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SUB-CHAPTER 3.5 – SAFETY RELATED INTERFACES

1. SAFETY INTERFACES IN THE NUCLEAR ISLAND BETWEEN THE MECHANICAL EQUIPMENT AND CIVIL STRUCTURES

1.1. INTRODUCTION

Specific requirements apply to connections between safety classified mechanical equipment and civil engineering structures.

These connections include:

- Standard supports and shock absorbers
- Pipe whip restraints
- Penetration junctions
- Barriers, shielding and casemates
- Anchors

The pool and containment inner wall liners are considered to form part of the civil structures and therefore are not considered in this sub-chapter.

1.2. FUNCTIONS

- a) Supports are installed and designed to keep the stresses, deformation and vibration of equipment and pipework within acceptable limits, enabling them to maintain their integrity and operability for all operating conditions of the plant.
- b) Shock absorbers are designed to protect the equipment and pipework from the effects of dynamic events, typically earthquakes, while allowing slow displacements such as thermal expansion and slow differential movements.
- c) Pipe-whip restraints are structures designed to eliminate or reduce the consequences of the free displacement or “whipping” of pipework sections presumed to have ruptured. They are installed to fulfil one or more of the following design functions:
 - avoidance of excessive impact loads on civil engineering works in their vicinity
 - prevention of impact damage to neighbouring pipes and components
 - limitation of the size of a breach and consequently of the depressurisation rate of the fluid circuit

d) Penetrations are of 3 basic types:

- Mechanical penetrations
- Electrical penetrations
- Special penetrations: equipment airlock, fuel transfer airlock and tube

e) Barriers, shielding and bunkers protect against the damaging effects of fire, flood, missiles, whipping and jets induced by a pipework rupture.

1.3. DESCRIPTION OF MECHANICAL DESIGN

a) In principle, supports and shock absorbers are designed to:

- Remain elastic in normal and abnormal operating conditions under:
 - Dead weight loads
 - Thermal expansion loads
 - Flow loads
- Remain elastic overall in accident conditions, including:
 - under loads due to pipework rupture, including ambient conditions. The effects of jet impingement and thrust loads are generally calculated for a double-ended guillotine breach, (2A breach, i.e. breach with complete off-set shear of the two pipe ends). If there is a whip restraint that limits the displacement of the free pipe ends, so that the flow area over which the fluid escapes is smaller than the pipe area (or the ruptured pipework is rigid enough to create the same result), a more realistic smaller area can be used to evaluate the loads due to the jet impingement and fluid thrust.
 - under earthquake loads in locations where the supported equipment is designed to resist displacements from earthquakes.

RCC-M [Ref] (see Sub-chapter 3.8) defines the design rules for the supports but other rules may be used (see Sub-chapter 3.2).

b) The preceding criteria do not apply to pipe whip restraints intended to sustain on a one-off basis the effects of ruptures for which they are designed. The parts intended to absorb the energy released by the whipping of the pipework are generally designed to become extremely plastic under these conditions. The other devices and anchors are designed to the same rules as supports for 4th category situations (see RCC-M).

c) A penetration junction with the internal containment envelope is usually made up of a flange welded on one side to the pipe itself and on the other to a flush mounted cylindrical sleeve (designed to Eurocode 2 [Ref]). A penetration junction with the exterior containment envelope is generally a flexible device welded to both the pipe and sleeve.

- d) The penetration junction with the internal envelope is a “fixed” support point for the pipework. It mechanically decouples the interior from the exterior. It is designed to adapt to all the loads that can be transmitted by the pipework from the interior to the exterior. This includes loads due to rupture of the pipework itself, seismic loads and all operating loads, as well as the maximum pressure that can be reached in the interior of the containment building.

Effects due to ruptured pipework to be taken into account include:

- forces transmitted directly by the pipework itself
 - forces from jet impingement
 - forces due to the local overpressure inside the sleeve
- e) All the equipment is designed to prevent the propagation of a rupture of the pipework, in accordance with the paragraph relating to internal events.

1.4. REQUIREMENTS APPLICABLE TO INTERFACE DEVICES

1.4.1. Supports and shock absorbers

- a) The support anchor plates must be large enough to distribute the load on the civil engineering structure in such a way that the stresses in the concrete remain within acceptable limits. The requirements for the interfaces between the anchors and the concrete structures can be found in ETC-C (see Sub-chapter 3.8) [Ref].
- b) Anchors traversing either of the two concrete containment wells must be designed to be leak tight. They must be avoided if possible.
- c) The supports must be designed to meet the temperature limits of the concrete as specified in Eurocode 2 [Ref].
- d) The supports must be designed to permit in-service inspection of the components and pipework that they support as well as their neighbouring components and pipework.

