific requirements are given in sections B.1.2 and B.2.3.6 of the Technical Guidelines (see Sub-chapter 3.1).

3.3. INTERNAL / EXTERNAL HAZARDS

3.3.1. Internal hazards

The RCP [RCS] must be protected against internal hazards, in accordance with Sub-chapter 13.2.

Measures must be taken against the possible hazard effects of a high energy pipe break (HEPB) on the RCP [RCS] and on pipework adjacent or connected to the RCP [RCS]. It must also be possible to isolate the RCP [RCS] in the event of a pipe break on connected systems.

Special measures must be taken to protect the PSRVs against the dynamic effects resulting from projectiles ejected in the event of a valve break or high energy pipe break in the vicinity of the pressuriser.

3.3.2. External hazards

The RCP [RCS] must be protected against external hazards, in accordance with Sub-chapter 13.1

4. TESTS

4.1. PRE-OPERATIONAL TESTS

Pre-operational tests must verify the design adequacy and performance of the RCP [RCS].

4.2. PERIODIC TESTS AND OPERATIONAL INSPECTIONS

Regular periodic tests will be carried out on the RCP [RCS] to demonstrate its continued ability to meet its design and functional performance requirements.

The layout and design of RCP [RCS] equipment must allow in-service inspections and periodic tests to be carried out in order to verify the components ability to fulfil their safety functions.

In-service inspections are performed at locations where in-service defects are most likely to develop. The design and configuration of the RCP [RCS] main coolant lines must allow access for testing and inspection, with limited personnel exposure.

The consequences of the loss of integrity of the RCP [RCS] must be limited as far as possible. As part of the defence-in-depth implementation, a leak detection system, displaying alarms in the Main Control Room (MCR) is installed to detect the leakage rate resulting from the presence of a stable through-wall defect. This leak detection system will be used to identify leaks before a complete pipe break can occur, thus enabling the unit to be brought to safe shutdown state.

Thermodynamic parameters, water chemistry, RCP [RCS] leakage and reactor vessel steel irradiation must be monitored.