Form10/00

UK ABWR

Document ID	:	GA91-9101-0101-20004
Document Number	:	HE-GD-5054
Revision Number	:	A

UK ABWR Generic Design Assessment

Generic PCSR Sub-chapter 20.4 : Protection and Provisions against Direct Radiation

Hitachi-GE Nuclear Energy, Ltd.

DISCLAIMERS

Proprietary Information

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

Copyright

Table of Contents

20.4.1 Scope

The primary objective of radiation shielding is to protect operating personnel and the general public from the external radiation emanating from the reactor, the turbine, the radwaste management systems, and the other systems, while maintaining appropriate access for Operation Condition I excluding outages as well as maintenance.

Specifically, shielding is required to perform the following function:

- Limit the radiation exposure for workers at the plant and of the public during Operation Condition I excluding outages to levels that are ALARP and within the regulatory requirements.

The aim of this section is to describe shielding design, shielding calculation method and shielding function for workers during Operation Condition I as well as spent fuel transport to and storage in the spent fuel pool.

Shielding design and dose calculation for the public from direct radiation of all radioactive sources will be discussed in PCSR Chapter 20.7 Dose Assessment for Public from Direct Radiation in Step 3.

Also, dose calculation for workers during design basis accidents and severe accidents will be provided in PCSR Chapter 20.8 Post Accident Accessibility.

In addition, dose calculations for workers associated with spent fuel interim storage and decommissioning will be discussed in PCSR Chapter 32 and 31, respectively.

20.4.2 Shielding Design during Operation Condition I Excluding Outages

In order to meet the regulatory requirements and ensure that radiation exposure for workers is ALARP, the following design considerations are used in the shielding calculations of the UK ABWR.

20.4.2.1 Modeling

The geometry and layout of components are considered in the calculation modeling. Equipment and piping are designed in accordance with the strategy to ensure to workers that the exposure is ALARP and this is discussed in PCSR Chapter 20.3.

The mathematical models used to represent a radioactive source and associate equipment and shielding are established to ensure conservative calculational results.

In general, cylindrically-shaped equipment such as tanks, heat exchangers and demineralisers are mathematically modeled as truncated cylinders. Equipment internals are sectionally homogenised to incorporate density variations where applicable.

Complex piping runs are conservatively modeled as truncated cylinder sources spaced along the piping run. The dimension of additional thickness established for construction (such as corrugated plate) is not considered in the shielding calculation as it is part of the effective shielding thickness provided by the floor slab.

20.4.2.2 Radioactive Sources

(1) Primary sources

Radioactive sources used in shielding calculations are discussed in PCSR Chapter 20.2.

(2) Representative energies

The "representative energy" is set for each plant system in the shielding calculation. In addition, this is determined to cover the energy spectrums of gamma rays emitted by radionuclides for a system.

In terms of fission products and corrosion products for shielding design, a list of representative energies used for shielding design is shown in Table 20.4-1.

Table 20.4-1: Representative Energy of FP and CP for the Shielding Design

Representative Energy (MeV)	Scope
0.5	Downstream of off-gas hold-up system (charcoal adsorber)
1.0	Feedwater system (downstream of condensate demineraliser)
2.0	Reactor water (upstream of CUW filter demineraliser)
2.5	Condensate system Upstream of off-gas hold-up system (charcoal adsorber)
1.5	Other than those above

In terms of N-16 for shielding design, the energy is 6.2 MeV per radioactive decay.

20.4.2.3 Radiation Zoning

All systems containing radioactivity are identified and shielded based on access and exposure level requirements of surrounding areas. The shielding thickness is determined to satisfy the limit of the dose rate for radiation zones.

The determination of radiation zones is based on optimised amount of radiation exposed works in Risk Assessment (this is discussed in PCSR Sub-chapter 20.3.8). Shielding thickness determined based on radiation zones includes Risk Assessment and this leads to minimising radiation exposure to workers.

The radiation zone maps indicate design radiation levels for equipment contributing to the dose rate in the area. Shielding is designed for this equipment to reduce the dose rate in the area. The radiation zone of the corridor corresponds to C (less than 0.05mSv/h) for shielding design. The classification of radiation zones is shown in PCSR Chapter 20.3.6.4.

