Development of the Program on Radioactivity Evaluation for SF Dry Storage

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1. Introduction

The radioactivity module included in the SCALE means an automatic module that can evaluate the inventory with Nuclear Power Plants during transporting the SNF(Spent Nuclear Fuel). SCALE program currently is a step to perform the verification and validation due to completion of design and development and its distributions 3rd version by this time.[1]

In this study, calculations for multiple fuels and automatically derivation of a report form for submiting to regulatory institute, the radiation dose considering the transport of multiple fuels, pre-verification for acceptance criteria for transport and data management system for SF emitted from the nuclear reactor.

The SCALE program evaluated to help operator to manage program and prevent errors on the transportation standards.

2. Methods and Results

The radioactivity evaluation module was developed to select the SCALE6.1-OrigenArp Express/Detail mode and express combustion profile applicable to Detail mode. Also, this module could implement a continuous calculation to the multiple fuels which are selected by users and have a relation with safety information for UCMS. The evaluation results for the radioactivity on the multiple fuels could be automatically printed out report format to be able to provide the final report with regulatory institute. Fig. 1 shows a main menu for radioactivity evaluation that can be connected with SCALE module.

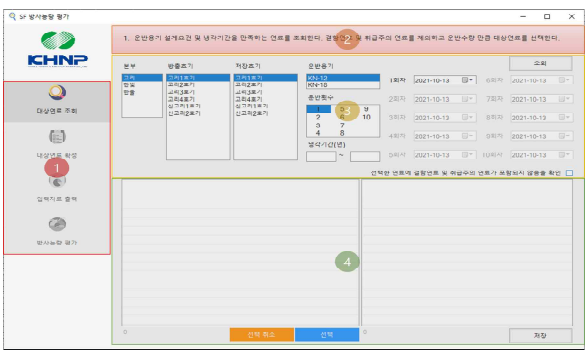


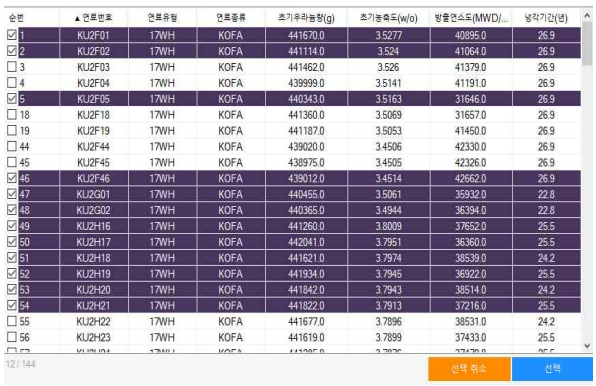
Fig. 1. Configurations for radioactivity evaluation module.

A function of SNF transportation on the main menu screen means to radioactivity evaluation. The radioactivity evaluation module was included such as "①radioactivity evaluation menu", "②information message", "③input menu", "②evaluation result" was activated. search for a target fuels, determination for a target fuels, deviation for input materials and evaluation radioactivity. SCALE program can be calculated multiple fuels and automatically derive a report form for submission to regulatory agencies.

2.1 Searching and determining for targets

The functions of target fuel to searching a target fuel for radioactivity assessment based on the spent fuel safety information stored in the UCMS. In case of inquiry, the headquarters, discharge and storage units can limit the target to those suitable for the conditions of the relevant power plant among all fuels stored in UCMS. The transport container can be limited to fuel that meets the design requirements of KN-12 and KN-18. The number of transports can be selected up to 10 times, and the transport date can be designated for each cycle as many times as selected. It made based on at least 7 years and there is no upper limit. It established a transport strategy by calculating the radiation dose considering the transport of multiple fuels.

As shown in Fig. 2, the target fuels are sorted in 'ascending order' based on the fuel number.



