Development of Numerical Model for Atmospheric Diffusion of Stack Gas from Nuclear Power Stations

Background

It is necessary to construct more nuclear power stations to realize a low-carbon society in the future. Atmospheric flow and stack gas diffusion from nuclear power stations have been evaluated for the safety analysis in Japan using wind tunnel facilities, and the effective stack height [*1] is analyzed using wind tunnel experimental results. Then, the effective stack height is used in evaluations of effective dose and relative concentration of stack gas for the people around nuclear power stations. However, experimental periods and financial budgets are being increased to perform wind tunnel experiments repeatedly with the variations of terrain and building conditions of nuclear power stations. To improve these situations using wind tunnel facilities, it is necessary to develop a numerical simulation model to predict atmospheric flow and stack gas diffusion for nuclear power stations to evaluate effective stack height.

Objectives

A numerical simulation model has been developed to predict atmospheric flow and stack gas diffusion, considering the buildings and complex terrain. The effective stack heights with wind directions are estimated by calculations results and compared with those obtained by the wind tunnel experiment. Then, effective dose and relative concentration of stack gas for the people around nuclear power stations are calculated using the effective stack heights both obtained by calculations and wind tunnel experiments.

Principal Results

1. Development of numerical simulation model for atmospheric diffusion from nuclear power station

The turbulence closure technique is used for flow calculation in a developed numerical model, and stack gas diffusion is predicted applying the Lagrangian particle model using flow calculation results. Then, effective dose and relative concentration are estimated using effective stack height both obtained by calculations and wind tunnel experiments and meteorological observation data as indicated in Fig. 1.

2. Adoption of numerical simulation model for nuclear power station

Developed numerical simulation model is applied to the nuclear power station and it is apparent that:

(1) The effective stack heights estimated by calculations are almost the same as those obtained by wind tunnel experiment under the normal and accidental plant operation conditions within all the wind directions bound for land area as indicated in Fig. 2, and

(2) The profiles of effective dose under the normal plant operation condition, and relative concentration under the state of accident, estimated with effective stack height from calculations, are almost the same as those using the effective stack height obtained by wind tunnel experiment as indicated in Fig. 3.

Future Developments

Developed numerical model will be applied to other nuclear power stations, and the standard describing a developed simulation model will be made.

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Reference
K. Sada, et al., 2006, "Numerical Simulation of Atmospheric Flow and Stack Gas Diffusion under Building and Complex Terrain Conditions – Estimations of Effective Stack Height and Comparisons with Wind Tunnel Experiments –", JSME Int. J. Series B, 49-1, pp. 48-59
K. Sada, et al., 2008, "Numerical Model for Stack Gas Diffusion in Terrain Containing Buildings – Application of Numerical Model to a Cubical Building and a Ridge Terrain –", Asian J. Atmos. Environ., 2-1, pp. 1-13

