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# Assessment of Radiation Doses to the Public from a Release of Airborne Radioactive Material under Hypothetical Accident Condition in Wolsong Unit 1.

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## 1. Introduction

A dose analysis of Wolsong 1 refurbishment safety analysis was carried out. The ADDAM code [1,2] developed by AECL was applied. The ADDAM code deals with the modeling of environmental transfer of radioactive material released to the atmosphere under accident conditions, and radiological doses to the public are calculated. In this paper, methods, input parameters, and dose results are illustrated for Large LOCA cases.

## 2. Methods and Input Parameters

### *2.1 Releases Characteristics*

The release data that ADDAM uses is specified in terms of the cumulative mass, M in kg, energy, E in J, and activity, Q in TBq, released as a function of time from each release path, i.e., $t_j$, $M_j$, $E_j$, and $Q_j$ where j=0,…,n and n is the number of release data past $t_0$=0. At time $t_0$=0, the cumulative mass, energy and activity released must be zero.

The release data is calculated by SMART computer code. The release duration is divided into two categories (referred to as short-term and prolonged-term releases) on which are based the atmospheric dispersion models:

- Short-term release: 10 $\leq \Delta t_R \leq$1 hour
- Prolonged-term release: 1 $< \Delta t_R \leq$ 24 hours

### *2.2 Atmospheric Dispersion*

Releases of radioactive material are dispersed in the atmosphere according to the terrain and meteorological conditions.

A terrain condition is defined by the roughness length. A meteorological condition is defined by a stability category, a wind velocity and the nature of any precipitation. During the release, meteorological conditions may change. The wind may not only swing along the main direction, but also change its main direction.

Gaussian dispersion model is used, which uses dispersion parameters determined empirically by field experiments for calculating dilution factors. ADDAM implements the short-term, prolonged-term and fumigation dispersion equations of N288.2 [3].

The short-term equation applies when the duration of release is between 10 minutes and 1 hour and for windy condition (u$\geq$2m/s). For low wind speed less than approximately 2m/s, the wind direction and speed vary in an unsystematic way with time that causes enhanced atmospheric dispersion. For this condition, referred to as meander, the prolonged-term release equation is used with the understanding that some degree of plume meander is accounted for.

The prolonged-term equation is used when the duration of release is between 1 hour and 24 hours. The equation is used whether meander occurs or not over that time period.

The short-term and prolonged-term equations are as follows, respectively.

$$\left(\frac{\chi}{Q}\right)_{short} = \frac{1}{2\pi u \Sigma_y \Sigma_z} \exp\left(\frac{-y^2}{2\Sigma_y^2}\right)\left[\exp\left(\frac{-(z-H)^2}{2\Sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\Sigma_z^2}\right)\right] f(\Sigma_z, H, h_i)$$

$$\left(\frac{\chi}{Q}\right)_{prol} = \left(\frac{1}{2\pi}\right)^{1/2} \frac{1}{\Sigma_z u x \theta_L}\left[\exp\left(\frac{-(z-H)^2}{2\Sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\Sigma_z^2}\right)\right] f(\Sigma_z, H, h_i)$$

### *2.2 Atmospheric Stability*

The atmospheric stability refers to the rate of mixing of the atmospheric surface layer. Simple methods define this layer as existing in one of three conditions: unstable, neutral and stable. A plume in a stable atmosphere is narrow both vertically and horizontally; a plume in an unstable atmosphere is broad both vertically and horizontally; and a plume in a neutral atmosphere is somewhere in between. The unstable and stable cases can be further divided into two or three categories each, making a total of six or seven Pasquill-Gifford stability classes, identified as class A, extremely unstable, through class D, neutral, through class F or G, extremely stable.

Atmospheric stability class is an input parameter to the N288.2 atmospheric dispersion model but the standard does not provide evidence on how to determine stability class among the six (A through F) which it considers. In this study, the seven (A through G) classes based on $\Delta$T method are applied according to the Notice No. 2009-37 of the Ministry of Education, Science and Technology.

### *2.3 Input Parameters and assumptions*

The input data for ADDAM code is composed of release and meteorological data, site data, population data for Wolsong 1 NPP. A set of data was prepared for Wolsong 1 refurbishment safety analysis. These data were mainly obtained from the code manual [1] and

Wolsong 2/3/4 safety analysis [4]. In case of the meteorological data, it was prepared from Wolsong NPP meteorological tower data in year from 2005 to 2007.

