THE MANAGEMENT OF INTERMEDIATE LEVEL RADIOACTIVE WASTE GENERATED DURING CERNAVODA UNIT 1 RETUBING PROJECT

ION POPESCU [*] *and DORIN DUMITRESCU*

[*] Former Cernavoda Nuclear Power Plant (CNE Cernavoda), Romania
Cernavoda Nuclear Power Plant (CNE Cernavoda), Romania
e-mail: jeanpopescu@yahoo.com; dorindumitrescu@nuclearelectrica.ro

Abstract

The design life of a CANDU reactor is about 30 years at 80% average capacity factor. By replacing the major reactor components including fuel channels, briefly by retubing, the life of a CANDU reactor could be extended with 25 – 30 years of operation. Cernavoda Unit 1 retubing will generate significant quantities of radioactive waste including replaced metallic components of the reactor. Partly, this waste is classified as Intermediate Level Waste – Long Life (ILW-LL), and requires adequate methods for collecting, packaging and interim storage before the disposal in an underground facility. This paper presents a synthesis of the main aspects related to the management of Intermediate Level Waste Long Life, ILW-L, produced during Cernavoda Unit 1 refurbishment and the proposed conceptual solutions to fulfil the legal provisions for nuclear and radiological safety of personnel, population and environment.

Keywords: *CANDU, Refurbishment, Radioactive, Waste, Management*

Introduction

By design, CANDU reactors have a life time of 30 years. Following a refurbishment process, this life time may be extended by another 30 years.

Nuclearelectrica is running a project for Unit 1 refurbishment, which has been in operation since 1996. Unit 1 reactor refurbishment will start effectively at the beginning of 2027. The replacement operations of fuel channels and feeders, shortly retubing, will produce a significant amount of radioactive waste including the activated metallic components of the reactor.

All radioactive waste which are removed from the reactor will be transferred to a new interim storage before their disposal.

CANDU Energy Inc., member of SNC-Lavalin Group, provided the technical solution to replace nuclear fuel channels, calandria tubes, and feeders of Cernavoda Unit 1 reactor [1]. After removal, the End Fittings (EF) will be placed in special containers, large waste containers (LWS) and loaded into a Large Waste Transfer Flask (LWTF) for transfer to the interim storage. The Volume Reduction System (VRS) designed by Candu Energy Inc. [1] is used to remove and crush pressure tubes (PT) and calandria tubes (CT) into small coupons. The volume reduced waste is deposited from the VRS into a small waste container (SWC) and loaded in the Small Waste Transfer Flask (SWTF) for transfer to the interim storage. The VRS also removes Calandria tube inserts from the reactor [1].

A feasibility study for Radioactive Waste Management provided the technical and economical solutions including processing and storage for all types of radioactive waste generated during Cernavoda Unit 1 refurbishment and during Units 1 and 2 operation after the refurbishment.

This study has been performed by Korea Hydro & Nuclear Power Co., Ltd. (KHNP) in collaboration with Korea Electric Power Corporation (KEPCO), Korea Atomic Energy Research Institute (KAERI), Sargent & Lundy, and RATEN-CITON [2].

The paper presents a synthesis of the main aspects related to the management of Intermediate Level Waste, Long Lived (ILW-LL), and the proposed solutions which fulfil the legal provisions for nuclear and radiological safety of personnel, population end environment.

Characterization of activated metallic waste from Unit 1 retubing

Before the start of retubing, the source term of activated metal waste must be estimated because it is necessary for the design of retubing technologies, for the prediction of worker's potential exposure, for establishing radiation protection measures, and performing the safety analyses. A reasonable source term evaluation is also desirable in order to exclude a too conservative design of waste storage facility. Table 1 presents the quantities of activated metallic waste susceptible to be classified as ILW-LL.

Table 1. Estimated quantities of metallic activated waste produced during Unit 1 reactor refurbishment

Component	**Material**	**Mass [kg]**	**Volume [m^3]**			**Density [kg/m^3]**
			Intrinsic	*Before compaction*	*After compaction*	
PT	Zirconium -Niobium	21,496	3.30	23.98	8.62	6500
CT	Zircaloy-2	8,312	1.30	31.48	5.71	6400
CTI	SS-410	149	0.02	0.72	0.72	7800
EF	-	170,000	-	54.54	54.54	-

The activation source term analysis performed in [3] resulted in a large list of radionuclides with different half-lives, from short to very long time spans. In terms of radioactive waste safety, a radionuclide with a half-life of less than about 30 years is considered to be short lived. Figs 1 and 2 illustrate the time variation of activity for the main short, and long lived radionuclides in PT.

