Development of MUST (Multi-Unit Source Term) Converter Version 1.0

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1. Introduction

Producing a source term input by converting the results of severe accident analysis is a fundamental procedure to perform Level 3 PSA. For both single-unit and multi-unit risk assessment, preparing appropriate source term input is necessary as the starting point of off-site consequence analysis.

There exists MelMACCS which is a software to convert the results of MELCOR code into an input of MACCS (MELCOR Accident Consequence Code System). However, there is no automation system for preparing a source term input from the results of MAAP (Modular Accident Analysis Program), which is another frequently used severe accident analysis code.

Automatic source term conversion system plays an important role especially for a multi-unit Level 3 PSA since there exists enormous number of source term combinations to build accident scenarios. The number of scenarios increases exponentially as the number of units or the number of STCs (source term categories) increase [1, 2].

MUST (Multi-Unit Source Term) Converter is developed to convert the results of MAAP into a source term input of MACCS to perform a single-unit or multi-unit Level 3 PSA.

2. Key Functions of MUST Converter

In order to produce a source term input of MACCS, a MAAP result file containing essential variables is needed. Essential variables for the source term calculation are comprised of

- Release mass of element (MRELEL),
- Initial mass of element (MFPIN),
- Fraction of aerosols in each particle size array (FMXRB),
- Fission product flow through junction (WFPJ),
- Initial mass of FP group (MFP0),
- Element mole faction in FP group (FAFP0),
- Initial number of FP atoms in group (MTFP0),
- Release height of each plume segment above ground level (PLHITE),
- Floor elevation of compartment relative to ground level (ZFRB),
- Bottom of junction height with respect to donor compartment floor (ZJUNC),
- Height of junction (XHJUNC),
- Enthalpy in compartment (HGRB),
- Mass flow rate through junction (WRB),
- Specific volume in compartment (VGRB), and
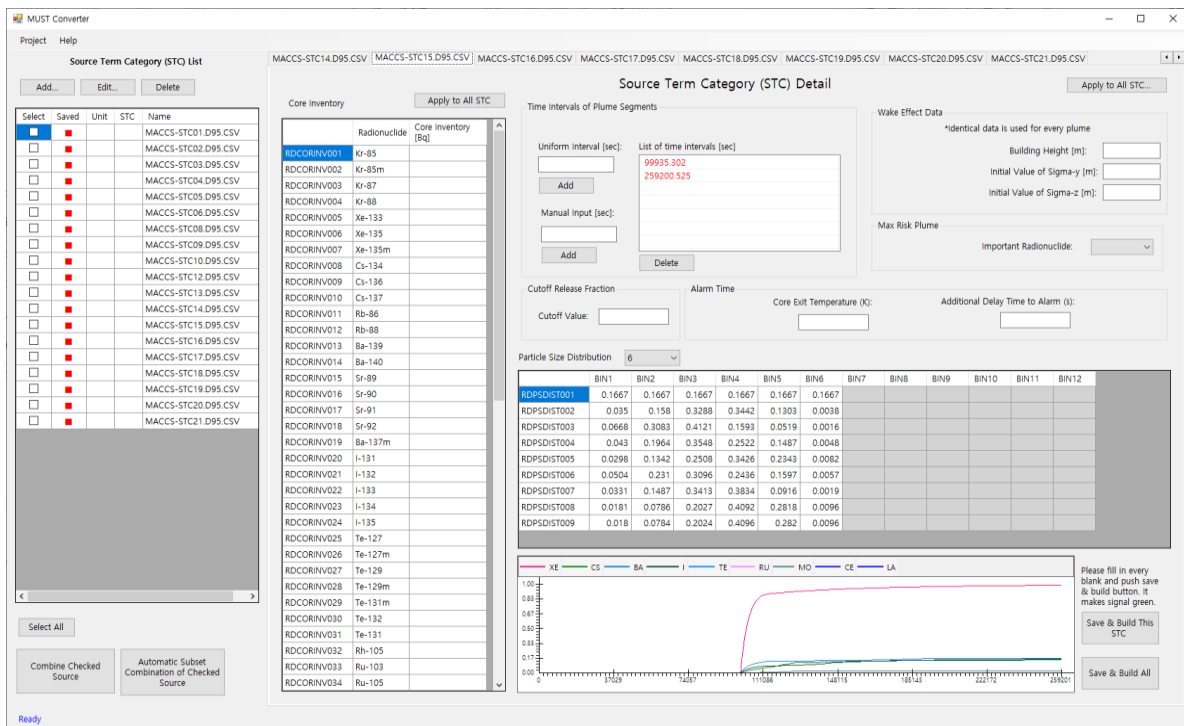- Pressure in the compartment (PEX0).

Fig. 1. Main window of MUST Converter Version 1.0

Fig. 1 shows the main window of MUST Converter Version 1.0. Multiple MAAP output files can be loaded into the STC list and can be treated tap by tap.