1.4.2. Pipe-whip and other restraints

- a) The whip restraints must be designed to maintain the loads transmitted to the support structure (a concrete structure in most cases) and to the components to which the ruptured pipework may be connected, at a low enough level to enable the support structure and components to fulfil their safety function.
- b) The space between the pipework restraints and the pipework itself must be large enough to prevent mechanical contact between them in all cases, other than that for which the restraint has been installed. In particular contact must be prevented under all normal operating conditions.
- c) The restraints must be designed in such a way that the temperature reached by the concrete stays within authorised limits (see Eurocode 2 [Ref]).
- d) The restraints must permit equipment to be inspected and serviced as required during operation.

1.4.3. Penetration junctions

- a) The containment penetrations are an integral part of the containment and must meet the criteria in Sub-chapter 3.3. The penetrations must remain leak tight in the case of a radioactivity leak within the interior of the containment and in the event of an earthquake. In particular, they must be designed to remain leak tight under the temperature and pressure conditions associated with a LOCA or a severe accident.
- b) Given that the penetration junctions are fixed rigidly to one of the two containment envelopes (usually the interior envelope), the penetration junction providing the leak tightness between the penetrating element (pipework, cables, airlocks, etc) and the other envelope, must be flexible in order to support all differential displacements that could occur between the two containment envelopes under normal, test, and accident conditions.
- c) The penetration junctions must be designed so that the temperature reached by the concrete remains within acceptable limits.
- d) The penetration junctions must also permit the vessel to be tested periodically for leak tightness.

1.4.4. Barriers, shielding and bunkers

These structures must be able to prevent loads imposed on them being transmitted to the structure of the building (i.e. loads due to events against which they provide protection), without losing their integrity.

2. INTERFACES RELATING TO THE SAFETY OF ELECTRICAL EQUIPMENT AND CIVIL ENGINEERING

2.1. INTRODUCTION

The requirements relate to the links between safety-classed electrical equipment and civil engineering structures.

These links relate to:

- the supports and anchors of the electrical equipment
- the electrical penetrations of the reactor building

2.2. FUNCTIONS

- a) The term "support" encompasses the mechanical devices: mountings, screws, etc necessary to absorb the loads due to electrical equipment (motors, cables, cupboards, panels, boxes and small equipment) and transmit them to supporting structures (concrete structures, steelwork, mechanical equipment, etc).

- b) The supports (and anchors) must withstand the effects of stresses and deformations capable of affecting the supported equipment so that they do not adversely affect the functioning of the equipment.
- c) The anchors provide the link between the concrete structures and the equipment supports.
- d) The electrical penetrations of the reactor building ensure a leak tight passage through the walls of the building for all electrical conductors for the conditions specified in the interface requirements.

2.3. DESIGN OF SUPPORTS OF MECHANICAL EQUIPMENT

For the mechanical design of the supports, anchors and penetrations, the criteria applied are those that permit the electrical equipment to fulfil their functions in a satisfactory manner under all operating conditions for the following loads:

- Dead weight loads
- Loads resulting from operation of the equipment or of certain components
- Loads due to:
 - Displacements imposed
 - Thermal expansion
 - Electrical transients
- Seismic loads when the equipment is supported or anchored are assigned a seismic classification.

RCC-M (see Sub-chapter 3.8) defines the design rules for the supports of equipment which are designed in accordance with RCC-M [Ref].

2.4. REQUIREMENTS RELATING TO INTERFACE DEVICES

2.4.1. Supports and anchors

- a) The analysis of supports and anchors must take into account the effects of seismic loads when the equipment supported or anchored is assigned a seismic classification.
- b) The requirements relating to anchors are covered by ETC-C (see Sub-chapter 3.8) [Ref].
- c) The supports and anchors must be designed to permit in-service inspection of the electrical equipment, if necessary.
- d) For safety-classified motors having supports separate from the equipment involved, RCC-M (see Sub-chapter 3.8) applies to the mechanical link between the supports and the anchors of the supports [Ref].

2.4.2. Electrical penetrations of the containment

The penetrations must be an integral part of the containment and satisfy the design criteria for the containment vessel (see Eurocode 2 [Ref]). They must, in particular, be designed to remain leak tight:

- under all operating conditions, including PCC and RRC.
- in the presence of the seismic loads (from earthquake events), that are considered in the design.
- following short-circuits in the electrical power supply.

Note: The design of the flanges conforms to RCC-M (see Sub-chapter 3.8) [Ref].

