Comparison of Calculated Radioactivity and Core Sample Analysis of Biological Shield Concrete Required for Study on Decommissioning of Tokai Power Station

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INTRODUCTION [1)]

The Tokai Power Station, a 166 MWe gas-cooled graphite-moderated reactor of advanced Calder-Hall type, ceased commercial operation in March 31, 1998 and at present spent fuels are being discharged. Meanwhile, a specific plan for the decommissioning scheduled to be performed after the fuel discharge is being studied.The vertical cross section of the reactor building is shown in Figure 1.Total electricity production from the begining of commercial operation to its permanent cessation was 29.0×10^9kWh and the cumulative run-time availability was 77.5%. A history of the reactor output during that period is shown in Figure 2.

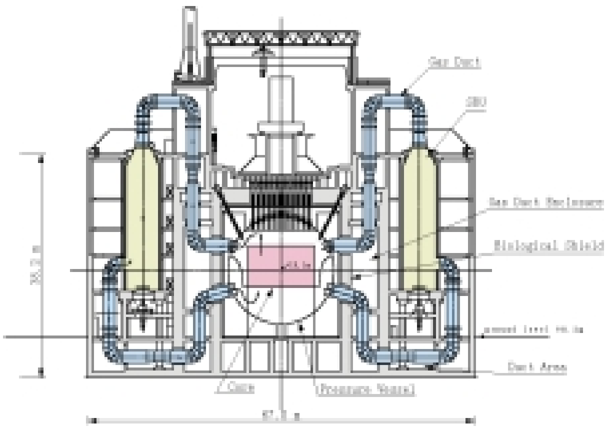

Figure 1 Vertical Cross Section of the Tokai Power Station

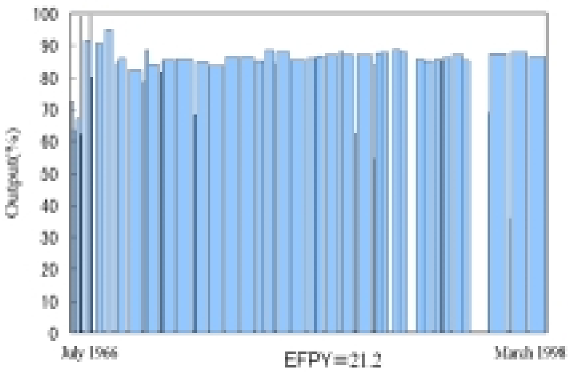

Figure 2 A history of the reactor output in Tokai Power Station

The amount of concrete of the Tokai Power Station is large and the waste of it will account more than 90% of the total waste that will be produced by dismantling. Further, radioactive nuclides concentration of it distributes widely from level of the low level radioactive waste (LLW) to below the clearance level. From these facts, it is important to evaluate precisely the radioactive concentration and amount of material corresponding to each concentration level for the purpose of estimating dismantling process, man-hour required for dismantling work, dismantling cost, disposal cost of the waste from dismantling, amount of released radioactivity as well as exposure of radiation work employees of the plant.

For this purpose, in a period from 1992 to1999, core samples were taken by boring from typical positions of the primary and secondary biological shield and data have been collected about (1) the distribution of radioactive concentration of major radioactive nuclides in the biological shield wall along the concrete thickness and (2) the spacial distribution of radioactive concentration in the primary and secondary shields. In this paper, results of radioactivity measurement and that of radioactivity calculation of major radioactive nuclides generated by neutron irradiation in these concrete are compared.

ANALYSIS[2),3)]

The evaluation of radioactive concentration necessary for preparation of the decommissioning plan has been performed based on the results of calculations, though composition of impurities and water content in the biological shields to be inputed into these calculations were determined based on actual measurements and partially on data in literature. Validity of the calculated values of neutron flux and radioactive inventory was confirmed by comparing them with the measured data such as those given in this report. A flowchart of these calculations for radioactive concentration is shown in Figure 3. The calculation codes used for the evaluation of radioactive concentration are equivalent to those used for a similar evaluation of LWR.