In addition to the variables from the MAAP result, users can give more information to MUST Converter by user input as follows:

- Core inventory,
- Time intervals of plume segments,
- Wake effect data,
- Important radionuclide to select the maximum risk plume,
- Cutoff release fraction, and
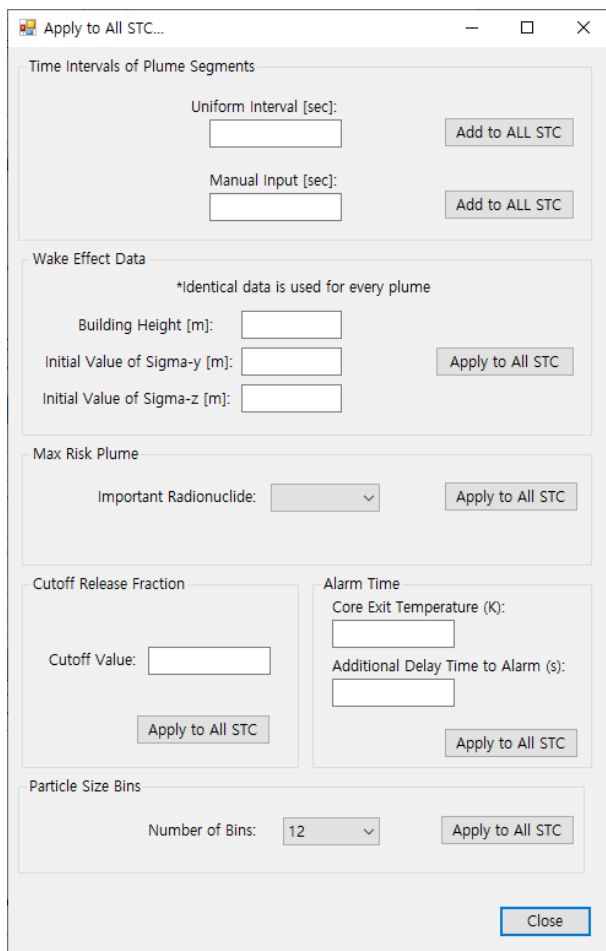- Data related with alarm time.

Fig. 2. Window of "Apply to All STC"

User inputs can be applied to all STCs by clicking "Apply to All STC" button as shown in Fig. 2. MUST Converter runs on a project basis so that work can be easily saved and loaded by users.

By using MAAP output variables and the information of user input, MUST Converter calculates release amount and release energy of each plume segment. Release energy is comprised of two types such as heat of release and density & mass flow rate of release. Alarm

time, particle size distributions, and height of release can be also calculated. MACCS uses height of release and energy of release to calculate effective release height which is one of the important factors to simulate atmospheric dispersion. MUST Converter is also installing a special treatment of SGTR scenario, since the parameters of MAAP output of SGTR scenario are different from those of other scenarios.

Detailed interfacing method between MAAP and MACCS and ways of source term calculation are introduced in Kim et al., 2021 [3].

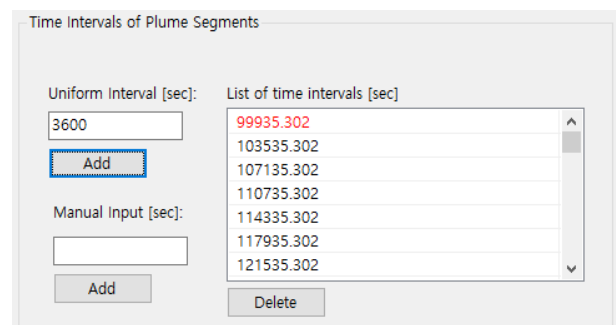*2.1 Single-Unit Source Term Conversion*

Fig. 3. Interface of user input for the setting of plume segments

As shown in Fig. 1, MUST Converter automatically scans and perceives the starting time of release and ending time of MAAP analysis. If a user enters a time interval, as depicted in Fig. 3, MUST Converter automatically inserts time steps by time interval from the beginning to the end of release. For example, when user enters 1 hour of time interval, MUST converter makes multiple plumes having 1-hour duration of release. User also can input individual time steps manually. This process is related with setting delay of plume (PDELAY), duration of plume (PLUDUR), and the number of plume segments (NUMREL) in MACCS. By applying multiple plume segments, MACCS can simulate dynamic property of a source release.

Wake effect data such as building height, initial sig-y, and initial sig-z are shared by all plumes.

When users select an important radionuclide, MUST Converter finds the maximum risk plume (MAXRIS) by searching the maximum release plume of the selected radionuclide.

A cutoff value of release fraction can be set in order to avoid to produce a plume segment for negligible amount of release. This function helps to reduce the running time of MACCS by reducing the number of plume segments.