순번	▲연료번호	연료유형	연료종류	초기우라늄량(g)	초기농축도(w/o)	방출연소도(MWD/...	냉각기간(년)
☑ 1	KU2F01	17WH	KOFA	441670.0	3.5277	40895.0	26.9
☑ 2	KU2F02	17WH	KOFA	441114.0	3.524	41064.0	26.9
☐ 3	KU2F03	17WH	KOFA	441462.0	3.526	41379.0	26.9
☐ 4	KU2F04	17WH	KOFA	439999.0	3.5141	41191.0	26.9
☑ 5	KU2F05	17WH	KOFA	440343.0	3.5163	31646.0	26.9
☐ 18	KU2F18	17WH	KOFA	441360.0	3.5069	31657.0	26.9
☐ 19	KU2F19	17WH	KOFA	441187.0	3.5053	41450.0	26.9
☐ 44	KU2F44	17WH	KOFA	439020.0	3.4506	42330.0	26.9
☐ 45	KU2F45	17WH	KOFA	438975.0	3.4505	42326.0	26.9
☑ 46	KU2F46	17WH	KOFA	439012.0	3.4514	42662.0	26.9
☑ 47	KU2G01	17WH	KOFA	440455.0	3.5061	35932.0	22.8
☑ 48	KU2G02	17WH	KOFA	440365.0	3.4944	36394.0	22.8
☑ 49	KU2H16	17WH	KOFA	441260.0	3.8009	37652.0	25.5
☑ 50	KU2H17	17WH	KOFA	442041.0	3.7951	36360.0	25.5
☑ 51	KU2H18	17WH	KOFA	441621.0	3.7974	38539.0	24.2
☑ 52	KU2H19	17WH	KOFA	441934.0	3.7945	36922.0	25.5
☑ 53	KU2H20	17WH	KOFA	441842.0	3.7943	38514.0	24.2
☑ 54	KU2H21	17WH	KOFA	441822.0	3.7913	37216.0	25.5
☐ 55	KU2H22	17WH	KOFA	441677.0	3.7896	38531.0	24.2
☐ 56	KU2H23	17WH	KOFA	441619.0	3.7899	37433.0	25.5

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Fig. 2. Configurations of result for output target

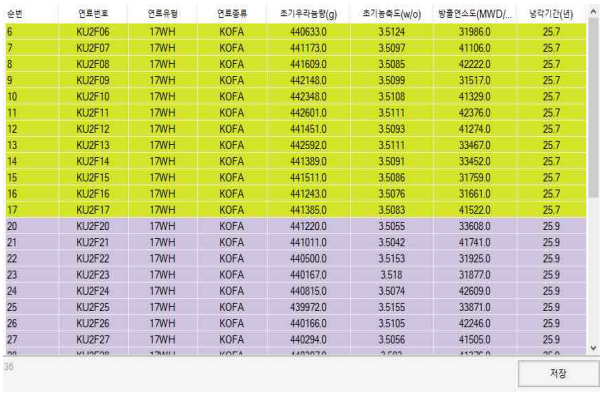
Among the searched fuels, the user selects the target fuel for which the radiation dose evaluation can be performed. For example, if 'KN-12' is selected for 'carrier', a total of 12 bundles are checked in the order of the sorted fuel, including the fuel checked in the checkbox, among the sorted fuels. As checking a fuel No. 3 in turn, No. 3 to No. 14 are checked at all.

The nuclear fuel emission unit or storage unit has a function of selecting only the nuclear fuel for which radioactivity is to be evaluated among the total fuel

stored in the UCMS. Additional selected SNF is selected as a total of 12 bundles or 18 bundles according to the transport container.

2.2 Output for Radioactivity evaluation

As searching for the target fuel, you can check the fuel that meets the design requirements and cooling period. Excluding defective fuels or fuels with handling precautions, target fuels with a large transport quantity can be selected. For the discharge unit and the storage unit, the selectable units are derived differently for each power plant selected. The finally selected fuels are sorted in 'ascending order' by classifying the colors for each cycle as shown in Fig. 3.