3. SAFETY RELATED INTERFACES BETWEEN THE NUCLEAR ISLAND AND NON-NUCLEAR AREAS

3.1. GENERAL PRINCIPLES

The basic principle is to achieve separation between the nuclear island and the non-nuclear areas of the installation. This is achieved by taking adequate implementation measures to avoid unacceptable effects on the nuclear island from the non-nuclear areas.

The interface requirements for the following systems are discussed below:

- Fluid systems
- Electrical systems
- Instrumentation and control systems
- Other interfaces

Details are provided in detailed design reports.

3.2. FLUID SYSTEMS

The following systems, described in other chapters, have interfaces with the nuclear island and the non-nuclear areas of the installation:

- Main steam system (see Sub-chapter 10.3)
- Main feedwater system, including start-up/shutdown feed pump (see Sub-chapter 10.6)
- Steam generator blowdown system (see Sub-chapter 10.4 and Sub-chapter 11.2)
- Essential service-water system (see Sub-chapter 9.2)

- System for purification, degassing, storage and treatment of primary coolant (see Sub-chapter 9.3 and Sub-chapter 11.2)
- Fire-fighting equipment (see Sub-chapter 9.5)
- System for storage and distribution of gases (see Sub-chapter 11.2 and Sub-chapter 11.4)
- System for treating liquid effluents (see Sub-chapter 11.4)

The interface criteria for the demineralised water distribution system and the hot water distribution system will be developed during the detailed design. The interface criteria for the condensate extraction system (CEX) are dependent on the detailed design of the conventional island and are outside the scope of GDA for the UK EPR.

3.3. ELECTRICAL SYSTEMS

As mentioned above under the general principles, unacceptable effects of the non-nuclear part of the installation on the nuclear island must be avoided by physical separation.

The following interfaces exist:

- Two independent links to the grid are required as follows:
 - A link to the main grid, equipped with a generator breaker on the high voltage side of the main transformer, providing sufficient power for normal shutdown and start-up of the plant.
 - A link to the auxiliary grid able to support shutdown operation of the plant via the auxiliary network. This link must be capable of allowing manual start-up of a primary coolant pump. Residual heat is removed by partially opening a bypass to the condenser with, at a minimum, an extraction pump, a circulation pump and a start-up/shutdown feed pump in operation. A main feedwater pump must also be able to be restarted.
- The two network connections must be sufficiently independent from each other so that an electrical failure of one of the connections cannot affect the second.
- The turbine must be capable of powering the electrical circuits of the nuclear island under house load operation.
- In case of a failure of the electrical connection to the main network, the event sequence is as follows:
 - Open the circuit-breaker, switch to house load
 - If this fails, switch to the auxiliary line
 - If this fails, open the 10kV circuit-breakers between the backup busbars of the conventional island and the nuclear island and start the backup diesel generators sets.

- The structure and number of normal electrical power supply circuit trains of the conventional island must be such that the loss of a train within the conventional island due to an electrical failure cannot affect more than one backup power train in the nuclear island.

3.4. INSTRUMENTATION AND CONTROL

Operational control of the entire plant must be possible from the main control room, via level 2 and level 1 systems. As mentioned in the general principles, unacceptable consequences of failures in the non-nuclear part of the plant on the nuclear island must be avoided by separation.

The following signals are supplied to the nuclear island from the non-nuclear part of the installation:

- Interlock and protection signals exchanged between the conventional island and nuclear island
- Turbine and generator control
- Turbine trip
- Stop signals for feedwater pumps
- Other signals for monitoring large components (not yet determined), for example feedwater pumps, condensate system etc.
- Condenser availability signal
- Position indicators for turbine stop valves
- Control signal for circuit carrying out steam dump to the condenser
- Signal indicating power level in the secondary circuit
- Signal regulating motor speed of ARE [MFWS] pumps (if necessary)
- Turbine first stage pressure signal
- Command signal for circuit-breaker(s) for the control rods
- Instrumentation used in incidents: meteorological instrumentation in the non-nuclear part of the installation.

3.5. OTHER INTERFACES

3.5.1. Pipework, ventilation

As mentioned in the general principles, unacceptable consequences of failures in the non-nuclear part due to plant on the nuclear island must be avoided by separation. This is achieved by construction measures (for example, the use of fixed restraints and/or anchors to prevent consequential damage) and by installing isolation devices.

