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REVISION HISTORY

Issue	Description	Date
00	First issue for INSA information	11-12-2007
01	Integration of technical and co-applicant comments	29-04-2008
02	PCSR June 2009 update including: - Text clarifications - Addition of references - Technical update to account for December 2008 Design Freeze notably suppression of automatic isolation of the cooling trains (9.1.3.4) new permissive for fuel handling (9.1.3) protection against pool emptying (9.1.3.3) fire sub-sectorisation (9.1.3) and use of ASG pump (9.1.3.4)	29-06-2009
03	Consolidated Step 4 PCSR update: - Minor editorial changes - Clarification of text - Update and addition of references - Addition of text regarding decay heat assumptions in spent fuel pool fault analyses (§2.2, §3.5.1) - Clarifications regarding lifting operations with cranes in the reactor building and fuel building (§5.2)	31-03-2011

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REVISION HISTORY (Cont'd)

Issue	Description	Date
04	Consolidated PCSR update: - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc - Minor editorial changes - Summary of design changes to be implemented for the fuel handling & PTR systems added, with cross-reference to Sub-chapter 16.4 (introduction and §1.3) - References and figure updated for the new fuel dry storage rack (§1, Section 9.1.1 - Figure 1) - Update of references and addition of design reference drawings - Update of text for clarification and consistency (§3.0.1.1, §3.0.2.1, §3.0.3.1, §3.2.1.1, §3.3.1.1.1, §3.3.1.1.2, §3.3.1.1.4, §3.3.1.2.1, §3.4.1, §3.5) - Addition of text covering availability of an Emergency Feed Water System pump (§3.4.3.2) - Update of initiating events not taken into account for draining of the fuel pool, consistent with update in Sub-chapter 16.4 (§3.4.3.3) - Correction of cross-reference to Sub-chapter 3.6 (§3.0.3.1, §3.5.2.3) - Addition of text covering lifting arrangements provided to improve safety and reduce reliance on the operator (§4.4.1.2.5) - Reference and text for Pools and Tanks Liner Methodology updated (§6.2) - ETC-C reference updated to 2010 AFCEN Edition and associated Companion Document (§6.6.1).	21-11-2012

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SUB-CHAPTER 9.1 – FUEL HANDLING AND STORAGE

Note: In order to tolerate the consequences of gross failure of the fuel transfer tube the civil structures surrounding the fuel transfer tube will be modified as follows:

- The rooms enclosing the transfer tube will be modified to be watertight to a pressure corresponding to the maximum water level in pools.
- Two independent watertight rooms (called transfer rooms) will be created on either side of the fixed point; each room will be equipped with a watertight personnel access to provide give easy access to the transfer tube for inspection and repairs, and devices necessary for draining of the rooms will be provided. Humidity sensors in the transfer rooms would enable a leak to be detected.

These design changes are not included in the description of the fuel handling systems provided in this sub-chapter. The incorporation of these design changes into the fuel pool safety case is described in Sub-chapter 16.4, and the design changes will be fully incorporated into this sub-chapter as part of the detailed design during the site licensing phase.

1. NEW FUEL DRY STORAGE RACK

1.0. SAFETY REQUIREMENTS

1.0.1. Safety functions

The new fuel dry storage rack contributes to achieving the following safety functions:

1.0.1.1. Reactivity control

The new fuel dry storage rack must be designed to maintain the fuel assemblies in a subcritical state.

1.0.1.2. Containment of radioactive substances

The new fuel dry storage rack must be designed to maintain the integrity of the fuel cladding.

1.0.2. Functional criteria

1.0.2.1. Reactivity control

The new fuel dry storage rack design must avoid any criticality risks in the most conservative homogenous moderation conditions (immersion in pure water or pure steam), assuming that the individual cells of the rack contain new fuel with the maximum permitted enrichment.

The design of the new fuel dry storage rack must prevent any geometrical deformation as a result of changes in operating or ambient conditions. The design must be stable against tipping; measures must be taken to prevent unintended movement of the fuel assemblies or of the storage rack itself.

The new fuel dry storage rack design must prevent more than one fuel assembly being placed in a single storage cell or a fuel assembly being placed or jammed between two storage cells.

1.0.2.2. Containment of radioactive substances

The geometry of the new fuel dry storage rack must be such that there is no risk of damage to the fuel cladding.

The new fuel dry storage rack must be suitably protected to:

- avoid any falling object, such as tools, during the handling operation,
- prevent any foreign material from being inserted into the cells.

1.0.3. Design requirements

1.0.3.1. Requirements from safety classifications

1.0.3.1.1. *Functional classifications*

Not applicable.

1.0.3.1.2. *Single failure criterion (active and passive)*

Not applicable.

1.0.3.1.3. *Emergency power supplies*

Not applicable.

1.0.3.1.4. *Qualification for operating conditions*

Not applicable.

1.0.3.1.5. *Mechanical, electrical, instrumentation and control classifications*

Not applicable.

1.0.3.1.6. *Seismic classification*

The new fuel dry storage rack must be seismically classified according to the classification principles defined in Sub-chapter 3.2.

1.0.3.1.7. *Periodic tests*

No periodic testing is required.

1.0.3.2. Other statutory requirements

1.0.3.2.1. *Regulatory requirements*

No specific official document applies to the new fuel dry storage rack.

1.0.3.2.2. *Basic safety rules*

No specific basic safety rule applies to the new fuel dry storage rack.

1.0.3.2.3. *Technical guidelines*

No specific condition from the Technical Guidelines applies to the new fuel dry storage rack.

1.0.3.2.4. *Specific EPR documents*

No specific EPR document applies to the new fuel dry storage rack.

1.0.3.3. Hazards

Hazards other than internal flooding, dropped loads, earthquake and aircraft crash have no specific impact on the fuel dry storage rack due to the installation of the rack in the fuel building.

1.0.3.3.1. *Internal hazards*

The location of the new fuel dry storage rack removes the requirement for protection against the following internal hazards:

- pipe break,
- tank, pump and valve failure,
- internal projectiles.

However, the new fuel dry storage rack must be protected against the following internal hazards:

- flooding,
- risks caused by dropped loads during handling operations,
- internal explosion,
- fire.

Protection against potential internal explosion will be afforded by the use of preventive measures.

1.0.3.3.2. ***External hazards***

The new fuel dry storage rack must be designed to withstand loads corresponding to the design earthquake and to shaking following an aircraft crash.

1.1. ROLE OF THE SYSTEM

The new fuel dry storage rack is used to store in air new UO_2 fuel assemblies that are required for core refuelling. The fuel dry storage rack is located in the new fuel dry storage area inside the fuel building and is designed to provide vertical storage for twelve new UO_2 fuel assemblies, either equipped with control rod clusters or not.

MOX new fuel assemblies cannot be stored in the new fuel dry storage rack; they are stored directly in the fuel underwater storage rack (see section 2).

1.2. DESIGN BASES

The design bases for the new fuel dry storage rack are the following [Ref-1]:

a) Prevention of criticality in the UO_2 new fuel dry storage rack is ensured by using physical systems and configurations that are geometrically safe. Its design is such that the K_{eff} multiplication factor does not exceed 0.98 with fuel of the highest enrichment and in optimum homogeneous moderation conditions [Ref-2].

b) During storage, the new fuel assemblies are protected by:

- a removable closure plug on each storage cell to provide protection from falling objects, such as tools, during handling operations,
- a metal grid covering the storage area to protect it from falling materials.

c) The new fuel dry storage rack is suitably protected against internal or external hazards:

- no water pipes are permitted to pass through the new fuel storage area,
- the new fuel dry storage rack is designed to maintain its integrity when it is subjected to design earthquake loads and to shaking following an aircraft crash.

d) The new fuel dry storage rack design prevents more than one fuel assembly being installed in a single storage cell or a fuel assembly being placed or jammed between two storage cells.

e) The new fuel dry storage rack design prevents any geometrical deformation due to ambient condition changes. The design is stable in relation to tipping over; measures are taken to prevent unexpected movement of the fuel or the rack.

1.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT [REF-1]

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The new fuel dry storage rack comprises twelve cells, each one able to hold one fuel assembly. The upper part of each cell is equipped with a guide cone to facilitate insertion of the fuel assembly. The lower part of each cell has one drain hole.

The new fuel dry storage rack is located next to the fuel storage pool and the new fuel container entry door. Each cell is a stainless steel continuous section square box equipped with a removable closure plug.

The base of each storage cell is bolted on to a lower support, whilst the upper section is clamped by bolting to allow positioning adjustments to be made and to respect pitch requirements.

1.4. PRELIMINARY SAFETY ANALYSIS

1.4.1. Compliance with the functional criteria

{CCI Removed} [b] Criticality calculations are based on new fuel assemblies with a maximum enrichment of 5% and immersed in pure water or pure steam. The assumptions used for the calculations are given in Sub-chapter 4.3. In the design conditions, the new fuel dry storage rack K_{eff} factor is calculated to remain below 0.98, making suitable allowances for all uncertainties [Ref-1].

When being inserted and withdrawn from the cells, the fuel assemblies are protected by guide cones and the internal storage cell surface finish prevents the fuel cladding from being damaged. The rack is designed so that it is impossible to insert or jam a fuel assembly between two adjacent storage cells.

Once stored, the fuel assemblies are protected by the following devices:

- a closure plug on each cell for protection against falling objects or tools,
- a storage area cover to protect it from falling objects or tools and to prevent unauthorised access. In addition, the storage area door is kept locked.

The fuel assemblies are identified and their position in the rack is recorded. Correct orientation of the fuel assemblies is provided by two positioning holes and an alignment hole for aligning the new fuel handling tool.

The new fuel dry storage rack is designed to support normal operating loads (deadweight of the fuel assemblies); the requirements regarding mechanical stresses are as follows:

- in normal operation, the maximum calculated stresses are below the allowable stresses for the structures and for all of the parts contributing to supporting the fuel assemblies, and the allowable stresses are less than 20% of the material ultimate tensile strength at normal operating temperature [Ref-2].

1.4.2. Compliance with the design requirements

1.4.2.1. Safety classifications

The seismic classification of the new fuel dry storage rack is presented in Sub-chapter 3.2.

1.4.2.2. Hazards

1.4.2.2.1. *Internal hazards*

Flooding

No water pipe may pass through the new fuel storage area.

In the event of flooding of the new fuel storage area following a fire event (e.g. by the use of mobile fire protection equipment), avoidance of any criticality risk is ensured by the design of the rack, which complies with the requirements provided in section 1.0.2.1.

Dropped loads

The design of the auxiliary hoist and the new fuel handling tool prevents the risk of dropped loads during handling operations (see section 4).

Avoidance of any criticality risk is ensured in air (currently load drop and flooding are not cumulated), as a result of the fuel assembly characteristics and the maximum number (twelve) of fuel assemblies stored in the new fuel dry storage rack.

Internal explosion

Protection against internal explosion is based on prevention of explosive gas release and design of the ventilation systems to avoid H_2 accumulation.

Fire event

Flammable materials will not be stored close to the new fuel dry storage rack in order to avoid, in the case of fire, any excessive temperature build-up which may finally spread to the fuel assemblies.

Design measures against flooding resulting from the use of fire protection equipment are described above.

<table>
<tr><th>Internal hazards</th><th>Protection required in principle</th><th>General protection</th><th>Specific protection introduced into the design</th></tr>
<tr><td>Pipe break</td><td rowspan="3">Not applicable</td><td rowspan="3">Location of dry storage in the fuel building</td><td rowspan="3">-</td></tr>
<tr><td>Tank, pump and valve failure</td></tr>
<tr><td>Internal projectile</td></tr>
<tr><td>Dropped load</td><td rowspan="2">Yes</td><td>Design of the auxiliary crane and the handling tool</td><td></td></tr>
<tr><td>Internal explosion</td><td>Preventive measures (prevention of explosive gas release, ventilation)</td><td></td></tr>
</table>

Internal hazards	Protection required in principle	General protection	Specific protection introduced into the design
Fire	Yes	Fuel building fire protection No flammable materials stored close to the new fuel dry storage area	See design for internal flooding
Internal flooding		Location in the fuel building No water pipes in the storage area	The new fuel dry storage rack is sized to ensure optimum moderation

1.4.2.2.2. *External hazards*

Earthquake and aircraft crash

The new fuel dry storage rack is designed to withstand design earthquake loads and shaking following an aircraft crash. Requirements regarding mechanical stresses are as follows:

- in design earthquakes or shaking following an aircraft crash, stresses must be lower than the yield strength of the material at normal operating temperature.

External hazards	Protection required in principle	General protection	Specific protection introduced into the design
Earthquake	Yes	Location in the fuel building	Seismic design
Aircraft crash			
External explosion			-
External flooding			
Snow and wind			
Extreme cold			
Electromagnetic interference			

1.5. TESTS, INSPECTION AND MAINTENANCE

1.5.1. Pre-operational tests

The alignment of cells is checked on site using a dummy assembly. Insertion tests are also carried out to confirm the adequacy of the tolerances.

1.5.2. In service inspection

Due to its function and its design, the new fuel dry storage rack requires no maintenance or inspection.

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2. UNDERWATER FUEL STORAGE RACK

2.0. SAFETY REQUIREMENTS

2.0.1. Safety functions

The underwater fuel storage rack does not directly take part in the fulfilling of safety functions, nevertheless it contributes to the following safety functions:

2.0.1.1. Reactivity control

The underwater fuel storage rack must be designed to maintain the fuel assemblies in a sub-critical state.

2.0.1.2. Decay heat removal

The underwater fuel storage rack must be designed to allow free circulation of the water in the pool.

2.0.1.3. Radioactive substance containment

The underwater fuel storage rack must be designed to maintain the integrity of the fuel cladding.

2.0.2. Functional criteria

2.0.2.1. Reactivity control

The design of the underwater fuel storage rack must exclude all risks of criticality, not only in normal storage conditions but also in the case of zero boron concentration in the pool water. The potential storage of incomplete fuel assemblies (from which 1 to 3 fuel rods have been extracted) is taken into account.

The design of the underwater fuel storage rack must prevent any geometrical deformation as a result of changes in operating or ambient conditions. The design must be stable against tipping; measures must be taken to prevent unintended movement of the fuel assemblies or of the storage rack itself.

The design of the underwater fuel storage rack must prevent more than one fuel assembly being placed in a single storage cell or a fuel assembly being jammed between two storage cells.

2.0.2.2. Decay heat removal

The design of the underwater fuel storage rack must allow free flow of water in the pool to cool the fuel assemblies.

2.0.2.3. Containment of radioactive substances

The geometry of the underwater fuel storage rack must be such that there is no risk of damage to the fuel cladding.

The underwater fuel storage rack must be suitably protected to:

- avoid any falling object, such as tools, during the handling operation,
- prevent any foreign material from being inserted into the cells.

2.0.3. Design-related requirements

2.0.3.1. Requirements from safety classifications

2.0.3.1.1. *Functional classification*

Not applicable

2.0.3.1.2. *Single failure criterion (active and passive)*

Not applicable

2.0.3.1.3. *Emergency power supplies*

Not applicable

2.0.3.1.4. *Qualification for operating conditions*

Not applicable

2.0.3.1.5. *Mechanical, electrical, instrumentation and control classifications*

The mechanical, electrical, instrumentation and control classification of safety elements must comply with the requirements of Sub-chapter 3.2.

2.0.3.1.6. *Seismic classification*

The underwater fuel storage rack must be seismically classified according to the classification principles defined in Sub-chapter 3.2.

2.0.3.1.7. *Periodic tests*

No periodic testing is required.

2.0.3.2. Other statutory requirements

2.0.3.2.1. *Regulatory requirements*

No specific official document applies to the underwater fuel storage rack.

2.0.3.2.2. *Basic safety rules*

No specific basic safety rule applies to the underwater fuel storage rack.

2.0.3.2.3. *Technical guidelines*

No specific condition from the Technical Guidelines applies to the underwater fuel storage rack.

2.0.3.2.4. *Specific EPR documents*

No specific EPR document applies to the underwater fuel storage rack.

2.0.3.3. Hazards

Hazards other than dropped loads, earthquake and aircraft crash have no specific impact on the underwater fuel storage rack due to the installation of the rack in the fuel building.

2.0.3.3.1. *Internal hazards*

The location of the underwater fuel storage rack in the fuel building removes the requirement for protection against the following internal hazards:

- pipe break,
- tank, pump and valve failure,
- internal projectiles.

However, the underwater fuel storage rack must be suitably protected against the following internal hazards:

- flooding,
- risks caused by dropped loads during handling operations,
- internal explosion,
- fire.

Protection against potential internal explosion will be afforded by the use of preventive measures.

2.0.3.3.2. *External hazards*

The underwater fuel storage rack must be designed to maintain its integrity when it is subjected to loads corresponding to the design earthquake and to shaking following an aircraft crash.

2.1. ROLE OF THE SYSTEM

The underwater fuel storage rack is used to store the following:

- UO_2 and MOX new fuel assemblies from the time of delivery to site until loading into the reactor core,
- UO_2 and MOX spent fuel assemblies following unloading of the core and prior to shipment out of the plant.

2.2. DESIGN BASIS

The design bases of the underwater fuel storage rack are as follows [Ref-1]:

a) The prevention of criticality in the underwater fuel storage rack is effected using physical systems and configurations that are geometrically safe. The design of the underwater fuel storage rack is such that the K_{eff} multiplication factor does not exceed the following levels, assuming fuel with the highest enrichment:

- 0.95 in normal operation,
- 0.98 in credible accident situations, i.e. zero boron content of the pool, situations resulting from the dropping of an assembly (assembly lying on the rack in borated water), and assembly placed between the rack and the pool wall in borated water [Ref-2].

b) The system design is such that no heavy load is handled above the spent fuel storage area.

c) Protection against external hazards:

- the fuel storage pool and the underwater fuel storage rack are designed so that their integrity (including leak tightness) will be maintained if they are subjected to design earthquake loads or shaking following an aircraft crash,
- the underwater fuel storage rack is suitably protected against internal and external hazards.

d) The design of the underwater fuel storage rack prevents the placing of more than one fuel assembly in a single storage cell or the placing or jamming of a fuel assembly between two storage cells.

e) The design of the underwater fuel storage rack prevents any geometrical deformation due to changes in operating or ambient conditions. The design is stable against tilting and measures are taken to prevent the following:

- unintended movement of fuel assemblies or the storage rack itself,

- damage to the pool lining.

f) The underwater fuel storage rack is designed to allow free circulation of water in the pool to cool the spent fuel assemblies. The residual power in the fuel pool is higher with a single zone design for the fuel storage rack, as a result of an increase in the number of fuel storage cells. The re-evaluation of decay heat power values [Ref-3] confirms that there is no impact on the sizing of the fuel pool cooling system during normal operation.

g) The design will prevent dry-out of the entire rack, even in case of inadvertent suction of pool water by a connected system.

2.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT [REF-1]

The underwater fuel storage rack consists of 19 modules as illustrated in Section 9.1.2 - Figure 1.

Each module is a self-supporting structure fabricated from stainless steel sheet, forming a square array of vertical cells as illustrated in Section 9.1.2 - Figures 2 and 3. Each cell contains a borated stainless box section in which an individual fuel assembly can be stored except for some modules where several cells are blocked out.

The support pads of module sit on the bottom of the pool, each fitted with a support plate mounted on a ball pivot. These support pads may be adjusted vertically to ensure compatibility of the load distribution and contact pressure dictated by civil engineering requirements.

Each module is connected to its neighbour at the level of the base plate by means of bolted connecting plates.

The geometry and design of modules are such that a fuel assembly may be inserted or extracted vertically using the overhead crane placed directly above a storage cell. No other handling operation is needed, thus avoiding any risk of collision with or damage to the fuel assembly.

One of the modules comprises five cells equipped with a filter near the base to hold defective fuel assemblies.

The total number of fuel storage cells is one thousand one hundred and sixty seven.

2.4. PRELIMINARY SAFETY ANALYSIS

2.4.1. Compliance with regulations

2.4.1.1. Technical directives

The temperature of the pool water assumed for the design of the rack is 100°C. The underwater fuel storage rack is designed to withstand a temperature of 100°C [Ref-1].

2.4.2. Compliance with functional criteria

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Criticality calculations are based on the following fuel assemblies:

- 5% U^{235} for UO_2 fuel assemblies,
- MOX fuel assemblies having the characteristics given in the tables below.

Pu isotopic composition of MOX fuel assemblies			
^{238}Pu		0 w%	
^{239}Pu		68 w%	
^{240}Pu		19 w%	
^{241}Pu		12 w%	
^{242}Pu		1 w%	
^{241}Am		0 w%	
Total Pu content		**Fissile Pu content**	
Region 1	7.44%	Region 1	5.95%
Region 2	6.44%	Region 2	5.15%
Region 3	3.44%	Region 3	2.75%
Mean value	7%	Mean value	5.6%

The optimal moderation assumptions used for the criticality calculations are given in Sub-chapter 4.3. In the design conditions, the underwater fuel storage rack has a K_{eff} factor, taking all uncertainties into account (including storage of incomplete fuel assemblies (3 missing fuel rods per fuel assembly in the most onerous condition), lower than:

- 0.95 in normal operation and taking into account the minimum boron concentration required in the Technical Specifications,
- 0.98 in a credible accident situation i.e. zero boron content of the pool, situations resulting from the dropping of an assembly (assembly lying on the rack in borated water), fuel assembly placed between the rack and the pool wall in borated water [Ref-1].

The modules of the underwater fuel storage rack are designed so that it is impossible to insert a fuel assembly between adjacent storage cells. The support pads of the module are designed to prevent the pool lining from being pierced, which could compromise leak tightness.

The design of the underwater fuel storage rack prevents any change to the geometry of fuel assemblies due to changes in operating or environmental conditions. Within a cell, the fuel assembly is protected over its full height.

During the insertion and withdrawal of fuel assemblies, they are protected by guide funnels as well as by the finish of the interior surface of the storage cells, which prevents damage to the fuel rods.

The lower part of each storage cell has one or more orifices to allow pool water to circulate freely and thus ensure cooling of the stored fuel assemblies.

UO_2 and MOX fuel assemblies are always stored and handled under water deep enough to ensure radiological protection.

The system design is such that no heavy load is handled above the underwater fuel storage area.

The underwater fuel storage rack is designed to withstand handling and normal operation loads (deadweight of the fuel assemblies). The requirements relating to mechanical stresses in normal operating conditions are given by the RCC-M code [Ref-2].

Given the relative height between the top of the rack and the lowest pipes of the connected pool systems, the amount of water remaining above the rack avoids any risk of dry-out of the fuel storage rack.

2.4.3. Compliance with design requirements

2.4.3.1. Safety classification

The seismic classification of the underwater fuel storage rack is presented in Sub-chapter 3.2.

2.4.3.2. Hazards

2.4.3.2.1. *Internal hazards*

Fire event

Design measures against flooding resulting from the use of fire protection equipment are described below.

Flooding

The underwater fuel storage rack is located in a pool. The risk from flooding is a reduction in the boron concentration of the pool water. Avoidance of any criticality risk is ensured by the design of the rack itself, which complies with the requirements provided in section 2.0.2.1.

Dropped loads

The design of the fuel handling equipment significantly reduces the risk of dropped loads during handling operations (see section 4).

The risk of criticality resulting from the dropped load has been assessed and confirms that a criticality will not occur as a result of a dropped fuel assembly.

Internal hazards	Protection required in principle	General protection	Specific protection introduced in the design of the system
Pipe break	Not applicable	-	-
Failure of tanks, pumps and valves			
Internal missiles			
Dropped loads	Yes	Design of handling equipment	Criticality analyses in situations resulting from fall of assembly Mechanical design towards fuel drop
Internal explosion		Preventive measures (prevention of explosive gas release, ventilation, pool water cooling)	Design of racks for residual heat removal of spent fuel assemblies
Fire		Fuel building fire protection	See design for internal flooding
Internal flooding		Location in the fuel building	Avoidance of criticality risk in the event of pure water ingress into the pool

2.4.3.2.2. *External hazards*

Earthquake and aircraft crash

The underwater fuel storage rack is designed to withstand design earthquake loads and shaking following an aircraft crash. The requirements relating to mechanical stresses in fault conditions are given by the RCC-M code x.

The underwater fuel storage rack is located inside the fuel building, which is designed to withstand aircraft crash and explosions (see Chapter 13).

External hazards	Protection required in principle	General protection	Specific protection introduced in the design of the system
Earthquake	Yes	Location in the fuel building	Seismic design
Aircraft crash			
External explosion			-
External flooding			
Snow and wind			
Extreme cold			
Electromagnetic interference			

2.5. TESTS, INSPECTION AND MAINTENANCE

2.5.1. Pre-operational tests

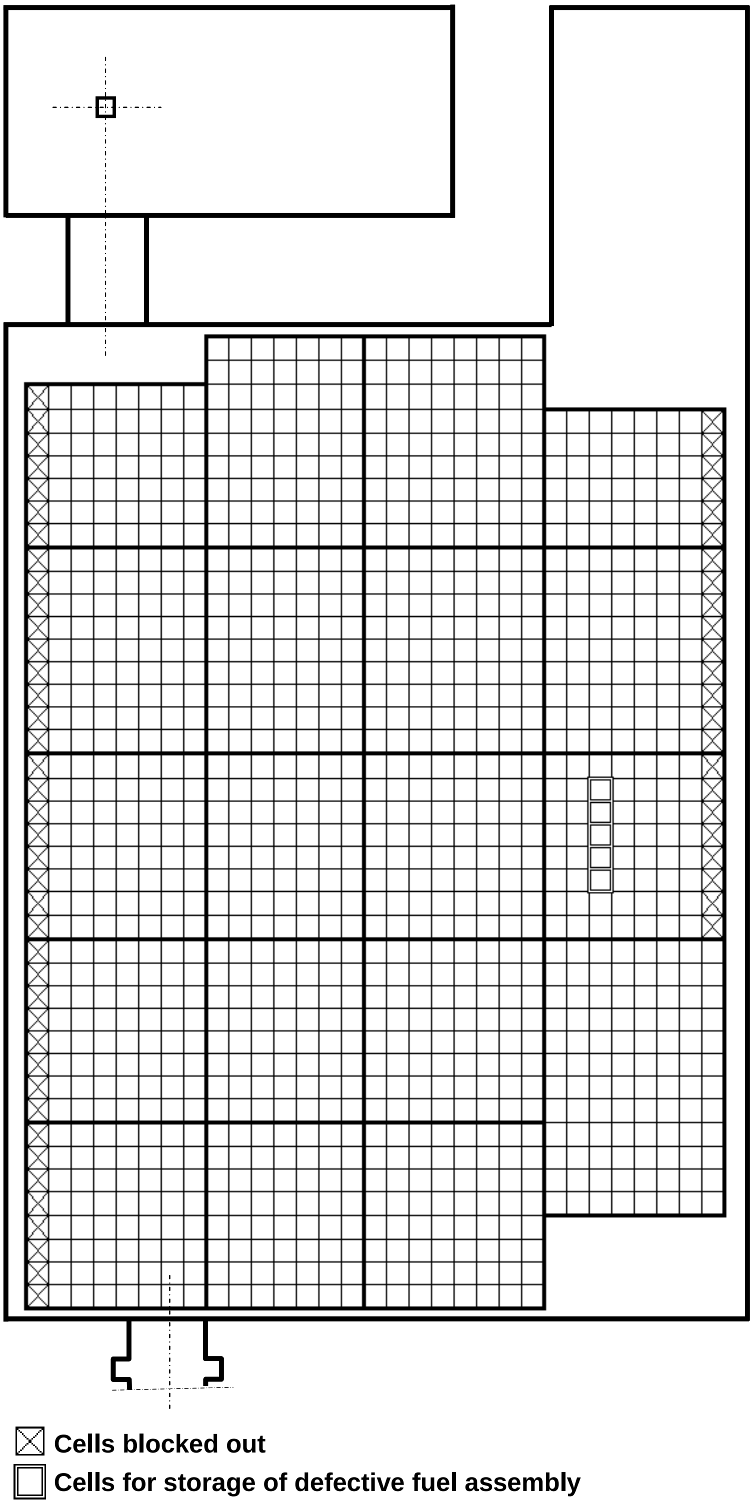
The alignment of modules is checked on site using a dummy fuel assembly. Insertion tests are also carried out to confirm the adequacy of tolerances.

