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Development of Atmospheric Dispersion Factor Calculation Module for DBA Conservatism Verification

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1. INTRODUCTION

In a design basis accident, an accident dose assessment should be performed together with thermal hydraulic analysis [1].
In particular, for accident impact assessment or dose analysis, atmospheric dispersion factor that simulates the behavior of radionuclides must be evaluated. In this study, in order to confirm and verify the conservatism of the atmospheric dispersion factor used in the design basis accident, an independent atmospheric dispersion factor calculation module was developed.
Here, the newly developed atmospheric dispersion calculation module are introduced, and the conservatism is verified by comparing with the calculation model of the traditional PAVAN code.
The newly developed calculation module is designed to calculate using the atmospheric dispersion experimental correlation equation.

2. METHODOLOGY

2.1. Experimental Correlation of Dispersion Factor

The calculation module was written in Perl Script to follow the calculation process of the traditional PAVAN code [2].
For the experimental correlation, instead of the NRC correlation of the PAVAN code, a correlation based on the results of the site diffusion experiment of the APR1400 nuclear power plant was applied [3].
New calculation module is linked to the modified PAVAN code. Data processing is carried out by separate pre-processing module.
And also, Pre-processing module is compiled by Perl Script and Perl system.

2.2. Experimental Correlation Derivation

As for atmospheric dispersion factor, the diffusion coefficient at each stability point is very important.
This is because the diffusion coefficient is inversely proportional to the atmospheric dispersion factor.
In this study, the diffusion coefficient related to the atmospheric stability in the traditional NRC model are listed, and the diffusion coefficient measured in the field diffusion experiment of the APR1400 NPP is compared with the NRC model's diffusion coefficient.

3. RESULTS AND DISCUSSIONS

3.1. Comparison between the NRC model's Diffusion Coefficient and the Experimental Diffusion Coefficient of APR1400 Field Experimental Test

As shown in Figure 1 below, the solid line is the diffusion coefficient graph for each atmospheric stability of the traditional NRC model.
On the other hand, square and rhombus data are diffusion coefficients at atmospheric stability D and E.
Through Figure 1, it can be seen that the diffusion coefficient is much larger than that of the NRC model.
This results show that the atmospheric dispersion factor according to the actual experimental correlation will be very small.

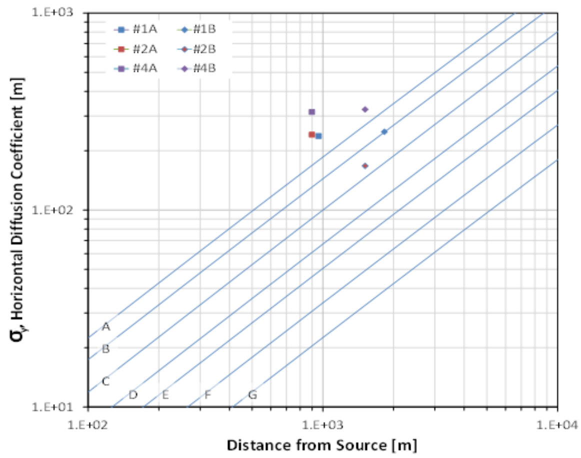

Fig. 1 Comparison between NRC model and experimental correlation model in stability D and E

$$\frac{\overline{X}}{Q}(x,k) = \frac{2.032}{x} RF_k(x) \sum_{ij} F_{ijk} \left\{ U_{ij}(10) [\sigma_{zj}^2(x) + \frac{cD^2}{\pi}]^{\frac{1}{2}} \right\}^{-1}$$
(1)

From Fig.1, equation (1) is controlled.
Equation (1) includes PAVAN's traditional dispersion correlation for atmospheric dispersion factor calculation.

3.2. Perl Script Compiling and Calculation System

The Perl system is very important in this study. All of this study's experimental correlation equation behavior is implemented using Perl.
Perl is a highly capable, feature-rich programming language over 30 years of development [2]. And

various program modules can be used. In this study, the Perl system was used to compile and create executable files.