To calculate distribution of neutron flux corresponding to that of radioactive concentration, a two-dimensional and a three-dimensional transport calculation codes, DOT 3.5[4)] and TORT[5)] respectively, were used.

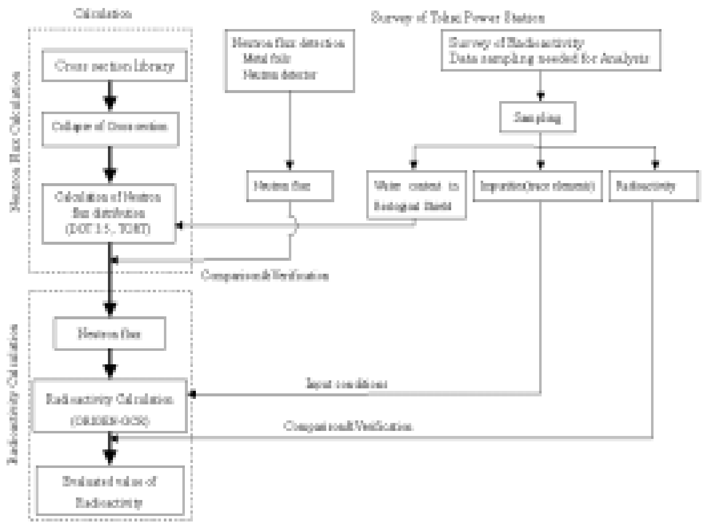

Figure 3 A flowchart of neutron flux and Radioactivity calculations

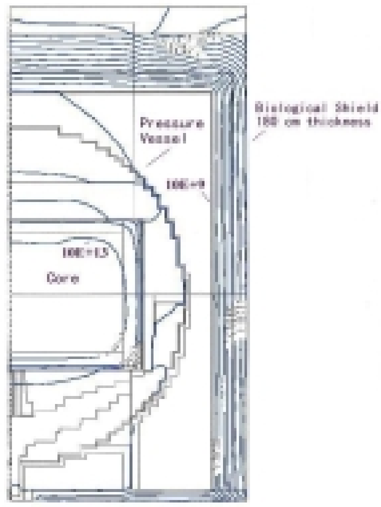

Figure 4 Flux distribution in the Biological Shield

The two-dimensional calculation was applied to an area surrounding the reactor core, that had a simple structure and the three-dimensional calculation was applied to the gas duct enclosure region that had a structure complicated by penetrations such as gas duct.

To calculate radioactivity based on the above neutron flux distribution, the ORIGEN-GCR[6] calculation code with an activation cross section library collapsed with Tokai reactor neutron spectrum was used. This cross section library is based on the nuclear data of JENDL-3[7].

Result of calculation of the neutron flux distribution surrounding the reactor core is shown in Figure 4. From this result, it can be seen that the total neutron flux which is on the order of 10^{13} (n/cm^2/sec) in the core region, is on the order of 10^9 (n/cm^2/sec) on the surface of the primary biological shield and that it has been attenuated by one order of magnitude at a depth of about 25 cm in the biological shield.

MEASUREMENT

In the Tokai Power Station, the neutron flux, radioactivity and composition have been surveyed continuously from 1992 in order to evaluate the residual radioactivity. Objects of the plant survey up to 1999 are given in Table 1. Radioactive concentration of the biological shield described in this report is the one obtained in the survey on the radioactivity.

