Designing of Radiation Shield for thermal plasma based vitrification system for treating LILW using Monte Carlo simulation

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Abstract
Today, thermal plasma technology (TPT) is considered as a new alternative method for the treatment of radioactive wastes. In this study, a radiation shield has been proposed for a laboratory scale design based on TPT and a plasma incineration- vitrification hybrid system for the treatment of Low and Intermediate Level Radioactive Waste (LILW). The results show that the optimal thickness of the shield (steel as a main component) to reduce the equivalent dose rate out of the furnace by about 10 uSv/hr is around 12 cm.

Keywords: Low and Intermediate Level Radioactive waste, treatment, thermal plasma technology, radiation shield.

Introduction
Advanced incineration systems use plasma to treat radioactive waste, and residual ash can be melted into quasi-mineral materials or glass composites. Plasma sources of heating (plasma torches) are alternatives to liquid-fuel nozzles or gas burners. The treatment of solid radioactive waste using plasma heating sources occurs in primary reaction chambers. Subsequent stages include those of thermal conversion of waste materials with the formation of inorganic slag, gasification of organic components, homogenization, melting slag residue, and pouring of the melt into receiving containers [1]. There are currently some plasma plants in operation, which apply thermal plasma technology (TPT) as a method of radioactive waste treatment, such as SIA RADON in Russia, ZWILAG in Switzerland, KOZLODUY in Bulgaria [2]. Considering the high demand for the treatment of radioactive waste, studies on different configurations of the plasma system are required. In this project, a laboratory scale of plasma incineration- vitrification hybrid system for the treatment of radioactive waste based on TPT has been proposed which uses three plasma torches manufactured in Plasma Physics and Nuclear Fusion Research School and the conceptual design of radiation shield has been investigated using the MCNP6 Monte Carlo code [3].

Material and methods
As stated, this proposed design includes three plasma torches for treatment and vitrification of LILW using TPT (Fig. 1). Based on the volume source activity of LILW (4.6 MBq/kg glass), 12 cm thick 316 stainless steel has been calculated as an outer radiation shield. The calculation has been performed using the variance reduction method (splitting and russian roulette). Flux to dose conversion factors using F4 tally have been used for dose monitoring in Steel as well as in air out of the furnace [4]. The source has been considered as a cylindrical volume source with a homogeneous distribution of the LILW composition (160 kg) from the VVER, low density (vapour) above plasma torches and high density (liquid) in the bottom. The material composition, as well as the final emission rate, has been modified for the branching ratio of gamma irradiation The main characteristics of LILW are presented in Table 1 [5].

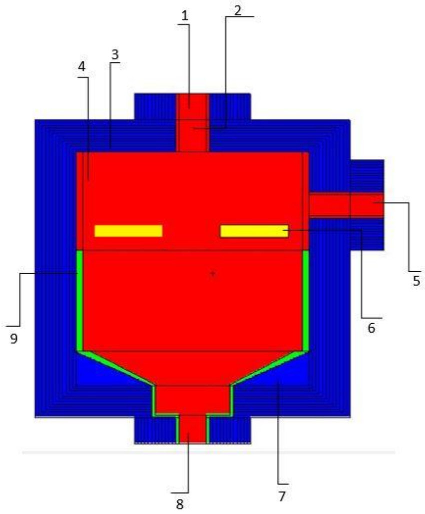

Fig. 1. Schematic view of the designed plasma incineration-vitrification hybrid system on a laboratory scale for the treatment of LILW, 1- RW, 2- batch feeding port, 3- Stainelss Steel 316 shield, 4- combustion chamber, 5- off-gas outlet, 6- Plasma torch, 7- Sloping insole, 8- Slag Outlet, 9- Refractory lining alumina.

