Using RASCAL Code to Analyze the Postulated UF_6 Fire Accident

J. R. Wang, Y. Chiang, W. S. Hsu, S. H. Chen, J. H. Yang, S. W. Chen, C. Shih, Y. F. Chang, Y. H. Huang, B. R. Shen

Abstract**—**In this research, the RASCAL code was used to simulate and analyze the postulated UF_6 fire accident which may occur in the Institute of Nuclear Energy Research (INER). There are four main steps in this research. In the first step, the UF_6 data of INER were collected. In the second step, the RASCAL analysis methodology and model was established by using these data. Third, this RASCAL model was used to perform the simulation and analysis of the postulated UF_6 fire accident. Three cases were simulated and analyzed in this step. Finally, the analysis results of RASCAL were compared with the hazardous levels of the chemicals. According to the compared results of three cases, Case 3 has the maximum danger in human health.

Keywords**—**RASCAL, UF6, Safety, Hydrogen fluoride.

I. Introduction

INER bought UF_6 from America and France to perform some research plans during 1979~1982. After the plans are finished, INER stored the UF_6 in a building. The amount UF_6 of is about 34770 kg. UF_6 is a hazardous chemical. UF_6 can react with water to form HF (hydrogen fluoride) and UO_2F_2 (uranyl fluoride). In addition, this reaction is an exothermic reaction. The HF is a highly corrosive chemical, and the UO_2F_2 is very toxic. Therefore, this study used the RASCAL code to perform three postulated cases for the safety of human which live around the INER.

The RASCAL code can calculate the doses of radioactive materials from a nuclear power plants, spent fuel storage pools and casks, fuel cycle facilities, etc. [1]. The RASCAL is one of Radiological protection computer code Analysis and Maintenance Program (RAMP) codes. U.S. NRC leads the RAMP international cooperation program. RAMP main research area is the radiation dose calculation, plant decommission, atmospheric dispersion factor, control room habitability, and so on. Our group (Tsing-Hua University, Taiwan) joined the RAMP program in 2016 and got the RASCAL code. Hence, based on learning some references [1]-[5], the RASCAL code is used in this research to establish an analysis methodology for UF_6 fire accident. Three postulated cases with the different release pathway and meteorology conditions were performed by using RASCAL in this study. Additionally, the analysis results of RASCAL compared with the criteria of hazardous levels [1], [2].

Y. Chiang, W. S. Hsu, S. H. Chen, J. H. Yang, S. W. Chen, C. Shih, Y. F. Chang, Y. H. Huang, B. R. Shen are with the Institute of Nuclear Engineering and Science, National Tsing-Hua University, Nuclear Science and Technology Development Center, and Nuclear and New Energy Education and Research Foundation, R.O.C., Taiwan.

J. R. Wang is with the Institute of Nuclear Engineering and Science, National Tsing-Hua University, Nuclear Science and Technology Development Center, and Nuclear and New Energy Education and Research Foundation, R.O.C., Taiwan (e-mail: jongrongwang@gmail.com).

II. The Description of Cases and Criteria

Table I presents three cases conditions. The mass of UF_6 is 34770 kg (solid). The release rate of UF_6 is assumed to 8 kg/sec. The differences of three cases are the release pathway and meteorology conditions which are also shown in Table I.

Fig. 1 shows the operation screen of RASCAL. The operation of RASCAL includes some parameters input and setting. There are six main operation steps in the analysis. These operation steps are event type, event location, source term, release path, meteorology, and calculate doses. In addition, Fig. 2 shows the RASCAL setting for the UF_6 analysis. Some date of UF_6 is input to the RASCAL in this step.

After the case analysis finished, the results of RASCAL compared with the criteria of hazardous levels for human health. These criteria for HF concentration and Uranium Intake are as follows:

For HF concentration: ERPG (Emergency Response Planning Guideline) estimates the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for 1 hour. A chemical has three ERPG values which correspond to a specific tier of health effects [3] (see Fig. 3):

- ERPG -1: <2 ppm
- ERPG-2: 2~20ppm
- ERPG-3: 20~50ppm

For Uranium Intake:

- Uranium Intake: < 10mg

No effect is in the human health.