Table 1 Objects of the plant survey

Item		1992	1993	1994	1995	1996	1997	1998	1999
Neutron flux	Detector			RSB roof, C/F, SRU roof B1F	RSB roof, SRU building, CCP building	Out of controlled area, controlled area of outdoors	RSB building, FHB building, SRU building, Outdoors		
	Metal foils	MH, BS (southern side), BCD SP room		Cold gas duct and BS(northern side)	Duct enclosure B1F～9F (southern side)	Duct enclosure B1F～9F (northern side), C/F			
Radioactivity	Biological shield	Primary biological shield	Primary and Secondary biological shield	Primary and Secondary biological shield	Secondary biological shield	Primary and Secondary biological shield		Primary and Secondary biological shield	Secondary biological shield
	Structure	Graphite and Carbon steel test pieces				Graphite test pieces			Graphite test pieces
Compositions	Impurities (trace elements)	Graphite moderator, Carbon steel, Concrete	Graphite moderator, Carbon steel, Concrete	Asbestos	Aluminum, Stainless steel	Stainless steel	Concrete (non radioactive)	Graphite reflector, Carbon steel	
	Water contents in biological shield				RSB 1F	BS 1F,3F,5F			

C/F : Operation floor of the reactor building, RSB : Reactor service building, FHB : Fuel handling building, SRU : Steam raising unit,
CCP : Cartridge cooling pond, BCD : Burst cartridge detector, BS : Blimp space, MH : Mortality hole

Sampling survey of the biological shield has been performed mainly for the purposes of determining the radioactive concentration and the area of the biological shield affected by irradiation. For the former purpose, distribution of the radioactive concentration of major nuclides in the primary biological shield in the direction of thickness was measured and for the latter purpose, spatial distributions of the radioactive concentration were measured. Nuclides measured radioactive concentration were Co-60 and Eu-152 that were the major product nuclides in the biological shield.

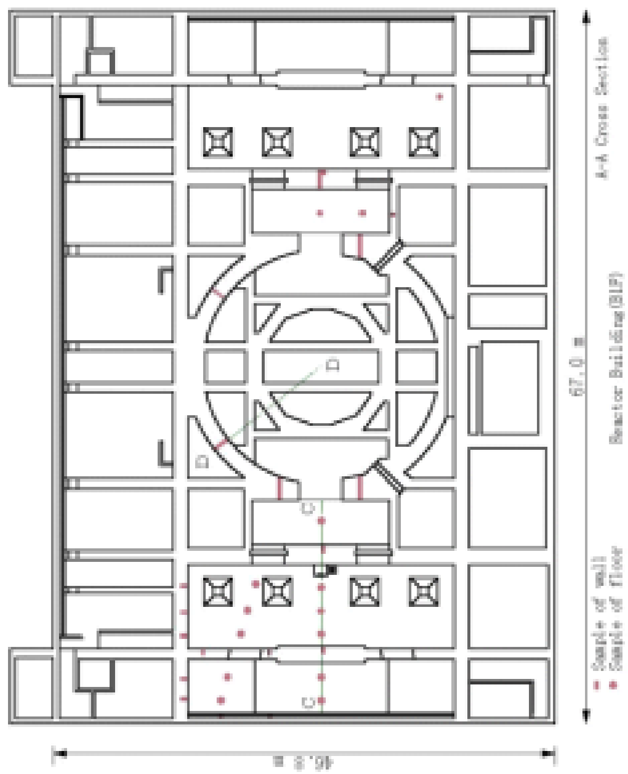

Figure 6 Example of the positions of the sampled cores in a horizontal cross section

