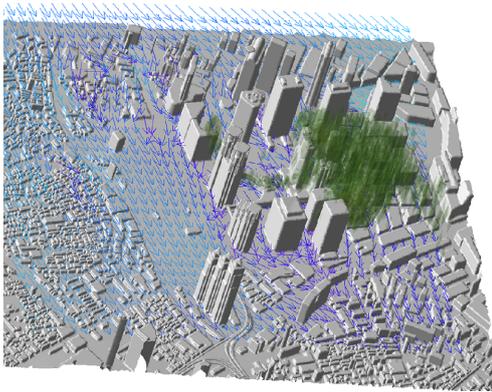


# Improvement of Nuclear Preparedness Technology and Application to Urban Safety



SHIGEHIRO NUKATSUKA \*1 RYOHI OHBA \*2

AKIYOSHI SATO \*3 TOMOHIRO HARA \*4

*We have developed the system “Multiple Radiological Emergency Assistance System for Urgent Response (MEASURES),” which grasps accident status, forecasts possible accident progression, and quickly and accurately predicts regional diffusion of radioactive materials in the case of emergency circumstances at a nuclear power plant. In addition, as we have developed a new model capable of evaluating hazardous gas diffusion in urban districts, MEASURES is now able to evaluate possible impacts of terrorist activities, taking into consideration effects of buildings. As this system is successfully developed, MEASURES is now usable for planning the central government’s nuclear disaster prevention measures in accordance with the “Act on Special Measures Concerning Nuclear Emergency Preparedness” as well as disaster mitigation measures or safety measures in urban areas in accordance with the “Civil Protection Law.”*

## 1. Introduction

If a nuclear accident occurs, it is necessary to analyze the accident, forecast/evaluate its status and possible impacts on the environment and provide such information for taking effective disaster prevention measures. We have developed the “Multiple Radiological Emergency Assistance System for Urgent Response (MEASURES)” as a tool to support nuclear disaster prevention activities at nuclear power plants in these circumstances and to assist decision-making/judgment of nuclear power plant’s disaster prevention staff. This system is not only operable by the central government and power plants but also useful for nuclear emergency preparedness drills. We have also developed a system usable for urban safety by upgrading the capabilities to forecast possible impacts on the environment and estimating the possible diffusion of hazardous materials. This article explains this system to support the handling of possible emergencies at the central government, local government and utility firm levels as a new system compatible with the “Act on Special Measures Concerning Nuclear Emergency Preparedness” and “Civil Protection Law,” which are designed to provide safety and a feeling of security among Japanese citizens.

## 2. Multiple Radiological Emergency Assistance System for Urgent Response

### 2.1 System configuration

MEASURES<sup>1</sup> (Multiple Radiological Emergency Assistance System for Urgent Response) is equipped with the four subsystems shown in **Figure 1** in order to support effective countermeasures and decision-making in the case of a nuclear accident.

\*1 Manager, Nuclear Energy Systems Engineering Center, Nuclear Energy Systems Headquarters