20.4.2.4 Shielding Materials

The primary materials used for shielding are standard concretes, iron, lead and water. The assumed density and primary scope of each shielding materials are shown in Table 20.4-2.

Table 20.4-2: Density of Shielding Materials

Shielding Materials	Density(g/cm^3)	Primary Scope
Standard Concrete	[TBD]	Shielding walls
Iron [Ref-1]	7.8	Structure or shielding materials
Lead [Ref-1]	11.3	Shielding materials
Water [Ref-1]	1.0	Sources in piping or tanks
Air [Ref-1]	1.2×10^{-3}	Atmosphere outside the building (293K,1013hPa)

20.4.2.5 Computer Codes

Different computer codes are used to calculate the necessary shielding thickness. The choice of a code is based on the calculation scope, source geometry and a type of radiation.

Table 20.4-3: Computer Codes used in Shielding Calculations

Computer Codes	Contents	Primary Scope
DORT [Ref-2 to 3]	Two Dimensional Discrete Ordinates Neutron/Photon Transport Code for gamma rays and neutrons	Calculation for - Reactor shielding wall - Primary shielding - Secondary shielding
QAD-CGGP2R [Ref-4 to 6]	Point–kernel Calculation Code for gamma rays	Calculation for - Auxiliary shieldings
MCNP5 [Ref-7 to 11]	A General Monte Carlo N-Particle Transport Code for gamma rays and neutrons	Calculation for - Direct radiation for public

20.4.2.6 Shielding Design Process

In accordance with the above-mentioned general design guides, radiation shielding thicknesses are determined to satisfy the limit of the radiation zone in adjacent rooms or areas.

The process of shielding design is shown below.

(1) Risk Assessment

Optimised amount of radiation exposed works is determined taking into account working procedure, working time, dose rate at the working area and collective dose. This is discussed in PCSR Sub-chapter 20.3.8.

(2) Determination of Radiation Zones

The radiation zones for each area are determined based on the optimised amount of work under radiation from the Risk Assessment. This is discussed in PCSR Sub-chapter 20.3.6.4.

(3) Determination of Shielding Thickness

(a) Calculating source strength based on representative energy and radioactive concentrations.
(b) Calculating the dose rate at outside surface on shielding such as walls and slabs taking into account the geometry and layout of the components in the plant by using an appropriate computer code.
(c) Determining the thickness of shielding (such as walls and slabs) to satisfy the dose rate limit of radiation zone in adjacent rooms or areas.