The following interfaces can be identified at the current design stage:

- Safeguard buildings:
 - Pipework branches in the backup feedwater circuit passing from the exterior to each of the safeguard buildings
 - Pipework branches in the liquid effluent treatment system passing between safeguard building no. 4 and the access building.
- Main steam valves / feedwater valves bunkers:
 - Main steam and feedwater pipework branches.
- Safety buildings, fuel building, nuclear auxiliary buildings, diesel buildings:
 - Pipework branches in fire-fighting circuits.
- Nuclear auxiliary buildings:
 - Pipework branches in auxiliary circuits (for example, demineralised water, compressed air, etc) passing from the exterior of the nuclear auxiliary building via a service duct
 - Pipework branches passing between the nuclear auxiliary building and the effluent treatment building, which are part of the above circuits and other circuits that terminate in the effluent treatment building (coolant purification system, coolant treatment systems, etc)
 - Ventilation branches passing between the access building and the nuclear auxiliary buildings via the safeguard building division 4
 - Ventilation branches passing between the nuclear auxiliary buildings and the effluent treatment building.
- Diesel buildings:
 - Pipework branches in auxiliary circuits (for example, compressed air, etc) passing from the exterior to the diesel buildings.

3.5.2. Turbine orientation

Installation of safety equipment inside the ejection zone of projectiles produced by disintegration of the low pressure turbine stage ($\pm 25^\circ$ to the turbine axis) is avoided if possible. If the placing of safety classified redundant equipment or redundant civil works in this zone is unavoidable, measures have to be taken: orientation of the turbine axis, geographical separation, "bunkerisation" (protection against falling projectiles such as antimissile wall), increase of redundancy, so that safety functions are maintained even in case of missile impact.

3.5.3. Civil engineering

The total collapse of buildings which are monoblocks and are not designed as seismic class 1 buildings, leading to production of debris, is not considered as credible.

However, earthquake induced collapse of buildings in the unprotected zone which are not monoblocks (for example, prefabricated structures) is considered in the design. Protective structures (for example, reinforced concrete tiles) are installed, as appropriate, based on an analysis of potential damage to seismic class 1 equipment due to the collapse.

3.5.4. Discharge and waste management

As discussed in Chapter 11, radioactive waste management systems provide containment, measurement and control of solid, liquid and gaseous radioactive discharges to the environment. This management involves interfaces with the nuclear part of the installation. The basic safety principle related to these interfaces is to achieve separation between the nuclear island and the non-nuclear areas dedicated to discharge and waste management. This is achieved by taking adequate implementation measures to avoid unacceptable effects on the nuclear island from the non-nuclear areas.

At the current design stage, the circuits/locations that transport the above radioactive waste are part of:

- the system for ventilation of the inter-containment space
- the system for treatment and cooling of storage tank water
- the chemical and volume control system
- the primary coolant purification system
- the system for ventilation of controlled zones
- the steam generator purge system
- the gaseous effluent treatment system
- the Nuclear Auxiliary Building - Effluent Treatment Building tunnel.

SUB-CHAPTER 3.5 – REFERENCES

External references are identified within this sub-chapter by the text **[Ref]** 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. SAFETY INTERFACES IN THE NUCLEAR ISLAND BETWEEN THE MECHANICAL EQUIPMENT AND CIVIL STRUCTURES

1.3. DESCRIPTION OF MECHANICAL DESIGN

[Ref] Design and Construction Rules for Mechanical Components of PWR Nuclear Islands. RCC-M 3rd modification. AFCEN. June 2007. (E)

[Ref] Eurocode 2 – Design of concrete structures. NF EN 1992-1-1. AFNOR. 2005. (E)

1.4. REQUIREMENTS APPLICABLE TO INTERFACE DEVICES

1.4.1. Supports and shock absorbers

[Ref] ETC-C (EPR Technical Code for Civil works). ENGSGC050076 Revision B. EDF. April 2006. (E)

[Ref] Eurocode 2 – Design of concrete structures. NF EN 1992-1-1. AFNOR. 2005. (E)

1.4.2. Pipe-whip and other restraints

[Ref] Eurocode 2 – Design of concrete structures. NF EN 1992-1-1. AFNOR. 2005. (E)

2. INTERFACES RELATING TO THE SAFETY OF ELECTRICAL EQUIPMENT AND CIVIL ENGINEERING

2.3. DESIGN OF SUPPORTS OF MECHANICAL EQUIPMENT

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2.4. REQUIREMENTS RELATING TO INTERFACE DEVICES

2.4.1. Supports and anchors

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[Ref] Design and Construction Rules for Mechanical Components of PWR Nuclear Islands. RCC-M 3rd modification. AFCEN. June 2007. (E)

2.4.2. Electrical penetrations of the containment

[Ref] Eurocode 2 – Design of concrete structures. NF EN 1992-1-1. AFNOR. 2005. (E)

[Ref] Design and Construction Rules for Mechanical Components of PWR Nuclear Islands. RCC-M 3rd modification. AFCEN. June 2007. (E)