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# Using HABIT to Estimate the Concentration of $CO_2$ and $H_2SO_4$ for Kuosheng Nuclear Power Plant

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***Abstract*—**In this research, the HABIT code was used to estimate the concentration under the $CO_2$ and $H_2SO_4$ 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 $CO_2$ and $H_2SO_4$ 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 $CO_2$ or $H_2SO_4$ 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.

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## 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 $CO_2$ or $H_2SO_4$ storage burst cases for Kuosheng NPP are performed in this study.

The stock of $CO_2$ is 48000 kg in the Kuosheng. Table I lists the HABIT input parameters and values for the $CO_2$ storage burst case. The stock of $H_2SO_4$ is 47525.1 kg in the Kuosheng. Table II lists the HABIT input parameters and values for the $H_2SO_4$ 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
$CO_2$ 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
$H_2SO_4$ Input Parameters

| Parameters | Values |
|---|---|
| $H_2SO_4$ initial mass (kg) | 47525.1 |
| $H_2SO_4$ 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 $CO_2$ 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 |

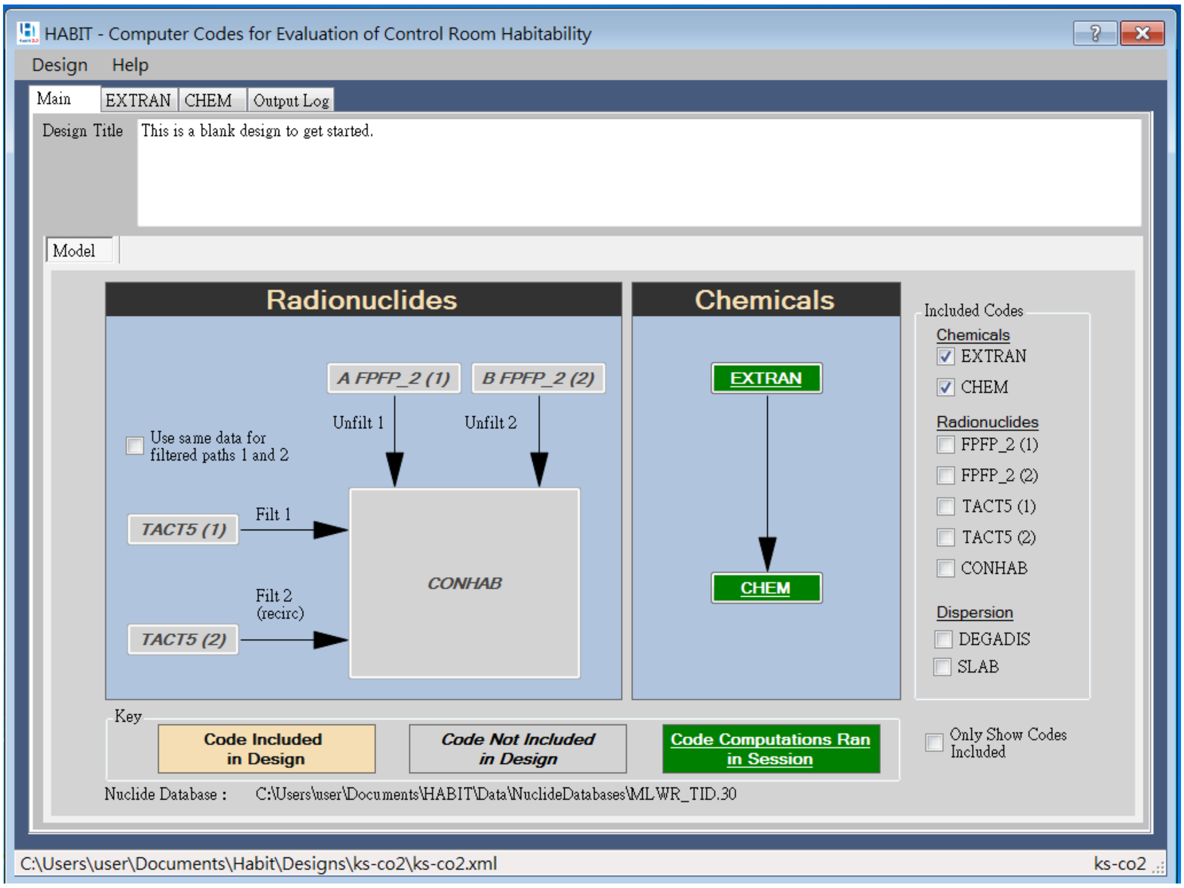


Fig. 1 The operation screen of HABIT

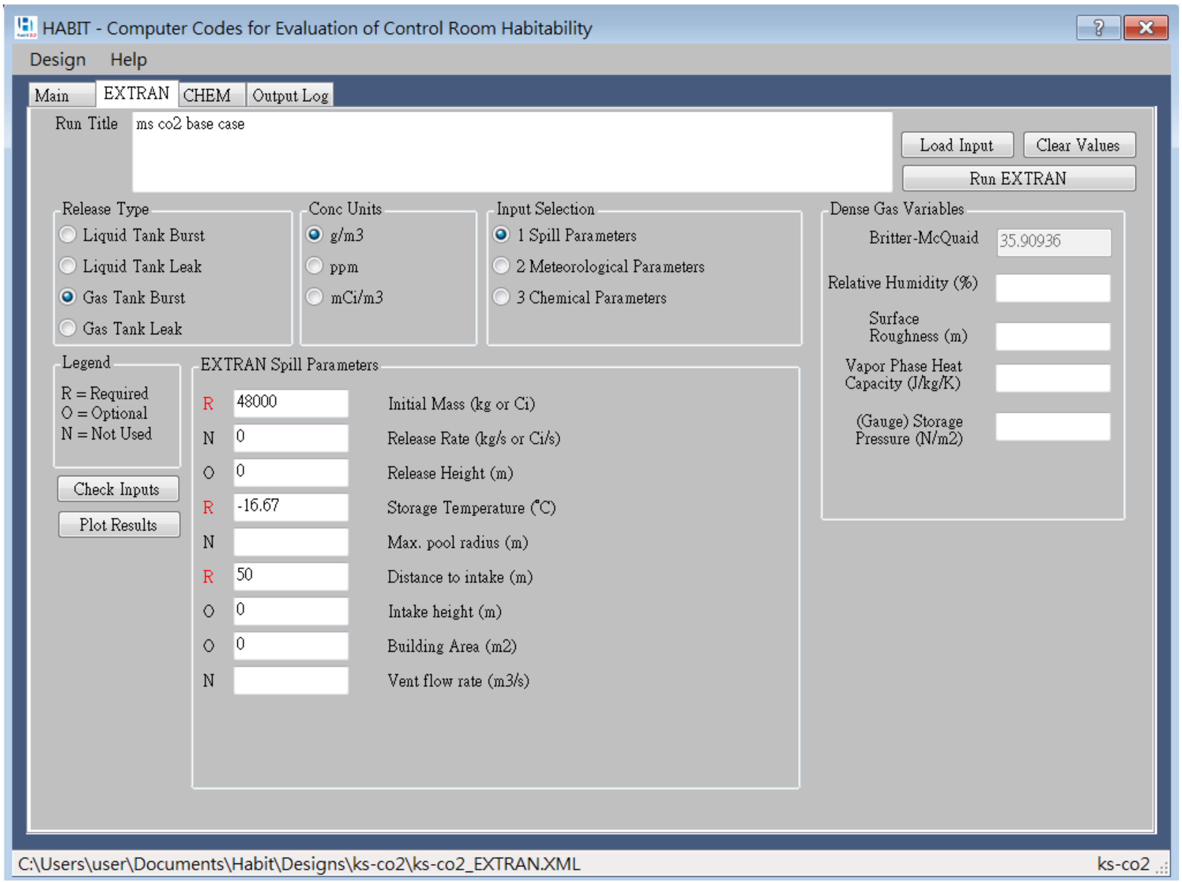


Fig. 2 The operation screen of EXTRAN

TABLE VI
THE SENSITIVITY STUDY- ATMOSPHERIC STABILITY CLASSIFICATION FOR THE $CO_2$ 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 $CO_2$ 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 $H_2SO_4$ storage burst case is presented in Table VIII. The concentration is $7.977 \times 10^{-5}$ $g/m^3$ and occurs at 9 minutes after the $H_2SO_4$ storage burst. However, this case analysis only runs 9 minutes due to the code function limit. The failure criterion is 0.015 $g/m^3$ according to R.G. 1.78 [4]. The analysis result of the HABIT for the $H_2SO_4$ case is below the failure criterion. This depicts that the control room habitability for Kuosheng NPP can be maintained in the $H_2SO_4$ 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 $CO_2$ case. $CO_2$ is gas in the 30 ℃ condition but $H_2SO_4$ 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 $H_2SO_4$ STORAGE BURST CASE

