

Using HABIT to Estimate the Concentration of CO₂ and H₂SO₄ for Kuosheng Nuclear Power Plant

Y. Chiang, W. Y. Li, J. R. Wang, S. W. Chen, W. S. Hsu, J. H. Yang, Y. S. Tseng, C. Shih

Abstract—In this research, the HABIT code was used to estimate the concentration under the CO₂ and H₂SO₄ storage burst conditions for Kuosheng nuclear power plant (NPP). The Final Safety Analysis Report (FSAR) and reports were used in this research. In addition, to evaluate the control room habitability for these cases, the HABIT analysis results were compared with the R.G. 1.78 failure criteria. The comparison results show that the HABIT results are below the criteria. Additionally, some sensitivity studies (stability classification, wind speed and control room intake rate) were performed in this study.

Keywords—BWR, HABIT, habitability, KUOSHENG.

I. INTRODUCTION

KUOSHENG NPP is the second plant in Taiwan and is a BWR/6 plant. Kuosheng NPP locates in Wanli District, New Taipei, Taiwan. Additionally, Kuosheng is designed and manufactured by General Electric.

Fukushima Daiichi NPP in Japan met the disaster in March 11, 2011. The tsunami which was induced by the earthquake caused this disaster. Hence, NPPs safety requirements for the world are increasing after that. Therefore, AEC (Atomic Energy Council) requires Taiwan Power Company to confirm and evaluate the control room habitability which is highly relative to the NPPs safety. For this purpose, Taiwan joined RAMP (Radiological protection computer code Analysis and Maintenance Program) international cooperation program in 2016. The RAMP program is led by U.S. NRC. The main research areas of the RAMP are the radiation dose calculation, NPPs decommission evaluation, control room habitability assessment, atmospheric dispersion factor calculation and so on. The HABIT code is from the RAMP program. HABIT can calculate the concentration of the toxic chemical and evaluate the control room habitability. Both the burst and leakage of the chemicals can be analyzed in the HABIT code [1]. The storage amount of CO₂ and H₂SO₄ in the Kuosheng NPP are 48000 and 47525.1 kg, respectively. Therefore, the purpose of this study is to evaluate the control room habitability under the CO₂ or H₂SO₄ storage burst conditions. We used HABIT code and the FSAR [1], reports [2], [3], R.G. 1.78 [4], R.G. 1.23 [5] data to perform the analysis. Additionally, the sensitivity studies of several parameters such as wind speed, atmospheric stability classification, and control room intake flow rate were performed in this research.

Y. Chiang, W. Y. Li, J. R. Wang, S. W. Chen, W. S. Hsu, J. H. Yang, Y. S. Tseng, C. Shih are with the Institute of Nuclear Engineering and Science, National Tsing-Hua University, and Nuclear and New Energy Education and Research Foundation, R.O.C., Taiwan (e-mail: jongrongwang@gmail.com).

II. METHODOLOGY

The newest version of HABIT is 2.0 and was used in this research. The operation screen of HABIT is presented in Fig. 1. Two sub-modules (EXTRAN and CHEM) are in the HABIT code. EXTRAN is the first sub-program in HABIT code. HABIT will run the CHEM program after the EXTRAN calculation is completed. The operation screen of EXTRAN is shown in Fig. 2 and can calculate the concentration of the toxic chemical at the location of the air intake for the control room. The operation screen of CHEM is presented in Fig. 3 and CHEM can use the EXTRAN results with the data (e.g. flow rate and control room volume) to calculate the concentration of the toxic chemical in the control room. Therefore, the CO₂ or H₂SO₄ storage burst cases for Kuosheng NPP are performed in this study.

The stock of CO₂ is 48000 kg in the Kuosheng. Table I lists the HABIT input parameters and values for the CO₂ storage burst case. The stock of H₂SO₄ is 47525.1 kg in the Kuosheng. Table II lists the HABIT input parameters and values for the H₂SO₄ storage burst case. In addition, the atmospheric stability classification is divided into “A” ~ “G” level and shown in Table III. These levels are from R.G. 1.23 [5]. The “A” level is extremely unstable and the “G” level is extremely stable.