Variables related with alarm time also can be entered by users. If a temperature criterion of emergency condition is entered, MUST converter extracts the time when maximum core exit temperature (CET of MAAP) reaches to the criterion. In addition to this time,

additional delay time to alarm can be entered. Various delay times can be considered as additional delay times by users, such as recognition time of emergency condition, delay to announce emergency, and delay to recommend public protection action.

Particle size distribution is calculated by counting total fraction of aerosols in each particle size array. The current version of MACCS does not account for particle size distribution of each plume segment, but considers one representative distribution for all plume segments [4].

Each source term file is saved in "Project Folder / Single-Unit / Folder named by MAAP output file." Format of source term file is CombineSource.out and detailed information is provided in Section 2.2.

If MAAP output file includes information of maximum core exit temperature (CET of MAAP) and a user enters the data related with alarm time, MUST converter produces OALARM.inp file in the same folder with CombineSource.out file.

2.2 Multi-Unit Source Term Conversion

The draft version of MUST Converter [5] used the method to integrate the release fractions of each unit into ATMOS input file and employed core scaling factor (CORSCA in MACCS) to avoid release fraction over 100%. However, the release version of MUST Converter does not use the complex method anymore and creates CombineSource.out file which is multi-unit source term file of MACCS. CombineSource.out file can be used not only for multi-unit source term but also for single-unit source term by applying a single MAAP output file.

Users can check STCs in the STC list in order to produce multi-unit source terms. MUST Converter is also installing automatic subset combination of checked sources. Each multi-unit source term file is saved in "Project Folder / Multi-Unit / Name of STC combination using unit number and STC number."

MUST Converter can also extract information about multi-unit source term scenarios (i.e., STC combinations and frequencies) from the result of SiTER [6] and automatically produces multi-unit source term files to perform consequence analyses.

3. Verification &Validation of MUST Converter

A manual source term calculation tool was built using Microsoft Excel and various test cases were tested by comparing the results calculated using MUST Converter and Microsoft Excel sheet.

In addition to the self-testing, a third-party tester who was not involved in the software development created another testing spreadsheet using Microsoft Excel after being told about the design of MUST Converter. Additional testing was performed using this testing tool

in order to enhance the quality and reliability of the software.

4. Interfacing with Execution Software

Mr (Multi-run) Manager was developed to manage multi-run of MACCS with source term files made by MUST Converter. A large number of calculations can be conducted with maintaining the number of concurrent processing which is set by a user considering the number of processors. Detailed information of Mr Manager is introduced in Kim, 2021 [7].

5. Conclusions

MUST Converter Version 1.0 was released after updating many functions from the draft version, such as source term calculation methods and source term combination method for multi-unit source term production.

It is expected that MUST Converter can be a choice for users who want to perform a consequence analysis from the result of MAPP analysis, regardless of single-unit or multi-unit Level 3 PSA.

It is also expected that MUST Converter suggests a solution to handle enormous number of multi-unit accident scenarios by collaboration with SiTER and Mr Manager.

Acknowledgements

REFERENCES

[1] S. Y. Kim, Y. H. Jung, S. H. Han, S. J. Han, and H. G. Lim, Multi-unit Level 3 Probabilistic Safety Assessment: Approaches and Their Application to a Six-unit Nuclear Power Plant Site, Nuclear Engineering and Technology, Vol 50(8), pp. 1246-1254, 2018.
[2] N. E. Bixler and S. Y. Kim, Performing a Multi-unit Level-3 PSA with MACCS, Nuclear Engineering and Technology, Vol 53 (2021), pp. 386-392, 2021.
[3] S.Y. Kim, K.H. Lee, S.Y. Park, S.J. Han, K.I. Ahn, and S.W. Hwang, Interfacing between MAAP and MACCS to perform radiological consequence analysis, Nuclear Engineering and Technology, Available online, 2021.
[4] N. E. Bixler, K. McFadden, L. Eubanks, F. Walton, R. Haaker, and J. Barr, MELCOR Accident Consequence Code System (MACCS) User's Guide and Reference Manual, U.S. Nuclear Regulatory Commission, Washington, DC, Draft, 2020.
[5] S. Y. Kim and D. S. Kim, Integration of Source Term in Multi-Unit Accident Scenario, International MACCS User Group (IMUG) Meeting 2019, June 10-11, 2019, North Bethesda, MD

[6] S. H. Han, K. M. Oh, H. G. Lim, and J. E. Yang, AIMS-MUPSA Software Package for Multi-Unit PSA, Nuclear Engineering and Technology, Vol. 50(8), pp. 1255-1265, 2018.

[7] S. Y. Kim, Development of Mr (Multi-run) Manager Version 1.0, Transactions of the Korean Nuclear Society Autumn Meeting, October 21-22, 2021, Changwon, Korea.