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Using ALOHA Code to Evaluate CO_2 Concentration for Maanshan Nuclear Power Plant

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***Abstract*—**ALOHA code was used to calculate the concentration under the CO_2 storage burst condition for Maanshan nuclear power plant (NPP) in this study. Five main data are input into ALOHA code including location, building, chemical, atmospheric, and source data. The data from Final Safety Analysis Report (FSAR) and some reports were used in this study. The ALOHA results are compared with the failure criteria of R.G. 1.78 to confirm the habitability of control room. The result of comparison presents that the ALOHA result is below the R.G. 1.78 criteria. This implies that the habitability of control room can be maintained in this case. The sensitivity study for atmospheric parameters was performed in this study. The results show that the wind speed has the larger effect in the concentration calculation.

***Keywords*—**PWR, ALOHA, habitability, Maanshan.

I. INTRODUCTION

FOUR NPPs are in Taiwan. The third one is Maanshan plant. Maanshan NPP locates in the south of Taiwan. In addition, Maanshan is a PWR plant which is designed and manufactured by Westinghouse.

In general, to maintain the operation and safety of NPP, some chemicals are used to fulfill these requests, for example: CO_2 are used for firefighting. Hence, NPPs store these chemicals. However, if the leakage or burst of chemicals occurs, the chemicals may affect the control room habitability. In addition, after the disaster of Fukushima Daiichi NPP happened, AEC (Atomic Energy Council) requires Taiwan Power Company to evaluate the habitability of control rooms for four NPPs.

ALOHA code can predict the spatial extent of volatile and flammable chemicals for the short-term accidental release according to the manual [1]. ALOHA can handle thermal radiation from chemical fires, human health hazards for inhalation of toxic chemical vapors, and the effects of the pressure wave from vapor-cloud explosions. ALOHA can present a threat zone based on analysis results.

The storage amount of CO_2 in Maanshan NPP is 45000 kg. Hence, the purpose of this study is to confirm the habitability of control room under the Maanshan CO_2 storage burst condition. Some data of FSAR [2], R.G. 1.78 [3], R.G. 1.23 [4], and report [5] were used to carry out this study and analysis.

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II. THE ALOHA ANALYSIS

Table I presents the input parameters of ALOHA. These parameters are used in this analysis to calculate the concentration under the CO_2 storage burst condition. The atmospheric conditions include that the wind speed is 10 kg/sec, atmospheric stability classification is ‘D’, and air temperature is 30 ^{o}C. The atmospheric stability classification is divided into “A” ~ “G” level according to R.G. 1.23 [4]. The extremely unstable is “A” level and the extremely stable is “G” level. In addition, the control room volume for Maanshan NPP is 73169 ft^3 and intake flow rate is 1000 ft^3/min.

Eight main steps are in the ALOHA analysis. First, the location data (elevation, latitude, longitude, etc.) are input into ALOHA. The operation screen for location data are presented in Fig. 1. Second, the building data are input into ALOHA (see Fig. 2). The building is the control room of Maanshan NPP in this study. Hence, the value for no. of air change is calculated by the intake flow rate and volume of control room. Third, CO_2 is chosen in the chemical data (see Fig. 3). Fourth, the atmospheric data (wind speed, air temperature, humidity, etc.) are input in to ALOHA. Fig. 4 shows the operation screen of atmospheric data. Fifth, the source data are input in to ALOHA (see Fig. 5). Sixth, Fig. 6 shows the toxic level setting screen. Three levels can be set in this step. Seventh, the setting of the distance between the source and evaluation point is shown in Fig. 7. Finally, Fig. 8 presents the ALOHA text summary screen for this analysis. All input parameters are clearly seen in this screen.