TABLE I
CO₂ INPUT PARAMETERS

Parameters	Values
CO ₂ initial mass (kg)	48000
CO ₂ storage temperature (°C)	-16.67
Wind speed (m/s)	3.11
Atmospheric stability classification	D
Air temperature (°C)	30
Control room volume (ft ³)	299000
Control room intake flow rate (ft ³ /min)	800

TABLE II
H₂SO₄ INPUT PARAMETERS

Parameters	Values
H ₂ SO ₄ initial mass (kg)	47525.1
H ₂ SO ₄ storage temperature (°C)	30
Wind speed (m/s)	3.11
Atmospheric stability classification	D
Air temperature (°C)	30
Control room volume (ft ³)	299000
Control room intake flow rate (ft ³ /min)	800

III. RESULTS

The result of the HABIT analysis for the CO₂ storage burst

case is shown in Table IV. The maximum concentration is 0.4912 g/m^3 and occurs at 1.85 minutes after the CO_2 storage burst. The failure criterion is 7.36 g/m^3 according to R.G. 1.78 [4]. The HABIT result for this case is below the failure criterion. This implies that the control room habitability for Kuosheng NPP can be maintained in this case. Tables V-VII show the results of the sensitivity studies. Table V shows the results for the wind speed cases. When the wind speed increases, the concentration for the 0.53 min decreases. Table VI presents the results for the atmospheric stability classification cases. When the atmospheric stability goes down, the concentration decreases. Additionally, the time point of the maximum concentration occurs later when the atmospheric stability decreases. Table VII depicts the results for the cases of the control room intake flow rate. When the intake flow rate goes up, the maximum concentration increases. Additionally, the time point of the maximum concentration occurs earlier when the intake flow rate increases.

TABLE III
THE STABILITY CLASSIFICATION [5]

Stability classification	Pasquill stability category
Extremely unstable	A
Moderately unstable	B
Slightly unstable	C
Neutral	D
Slightly stable	E
Moderately stable	F
Extremely stable	G

TABLE IV
THE HABIT RESULTS FOR THE CO_2 STORAGE BURST CASE

	Time (min)	Max. concentration (g/m^3)
HABIT	1.85	0.4912
RG 1.78 failure criteria	-----	7.36

TABLE V
THE SENSITIVITY STUDY- WIND SPEED FOR THE CO_2 STORAGE BURST CASE

Wind speed (m/s)	Time (min)	Concentration (g/m^3)
3.11	0.53	0.4473
1.0	0.53	0.51
10	0.53	0.1919