2.5.2. In service inspection

Due to its function and design, the underwater fuel storage rack requires no maintenance or inspection.

SECTION 9.1.2 - FIGURE 1 [REF-1]

Underwater fuel storage rack - Layout

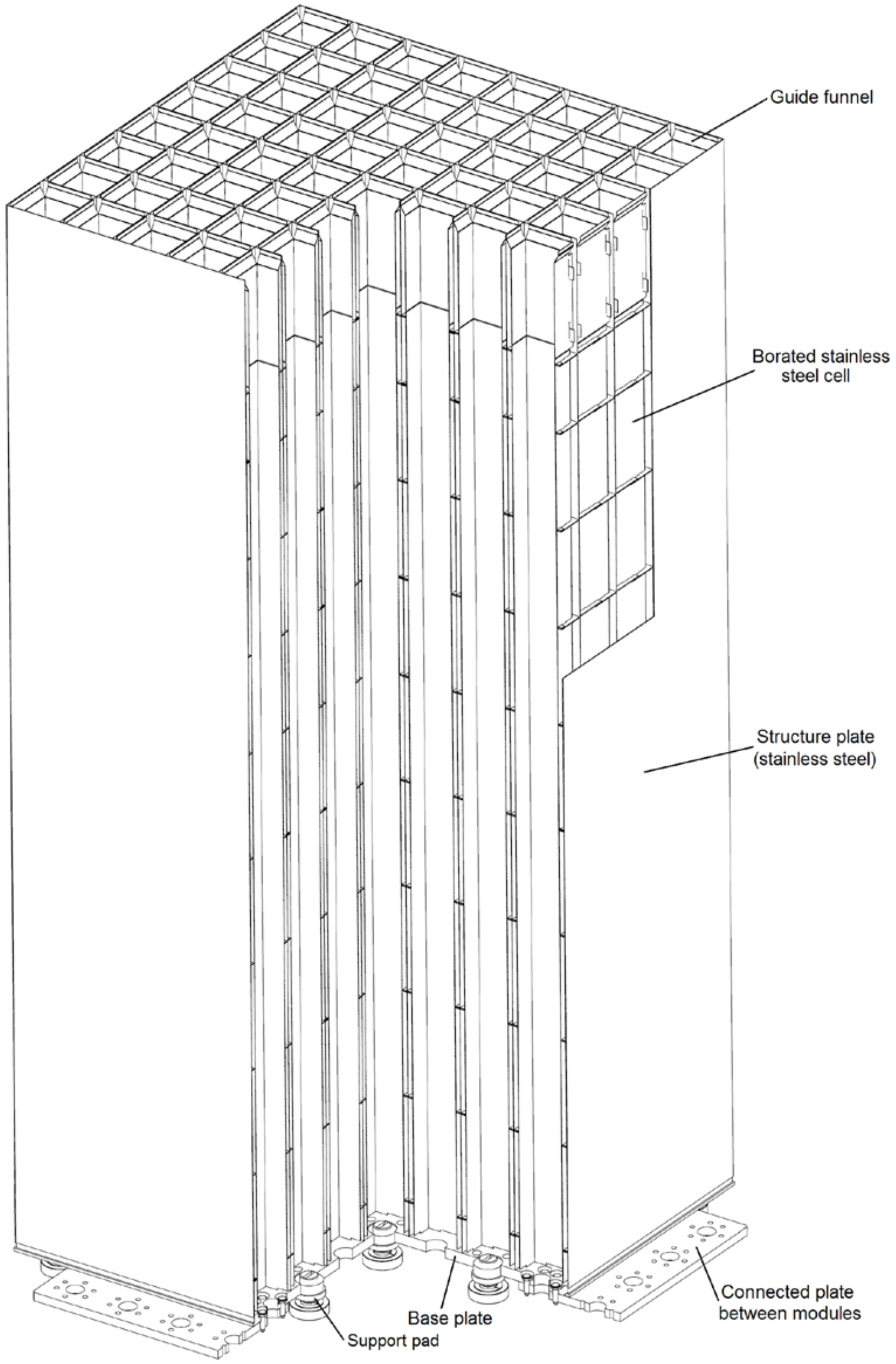


Cells blocked out

Cells for storage of defective fuel assembly

SECTION 9.1.2 - FIGURE 2 [REF-2]

Underwater fuel storage rack – Cutaway view of typical module



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3. SPENT FUEL COOLING AND PURIFICATION SYSTEM (PTR [FPPS/FPCS]) – EXCLUDING IRWST [REF-1] TO [REF-6]

Several design changes will be implemented for the PTR [FPPS/FPCS] as follows. In order to prevent pool drainage due to gross failure of the PTR [FPPS] purification lines, removable cover plates will be added to the bottom connections of the PTR [FPPS] lines in the reactor building and fuel building transfer compartments and the Cask Loading Pit, and removable standpipes will be added above the bottom connections of the PTR [FPPS] lines inside the reactor building and core internal storage compartment. In addition, to prevent pool drainage due to failure of the personnel access doors on the fuel path, these access doors (in the reactor building vessel and transfer compartments, and in the fuel building transfer compartment for conveyer maintenance) will be removed.

These design changes are not included in the description of the PTR [FPPS/FPCS] provided in this section. The incorporation of these design changes into the fuel pool safety case is described in Sub-chapter 16.4, and the design changes will be fully incorporated into this sub-chapter as part of the detailed design during the site licensing phase.

3.0. SAFETY REQUIREMENTS

3.0.1. Safety Functions

The contribution of the PTR [FPPS/FPCS] (treatment and cooling of pool water) to the three basic safety functions is described below:

3.0.1.1. Control of reactivity

The PTR [FPPS/FPCS] shall maintain sub-criticality in the spent fuel pool in normal and accident storage configurations.

3.0.1.2. Decay heat removal

The PTR [FPPS/FPCS] cooling system shall remove the decay heat from the spent fuel assemblies stored in the spent fuel pool.

3.0.1.3. Radioactive substance containment

The PTR [FPPS/FPCS] shall contribute to the containment of radioactive substances by ensuring capability for isolation of the fuel building.

Furthermore, in the event of accidental draining of the fuel building pool, the PTR [FPPS/FPCS] shall assist in avoiding even partial uncovering of fuel in the storage rack and also of a fuel assembly during handling.

3.0.2. Functional criteria

The water in the pools above the spent fuel assemblies shall be deep enough to ensure radiological protection of staff.

3.0.2.1. Control of reactivity

The requirements relating to the geometry of the fuel storage arrangement are given in section 2. In particular, the space between fuel assembly storage cells shall be sufficient to avoid any risk of criticality, except in accidental storage configurations.

The characteristics of the water in the spent fuel pool shall ensure that sub-criticality is maintained in all accidental storage configurations (with an assembly lying on top of the rack or between the rack and the pool wall).

3.0.2.2. Decay heat removal

The PTR [FPPS/FPCS] cooling system heat exchange capacity shall be sufficient to remove the decay heat from fuel assemblies and prevent boiling, with suitable margins.

Nevertheless, the PTR [FPPS/FPCS] shall be able to restart when the fuel building pool is at 100°C.

3.0.2.3. Containment radioactive substances

The closure and leaktightness of the transfer tube and the PTR [FPPS/FPCS] containment isolation valves shall ensure the integrity of the containment.

With respect to uncovering of the fuel:

- A leak or a break in any circuit connected to the pools (spent fuel pool or adjacent compartments or reactor building pool) shall not lead to direct uncovering of the fuel stored in the rack, even without any isolation action.
- In the event of draining through a pipe connected to a pool (in the fuel building or reactor building), it shall be possible either to isolate the drainage pipe before direct uncovering of an assembly in the process of being handled, or to place the assembly in a safe position before it is uncovered.
- In the event of drainage leading to loss of cooling of the pool, an emergency make-up system will help to avoid delayed uncovering of the fuel in the rack and to re-establish a sufficient level in the pool to allow restarting of at least one main cooling train.

N.B.: direct uncovering corresponds to stabilisation of the pool level, either naturally or by manual or automatic isolation actions, at a level below the top of the fuel. Delayed uncovering corresponds to a lowering of the level in the pool by evaporation or boiling, to a height below the top of the fuel, following loss of pool cooling.

3.0.3. Design-related requirements

3.0.3.1. Requirements arising from safety classifications

Safety classification

The PTR [FPPS/FPCS] is safety-classified in accordance with the classification in Sub-chapter 3.2.

Single failure criterion (active and passive)

The active single failure criterion shall be applied to the main cooling system, to the isolation of drainage lines of compartments, to the valves for the drainage of the instrumentation lance compartment and the opening of the reactor cavity overflow line, and to the containment isolation.

The Technical Guidelines permit the cooling system to be exempted from the requirements of the passive single failure criterion for the following reasons:

- Low pressure and temperature
- Application of strict inspection requirements to the passive components of the cooling system and RRI [CCWS] headers at the construction stages and when in-service.

Emergency power supply

The PTR [FPPS/FPCS] cooling system is supplied by independent power trains which shall be backed up by the main diesels.

The automatic isolation function of the drainage lines of the reactor building and fuel building compartments shall also be backed up by the main diesels.

The PTR [FPPS/FPCS] third cooling train shall be backed up by an ultimate diesel generator in plant states D, E and F.

Qualification for operating conditions

The equipment of the PTR [FPPS/FPCS] cooling system and the fuel building pool (pumps, heat exchangers, pipes, valves, instrumentation, etc.) shall be qualified to withstand water temperatures of 100°C and corresponding environmental temperatures, in accordance with the requirements of Sub-chapter 3.6.

Mechanical, electrical and instrumentation and control classifications

Certain mechanical, electrical and instrumentation and control components of the PTR [FPPS/FPCS] shall be classified in accordance with the classification requirements in Sub-chapter 3.2.

Seismic classification

Certain components of the PTR [FPPS/FPCS] shall be seismically classified in accordance with the classification requirements in Sub-chapter 3.2.

Periodic tests

Periodic tests are performed on safety-classified functions of the PTR [FPPS/FPCS] in order to ensure their availability with a sufficient degree of reliability.

3.0.3.2. Other regulatory requirements

- Regulations: No official text specifically applies to the PTR [FPPS/FPCS]
- Specific EPR texts: not applicable

3.0.3.3. Hazards

The PTR [FPPS/FPCS] is protected from external and internal hazards in accordance with criteria and rules for protection against the hazards presented in Chapter 13.

3.1. ROLE OF THE SYSTEM

The PTR [FPCS] cools the spent fuel pool.

The PTR [FPPS] performs the following functions:

- Purification of the water in the reactor building and fuel building pools and the IRWST (in particular, control of radioactivity using its demineralisers and filters)
- Filling and draining of the fuel building transfer compartment, the cask loading pit, the reactor building pool and the IRWST.
- Water make-up for the fuel building pool, the lance instrumentation compartment and the IRWST

The PTR [FPPS/FPCS] may also be used for taking water samples from the IRWST and the fuel building or reactor building pools for controlling the boron content or checking radioactivity levels.

3.2. DESIGN BASIS

3.2.1. General assumptions

3.2.1.1. Spent fuel pool cooling system

This system cools the spent fuel pool.

The system design is based on the following general assumptions:

- the reactor thermal power used for design is 4500 MWth
- the entire core is assumed to be unloaded at each unloading. Unloading starts 71 hours and ends 111 hours after the control rods are inserted
- all cells of the spent fuel pool are assumed occupied (see section 2 of this sub-chapter)
- bounding values are assumed for all planned fuel management with UO2 enriched at 5% and MOX, as well as planned outages (reloading only in 11 days and reloading and partial inspection in 16 days).
- heat loads inside the fuel pool are derived from ORIGEN-S calculations. For PCC-2 to PCC-4 and RRC-A events, {CCI Removed} [b] are assumed. A bounding approach, in comparison with requirements resulting from RRC-A studies, is taken into account in the design of the PTR [FPPS/FPCS] third train. For a PCC-1 event, no uncertainty is taken into account.

The heat exchangers of the main trains shall be sized assuming an RRI [CCWS] “standardised” temperature and the third-line heat exchanger with a “cold coastal standardised” temperature. In the event of loss of the pumping station caused by loss of offsite power (LOOP) or loss of ultimate heat sink (LUHS), the diverse heat sink consists of pumping water from the discharge station whose temperature in state E (refuelling outage) or state F (full core discharge) is 8°C higher than that of the sea [Ref-1].

The design criteria for the cooling system are as follows [Ref-2]:

Event	Period of cycle	Trains operating	SRU [ultimate heat sink] or RRI [CCWS] temperature	Decay heat	Final temperature to be maintained in the pool
PCC-1	Start of cycle	1 main train	$T_{RRI\ [CCWS]}$ = 38°C	5.05 MW	$T_{pool.}$ < 50°C
	State E and F	2 main trains	$T_{RRI\ [CCWS]}$ = 38°C	18.23 MW	
PCC 2-4	State E and F	1 main train	$T_{RRI\ [CCWS]}$ = 38°C	20.23 MW	$T_{pool.}$ < 80°C
	Start of cycle	3rd line alone	$T_{SRU\ [ultimate\ heat\ sink]}$ = 26°C	5.67 MW	
RRC-A	State E and F	3rd line alone	$T_{SRU\ [ultimate\ heat\ sink]}$ = 34°C	20.23 MW	$T_{pool.}$ < 95°C

The PTR [FPPS/FPCS] cooling system shall be capable of being restarted and operated when the fuel building pool is at 100°C.

A leak or breach in a main cooling train shall not compromise the operational characteristics of the third train. Moreover, in the event of drainage leading to loss of cooling in the pool, an emergency back-up system shall be in place to allow the main cooling train to be restarted before boiling occurs in the pool.

A leak or breach in the cooling system shall not lead to direct uncovering of an assembly in the process of being handled, even in the absence of any isolation action (terminating drainage with a syphon breaker is not considered to be an isolation action).

3.2.1.2. Purification system

This system purifies the water in the fuel building and reactor building and IRWST pools in accordance with the following requirements:

- The maximum operating temperature of the system takes into account the maximum design temperature of the filters and ion-exchange resins
- The purification flow is required to renew the water volume in the spent fuel pool or the total water volume in the reactor building pool in about 24 hours
- The fineness of filtration shall be sufficient to ensure clarity of the pool water so that fuel handling operations can be monitored under water.

A leak or breach in the purification system connected to the spent fuel pool shall not lead to the direct uncovering of an assembly in the process of being handled, even in the absence of any isolation action (terminating drainage with a syphon breaker is not considered to be an isolation action).

3.2.1.3. Surface skimming system

This system enables surface skimming of the pools in accordance with the following requirements:

- The system maximum operating temperature shall be assumed in the design of the filters and ion-exchange resins
- The flow rate and fineness of filtering is required to improve the clarity of the water in the spent fuel pool and the reactor building pool
- The skimming system is required for the monitoring of water level variations in the spent fuel pool and the reactor cavity.

3.2.1.4. Water transfers

The PTR [FPPS/FPCS] is designed for the following water transfers:

- Transfer of water from the fuel building pool
- Transfer of water from the reactor building pool
- Transfer of water from the IRWST

3.2.2. Availability

The PTR [FPPS/FPCS] cooling system shall be available whenever spent fuel assemblies are present in the spent fuel pool.

3.2.3. Choice of materials

Given the chemical characteristics of the pool water (boron content), all PTR [FPPS/FPCS] equipment is constructed from stainless steel.

3.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

3.3.1. General description [Ref-1]

3.3.1.1. Fuel building pool installation

The pool in the fuel building is divided into three compartments which can be isolated by doors and a sluice gate, as follows:

- the spent fuel pool where the spent fuel assemblies are stored during the decay period, together with certain new fuel elements before they are loaded into the core

- the fuel building transfer compartment, in which the transfer tube outlet is located. The transfer tube is used for transit of fuel assemblies between the reactor building pool and the spent fuel pool and vice versa. The transfer tube is closed in normal operation, by an isolation valve on the fuel building side and a plug on the reactor building side.

- the cask loading pit where the fuel assemblies are loaded and unloaded

3.3.1.1.1. Spent fuel pool cooling system

The PTR [FPPS/FPCS] cooling system comprises the following:

- ***Two identical main trains***, each equipped with two pumps and a heat exchanger cooled by the reactor component cooling system (RRI [CCWS]). Each train is assigned to one of the two RRI [CCWS] headers, each supplied by one of the two RRI [CCWS] trains (e.g. PTR main train 1 [FPPS/FPCS] – RRI [CCWS] shared header 1– RRI [CCWS] train 1 or 2)

  Each train is supplied by a different electrical train and may be supplied by a neighbouring train during electrical switchboard maintenance operations: PTR [FPPS/FPCS] main train 1 (resp. 2) supplied by division 1 (resp. 4) and may be inter-connected to division 2 (resp. 3) during maintenance.

- ***A third train*** equipped with a pump and a heat exchanger cooled by a component cooling train shared with the EVU [CHRS] system and fully independent of the RRI [CCWS] (see Sub-chapter 6.2), which is connected to the SRU [UCWS] cooling train, independent of the SEC [ESWS] (see Sub-chapter 9.2).

  This train is supplied by electrical division 1 and may be supplied by electrical division 2 during electrical switchboard maintenance operations.

The suction and discharge pipes of the PTR [FPPS/FPCS] cooling system are described in Section 9.1.3 - Figure 1. The inverts of the piping penetrations are located {CCI Removed} [a] for the suction of the third train and {CCI} [a] for the suction of the main trains. The lower ends of the discharge penetrations in the pool are located {CCI Removed} [a] so that cooling by a main train can be ensured after makeup {CCI} [a] without requiring isolation of cooling discharge pipes.

Two isolation units are installed as standard on each suction pipe to isolate a downstream breach.

The suction and discharge pipes are installed so as to ensure circulation of water in and around the fuel assemblies.

Syphon-breakers {CCI} [a] are installed on the pipes descending into the spent fuel pool (excluding the suction of the third train) in order to prevent drainage even in the event of a clean break of a pipe. Drainage is stopped {CCI} [a] in the event of a break in the cooling suction pipes and {CCI} [a] following a break in the cooling discharge pipes

The following measures are taken to ensure the effectiveness of the syphon-breakers so that their failure need not be considered: absence of isolation valves; a design margin in the diameter of the syphon-breaker; the syphon-breaker line discharges above the normal level of suction pipes (to prevent plugging by a foreign body in the pool due to negative back-pressure); periodic checking for blockages; protection against objects falling from openings above the normal level. In addition, in normal operation, the syphon-breaker lines in the form of a J-tube are either fully covered by water or completely out of the water, preventing crystallisation of boron.

Check valves are installed in the discharge pipes.

The boron concentration and activity of the spent fuel pool are checked by taking samples from the cooling system.

The RRI [CCWS] flow rate through the heat exchangers of the main PTR [FPPS/FPCS] trains is regulated by valves.

3.3.1.1.2. Spent fuel pool purification system

This system which is connected to the purification system of the reactor building pool and the IRWST, is independent of the cooling system.

It comprises the following:

- suction pipes located at the bottom of each compartment of the fuel building) (except the spent fuel pool)
- a suction pipe descending into the spent fuel pool
- discharge pipes located in each compartment of the fuel building
- a pump in parallel to the purification pump of the reactor building pool (isolated by manual valves), which is supplied by train 4 and may be interconnected to train 3 during maintenance of electrical switchboards
- a purification train comprising three cartridge filters and a demineraliser
- a regulating valve
- two baskets at the bottom of the fuel building transfer compartments and the cask loading pit which may be removed after draining of the compartments

The boron content and the activity of the spent fuel pool are checked by taking samples from the purification system.

The first two isolation valves in the fuel building compartment drain lines are motorised and controlled remotely, with automatic closure on low level in the spent fuel pool {CCI Removed} [a]. This motor-driven system shall ensure automatic double isolation during fast pool draining events.

The purification pipes are located in the spent fuel pool. The lower ends of the penetrations in the pool and in the fuel building compartments are located {CCI} [a] so that cooling by a main train can be maintained without requiring makeup or isolation of the break in the event of syphoning from the purification system.

Syphon-breakers {CCI} [a] are installed in the suction pipe (of the spent fuel pool) and on the discharge pipes of the purification system, in order to prevent pool draining even in the event of a clean break in a pipe. Drainage is stopped {CCI} [a] in the event of a break in the purification pipes.

The following measures are taken to ensure the effectiveness of the syphon-breakers so that their failure need not be considered: absence of isolation valves; a design margin in the diameter of the syphon-breaker; the syphon-breaker line discharges above the normal level of suction pipes (to prevent plugging by a foreign body in the pool due to negative back-pressure); periodic checking for blockages; protection against objects falling from openings above the normal level. In addition, in normal operation, the syphon-breaker lines in the form of a J-tube are either fully covered by water or completely out of the water, preventing crystallisation of boron.

Check valves are installed in the purification discharge pipes.

The purification pump of the reactor building pool may be used to back-up the purification pump of the fuel building pool.

3.3.1.1.3. Transfer of water from the fuel building pool

The purification system of the spent fuel pool may also be used to transfer water between the compartments of the fuel building pool; only the purification train is bypassed.

The water needed to fill the cask loading pit is stored in the pit itself or in the fuel building transfer compartment.

The REA [RBWMS] system directly supplies the spent fuel pool with borated water for its first fill or for refilling following leaks.

3.3.1.1.4. Spent fuel pool surface skimming system

This system is fully independent of the other systems. It consists of the following:

- a suction line with a floating suction mechanism to follow the variation in water level in the spent fuel pool
- a pump supplied by train 4 and inter-connectable to train 3 during maintenance of electrical switchboards
- a filter
- a control valve
- several outlets located at the edge of the spent fuel pool below the normal water level so as to create a surface current towards the suction line.

3.3.1.2. Reactor building pool installation

The reactor building pool is divided into four compartments as follows, isolated by sluice gates:

- the reactor cavity containing the reactor vessel

- the reactor building transfer compartment, in which the transfer tube outlet is located. The transfer tube is used for the transit of fuel assemblies between the reactor building pool and the spent fuel pool and vice versa. During normal operation, the transfer tube is closed by an isolation valve on the fuel building side and a plug on the reactor building side

- the set-down compartment for core internals, where the upper and lower internals of the vessel are stored (under water and in a single compartment) when they are removed during outages

- the instrumentation lance compartment, where twelve instrumentation lances and four vessel-level measuring probes, are stored under water for reloading after removal from the reactor vessel at shutdowns.

3.3.1.2.1. Purification system for the reactor building pool and the IRWST

This system comprises the following:

- suction pipes located at the bottom of each compartment of the reactor building pool

- suction from the IRWST via the EVU [CHRS] suction pipe in the IRWST

- a pump in parallel with the spent fuel pool purification pump (isolated by manual valves) which is supplied by electrical train 1 and may be interconnected to train 2 during maintenance of electrical switchboards

- a control valve

- discharge pipes in each compartment of the reactor building pool

- a discharge pipe to the IRWST

- a basket on the instrumentation lance compartment

- baskets during refuelling outage and grids in operation in the other compartments of the reactor building

The water in the reactor building pool and the IRWST may also be purified by a spent fuel pool purification train or an RCV [CVCS] treatment train (i.e. the filters and demineralisers of the RCV [CVCS]).

The first two isolation valves on the drainage lines from the reactor building compartments are motorised and controlled remotely, closing automatically on detection of low water level in the spent fuel pool {CCI Removed} [a]. This system shall ensure automatic double isolation during fast pool draining events (except for the instrumentation lance compartment which is isolated during fuel handling phases).

The lower ends of the penetrations in the reactor building compartments are located {CCI} [a] so that cooling by a main train can be maintained without requiring makeup isolation of the break in the event of syphoning from the purification system.

Syphon-breakers {CCI} [a] are installed on the purification discharge pipes able to prevent pool draining even in the event of clean break of a pipes. Drainage is stopped {CCI} [a] in the event of a break in the purification pipes.

Measures are taken as follows to ensure the effectiveness of syphon-breakers so that their failure need not be considered: absence of isolation valves; a design margin in the diameter of the syphon-breaker. In addition, in normal operation, the syphon-breaker lines in the form of a J-tube are either fully covered by water or completely out of the water to avoid crystallisation of boron.

Check valves are installed on the purification discharge lines (except for the instrumentation lance compartment).

The purification pump of the spent fuel pool may be used to back-up the reactor building pool purification pump.

3.3.1.2.2. Transfer of water from reactor building pools and the IRWST

The purification system of the reactor building pools and the IRWST can also be used to transfer water between the IRWST and the various compartments of the reactor building pool.

The water needed to fill the reactor building pool during shutdown for reloading is stored in the IRWST.

The reactor building pool may be drained into the IRWST using the reactor building pool purification pump and the purification train of the PTR [FPPS/FPCS]. For faster draining, the RCV [CVCS] treatment train, if available, and the fuel building pool purification pump may be used in parallel.

Motor-driven control valves are installed downstream of the purification pumps and are regulated to adjust the flow rate according to the configuration in use (one or two pumps in operation) and to offset clogging of filters.

The instrumentation lance compartment remains water-filled in all shutdown states. The first filling or subsequent fillings are carried out using water from the IRWST.

The REA [RBWMS] supplies the IRWST with borated water for the first filling or for refilling following leakage.

3.3.1.2.3. Surface skimming system of the reactor building pool

This system is connected to the reactor building pool purification system and uses its purification train and its discharge pipes. It comprises the following:

- a suction pipe in the reactor cavity, equipped with a floating suction mechanism able to follow water level variations in the reactor building pool
- a self-priming pump located in the reactor building, supplied by electrical train 1 and interconnectable to train 2 during maintenance of electrical switchboards. This pump discharges into the suction line of the reactor building pool purification pump

3.3.1.2.4. Drainage line of the instrumentation lance compartment

In an accident situation, the drainage line of the lance compartment enables a water inventory to be rapidly reconstituted in the IRWST when the reactor building pools are full. Two redundant drainage valves, supplied in division 1 and 4, are installed on the line.

3.3.1.2.5. Reactor cavity overflow line

The reactor cavity overflow line is installed in the reactor cavity. The invert level of the penetration in the reactor cavity is located at +18.10m. In an accident situation, opening this line can be used to pump out a flow to the IRWST. Two redundant overflow valves are installed on the line, supplied in division 1 and 4.

3.3.2. Characteristics of equipment

Volumes of pools

{CCI Removed}

a

3.4. OPERATING CONDITIONS

3.4.1. Normal condition

The normal condition for the PTR [FPPS/FPCS] corresponds to normal operation.

