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DEVELOPMENT OF TYPE IP-2 PACKAGES FOR LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE

Sunghwan Chung
Nuclear Engineering and Technology Institute
Korea Hydro and Nuclear Power Co., Ltd.

Jongrak Choi
Nuclear Engineering and Technology Institute
Korea Hydro and Nuclear Power Co., Ltd.

Minchul Kim
Nuclear Engineering and Technology Institute
Korea Hydro and Nuclear Power Co., Ltd.

Seungho Lee
Nuclear Engineering and Technology Institute
Korea Hydro and Nuclear Power Co., Ltd.

ABSTRACT

Korea Hydro and Nuclear Power Co., Ltd.(KHNP) is developing two kinds of IP-2 packages to transport low and intermediate radioactive waste(LILW) from nuclear power plants(NPPs) to the disposal facility in Korea in accordance with IAEA and domestic transport regulations. This paper describes the radiation and structural evaluations carried out to demonstrate the performance of the packages and their compliance with the regulatory requirements.

INTRODUCTION

In November 2005, KHNP, which has twenty commercially operating NPPs and is responsible for the radioactive waste management in Korea, has successfully designated Wolsong in the southeast of Korea as the site of LILW disposal facility, which was one of the national problems. Since then, KHNP has been in the process of constructing the disposal facility smoothly. Operation of the disposal facility for LILW will commence in 2009 with a capacity of 100,000 drums in the first stage and 800,000 drums total.

KHNP is developing two kinds of IP-2 packages to transport LILW steel drums from the on-site temporary storage facilities of NPPs to the disposal facility. The packages are being designed to comply with the requirements of IAEA and domestic transport regulations for Type IP-2 packages. Most of LILW generated from NPPs including dry active waste, spent resin, spent filter and concentrated waste are packaged into DOT-17 type steel waste drums of 200-liter and 320-liter, and temporarily stored on NPP sites. One package is able to contain eight 200-liter steel waste drums and also another package eight 320-liter steel waste drums. Both packages including waste drums do not exceed six tons of total weight, and their structure and external dimension are identical. Structural performance of the packages is demonstrated by analyses and confirmed by safety tests. And dose rate limits of LILW waste drums to be containable in the packages by using computer code are determined.

DESCRIPTION OF IP-2 PACKAGES

Two kind of IP-2 packages are designed to transport eight LILW steel drums of 200-liter and 320-liter with the same external dimensions of 1.6m(W) x 3.4m(L) x 1.2m(H), and to comply with the regulatory requirements of IAEA Safety Standards Series No.TS-R-1 and Korea Atomic Energy Act for Type IP-2 packages.

The package as shown in Figure 1 consists of a body, a lid, lid bolts and internal drums. The body of package is made of carbon steel and shielding wall thickness of the body and the lid is 12mm.The lid is securely fastened down with lid bolts and waste drums are secured firmly by internal drum supports to ensure that they do not move during transport. The packages including eight waste drums do not exceed six tons of total weight due to the capacity of the gantry type on-board crane of the purpose-built transport vessel.

The content in the packages is 14 kinds of LILW drums as classified in Table 1. The packages are so designed that the radiation level does not exceed 2mSv/h at any point on, and 0.1mSv/h at 2m from, the external surface of the packages.