- Uranium Intake: 10mg ~ 40mg

The health effect is transient renal injury.

- Uranium Intake: 40mg ~ 230mg

The health effect is permanent renal damage.

- Uranium Intake: > 230mg

The health effect is 50% lethality.

III. Results

Table II shows the analysis results of RASCAL for the three cases. These results include HF concentration, HF deposition, Uranium intake mass, Uranium TEDE, Uranium deposition, and the distance from release point. By comparing the results of three cases, it depicts that Case 3 has the maximum values of HF concentration, HF deposition, Uranium intake, Uranium TEDE, Uranium deposition in the cases. This indicates that Case 3 has the maximum danger in human health. In addition, Table II also presents the distance at which the maximum values occur. The distances of Case 1 and 3 are 0.16 km, and Case 2 is 0.32 km.

TABLE I
CASE CONDITIONS

Case	UF_6	Release pathway	Meteorology
1	Mass: 34770 kg, solid Release rate: 8 kg/sec	Postulated fire occurring, UF_6 is releasing from a building	West wind (1m/s), D stability, 25 ℃, no raining
2		Postulated fire occurring, UF_6 is releasing directly	D stability, 25℃, no raining
3		Postulated fire occurring, UF_6 is releasing directly	D stability, 25 ℃, raining

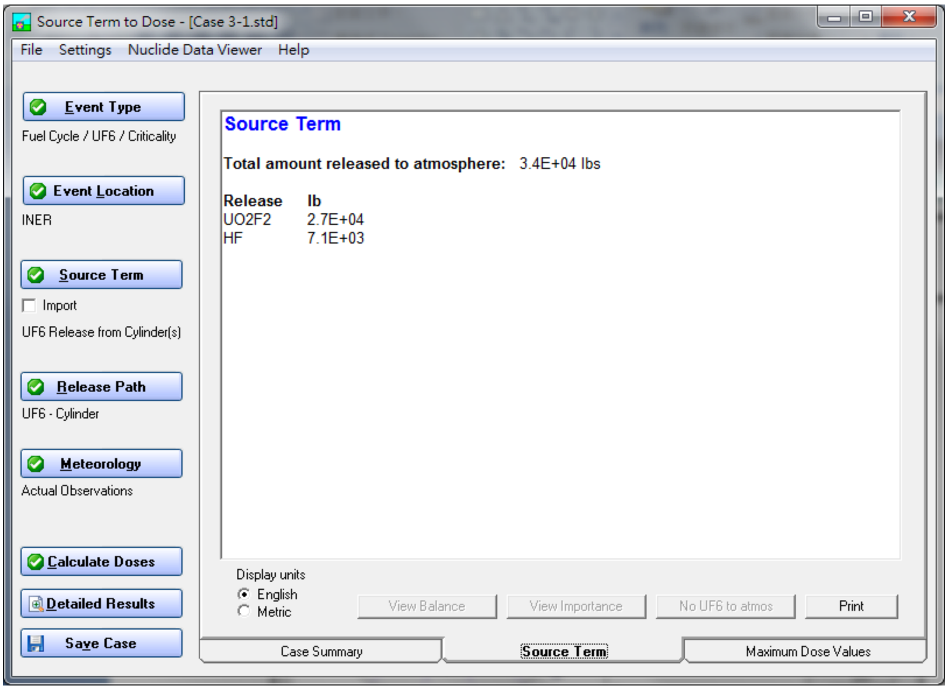

Fig. 1 The RASCAL screen

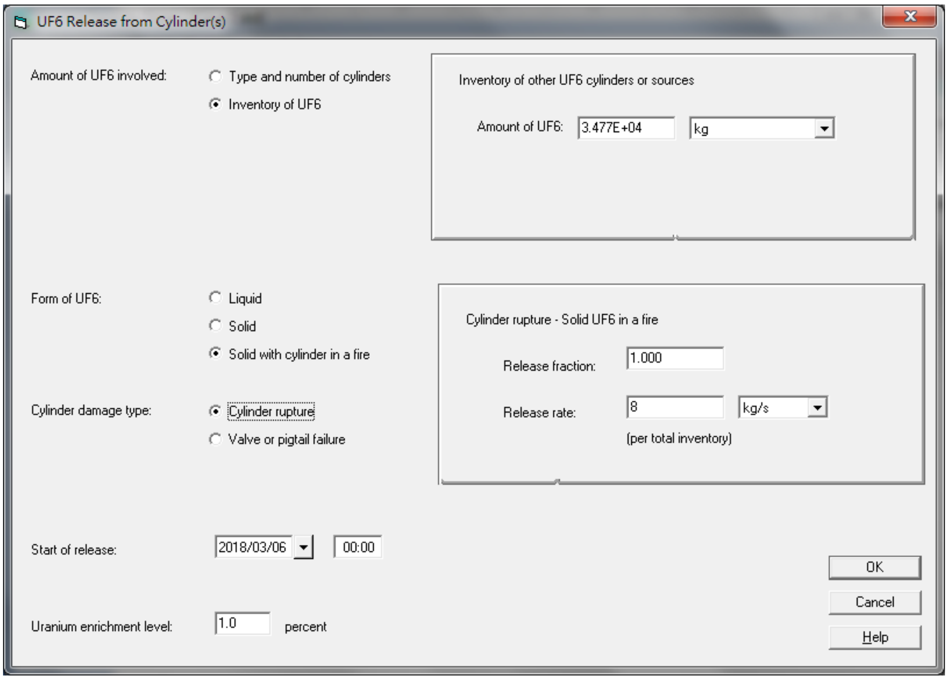

Fig. 2 The RASCAL setting for UF_6 analysis

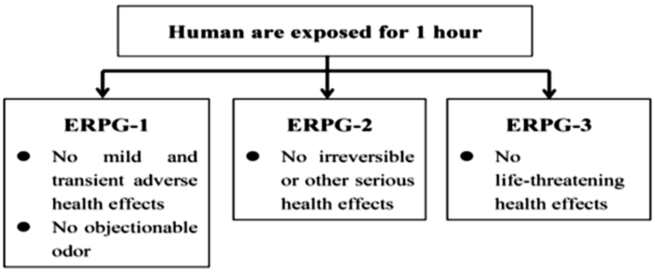

Fig. 3 The health effects for ERPG