Fuel building pool systems

The spent fuel pool is permanently filled with water when spent fuel assemblies are stored in the pool.

The fuel building transfer compartment is full of water.

The cask loading pool is empty. The water needed to fill this is stored in the fuel building transfer compartment.

Reactor building pool systems

The instrumentation lance compartment of the reactor building pool is permanently filled with water.

All the other compartments are empty.

The water needed to fill each compartment of the reactor building pool is stored in the IRWST.

The system normal operational mode is as follows:

- the ***cooling system of the spent fuel pool*** operates from the first unloading of the reactor for as long as spent fuel assemblies are stored in the spent fuel pool. A single PTR [FPPS/FPCS] main cooling train with a single pump operates continuously. The second PTR [FPPS/FPCS] main cooling train and pump serve as a back-up.

- the ***third PTR [FPPS/FPCS] train*** is set to start in the event of a scheduled non-availability of a main cooling train for maintenance on the PTR [FPPS/FPCS] or one of its support systems. This protects against the third pump failing to start on demand. When this train is not in service, it is permanently isolated from the spent fuel pool by closure of each motor-driven isolation valve installed at the suction and discharge

- the ***spent fuel pool purification system*** operates continuously if necessary. This system may be interrupted if the quality of water in the spent fuel pool no longer needs purifying or if its purification train is required for treatment of the IRWST or the instrumentation lance compartment. The purification pump of the reactor building pool may be used to back-up the purification pump of the spent fuel pool. The purification function is disabled before replacement of the resins in the mixed-bed demineraliser or filter cartridges

- the ***spent fuel pool surface skimming system*** is started manually in case of presence of impurities on the surface of the spent fuel pool. The water shall be clear to ensure sufficient visibility and to reduce exposure to radiation due to activation of impurities

- the ***reactor building pool systems*** does not operate when the system is in normal operation. Only some parts of the systems of the reactor building pool may be used, when they back-up functions performed by the spent fuel pool systems. The instrumentation lance compartment or the IRWST may also be purified during operation using the purification train of the spent fuel pool.

3.4.2. Permanent conditions

3.4.2.1. Unit Shutdown

This condition corresponds to the full pool cold shutdown states encountered during the various scheduled shutdowns for reloading or unplanned shutdowns requiring unloading of fuel.

Fuel building pool systems

The spent fuel pool is permanently filled with water.

The fuel building transfer compartment is full of water.

Reactor building pool system

The reactor building pool is filled with water (from the IRWST) during fuel handling periods. When the core is unloaded, the reactor cavity may be emptied; the set-down compartment for core internals shall remain filled with water.

The instrumentation lance compartment is permanently filled with water.

During unit shutdown:

- the two ***PTR [FPPS/FPCS] main cooling trains*** (with one pump per train) operate continuously from the start of unloading to the end of reloading. In some cases, the two trains may operate together temporarily after reloading to maintain the temperature of the fuel building pool at less than 50°C

- the ***third PTR [FPPS/FPCS] cooling train*** does not operate but is available. It is isolated from the spent fuel pool by closure of the motor-driven isolation valves in its suction and discharge lines

- operation of the spent fuel pool ***purification and skimming systems*** is identical to that described in section 3.4.1 above.

- the ***reactor building pool purification system*** operates continuously as long as the compartments of the reactor building pool are filled with water using the treatment train of the RCV [CVCS]

- the ***reactor building pool surface skimming system*** operates when the presence of impurities on the surface of the reactor building pool requires it. The water shall be clear in order to monitor fuel handling and reduce exposure to radiation due to activation of impurities

- the ***IRWST purification system*** operates when the water contained in the reactor building pool has been drained to the IRWST and if the quality of the water requires it

- the ***reactor building pool water transfer system*** is used to transfer water from the IRWST to one of the reactor building pool compartments and vice versa

3.4.2.2. Fuel handling in the Fuel building during normal operation

This condition corresponds to the handling of fuel elements between the spent fuel pool and the cask loading pit. The handling is performed during normal operation.

Before loading and unloading operations from a pool, the fuel building transfer compartment is drained into the cask loading pool in order that the fuel can be handled under water. Since this water transfer is performed by the spent fuel pool purification pump, purification function is disabled during these operations.

3.4.2.3. Draining and filling of the fuel building transfer compartment

This condition corresponds to draining of the fuel building transfer compartment for maintenance. It takes place either during operation or during refuelling outage.

If repairs to the fuel building transfer compartment are needed, it is emptied into the cask loading pool (see section 3.4.2.2).

3.4.2.4. Filling of the spent fuel pool

This condition applies to filling of the spent fuel pool with borated water.

The REA [RBWMS] supplies the spent fuel pool with borated water for its first fill or for refilling following leaks.

3.4.2.5. Water make-up in pools

This condition applies to the supply of make-up water to the spent fuel pool and the instrumentation lance compartment.

The demineralised water system (SED) supplies the fuel building spent fuel pool and the reactor building instrumentation lance compartment with water to make-up for evaporation. The make-up valve in the instrumentation lance compartment is motorised, which enables make-up to be carried out without entering the reactor building.

3.4.3. Transient states

3.4.3.1. Normal start-up

The connection between the discharge line of the reactor building skimming pump and the purification return line enables venting of the line and skimming pump to the reactor building pool, before alignment to the purification pump. The skimming pump by-pass line enables this pump to be bypassed and stopped when priming is performed.

The motor-driven valves located downstream of the third train cooling pump is closed before the pump is started and is automatically opened when the pump starts up.

For the main trains, the correct alignment has to be checked before starting one of the two pumps.

3.4.3.2. Partial or total loss of the spent fuel pool cooling system

Main contributors of direct or indirect loss of the spent fuel pool cooling system are addressed in chapters related to safety analyses of the PTR [FPPS/FPCS] (see Chapters 14 and 16).

Note: In the case of a hypothetical total loss of the PTR [FPPS/FPCS] cooling system, the loss of water by boiling or evaporation in the spent fuel pool may be mitigated by the following make-up systems, used as defence in depth:

- IRWST via the fuel building pool purification system
- REA [RBWMS]
- SED (demineralised water)
- Fire protection systems (JPI system with a Fire Fighting Water Supply System (JAC) pump or an Emergency Feed Water System (ASG [EFWS]) pump)

3.4.3.3. Accidental draining of the spent fuel pool

The rules relating to pipe breaks are defined in Sub-chapter 3.4. In order to account for potential failures due to human error (alignment errors, inappropriate maintenance actions), breaks equivalent to the full pipe area are considered for reasons of simplicity and conservatism.

Faults causing drainage are studied in the sub-chapters dealing with safety analyses of the PTR [FPPS/FPCS] (see Chapter 14).

The following initiating events are not taken into account:

- break of the transfer tube
- failure of a steam generator nozzle dam: the use of nozzle dams during unloading or reloading of the core is not authorised on the EPR at this stage of the design (see Sub-chapter 18.2).

3.5. PRELIMINARY SAFETY ASSESSMENT

Compliance with requirements specific to the containment isolation valves of the PTR [FPPS/FPCS] purification system is described in Sub-chapter 6.2.

Compliance with requirements specific to isolation of the transfer tube is described in section 4 of this sub-chapter.

3.5.1. Compliance with functional criteria

The cooling system has sufficient capacity to permanently remove decay heat from the fuel assemblies [Ref-1]. The residual power in the fuel pool is higher with a single zone design for the fuel storage rack, as a result of an increase in the number of fuel storage cells. The re-evaluation of decay heat power values [Ref-2] confirms that there is no impact on the sizing of the fuel pool cooling system during normal operation.

A break in any system connected to the pools will not lead to direct uncovering of the fuel stored in the racks given that no pipe connection are located in the spent fuel pool below the top of the racks and the elevation of the bottom of the sluice gate is above the top of the racks. Furthermore, the use of syphon breakers on the pipes located in the pools, and the provision of automatic isolation of compartments on detection of low level in the spent fuel pool, prevents draining following a break in the purification or cooling system before direct uncovering of an assembly in the process of being handled.

In the event of drainage leading to loss of cooling in the pool, an emergency make-up system prevents delayed uncovering of the fuel stored in the rack and allows start-up of at least one main cooling train after restoration to a minimum level of 18 m (to avoid air being drawn into pipes) [Ref-3][1].

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[1] This analysis is a Flamanville 3 (FA3) study that takes into account some specific features of the FA3 design but the results are bounding for the UK design. In particular, the analysis considers that the third PTR [FPCS] train is lower than for the UK design. Therefore, the calculations are conservative

3.5.2. Compliance with design requirements

3.5.2.1. Safety classifications

The compliance of design and manufacture of materials and equipment with requirements derived from classification rules is detailed in Sub-chapter 3.2.

3.5.2.2. Single Failure Criterion and redundancy

The main PTR [FPPS/FPCS] cooling system meets the single failure criterion. In the event of failure of a pump, the 2 x 100% capacity of each main train ensures adequate cooling of the spent fuel pool.

The isolation of the compartment drainage lines meets the single failure criterion. In the event of failure to close a valve at the bottom of the compartment, isolation is achieved by closure of valves located on the draining headers of the reactor building and fuel building compartments.

The valves for the drainage of the instrumentation lance compartment and the opening of the reactor cavity overflow line meets the single failure criterion. In the event of failure to open of one valve, the opening is achieved by the other one installed in parallel.

On failure of a PTR [FPPS/FPCS] main train, the independence of the main trains (physical separation, RRI [CCWS] headers and different electrical supply trains) ensures availability of the other main train.

Additionally, the third PTR [FPPS/FPCS] train is started up in preventive mode during maintenance on a main train.

3.5.2.3. Qualification

The equipment is qualified in accordance with the requirements described in Sub-chapter 3.6.

3.5.2.4. Instrumentation and control

The compliance of the design and manufacture of equipment with the requirements of the instrumentation and control classification rules is detailed in Sub-chapter 3.2.

3.5.2.5. Emergency power supplies

The equipment of the three PTR [FPPS/FPCS] cooling trains, the isolation valves of the pool compartment drainage pipes and the valves for the drainage of the instrumentation lance compartment and the opening of the reactor cavity overflow line are supplied by emergency-supplied switchboards in the event of LOOP.

The third train, supplied by an electrical sub-panel separate from those of the main trains, is also emergency supplied in the event of station black-out during states D, E and F (by shutting down the ASG [EFWS]), a few hours after the start of the transient.

3.5.2.6. Hazards

The PTR [FPPS/FPCS] cooling system trains are designed to withstand the following hazards:

Internal hazards	Protection required in principle	General protection	Specific protection introduced in the design of the system
pipes breaks	No loss of more than one train	Physical separation	-
tanks, pumps and valves failures		Physical separation	-
Internal missiles		Physical separation	-
Dropped loads		Physical separation	-
Internal explosion		Physical separation	-
Fire		Physical separation	-
Internal flooding		Physical separation	-

External hazards	Protection required in principle	General protection	Specific protection introduced in the design of the system
Earthquake	yes	Location in fuel building (main trains) and safeguard building	Seismic design
Aircraft crash	yes (main trains)	Location in fuel building	Seismic design
External explosion	yes (main trains)	location in fuel building	-
External flooding	yes	Location in fuel building (main trains) and safeguard building	-
Snow and wind	yes	location in fuel building (main trains) and safeguard building	-
Extreme cold	yes	Location in fuel building (main trains) and safeguard building	-
Lightning	yes	location in fuel building (main trains) and safeguard building	-

The third PTR [FPPS/FPCS] train is protected from aircraft crash and external explosion up to the motor-driven isolation valve installed at its suction (second isolation unit) and discharge.

The purification system is not designed against internal hazards, with the exception of the containment penetrations and the drainage pipes in the different compartments of the fuel building and reactor building pools, up to the second isolation valve.

The purification system is not designed against external hazards, with the exception of the containment penetrations and the drainage pipes in the different compartments of the fuel building and reactor building pools, up to the second isolation valve, which are designed to withstand earthquakes.

3.6. TESTS, INSPECTION AND MAINTENANCE

3.6.1. Periodic tests

The safety functions are subject to periodic tests.

3.6.2. Inspection and maintenance

The general maintenance principles are described in Sub-chapter 18.2.

Surveillance during operation shall be carried out on pipe sections where a pipe break is not considered as a potential initiator of accidental drainage.

3.6.2.1. Maintenance of PTR [FPPS/FPCS] cooling system

Preventive maintenance on the PTR [FPPS/FPCS] cooling trains (main trains and third train) is normally performed at the end of the cycle, when the decay heat level in the spent fuel pool is sufficiently low and the grace period sufficiently long. However, preventive maintenance on PTR [FPPS/FPCS] cooling trains may be considered at a higher decay heat if the temperature of the heat sink is low.

Preventive maintenance work can be scheduled on only one train at a time (a main train or the third train). During maintenance of one of the two main trains, the third train is available and in service as a precautionary measure.

Maintenance work on the RRI [CCWS] headers cooling the main PTR [FPPS/FPCS] cooling trains, on the cooling train dedicated to the EVU [CHRS], on the third PTR [FPPS/FPCS] cooling train (component cooling train and essential cooling train) and on the sub-distribution dedicated to the PTR [FPPS/FPCS] shall be performed at the same time as maintenance work on the corresponding PTR [FPPS/FPCS] cooling train.

3.6.2.2. Maintenance of PTR [FPPS/FPCS] treatment systems

Preventive maintenance on the water purification and transfer systems is possible during normal operation, with the exception of equipment in the reactor building).

Maintenance work on part of the reactor building pool purification system and the reactor building pool skimming pump may be performed after draining of the reactor building pool compartments. Maintenance on the parts of the reactor building pool purification system outside the reactor building may be performed during normal operation.

Maintenance work on the spent fuel pool purification system may be performed if the quality of water in the spent fuel pool is confirmed by sampling. Maintenance work on the spent fuel pool skimming system shall be performed during normal operation, outside of fuel handling periods.

The PTR [FPPS/FPCS] filter cartridges are replaced when a differential pressure criterion or activity criterion are met. The replacement is performed using a filter-changing machine. The cover of the pressurised enclosure has a window to enable visual inspection. The spent mixed-bed filter resins are drained into the spent resin storage system. Hand-holes are provided to enable visual inspection.

Maintenance on filters is performed when the reactor building pool or fuel building pool purification system is not in operation.

3.7. DIAGRAMS

Functional flow diagram of the PTR [FPPS/FPCS]: see Section 9.1.3 - Figures 2 to 4.

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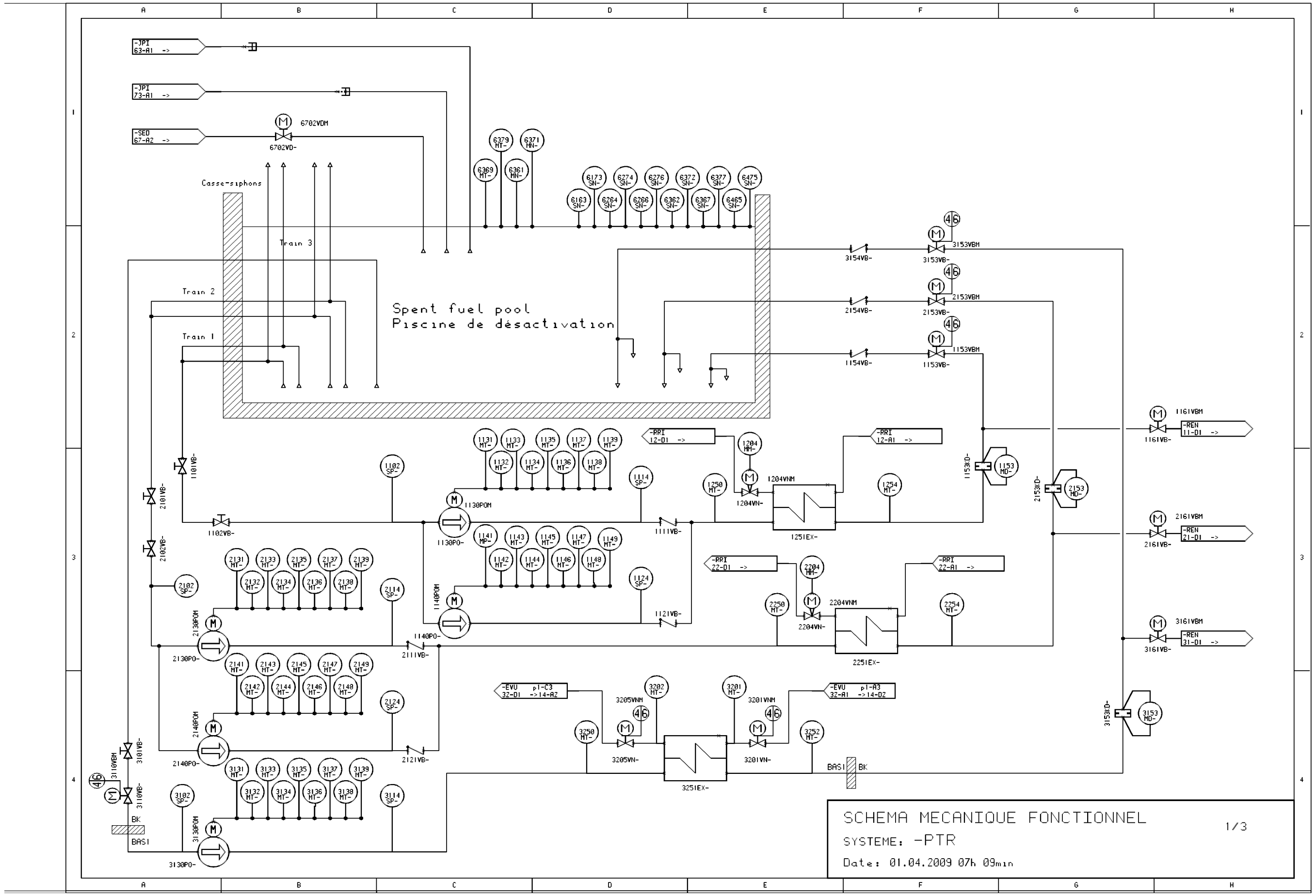
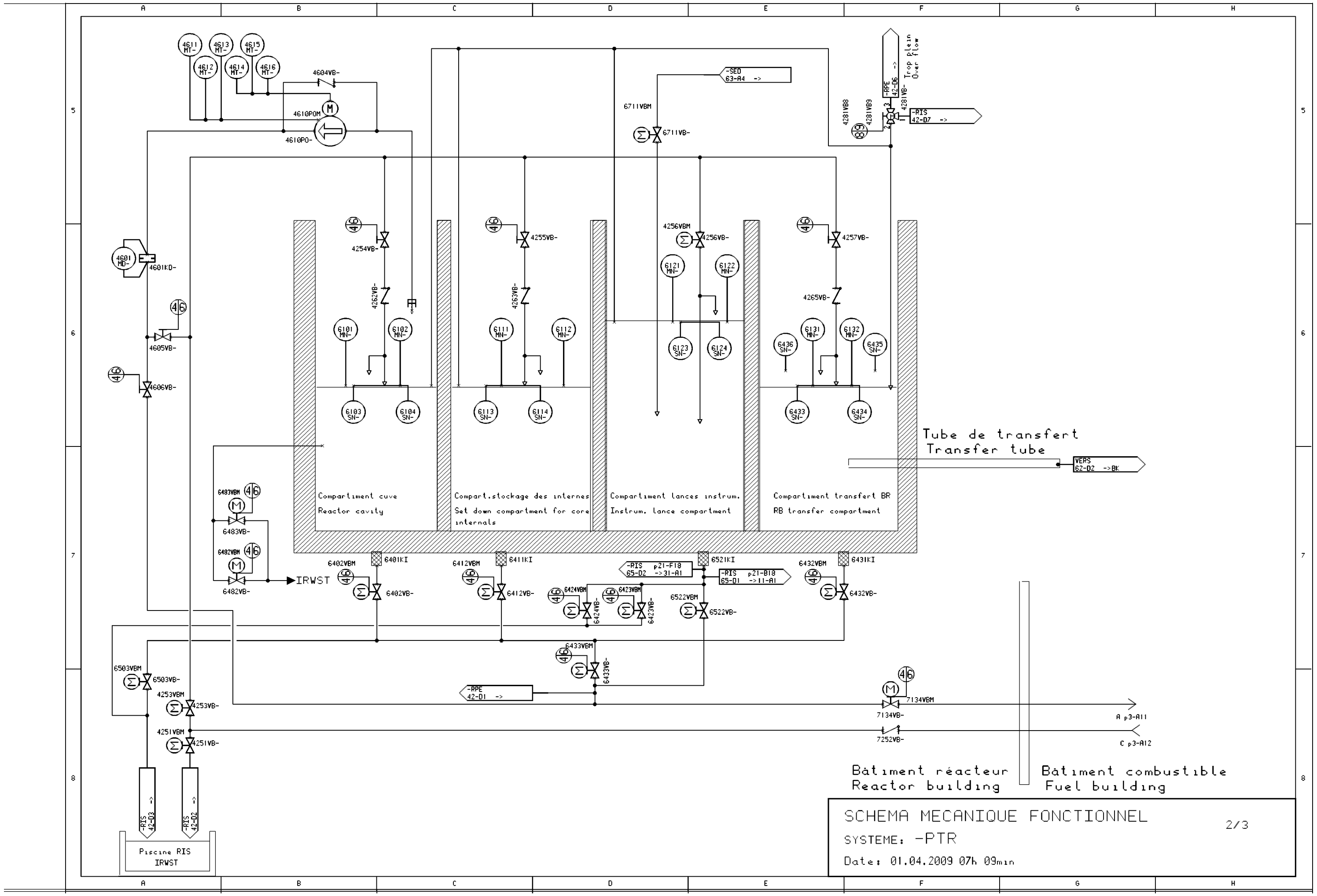
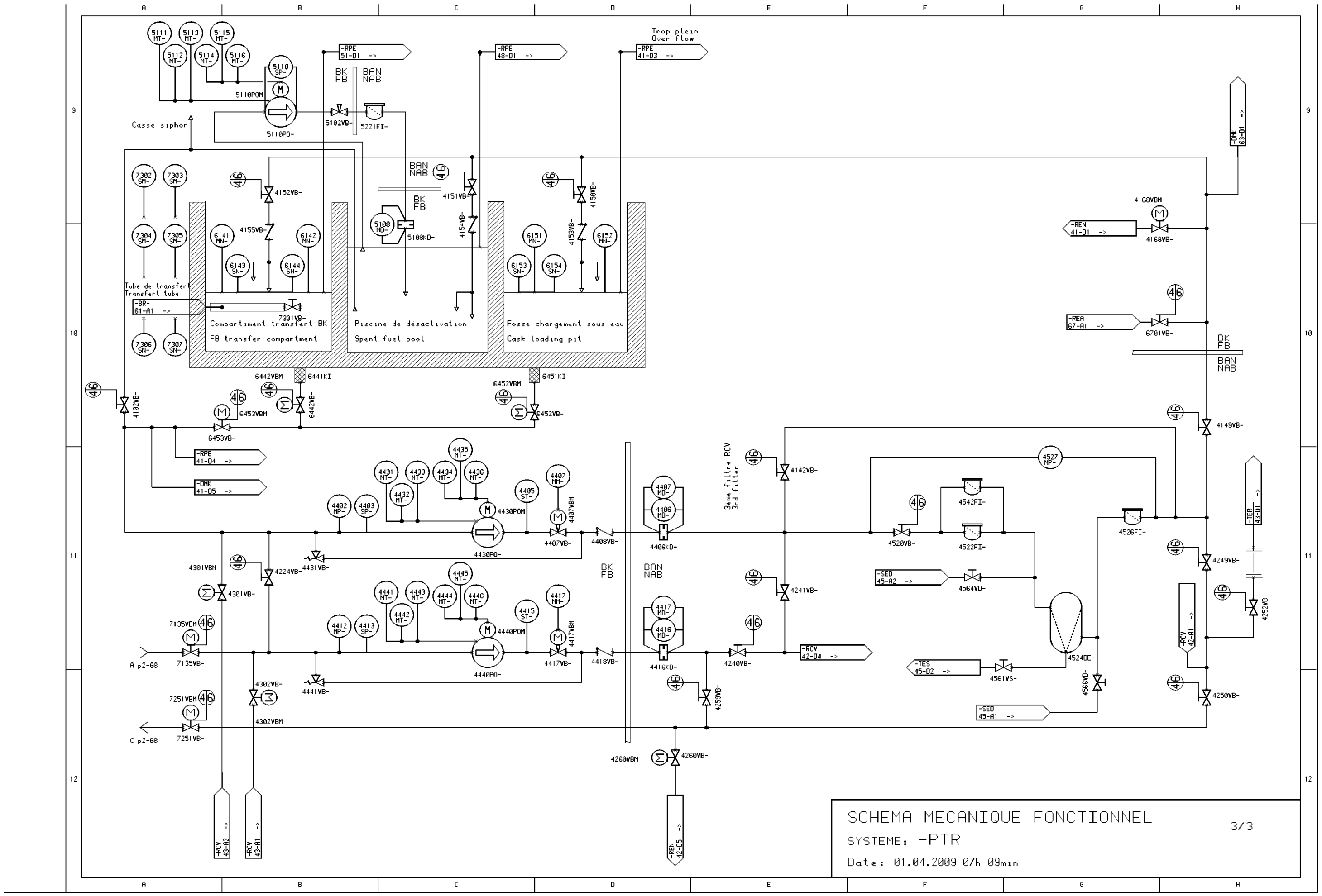
SECTION 9.1.3 - FIGURE 2 : SPENT FUEL COOLING SYSTEM PTR [FPCS] [REF-2]



SECTION 9.1.3 - FIGURE 3 : REACTOR BUILDING PURIFICATION SYSTEM PTR [FPPS] [REF-2]



SECTION 9.1.3 - FIGURE 4 : FUEL BUILDING PURIFICATION SYSTEM PTR [FPPS] [REF-2]



4. FUEL HANDLING SYSTEM

4.0. SAFETY REQUIREMENTS

4.0.1. Safety functions

The fuel handling system, whose main role is to unload and reload the core, does not directly fulfil a safety function. This system must be designed to prevent, during normal operation or accident conditions, any accidental criticality, any unjustified exposure to ionising radiation and any unacceptable discharge of radioactive substances (in particular arising from dropping or collision of fuel assemblies).

4.0.1.1. Reactivity control

The fuel handling system must be designed to maintain the sub-critical state of the fuel assemblies.

4.0.1.2. Decay heat removal

The fuel handling system must be designed to ensure removal of the decay heat from fuel assemblies.

4.0.1.3. Radioactive substance containment

The fuel handling system must be designed to maintain the integrity of the fuel cladding. The fuel transfer facility tube is an integral part of containment isolation.

4.0.2. Functional criteria

4.0.2.1. Reactivity control

During all normal operations performed in the fuel building (handling, inspection, etc.) and during all fault situations including zero boron content in the pool water, all risks of criticality must be excluded.

Although the fuel handling system is designed to prevent assemblies from being dropped, it must be confirmed that sub-criticality will be maintained following an assembly being dropped in the fuel building pool (with or without loss of integrity of the assembly), assuming the minimum boron concentration specified by technical specifications.

The fuel handling system must be designed to limit the risk of incorrect positioning of an assembly in the vessel during core refuelling operations.

4.0.2.2. Decay heat removal

The fuel handling system must be designed to ensure cooling of the irradiated fuel assemblies.