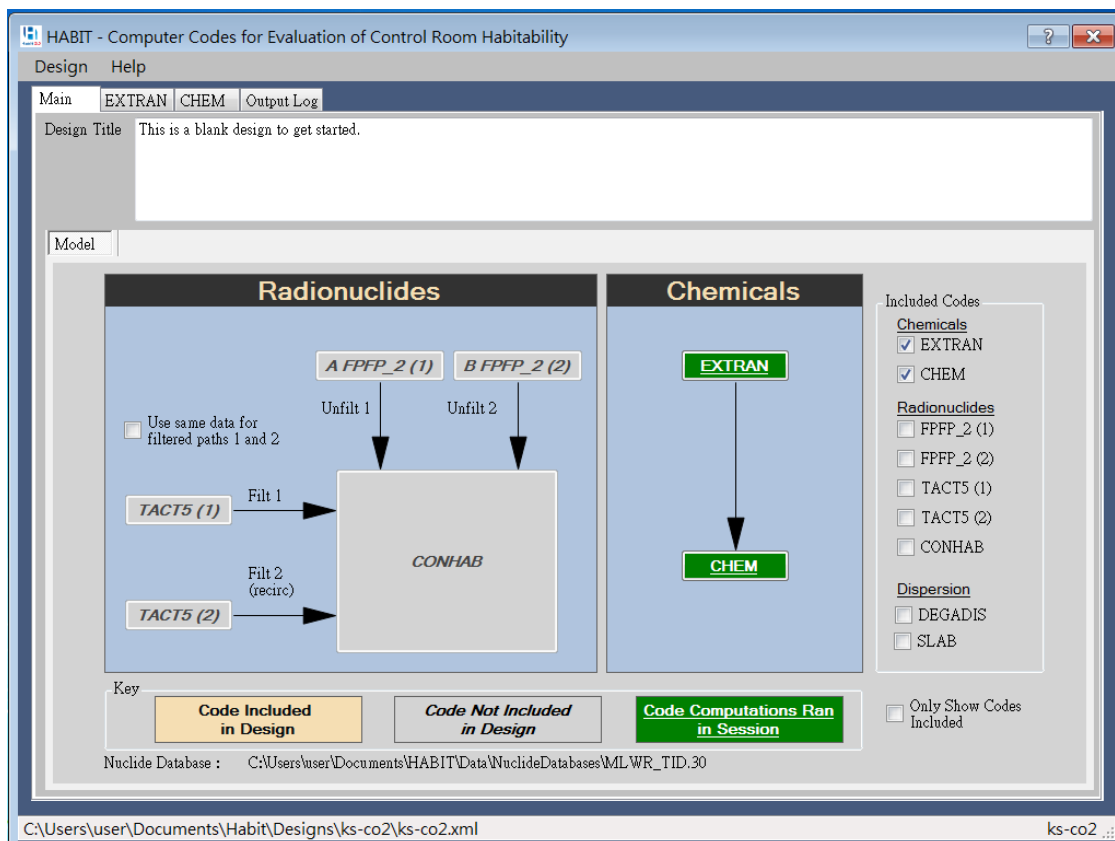


Fig. 1 The operation screen of HABIT

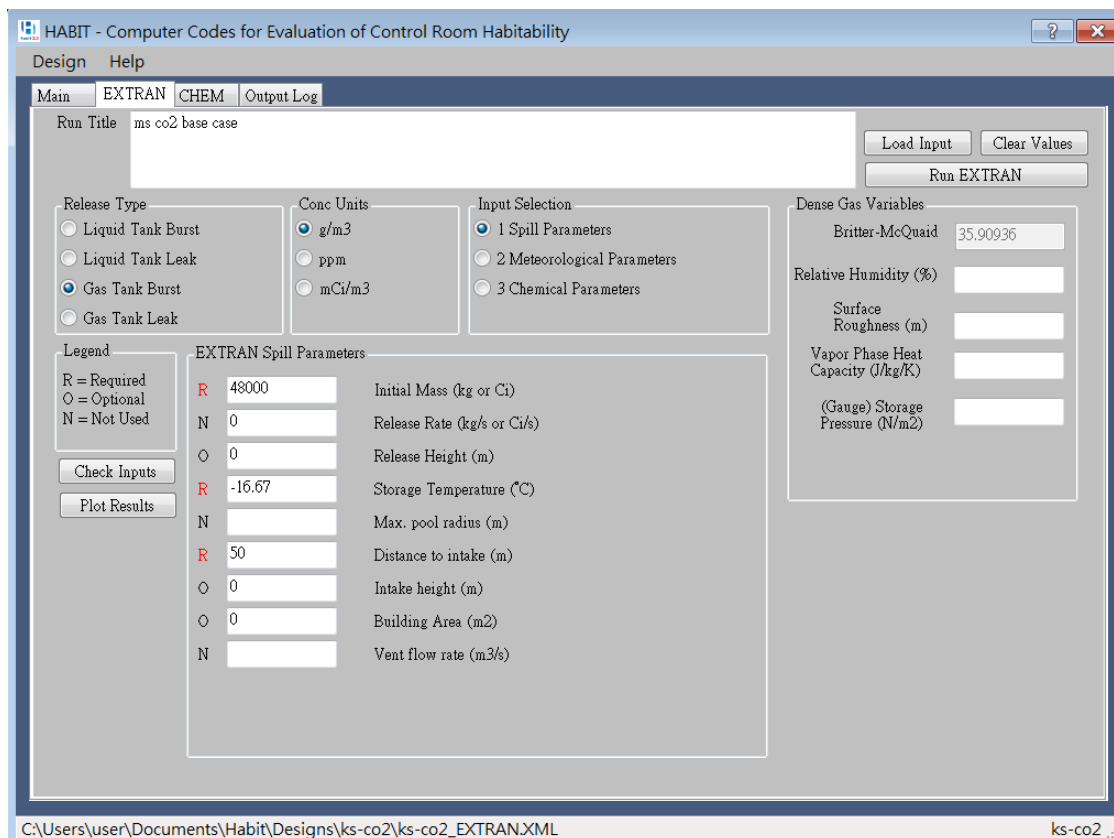


Fig. 2 The operation screen of EXTRAN

TABLE VI

THE SENSITIVITY STUDY- ATMOSPHERIC STABILITY CLASSIFICATION FOR THE CO₂ STORAGE BURST CASE

Atmospheric stability classification	Time (min)	Max. concentration (g/m ³)
A	2.08	0.1686
D	1.85	0.4912
G	1.6	0.6939

TABLE VII

THE SENSITIVITY STUDY- CONTROL ROOM INTAKE FLOW RATE FOR THE CO₂ STORAGE BURST CASE

Control room intake flow rate (ft ³ /min)	Time (min)	Max. concentration (g/m ³)
800	1.85	0.4912
1500	1.65	0.9178
3000	1.45	1.8234
6000	1.25	3.6047

The result of the HABIT analysis for the H₂SO₄ storage burst case is presented in Table VIII. The concentration is 7.977×10^{-5} g/m³ and occurs at 9 minutes after the H₂SO₄ storage burst. However, this case analysis only runs 9 minutes due to the code function limit. The failure criterion is 0.015 g/m³ according to R.G. 1.78 [4]. The analysis result of the HABIT for the H₂SO₄ case is below the failure criterion. This depicts that the control room habitability for Kuosheng NPP

can be maintained in the H₂SO₄ case. Table IX~XI list the results of the sensitivity studies. Table IX presents the results for the wind speed cases. When the wind speed increases, the concentration for the 3 min increases. This trend is different with the CO₂ case. CO₂ is gas in the 30 °C condition but H₂SO₄ is liquid. This is the reason that causes this difference. Table X shows the analysis results for the atmospheric stability classification cases. When the atmospheric stability decreases, the concentration goes down. Table XI presents the results for the cases of the control room intake flow rate. When the intake flow rate increases, the concentration increases.

TABLE VIII

THE HABIT RESULTS FOR THE H₂SO₄ STORAGE BURST CASE

	Time (min)	Concentration (g/m ³)
HABIT	9	7.977×10^{-5}
RG 1.78 failure criteria	-----	0.015

TABLE IX

THE SENSITIVITY STUDY- WIND SPEED FOR THE H₂SO₄ STORAGE BURST CASE

Wind speed (m/s)	Time (min)	Concentration (g/m ³)
3.11	3	1.875×10^{-5}
1	3	5.54×10^{-6}
10	3	2.348×10^{-5}