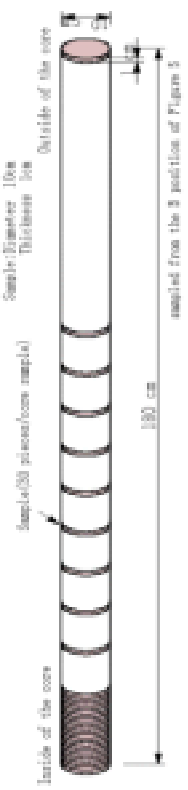

Figure 7 Example of the positions of the measured samples in the concrete core

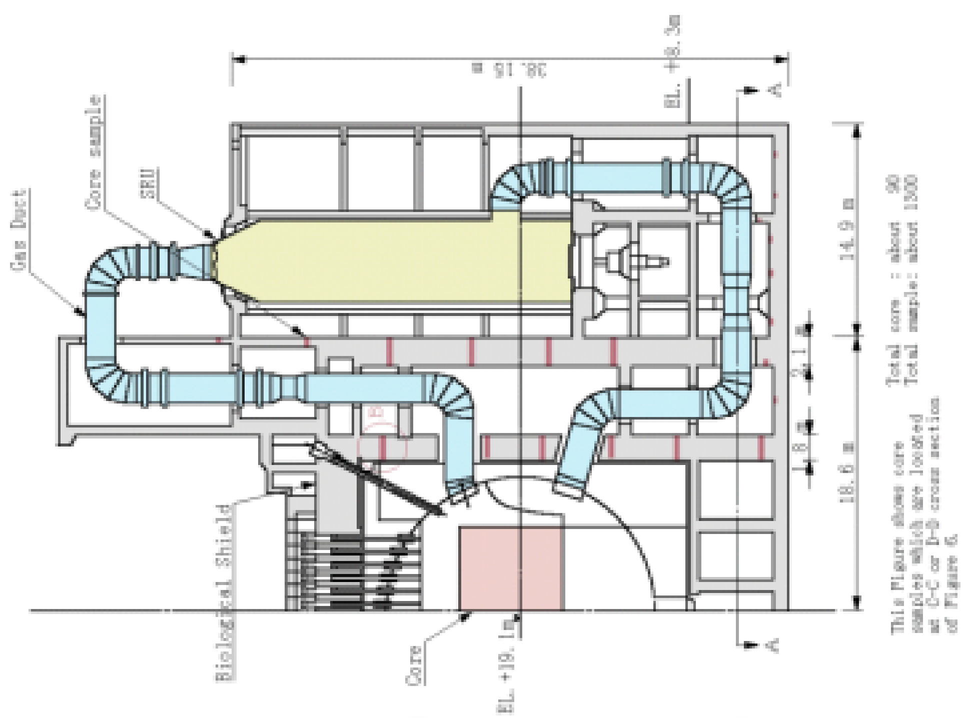

Figure 5 Example of the positions of the sampled cores in a vertical cross section

As a example, positions of the sampled concrete cores in a typical vertical cross section are shown in Figure 5. and those in a horizontal cross section on the basement level are shown in Figure 6. The concrete cores were taken from positions of horizontal sections and heights so that the features of irradiation of the biological shield could be grasped. Further, after the permanent cessation, as for the primary biological shield, concrete cores were taken to an extent where the reactor core-side surfaces were included because it had become possible to hollow out the concrete cores from the outside of the primary biological shield to the inside of it. Sampled concrete cores were about 90 in number.

Measurement of the radioactive concentration of samples in the concrete core was performed at closer intervals along the thickness direction for region near the core-side surface where change of the radioactive concentration had been supposed to be remarkable and at larger intervals for region other than that where change of the radioactive concentration had been monotone, as is seen in Figure 7. Concrete samples used for the measurement of radioactive concentration were about 1300 in number.

RESULTS

Calculated and measured distributions of radioactive concentration of Co-60 and Eu-152 of typical concrete samples from the primary biological shield in thickness direction are given in comparison in Figure 8. In this figure, it is seen that the measured values for points deeper than 1 m from the reactor core-side surface of the primary biological shield are below the detectable limit. Measured values of the radioactive concentration tend to exceed the calculated values, however both of them coincide well with respect to values for thickness direction. Similar tendency is observed about the concrete samples other than that shown in Figure 8.