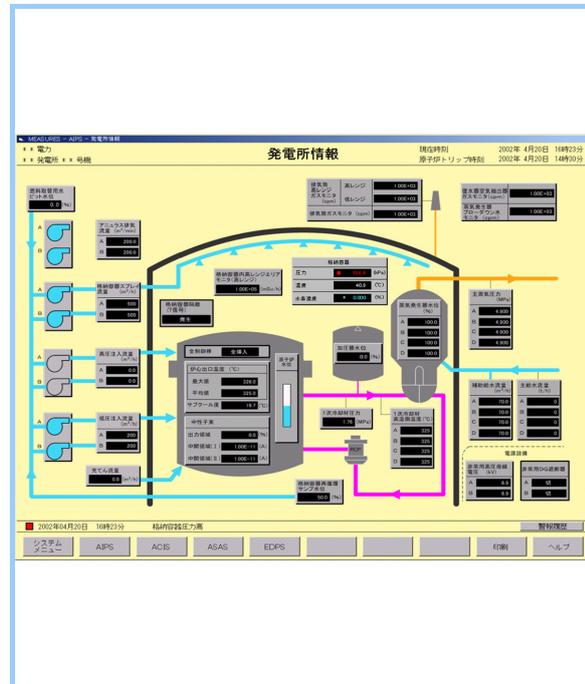
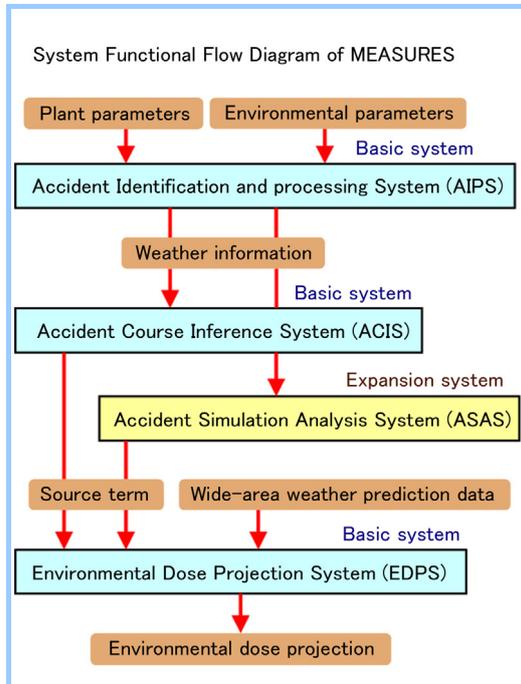
\*2 Manager, Nagasaki Research and Development Center, Technical Headquarters

\*3 Nuclear Energy Systems Engineering Center, Nuclear Energy Systems Headquarters

\*4 Nagasaki Research and Development Center, Technical Headquarters

## (1) Accident Identification &amp; Processing System (AIPS)

AIPS is responsible for collecting data, displaying plant status, and identifying possible causes of an accident. The data it processes include plant status data, environmental monitoring data, and meteorological data, such as wind directions and speeds. This system displays these data in a clear concise format, as shown in **Figure 2**. Furthermore, AIPS diagnoses and displays initiating events that have triggered the accident by checking the plant status data collected as well as the Accident Diagnostic Table based on previously accumulated data.



**Figure 1** System function flow diagram of MEASURES

**Figure 2** Example of plant status display

## (2) Accident Course Inference System (ACIS)

Based on AIPS' diagnosis of initiating events, ACIS quickly infers the future event progression and assesses when the release of radioactive materials will begin and how long it will last and at what rate. Data concerning the course of the accident and the amount of radioactive materials released are analyzed in advance and stored in the database for inference purposes. ACIS displays the accident progression on an Event Tree screen.

## (3) Accident Simulation Analysis System (ASAS)

ASAS is designed to infer accident progression and the amount of radioactivity released more realistically and accurately by utilizing the Best Estimate Analysis Program. This system is able to accurately analyze the accident in real time from an early stage, rather than making inference based on a database such as ACIS.

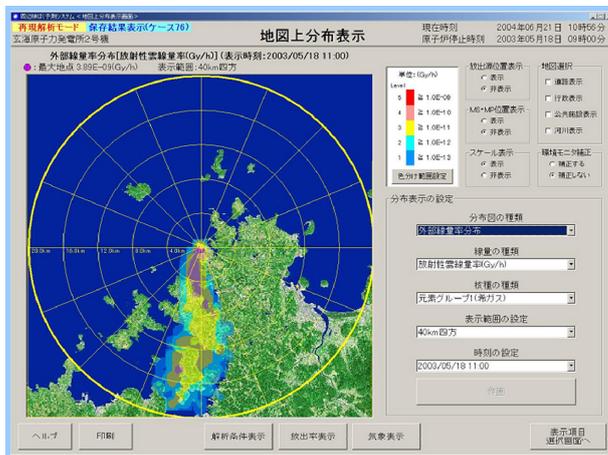
## (4) Environment Dose Projection System (EDPS)

EDPS quickly and accurately forecasts variations in atmospheric air flow and dispersion of radioactive materials around the power plant, as well as changes in the concentration of radioactive materials and distribution of dose rates. Employing regional atmospheric data (GPV: Grid Point Value), the meteorological dynamic model (RAMS: Regional Atmospheric Modeling System) and non-steady state 3-D atmospheric dispersion model adopting the Hybrid Particle and Concentration Transport (HYPACT) code enables the system to provide detailed projections.