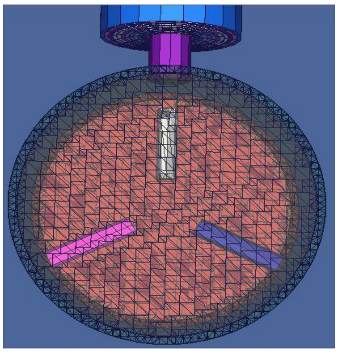

Fig. 2. Position of plasma torches inside the furnace

Table 1. Main Features of liquid LILW from NPPs with PWR (VVER) [5].

Characteristic of LILW	Tver NPP
Total concentration of salts, kg/m^3	350-500
Concentration of dissolved salts, kg/m^3	350-500
Concentration of insoluble substances, kg/m^3	<5
Density, kg/dm^3	1.2-1.5
pH	10.5
Crystalline Phases:	$NaNO_3$ $NaB(OH)_4$ NaOH
Radionuclides	**Activity (Bq/m^3)**
Cs-137	1.9×10^9
Cs-134	1×10^9
Sr-90	1×10^7
Co-60	4.5×10^7
α-irradiator	1×10^5

Results and discussion

As stated before, dose rate duo to source activity has been calculated surrounding furnace according to distance as well as to the height of the furnace. The simulation results of the dose rate for the proposed plasma melting furnace are shown in Figs. 3 -5.

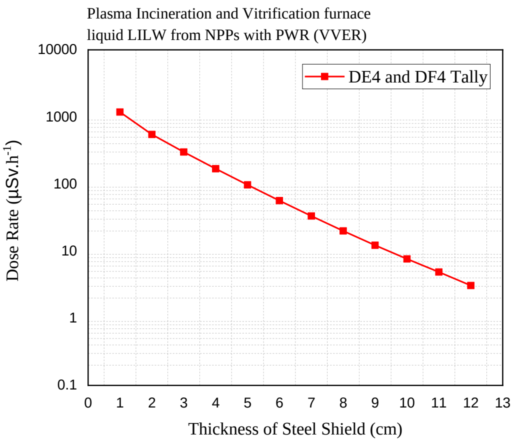

Fig. 3. Dose rate in the main shield layers

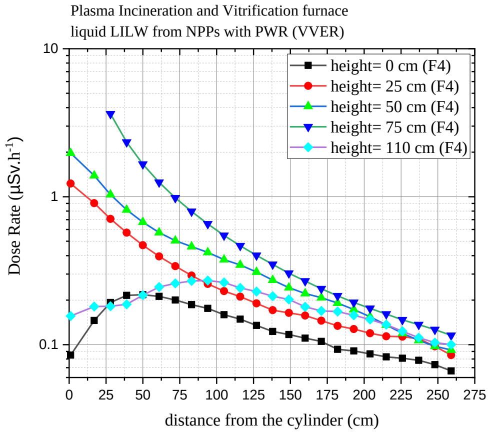

Fig. 4. Equivalent dose rate at different distances from the proposed system.

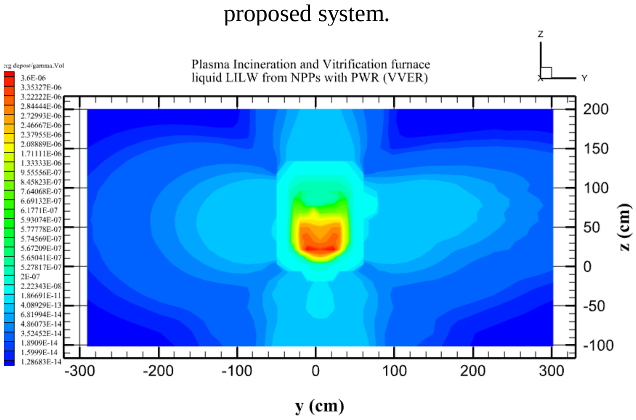

Fig. 5. Variation of Equivalent dose rate surrounding the furnace (Mesh Tally).

Conclusions

According to the conceptual design of laboratory scale system containing three plasma torches, the proposed treatment system with this shield is safe and the dose rate in distances larger than 1 m reduces less than 1 uSv/h. Results are in agree with ZWILAG design.

References

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