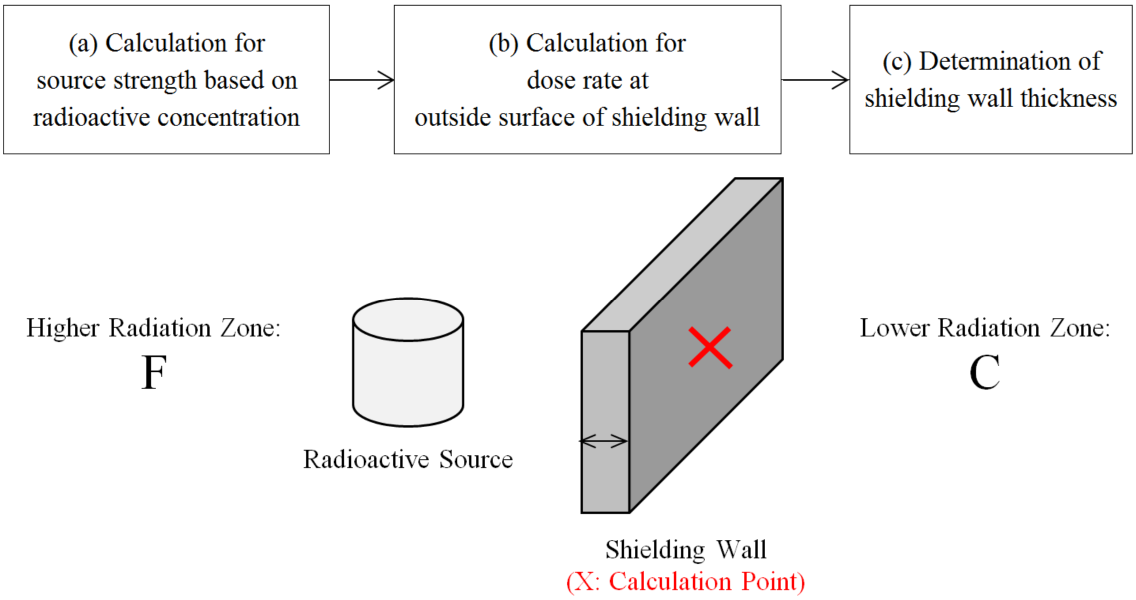

Figure 20.4-1: Calculation Procedure to determine Shielding Thickness

The parameters for basic shielding data such as cross-sections, build-up factors and radioisotope decay information are considered in the calculations.

20.4.3 Shielding Design during Outages

In addition to the considerations of the shielding design for Operation Condition I excluding outages, the shielding calculation during outages is conducted for areas in which:

- The dose rate based on actual measured data is higher than expected in shielding design, and
- The necessity of access for workers exists during outages for maintenance.

These are determined by operating experience for BWR plants.

20.4.4 Shielding Design during Spent Fuel Interim Storage

The input for shielding calculations depends on the design of the facility, the kind of interim storage (dry/wet), the planned amount of radioactivity to be stored and the other factors.

Shielding design of the interim storage facility for the public will be discussed in PCSR Sub-chapter 20.7 in Step 3. In addition, dose calculations associated with spent fuel interim storage for workers will be provided in PCSR Chapter 32.

20.4.5 Shielding Functions

20.4.5.1 Reactor Building

The five main types and locations of radiation shielding in reactor building are illustrated in Figure 20.4-2.

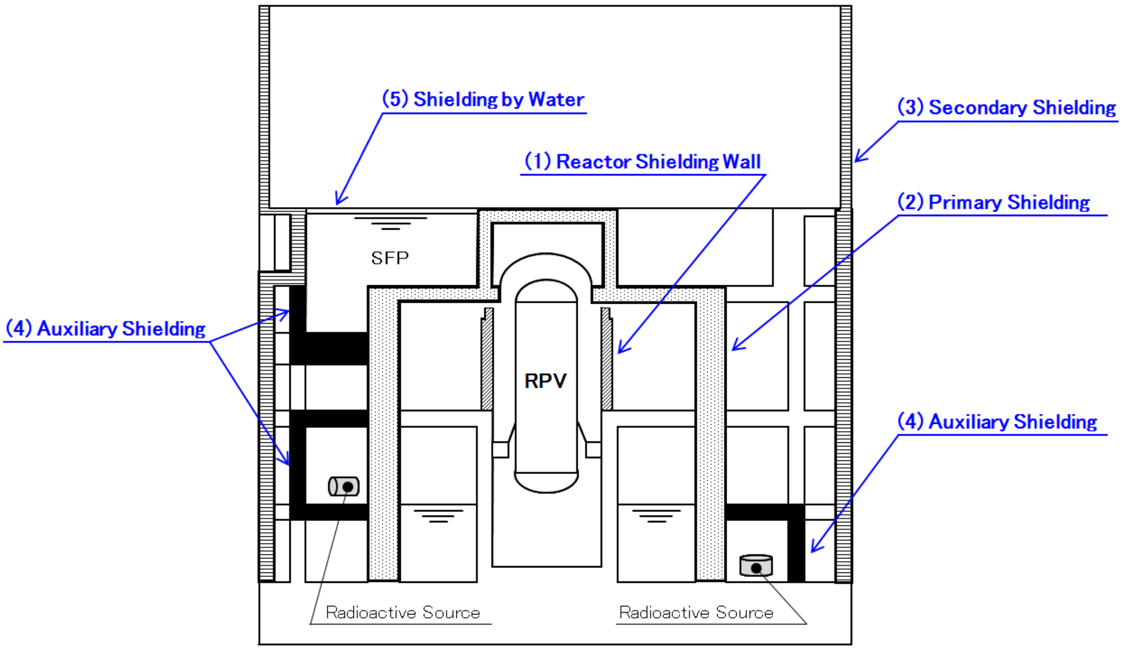

Figure 20.4-2: Main Radiation Shielding

(1) Reactor shielding wall

The reactor shielding wall attenuates radiation from the reactor during Operation Condition I excluding outages. This shielding wall protects maintenance workers in the primary containment vessel from excessive occupational exposure during outages.