As for nuclear species or radioactive release from the plant, the system automatically utilizes data from ACIS and ASAS, or alternately, data entered by plant personnel manually. Onscreen displays available from EDPS include a Wind Speed Vector Diagram, Distribution of Airborne Concentration, Radioactivity Distribution Deposited on the Ground, Dose Rate Distribution, and Total Dose Rate Distribution.

**Figure 3** illustrates an example of dose rate distribution. In order to provide these projections accurately and quickly, the system adopts parallel computation or a multigrid approach (nesting technique) that gradually narrows the computational domain in the case of time-consuming analyses such as analysis on 3D airflow distribution.

MEASURES has a system configuration capable of operating as an integral system by coordinating individual modules necessary for countermeasure assistance or decision-making at the time of a nuclear emergency, while each module is also able to work as an individual system. Taking into consideration possible system expansion in the future, MEASURES is also designed to facilitate incorporation of various analysis codes.



**Figure 3** Example of dose rate distribution display, taking account of terrain and airflow conditions around the nuclear power station



**Figure 4** Example of evacuation and indoor evacuation areas in nuclear emergency preparedness drills

## 2.2 Application to nuclear emergency preparedness drills/exercises/trainings

MEASURES is developed to support nuclear disaster prevention activities. In addition, by using MEASURES for the central/local government's comprehensive nuclear emergency preparedness drills, disaster drills at power plants and ordinary drills/exercises/trainings for disaster prevention staff, users are able to conduct effective drills/exercises/trainings based on their nuclear accident scenarios.

MEASURES are usable for the following drills/exercises/trainings.

- Nuclear emergency preparedness drills (comprehensive drills, drills at power plant and drills/exercises/trainings for staff) in line with accident scenarios
- In line with accident scenario, users are able to use MEASURES for:
  - Training for identifying plant accident progress;
  - Training for quickly forecasting radiation-damaged areas;
  - Training for reporting to the central government, etc.
- Assisting appropriate decision-making of the accident/disaster response team
- Providing support information useful for decision-making
- Supporting effective nuclear emergency preparedness drills in line with concrete accident scenarios
- Supporting day-to-day exercises/training for upgrading disaster prevention staff's skills
- Verifying disaster prevention plans

In order to decide on evacuation areas (i.e., the areas where residents need evacuation or indoor evacuation) in cooperation between the central government's resident safety teams and local governments, it is necessary to decide evacuation areas/districts based on accurate estimates of affected areas, taking into consideration terrain and meteorological variation as shown in **Figure 4**. In this context, MEASURES is also useful for upgrading skills and as a tool for conducting effective drills/exercises/trainings.

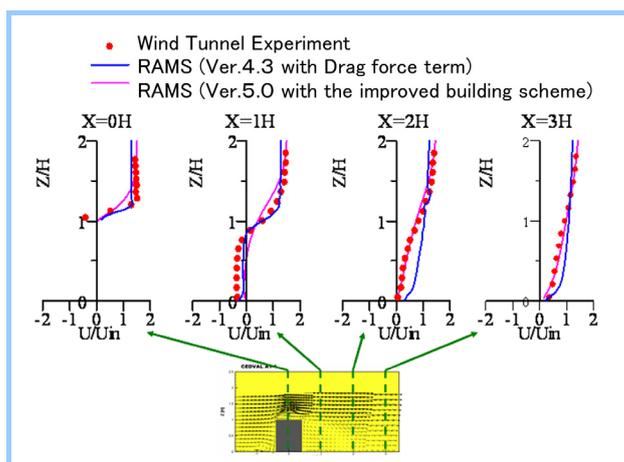
### 3. Application to urban safety

As the Environment Dose Projection System (EDPS) gets upgraded, MEASURES is expanded as an urban safety system to forecast emission/leakage of hazardous materials in urban areas, estimate atmospheric diffusion of hazardous materials emitted/released from power plants, chemical plants, transportation facilities or storage facilities, and support drafting emergency plans for urban areas. This system employs improved RAMS for airflow computation and improved HYPACT for diffusion calculation. The calculations will take the following steps.