Figure 1. Overview of an IP-2 package

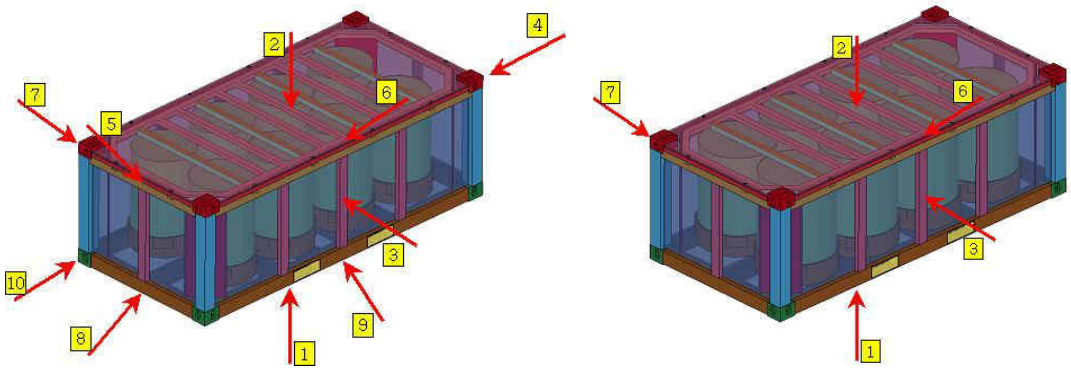
Table 1. LILW drum classification

<table>
<tr><th>Dry active waste</th><th>Concentrated waste</th><th>Spent resin</th><th>Spent filter</th></tr>
<tr><td>General
. 200-liter drum
. 320-liter drum</td><td>Cement solid.
. 200-liter drum
. 320-liter drum</td><td>Cement solid.
. 200-liter drum
. 320-liter drum</td><td rowspan="3">Concrete
. 200-liter drum
. 320-liter drum</td></tr>
<tr><td>Shielded
. 200-liter drum</td><td rowspan="2">Paraffin solid.
. 200-liter drum
. 320-liter drum</td><td rowspan="2">Dried
. 200-liter drum
. 320-liter drum</td></tr>
<tr><td>Super compacted
. 320-liter drum</td></tr>
</table>

STRUCTURAL EVALUATION

Structural performance of two IP-2 packages in normal conditions of transport in accordance with the transport regulations was demonstrated by a combination of analyses using the computer codes and safety tests carried out on two prototype test models.

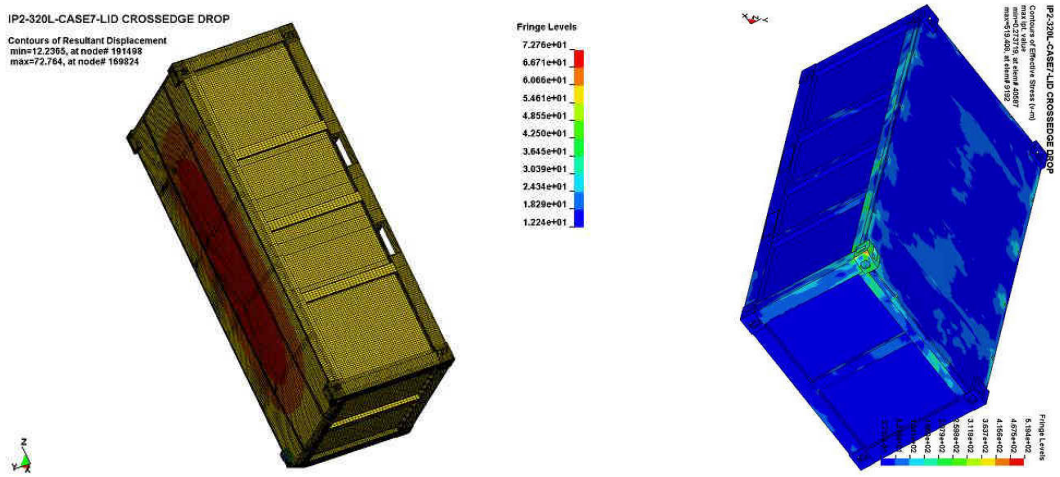
Impact analyses to ensure that the integrity of packages is maintained under all credible loads for free drop conditions specified in the transport regulations were performed using LS-DYNA explicit FEM code. Analyses for 0.9m free drop conditions were carried out for a total of 15 drop directions for two packages as shown in Figure 2 such as vertical, side, corner and oblique because it is difficult to define the impact direction for which maximum damage is expected



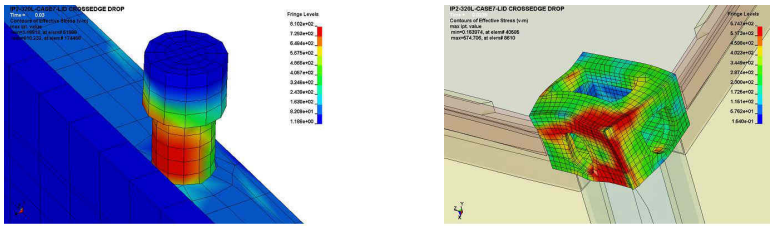
a. 200-liter drum package b. 320-liter drum package

Figure 2. Drop directions

For example, the analysis results for corner drop impact (drop direction 7 in Figure 2b) are shown Figure 3.



a. Maximum displacement contour b. Maximum stress contour



c. Stress contour of lid bolt d. Stress contour of corner fitting

Figure 3. Impact analysis under corner drop condition

And, stress analysis under stacking condition specified in the regulations were carried out using ABAQUS/Standard implicit FEM code.