4.0.2.3. Radioactive substance containment

The fuel handling system must be designed to prevent any dropped load or any impact on fuel assemblies in the event of earthquake or loss of electrical power.

Moreover, the handling operations must be performed without fuel assemblies being subjected to unacceptable strain or deformation.

The isolation arrangements for the containment penetration associated with the fuel transfer tube must ensure isolation of the reactor building even in the event of earthquake or vibration following an aircraft crash.

4.0.3. Design-related requirements

4.0.3.1. Requirements resulting from safety classifications

4.0.3.1.1. Safety classifications

The fuel handling system, and in particular the fuel transfer tube, the blind flange and the manual isolation valve must be classified according to the principles given in Sub-chapter 3.2.

4.0.3.1.2. Single failure criterion (active and passive)

Although the single failure criterion does not apply to the fuel handling system, certain of its components are designed with redundancy to prevent a dropped load if one of these components fails.

4.0.3.1.3. Emergency power supplies

Not applicable.

4.0.3.1.4. Qualification for operating conditions

Not applicable, except for isolation features of the fuel transfer tube.

4.0.3.1.5. Mechanical, electrical, instrumentation and control classifications

The classification of safety features must comply with the requirements in Sub-chapter 3.2.

4.0.3.1.6. Seismic classification

The fuel handling system must be seismically classified in accordance with the principles given in Sub-chapter 3.2.

4.0.3.1.7. Periodic tests

The fuel handling system is subject to periodic tests which ensure its ability to fulfil its function and confirm the service ability of safety significant components. Specifically, features that are necessary for containment isolation must be tested for correct functioning following a refuelling shutdown.

4.0.3.2. Other regulatory requirements

4.0.3.2.1. Statutory requirements

No official text specifically applies to the fuel handling system.

4.0.3.2.2. Basic Safety Rules

Not applicable to UK EPR.

4.0.3.2.3. Technical Directives

None of the Technical Guidelines specifically applies to the fuel handling system.

4.0.3.2.4. Specific EPR texts

Not applicable.

4.0.3.3. Hazards

The fuel handling system must be protected against internal and external hazards.

4.0.3.3.1. Internal hazards

The fuel handling system must be protected against internal hazards in accordance with Sub-chapter 13.2.

4.0.3.3.2. External hazards

External hazards other than earthquakes and aircraft crashes have no specific impact on the fuel handling system due to the installation of the system in the fuel building and in the reactor building.

The following elements of the fuel handling system must maintain their integrity, with a handled load, under the effects of the design basis earthquake and vibration caused by an aircraft crash:

- refuelling machine,
- reactor building platform,
- fuel transfer facility,
- spent fuel mast bridge,
- new fuel elevator,
- auxiliary crane,
- new fuel handling tool,
- spent fuel handling manual tool,

- fuel cluster handling tool.

4.1. ROLE OF THE SYSTEM

The fuel handling system, comprising equipment and structures, is used for handling new and irradiated fuel assemblies during normal and unscheduled refuelling operations.

4.2. DESIGN BASES

The bases of the fuel handling system design are as follows [Ref-1] [Ref-2]:

a) The fuel handling system is designed to limit the risk of dropping or damaging the fuel assemblies during transfer from one location to another. The fuel assembly handling equipment is fail safe in the event of loss of power.

b) The fuel handling equipment inside and outside the containment may be stopped on demand.

c) The following elements of the fuel handling system are designed to maintain their integrity, with a handled load, under the effects of the design basis earthquake and vibration caused by an aircraft crash:

- refuelling machine,
- reactor building platform,
- fuel transfer facility,
- spent fuel mast bridge,
- new fuel elevator,
- auxiliary crane,
- new fuel handling tool,
- spent fuel handling manual tool,
- fuel cluster handling tool.

d) All operations relating to fuel handling are designed to ensure protection of staff against radiation and to prevent overheating of the fuel.

e) The calculation of the radiological consequences of a fuel handling accident takes account of the general installation of the equipment (structures, systems and elements) to ensure the safety and protection of the general public.

f) The components that handle the fuel assemblies between the reactor building and the fuel building are designed to limit as far as possible the risk of clogging or blockage. If a blockage occurs, the design must allow the fuel assembly to be extracted manually.

g) The following elements of the fuel handling system are designed either according to the requirements of the KTA 3902 code “Design of lifting equipment in nuclear power plants” or the requirements of the CST 60.C.007.03 “High safety lifting and handling machine” [Ref-3]:

- refuelling machine,
- reactor building platform,
- instrumentation lances platform,
- fuel transfer facility (excluding blind flange, valve, tube and compensators),
- spent fuel mast bridge,
- new fuel elevator,
- auxiliary crane,
- new fuel handling tool,
- spent fuel handling manual tool,
- fuel cluster handling tool.

4.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

4.3.1. Description of the system

The fuel handling system comprises the equipment needed for refuelling the reactor core, i.e.: refuelling machine, fuel transfer facility and spent fuel mast bridge. The areas associated with the fuel handling equipment are the reactor pool, the transfer pool in the reactor building and the fuel building [Ref-1] to [Ref-3].

4.3.1.1. Description of fuel handling operations

Receipt of new fuel assemblies:

The new UO_2 fuel assemblies received to replace the spent fuel are individually extracted from the transport container, examined by visual inspection, introduced into the storage pool by the new fuel elevator and then stored in the underwater fuel storage rack. The new UO_2 fuel assemblies can also be temporarily stored in the dry fuel storage rack.

MOX assemblies are received underwater via the spent fuel cask transfer facility. The new MOX fuel assemblies are individually extracted from the container, examined using a video camera and then stored in the underwater fuel storage rack.

In the reactor building, fuel assembly handling is performed by the refuelling machine.

In the fuel building, dry handling of new UO_2 fuel assemblies is performed by the auxiliary crane equipped with the new fuel handling tool. Underwater handling of new and irradiated fuel is performed using the spent fuel mast bridge. The new UO_2 assemblies are taken down to the bottom of the storage pool using the new fuel elevator.

The fuel handling system is also equipped to allow receipt of new MOX fuel assemblies in an air atmosphere.

Transfer from the reactor building pool to the fuel building pool:

The reactor pool and the transfer pool within the reactor building are only filled with water during shutdown of the reactor for refuelling. However, the fuel storage pool is permanently filled with water and is always accessible to operations staff. The fuel transfer tube links the reactor building and the fuel building. This tube is equipped with a blind flange on the reactor building side and a valve on the fuel building side. The blind flange is in place except during refuelling to ensure containment isolation. The refuelling machine handles the fuel assembly between the reactor vessel and the fuel transfer facility.

The fuel transfer facility is used to handle fuel assemblies through the tube between the reactor building and the fuel building. After a fuel assembly is inserted into the fuel transfer facility container in the vertical position, the container swings to the horizontal position to allow it to pass through the transfer tube using a submerged trolley.

Once the submerged trolley has transported the assembly to the other end of the transfer tube, the swinging chassis at this end of the tube swings the transfer container into the vertical position to allow the assembly to be removed.

Spent fuel assembly removal:

The fuel handling equipment is designed to handle a fuel assembly underwater, from the time it enters the storage pool to the time it is placed in a transport cask for shipment off the site. Underwater handling of irradiated fuel assemblies provides an efficient, economical and transparent means of protection against radiation, as well as a reliable means of cooling to remove decay heat. The concentration of boric acid in the water is sufficient to prevent any risk of criticality.

The pool cooling system removes the decay heat of the irradiated fuel assemblies in the spent fuel pool. After a sufficient decay period, the spent fuel assemblies may be removed from the underwater storage rack and placed in a transport cask to be shipped off the site.

4.3.1.2. Refuelling procedure

The main defuelling and refuelling operations are as follows:

- removal from the core of all fuel assemblies for transfer to the underwater fuel storage rack in the fuel building,
- changing of fuel clusters in the fuel building between the assemblies,
- loading into the core of fuel assemblies from the underwater fuel storage rack.

The fuel handling system is designed to allow refuelling by partial unloading of the core. The refuelling machine is equipped with a second mast for handling fuel clusters, which enables rod cluster control assemblies (RCCA) and thimble plug assemblies (TPA) to be changed in the reactor building. In this case, it is not necessary to unload all the assemblies in the fuel building.

Reactor building and fuel building pool configuration:

The fuel handling system is divided into several zones:

Fuel building side:

- the fuel storage pool is always filled with water and always accessible to operations staff,
- the new fuel dry storage zone,
- the loading pit located near the fuel storage pool, filled with water during removal of spent fuel assemblies or during introduction of new MOX fuel assemblies,
- the transfer pool in the fuel building.

Reactor building side:

- the reactor pool which is filled with water only during reactor shutdown to allow refuelling,
- the instrumentation lance pool, always filled with water,
- the transfer pool in the reactor building.

The fuel storage pool and the transfer pool are linked by an opening. This opening is kept closed using a door and a sluice gate, except during refuelling operations.

The fuel storage pool and the loading pit are linked by an opening. This opening is kept closed using a door and a sluice gate, except during fuel removal operations and during introduction of MOX assemblies.

The fuel transfer tube is closed by means of a blind flange on the reactor building side and a valve on the fuel building side.

Handling operations during refuelling:

The various handling and transfer operations performed during refuelling are described below:

- the refuelling machine is positioned above the first fuel assembly to be removed,
- the fuel assembly is raised high enough to pass above the vessel whilst remaining submerged in water, in order to minimise any risk of exposure of operations staff to radiation,
- the transfer system container is placed in a vertical position by the swinging chassis of the fuel transfer facility,
- the refuelling machine introduces the fuel assembly into the fuel transfer facility container,
- the fuel transfer facility container is placed in a horizontal position by the swinging chassis of the fuel transfer facility,

- the conveyor trolley carrying the container is moved through the fuel transfer tube towards the transfer pool of the fuel building,
- the container is placed in the vertical position by the swinging chassis of the fuel transfer facility,
- the fuel assembly is removed from the container by the spent fuel mast bridge,
- the fuel assembly is inserted into a cell in the underwater fuel storage rack or, if necessary, in a storage cell for defective assemblies,
- when all the fuel assemblies have been transferred into the underwater fuel storage rack, the control clusters and the thimble plugs are changed between the fuel assemblies using the spent fuel mast bridge.

Refuelling of the core with new and irradiated fuel assemblies consists essentially of performing the above operations in reverse.

4.3.2. Description of equipment

4.3.2.1. Reactor building platform [Ref-1]

The reactor building platform is a bridge which can travel above the reactor pool. It is moved manually and uses the same runway track as the refuelling machine.

Its main function is to provide access above the reactor pool in order to carry out the following operations during shutdown for refuelling:

- manoeuvring the tool for latching/unlatching the control rod drive shaft,
- providing access to the closure head handling equipment,
- supporting the coupling device for the different mast tools (e.g. handling tool of the reactor vessel water level measurement device, back-up remote-controlled tool of the internals handling device, …),
- operating and connecting different mast tools.

4.3.2.2. Instrumentation lances platform [Ref-1]

The instrumentation lance platform is a platform which is manually moved above the instrumentation lance pool. It uses an independent runway track.

Its main function is to allow access above the instrumentation lance pool in order to carry out the following operations during shutdown for refuelling:

- supporting the instrumentation lances finger exchange station,
- operating the instrumentation lances handling tool,
- operating the control rod drives handling tool.

4.3.2.3. Refuelling machine

The main function of the refuelling machine is to handle the new or irradiated fuel assemblies under water in the reactor building.

The refuelling machine comprises a bridge, a trolley and two fuel hoisting masts (see Section 9.1.4 - Figure 1). The gripper, located on the lower end of the first hoisting mast, may grasp a fuel assembly and move it in three directions (X, Y, Z) in the reactor pool. The second mast, dedicated to handling fuel clusters, allows changing of rod cluster control assemblies (RCCA) and thimble plug assemblies (TPA) in the reactor building in the event of partial unloading of the core.

The refuelling machine is equipped with an Integrated Refuelling Assistance Tool (IRAT) to assist with loading fuel assemblies. The IRATs are used to insert fuel assemblies into the reactor and help guide the lower end of the fuel assembly when it reaches the lower core plate. There are four separate IRATs which may be used in all parts of the reactor vessel without rotation of the fuel mast.

The refuelling machine is also equipped with the following devices:

- a control console placed on the service floor of the reactor building linked to the instrumentation and control devices needed to operate the refuelling machine via two Programmable Logic Controllers (PLC),
- sensors and positioning devices which provide the two PLCs with information such as the position (X, Y, Z) of the fuel mast,
- a system for permanent control of the handled load with automatic shutdown if there is excess load or under-load.

In addition to its main function, the refuelling machine performs the following functions:

- checking for leakage from fuel assemblies using mast sipping equipment,
- mapping of the core (identification and control of the position of assemblies in the core after reloading).

A detailed analysis of design and manufacturing arrangements implemented according to the applicable construction rules has shown that measures are taken to ensure the safe handling operation of the Refuelling Machine [Ref-1].

4.3.2.4. Fuel transfer facility

The fuel transfer facility is used to transport fuel assemblies between the reactor building and the fuel building and vice versa, through the containment penetration formed by the fuel transfer tube (see Section 9.1.4 - Figure 2).

A container used to transport a fuel assembly is mounted on a conveyor trolley. The trolley is moved horizontally on runway tracks by a rigid pusher chain driven by an electric motor located on the service floor.

At each end of the transfer tube, a swinging chassis is used to place the container in the horizontal or vertical position. The fuel assemblies are placed into and removed from the container using the refuelling machine or the spent fuel mast bridge.

The chassis is swung by electrical winches located at the service floors and is controlled locally from two control consoles: one in the fuel building, which also controls the lateral movement of the conveyor trolley, and the other in the reactor building.

During operation of the reactor, the transfer tube is isolated on the fuel building side by a manual valve and on the reactor building side by a blind flange with rapid opening and closing features.

4.3.2.5. Spent fuel mast bridge

The spent fuel mast bridge is used to handle the fuel assemblies, underwater in the fuel building, between the following equipment: new fuel elevator, underwater storage rack, fuel transfer facility, and spent fuel cask transfer facility. The spent fuel mast bridge is also used to change the rod control clusters.

The spent fuel mast bridge is a bridge equipped with a trolley and a hoisting mast (see Section 9.1.4 - Figure 3). A double gripper, attached to the lower end of the hoisting mast, is used to move a fuel assembly in three directions (X, Y, Z) in the fuel building pools. The spent fuel mast bridge is equipped with lateral guide rails to help insert a deformed fuel assembly into a compartment in an underwater storage rack.

The spent fuel mast bridge is also equipped with the following devices:

- a control console linked to all the instrumentation and control systems needed to operate the spent fuel mast bridge via two operating PLCs,
- sensors and positioning devices which provide the two PLCs with information such as the position (X, Y, Z) of the hoisting mast,
- a system for permanent control of the handled load, with automatic shutdown if there is excess load or under-load,
- a mast sipping equipment for checking for leakage from fuel assemblies.

A detailed analysis of Design and Manufacturing arrangements implemented according to the applicable Construction rules has shown that measures are taken to ensure the safe handling operation of the Spent Fuel Mast Bridge [Ref-1].

4.3.2.6. Centralised Control Units (CCUs)

The fuel handling system is equipped with a Centralised Control Unit located in the reactor building and another located in the fuel building, used to manage and monitor all fuel handling in the reactor building and the fuel building.

The two CCUs are connected to video cameras for viewing of handling operations and to the PLCs of the refuelling machine, the fuel transfer facility and the spent fuel mast bridge via a data exchange network.

The CCU in the reactor building is only used during unloading and reloading operations. It is installed during shutdown for reloading and may be dismantled following reloading.

The CCU in the fuel building is permanent.

During unloading and reloading operations, the two CCUs are interconnected via the data exchange network.

4.3.2.7. New fuel elevator

The new fuel elevator comprises a basket travelling on two vertical rails using an electric winch located on the service floor (see Section 9.1.4 - Figure 4). It is used to take new UO_2 fuel assemblies from the surface of the storage pool to the bottom of the pool.

In repair mode, the new fuel elevator can bring the assembly up to the surface for any intervention, under water deep enough to ensure biological protection.

In examination mode, it is equipped with a system for under water video inspection of irradiated fuel assemblies. All mechanical faults observed can be checked and evaluated to decide whether or not an assembly can be loaded into the core.

The new fuel elevator fuel basket is open on one side and comprises an inspection carriage that travels vertically along this side. The inspection carriage supports a table that travels horizontally and also supports the video system.

The fuel basket also comprises an upper and a lower rotating table that allow rotation of the fuel assembly during inspection.

4.3.2.8. Auxiliary crane

The fuel building auxiliary crane travels along a runway track attached to cantilevers located at the top of the building walls (see Section 9.1.4 - Figure 5).

The auxiliary crane is used during the construction phase to install the main equipment inside the fuel building (e.g. the underwater fuel storage rack). During the operational phase, the auxiliary crane is used to handle the following:

- the new UO_2 fuel assemblies,
- the sluice gate of the loading pit or the transfer pool,
- the fuel assemblies and control rod clusters in the event of failure of the spent fuel mast bridge hoisting function,
- the container for transporting new UO_2 fuel.

Even though the MOX assemblies are received underwater via the spent fuel cask transfer facility, the auxiliary crane is also designed to handle, in air, new MOX fuel containers and new MOX assemblies themselves.

The auxiliary crane comprises a trolley equipped with a 23 tonne winch.

A detailed analysis of design and manufacturing arrangements implemented according to the applicable construction rules has shown that measures are taken to ensure the safe handling operation of the Auxiliary Crane [Ref-1].

4.3.2.9. Handling tools [Ref-1]

A detailed analysis of rigging arrangements including dedicated handling tools has shown that measures are taken to ensure the safe coupling between the loads and the handling devices [Ref-2].

4.3.2.9.1. New fuel handling tool

The new fuel handling tool is hooked up to the auxiliary crane winch and is used to handle the new UO_2 fuel assemblies, above the pool surface, between the following areas:

- receipt of the transport container,
- new fuel dry storage rack,
- new fuel elevator.

The fuel assembly gripper mechanism features a mechanical locking device. Two guiding pins align the tool on to the fuel assembly head.

For receipt of new MOX assemblies in air, the new fuel handling tool will be equipped with a motor enabling rotation of the assembly to allow fuel inspection.

4.3.2.9.2. Spent fuel handling tool

The spent fuel handling tool is used for underwater handling of fuel assemblies in the event of breakdown of the refuelling machine or the spent fuel mast bridge hoisting function. It may be used as follows:

- in the reactor building using the auxiliary winch of the polar crane,
- in the fuel building using the auxiliary crane winch.

The polar crane and the auxiliary crane are equipped with a limit switch to prevent the risk of lifting the fuel assembly higher than the required level, ensuring protection against radiation.

The gripping fingers of the tool are activated using a locking control which is built into the tool.

4.3.2.9.3. Fuel cluster handling tool

The fuel cluster handling tool is used, in the event of breakdown of the spent fuel mast bridge hoisting function, to change the control clusters and the thimble plugs between the fuel assemblies. It is hooked up to the auxiliary crane winch.

It comprises an upper part and a lower part.

The lower part comprises guide plates perpendicular to the tool axis. The geometry of each plate guides the free movement of the cluster along the tool axis. The lower end is equipped with two guide pins which fit into the upper end of the fuel assembly when a cluster is withdrawn or inserted.

A gripper activated from the upper part of the tool moves vertically inside the lower part where it is guided by the plates.

The upper part of the tool is equipped with a manual winch, with a brake, for raising and lowering the gripper. A control mechanism allows the gripper to be engaged or disengaged. The upper part of the tool is also equipped with a lifting ring.

4.4. SAFETY ANALYSIS

4.4.1. Compliance with functional criteria

4.4.1.1. General provisions

4.4.1.1.1. Control of reactivity

Maintenance of the sub-critical state of fuel assemblies

During all operations in normal conditions performed in the fuel building (handling, repair, inspection of assembly, etc.), sub-criticality is ensured at the minimum boron content specified by technical specifications (K_{eff} < 0.95) and also in pure water conditions (K_{eff} < 0.98). [Ref-1]

Moreover, the minimum boron content specified by the technical specifications ensures a K_{eff} value below 0.98 following dropping of an assembly into the fuel building pool, resulting in [Ref-1]:

- an assembly lying on the rack or between the rack and the pool wall,
- a disordered pile of fuel rods due to a loss of integrity of the assembly,
- a significant pile of fuel pellets due to the gathering of scattered fuel pellets.

Prevention of risk of core loading error

The two Control Centralised Units (CCUs) help to ensure traceability of movements of assemblies and clusters. All movements of an assembly or a cluster, from its initial position to its final position, are recorded in a movement file.

To ensure core loading complies with the plan, the fuel handling system operating mode defines the following steps:

- The loading plan and sequences for the fuel building and reactor building are programmed at one of the supervision stations before fuel movement starts.
- Each sequence (movement of an assembly or a cluster from one position to another) is automatically provided, to the relevant loading manager, for verification of compliance with the plan.
- After verification by the loading manager, the following data is transmitted to the relevant equipment by the sequence:
    - o the coordinates of the pick-up and set-down positions, in the case of the refuelling machine or the spent fuel mast bridge,
    - o the transfer order between the fuel building and the reactor building, in the case of the fuel transfer facility.
- The operator of the refuelling machine or of the spent fuel mast bridge makes joystick movements as instructed by the operating machine PLC to perform the sequence as requested by the supervisor. The movement is interrupted as soon as the operator stops activating the joystick.

- In the case of the refuelling machine, the next movement sequence is only possible once the loading manager, on the reactor building side, has closed the file for the movement in progress. In order to close the file, the loading manager must enter the ID number of the assembly being handled by the refuelling machine. Closure is authorised if the number corresponds to the number given in the loading plan.

Furthermore, the CCUs allow monitoring of the occupancy plans for the fuel building pool and the core throughout the course of fuel assembly movements.

The CCUs enable collection of the data required during handling and provide a central means of communication.

At the end of reloading, the refuelling machine is used to perform the core mapping (identification of the ID number and the position in the core of each fuel assembly).

4.4.1.1.2. Decay heat removal

Handling of irradiated fuel assemblies and/or their clusters is performed under borated water. This water is cooled by the PTR [FPPS/FPCS] system which enables removal of the decay heat from the fuel assemblies. In addition, it enables visual monitoring of the operations and ensures adequate radiological protection.

4.4.1.1.3. Containment of radioactive substances

The handling system equipment is designed to ensure individual handling of fuel assemblies. The grippers can handle only one assembly at a time and the baskets can hold only one assembly. Interlocks are provided to prohibit the transfer of a fuel assembly to an item of equipment that already holds an assembly.

The equipment is designed to minimise the risk of dropping or damaging a fuel assembly during handling operations.

The rules of the KTA 3902 code or the specifications of the CST 60.C.007.03 (Book of Technical Specifications [Ref-1]) contain provisions for load control (redundant brakes and cables, anti-drop mechanisms) in the event of failure of certain components of the fuel handling system equipment.

The design minimises the risk of collision between fuel assemblies or against columns or other structures during handling operations.

The fuel assemblies are not raised or handled in the horizontal position unless they are supported along their entire length.

They are stored in a vertical position.

The fuel assemblies are never stored in the vertical position without side support, except when they are loaded into the core or in the new fuel elevator basket. Fuel movements that place the grids of assemblies in contact with other assemblies are performed at low speed.

Longitudinal and transverse accelerations and decelerations during any part of fuel movements are less than 2 g, including gravity.

The axial load on a fuel assembly that is not supported at the sides does not exceed 4500 N. The axial load on a fuel assembly that is supported at the sides does not exceed 9000 N. [Ref-2]

The fuel rods have no contact with any external items during storage and handling operations.

The fuel handling system and associated equipment are designed to exclude the risk of any items falling into a pool or onto a service floor.

All travel limit switches and locking mechanisms are designed in accordance with the principle of positive mechanical activation of command controls.

The safe position is ensured by mechanical components in the event of loss of electrical power.

4.4.1.2. Specific provisions

A detailed analysis of the specific provisions has shown that the implementation of a complete set of arrangements, including brakes and interlock devices, allows the functional criteria to be met [Ref-1].

4.4.1.2.1. Refuelling machine

4.4.1.2.1.1. Decay heat removal

If there is no position available in the core to rapidly place a fuel assembly safely in the event of accidental draining of the pool, an interlock ensures that the fuel transfer facility container is kept in the reactor building in the vertical position. This enables the fuel assembly to be placed in the container which is then placed in the horizontal position.

4.4.1.2.1.2. Containment of radioactive substances

The refuelling machine is seismic class 2 (SC2). Its integrity, including consideration of the load, is ensured in the event of design basis earthquake.

The refuelling machine hoisting winch comprises an open loop drive train featuring the following:

- a service brake,
- a safety brake which acts on the drum in the event of either excess speed, failure of the drive train or static and dynamic reversals,
- an emergency brake.

The hoisting mast is suspended by two cables and comprises a balancing system and a cable breakage detector.

A travel limit switch limits the maximum raising of the mast.

A load cell measures the weight of the suspended load and trips the compensator allowing the activation of the break during upward or downward movement, if the weight of the suspended load is higher or lower than predefines thresholds. The brakes are designed to close on loss of power. They also close in the event of malfunction of the hoisting drive train.

A load compensator protects the fuel assembly during normal handling movements in the core in the event of contact between two fuel assemblies. It has the following main functions:

- limiting loads applied to the fuel assembly grids,
- limiting loads applied to the ends of fuel assemblies.

In a normal situation, the refuelling machine may move horizontally only within a defined travel area to avoid any risk of collision. The travel area is determined by coders and limit switches.

The following interlocks are provided:

- the movements of the bridge, the trolley and the hoisting mast are interlocked to avoid simultaneous horizontal movements and hoisting movements; however, simultaneous movements of the bridge and the trolley are permitted,
- outside of approach phases and during core mapping, operation of the trolley and the bridge is possible only when the hoisting mast is in the uppermost position, loaded or empty,
- the winch control systems can only be activated when the position limit switches indicate that the gripper fingers are either fully engaged or fully disengaged,
- the refuelling machine cannot insert a fuel assembly into the fuel transfer facility container if the latter already contains a fuel assembly,
- the refuelling machine is interlocked with the fuel transfer facility to exclude any simultaneous displacement of the refuelling machine and the fuel transfer facility if the refuelling machine is above the transfer container and the hoisting mast is not in the top position, loaded or empty,
- the gripper mechanism comprises an internal mechanical locking system that prevents the fingers moving, unless the gripper is placed on a fuel assembly, and it bears the full weight of the hoisting mast helping by the compensator.

In addition, the gripper fingers are mechanically locked (engaged or disengaged). They cannot be activated by an impact or by radial loads. This locking acts as a safety mechanism to prevent dropped loads during movement of fuel assemblies.

A detailed description of the specific measures applied to the Refuelling Machine construction, including brakes and interlocks, has been established in order to provide a comprehensive list of design arrangements [Ref-1].

4.4.1.2.2. Fuel transfer facility

4.4.1.2.2.1. Decay heat removal

The fuel transfer facility container has sufficient holes to ensure cooling of the transferred assembly.

Cooling via natural convection is sufficient to ensure the integrity of fuel assemblies indefinitely if the conveyor trolley remains stuck in the open transfer tube. Thus no maximum time limit is imposed for non-availability of the system.

4.4.1.2.2.2. Containment of radioactive substances

The fuel transfer facility is seismic class 1 (SC1).