Figure 2 is the executable files created by the Perl System. The "Calculation_moule_2023.exe" is a calculation module loaded with the experimental correlation equation and the "PAVAN_Link_2022.exe" operates when the calculation module calculates the atmospheric dispersion factor based on the experimental correlation equation by linking the PAVAN code. The "Pre_processing_2021.exe" is a preprocessing program that generates input statements.

Fig. 2 Calculation Module Compiling by Perl System

The Perl system shown in Fig.2 controls the execution sequence and subroutines of PAVAN programs. Fig.3 shows the structure of the calculation controlling by Perl system.
Eventually, at the point of applying the diffusion coefficient, the Perl system temporarily stops the PAVAN program and replaces the diffusion coefficient correlation of the subroutine with the experimental correlation equation to control the calculation of atmospheric dispersion factors.

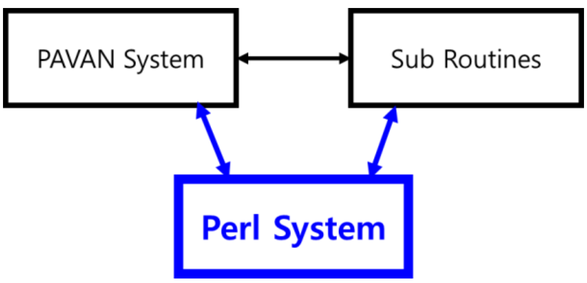

Fig. 3 Calculation Controlling by Perl System

3.3. NRC model's Conservatism

In order confirm and verify the conservatism of the NRC model, the results of the calculation performed by the calculation module loaded with the experimental correlation equation are shown in Table1.

Table1 shows the 95% cutoff calculation results by the NRC model, the 50% cutoff calculation results by the NRC model, and the 95% cutoff calculation results by the experimental correlation model.

As can be seen from the results, it can be seen that the 95% cutoff calculation results by the experimental correlation is significantly smaller than the 50% cutoff calculation results of the NRC model.

The meaning of this results means that the 50% cutoff calculation of the NRC model is sufficiently larger than any value of the experimental correlation model.

Table 1. Result between NRC model and Experimental Correlation model

Model	0~2 hours	0~8 hours	8~24 hours	24~96 hours	96~720 hours
95%cut off PAVAN NRC model	4.59E-04	2.29E-04	1.62E-04	7.60E-05	2.57E-05
50%cut off PAVAN NRC model	1.07E-04	6.68E-05	5.33E-05	3.26E-05	1.62E-05
95% cutoff experimental correlation model	4.131E-05	2.061E-05	1.458E-05	6.840E-06	2.313E-06

In conclusion, since it means that the PAVAN model is sufficiently larger than any atmospheric dispersion factor of natural phenomena, the results of Table1 can be seen as sufficiently verifying the conservatism of the NRC model.

4. CONCLUSIONS

In this study, the following conclusions can be obtained from Figure 1 and Table 1.
First, it was found that the diffusion coefficient by the experimental correlation was significantly larger than that of the traditional NRC model.

Second, Perl Script was developed as a calculation module loaded with experimental correlation equations

Third, from the result of calculating the atmospheric dispersion factor using the calculation module equipped with the experimental correlation equation, it was confirmed that the 50% cutoff calculation results of the NRC model is sufficiently larger than the 95% cutoff calculation results of the diffusion experimental correlation model.

In this study, it was confirmed that the significant difference in the diffusion coefficient makes the evaluation of the atmospheric dispersion factor by the NRC model conservatism in Hanul Site in APR 1400.

REFERENCES

[1] KHNP-CRI, Seung-Chan LEE, "Study for Atmospheric Dispersion Factors and Stability in NPP Sites", KNS Virtual Autumn Meeting, October (2021).
[2]Larry Wall, "Programming Perl", (2000).
[3] KHNP-CRI, "Suitability Validation of Radioactivity Atmospheric Dispersion Assessment Model for Hanul Site"(2018).