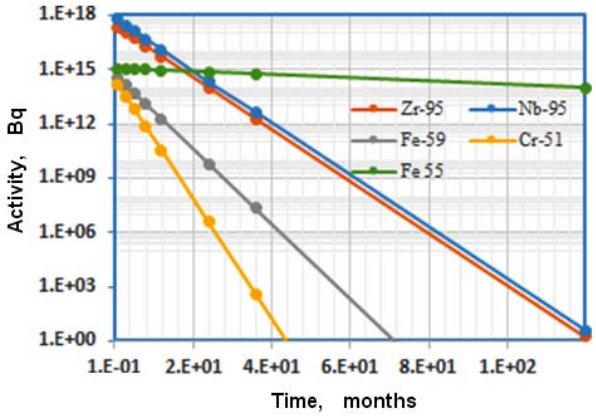


Fig.1. Decay of short lived radionuclides in PT

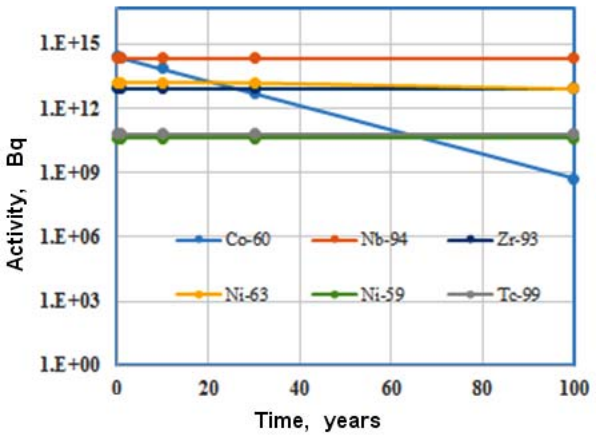


Fig.2. Decay of Co-60 and the main long lived radionuclides in PT

Details on the models and methods used to estimate the neutron flux distribution and structural components of Unit 1 reactor activation can be found in [3]. Geometry and material composition data for PT, CT, CTI were provided by CNE Cernavoda. The explicit and implicit data for geometry and material composition of End Fittings (EF) were also supplied by CNE Cernavoda.

The operation history for Unit 1 reactor from 1997 to 2020 has been provided as input for computer code calculations. An average capacity factor of 90.8% was used for the remaining period between July 2020 and December 2026.

Three major short lived radionuclides have been identified in the activated PT waste: Zr-95, Nb-95, and Fe-55, as can be seen in Fig. 1. Fig. 2 illustrates the time variation of activity for Co-60 and long lived radionuclides, such as Nb-94, Ni-63, Tc-99, and Ni-59, in PT. After 8 months from the reactor shut down, when the retubing is supposed to start, the replaced components of the reactor are still highly radioactive, with total activities about 10^{17} – 10^{18} Bq [3].

Classification of activated metallic waste from Unit 1 retubing

Among other things, the waste classifications are based upon the concentrations of long-lived radionuclides in the waste materials which shall to comply with disposal requirements. The boundary between the LLW (Low Level Waste) class and the ILW class cannot be specified in a general manner with respect to activity concentration levels, because the allowable levels will depend on the actual waste disposal facility and its associated safety case supporting safety assessment [3].

Intermediate level waste is defined as waste containing long lived radionuclides in quantities that need a greater degree of containment and isolation from the biosphere than is provided by near surface disposal. Disposal in a facility at a depth between a few tens and a few hundreds of metres is indicated for ILW. Heat dissipation is not an important factor that has to be taken into account in the design of geological disposal facilities for ILW-LL.

International Atomic Energy Agency (IAEA) recommended generic criteria for LLW average activity concentrations of long life nuclides up to tens of MBq per kg [4], but these may be specific to the site and disposal facility.

An assessment of the radiological impact of radionuclides associated with neutron activated metals is given in [5]. Waste acceptance criteria for Romanian Disposal for Low and Intermediate Level Waste – DFDSMA haven't been finalized, and the Deep Geological Repository is "realistically expected to become functional around the year 2055", [6].

