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An Establishment of MELCOR code to Generate Source Terms for Off-Site Consequence Analysis

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1. Introduction

Since the Fukushima accident, an effective approach to a source term analysis for off-site consequence analyses has been needed. The MELCOR code has the capability to assess the source term characteristics for this kind of demand [1]. A comprehensive effort is required to use the MELCOR code for a source term analysis effectively.

For this purpose, the following works are required:

- Review and assess the MELCOR model relevant to source term characterization
- Generate input files for source term analysis
- Utilize the source term parameters

This paper shows an effort to establish the MELCOR code to generate source terms for an off-site consequence analysis.

2. Methods and Results

In this section some of the techniques used to model and analyze an accident scenario are described. The NPP used is an OPR1000, and the scenario is an SBO accident.

2.1 MELCOR Model and Input

The nuclear power plant used in this case is an OPR-1000 plant, the power of which is 2,815 MWth PWR, it has 2 loops (2SGs, 4RCPs) and 3 PSVs. In addition it has 7 rings in the core. The nodalization of the containment is shown in Fig.1.

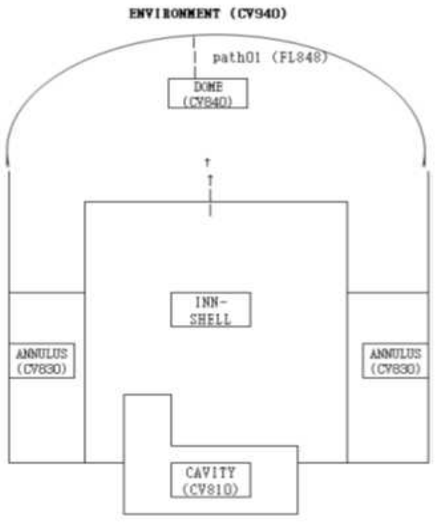


Fig. 1. Nodalization of containment

To analyze the radionuclides for an accident scenario, the MELCOR input records need to be defined. The 'MACCSnn' records for the release path must be defined, and major related records are defined such as the control volume for nodalization, the flow path, the decay heat, and the radionuclides, as shown in Table 1 (MELCOR Input Records) [1].

The MELCOR input for the OPR1000 case is as follows: Release path 01 is allowed to identify flow path 848, which serves as "release" paths for the consequences code MACCS. Flow path 848 is connected from control volume 840 (dome) to control volume 940 (environment). For the radionuclides, the number of sections (size group) is defined in the RN1001 record of input as 10.

To obtain the radionuclides results, the radionuclide variables need to be defined, which are shown in Table 1 (MELCOR Output Variable for MELMACCS) [1]. These are also the major variables for MELMACCS input. Sometimes, some calculations through user-functions such as cumulative mass and fluid mole are needed. When executing the MELCOR code, the output data used for MELMACCS are accumulated in a plot file. After execution with some confirmation of the major parameters of the scenario, MELMACCS can be analyzed through these plot data.

Table 1. MELCOR Input/Output (MACCS related part)

MELCOR Input Records	MELCOR Output Variable for MELMACCS
CVnnn00	FL-I-MFLOW.m.n
DCHNEMnn00	MACCS-nn-PLTEMP
DCHCLSnnn0	MACCS-nn-PLMFLO
DCHCLSnnnm	MACCS-nn-PLMWT
DCHDEFCLSm	MACCS-nn-M-RE-cc.ii
FLnnn00	MACCS-nn-M-RE-cc.AER
MACCSnn	MACCS-nn-M-RE-cc.TOT
RN1000	RN1-TYCLT-x-1.ty
RN1001	RN1-TYCLT-x-2.ty
RNCCXXX	RN1-TYTOT-1.ty
RNFP000	RN1-TYTOT-2.ty
RNFPNijjXX	
RNGAPijjXX	
RN1100	
RNCLSNNXX	

In this case, an SBO scenario for OPR1000 was used. The conditions of the SBO accident sequence are as follows: The initiating event is a station blackout with DC power loss. The reactor is tripped during an off-site power off. The reactor coolant pump is tripped during an off-site power off. The auxiliary feed water fails. The

HPSI and LPSI are not activated. The 4 SITs are operable. The containment spray power is recovered at 3 hours. The spray recirculation fails due to the energetic S/E at RV failure. The containment is ruptured by the energetic S/E at RV failure. In the MELCOR code, there are 16 classes of radionuclides that can be treated (Shown in Table 2). Among these RN classes, the latter 3 classes are discarded, and the remaining 13 RN classes are analyzed.