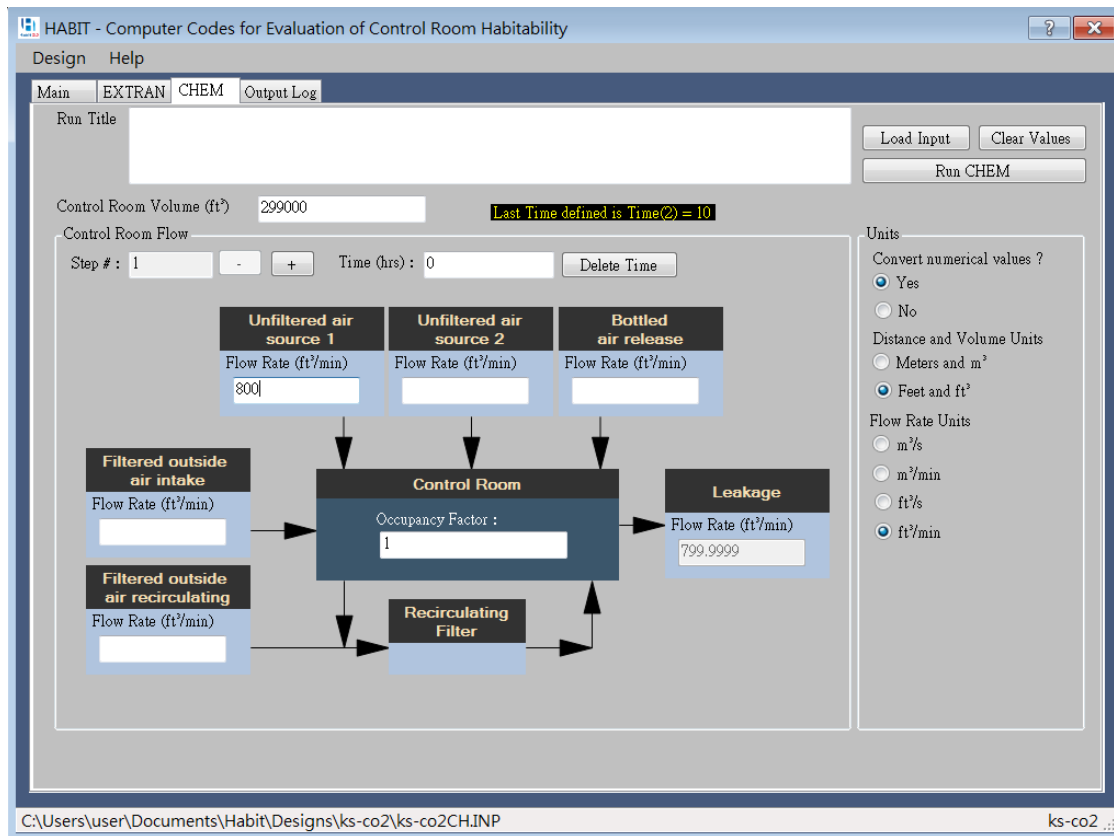


Fig. 3 The operation screen of CHEM

TABLE X

THE SENSITIVITY STUDY- ATMOSPHERIC STABILITY CLASSIFICATION FOR THE H₂SO₄ STORAGE BURST CASE

Atmospheric stability classification	Time (min)	Concentration (g/m ³)
A	7.5	2.392 x10 ⁻⁵
D	9	7.977 x10 ⁻⁵
G	9	1.171 x10 ⁻⁴

TABLE XI

THE SENSITIVITY STUDY- CONTROL ROOM INTAKE FLOW RATE FOR THE H₂SO₄ STORAGE BURST CASE

Control room intake flow rate (ft ³ /min)	Time (min)	Concentration (g/m ³)
800	9	7.977 x10 ⁻⁵
1500	9	1.483 x10 ⁻⁴
3000	9	2.909 x10 ⁻⁴
6000	9	5.603 x10 ⁻⁴

IV. CONCLUSION

The main purpose of this study is to use the HABIT code to analyze the concentration under the CO₂ and H₂SO₄ storage burst conditions for Kuosheng NPP. The HABIT results are below the R.G. 1.78 failure criteria. These imply that the control room habitability for Kuosheng can be maintained for these cases. Additionally, the results of the sensitivity studies indicate that the atmospheric stability classification, control room intake flow rate, and wind speed can affect the concentration calculation.

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