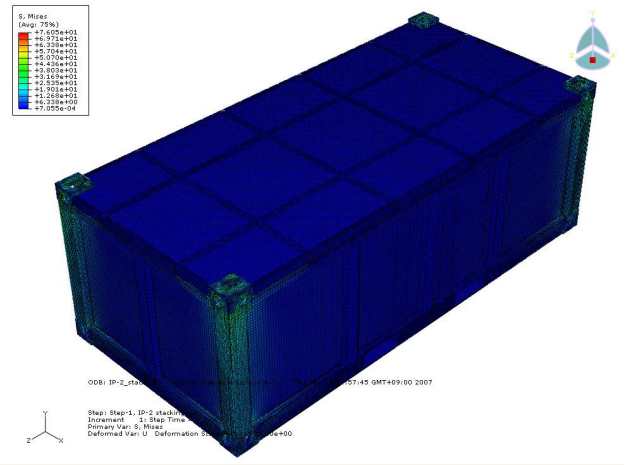


Figure 4. Stress analysis under stacking condition

For confirmation and verification of the analysis results, a total of five free drop tests from 0.9m height onto a rigid target in different drop positions, as shown in Figure 4 were performed using two prototype package models.

a. Bottom vertical drop test

b. Lid vertical drop test

c. Longitudinal side test

d. Lid corner drop test

e. Lid oblique drop test

f. Deformed corner fitting

Figure 5. Free drop tests

Stacking test as shown in Figure 6 was carried out under a compressive load of 5 times the weight of the package for a period of 24 hours in accordance with the transport regulations.

a. Stacking dummy weight

b. Laser displacement sensor

c. Strain gauge

Figure 6. Stacking test

RADIATION SHIELDING EVALUATION

In order to evaluate radiation shielding integrity of the packages and determine dose rate limits of LILW drums to be containable in the packages, radiation shielding evaluation were carried out by using MCNP analysis code. To convert the flux at tally points with respective energy bands to actual dose rate, flux-to-dose conversion factor, ANSI/ANS-6.1.1 was applied.

LILW drums of 200-liter and 320-liter were modeled and average radioactivity of nuclides in accordance with each kind of radioactive waste at temporary storage facilities of NPPs as a source term was considered to be homogeneous. Various tally positions to evaluate dose rate on and at 2m from the external surface of the top and side of the packages are shown in Figure 7. To find out the positions presenting the maximum dose rate, multiple dose assessment was conducted. It was found that dose rate at 2m from the external surface of the package was more dominant than dose rate on the surface and dose rate over the top of the package was higher than dose rate from the side. Thereupon dose rates at 2m from the external surface of the top and the side of each package were calculated. On the basis of the calculated dose rates at 2m from the external surface of the top and the side of the packages, dose rate limits for single package of each LILW drum to be containable in the packages were tabulated in Table 2.

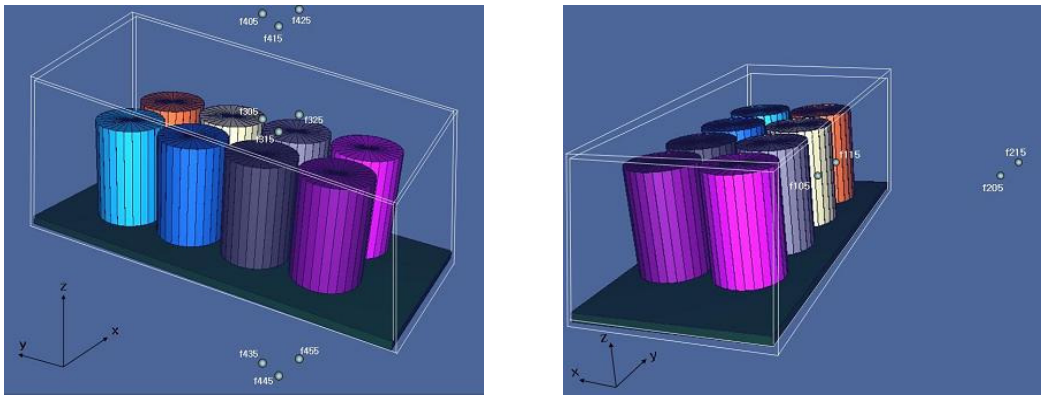


Figure 7. Positions to assess dose rates for single package

Table 2. Containable dose rate limits of waste drums for single package

LILW	200-liter drum(mSv/h)		320-liter drum(mSv/h)	
	top	side	top	side
Spent resin, cement	1.120	0.991	1.132	0.982
Spent resin, dried	1.035	0.962	0.909	0.803
Concentrated waste, cement	1.236	1.045	1.055	0.863
Concentrated waste, paraffin	1.087	1.002	0.953	0.835
Spent filter	0.896	1.378	0.975	1.115
Dry active waste, general	0.942	0.721	0.837	0.774
Dry active waste, shielded	0.900	1.011	-	-
Dry active waste, super compacted	-	-	0.644	0.643