TABLE I
ALOHA INPUT PARAMETERS

Parameters	Values
CO_2 initial mass (kg)	45000
Wind speed (m/s)	10
Atmospheric stability classification	D
Air temperature (°C)	30
Control room intake flow rate (ft^3/min)	1000
Control room volume (ft^3)	73169

TABLE II
ATMOSPHERIC STABILITY CLASSIFICATION FROM RG 1.23 [4]

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

III. Results

The stationary stock of CO_2 at the Maanshan NPP cannot be screened out in accordance with R.G. 1.78 [3] as shown in Fig. 9; hence, an analysis for the CO_2 storage tank burst scenario is performed by using the ALOHA code. Fig. 10 and Table III show the ALOHA analysis results. Table III also presents that the failure criterion is 7.36 g/m^3 according to R.G. 1.78 [3]. Therefore, the ALOHA analysis result is below the failure criterion of R.G. 1.78. This indicates that the control room habitability for Maanshan NPP can be maintained in this case. In addition, the dispersion range of CO_2 concentration is presented in Fig. 10. Three levels (7.36, 3.166, and 2.834 g/cm^3) are in the dispersion range of CO_2 concentration. The range for 7.36 g/cm^3 is about 0~0.8 miles which is the hazard area.

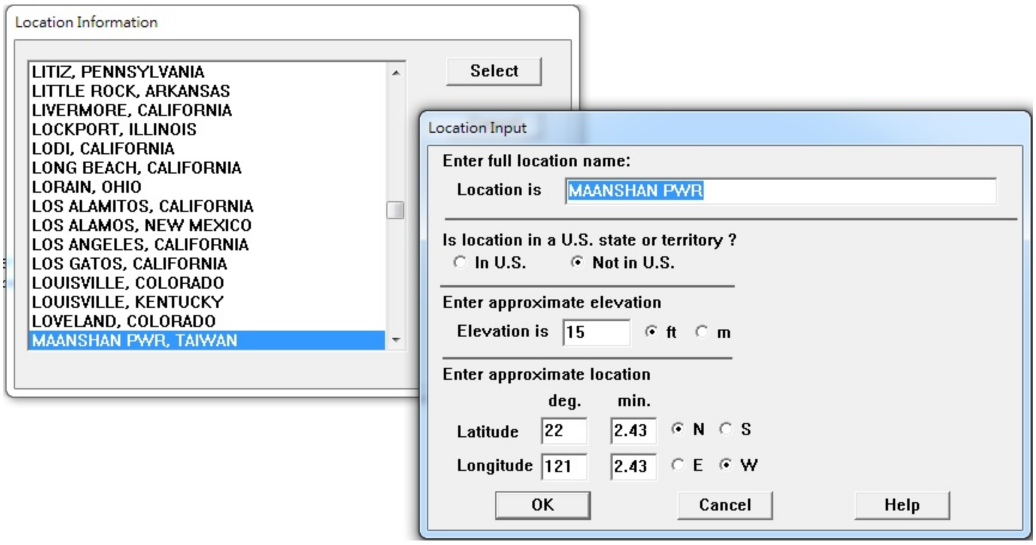

Fig. 1 The ALOHA operation screen for location data

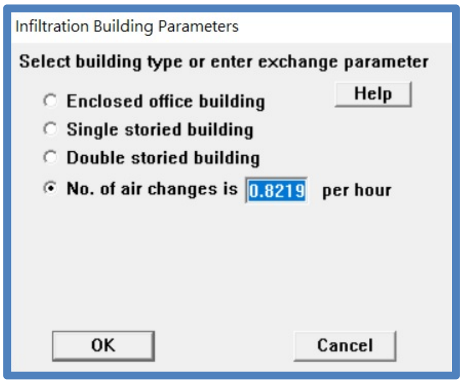

Fig. 2 The ALOHA operation screen for building data

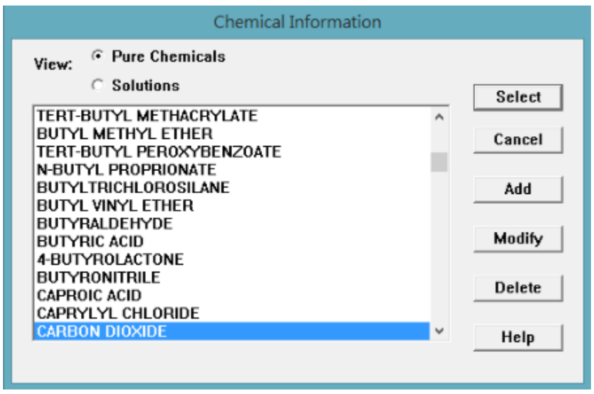

Fig. 3 The ALOHA operation screen for chemical data

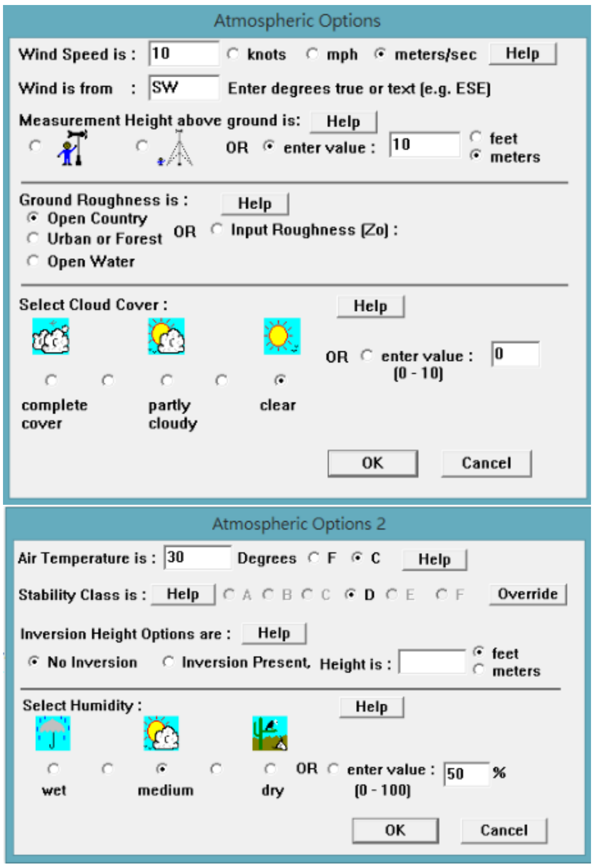

Fig. 4 The ALOHA operation screen for atmospheric data

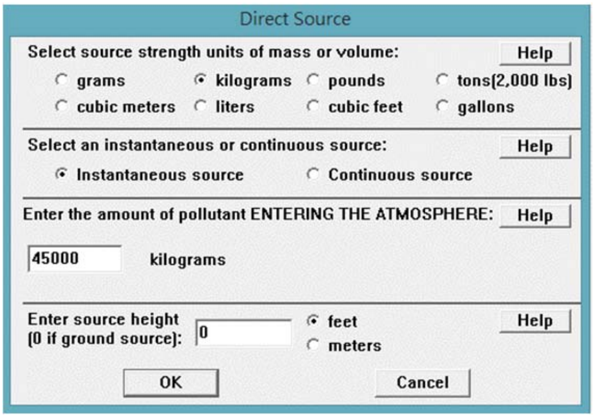

Fig. 5 The ALOHA operation screen for source data

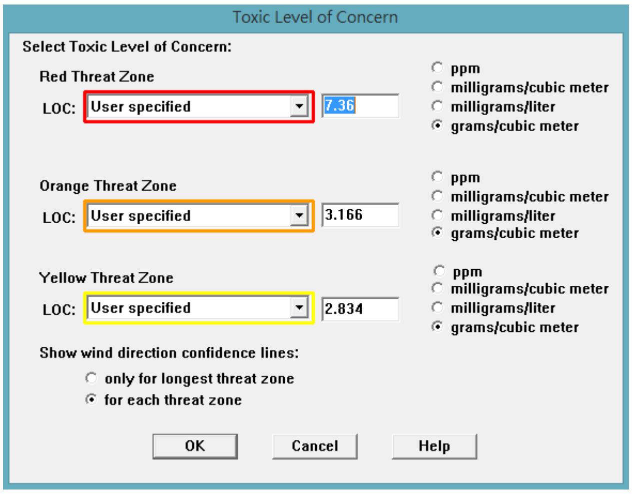

Fig. 6 The ALOHA operation screen for toxic level

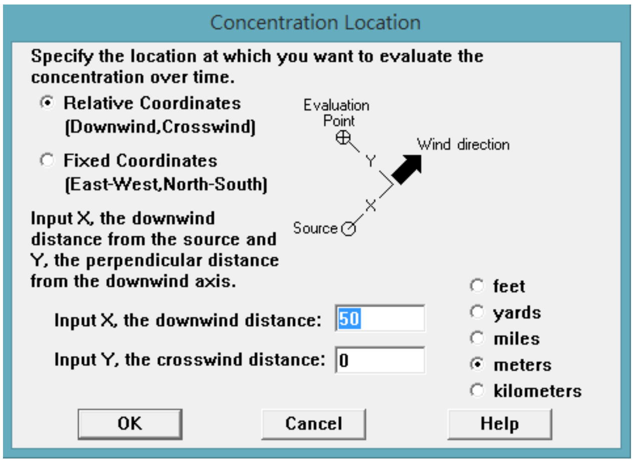

Fig. 7 The ALOHA operation screen for concentration location

TABLE III
ALOHA RESULTS FOR CONTROL ROOM

	Max. concentration (g/m^3)
ALOHA	4.06
R.G. 1.78 failure criteria	7.36

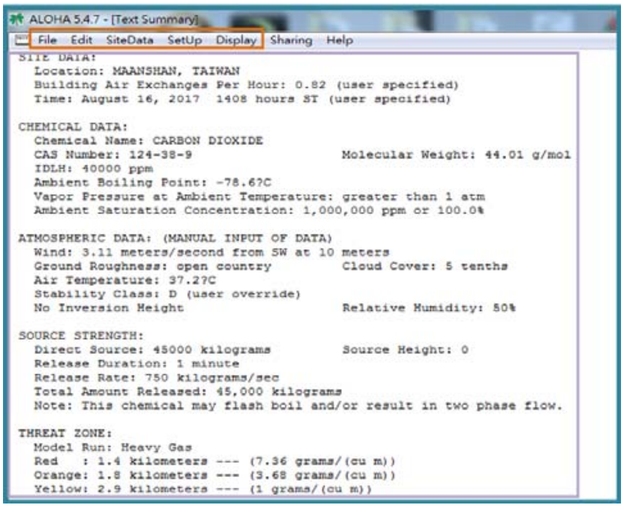

Fig. 8 The ALOHA text summary screen

Tables IV-VI present the ALOHA analysis results for the sensitivity study of atmospheric parameters (wind speed, atmospheric stability classification, and air temperature). Four cases (5, 10, 20, and 30 m/s) for the sensitivity study of wind speed are shown in Table IV. The atmospheric concentration is 423 g/m^3 and control room concentration is 5.33 g/m^3 for "5 m/s" case. In addition, as the wind speed increases, the atmospheric concentration and control room concentration decrease. Table V depicts three cases (A, D, and F level) in the sensitivity study of atmospheric stability classification. The maximum concentration is in case for F level which is 373 g/m^3 for atmospheric concentration and 4.49 g/m^3 for control room concentration. Additionally, as the atmospheric stability is more stable, the atmospheric and control room concentrations increase. Table VI shows four cases (10, 20, 30, and 40 ^{o}C) in the sensitivity study of air temperature. The maximum concentration is in case for 10 ^{o}C which is 360 g/m^3 for atmospheric concentration and 4.26 g/m^3 for control room concentration. In addition, as the air temperature goes up, the atmospheric concentration and control room concentration decrease. Finally, by compared the result for the wind speed, atmospheric stability classification, and air temperature, the wind speed has the larger effect in the calculation of CO_2 concentration.