In the event of a design basis earthquake, the stability and integrity of all equipment, with consideration of the load, is ensured.

After an earthquake, the operability of the following components is ensured, noting that the operations required to perform each movement are performed manually:

- conveyor trolley,
- tilting frame,
- tilting frame winches,
- transfer tube isolation valve.

Each hoisting winch of the fuel transfer facility comprises an open loop drive train featuring the following:

- a service brake,
- a safety brake which acts on the drum in the event of excess speed, failure of the drive train or static and dynamic reversals.

The brakes are designed to close on loss of power and in the event of malfunction of the hoisting drive train.

The attachment of the transfer tube to the wall of the internal enclosure of the reactor building is rigid and sealed, so as not to compromise the integrity of the containment. The use of a blind flange and a manual valve as isolation units ensures the air-tightness of the tube, which is checked under pressure both at works and on site after installation.

The leak tightness of the pools is guaranteed at each end of the transfer tube by two metallic compensators. These compensators are welded to both the tube and the supports of the civil engineering structure, which in turn are welded to the walls of the transfer pools.

These compensators feature a leak detection sensor. The sensors deliver the information via an alarm sent to the control room. These two detectors are powered permanently and they operate independently of the commissioning of the fuel transfer facility.

A compensator is also used to make the connection between the transfer tube and the exterior enclosure of the reactor building.

The compensators also absorb the differential expansions and displacements between the internal enclosure, which is firmly attached to the transfer tube, and to the external enclosure and the walls of the transfer pools.

A redundant translation system controlled from the fuel building may be used to bring the conveyor trolley into the fuel building from any position in its normal travel, in the event of malfunction of the control system. After return of the trolley, the valve may be closed manually to restore containment integrity.

In the event of mechanical or electrical failure, the fuel assembly present in the fuel transfer facility may be transferred to the fuel building and presented to the spent fuel mast bridge using the redundant translation system or manual controls.

A redundant load cell prevents the fuel transfer facility from operating if there is excess load or if a cable is slack. Manual emergency controls are provided. The winches are also equipped with redundant cables to prevent swinging baskets from falling into the horizontal position if a cable breaks. The remaining cable is sufficient for performing the operation required.

Swinging and transfer operations are stopped at low speed. Accelerations and decelerations are gradual to avoid any impact with the fuel assembly.

Each control console is equipped with an emergency stop which is used to open the main circuit breakers in the event that the operator notes a malfunction.

In addition to the limit switches, the fuel transfer facility is equipped with interlock systems that prevent the following:

- the horizontal movement of the conveyor trolley when the two tilting frames are not simultaneously in the horizontal position,
- swinging of the tilting frame when the conveyor trolley is not in the extreme position on the reactor building side or the fuel building side,
- swinging when the spent fuel mast bridge or the refuelling machine is above the container and the gripper is not in the top position, empty or loaded,
- the horizontal displacement of the conveyor trolley when the valve is closed.

4.4.1.2.3. Spent fuel mast bridge

The specific provisions relating to the spent fuel mast bridge mainly concern the containment of radioactive substance.

The spent fuel mast bridge is seismic class 2 (SC2). Its integrity is ensured in the event of a design basis earthquake, including the loaded state.

The spent fuel mast bridge hoisting winch comprises an open loop drive train featuring the following:

- a service brake,
- a safety brake which acts on the drum in the event of either excess speed, failure of the drive train or static and dynamic reversals,
- an emergency brake .

The brakes are designed to close on loss of power or in the event of a malfunction of the hoisting drive train.

The spent fuel mast bridge travel area is limited so as to prevent fuel assemblies from hitting the walls of the spent fuel and transfer pools and the loading pit.

The hoisting mast is suspended by two cables and comprises a cable balancing system and a cable breakage detector.

A travel limit switch stops the mast rising above the top limit position.

A redundant load cell controls the suspended load and stops hoisting if there is excess load or under-load.

The following interlocks are provided:

- the movements of the bridge, the trolley and the hoisting mast are interlocked to avoid simultaneous horizontal and hoisting movements; however, simultaneous movements of the bridge and the trolley are permitted,
- operation of the trolley and the bridge is possible only when the hoisting mast is in the top position, loaded or empty (except in approach phases and at the bottom of the loading pit),
- the winch control systems can only be activated when the position limit switches indicate that the gripper fingers are locked in either the engaged or disengaged positions,
- the spent fuel mast bridge is interlocked with the fuel transfer facility to prevent them being moved simultaneously if the spent fuel mast bridge is above the transfer container and the hoisting mast is not in the top position, loaded or empty,
- the spent fuel mast bridge cannot insert a fuel assembly into the fuel transfer device container if the latter already contains a fuel assembly,
- the spent fuel mast bridge is interlocked with the new fuel elevator such that it can only approach the new fuel elevator descent axis if the new fuel elevator is in its lowest position and:
    - o the spent fuel mast bridge assembly gripper is in its uppermost position with no load,
    - o the spent fuel mast bridge assembly gripper is in its uppermost position with load and the new fuel elevator basket is not occupied with a fuel assembly.
- the mechanism for hooking fuel assemblies is equipped with an internal mechanical locking system. This device locks the gripper mechanism and prevents it from operating unless the gripper is positioned on a fuel assembly, and it bears the full weight of the hoisting mast helping by the compensator ,
- the mechanism for hooking clusters is equipped with an internal mechanical locking system. This device locks the gripper mechanism and prevents it from operating unless the gripper is positioned on a cluster. It cannot be activated by an impact or radial loads. This locking system is designed to prevent dropped load during handling operations,
- the spent fuel mast bridge is interlocked with the auxiliary crane to prevent it from passing below the auxiliary crane if the auxiliary crane hook is not in the top position with no load.

A detailed description of the specific measures applied to the spent fuel mast bridge construction, including brakes and interlocks, has been established in order to provide a comprehensive list of design arrangements [Ref-1].

4.4.1.2.4. New fuel elevator

The specific provisions relating to the new fuel elevator concern mainly the containment of radioactive substances.

The new fuel elevator is seismic class 2 (SC2). Its integrity is ensured in the event of a design basis earthquake, including in the loaded state.

The new fuel elevator hoisting winch comprises an open loop drive train featuring the following:

- a service brake,
- a safety brake which acts on the drum in the event of excess speed, failure of the drive train or static and dynamic reversals.

The winch is equipped with limit switches and a redundant load cell which stops the winch if the trolley is overloaded. It also has a manual emergency control.

The new fuel elevator basket is equipped with a shock absorber mounted on the perforated base plate. The shock absorber is installed to minimise damage in the event that the basket reaches the lower limit at high-speed (in the event of a failure to switch from high speed to low speed).

The brakes are designed to close on loss of power or in the event of a malfunction of the hoisting drive train.

Only slow accelerations and decelerations are permitted to avoid damage to fuel elements. The elevator speed is very low as it approaches the stop.

The open portion of the basket is bell-mouthed and the sides are smooth so that it is possible to insert and withdraw the fuel assemblies easily.

The following interlocks are provided:

- no movement is permitted in the event of electrical or mechanical failure (particularly in the event of breakage of one of the cables),
- except in repair mode, the basket cannot be raised when it contains an irradiated fuel assembly,
- use of the new fuel elevator is not possible when the auxiliary crane is located directly above the basket and the hook is not in the uppermost position, with or without load,
- use of the new fuel elevator is not possible when the spent fuel mast bridge is in the new fuel elevator area,
- the spent fuel mast bridge may access the new fuel elevator only when the basket is in the bottom position and if the spent fuel mast bridge gripper is in the top position.

4.4.1.2.5. Auxiliary crane

The specific provisions relating to the auxiliary crane concern mainly the containment of radioactive substances.

The auxiliary crane is seismic class 2 (SC2). Its integrity is ensured in the event of a design basis earthquake, including the loaded state.

The auxiliary crane hoisting winch comprises an open loop drive train featuring the following:

- a service brake,
- a safety brake which acts on the drum in the event of either excess speed, failure of the drive train or static and dynamic reversals,
- an emergency brake.

The brakes are designed to close on loss of power and in the event of a malfunction of the drive train.

The following interlocks are provided with other equipment:

- the auxiliary crane is interlocked with the new fuel elevator: during the new fuel loading, the auxiliary crane hook may be lowered above the new fuel elevator only if the basket is empty in the top position.
- the auxiliary crane is interlocked with the spent fuel mast bridge as defined in section 4.4.1.2.3.

In addition to these interlocks, the following lifting arrangements are provided to improve safety and reduce reliance on the operator:

- provision of six different lifting zones from a control perspective (dependent on the handling mode selected),
- electronic indexing above the new fuel elevator.

A detailed description of specific provisions applied to the Auxiliary Crane construction, including brakes and interlocks, has been established in order to provide a comprehensive list of design arrangements [Ref-1].

4.4.1.2.6. Fuel handling tools

The specific provisions relating to fuel handling tools mainly concern the containment of radioactive substances.

The handling tools are equipped with positioning and locking mechanisms which allow the following:

- correct alignment of the tool with the fuel assembly to be handled using centring devices,
- correct placement of the tool with respect to the fuel assembly,
- correct pick-up of the fuel assembly (pick-up is enabled if the centring devices are properly inserted),
- complete security in handling the fuel assembly by blocking the gripper finger movement mechanism.

In addition, a detailed analysis of rigging arrangements, including dedicated handling tools, has shown that measures are taken to ensure the safe coupling between the loads and the handling devices [Ref-1].

4.4.2. Compliance with design requirements

4.4.2.1. Safety classifications

The classification of the fuel handling system equipment is presented in Sub-chapter 3.2.

4.4.2.2. Hazards

4.4.2.2.1. Internal hazards

Internal Hazards	Protection required in principle	General protection	Specific protection in the design of the system
Pipe break	Yes	Location in the fuel building and the reactor building	-
Failure of tanks, pumps and valves	Yes		
Internal missile	Yes	Reactor building compartment	-
Dropped loads	Yes	Design of handling equipment	-
Internal explosion	Yes	Prevention and reactor building compartment	-
Fire	Yes	Fuel building and reactor building fire protection	-
Internal flooding	Not applicable	-	-

4.4.2.2.2. External hazards

The following elements of the fuel handling system are designed such that their integrity will be maintained, with a handled load, under the effects of a design basis earthquake or the vibration caused by an aircraft crash:

- refuelling machine,
- reactor building platform,
- fuel transfer facility,
- spent fuel mast bridge,
- new fuel elevator,
- auxiliary crane,
- new fuel handling tool,

- spent fuel handling tool,
- fuel cluster handling tool.

In addition, the following elements of the fuel transfer facility are designed to maintain their operability after a design basis earthquake or after vibration caused by an aircraft crash. It is assumed that the operations required for each movement (swinging, translation and closure of the valve) are performed manually:

- conveyor trolley,
- swinging chassis,
- swinging chassis winches,
- transfer tube valve.

External Hazards	Protection required in principle	General protection	Specific protection in the design of the system
Earthquake	Yes	Location in the reactor building and the fuel building	Seismic design (Stress analyses)
Aircraft crash	Yes	Location in the reactor building and the fuel building	Seismic design (Stress analyses)
External explosion	Yes	Location in the reactor building and the fuel building	-
External flooding	Yes	Location in the reactor building and the fuel building	-
Snow and wind	Yes	Location in the reactor building and the fuel building	-
Extreme cold	Yes	Location in the reactor building and the fuel building	-
Electromagnetic interference	Yes	Location in the reactor building and the fuel building	-

4.5. TESTS, INSPECTION AND MAINTENANCE

4.5.1. Pre-operational testing

The fuel handling system must undergo a series of pre-operational tests. The tests required will be defined in a test procedure to include handling sequence tests, electrical circuit tests, leak resistance tests and load tests. Tests on this equipment will be performed at the manufacturer's premises and on site. Handling tests will be performed using a dummy fuel assembly.

At acceptance on site, the components must be inspected to check that there is no damage caused by transport and storage. At on-site testing, the equipment must satisfy a set of checks to ensure the satisfactory operation of the fuel handling system at the end of assembly.

For the Auxiliary Crane, tests with normal load and excess load must be performed in accordance with regulations in force.

A static test and a dynamic test with excess load are performed (refuelling machine, fuel transfer facility, spent fuel mast bridge, new fuel elevator and auxiliary crane), accordingly to the requirements of the KTA 3902 code “Design of lifting equipment in nuclear power plants” or the requirements of the CST 60.C.007.03 “High safety lifting and handling machine” [Ref-1].

4.5.2. Surveillance in operation

At each refuelling cycle, the fuel handling system must undergo a range of re-qualification tests. The tests must ascertain the availability of the system and perform surveillance and maintenance operations. Surveillance concerns mainly visual inspection. The maintenance portion comprises maintenance of mobile parts and periodic replacement of worn parts.

The following maintenance and control operations are performed before use:

- visual examination to search for loose parts, foreign material and signs of damage and to check for cleanliness and absence of grease,
- lubrication of visible gears using a suitable lubricant,
- checking of hoisting cables to detect worn or broken strands,
- visual examination of all travel limit switches and their control devices to identify any signs of damaged or broken parts,
- checking of correct operation of the equipment.

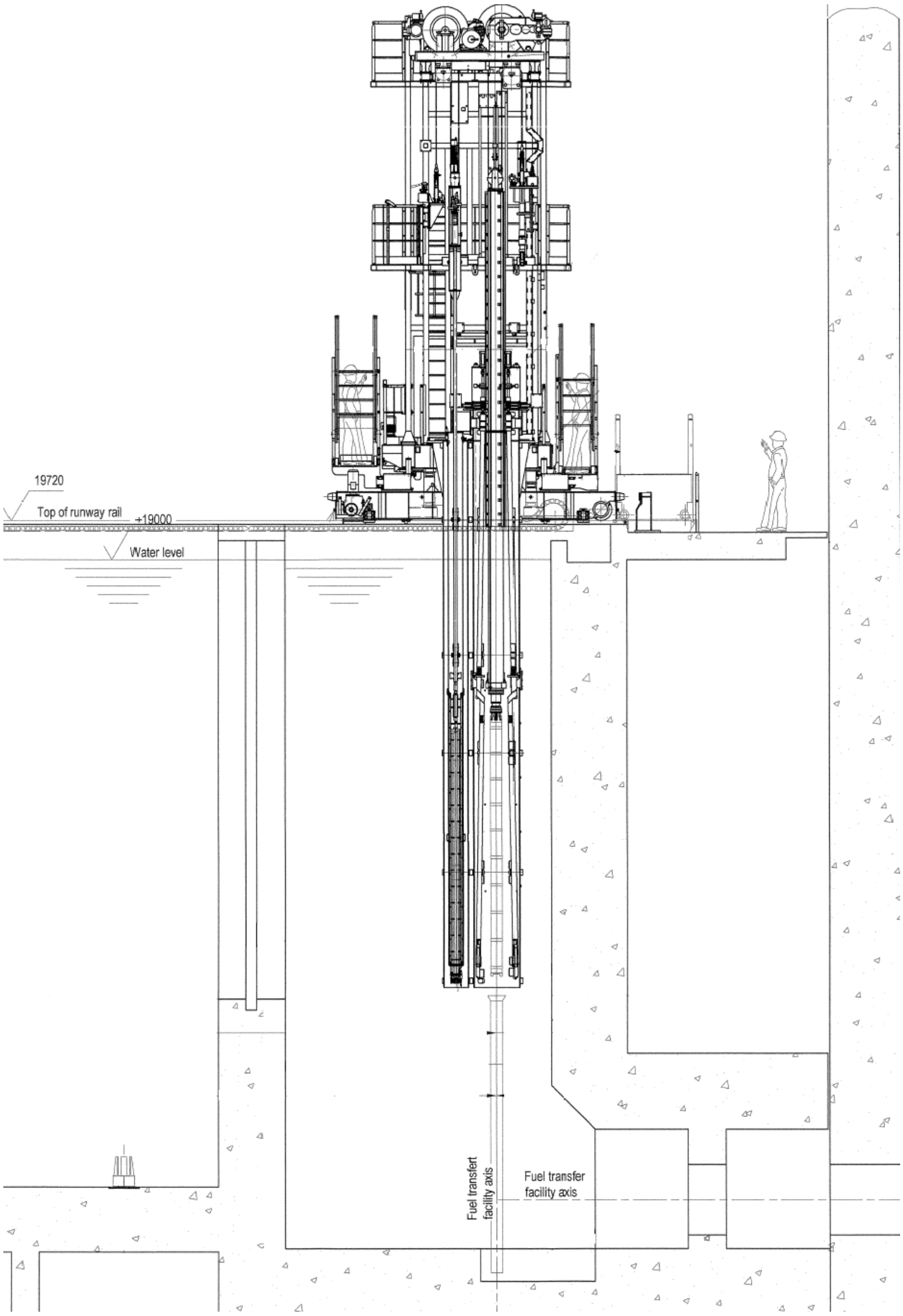
For the auxiliary crane, load tests must be performed in accordance with regulations in force.

4.5.3. Periodic tests

The fuel handling system must undergo periodic tests to ensure its ability to fulfil its function and to check the state of all safety related components. Specifically items forming part of the containment isolation must be tested to check they are leak tight following shutdown for refuelling.

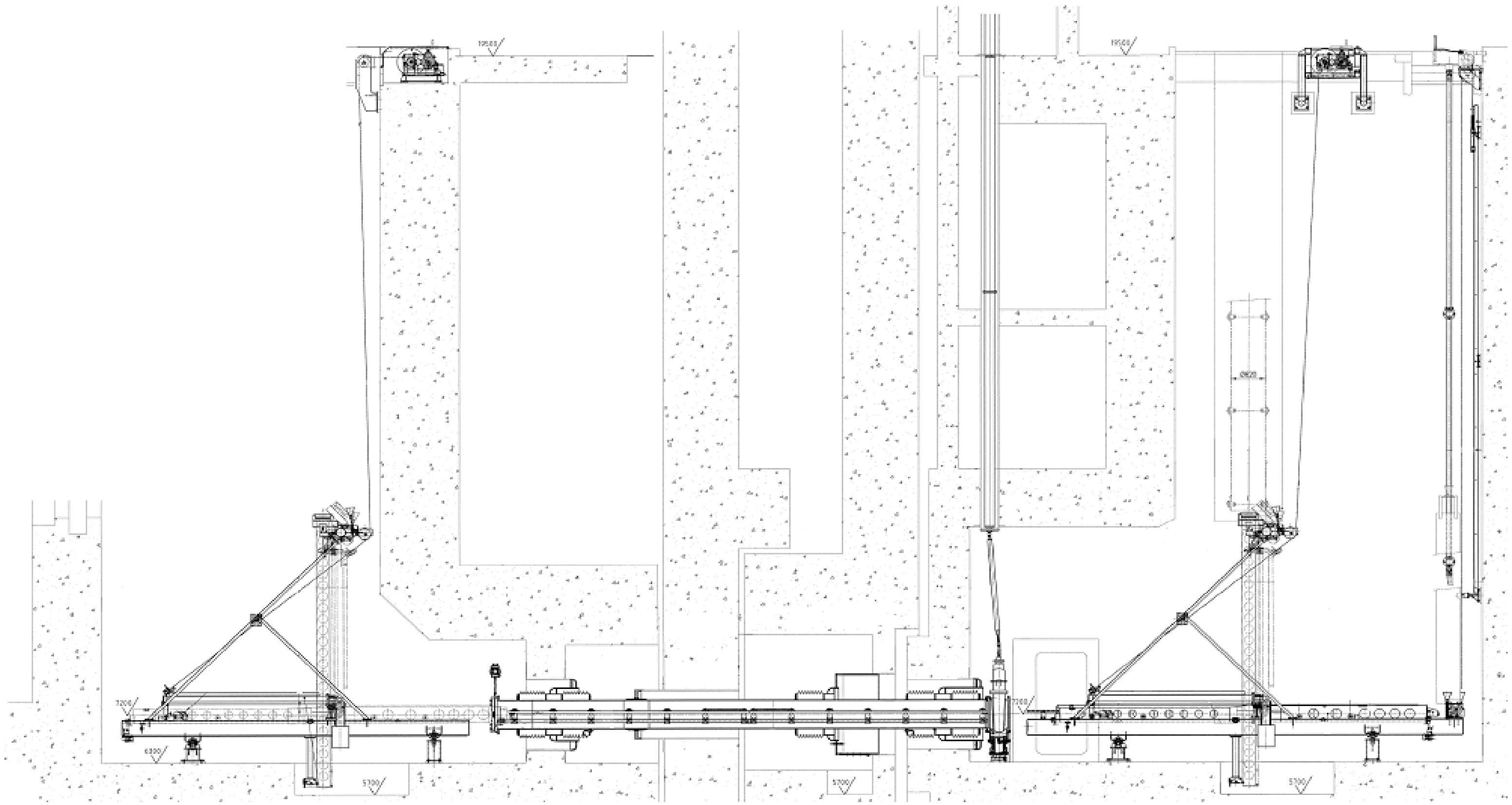
SECTION 9.1.4 - FIGURE 1

Refuelling Machine



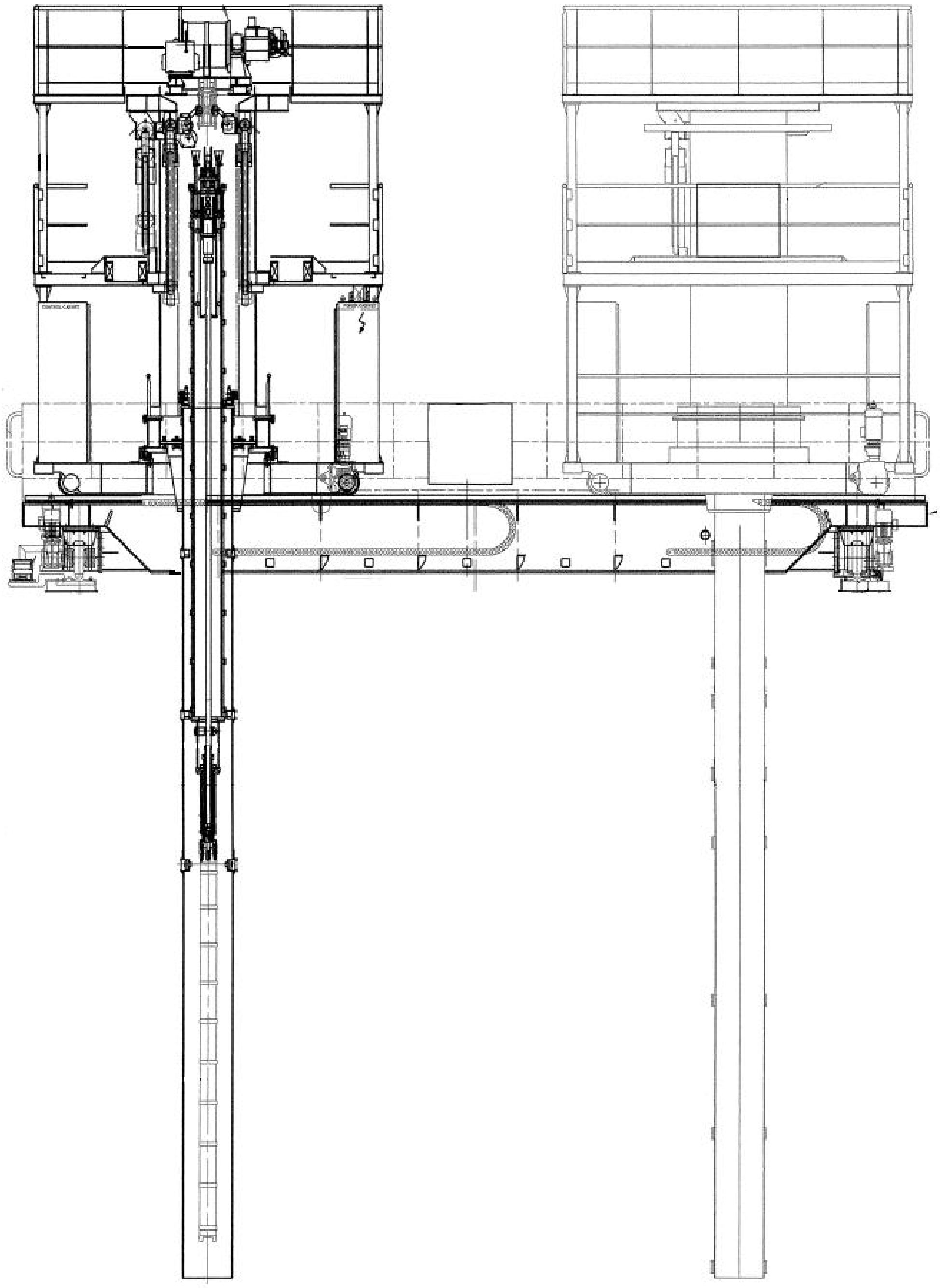
SECTION 9.1.4 - FIGURE 2

Fuel Transfer Facility



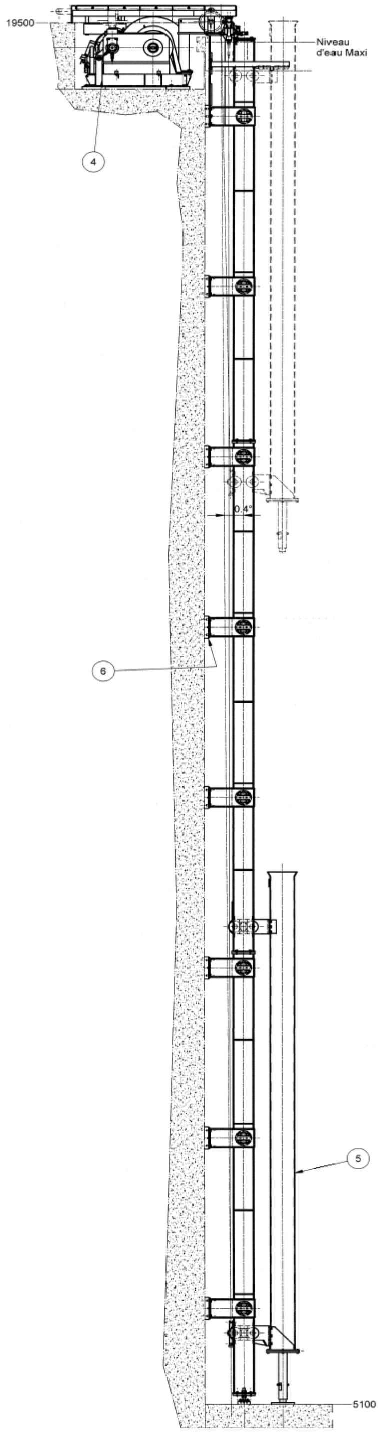
SECTION 9.1.4 - FIGURE 3

Spent Fuel Mast Bridge



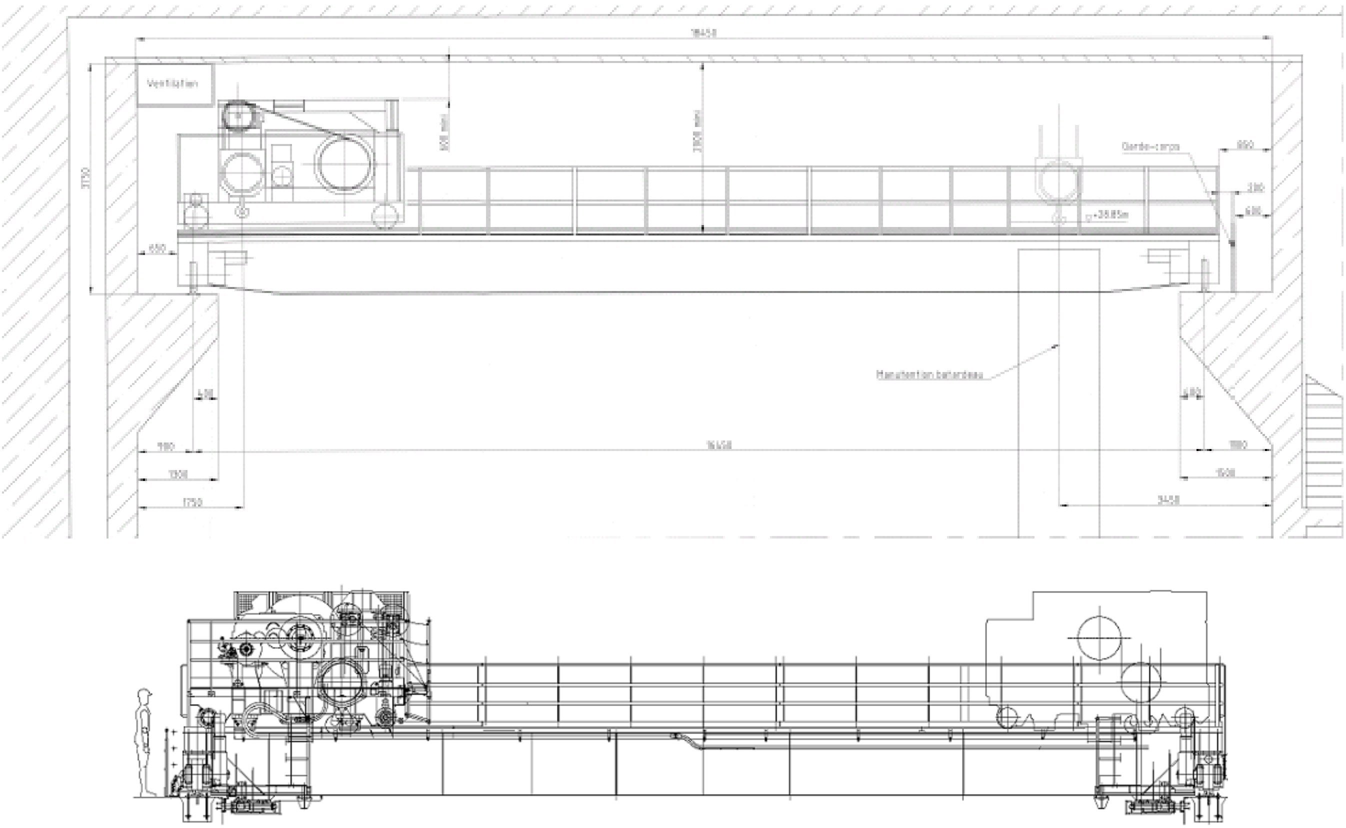
SECTION 9.1.4 - FIGURE 4

New Fuel Elevator



SECTION 9.1.4 - FIGURE 5

Auxiliary crane



5. OTHER HANDLING SYSTEMS

5.1. SPENT FUEL CASK TRANSFER FACILITY (DMK)

5.1.0. Safety requirements

5.1.0.1. Safety functions

The main functions of the Spent Fuel Cask Transfer Facility are the transport of irradiated fuel casks from the cask lifting crane to the penetration located at the bottom of the fuel loading pit, the placing of the cask in the loading pit and the preparation and conditioning of the cask. It plays a direct part in fulfilling the cask emergency cooling safety functions. It must also contribute to the following safety functions:

5.1.0.1.1. Control of reactivity

The Spent Fuel Cask Transfer Facility must prevent a criticality accident following the dropping of a cask.