In practice, two IP-2 packages will be loaded on a vehicle and transported at a time in the sites of NPPs and the disposal facility. Hence radiation shielding evaluation for two serial packages was carried out as shown in Figure 8. A space of at least 22cm between packages on the vehicle was assumed. The method of radiation shielding evaluation for two serial packages was identical to the single package. Containable dose rate limits for two serial packages are tabulated in Table 3.

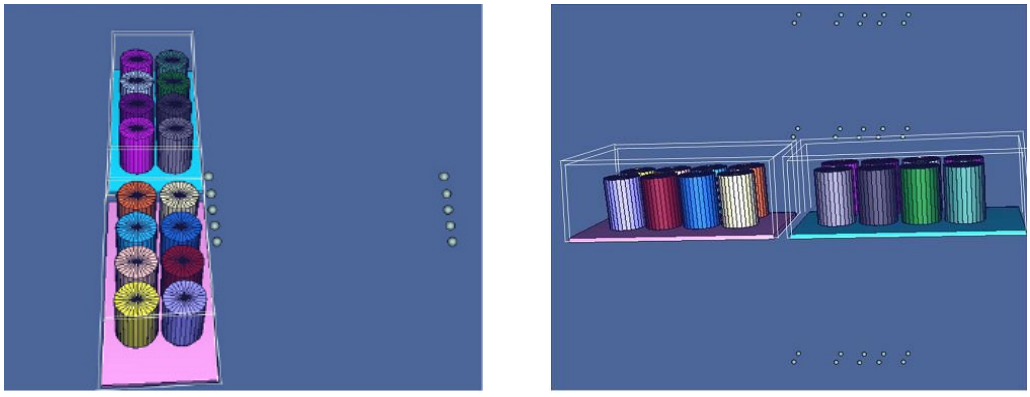


Figure 8. Positions to assess dose rates for 2 serial package

Table 3. Containable dose rate limits of waste drums for 2 serial package

LILW	200-liter drum(mSv/h)		320-liter drum(mSv/h)	
	top	side	top	side
Spent resin, cement	0.854	0.757	0.784	0.657
Spent resin, dried	0.787	0.732	0.858	0.758
Concentrated waste, cement	0.939	0.794	0.846	0.692
Concentrated waste, paraffin	0.829	0.765	0.768	0.673
Spent filter	0.932	1.433	0.913	1.038
Dry active waste, general	0.713	0.696	0.649	0.600
Dry active waste, shielded	0.832	0.829	-	-
Dry active waste, super compacted	-	-	0.503	0.502

CONCLUSIONS

Structural performance of two kinds of IP-2 packages under normal conditions of transport such as free drop and stacking was demonstrated by a combination of analyses using the computer codes, and safety tests carried out on two prototype test models. The structural analyses and safety tests demonstrated that the packages comply with the regulatory requirements of IAEA and domestic transport regulations. And, radiation shielding evaluation to determine dose rate limits of LILW drums to be containable in the packages was carried out by using the computer code. From the distribution of dose rate of LILW drums stored in the on-site storage facility of NPPs, it is estimated that about 65% of 200-liter LILW drums and about 95% of 320-liter LILW drums are transportable with the 12mm thick-walled IP-2 packages being currently developed.

Therefore, new packages with thicker wall than 12mm to transport all LILW drum stored in the on-site storage facility of NPPs need to be developed and KHNP intends to design new packages for the remaining LILW drums.

REFERENCES

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[3] Korea MOST Notice No.2001-23, Regulation for Packaging and Transport of Radioactive Material. 2001

[4] ANS/ANS-6.1, American National Standards for Neutron and Gamma-Ray Fluence-to-Dose Factors, 2991

[5] KHNP, Safety Analysis Report for LILW Disposal Facility, 2006