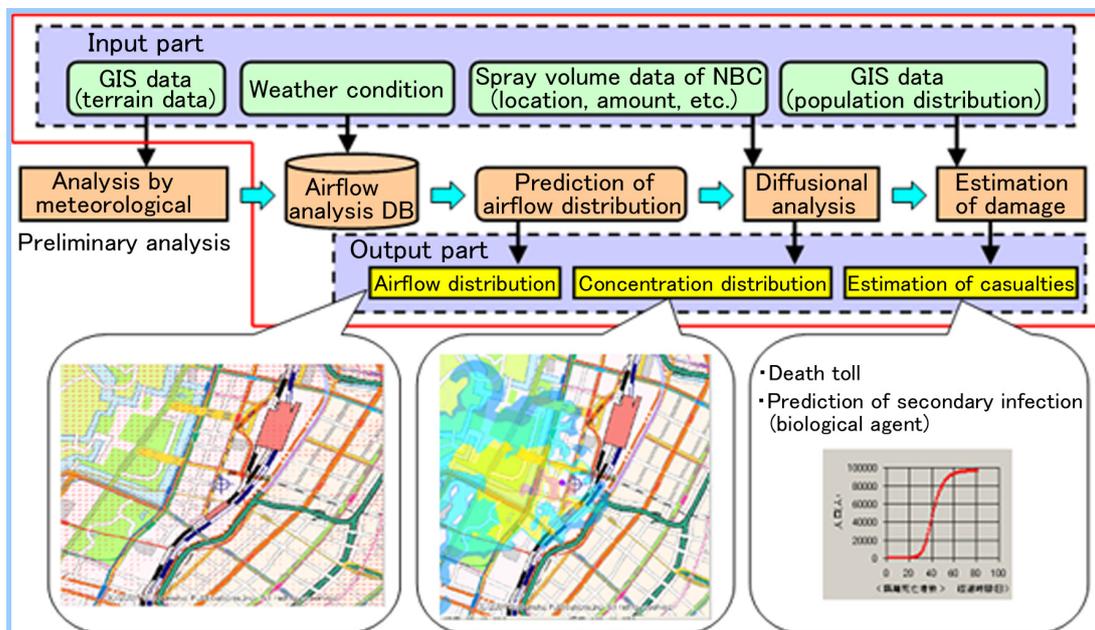
- i) Calculating 3D narrow-area airflow database under typical weather conditions
- ii) Manually entering weather condition data (wind directions, wind speed and atmospheric stability) or automatically entering GPV data
- iii) Conducting interpolative calculation of gas-flow field's temporal variation based on weather conditions by using airflow database
- iv) Conducting 3D nonstationary diffusion calculation by using the airflow temporal variance data calculated from the interpolative calculation

#### 3.1 Meteorological dynamic models

Many meteorological dynamic models are publicly available to users as open codes, such as RAMS, WRF and MM5. To calculate the airflow around buildings in urban areas in several-meter mesh size, we improved RAMS in the following manner. First, to accurately reproduce the airflow around buildings and terrains in a narrow area, we improved a RAMS turbulence model by replacing the Mellor and Yamada model (1982)<sup>2</sup> with the Castelli model (2006)<sup>3</sup>. Calculation results on the airflow around a standalone building has yielded a decent outcome when compared with Hamburg University's disclosed wind-tunnel experiment database<sup>4</sup>, as shown in **Figure 5**.