The RASCAL predictions are compared with the criteria of hazardous levels in this study. Table III shows the results of Case 1~3 for the hazardous level and distance from release point. For Case 1, the distance where the HF concentration is above the ERPG-3 is below 160 m; the distance where the HF concentration is between the ERPG-2 and ERPG-3 is between 320 m and 160 m; the distance where the HF concentration is between the ERPG-1 and ERPG-2 is between 2410 m and 320 m. For Case 2, the distance where the HF concentration is between the ERPG-2 and ERPG-3 is below 480 m; the distance where the HF concentration is between the ERPG-1 and ERPG-2 is between 480 m and 3220 m. For Case 3, the distance where the HF concentration is above the ERPG-3 is below 320 m; the distance where the HF concentration is between the ERPG-2 and ERPG-3 is between 480 m and 320 m; the distance where the HF concentration is between the ERPG-1 and ERPG-2 is between 480 m and 3220 m. In summary, the distance which HF may cause life-threatening health effects is 0~320 m for the three cases.

TABLE II
THE RESULTS (MAX. VALUE) OF CASE 1~3

	Case 1	Case 2	Case 3
HF Lung – 1h Eq (ppm)	79	29	1500
HF Deposition (g/m^2)	1.4	0.61	3.6
Uranium Intake (mg)	290	130	550
Uranium TEDE (Sv)	0.47	0.21	0.9
Uranium Deposition (g/m^2)	2.7	1.2	120
Distance from release (km)	0.16	0.32	0.16

TABLE III
THE RESULTS OF CASE 1~3 FOR THE HAZARDOUS LEVEL AND DISTANCE FROM RELEASE POINT

	Hazardous Level	Case 1	Case 2	Case 3
HF Lung 1h Eq (ppm)	> ERPG - 1 (2 ppm)	< 2410 m	3220 m*	3220 m*
	> ERPG - 2 (20 ppm)	< 320 m	< 480 m	< 480 m
	> ERPG - 3 (50 ppm)	< 160 m	---	< 320 m
Uranium Intake (mg)	> 10 mg	< 1610 m	3220 m*	< 1130 m
	> 40 mg	< 500 m	< 1100 m	< 700 m
	> 230 mg	< 200 m	---	< 300 m

*The distance is only to 3220 m in this study.