Based on the Korean experience, 10 radionuclides concentrations have been selected as classification criteria for activated metal waste produced during retubing [2]. These radionuclides were selected due to their long half-lives, high environmental mobility, and potential to be present in wastes in significant concentrations.

Table 2 presents the specific activities of the radionuclides considered for ILW-LL classification for all replaced reactor components from Unit 1 reactor, calculated at 30 years after the reactor shut down.

Table 2. Specific activity of the reference radionuclides after 30 years from the reactor shut down

Radionuclide	Concentrations Limit for LLW [Bq/kg]	Specific activity [Bq/kg]			
		PT	CT	CTI	EF
Ni-59	7.40E+07 [7]	1.97E+06	3.13E+07	1.90E+08	1.21E+06
Ni-63	1.11E+10 [7]	7.07E+08	9.81E+09	6.52E+10	1.35E+08
Zr-93	~1.0E+07 [4]	3.81E+08	3.92E+08	1.03E+04	6.42E-02
Nb-94	1.11E+05 [7]	1.05E+10	1.35E+04	1.21E+07	8.06E+00
Tc-99	1.11E+06 [7]	2.92E+06	2.79E+06	2.03E+06	2.01E+04
C-14	2.22E+08 [7]	4.30E-08	1.16E-07	5.74E+09	1.51E+03
H-3	1.11E+09 [7]	2.60E+07	2.55E+07	4.63E+07	4.08E+04
Co-60	3.70E+10 [7]	2.40E+08	1.26E+09	7.92E+11	3.60E+07

Fig. 3 presents the time variation of the total specific activities of replaced metallic components illustrating the presence of long lived radionuclides.

It is obvious that End Fittings radioactivity decreases faster than radioactivity of PT, CT and CTI, so that after 30 years this waste could be classified as LLW and potentially disposable in a shallow land disposal facility.

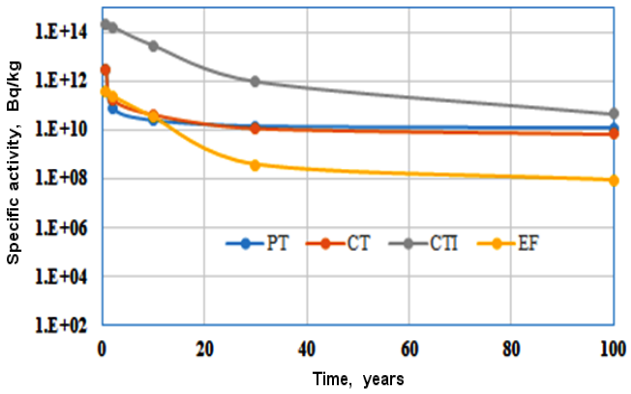


Fig. 3. Specific activity of activated metal waste

Storage solution for activated metal waste from Unit 1 retubing

Up to now, two distinct solutions have been applied for the storage of ILW-LL from CANDU NPPs retubing in order to provide adequate containment and shielding: storage in concrete structures (Fig. 4) and storage in metal certified containers (Fig. 5).



Fig. 4. Point Lepreau concrete structures for activated waste storage [8]



Fig. 5. Storage containers for activated waste from Darlington Unit 2 refurbishment [9]

The current storage facility of Cernavoda NPP has a limited capacity for LLW and it is not designed to accommodate the activated metallic waste from Unit 1 retubing. A new storage facility is necessary to provide storage areas for all radioactive waste produced during Unit 1 reactor refurbishment, for radiological and security control areas and radioactive waste processing equipment.

The feasibility study [2] demonstrated that the optimal solution from both technical and economical point of view is the conversion of Unit 5 Reactor Building into a structure with one basement level and five levels above ground. To be mentioned that the NPP built on Cernavoda site was equipped with 5 CANDU 6 type units. Unit 1 and Unit2 are in operation since 1996 and 2007, respectively; Units 3 and 4 are in construction stage (political decision sustained by national strategic documents). For Unit 5 the construction was cancelled, existing structures being used as support for the other units' operation.

Based on the conclusions of the feasibility study [2], Cernavoda NPP will use certified metal containers for ILW storage.