(2) Primary shielding

The primary shielding is a structure that encloses the primary containment vessel and attenuates radiation from the reactor during Operation Condition I excluding outages.

(3) Secondary shielding

Secondary shielding is a concrete wall that encloses the boundary of secondary containment vessel. That shielding attenuates radiation from the reactor in combination with the primary shielding.

Secondary shielding is designed to ensure that the dose rate outside the secondary shielding is less than the dose rate required to satisfy the criteria for a non-controlled area.

(4) Auxiliary shieldings

Auxiliary shieldings are the shielding structures that enclose components such as equipment and piping containing radioactive substances in the reactor, turbine and radwaste buildings etc. This shielding attenuates the radiation emitted by radioactive sources in the components. In addition, it is installed to satisfy the dose rate for radiation zones in surrounding areas.

(5) Shielding by water

Shielding by water is considered during spent fuel transport between the reactor and the spent fuel pool (SFP), and during spent fuel storage in the SFP. Considerations for shielding calculations during those conditions are shown below. The calculational model and the calculation point in these conditions are shown in Figure 20.4-3.

(a) Spent Fuel Transport

It is assumed that one spent fuel assembly is transported. The calculation point is located on the center of the storage rack and on the level of the refueling machine. The radioactive source in this situation is provided in PCSR Chapter 20.2.

(b) Spent Fuel Storage

It is assumed that spent fuel is loaded in all of the spent fuel storage racks. The calculation point is located at the center of the fuel assembly and at the level of the refueling machine. The radioactive source in this situation is provided in PCSR Chapter 20.2.