For the source term analysis, the RN per class, RN section (size group), control volume type and sequence conditions of the system need to be analyzed. With these analyses, the plot data, which are the results of the MELCOR code, can be analyzed for an off-site consequence analysis.

Table -2. Radionuclide Release Groups

Class	Name	Element
1	Noble Gas	Xe
2	Alkali Metals	Cs
3	Alkaline Earths	Ba
4	Halogens	I (I_2)
5	Chalcogens	Te
6	Platinoids	Ru
7	Early Transition Elements	Mo (Fe)
8	Tetravalent	Ce
9	Trivalents	La
10	Uranium	U (UO_2)
11	More Volatile Main Group	Cd
12	Less Volatile Main Group	Sn (Ag)
16	Cesium iodide	CsI
13	Boron	B (BO_2)
14	Water	H_2O
15	Concrete	[Con]

2.2 Inspection of Accident Progression and Conditions

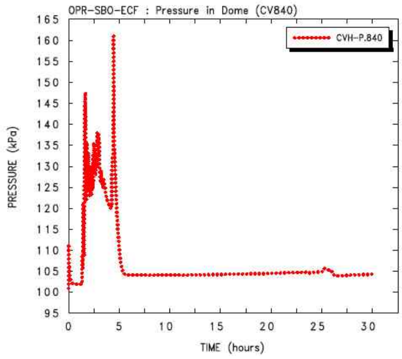
With the progression of the SBO accident, the major events are shown in Table-3. The end time is defined as 108,000 seconds.

Table-3. Major Events of SBO scenario.

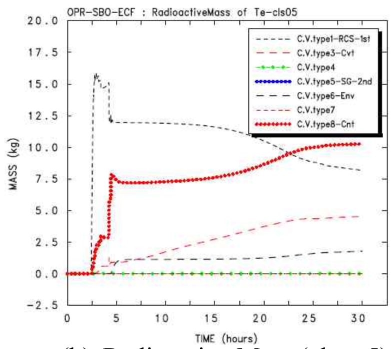
Time (sec)	Major Event
0.0	Reactor Trip
0.0	MSIV closed
0.0	RCP Trip
0.0	Main FW Stop
6.0	SRV first open
3438.5	Start SG dryout
6555.8	Start Core Uncover
7632.3	Gap release start
8645.3	support structure failure start
8748.8	Cladding melt start
8826.3	Fuel melt start
10120.1	Hydrogen burn occurs
10800.8	Containment Spray Start
15237.4	Lower head failed
15418.3	SIT start injection
15961.2	Containment Rupture
93336.0	Cavity dryout

2.3 Results

The input and results of the MELCOR code can be confirmed and analyzed for an off-site consequence analysis. In these results of the related source term, the following can be analyzed: nominal aerosol density, fluid temperature, cumulative fluid mass flow, fluid molecules, released radioactive mass, released radioactive aerosol mass, and total released radioactive mass. In this SBO case, 2 of the major results are shown in Fig.2.



(a) Pressure in Dome



(b) Radioactive Mass (class 5)

Fig. 2. Major Results for SBO case in OPR1000.

3. Conclusions

To utilize the MELCOR code for a consequence analysis, the present study investigated the MELCOR code and the relevant utility program, MELMACCS. For sufficiently utilizing the MELCOR code, specific works for the source term groups and relevant parameters were required. For these works, the input files related to the source term were modified and derived, and the output parameters for 'MACCS' optional parameters were developed for investigating the source term characteristics.

REFERENCES

[1] R.O. Gauntt et al., "MELCOR Computer Code Manuals Vol. 1: Primer and Users' Guide Version 1.8.6", Sandia National Laboratories, Albuquerque, NUREG/CR-6119, Vol.1, Rev.3, September 2005.

[2] Katherine McFadden et al, "MELMACCS Models Document", Sigma Software L.L.C. Draft, January 2011.