순번	연료번호	연료유형	연료종류	초기우라늄량(g)	초기농축도(w/o)	방출연소도(MWD/..	냉각기간(년)
6	KU2F06	17WH	KOFA	440633.0	3.5124	31986.0	25.7
7	KU2F07	17WH	KOFA	441173.0	3.5097	41106.0	25.7
8	KU2F08	17WH	KOFA	441609.0	3.5085	42222.0	25.7
9	KU2F09	17WH	KOFA	442148.0	3.5099	31517.0	25.7
10	KU2F10	17WH	KOFA	442348.0	3.5108	41329.0	25.7
11	KU2F11	17WH	KOFA	442601.0	3.5111	42376.0	25.7
12	KU2F12	17WH	KOFA	441451.0	3.5093	41274.0	25.7
13	KU2F13	17WH	KOFA	442592.0	3.5111	33467.0	25.7
14	KU2F14	17WH	KOFA	441389.0	3.5091	33452.0	25.7
15	KU2F15	17WH	KOFA	441511.0	3.5086	31759.0	25.7
16	KU2F16	17WH	KOFA	441243.0	3.5076	31661.0	25.7
17	KU2F17	17WH	KOFA	441385.0	3.5083	41522.0	25.7
20	KU2F20	17WH	KOFA	441220.0	3.5055	33608.0	25.9
21	KU2F21	17WH	KOFA	441011.0	3.5042	41741.0	25.9
22	KU2F22	17WH	KOFA	440500.0	3.5153	31925.0	25.9
23	KU2F23	17WH	KOFA	440167.0	3.518	31877.0	25.9
24	KU2F24	17WH	KOFA	440815.0	3.5074	42609.0	25.9
25	KU2F25	17WH	KOFA	439972.0	3.5155	33871.0	25.9
26	KU2F26	17WH	KOFA	440166.0	3.5105	42246.0	25.9
27	KU2F27	17WH	KOFA	440294.0	3.5056	41505.0	25.9

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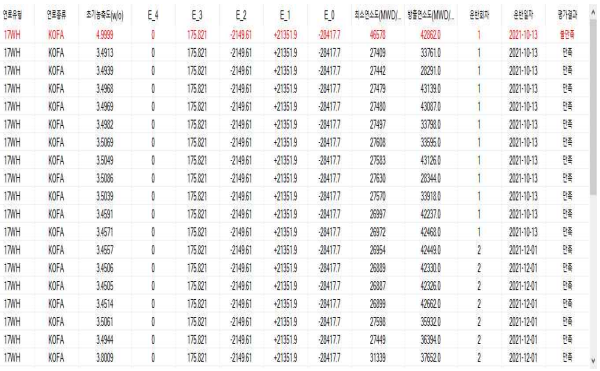
Fig. 3. Evaluation results for target spent fuel.

As shown in Fig. 4, the target fuel confirmation menu evaluates whether the fuel selected in the previous step satisfies the storage requirements of the unit to be transported and stored (hereinafter referred to as the receiving unit), and the final radioactivity evaluation for the fuel that meets the storage requirements.