The storage concept for ILW waste has been developed based on the operating experience of other CANDU NPPs and adapted to the specific conditions of Cernavoda NPP site. SNC Lavalin proposed to use a single design of storage containers (KBox) that can provide modular storage of both LWC (large waste containers) and SWC (small waste containers) in the new storage arranged into Unit 5 Reactor Building, as can be seen in Figs. 6 and 7.

K-Boxes will be certified as Type B package and the model will be approved by CNCAN, the Romanian regulatory body.

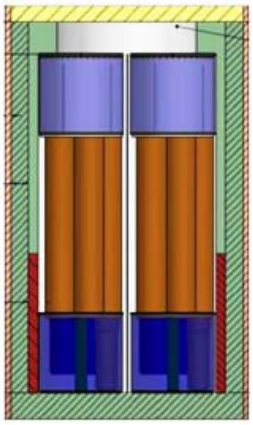


Fig. 6. K-Box with Large Waste Containers - LWC

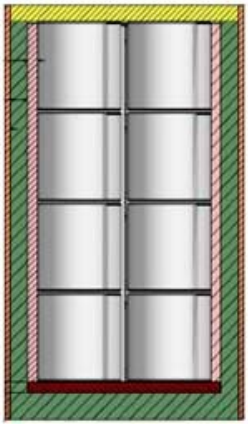


Fig. 7. K-Box with Small Waste Containers – SWC

This solution has some advantages represented by an improved waste retrievability for disposal and also reduced cost of decommissioning and ILW-LL disposal.

Conclusions

Retubing of the Unit 1 reactor from Cernavoda NPP will produce about 70 m^3 intermediate level radioactive waste, which represent a relatively small amount of Intermediate Level Waste – ILW.

After 30 years of storage, the volume of waste potentially classified as ILW-LL will be considerably reduced at about 15 m^3.

A significant cost reduction will be achieved for the refurbishment waste management by using U5 Reactor Building as radioactive waste storage.

The conceptual solution for ILW storage has great advantages by improved waste retrievability and reduced costs of decommissioning and disposal.

EF waste could be treated as LLW-SL (Low Level Waste, Short Lived) and are susceptible to be transferred into a shallow land disposal.

References

[1] Sheikh, N., Belyea, S.A., Hwang, K. "Technical Solution to Replace Nuclear Fuel Channels, Calandria Tubes and Feeders of the Cernavoda NPP U1 Reactor", 79-01000-PLA-002, CANDU Energy Inc., SNC Lavalin CEInc.

[2] Korea Hydro & Nuclear Power Co., Ltd. "Feasibility Study on Management of Radwaste Generated during Unit 1 Refurbishment and Operation of Unit 1, 2 in CNE Cernavoda", RWM-E-T8-001R, KHNP.

[3] Korea Hydro & Nuclear Power Co., Ltd. in collaboration with Korea Electric Power Corporation "Technical Report for Evaluation of Radwaste Inventory", RWM-E-T2-000R3, KHNP, KEPCO.

[4] International Atomic Energy Agency (2009) "Classification of Radioactive Waste", Safety Standards Series No. GSG-1.

[5] Robertson, D.E., Thomas, C.W., Pratt, S.L., Lepel, E.A., Thomas, V.W. (2000) "Low-Level Radioactive Waste Classification, Characterization, and Assessment: Waste Streams and Neutron-Activated Metals", NUREG/CR-6567 PNNL-11659, US NRC.

[6] Government of Romania, Ministry of Energy, Nuclear and Radioactive Waste Agency (2022) "Romanian Strategy on medium and long term for Safe Management of Spent Fuel and Radioactive Waste", available (in Romanian), http://andr.ro/gospodarirea-deseurilor-radioactive/strategii-si-programe/.

[7] Government of Korea, Nuclear Safety and Security Commission in Korea (2020) "Regulation on Radioactive Waste Classification and Clearance Standards, Nuclear Safety and Security Notification", No. 2020-6, https://www.law.go.kr

[8] Government of Canada, Canadian Nuclear Safety Commission (2011) "Canadian National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management", https://nuclearsafety.gc.ca/eng/resources/publications/reports/jointconvention/index.cfm

[9] Ontario Power Generation (2018) "Darlington Refurb uses state-of-the-art waste facility", https://www.opg.com/news/darlington-refurb-waste-facility/ .

.