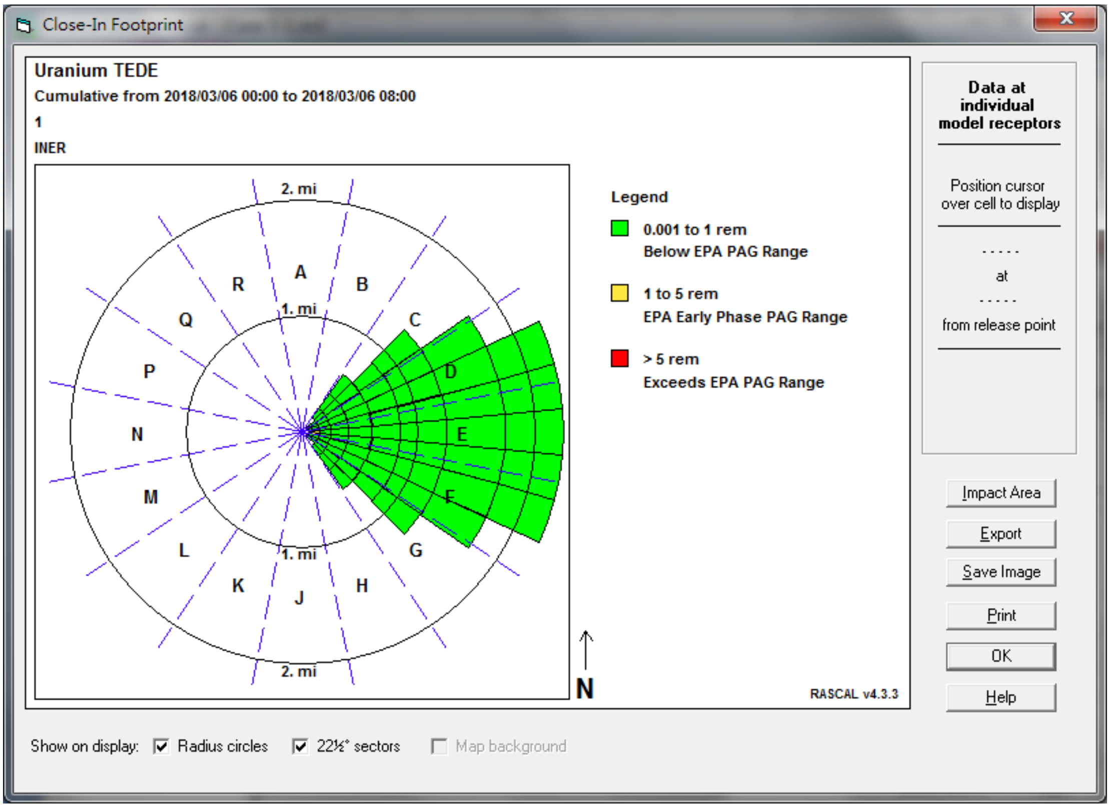

Fig. 4 The UF6 analysis result for Uranium TEDE

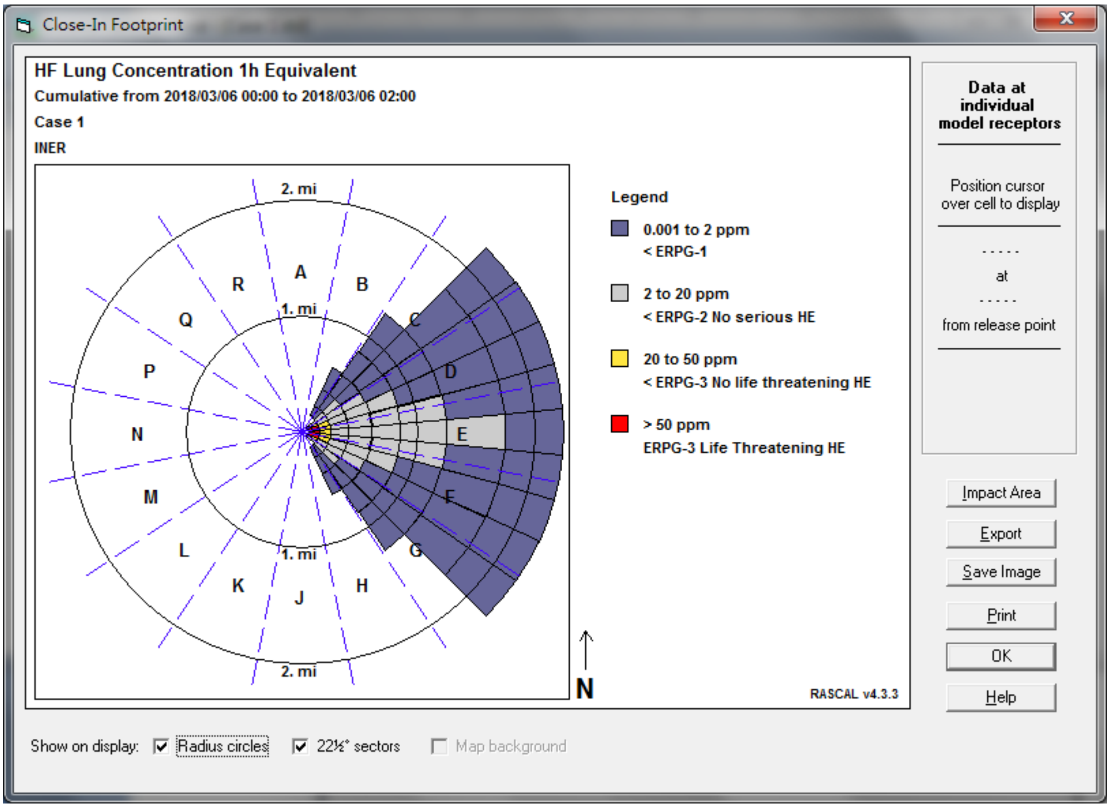

Fig. 5 The UF6 analysis result for HF lung concentration

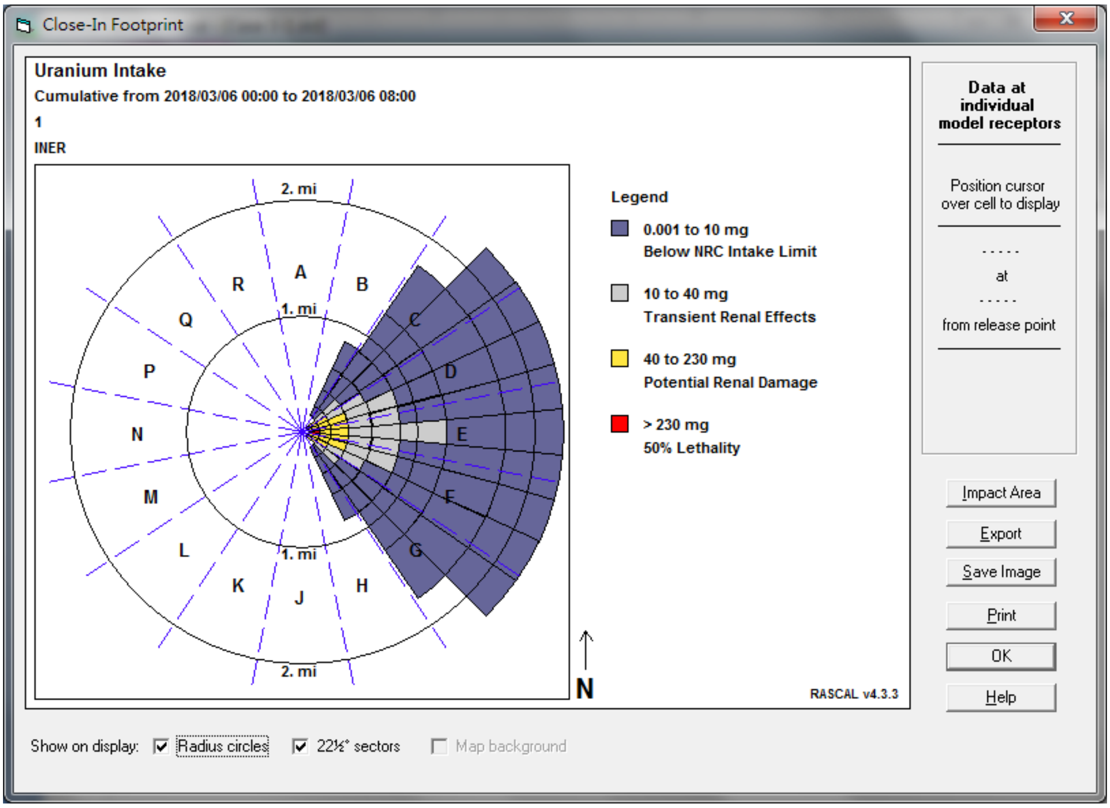

Fig. 6 The UF6 analysis result for Uranium intake

Table III also presents the uranium intake results. For Case 1, the distance which the uranium intake is above the 230 mg is below 200 m; the distance which the uranium intake is between the 40 mg and 230 mg is between 500 m and 200 m; the distance which the uranium intake is between the 10 mg and 40 mg is between 1610 m and 520 m. For Case 2, the distance which the uranium intake is between the 230 mg and 40 mg is below 1100 m; the distance where the Uranium intake is between the 40 mg and 10 mg is between 1100 m and 3220 m. For Case 3, the distance where the uranium intake is above the 230 mg is below 300 m; the distance where the Uranium intake is between the 230 mg and 40 mg is between 300 m and 700 m; the distance where the uranium intake is between the 40 mg and 10 mg is between 700 m and 