**Figure 5 Comparison between RAMS calculation results and Hamburg University's disclosed wind-tunnel experiment database**



**Figure 6 Outline of damage projection system for urban safety purposes**

### 3.2 Air diffusion models

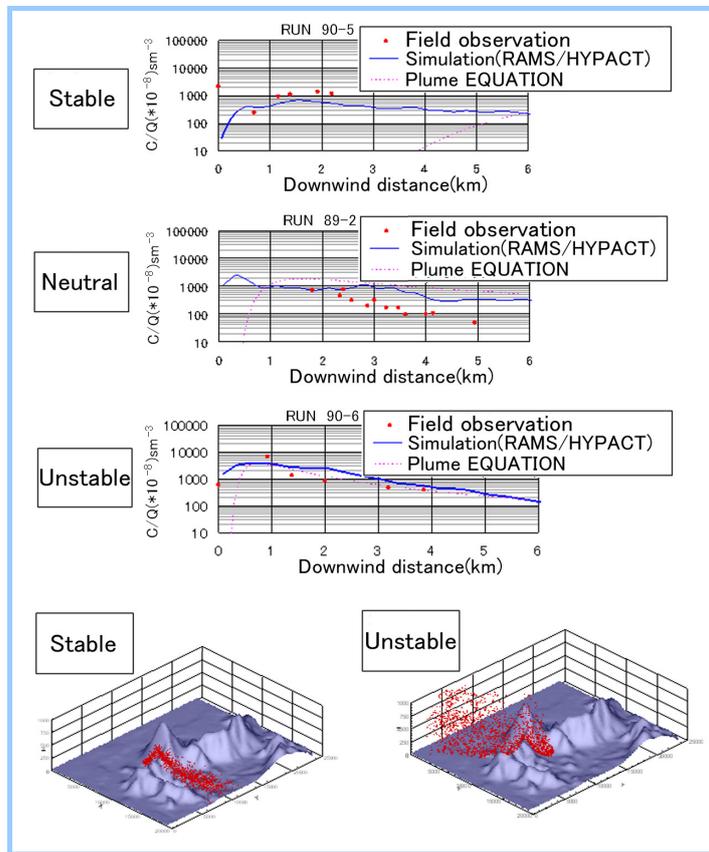
HYPACT code is an air diffusion code closely related with RAMS. This code is a Lagrange-type particle diffusion model and satisfies the law of mass conservation even in complicated gas-flow fields. When used for long distance, this code is also usable with the difference method calculus in order to reduce the computing time. The gas concentration calculation results are compared with the long-term diffusion experimental results obtained from Japan Atomic Energy Research Institute's experiments at Tokai Village in 1991 and 1992. The impacts of buildings on the airflow is well reproduced in terms of wind speed and turbulent intensity<sup>5</sup>.

## 4. System configuration

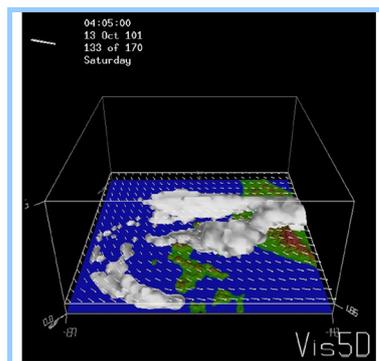
As shown in **Figure 6**, this system consists of an airflow database, diffusion model and impact projection model. Regional meteorological data are provided from an outside source via the Internet. Database on the airflow, terrains and population are also stored in the system in advance. Calculations necessary for computation 1 hour ahead will take less than 1 minute. Calculation results, such as wind speed distribution, gas concentration and the number of victims will be displayed on the screen at a 10-minute interval. They are available for users during the calculation process and after completion of the calculation.



**Figure 7** Reproducible calculation of diffusion experiment in Downtown Oklahoma City



**Figure 8** Calculation results of particle diffusion distribution around Mt. Tsukuba



**Figure 9** Display example of Mt. Usu volcanic smoke behavior simulation

In addition, as calculation for the airflow database is rather time-consuming, the system uses parallel computers. Diffusion calculation requires only one ordinary PC by using the database, and takes only several minutes for calculating event progression for 24 hours later.

## 5. Validation examples

Comparison between the actually measured values from the Meteorological Agency's regional weather observation system (AMeDAS, Automated Meteorological Data Acquisition System of JAPAN) and the projected values from MEASURES has revealed that MEASURES projection results for dates and times that were designated beforehand (temporal variations in air temperature, wind direction and wind speed at observation points) show good agreement with those given by AMeDAS<sup>1</sup>.