TABLE IV
THE SENSITIVITY STUDY- WIND SPEED

Wind speed (m/s)	Atmospheric concentration (g/m^3)	Control room concentration (g/m^3)
5	423	5.33
10	343	4.06
20	309	3.55
30	289	3.29

TABLE V
THE SENSITIVITY STUDY- ATMOSPHERIC STABILITY CLASSIFICATION

Atmospheric stability classification	Atmospheric concentration (g/m^3)	Control room concentration (g/m^3)
A	326	3.86
D	343	4.06
F	373	4.49

TABLE VI
THE SENSITIVITY STUDY- AIR TEMPERATURE

Air temperature (°C)	Atmospheric concentration (g/m^3)	Control room concentration (g/m^3)
10	360	4.26
20	353	4.17
30	343	4.06
40	336	3.97

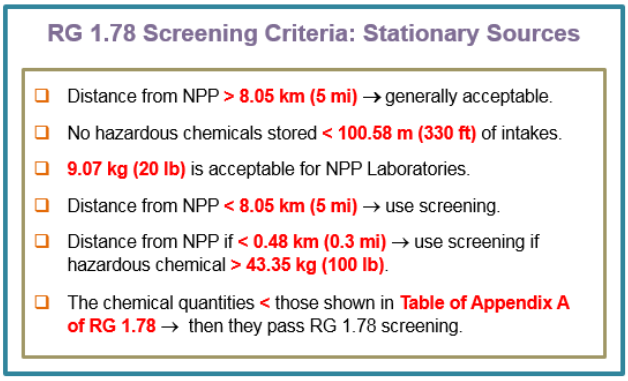

Fig. 9 R.G. 1.78 screening for stationary chemical sources

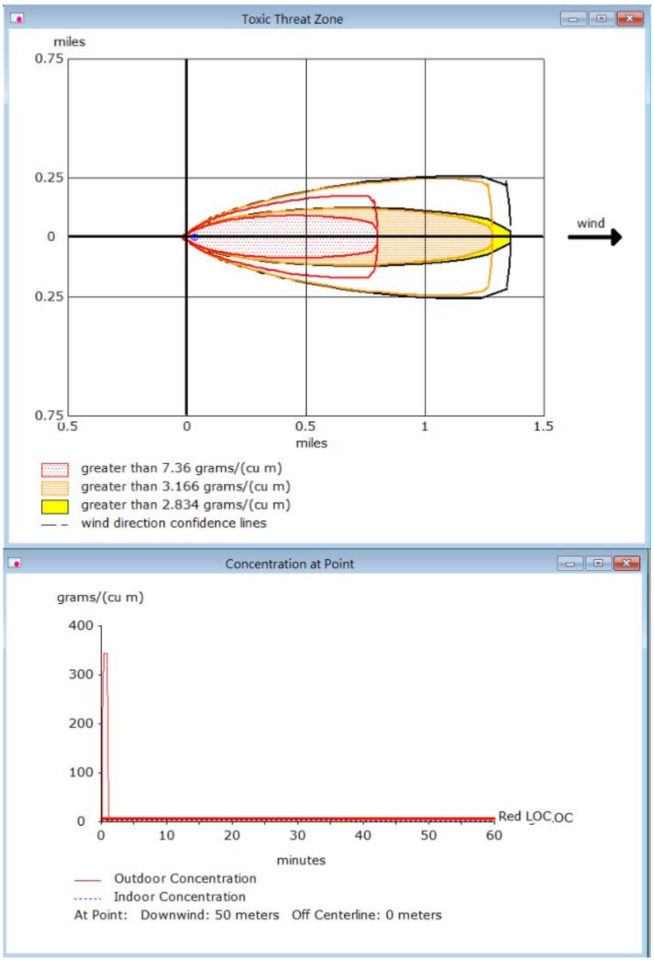

Fig. 10 The ALOHA results

IV. CONCLUSION

The main purpose of this study is to use ALOHA code to calculate the concentration under the CO_2 storage burst condition and evaluate the control room habitability for Maanshan NPP. The ALOHA result for the CO_2 burst case is below the R.G. 1.78 failure criteria. This implies that the control room habitability for Maanshan NPP can be maintained for this case. In addition, the sensitivity study for atmospheric parameters (wind speed, atmospheric stability classification, and air temperature) was also performed in this study. According to the results, the wind speed has the larger effect in the prediction of CO_2 concentration.

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