1130 m. In summary, the distance which Uranium intake may cause 50% lethality is 0~300 m for the three cases. In addition, the RASCAL code can present the results of region (0~2 miles) in this study. For Case 1, Figs. 4~6 show the RASCAL predictions. Fig. 4 depicts the UF_6 analysis result for Uranium TEDE. Three levels of doses are shown in this figure: the green level is 0.001~1 rem; the yellow level is 1~5 rem; the red level is above 5 rem. Fig. 5 presents the UF_6 analysis result for HF lung concentration. Four levels of concentration are shown in this figure: the purple level is 0.001~2 ppm; the gray level is 2~20 ppm; the yellow level is 20~50 rem; the red level is above 50 ppm. Fig. 6 shows the UF_6 analysis result for uranium intake. Four levels of mass are presented in this figure: the purple level is 0.001~10 mg; the gray level is 10~40 mg; the yellow level is 40~230 mg; the red level is above 230 mg.

IV. Conclusion

By using the RASCAL code, three postulated cases under UF_6 fire accident condition were analyzed and simulated in this study. The predictions of RASCAL were compared with the criteria of hazardous levels. According to the compared results of the cases, Case 3 has the maximum danger in human health. In addition, these analysis results can be a reference for the preparing of emergency plans which handle the release of UF_6.

References

[1] G. F. Athey, J. P. Rishel, J. V. Ramsdell, Jr., and J. J. Tomon, RASCAL 4.3: User's Guide, U.S. Nuclear Regulatory Commission, Washington, DC, 2015.
[2] J. V. Ramsdell, Jr., G. F. Athey, and J. P. Rishel, RASCAL 4.3: Description of Models and Methods, U.S. Nuclear Regulatory Commission, Washington, DC, 2015.
[3] AIHA Guideline Foundation, 2016 ERPG/WEEL Handbook, 2016.
[4] R. Ahangari, O. Noori-Kalkhoran, N. Sadeghi, Radiological dose assessment for the hypothetical severe accident of the Tehran Research Reactor and corresponding emergency response, Annals of Nuclear Energy, Vol. 99, p. 272–278, 2017.
[5] Y. Zhao, L. Zhang, J. Tong, Development of rapid atmospheric source term estimation system for AP1000 nuclear power plant, Progress in Nuclear Energy, Vol. 81, p. 264-275, 2015.