연료유형	연료종류	초기농축도(w/o)	E_4	E_3	E_2	E_1	E_0	최소연소도(MWD/..	방출연소도(MWD/..	순번파악	순번일자	평가결과
17WH	KOFA	4.9999	0	175.021	-2149.61	+21351.9	-28417.7	46570	42682.0	1	2021-10-13	불만족
17WH	KOFA	3.4913	0	175.021	-2149.61	+21351.9	-28417.7	27409	33761.0	1	2021-10-13	만족
17WH	KOFA	3.4939	0	175.021	-2149.61	+21351.9	-28417.7	27442	28291.0	1	2021-10-13	만족
17WH	KOFA	3.4968	0	175.021	-2149.61	+21351.9	-28417.7	27479	43139.0	1	2021-10-13	만족
17WH	KOFA	3.4969	0	175.021	-2149.61	+21351.9	-28417.7	27480	43007.0	1	2021-10-13	만족
17WH	KOFA	3.4982	0	175.021	-2149.61	+21351.9	-28417.7	27497	33768.0	1	2021-10-13	만족
17WH	KOFA	3.5069	0	175.021	-2149.61	+21351.9	-28417.7	27608	33595.0	1	2021-10-13	만족
17WH	KOFA	3.5049	0	175.021	-2149.61	+21351.9	-28417.7	27583	43126.0	1	2021-10-13	만족
17WH	KOFA	3.5086	0	175.021	-2149.61	+21351.9	-28417.7	27630	28344.0	1	2021-10-13	만족
17WH	KOFA	3.5039	0	175.021	-2149.61	+21351.9	-28417.7	27570	33918.0	1	2021-10-13	만족
17WH	KOFA	3.4691	0	175.021	-2149.61	+21351.9	-28417.7	26997	42237.0	1	2021-10-13	만족
17WH	KOFA	3.4571	0	175.021	-2149.61	+21351.9	-28417.7	26972	42468.0	1	2021-10-13	만족
17WH	KOFA	3.4557	0	175.021	-2149.61	+21351.9	-28417.7	26954	42448.0	2	2021-12-01	만족
17WH	KOFA	3.4536	0	175.021	-2149.61	+21351.9	-28417.7	26889	42330.0	2	2021-12-01	만족
17WH	KOFA	3.4535	0	175.021	-2149.61	+21351.9	-28417.7	26887	42326.0	2	2021-12-01	만족
17WH	KOFA	3.4514	0	175.021	-2149.61	+21351.9	-28417.7	26899	42662.0	2	2021-12-01	만족
17WH	KOFA	3.5061	0	175.021	-2149.61	+21351.9	-28417.7	27598	35932.0	2	2021-12-01	만족
17WH	KOFA	3.4944	0	175.021	-2149.61	+21351.9	-28417.7	27449	36394.0	2	2021-12-01	만족
17WH	KOFA	3.8009	0	175.021	-2149.61	+21351.9	-28417.7	31339	37652.0	2	2021-12-01	만족

Fig. 4. Configurations for target determination.

Duplicate selections are applied to all fuels subject to evaluation if they are selected only once before evaluation. The evaluation result can be checked in the output file, and the radiation dose evaluation result can be derived based on the last information of the input data. In particular, the evaluation result in the form of a procedure is automatically generated as a file. After the radiation dose evaluation, the result of the total radiation dose for each container is derived, and the safety criterion is "less than $3.75*10^6$ Ci" in the case of KN-12 and "less than $6.018*10^6$ Ci" in the case of KN-18, evaluated as satisfactory. A pre-verification system was applied to ensure that the selected fuel satisfies the acceptance criteria for transport containers to prevent errors due to improper loading. Furthermore, Data management system (Fig.4) was facilitated by establishing a DB for SF emitted from the nuclear reactor.

3. Conclusions

The main functions applied to this program are as follows. 1. Calculate multiple fuels and automatically derive a report form for submission to regulatory agencies. 2. It is possible to establish a transport strategy in advance by calculating the radiation dose considering the transport of multiple fuels. 3. A pre-verification system was applied to ensure that the selected fuel satisfies the acceptance criteria for transport containers to prevent errors due to improper loading. 4. Data management was facilitated by establishing a DB for SF emitted from the nuclear reactor. 5. It was made possible to verify in advance whether it conforms to the loading curve of the acquired unit. This program was evaluated to be able to help increase operator convenience and prevent errors in transportation standards.

REFERENCES

[1] Korea Hydro & Nuclear Power Co., LTD, "Characteristic Inspection and Evaluation of spent fuel for Dry Storage".
[2] NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility — Final Report", July 2010.
[3] IAEA Safety Series No. 116 "Design of Spent Fuel Storage Facilities",1995.
[4] 10 CFR 72 - "LICENSING REQUIREMENTS FOR THE INDEPENDENT STORAGE OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND REACTOR-RELATED GREATER THAN CLASS C WASTE", Jan., 2017.