**Figure 7** shows the results of an outdoor diffusion experiment in Downtown Oklahoma City in US. Estimated concentration data are relatively coherent with the actually measured concentration. As shown in **Figure 8**, comparison with Japan Atomic Energy Research Institute's outdoor diffusion experiment around Mt. Tsukuba<sup>6</sup> has revealed that the calculation results would best agree with the actually measured data if the atmosphere is highly stable.

## 6. Application cases

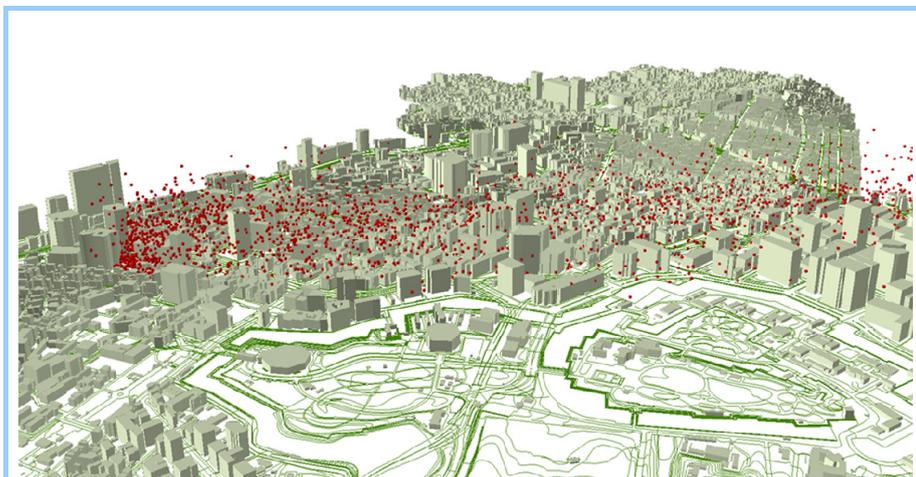
### (1) Diffusion projection system on complex terrains

As mentioned earlier, MEASURES is usable for forecasting gas diffusion emitted from nuclear/thermal power plants. In addition, MEASURES is also useful for estimating the diffusion of volcanic smoke from volcanoes or forecasting how much yellow sand flying from China would impact on Japan. Terrestrial gas diffusion evaluation is difficult due to the complexity of terrain and gaps in vegetation distribution, but diffusion projection/evaluation is important for disaster prevention and environment assessment purposes.

**Figure 9** illustrates a calculation example of Mt. Usu smoke diffusion, taking into consideration the terrain and meteorological variation. By closely evaluating/analyzing volcanic smoke diffusion in this way, this system is able to quickly analyze useful information for planning countermeasures or making decisions related with various disasters, such as natural disasters.

### (2) Urban district diffusion projection system

For urban plans on urban district roads or high-rise buildings as well as CBR (chemical, bio and radioactive agents) anti-terrorism drills, diffusion calculation incorporating building's effects is absolutely necessary. **Figure 10** shows PC-based diffusion calculation that incorporates building's possible effects by using an airflow database, which is a major characteristic of this system. We have developed this system, assuming that first responders, such as local governments, fire authorities and police stations, would be able to effectively use it. For this reason, this system uses ordinary PCs and is capable of quickly evaluating the hazardous gas diffusion status.



**Figure 10** Airflow and diffusion around high-rise buildings in urban areas

## 7. Conclusion

We have developed MEASURES as a tool to assist appropriate decision-making, which is important for power plant operators to take effective action in the case of nuclear emergencies. By introducing a metrological dynamic model, MEASURES is able to forecast radioactive materials diffusion, taking into consideration meteorological variations. By adopting parallel computing techniques and new calculation algorithms, we have successfully cut down the computation time significantly. In addition, MEASURES is now usable not only for taking countermeasures on nuclear emergencies but also for other purposes, such as forecasting impacts of hazardous gas diffusion or various types of pollution. For example, we have recently developed a new projection system for possible gas diffusion in squalid urban areas in order to evaluate urban safety. By using a high-resolution airflow database created in advance, this system is able to conduct calculations in double-digit quicker than the cases without the airflow database, and it is also capable of correctly calculating the airflow and diffusion status around buildings as accurate as Computational Fluid Dynamics (CFD).

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