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Effects of Source Term Characteristics on Off-Site Consequence

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1. Introduction

Off-site consequence analysis in Level 3 PSA is mainly affected by source term release characteristics of nuclear plant. The severe accident analysis codes for quantifying the source term release characteristics such as MELCOR and MAAP provide detailed information of these characteristics to assess the off-site consequence. The aforementioned characteristics, however, have not been considered in the consequence analysis of domestic plants because of large uncertainty in these characteristics so far. Recently, the USNRC SOARCA report [1] showed an approach to utilize detailed source term characteristics provided by MELCOR code to quantify the off-site consequence more realistically.

Main purpose of this study is to assess effects of the MELCOR source term characteristics on the off-site consequence analysis of a domestic nuclear power plant, in a similar fashion to the SOARCA approach. Among many features characterizing source term, the most important one is to determine initial and boundary conditions of atmospheric dispersion such as:

- Release amounts of source term
- Release time and duration

Moreover, plumes features (i.e., radiation clouds) affect atmospheric dispersion that shapes plume characteristics as follows:

- Initial dimension of plumes
- Plume rise
- Deposition of radioactive materials during dispersion

Although the current severe accident codes have some limitation in providing the entire source term release characteristics needed in the consequence analysis, the essential information for these features could be obtained from these codes. It is noted that the typical approaches, which generate source term information for the consequence analysis from the severe accident codes, should require a technical manipulation by the experts of consequence analysis. The present effort focused on an identification of insights to utilize source term characteristics of the severe accident codes.

2. Source term characteristics in MELCOR

The MELCOR code provides essential features of source term characteristics for consequence analysis [2], in terms of an optional parameter, i.e., ‘MACCS’ as the MELCOR input variable. If a user includes this option in input files, the relevant source term parameters are automatically generated by the code to provide source term information. In addition, the MELMACCS code [3], which is a utility program, can also generate MACCS code input for an off-site consequence analysis [4]. The present study utilizes these features to assess the effects of off-site consequence.

An early containment failure scenario, which is expected during a fast station black-out (SBO) accident for OPR1000 plant [5], was selected as a reference case for this study.

3. Results and Discussion

An early containment failure which is the most possible source term release path in a fast SBO accident could occur due to several causes. In this study, only two failure modes were considered (1) over-pressurization and (2) energetic ex-vessel steam explosion. A difference between two scenarios may be caused from cavity flooding conditions during a fact SBO accident progression.

For these two scenarios, the effects of following features on off-site consequences were assessed:

- plume characteristics
- sensible heat
- deposition velocity

In order to utilize the source term results from the MELOCR code, the aforementioned features should be manipulated by an expert. As a preliminary work for obtaining insights, a sensitivity of corresponding parameters was assessed. Table 1 shows each effect on the off-site consequence according to source term features. For each feature, insights have been observed as follows:

- Dynamic characteristics of plume release should be considered.
- Release time is a dominant factor of the evacuation
- Sensible heat to determine plume rise should be considered.
- Deposition characteristics should be considered.

4. Concluding Remark

A realistic estimation in the off-site consequence analysis has been a long-lasting issue, due to large uncertainty in the source term estimation. In recent times, however, there were more understandings on severe accident phenomenology and progress in simulation tools such as MELCOR, making it possible to assess more realistically the off-site consequence.

As a result, the present study showed a greater or lesser impact of initial and boundary conditions of atmospheric dispersion. This study provided insights of the effects of source term release characteristics provided by the MELCOR code, of which insights could be applied to more realistic and precise off-site consequence analysis. For more realistic estimation, various MELCOR analysis results should be explicitly reflected into the off-site consequence analysis.

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REFERENCES

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Table 1. Effects on the off-site consequence according to source term features

Scenario	Source Term		Start	Duration	Sensible Heat	Height	Deposition Model	Population Dose (man.Sv)		CP of Individual EF(man.Sv)		CP of Individual LCF (< 16Km)	
	I	Cs						Evc.	No Evc.	Evc.	No Evc.	Evc	No Evc
Base Case													
Spray Off	2.0E-01	5.4E-02	16050	3150	5.85E+05	20	DM10	0	3.53E+03	0	9.16E-04	0	6.55E-03
Spray On	8.2E-02	1.5E-02	15971	2980	5.43E+05	20	DM10	0	1.67E+03	0	4.23E-04	0	2.69E-03
a. Effect of Plume Characteristics													
a.1 Plume Numbers													
PN1	8.1E-02	2.7E-02	16050	3150	5.85E+05	20	DM10	0	1.86E+03	0	6.20E-04	0	2.80E-03
PN2	1.2E-01	2.7E-02	16050	72000	1.84E+05	20	DM10	0	1.91E+03	0	3.18E-04	0	4.18E-03
a.2 Accumulate Single Plume													
PN1All	2.0E-01	5.4E-02	16050	3150	5.85E+05	20	DM10	0	6.62E+03	0	4.69E-03	0	6.98E-03
a.3 Release Time													
TDS00	2.0E-01	5.4E-02	16050	3150	5.85E+05	20	DM10	0	3.53E+03	0	9.16E-04	0	6.55E-03
TDS01	2.0E-01	5.4E-02	0	3150	5.85E+05	20	DM10	1.8E3	4.02E+03	5.1E-4	1.64E-03	2.8E-3	6.97E-03
TDS02	2.0E-01	5.4E-02	3600	3150	5.85E+05	20	DM10	1.5E3	3.84E+03	3.0E-4	1.34E-03	2.4E-3	6.84E-03
TDS03	2.0E-01	5.4E-02	7200	3150	5.85E+05	20	DM10	1.4E3	3.72E+03	5.1E-5	1.16E-03	2.7E-3	6.74E-03
TDS04	2.0E-01	5.4E-02	10800	3150	5.85E+05	20	DM10	7.3E1	3.63E+03	0	1.04E-03	9.5E-5	6.66E-03
b. Effect of Sensible Heat													
SH01	2.0E-01	5.4E-02	16050	3150	5.00E+04	20	DM10	0	3.59E+03	0	9.44E-04	0	6.54E-03
SH02	2.0E-01	5.4E-02	16050	3151	1.00E+05	24.1	DM10	0	3.64E+03	0	9.33E-04	0	6.54E-03
SH03	2.0E-01	5.4E-02	16050	3152	5.00E+05	32.7	DM10	0	3.53E+03	0	9.17E-04	0	6.55E-03
SH04	2.0E-01	5.4E-02	16050	3153	1.00E+06	40.9	DM10	0	3.49E+03	0	9.02E-04	0	6.55E-03
SH05	2.0E-01	5.4E-02	16050	3154	5.00E+06	92.2	DM10	0	3.30E+03	0	8.00E-04	0	6.53E-03
c. Effect of Deposition Velocity													
DV01	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-2	0	3.49E+03	0	6.62E-04	0	6.88E-03
DV02	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-3	0	3.46E+03	0	4.73E-04	0	7.14E-03
DV03	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-4	0	3.46E+03	0	4.47E-04	0	7.18E-03
DV04	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-5	0	3.46E+03	0	4.68E-04	0	7.15E-03
DV05	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-6	0	3.48E+03	0	5.68E-04	0	7.01E-03
DV06	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-7	0	3.53E+03	0	9.22E-04	0	6.54E-03
DV07	2.0E-01	5.4E-02	16050	3151	5.85E+05	20	DM01-8	0	3.63E+03	0	1.65E-03	0	5.66E-03