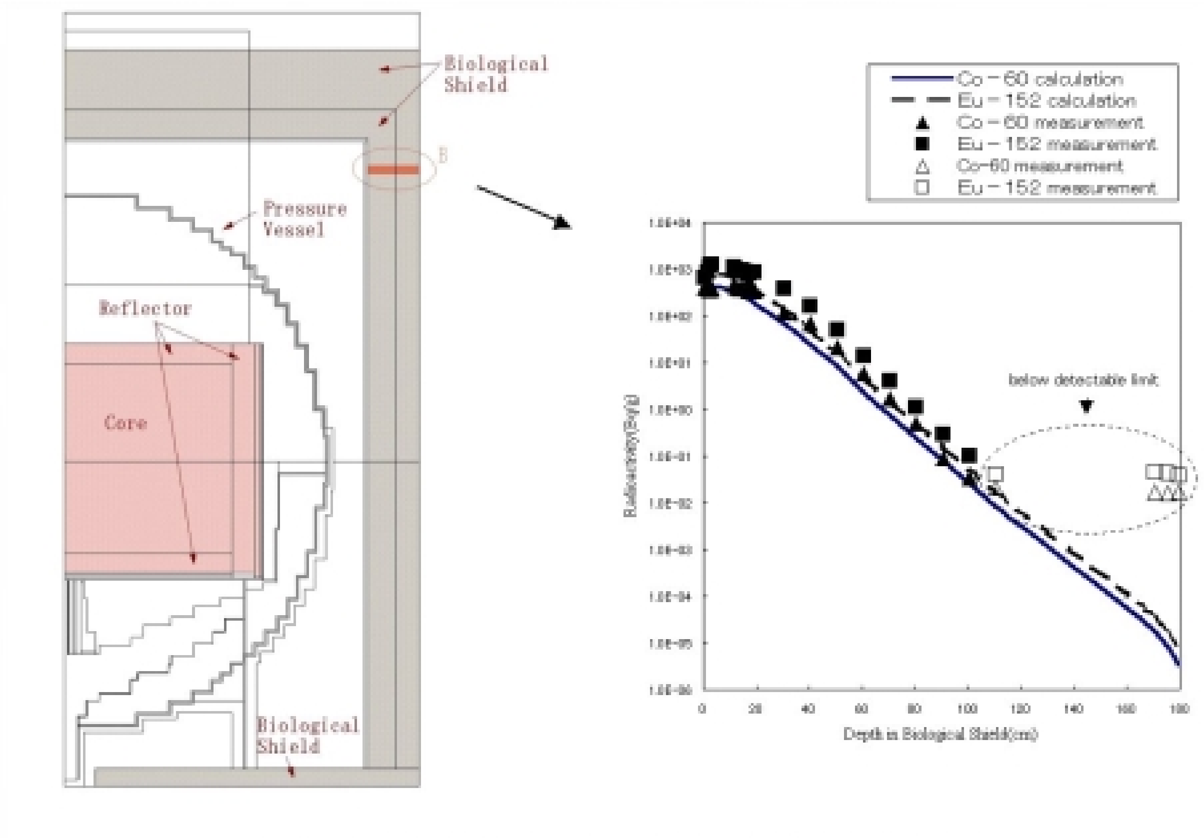

Figure 8 Horizontal radioactivity distribution of Co-60 and Eu-152 along B-line

Figure 9 shows a comparison of calculated and measured radioactivity of Co-60 and Eu-152 at typical heights on the core-side surface of the primary biological shield. At each height, both of them show a good coincidence and it is understood that the calculated values of radioactive concentration evaluate the spatial distribution of the radioactive concentration with good precision. Further, it is also shown that the calculated and measured distributions of radioactive concentration for the duct enclosure region and duct area that exist outside of the primary biological shield are in good coincidence[8].

Therefore, it would be possible to evaluate precisely the radioactivity of the biological shield in the future by taking account of the measurement results into calculation results.