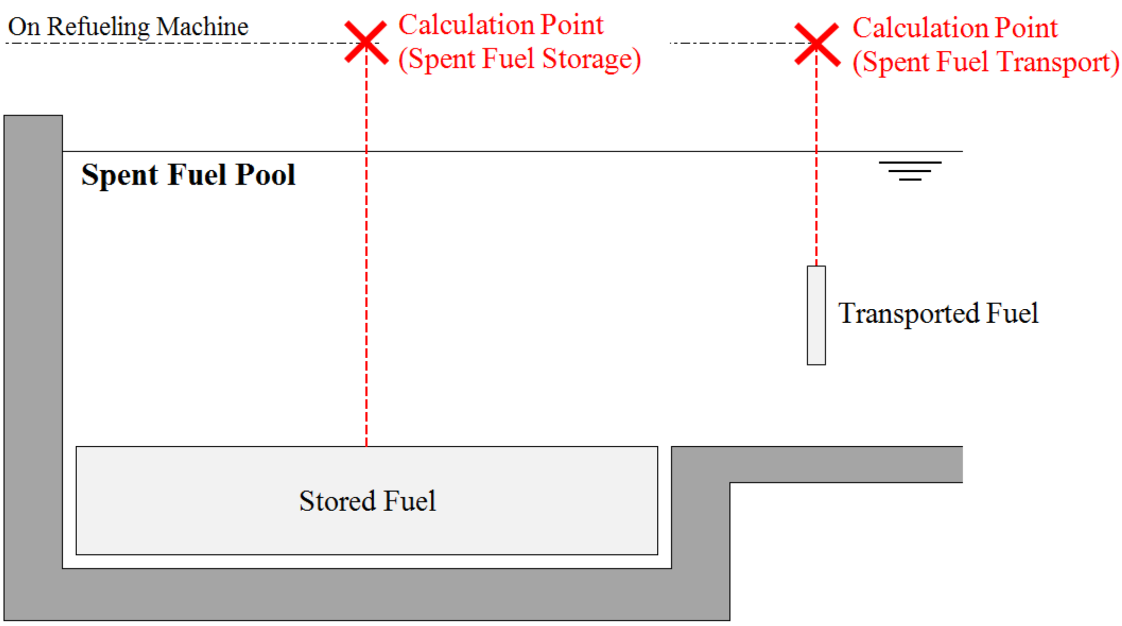

Figure 20.4-3: Calculational Models and Points

20.4.5.2 Other Buildings

(1) Main Control Room

The shielding of the main control room is installed to satisfy the dose rate for radiation zones in surrounding areas during Operation Condition I excluding outages. In addition, it is also set to protect the operators, who need to stay in this room to manage accidents, from the excessive occupational exposure during accident conditions.

(2) Other Buildings including Turbine Building and Radwaste Building

The radiation shieldings in other buildings including turbine building and radwaste building are included in auxiliary shielding.

20.4.6 References

[Ref-1] Chronological Scientific Tables 2007 Version, National Institutes of Natural Sciences (NINS), National Astronomical Observatory of Japan

[Ref-2] M. B. Emmett, W. A. Rhoades, R. L. Childs, and J. O. Johnson: The DORT section of "A User's Manual for Mash 1.0 – A Monte Carlo Adjoint Shielding Code System", ORNL/TM-11778
(http://web.ornl.gov/info/reports/1992/3445603532498.pdf)

[Ref-3] N. Yamano: "Integral Test of JENDL-3.3 with Shielding Benchmarks", Shielding Integral Test Working Group, Japanese Nuclear Data Committee
(http://wwwndc.jaea.go.jp/nds/proceedings/2002/yamano_nO.pdf)

[Ref-4] Y. Sakamoto, S. Tanaka: "QAD-CGGP2 AND G33-GP2: REVISED VERSIONS OF QADCGGP AND G33-GP," JAERI-M 90-110, Japan Atomic Energy Research Institute, (1990)
(http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAERI-M-90-110.pdf)

[Ref-5] The QAD section of "Gamma Rays Shielding Design Handbook", Atomic Energy Society of Japan (January 1998)

[Ref-6] Y. Kanai and K. Ueki: "Evaluation of Shielding Design Methods for Gamma-Ray Problems Applicable to Nuclear Radwaste Facility" (1983)
(http://www.nmri.go.jp/main/publications/paper/pdf/12/20/06/PNM12200604-00.pdf)

[Ref-7] X-5 Monte Carlo Team: MCNP – A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory, LA-UR-03-1987 (April 24, 2003)
(http://www.nucleonica.net/wiki/images/8/89/MCNPvolI.pdf)

[Ref-8] X-5 Monte Carlo Team: MCNP – A General Monte Carlo N-Particle Transport Code, Version 5, Volume II: User's Guide, LA-CP-03-0245 (April 24, 2003)
(http://catatanstudi.files.wordpress.com/2009/10/mcnp5_manual_vol_ii.pdf)

[Ref-9] X-5 Monte Carlo Team: MCNP – A General Monte Carlo N-Particle Transport Code, Version 5, Volume III: Developer's Guide, LA-CP-03-0284 (April 24, 2003)
(http://moreira.tamu.edu/BAEN625/Labs-HMW_files/MCNP5_manual_VOL_III.pdf)

[Ref-10] I. Kinoshita and K. Ueki: "Comparison of Gamma-ray Skyshine Dose Evaluation Performance among Monte Carlo Codes; EGS, MVP, MCNP"
(http://www.inss.co.jp/seika/pdf/16/282.pdf)

[Ref-11] R. Tayama, K. Wakasugi, I. Kawanaka, Y. Kadota and Y. Murakami: "Verification of BWR Turbine Skyshine Dose with the MCNP5 Code Based on an Experiment Made at SHIMANE Nuclear Power Station", The Japan Society of Mechanical Engineers, Journal of Power and Energy Systems, Vol.4, No.1, 2010
(https://www.jstage.jst.go.jp/article/jpes/4/1/4_1_54/_pdf)