5.1.0.1.2. Decay heat removal

The Spent Fuel Cask Transfer Facility must be designed to remove the decay heat of the fuel assemblies.

5.1.0.1.3. Containment of radioactive substances

The Spent Fuel Cask Transfer Facility must be designed to preserve the integrity of the fuel cladding.

5.1.0.2. Functional criteria

5.1.0.2.1. Decay heat removal

The Spent Fuel Cask Transfer Facility must be designed to cool the fuel in the cask before conditioning. In particular, it must ensure the cask emergency cooling.

The Spent Fuel Cask Transfer Facility must ensure no dewatering of the fuel assemblies before complete closure of the cask.

5.1.0.2.2. Controlling reactivity and containing radioactive products

The Spent Fuel Cask Transfer Facility must be designed to prevent a fuel cask from being dropped during handling.

The Spent Fuel Cask Transfer Facility must be designed to prevent an unconditioned fuel cask from falling in the event of a design basis earthquake or the vibration following an aircraft crash.

5.1.0.3. Design-related requirements

5.1.0.3.1. Requirements resulting from safety classifications

5.1.0.3.1.1. Safety classifications

The Spent Fuel Cask Transfer Facility must be classified according to the principles given in Sub-chapter 3.2.

5.1.0.3.1.2. Single failure criterion (active and passive)

Not applicable.

5.1.0.3.1.3. Uninterruptible power supplies

The temperature sensor of the fuel cask must be backed up.

5.1.0.3.1.4. Qualification to operating conditions

Not applicable.

5.1.0.3.1.5. Mechanical, electrical and instrumentation and control classifications

The mechanical, electrical and instrumentation and control classification of safety features must comply with the requirements of Sub-chapter 3.2.

5.1.0.3.1.6. Seismic classification

The Spent Fuel Cask Transfer Facility must be seismically classified in accordance with the principles given in Sub-chapter 3.2.

5.1.0.3.1.7. Periodic tests

The Spent Fuel Cask Transfer Facility is subject to periodic tests to check the state of safety related components and in particular to ensure its ability to fulfil its cask emergency cooling function by the cooling skirt via the fire protection system.

5.1.0.3.2. Other regulatory requirements

5.1.0.3.2.1. Official texts, laws, orders and decrees

No official text specifically applies to the Spent Fuel Cask Transfer Facility.

5.1.0.3.2.2. Basic Safety Rules

Not applicable to UK EPR.

5.1.0.3.2.3. Technical Directives

None of the Technical Guidelines specifically applies to the Spent Fuel Cask Transfer Facility.

5.1.0.3.2.4. Specific EPR documents

Not applicable.

5.1.0.3.3. Hazards

The Spent Fuel Cask Transfer Facility must be protected against internal and external hazards.

5.1.0.3.3.1. Internal hazards

The Spent Fuel Cask Transfer Facility must be protected against internal hazards in accordance with Sub-chapter 13.2.

5.1.0.3.3.2. External hazards

External hazards other than earthquake and aircraft crash have no specific impact on the Spent Fuel Cask Transfer Facility due to the installation of the facility in the fuel building.

Seismic hazard

The Spent Fuel Cask Transfer Facility must be designed so that its integrity will be preserved when the fuel cask is inside the fuel building, following the design basis earthquake.

Aircraft crash

The Spent Fuel Cask Transfer Facility must be designed so that its integrity will be preserved when the fuel cask is inside the fuel building, following vibration caused by an aircraft crash.

5.1.1. Role of the system

The Spent Fuel Cask Transfer Facility is used for:

- the delivery, preparation and opening of the cask before its loading with fuel assemblies,
- the loading of the cask with the transfer machine docked to a loading pit, through a penetration,
- the closing, conditioning and preparation of the cask before its transport out of the fuel building,
- the transport of the conditioned cask from the fuel building to the lifting crane.

The Spent Fuel Cask Transfer Facility can also be used to receive under water the new MOX fuel casks.

5.1.2. Design bases

The design complies with the following requirements [Ref-1]:

a) The Spent Fuel Cask Transfer Facility is designed to limit the risk of dropping or damaging the fuel casks during transfer from one location to another. The equipment is fail-safe in the event of loss of power.

b) Movement of the Spent Fuel Cask Transfer Facility may be stopped on demand.

c) The Spent Fuel Cask Transfer Facility is designed to avoid dropped load during loading operations following a design basis earthquake or following vibration caused by an aircraft crash.

d) All operations relating to fuel cask handling are designed to ensure protection of staff against radiation and to prevent overheating of the fuel.

e) The evaluation of the radiological consequences of a fuel handling accident takes account of the general installation of the equipment (structures, systems and components) to ensure the safety and protection of the general public.

f) The transfer machine, the penetration upper cover hoist, the biological lid handling station and the penetration docking device are designed either according to the requirements of the KTA 3902 code “Design of lifting equipment in nuclear power plants” or of CST 60.C.007.03 “High safety lifting and handling machine” [Ref-2].

g) The safety classification of the components of the irradiated fuel cask handling system is presented in Sub-chapter 3.2.

5.1.3. Description, characteristics of equipment [Ref-1] [Ref-2]

The Spent Fuel Cask Transfer Facility comprises primarily the fuel cask transfer machine and the various pieces of equipment installed in the unit (see Section 9.1.5.1 - Figure 1).

The fuel cask transfer machine is used to transport the cask from the irradiated fuel cask lifting crane to the fuel building loading hall.

In addition, the fuel cask transfer machine allows access to the cask and to the penetration during cask preparation and conditioning. It supports a part of the fluid systems needed during fuel removal.

The fuel cask transfer machine travels on rails and is guided sideways into the fuel building.

The following equipment is installed on the unit:

- the penetration used for connecting the spent fuel loading pit to the cask,
- the biological lid handling station allowing removal and replacement of the biological lid on the cask,
- the penetration upper cover manoeuvred using a hoist,
- the control room from which most automatic tasks on the machine are controlled and monitored remotely,

- the fluid module (fixed pipes connected to different systems of the unit),
- the rails and the guiding mechanism.

Irradiated fuel cask handling operations are as follows for fuel removal:

- the irradiated fuel cask arrives on site in the horizontal position on a trailer or a wagon. After removal of shock absorbers and radiological checks, it is lifted and placed in the vertical position using the irradiated fuel cask lifting crane before being placed on the irradiated fuel cask transfer machine;
- the fuel cask transfer machine containing the cask positioned vertically is transferred in the fuel building loading hall to the handling opening station;
- the fuel cask transfer machine is secured to the building structure using seismic restraints;
- the fluid, electrical and instrumentation and control systems of the transfer machine are connected to the unit;
- the following operations are performed:
    - cask air tightness checks,
    - biological lid cover removal,
    - placement on the cask of the blocking/centring ring of the penetration flange,
    - loosening of the biological lid,
    - filling the cask with water.
- the seismic restraints are unlocked and the fuel cask transfer machine is moved beneath the biological lid handling station;
- the fuel cask transfer machine is secured to the building structure using seismic restraints;
- the biological lid is removed;
- the seismic restraints are unlocked and the fuel cask transfer machine is positioned beneath the penetration, in the lower part of the loading pit;
- the fuel cask transfer machine is secured to the building structure using seismic restraints;
- the penetration is placed in contact with the cask at the cask sealing surface using a sealing device. This device consists in a sealing flange, a double-walled bellows seal and a connection flange between the bellows seal and the sealing flange;
- the penetration is filled;
- the loading pit is filled;
- the penetration upper cover is opened;

- the sluice gate between the spent fuel pool and the loading pit is opened;
- the spent fuel assemblies are loaded under water into the cask using the spent fuel mast bridge;
- the sluice gate between the two compartments of the pool is closed;
- the penetration upper cover is closed;
- the penetration is emptied;
- the cask is partially drained;
- the penetration is flushed and dried;
- the sealing flange is disconnected from the cask sealing surface;
- the seismic restraints are unlocked and the fuel cask transfer machine is positioned beneath the biological lid handling station;
- the fuel cask transfer machine is secured to the building structure using seismic restraints;
- the biological lid is replaced;
- the seismic restraints are unlocked and the fuel cask transfer machine is finally positioned beneath the handling opening;
- the fuel cask transfer machine is secured to the building structure using seismic restraints;
- the final cask conditioning operations are performed:
  - locking of the cask biological lid,
  - complete drainage of the cask,
  - drying of the cask if necessary,
  - biological lid cover setting,
  - checks for air tightness and radioactivity of the cask.
- the fluid, electrical and instrumentation and control systems of the transfer machine are disconnected from the unit;
- the seismic restraints are unlocked and the fuel cask transfer machine is removed from the building and taken to the irradiated fuel cask lifting crane;
- the cask is lifted vertically using the irradiated fuel cask lifting crane and is placed in the horizontal position on the wagon or the trailer;
- after the final preparations, the cask is ready to leave the site.

N.B.: the fuel cask handling system may also be used to hold new MOX fuel casks, using a process similar to the one described above.

5.1.4. Safety analysis

5.1.4.1. Compliance with functional criteria

5.1.4.1.1. Decay heat removal

The Spent Fuel Cask Transfer Facility is designed to ensure the cooling of the fuel assemblies in the cask before conditioning and no uncovering of the fuel assemblies before complete closure of the cask. This is achieved by the following means.

The spent fuel assemblies are handled under water deep enough to ensure adequate biological protection and cooling.

All measures are taken to prevent accidental emptying of the cask. The layout of the system prohibits complete emptying of the cask before the lid has been replaced.

All measures are taken to prevent accidental emptying of the fuel storage pool:

- The seals are doubled; the area below the seals is double-walled and is designed to be leak tight following a design basis earthquake or following the vibrations caused by an aircraft crash; the hoses have a small diameter.
- In the event of a hose or pipe leakage, it is possible to close the valve-tool connected to this hose or pipe.
- The pipes connected to the penetration have a small diameter. Moreover, in the event of a leak a pipe, it is possible to close the penetration upper cover, or the sluice gate, or both. Then the handling fuel assembly can be placed in the cask or unloaded.

When the cask is filled with water in the fuel building and loaded with irradiated assemblies, the system ensures back-up cooling of the cask in any position, in the event of abnormal heating due to its being in a prolonged stationary position. The following back-up cooling facilities are foreseen:

- back-up cooling by gravity draining of the loading pit,
- emergency cooling by the skirt via the fire protection system in the fuel building loading hall and the cask lifting crane.

Moreover, the following design features ensure the integrity of the spent fuel cask transfer facility:

The seals are double-barrier type (valve, check valve, dashpot, seal or full plug). When the double isolation comprises two valves, at least one of them is motor-driven.

Incorrect movements are prevented by electrical interlocks. The motor-driven valves close in the event of loss of power. All the mechanical components and valves feature a manual emergency control for completion of operations.

Accidental leaks from the cask or the loading pit are detected by sensors with threshold alarms.

The penetration between the loading pit and the cask is designed to maintain its seals during a design basis earthquake or under the effects of vibration caused by an aircraft crash.

The piping is designed to maintain its integrity in the event of a design basis earthquake or under the effects of vibration caused by an aircraft crash.

Interlocks are provided to ensure the integrity of the penetration during the various operations (see section 5.1.4.1.2 below).

5.1.4.1.2. Controlling reactivity and containing radioactive products

<u>Prevention of cask drop</u>:

The design of the cask/loading pit eliminates the risk of dropping or damaging the cask during handling operations in the fuel building. The cask is not lifted but is attached to the transfer machine which sits directly on the floor.

The irradiated fuel cask remains on the irradiated fuel cask transfer machine, which is designed to hold it and remain stable, even in the event of an earthquake or vibration caused by an aircraft crash. This statement is valid when the transfer machine is in the fuel building with the assumption that the cask is loaded, positioned and stowed on the handling system, which in turn is connected to the civil engineering structure by seismic restraints. The transfer machine holding the conditioned irradiated fuel cask may tip over in the event of an earthquake with the EPR loading spectrum, if it is located outside the fuel building. This event would not damage the integrity of the irradiated fuel cask.

The design eliminates any collision between fuel casks or against columns or other structures during handling operations.

The parts of the irradiated fuel cask handling equipment, or equipment linked to it, are designed to preclude the risk of their falling into a pool or on to a service floor in the fuel building.

In the event of a design basis earthquake or vibration caused by an aircraft crash, the cask is secured in all directions by the fuel cask transfer machine, which is held in place by seismic restraints when it is in the fuel building. The rail guards block any vertical displacements and displacements perpendicular to the runway track, and the seismic restraints block the displacements along the runway track axis.

The transfer machine is equipped with an electrical brake and a failsafe pneumatic brake. The transfer machine is equipped with buffers at the end of the track to absorb kinetic energy.

The transfer machine is equipped with anti-slip pads close to the wheels with minimal interplay above the tracks, so that breakage of a roller, bearing or axle has no impact on the integrity of the cask or of the fuel.

<u>Contaminated water dispersion limitation</u>:

Following operational feedback from the French 1300 MWe and 1450MWe units, the transfer machine is designed to limit dispersion of contaminated water. It is equipped with low leakage piping connections, a modified overflow tank to avoid overflows at closure of the cask and devices to recover any drips.

The transfer machine is also designed to limit the exposure of staff to radiation by limiting the accumulation of contamination as well as the duration of cask operations. It is equipped with simplified fluid systems that promote flow and facilitate decontamination, motor-driven valves which can be operated remotely, a blocking/centring ring at the level of the penetration and a horizontally adjustable lid lifting device.

In normal operation, possible drip-off is collected by the five floor drains in the hall of the fuel building, and sent to the RPE [NVDS].

In the event of a break, effluents are collected by two collectors in the hall of the fuel building, and are sent toward the retention pit(temporary storage), before removal by a pump toward the RPE [NVDS].The following interlocks are provided:

Operation	**Prior condition**
Positioning of the transfer machine for removing the lid	- door of the fuel building loading hall closed - handling opening closed - lid gripper in its uppermost position - anti-seismic locking devices unlocked - penetration in upper position
Lifting of the lid	- lid gripper in lower position - gripper claw closed - anti-seismic locking devices locked
Positioning of the transfer machine beneath the penetration	- lid locked in the top position - electrical power of the lid station cut off - penetration in its uppermost position - anti-seismic locking devices unlocked - door of the loading hall closed - penetration lower cover open
Lowering of the penetration	- transfer machine positioned with translation supply isolated - anti-seismic locking devices locked
Opening of the vent and filling of the penetration with water	- all electrical power supplies isolated except that of the penetration upper cover
Opening of the penetration upper cover	- counterweight unlocked - pool sluice gate closed - spent fuel mast bridge not in the loading pit
Opening of the sluice gate between the pool and loading pit	- all electrical supplies are isolated
Emptying of the penetration	- penetration upper cover closed - counterweight locked - pool sluice gate closed - anti-seismic locking devices locked
Unlocking and lifting of the penetration seal	- penetration empty of water - counterweight locked - anti-seismic locking devices locked
Movement of the transfer machine to the lid lifting station	- anti-seismic locking devices unlocked - penetration in top position - lid and gripper locked in top position - door of the loading hall closed

5.1.4.2. Compliance with design requirements

5.1.4.2.1. Safety classifications

The classification of the components of the irradiated fuel cask handling system is presented in Sub-chapter 3.2.

5.1.4.2.2. Uninterruptible power supplies

The temperature sensor of the cask is backed up by batteries ensuring autonomous supply for 24 hours.

5.1.4.2.3. Hazards

5.1.4.2.3.1. Internal hazards

Internal hazards	Protection required in principle	General protection	Specific protection in the design of the system
Pipe breaks	Not applicable	-	-
Failure of tanks, pumps and valves	Not applicable	-	-
Internal missile	Not applicable	-	-
Dropped loads	Yes	Design of handling equipment	-
Internal explosion	Yes	Prevention	-
Fire	Yes	Fuel building fire protection	-
Internal flooding	Yes	Fuel building installation	-

5.1.4.2.3.2. External hazards

Earthquake

The Spent Fuel Cask Transfer Facility is designed to maintain its integrity under the effects of a design basis earthquake with the assumption that the cask is loaded, positioned and stowed on the transfer machine, which in turn is connected to the civil engineering structure by seismic restraints.

The connecting piping is designed to maintain its integrity in the event of a design basis earthquake.

The seal between the penetration and the cask is required to remain intact in the event of an earthquake.

Operation of the electrical equipment is not guaranteed during or after an earthquake but the manual controls of the seismic class 1 (SC1) mechanical units enable related functions to be performed.

When transporting the conditioned cask out of the Fuel building, the transfer machine may tip over in the event of an earthquake with the EPR loading spectrum. This situation does not reduce the integrity of the irradiated fuel cask.

Aircraft crash

The Spent Fuel Cask Transfer Facility is designed to maintain its integrity under the effects of vibration caused by an aircraft crash, with the assumption that the cask is loaded, positioned and stowed on the transfer machine, which in turn is connected to the civil engineering structure by seismic restraints.

The connecting piping is designed so its integrity will be maintained under the effects of the vibration potentially caused by an aircraft crash.

The seal between the penetration and the cask is required to withstand the effects of vibration caused by an aircraft crash.

Operation of the electrical equipment is not guaranteed during or after an aircraft crash but the manual controls of seismic class 1 (SC1) mechanical units enable related functions to be performed.

External hazards	Protection required in principle	General protection	Specific protection in the design of the system
Earthquake	Yes	Location in fuel building	Seismic design (Stress analyses)
Aircraft crash	Yes	Location in fuel building	Seismic design (Stress analyses)
External explosion	Yes	Location in fuel building	-
External flooding	Yes	Location in fuel building	-
Snow and wind	Yes	Location in fuel building	-
Extreme cold	Yes	Location in fuel building	-
Electromagnetic interference	Yes	Location in fuel building	-

5.1.5. Testing, inspection and maintenance

5.1.5.1. Pre-operational testing

The irradiated fuel cask pit handling system must undergo a range of pre-operational tests. The tests required will be defined in a test procedure and will include handling sequence tests, electrical circuit tests, leak resistance tests and load tests. Tests on this equipment will be performed at the manufacturer’s premises and on site.

At acceptance on site, the components must be inspected to check that no damage has been caused by transport and storage. In on-site testing, the equipment must satisfy a set of checks to ensure satisfactory operation of the pit fuel handling system following assembly.

5.1.5.2. Surveillance in operation

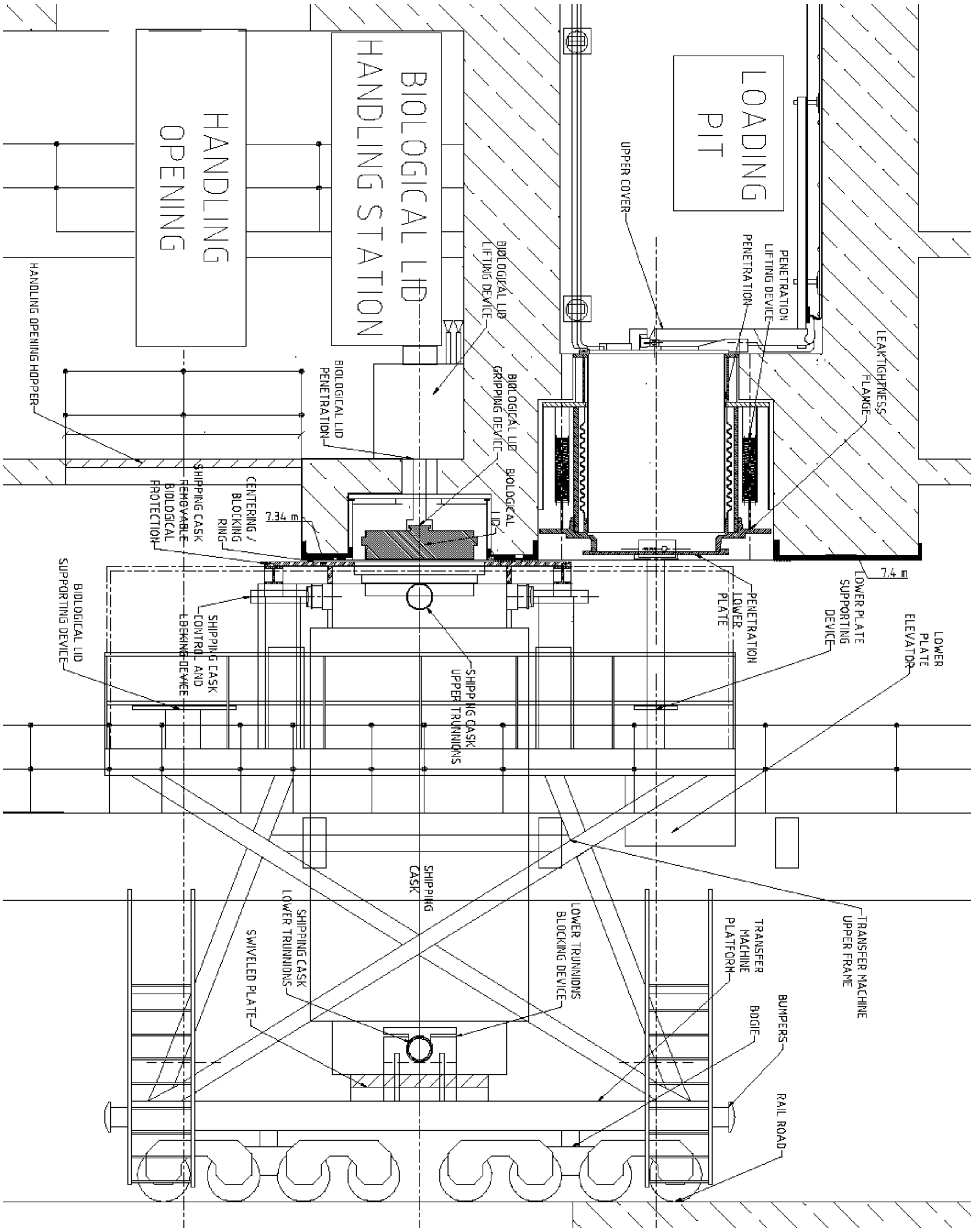
Before each usage campaign, the irradiated fuel cask pit handling system must undergo a series of re-qualification tests. The tests are designed to confirm the availability of the system, and involve surveillance and maintenance operations. Surveillance involves mainly visual inspections. The maintenance operations comprise maintenance of moving parts and periodic replacement of worn parts.

5.1.5.3. Periodic tests

The system must be designed to enable periodic tests to be carried out, particularly to check the state of safety related components.

SECTION 9.1.5.1 - FIGURE 1 [Ref-1]

Spent Fuel Cask Transfer facility



5.2. POLAR CRANE (DMR)

5.2.0. Safety requirements

5.2.0.1. Safety functions

The polar crane, whose main role is to carry out heavy handling in the reactor building, does not directly fulfil any safety functions.

However, the machine is designed to prevent, during normal or accident operation, any accidental criticality, unjustified exposure to ionising radiation or unacceptable discharge of radioactive substances (arising firstly from the risk of dropped load or collisions).

The polar crane and the load it handles must not pose hazards to safety related systems and equipment, specifically:

- the fuel assemblies (during shutdown/unloading and reloading/start-up phases, during handling of the vessel upper head and the upper internals),
- the reactor cavity and the internals (ditto),
- the watertight liner of the reactor building pool,
- the containment,
- the parts of the safeguard circuit fixed to the containment at the level of the polar crane,
- safety related systems located vertically below the crane or its handled load.

5.2.0.2. Functional criteria

The polar crane must be designed to avoid dropped load or any impact during load handling.

The polar crane must be designed to avoid the dropping of parts from the crane.

The polar crane must be designed to avoid any interference with the Reactor Building and the EVU [CHRS] piping.

5.2.0.3. Design requirements

5.2.0.3.1. Safety classification requirements

5.2.0.3.1.1. Safety classifications

The polar crane must be classified according to the principles given in Sub-chapter 3.2.