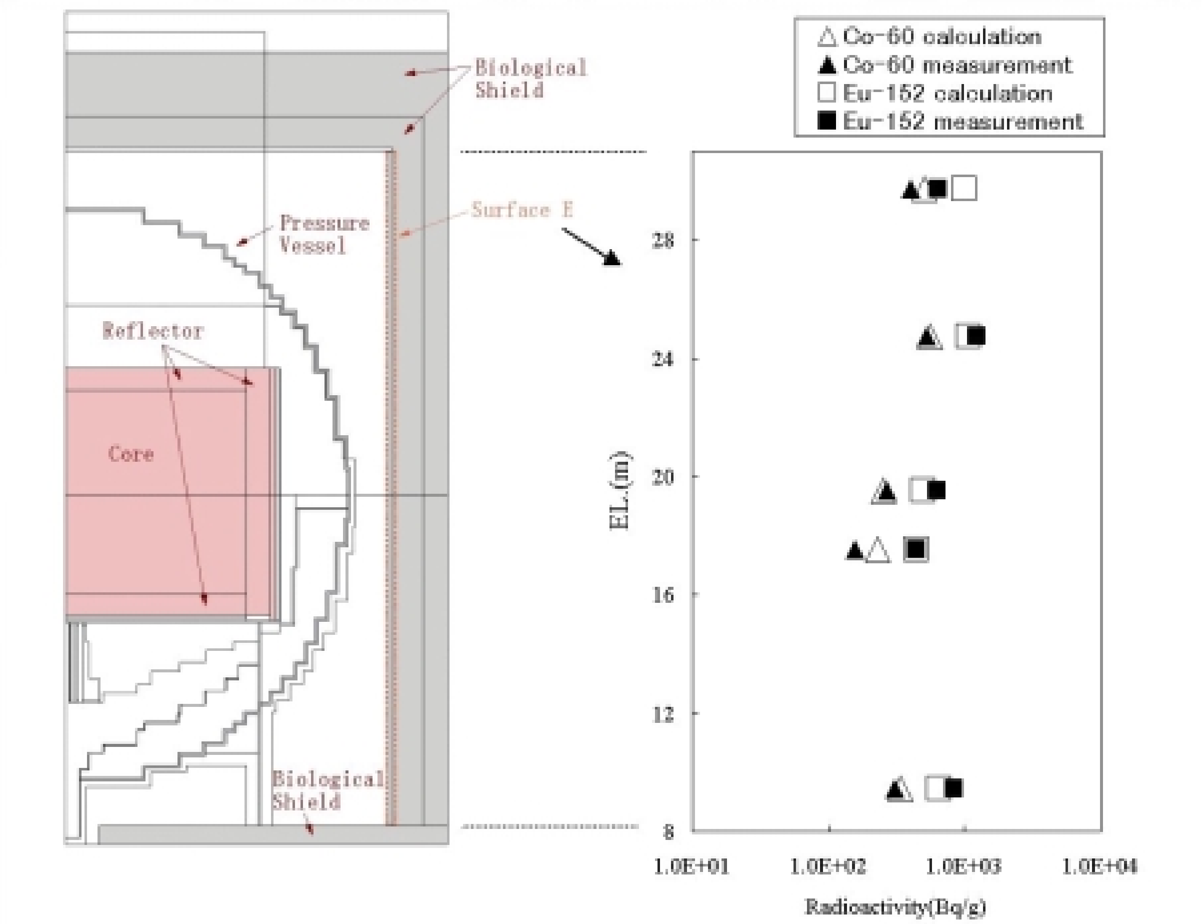

Figure 9 Vertical radioactivity distribution of Co-60 and Eu-152 along E surface

CONCLUSION

Calculated and measured radioactive concentration of the biological shield were compared and examined for the purpose of establishing the precise evaluation of the radioactive concentration and amount of material corresponding to each concentration level. As a result, it was clarified that the distributions of radioactive concentration of major nuclides in the primary biological shield along the depth in thickness direction as well as the distributions of radioactive concentration of major nuclides on the surfaces of the primary and secondary biological shields can be estimated by calculation with good precision. And we could make sure that it would be possible to evaluate precisely the radioactivity of the biological shield in the future by taking account of the measurement results into calculation results.

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