Research and Development of High-dose Radioactive Material Transport Wagon Using Water Shielding

Dong Hyun Park, Sang Tae Lee, Myeong Ho Kim, Jeon Joon, and Sung Jun Hong
HANA Nuclear Power Engineering, Co., Ltd., 804, Hanam-daero, Hanam-si, Gyeongi-do, Republic of Korea
*pdh200@hanarad.com

1. Introduction

During the Overhaul(outage) period of Nuclear Power Plant(NPP), generated high dose radioactive materials in reactor buildings and elsewhere are transport to attenuation storage areas or waste treatment rooms for radiation dose reduction or waste treatment. Therefore, lead shielding has been used to reduce the radiation exposure of workers or movement path during high-dose radioactive material movement. However, due to the characteristics of the lead shield, the lead weight is too heavy to handle and it is difficult to fix the shield to the wagon. In addition, there is a possibility that the wagon may be shaken due to various equipments or protrusions installed on the movement route, or the lead shielding body may be dropped by some impacts. To solve these problems, we have developed a carriage wagon that relatively light and easy to handle, and can move stably even under the harsh route conditions for high dose radioactive materials that frequently generated in reactor building of NPP.

2. Production of shielded wagon

The shielded wagons should have shielding capacity of 70 ~ 80% based on the radiation dose rate for high dose radioactive materials and should be more efficient than the existing transportation method. Therefore, the method of filling water for shielding in cavity structure made of a double SUS material outside of a wagon that having a space in which radioactive materials can be sufficiently store was selected in this study. In addition, the water for shielding is designed to be easy to fill and drain if necessary. It is designed to be drained state when moving to the area for loading radioactive materials to be easily moving. And It can be shielded by adding water before loading high dose radioactive materials. Also, in order to minimize the impact caused by the obstruction of the moving path or the protrusion of some equipments, the wheel was used as a shock absorber wheel. This proved its effectiveness in actual field applications.

Since water is used as a shielding material, all materials used are SUS 304, which has high corrosion resistance against water. And, in order to prepare for higher radioactive material than anticipated, connection rings were equipped to outside of the shielded wagon for the existing lead blanket could be attached. This connection rings are designed to be securely fixed to wagon. It differs from the existing method of temporarily using a lead shield in wagons.

2.1 Estimated shielding ability calculation

Designed to attenuate more than 72%

I_{total} = 0.755(shielding ability of wagon) × 0.370(shielding ability of water) = 0.279

Therefore, the shielding effect,

Dose before shielding × 0.279(shielding ability of shielded wagon) = Dose after shielding

$$I = I_0 e^{-\frac{0.693t}{T}} \quad (1)$$

I : Radiation intensity after shielding,
I_0 : Radiation intensity before shielding
T : Half-value layer thickness,
t : Thickness of shielding material

Shielding ability of wagon material (applied steel plate)

[Density(g/cm^3) : steel=7.87, SUS 304=7.90]
$I_{SUS} = 100\% \ e^{-\frac{0.693 * 0.60cm}{1.48cm}} = 75.5\%$
(T : 1.48 cm, t : 0.6 cm)

Shielding ability of water

$I_{water} = 100\ \% \ e^{-\frac{0.693 * 14cm}{9.8cm}} = 37.0\ \%$
(T : 9.80 cm, t : 14.0 cm)

2.2 Estimated weight of shielded wagon

The weight was calculated using the amount of SUS used and the density (7.9 g/cm^3) used in the shielded wagon with reference to the production drawings. The weight of the SUS used in the shielded wagon body is about 68 kg, and the amount of water to be filled with the shielding is 128 liters, and 20 kg is added by wheels, reinforcements and handles. Therefore, the weight of the shielded wagon that was filled with water was estimated to be about 216 kg.

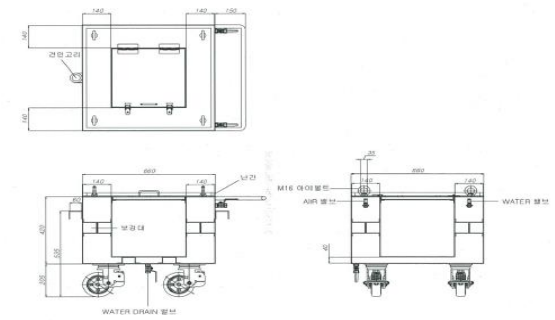

Fig. 1. Drawings of shielding wagon.

3. Field Application Results

The actual shielded wagon, which was actually made, weighed about 224 kg when water was injected, it is 8 kg heavier than expected. However, it was considered that there would be no problems for safely moving from the reactor building to the attenuation storage area or the waste treatment room. The shielded wagon tested the shielding ability before application in field. As a result of storing radioactive materials with a surface radiation dose rate of 2 mSv/h in the shielded wagon, it was confirmed that they had a shielding ability of about 90%.

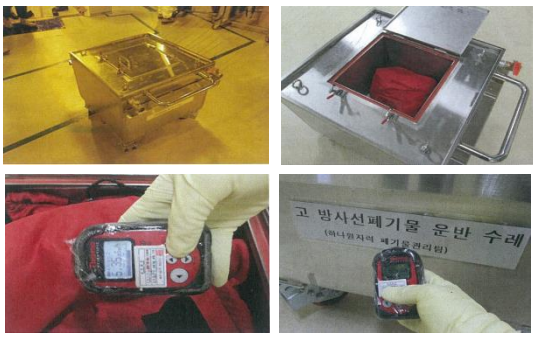

Fig. 2. Field applied Shielded wagon.

The results of field application after shielding ability test are as follows.

Table 1. Field application results of water shielded wagon

Radio active waste	Surface radiation dose rate (mSv/h)		1m Radiation dose rate (mSv/h)		Shielding ability (Based on surface)
	Before shielding	After shielding	Before shielding	After shielding	
Concentrated waste liquid granules	4	0.5	0.13	0.027	87.5%
Concentrated waste liquid granules	2	0.13	0.05	0.006	93.5%
VGS Decontamination waste	7	0.8	0.2	0.05	88.6%
Cavity Decontamination waste	5	0.6	0.14	0.003	88.0%
Cavity Decontamination waste	1.6	0.2	0.06	0.008	81.3%
ICI working waste	8	1	0.4	0.06	87.5%
ICI working waste	4.8	0.6	0.2	0.037	87.5%
Cavity Bottom sludge	20	2.1	-	0.3	89.5%

4. Conclusion

The purpose of this study was development the shielded wagon that can effectively and safely carrying for high dose radioactive materials, which are frequently generated in reactor buildings, during overhaul period of NPP. This includes reducing radiation exposure of workers and radiation of movement path during high-dose radioactive material movement. We have developed the 'water-shielding wagon' by improving the existing universal method of loading radioactive material on a wagon and shielding it with a lead shield temporarily. This will contribute to the reduction of the radiation workers' exposure and quality improvement of radiation safety management.

REFERENCES

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[2] Regulations on packaging and transportation of radioactive materials (Notification 2014-050).
[3] Metal material comparison handbook “Published by Gold” (Lee eui jong).
[4] Nuclear Safety Commission Act and Radioactive Waste Management Act.