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

TABLE IX
THE SENSITIVITY STUDY- WIND SPEED FOR THE $H_2SO_4$ STORAGE BURST CASE

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

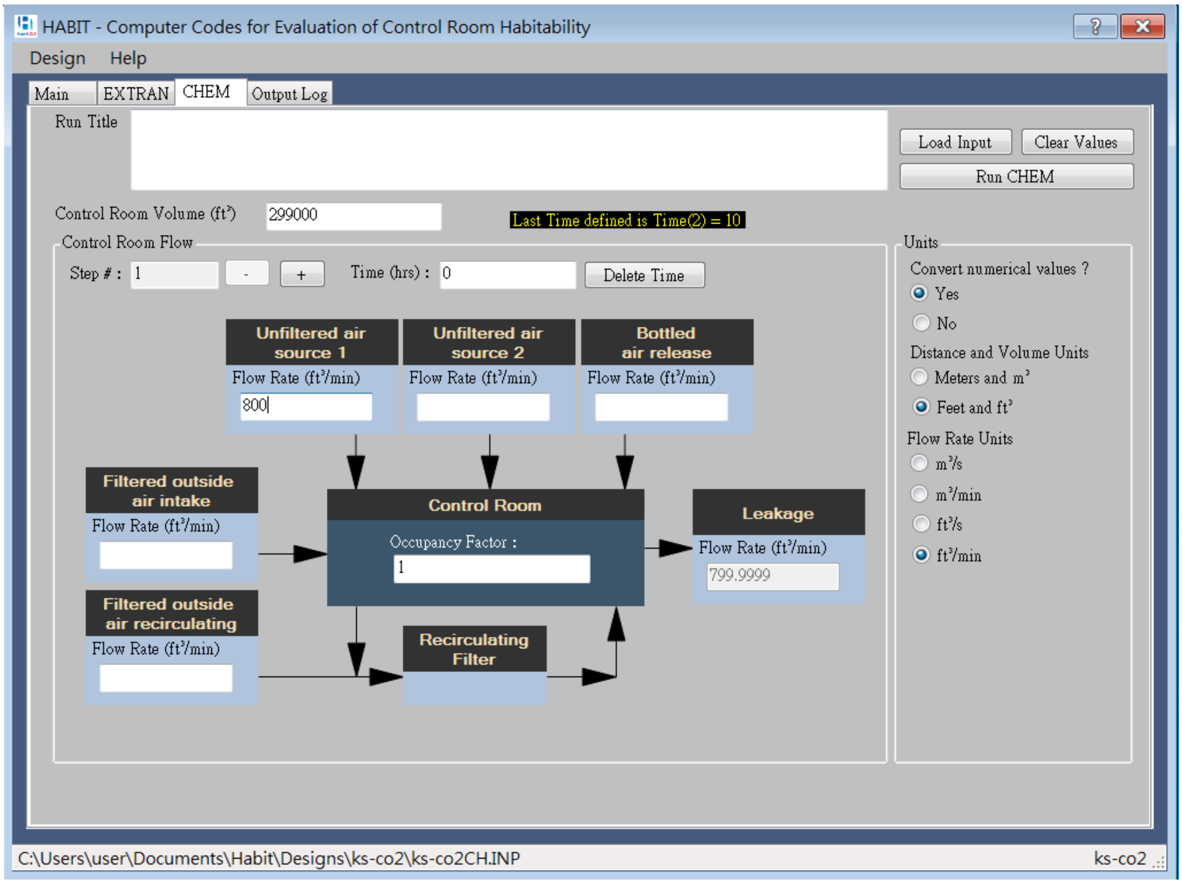


Fig. 3 The operation screen of CHEM

TABLE X
THE SENSITIVITY STUDY- ATMOSPHERIC STABILITY CLASSIFICATION FOR THE $H_2SO_4$ STORAGE BURST CASE

| Atmospheric stability classification | Time (min) | Concentration (g/m$^3$) |
|---|---|---|
| A | 7.5 | 2.392 x$10^{-5}$ |
| D | 9 | 7.977 x$10^{-5}$ |
| G | 9 | 1.171 x$10^{-4}$ |

TABLE XI
THE SENSITIVITY STUDY- CONTROL ROOM INTAKE FLOW RATE FOR THE $H_2SO_4$ STORAGE BURST CASE

| Control room intake flow rate (ft$^3$/min) | Time (min) | Concentration (g/m$^3$) |
|---|---|---|
| 800 | 9 | 7.977 x$10^{-5}$ |
| 1500 | 9 | 1.483 x$10^{-4}$ |
| 3000 | 9 | 2.909 x$10^{-4}$ |
| 6000 | 9 | 5.603 x$10^{-4}$ |

## IV. CONCLUSION

The main purpose of this study is to use the HABIT code to analyze the concentration under the $CO_2$ and $H_2SO_4$ 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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