5.2.0.3.1.2. Single failure criterion (active and passive)

Not applicable for the polar crane in its entirety.

Although the single failure criterion does not apply to the polar crane, certain components are designed with redundancy in order to prevent dropped load in the event of failure of a single component, in accordance with the Technical Specifications for “high safety” lifting and handling machines [Ref-1].

5.2.0.3.1.3. Uninterruptible power supplies

The polar crane lighting and collapse device must be backed up.

5.2.0.3.1.4. Qualification for operating conditions

Not applicable.

5.2.0.3.1.5. Mechanical, electrical and instrumentation and control classifications

The mechanical, electrical and instrumentation and control classification of safety components must comply with the requirements in Sub-chapter 3.2.

5.2.0.3.1.6. Seismic classification

The polar crane must be seismically classified in accordance with the principles given in Sub-chapter 3.2.

5.2.0.3.1.7. Periodic tests

The polar crane is subjected to periodic tests.

A maintenance schedule is developed, which is used to check the condition of safety significant crane components, and also to ensure the ability of the polar crane to fulfil its function.

The polar crane is subjected to periodic tests that may be required by the national regulatory regime.

5.2.0.3.2. Other regulatory requirements

5.2.0.3.2.1. Statutory requirements

No statutory requirements specifically applies to the polar crane.

5.2.0.3.2.2. Basic safety rules

.Not applicable to UK EPR.

5.2.0.3.2.3. Technical Directives

No specific Technical Guidelines are applicable to the polar crane.

5.2.0.3.2.4. Specific EPR texts

Not applicable.

5.2.0.3.3. Hazards

The polar crane must be protected against internal and external hazards.

5.2.0.3.3.1. `Internal hazards

Hazards other than fire and breaks in pipes, tanks, pumps and valves, have no impact on the polar crane given the protective role of the reactor building containment and the elevated position of the polar crane in the building.

Fire

Given that the polar crane is installed in the reactor building, only fire on the crane is taken into account, and in particular fire in the electrical equipment.

A specific protection against fire on the crane is ensured by detectors and fire extinguishers.

Breaks of pipes, tanks, pumps or valves

The support arrangements for high-energy pipes, and the relative position of the crane in relation to the pipes, tanks, pumps and valves, ensure that the mechanical effects of failure of these components is negligible for the polar crane.

Following a failure of any pipe, tank, pump or valve, the over-pressurisation and temperature increase in the reactor building must not cause structural failure of the polar crane.

5.2.0.3.3.2. External hazards

Hazards other than earthquake and aircraft crash have no impact on the polar crane given the protective role of the reactor building containment and the elevated position of the polar crane in the building.

Earthquake

The polar crane must be designed to withstand a design basis earthquake.

Control of the transported load, and integrity of the crane, must be maintained during and after an earthquake.

Operability of the crane without the need for maintenance or repair is not required during or after an earthquake.

The crane must not generate any unacceptable stresses on its runway track and on the Reactor building in an earthquake.

The crane must not damage the EVU [CHRS] pipes used for heat removal from the containment in an earthquake.

Aircraft crash

The polar crane must be designed to withstand vibration caused by an aircraft crash.

Control of the transported load, and integrity of the crane, must be maintained after vibration caused by an aircraft crash.

Operability of the crane without the need for maintenance or repair is not required during or after an aircraft crash. The crane must not generate any non-allowable stresses on its runway track and on the enclosure during vibration caused by an aircraft crash.

The crane must not damage the EVU [CHRS] pipes used for decay heat removal from the containment during vibration caused by an aircraft crash.

5.2.1. Role of the system

The polar crane is used during erection phase to install the main components in the reactor building (reactor vessel, steam generators, pressuriser,…) and during plant outages for the following operations [Ref-1]:

With the main hoist (capacity 320 tons):

- lifting and removal of the reactor cavity cover slabs,
- lifting of the reactor building pool slot gate,
- lifting and transport to its set-down position of the Multiple Stud Tensioning Machine,
- lifting and transport of the reactor vessel pressure head,
- lifting of the lower and upper internals.

With the secondary hoist (capacity 35 tons):

- lifting and transport of the instrumentation lances storage pit slot gate,
- fuel transfer pit slot gate.

With the auxiliary hoist (capacity 5 tons):

- removal of the instrumentation lances,
- lifting of the water level measuring devices,
- lifting of the Rod Cluster Control Assembly (RCCA) drive shafts,
- transport of the RCCA drive shaft unlatching/latching tool.

5.2.2. Design basis

The design complies with the following requirements [Ref-1] [Ref-2]:

a) The polar crane is designed to avoid the risk of dropped load. The equipment is failsafe in the event of loss of power. Any internal failure of an essential element or loss of electrical power causes the movement to be stopped.

b) Movement of the polar crane may be stopped on demand.

c) The polar crane is designed to withstand a design basis earthquake and vibration following an aircraft crash, with and without a lifted load.

d) The polar crane is designed according to the requirements of the CST 60.C.007.03 “High safety lifting and handling machine” [Ref-3].

e) The safety classification of the polar crane is given in Sub-chapter 3.2.

5.2.3. Description, characteristics of equipment [Ref-1]

5.2.3.1. Description of the system

The polar crane is used during the construction phase of the reactor to install the main components in the reactor building (the reactor vessel, the steam generators, the pressuriser, etc.) and during fuel reloading operations for handling the vessel upper head and other tools and equipment (see Section 9.1.5.2 - Figures 1, 2 and 3).

5.2.3.2. Description of components

The polar crane travels on a runway track consisting of a circular metal frame supported on metal brackets attached to the containment.

The crane has three trolleys:

- a main trolley equipped with a 320 tonne main hoist,
- a secondary trolley equipped with a 35 tonne secondary hoist,
- an auxiliary trolley equipped with a 5 tonne auxiliary hoist.

The 5 tonne hoist also enables back-up handling of fuel assemblies, using the spent fuel handling tool, in the event of failure of the refuelling machine.

5.2.4. Safety analysis

5.2.4.1. Compliance with functional criteria

<u>Prevention of load drop and impact during handling</u>:

The specifications of CST 60.C.007.03 [Ref-1] contain provisions for load control (redundant brakes and cables, drop-prevention mechanisms) in the event of failure of certain components of the polar crane.

The polar crane is designed to maintain its structural integrity in all accident conditions, including the design basis earthquake, vibration caused by an aircraft crash, and a loss of primary coolant accident.

The polar crane is designed to prevent inadvertent movement following loss of power supplies.

The brakes engage automatically as soon as the controlled movement ceases. They are designed to ensure a gradual (jerk-free) stop. The hoist control devices are designed to avoid any uncontrolled acceleration of the load during the lowering operation.

The brakes are designed to operate on power under-voltage and as soon as a malfunction in the hoisting drive train is detected.

Each hoist is equipped with a system for measuring the load. For the auxiliary hoist, a specific threshold exists for fuel assembly handling operations in the event of failure of the refuelling machine. If a fault is detected, the movement is stopped.

Interlocks are installed to prevent unacceptable speed or position of the crane.

The polar crane is designed to facilitate load lowering in the event of a malfunction in the hoisting drive train.

A detailed analysis of design and manufacturing arrangements implemented according to the applicable construction rules has shown that measures are taken to ensure the safe handling operation of the Polar Crane and reinforce the drop load prevention [Ref-1].

Main hoist (320 tonne)

The polar crane main hoist is equipped with a closed loop drive train featuring the following:

- two operational brakes,
- two emergency brakes.

The drive train is equipped with a device for surveillance in operation that controls the loss of synchronisation between the two reduction gears.

Secondary hoist (35 tonne)

The polar crane secondary hoist is equipped with a closed loop drive train that features the following:

- two operational brakes,
- two emergency brakes

Auxiliary hoist (5 tonne)

The polar crane auxiliary hoist is equipped with an open loop drive train featuring the following:

- an operational brake,
- an emergency brake,
- a safety brake.

<u>Note</u>: the loop drive train could also be composed of an operational brake and a secure motorised movement system.

Because of the auxiliary hoist limit switch adjustment, the dewatering of the handled fuel assembly with the spent fuel handling tool is not possible.

<u>Prevention of dropping of parts from the crane</u>:

The specifications of CST 60.C.007.03 [Ref-1] contain provisions to prevent the dropping of parts.

The polar crane is designed to maintain its structural integrity in all accident conditions, including the design basis earthquake, vibration caused by an aircraft crash, and a loss of primary coolant accident.

Interference with the Reactor Building and the EVU [CHRS] piping:

The polar crane is designed so its movements avoid any interference with the Reactor Building and the EVU [CHRS] piping in normal conditions and in all accident conditions, including the design basis earthquake and vibration caused by an aircraft crash.

5.2.4.2. Compliance with design requirements

5.2.4.2.1. Safety classifications

The classification of the polar crane is given in Sub-chapter 3.2.

5.2.4.2.2. Hazards

5.2.4.2.2.1. Internal hazards

Pipe breaks

Polar crane box structures are designed to withstand containment tests and to remain intact in the event of a LOCA. The crane structural behaviour is confirmed to be acceptable, taking into account temperature increases resulting from pipe break accidents, for the most pessimistic accident conditions.

Fire

The crane electrical service room is equipped with a fire detector consisting in smoke detectors located above the risk areas in a position that takes into account the partitioning of the beams. The detectors trigger an alarm on the polar crane control stations and in the main control room.

The polar crane is equipped with an automatic extinguishing system located in the electrical service room and with fire extinguishers located in the crane access and on the carriages.

Internal hazards	Protection required in principle	General protection	Specific protection in the design of the system
Pipe breaks	Yes	Elevated position in the reactor building	Pressure balancing orifices. Verification of the structure at high temperatures (Stress analyses).
Failure of tanks, pumps and valves	Yes		
Internal missile	Yes	Reactor building compartment	-
Dropped loads	Not applicable	-	-
Internal explosion	Yes	Prevention and reactor building compartment	-
Fire	Yes	Reactor building fire protection	Extinguishing system. Fire detection.

Internal hazards	Protection required in principle	General protection	Specific protection in the design of the system
Internal flooding	Not applicable	-	-

5.2.4.2.2.2. External hazards

Seismic hazard

The polar crane is designed such that its integrity will be maintained and it will not drop its load under the effects of the design basis earthquake. The design addresses the following load cases:

- with the crane in its parked position with no load,
- with the maximum operating load suspended in the centre of the crane.

The polar crane is designed so its movements during an earthquake avoid any interference with the Reactor Building and the EVU [CHRS] piping.

The calculation for earthquake is a non-linear dynamic stress calculation (using the time-history method).

Aircraft crash

The polar crane is designed to maintain its integrity and not to drop its load under the effects of vibration caused by an aircraft crash. Load cases described above are addressed.

External hazards	Protection required in principle	General protection	Specific protection in the design of the system
Earthquake	Yes	Located in the reactor building	Seismic design (Stress analyses)
Aircraft crash	Yes	Located in the reactor building	Seismic design (Stress analyses)
External explosion	Yes	Located in the reactor building	-
External flooding	Yes	Located in the reactor building	-
Snow and wind	Yes	Located in the reactor building	-
Extreme cold	Yes	Located in the reactor building	-
Electromagnetic interference	Yes	Located in the reactor building	-

5.2.5. Testing, inspection and maintenance

Measures must be taken to enable access for inspection and testing of load bearing components.

5.2.5.1. Tests before commissioning

The polar crane must undergo full acceptance tests prior to commissioning:

- operating tests unloaded and fully loaded,
- static and dynamic load tests in accordance with CST 60.C.007.03 [Ref-1].

5.2.5.2. Surveillance in operation

In compliance with applicable national regulations, the polar crane will undergo regular tests of safety related components and other periodic checks as appropriate. These tests may be conducted with the unit in operation.

Given the considerable size of the test load needed to test the crane to its maximum capacity, and the consequences on the facility in the event of a dropped load, the crane tests will be carried out with a reduced load.

In the event that the regulatory test frequency is not met due to the duration of the reactor operating cycle, regulatory tests will be carried out before the crane is used again.

Before use of the crane, it must be inspected as follows:

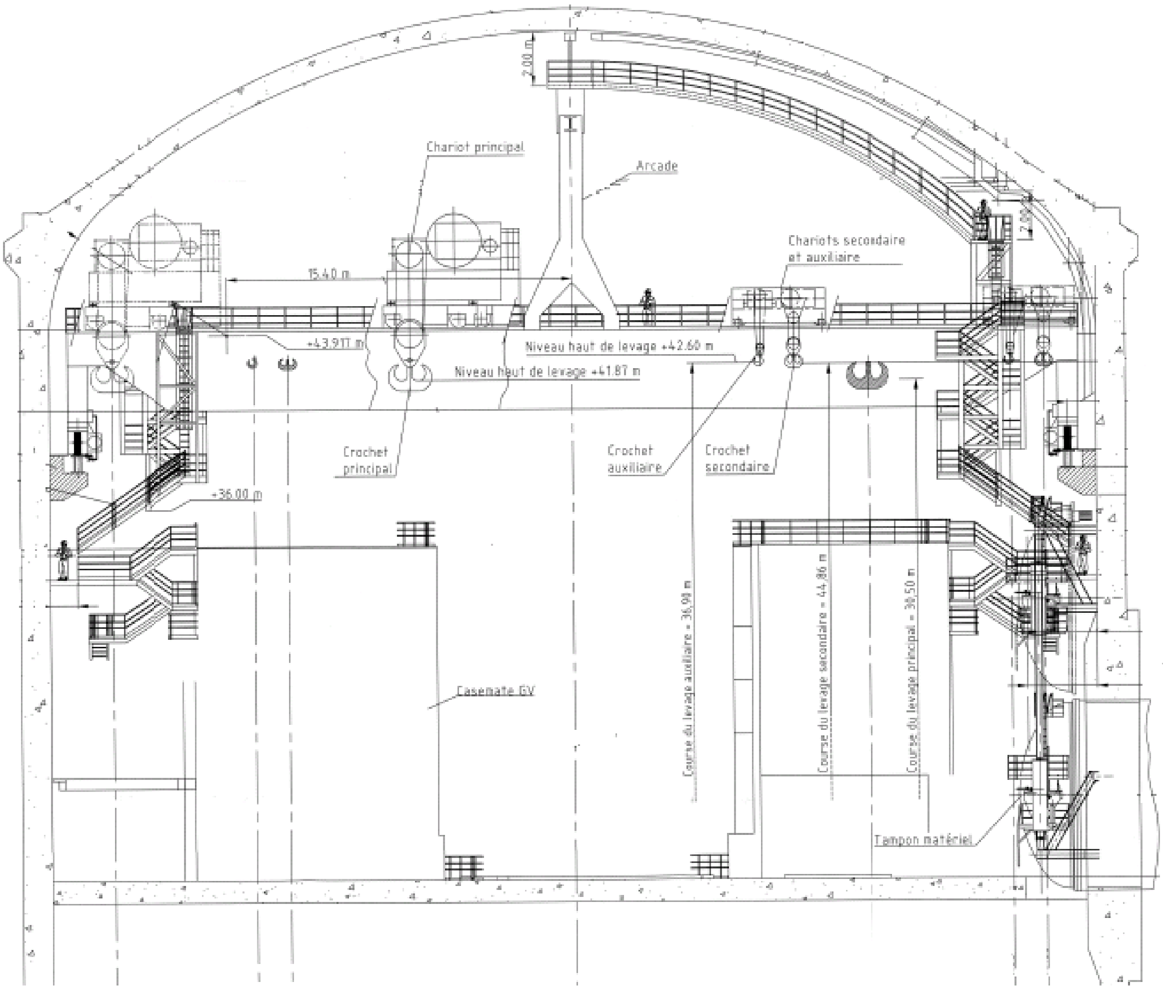
- visual inspection to check the absence of unattached or foreign parts and absence of dust or grease,
- inspection of lifting cables for worn or broken strands,
- visual inspection of all travel limit switches and switch activators to ensure that no part is damaged or broken,
- checking of correct operation of the equipment.

5.2.5.3. Periodic tests

The polar crane must undergo periodic tests to ensure its ability to fulfil its function and to check the state of all safety related components.

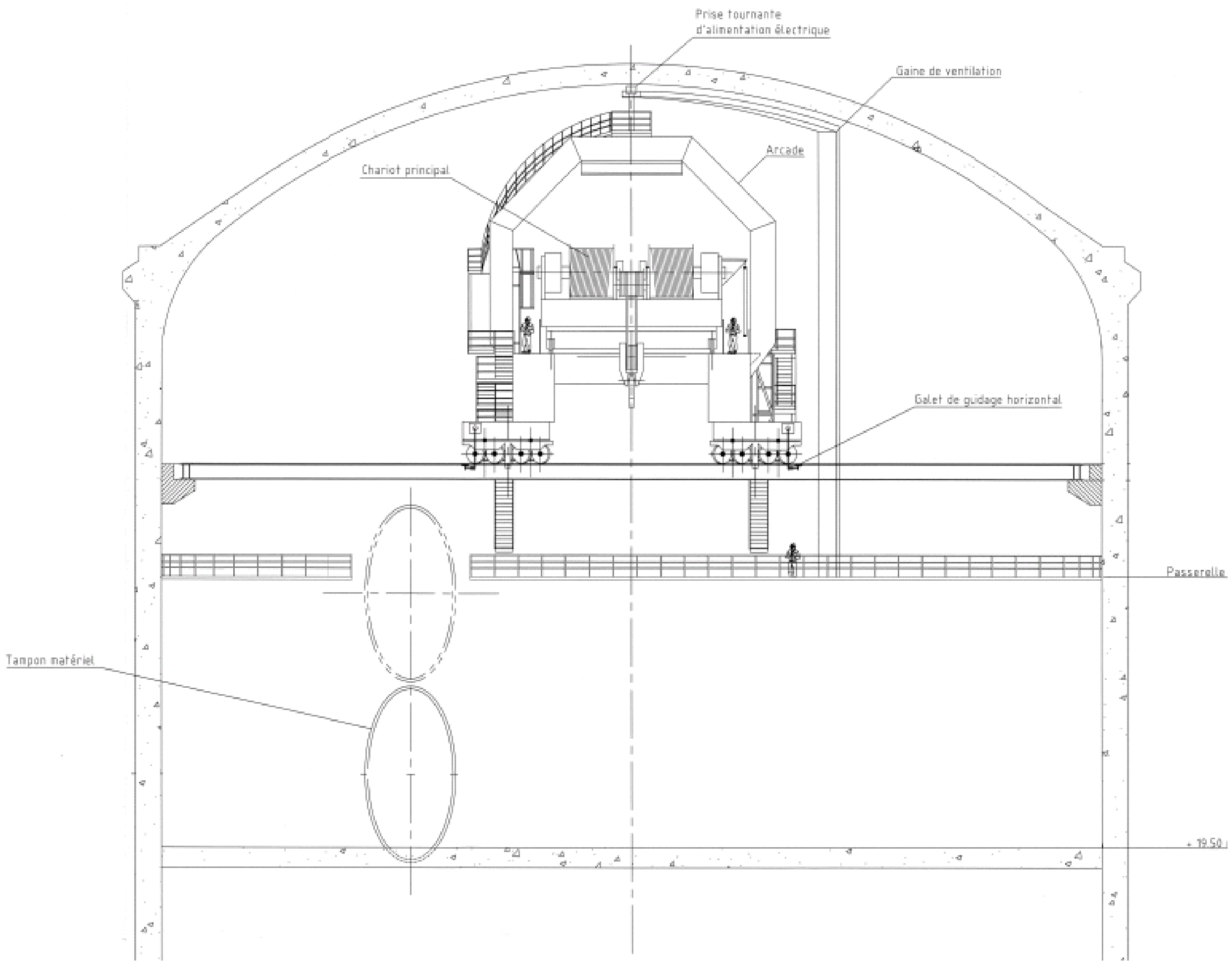
SECTION 9.1.5.2 - FIGURE 1

Polar Crane, front view



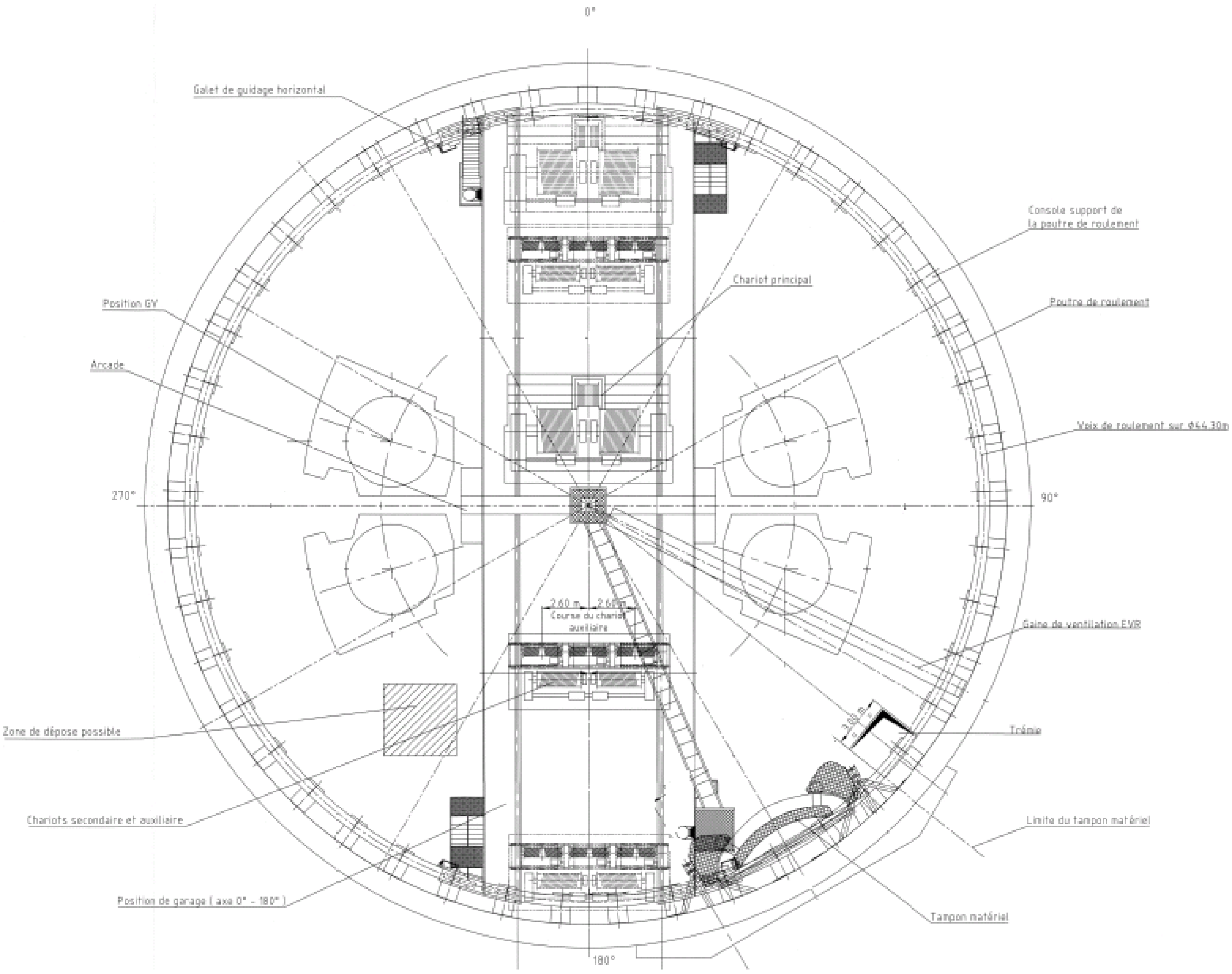
SECTION 9.1.5.2 - FIGURE 2

Polar crane, side view



SECTION 9.1.5.2 - FIGURE 3

Polar crane, top view



6. DESIGN OF POOL LINERS (EXCEPT IRWST)

6.0. SAFETY REQUIREMENTS

The safety requirements are presented in Chapter 3.

6.1. ROLE OF THE LINER

The EPR pools are compartments used for fuel storage and handling. Water-tightness of the pools is achieved with a metallic liner covering the pool concrete walls. The pool liner consists of metal panels welded onto anchors sealed into the concrete. It has no structural function.

The liner is required to be watertight in order to:

- keep the fuel under water,
- prevent damage to the concrete structure,
- ensure radiological protection (containment of radioactive material).

6.2. LINER DESIGN BASIS

The liner design requirments are presented in the design requirements and methodology [Ref-1]. The safety role of the liner is to ensure that the various pool compartments and tanks remain leaktight under normal operating, exceptional and accidental load conditions (including at the location of equipment anchors plates and pipework penetrations), over their entire height. Each liner is composed of welded steel panels. It is designed to be resistant to irradiation and to avoid the presence of dead zones that could promote formation of contamination deposits.

The liner panels are anchored to the concrete structure via a stainless steel support frame embedded in the concrete. A mechanism in the support frames allows vertical adjustment of the liner (where necessary) to ensure the ETC-C [Ref-2] flatness criteria are met. The anchors are vertical and horizontal and laid out on a regular grid pattern. The liner panels made are of austenitic stainless steel sheets free of molybdenum with characteristics described in the ETC-C [Ref-2]. The liner thickness is 4 mm for the vertical sheets and 6 mm for the bottom of the pools.

The role of the liner anchorage system is to maintain liner leaktightness by withstanding the maximum concrete deformation without failing. To meet liner deformation limits under conditions when the stresses in the concrete are significant (e.g. cracking due to the seismic loading), a minimum distance between anchorages is specified.

Equipment located in the pools is fixed to plates anchored directly to the structural concrete wall in order to avoid the transmission of stresses to the liner.

A system is provided for detecting, locating and collecting leakage in the liners of all pools and tanks. The system is installed at the location of welds underneath the liner, and consists of leakage channels and pipes and monitoring cabinets containing collection devices. Tests are performed on each leakage pipe during erection to verify the absence of obstructions and allow correct identification of each pipe. Any leak in service must be detected, the leakage collected and the leak repaired.

The principal design code for the pool liners is the ETC-C code [Ref-2] and the UK Companion Document [Ref-3]. The liner design methodology is presented in [Ref-1], which describes:

- the design process to be followed
- the assumptions to be applied in the design of the pools and tanks
- the methods and codes applicable for liner anchorages in concrete
- the design methods and codes applicable for liner welds
- the design methods and codes applicable to liner singular zones

When full, the pools contain demineralised borated water.

6.2.1. Requirements during operation

In order to ensure the leak resistance of the spent fuel pool doors (autoclave doors) in the fuel building, the water level in this compartment must always be higher than that of adjacent compartments.

6.2.2. Temperature

During the normal operation and the refuelling operation, the temperature is between 12°C and 50°C.

The design temperature of the pools is 80°C.

The integrity of the spent fuel pool and its metal liner must be ensured for an accident temperature of 100°C until the cooling system is restarted.

6.3. DESCRIPTION OF THE POOLS

6.3.1. Reactor building [Ref-1]

The reactor building pool is located in the containment above the reactor vessel and comprises four compartments:

- <u>the reactor vessel compartment</u> is located directly above the reactor vessel. During the reactor shut down, this compartment is filled with water. After dismantling the vessel head, it allows the refuelling of the reactor. The seal between the reactor vessel and the metal liner is ensured by a metal ring at the level of the support of the reactor vessel. This compartment is empty during normal operation.