Projected population distribution in year 2038 in inhabited sectors was used.

Dose conversion factors (DCFs) for cloud-shine are from Table III.1, DCFs for ground-shine are from Table III.3 in the US EPA Federal Guidance Report No. 12 [5]. DCFs for inhalation are from Table 2.1 in the US EPA Federal Guidance Report No. 11 [6]. The above DCFs are based on the ICRP Publication 26.

The DCFs for inhalation were derived by multiplying the values (Sv/Bq) in Table 2.1 in the US EPA Federal Guidance Report No. 11 by the breathing rate for the Korean adult (7,400 $m^3$/yr).

The ground level release and no plume rise were assumed to conservatively calculate the atmospheric dispersion factor.

### 3. Results and Conclusion

Dose results for Large LOCA cases are illustrated at Table 1. The 99.5 percentile dose for each accident case was selected for adverse weather condition. Thyroid and effective doses are sum of the cloud-shine, ground-shine, and inhalation doses.

The maximum value of thyroid dose is 302.2mSv, and effective dose is 81.6mSv. Both the effective and thyroid doses are below the acceptable limits [7] for all cases of the large LOCAs.

Table 1. Result of Dose Analysis

| W1 FSAR | | Accidents | Dose limit | | Dose result | |
|---|---|---|---|---|---|---|
| | | | Thyroid | Effective | Thyroid | Effective |
| 15.2.1.1 Large LOCA | Part A | with available safety system | 30 | 5 | 1.5 | 0.4 |
| | Part B | Total loss of isolation logic | 2500 | 250 | 25.5 | 5.6 |
| | | Open ventilation inlet | 2500 | 250 | 17.3 | 3.8 |
| | | Open ventilation outlet | 2500 | 250 | 16.5 | 3.7 |
| | | Deflated personel air lock door | 2500 | 250 | 15.1 | 3.4 |
| | | Deflated equipment air lock doo | 2500 | 250 | 14.7 | 3.2 |
| | | Open personel air lock door | 2500 | 250 | 64.7 | 13.2 |
| | | Open equipment air lock door | 2500 | 250 | 299.2 | 58.1 |
| | | Minimum detectable hole size | 2500 | 250 | 3.0 | 0.8 |
| | | Loss of dousing | 2500 | 250 | 1.2 | 0.3 |
| | | Loss of air cooler | 2500 | 250 | 1.1 | 0.3 |
| | Part C | Loss of emergency core cooling | 2500 | 250 | 302.2 | 58.7 |
| Large LOCA+Loss of IV Class Power | Part D | with available safety system | 2500 | 250 | 22.4 | 8.7 |
| | Part E | Total loss of isolation logic | 2500 | 250 | 236.6 | 81.6 |
| | | Open ventilation inlet | 2500 | 250 | 130.6 | 28.7 |
| | | Open ventilation outlet | 2500 | 250 | 153.6 | 61.2 |
| | | Loss of dousing | 2500 | 250 | 22.1 | 8.4 |
| | | Loss of air cooler | 2500 | 250 | 23.8 | 10.2 |
| | Part F | Loss of emergency core cooling | 2500 | 250 | 92.3 | 20.1 |

### REFERENCES

[1] Sabourin, G., "ADDAM Version 1.0 User Manual", AECL, CW-111090-225-008, Revision 0, June 2003.

[2] AECL, "Computer Code Documentation for Calculation and Analyses; ADDAM Version 1.0 Theory Manual", Rev 0, 2003 June.

[3] CAN/CSA-N288.2-M91 "Guidelines for Calculating Radiation Doses to the Public from a Release of Airborne Radioactive Material under Hypothetical Accident Conditions in Nuclear Reactors", 1991 April.

[4] Korea Electric Power Co., "Wolsong Nuclear Power Plant Unit N0. 2/3/4 Final Safety Analysis Report, 1995.

[5] US EPA, "External Exposure to Radionuclides in Air, Water, and Soil", Federal Guidance Report No. 12, 1993.

[6] US EPA, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", Federal Guidance Report No. 11, 1988.

[7] AECB C-6 Rev. 1, "Requirements for the Safety Analysis of CANDU Nuclear Power Plants", May 31, 1994.