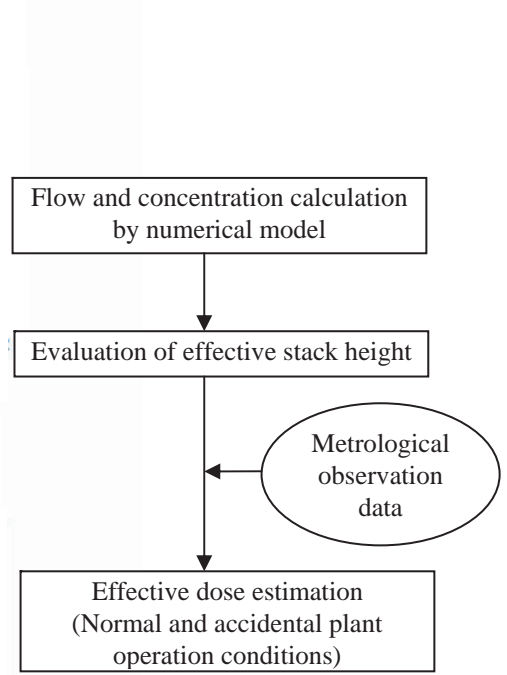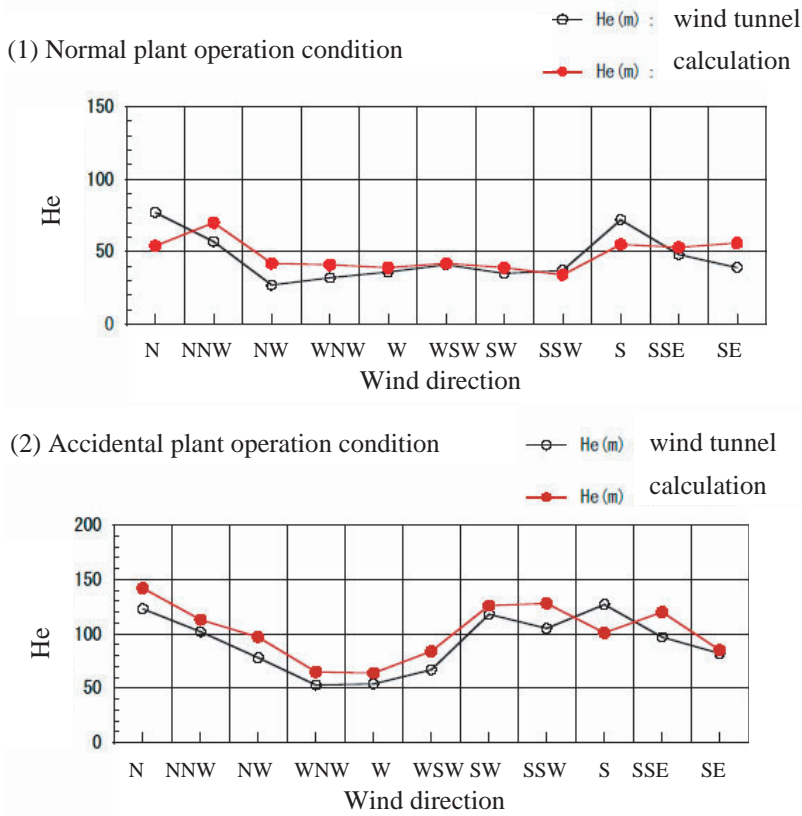＊1：virtual stack height as concidering the terrain and building effects for the stack gas diffusion

(1) Normal plant operation condition

(2) Accidental plant operation condition

Fig.2 Effective stack height (He) with wind direction (B-site)

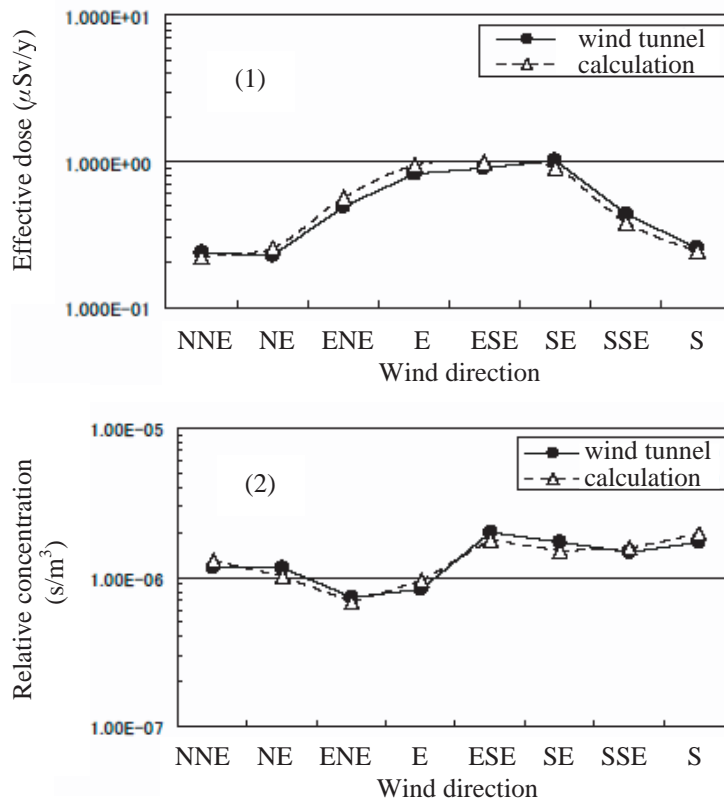**Fig.1** Estimation procedure of effective dose

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Fig.3 (1) Effective dose by γ-ray of noble gas with wind direction under normal plant operation condition and (2) Relative concentration with wind direction under the state of accident (A-site)