- the reactor internals compartment, which is associated with the reactor vessel compartment (same pit). The internal equipment of the reactor is stored in this compartment during the refuelling operation. This compartment is empty during normal operation.

- the transfer compartment, which is used to transfer fuel between the reactor building and the fuel building. (The transfer tube connecting the transfer compartments of the two buildings is an integral part of this compartment). This compartment is empty during normal operation.

- the equipment storage compartment, which is located next to the transfer compartment, between the reactor internals compartment and the containment. This compartment is used to store the core instrumentation tubes during the refuelling operation. The compartment is constantly full of water.

These four compartments (see Section 9.1.6 – Figure 1) can be isolated from one another by removable sluice gates with the following acceptable configurations:

- sluice gate between the reactor compartment and the reactor internals compartment: open during normal operation and closed for occasional operations such as repairs to the reactor

- sluice gate between the reactor internals compartment and the transfer compartment: open during normal operation

- sluice gate between the reactor internals compartment and the equipment storage compartment: closed during normal operation

6.3.2. Fuel building [Ref-1]

The fuel building pool is located in the fuel building and is divided into three compartments:

- the spent fuel pool contains the spent fuel assemblies for decay and cooling (also used for buffer storage at each unloading/reloading campaign.)

- the transfer compartment which is used to transfer the fuel from the reactor building to the fuel building during the loading/unloading of fuel operations.

- the loading pit, which is the dedicated compartment for loading and unloading the fuel via a trap in the bottom of the pit. The spent fuel assemblies and the spent fuel rods are loaded into lead casks before being transported off the site. During this operation, the loading pit is full of water and the transfer compartment is empty. The loading pit or the transfer compartment can be full of water.

These three compartments (see Section 9.1.6 - Figure 2) can be isolated from one another using doors, as follows:

- isolation between the spent fuel pool and the transfer compartment is achieved using a revolving door near the spent fuel pool in addition to a sluice gate. These devices are closed during normal operation.

- isolation between the spent fuel pool and the loading pit is achieved with a door identical to that described above. It is also closed during normal operation. Additional isolation may be achieved using a sluice gate inserted between the two compartments.

- isolation between the transfer compartment in the reactor building and that in the fuel building, in the transfer duct, is achieved using a plug on the reactor building side and an isolation valve on the fuel building side. This plug is closed during normal operation. N.B.: In the finalised design, the plug may be replaced by a valve identical to the one in the fuel building.

6.4. CHARACTERISTICS OF EQUIPMENT

6.4.1. Pool liner

As described in section 6.2 above, the watertight liner is made of metal panels of austenitic stainless steel sheets free of molybdenum with characteristics described in the ETC-C.

Its minimum thickness is 4 mm for the vertical sheets and 6 mm for the bottom of the pools.

The metal panels are welded onto anchors set into the structural concrete. These anchors, vertical and horizontal, are laid out on a regular grid pattern.

The transfer compartments have a recess near the extremity of the transfer tube. The top of these recesses is covered with metal panels anchored using the same method as for the vertical walls and bottoms of the compartments.

6.4.2. Racks for storage and attachment of equipment

The equipment located in the pools (stands for storing reactor vessel internals and other equipment) is directly attached to anchoring plates which are directly attached to the structural concrete in order to avoid the transfer of load through the liner.

The liner is welded onto these anchor plates.

The surface of the liner, including anchor plates, must be smooth in order to allow easy decontamination.

The fuel storage racks are seated on the floor (without anchors).

6.4.3. Piping penetrating the pool wall

The pipes are connected to the pool liner in such a way that no additional stress is placed on the watertight liner.

The leak tightness of these connections is checked.

6.4.4. Leak detection and drainage

A leak detection, location and drainage system is installed in the area of the welds, behind the watertight liner. The leak drainage channels are installed along the anchoring grid of the metal liner, on the vertical walls and the bottom of the pool.

Any leakage is collected from each panel. Each drain can be isolated in order to locate the leak. A flow meter is installed on each drain header inlet.

The drains are equipped with isolation valves to control loss of water from the pool in the event of a leak.

It may be possible to do a radiographic control on the welds of the pools that can't be drained, for example the fuel building pool.

The welds of the compartments that can be drained may not be controlled by radiography.

Radiographic control can be extended to all the "always filled with water" compartments (even if they can be drained) when it is technically possible.

6.4.5. Gates and doors

Every compartment in each of the pools can be isolated from adjacent compartments by removable gates and/or doors so that each compartment is sealed with respect to the others.

As far as the compartments that are permanently full of water are concerned, (spent fuel pool and equipment storage compartment), the gates must be water-tight and capable of holding a hydrostatic pressure in the direction "full water compartment" towards "other compartments".

6.4.6. Lighting

The pools are equipped with an interior lighting system. The lighting is waterproof and protected against corrosion.

6.5. SAFETY ANALYSIS

6.5.1. Compliance with regulations

The design of the pools complies with the national regulations in force.

6.5.2. Other regulatory requirements: specific EPR texts

The pool liners comply with the requirements given in the ETC-C [Ref-1] [Ref-2].

6.5.3. Functional criteria regarding leak resistance

Any leak in the pool liner is detected by measuring water flow by means of the leak detection and drainage system. The damaged liner panel can be located to enable repairs.

If a serious leak occurs, loss of water from the pool can be stopped using isolation valves located on the drainage channels. Water losses are thus always minimal.

6.5.4. Design requirements regarding internal and external hazards

The pools are designed to resist earthquakes, in compliance with the ETC-C [Ref-1] [Ref-2].

The temperature increases resulting from an earthquake are studied in the design [Ref-3].

In the case of the spent fuel pool which is always filled with water, containment is also ensured for loads associated with reference incidents and accidents and operating conditions involving multiple failures (RRC-A).

6.6. TESTING, INSPECTION AND MAINTENANCE

6.6.1. Operational testing

Different tests are performed to validate the performance of the metallic liner before the pools are filled:

- Tests and checking of the water-tightness,
- Tests and checking of materials,
- Tests and checking of doors and gates,
- Tests and checking of leak detection and drainage system.

These tests are described in the ETC-C [Ref-1] [Ref-2] and are also mentioned in the specification for leaktightness testing [Ref-3].

6.6.2. Periodic tests

The types of tests, their evaluation, frequency and the measuring devices used are defined in the inspection follow-up document.

The main visual inspections of the metal liner are performed using a waterproof camera.

6.6.3. Maintenance and inspection

The metal liner of the pools does not require preventive maintenance.

The leak detection system is fitted on all anchors on the liner of compartments in the two pools. All leaks can be detected, located and repaired.

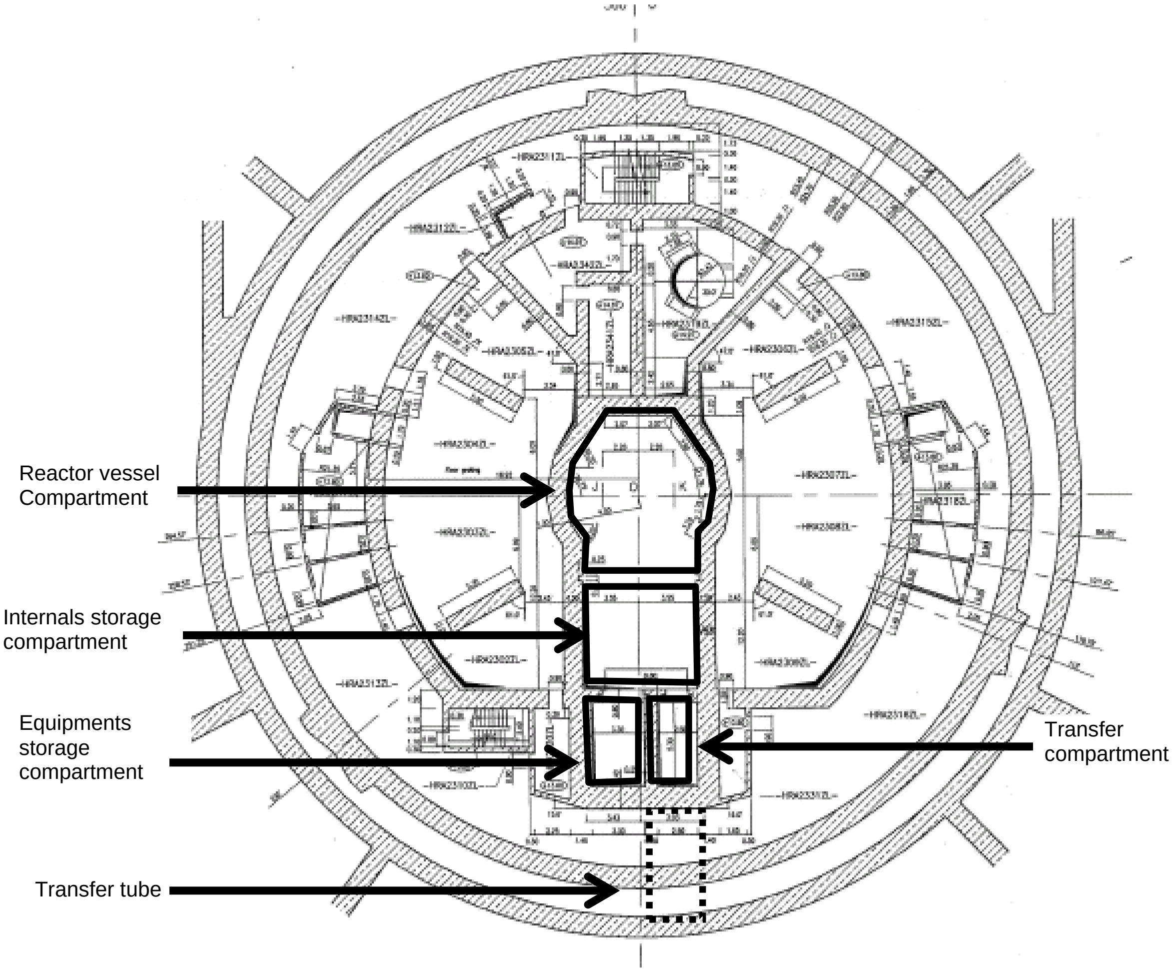
For inspection of the deactivation compartment, which is permanently filled with water, a weld radiography system is fitted on the walls of the fuel building pool.

Corrective maintenance concerns only welds and welded components of the pool liners.

Temporary welds may be made when a leak is detected. Such temporary welds are valid only for the time until a permanent repair can be performed.

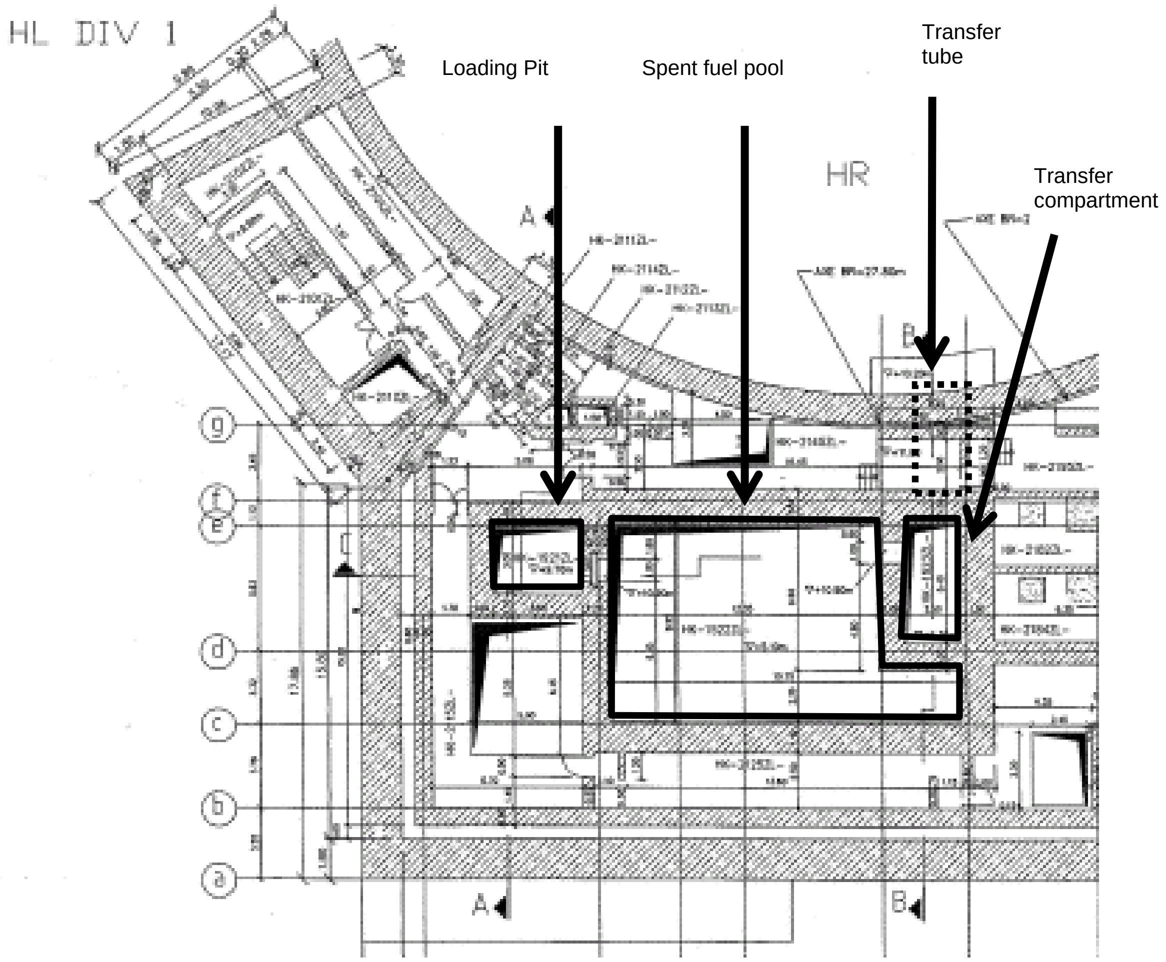
SECTION 9.1.6 - FIGURE 1 [REF-1]

Pool and compartments of HR Building



SECTION 9.1.6 - FIGURE 2 [REF-1]

Pool and compartments of HK Building



SUB-CHAPTER 9.1 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. NEW FUEL DRY STORAGE RACK

1.2. DESIGN BASES

[Ref-1] N Leriquier. Equipment specification for new fuel dry storage rack
NEER-F DC 102 Revision D. AREVA NP. March 2009. (E)

[Ref-2] EPR - FA3 Criticality study of the new fuel dry storage rack.
NEPC-F DC 364 Revision A. AREVA. January 2010. (E)

NEPC-F DC 364 Revision A is the English translation of NEPC-F DC 21 Revision B.

1.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

[Ref-1] N Leriquier. Equipment specification for new fuel dry storage rack
NEER-F DC 102 Revision D. AREVA NP. March 2009 (E)

1.4. PRELIMINARY SAFETY ANALYSIS

1.4.1. Compliance with the functional criteria

[Ref-1] EPR - FA3 Criticality study of the new fuel dry storage rack.
NEPC-F DC 364 Revision A. AREVA. January 2010. (E)

NEPC-F DC 364 Revision A is the English translation of NEPC-F DC 21 Revision B.

[Ref-2] Ph Gauthier. Mechanical analyses of new fuel dry storage rack
NEER-F DC 112 Revision C. AREVA NP. September 2009. (E)

SECTION 9.1.1 - FIGURE 1

[Ref-1] Priol. New fuel dry storage rack, Equipment drawing
NEER-F DB 1286 Revision E. AREVA NP. August 2009. (E)

2. UNDERWATER FUEL STORAGE RACK

2.2. DESIGN BASIS

[Ref-1] N. Leriquier. Equipment specification for underwater fuel storage rack NEER-F DC 100 Revision D. AREVA NP. February 2009. (E)

[Ref-2] C Van Frank. EPR - FA3 Underwater fuel storage racks, Neutronic calculations NEPC-F DC 33 Revision B. AREVA NP. July 2007. (E)

[Ref-3] Residual Decay Heat Curves for Major Components Design Purposes Heat Load inside the Fuel Pool. NEPC-F DC 164 Revision B. AREVA NP. November 2008. (E)

2.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

[Ref-1] N. Leriquier. Equipment specification for underwater fuel storage rack NEER-F DC 100 Revision D. AREVA NP. February 2009. (E)

2.4. PRELIMINARY SAFETY ANALYSIS

2.4.1 Compliance with regulations

2.4.1.1. Technical directives

[Ref-1] Technical Guidelines for the design of the next generation of nuclear power plants with pressurized water reactors (index G1). DGSNR/SD2/0729. September 2004. (E)

2.4.2. Compliance with functional criteria

[Ref-1] C Van Frank. EPR - FA3 Underwater fuel storage racks, Neutronic calculations NEPC-F DC 33 Revision B. AREVA NP. July 2007. (E)

[Ref-2] L Mercier. Underwater fuel storage rack, Mechanical analyses NEER-F DC 113 Revision D. AREVA NP. March 2009. (E)

SECTION 9.1.2 - FIGURES 1 TO 3

[Ref-1] Priol. Underwater fuel storage rack, Layout drawing NEER-F DB 1285 Revision E. AREVA NP. March 2009. (E)

[Ref-2] Priol. Underwater fuel storage rack, Equipment drawing NEER-F DB 1287 Revision E. AREVA NP. March 2009. (E)

3. SPENT FUEL COOLING AND PURIFICATION SYSTEM (PTR [FPPS/FPCS]) – EXCLUDING IRWST

[Ref-1] System Design Manual - PTR Fuel Pool Cooling System - Part 2 System Operation, SFL–EF-MF 2006-712 Revision G1. Sofinel. August 2009. (E)

[Ref-2] System Design Manual - Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P3 – System and component design. EYTF/2007/fr/0055 Revision E1. Sofinel. September 2009. (E)

[Ref-3] System Design Manual Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P4 – Flow diagrams. SFL-EFMF 2006.759 Revision F. SOFINEL. September 2008. (E)

[Ref-4] Dossier de Système Élémentaire PTR, P4.1 – Schémas Mécaniques Fonctionnels [System Design Manual Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P4.1 – System flow diagrams] EYRC/2006/fr/0004 Revision B. SOFINEL. February 2007.

[Ref-5] Dossier de Système Élémentaire PTR, P4.2 – Schéma Mécanique Detaille [System Design Manual Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P4.2 – Detailed flow diagrams] SFL-EFMF 2006.1559 Revision E. SOFINEL. August 2008.

[Ref-6] System Design Manual - Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]) P5 – Instrumentation and Control. SFL EF MF 2006.751 Revision F1. Sofinel. September 2009. (E)

3.2. DESIGN BASIS

3.2.1. General assumptions

3.2.1.1. Spent fuel pool cooling system

[Ref-1] Operating situation with diversification of the heat sink by the outfall structure. ECEF060501 Revision A1. EDF. October 2012. (E)

ECEF060501 Revision A1 is the English translation of ECEF060501 Revision A.

[Ref-2] System Design Manual - Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P3 – System and component design. EYTF/2007/fr/0055 Revision E1. Sofinel. September 2009. (E)

3.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

3.3.1. General description

[Ref-1] System Design Manual - PTR Fuel Pool Cooling System - Part 2 System Operation, SFL–EFMF 2006.712 Revision G1. Sofinel. August 2009. (E)

3.5. PRELIMINARY SAFETY ASSESSMENT

3.5.1. Compliance with functional criteria

[Ref-1] System Design Manual - Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P3 – System and component design. EYTF/2007/fr/0055 Revision E1. Sofinel. September 2009. (E)

[Ref-2] Residual Decay Heat Curves for Major Components Design Purposes Heat Load inside the Fuel Pool. NEPC-F DC 164 Revision B. AREVA NP. November 2008. (E)

[Ref-3] Functional study on the treatment of PCCs and RRC-As involving spent fuel pool cooling loss and draining. ECEF080499 Revision B1. EDF. November 2012. (E)

SECTION 9.1.3 - FIGURES 1 TO 4

[Ref-1] System Design Manual - PTR Fuel Pool Cooling System - Part 2 System Operation, SFL–EFMF 2006.712 Revision G1. Sofinel. August 2009. (E)

[Ref-2] Dossier de Système Élémentaire PTR, P4.1 – Schéma mécanique fonctionnel [System Design Manual Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS]), P4.1 – System flow diagrams] ECEF072078 Revision B. June 2010.

4. FUEL HANDLING SYSTEM

4.2. DESIGN BASES

[Ref-1] F.Darcel. System Design Manual. PMC (Fuel Handling) System Specifications. ECEMA061033 Revision A1. EDF. July 2009. (E)

[Ref-2] F Darcel. System Design Manual. DMK (Spent Fuel Casks Transfer Facility) System Specifications. ECEMA060983 Revision A1. EDF. March 2009. (E)

[Ref-3] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

4.3. DESCRIPTION AND CHARACTERISTICS OF EQUIPMENT

4.3.1. Description of the system

[Ref-1] F.Darcel. System Design Manual. PMC (Fuel Handling) System Specifications. ECEMA061033 Revision A1. EDF. July 2009. (E)

[Ref-2] F Darcel. System Design Manual. DMK (Spent Fuel Casks Transfer Facility) System Specifications. ECEMA060983 Revision A1. EDF. March 2009. (E)

[Ref-3] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

4.3.2. Description of equipment

4.3.2.1. Reactor building platform

[Ref-1] F Darcel. System Design Manual. PMO System Specifications. ECEMA070399 Revision A1. EDF. April 2009. (E)

4.3.2.2. Instrumentation lances platform

[Ref-1] F Darcel. System Design Manual. PMO System Specifications. ECEMA070399 Revision A1. EDF. April 2009. (E)

4.3.2.3. Refuelling Machine

[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

4.3.2.5. Spent Fuel Mast Bridge

[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

4.3.2.8. Auxiliary Crane

[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

4.3.2.9. Handling tools

[Ref-1] F Darcel. System Design Manual. PMO System Specifications. ECEMA070399 Revision A1. EDF. April 2009. (E)

[Ref-2] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

4.4. SAFETY ANALYSIS

4.4.1. Compliance with functional criteria

4.4.1.1. General provisions

4.4.1.1.1. Control of reactivity

<u>Maintenance of the sub-critical state of fuel assemblies</u>

[Ref-1] Jamet. Functional Requirements and Interfaces – Fuel Control Rods. NEPC-F DC 18 Revision E. AREVA. 2008. (E)

4.4.1.1.3. Containment of radioactive substances

[Ref-1] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

[Ref-2] Jamet. Functional Requirements and Interfaces – Fuel Control Rods. NEPC-F DC 18 Revision E. AREVA. 2008. (E)

4.4.1.2. Specific provisions

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[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

4.5. TESTS, INSPECTION AND MAINTENANCE

4.5.1. Pre-operational testing

[Ref-1] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5. OTHER HANDLING SYSTEMS

5.1. SPENT FUEL CASK TRANSFER FACILITY (DMK)

5.1.2. Design bases

[Ref-1] F Darcel. System Design Manual. DMK (Spent Fuel Casks Transfer Facility) System Specifications. ECEMA060983 Revision A1. EDF. March 2009. (E)

[Ref-2] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5.1.3. Description, characteristics of equipment

[Ref-1] F Darcel. System Design Manual. DMK (Spent Fuel Casks Transfer Facility) System Specifications. ECEMA060983 Revision A1. EDF. March 2009. (E)

[Ref-2] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

SECTION 9.1.5.1 - FIGURE 1

[Ref-1] F Darcel. System Design Manual. DMK (Spent Fuel Casks Transfer Facility) System Specifications. ECEMA060983 Revision A1. EDF. March 2009. (E)

5.2. POLAR CRANE (DMR)

5.2.0. Safety requirements

5.2.0.3. Design requirements

5.2.0.3.1. Safety classification requirements

5.2.0.3.1.2. Single failure criterion

[Ref-1] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5.2.1. Role of the System

[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

5.2.2. Design basis

[Ref-1] J Belair, P Boursat. Reactor Building Handling Equipment – DMR – HR
Plant System File P2 – System Operation.
EYTM/2009/FR/0074 Revision B1. Sofinel. 2009. (E)

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[Ref-2] J Belair, P Boursat. Reactor Building Handling Equipment – DMR – HR
System Description P3 – Design of systems and components.
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EYTM/2009/FR/0075 Revision B1 is the English translation of EYTM/2009/FR/0075 Revision B

[Ref-3] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5.2.4.1. Compliance with functional criteria

[Ref-1] N Dutheil UK EPR GDA - Management of Nuclear Safety Significant Lifting ECEMA101802 Revision B. EDF. December 2010. (E)

5.2.3. Description, characteristics of equipment

[Ref-1] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5.2.4. Safety analysis

5.2.4.1. Compliance with functional criteria

[Ref-1] Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

5.2.5. Testing, inspection and maintenance

5.2.5.1. Tests before commissioning

[Ref-1] D. Revaud. Book of Technical Specifications (TS) – “High safety” lifting and handling machines. CST 60.C.007.03. EDF (SEPTEN). 2004. (E)

6. DESIGN OF POOL LINERS (EXCEPT IRWST)

6.2. LINER DESIGN BASIS

[Ref-1] Pools and Tanks Liner Design Requirements and Methodology. ENGSGC110243 Revision B. EDF. February 2012. (E)

[Ref-2] EPR Technical Code for Civil Works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-3] UK Companion Document to AFCEN ETC-C – Part 1. ENGSGC110015 Revision E. EDF. August 2012. (E)

6.3. DESCRIPTION OF THE POOLS

6.3.1. Reactor building

[Ref-1] Design, Construction and Testing of EPR Pool Liners ECEIG060543 Revision C1. EDF. June 2009. (E)

ECEIG060543 Revision C1 is the English translation of ECEIG060543 Revision C.

6.3.2. Fuel building

[Ref-1] Design, Construction and Testing of EPR Pool Liners
ECEIG060543 Revision C1. EDF. June 2009. (E)

ECEIG060543 Revision C1 is the English translation of ECEIG060543 Revision C.

6.5. SAFETY ANALYSIS

6.5.2. Other regulatory requirements: specific EPR texts

[Ref-1] EPR Technical Code for Civil Works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-2] UK Companion Document to AFCEN ETC-C – Part 1. ENGSGC110015 Revision E. EDF. August 2012. (E)

6.5.4. Design requirements regarding internal and external hazards

[Ref-1] EPR Technical Code for Civil Works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-2] UK Companion Document to AFCEN ETC-C – Part 1. ENGSGC110015 Revision E. EDF. August 2012. (E)

[Ref-3] Design, Construction and Testing of EPR Pool Liners
ECEIG060543 Revision C1. EDF. June 2009. (E)

ECEIG060543 Revision C1 is the English translation of ECEIG060543 Revision C.

6.6. TESTING, INSPECTION AND MAINTENANCE

6.6.1. Operational testing

[Ref-1] EPR Technical Code for Civil Works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-2] UK Companion Document to AFCEN ETC-C – Part 1. ENGSGC110015 Revision E. EDF. August 2012. (E)

[Ref-3] Design, Construction and Testing of EPR Pool Liners
ECEIG060543 Revision C1. EDF. June 2009. (E)

ECEIG060543 Revision C1 is the English translation of ECEIG060543 Revision C.

SECTION 9.1.6 - FIGURES 1 AND 2

[Ref-1] Design, Construction and Testing of EPR Pool Liners
ECEIG060543 Revision C1. EDF. June 2009. (E)

ECEIG060543 Revision C1 is the English translation of ECEIG060543 Revision C.