Linking Radionuclides Release and Source Terms to MACCS2 Code, PSA Levels 1, 2 & 3 results, with a New Algorithm of Nuclear Consequence Measure (NCM)

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ABSTRACT

This paper introduces a newly developed algorithm of "Nuclear Consequence Measure (NCM)." The algorithm will serve as an efficient and viable link, by accurately treating the Radionuclides Release Fraction and Source Terms inputs for the MACCS2 code. In addition, it will assist in the process of MACCS2 codification.

The main focus of this paper is first to assess the root causes of Core Melt Damage (CMD), which could be initiated and induced by a combination of Plant Damage State (PDS) sets, or Severe Accident Sequences. These could prompt further progression of Reactor Pressure Vessel (RPV) and Containment failures, resulting in the release of some fraction of the Radionuclides and Source Terms to the environment, if the RPV is not controlled and managed.

Thus, the main objective of this paper is to discuss the following features, which are essential to revealing the underlying thought processes for this paper:

1. Understanding all the significant state variables associated with the thermal hydraulic model and its transport fluid phenomena analyses, reflected by the degradation progression of RPV and Containment failures;

2. Identifying those physical state variables from thermal hydraulic phenomena, and designating a series of discrete physical blocks or terms, so they can still represent the whole phenomenological process;

3. Searching the governing equations for those failure progressions, to see how radionuclides transport were under progression, which could result in a release to the environment;

4. Formulating a meaningful synthesis of those governing equations into one integral expression to measure the total likelihood of release consequence to the environment;

5. Verifying those root causes of failure, damage, and/or degradation in Structure, System, Component (SSC), Equipment, Man-made Error/Fault, etc, associated with the specifically failed PDS or accident event sequence. Then ascertaining whether its failure probability was assigned "1.0" as the total damage/failure state for encoding into In-vessel and Ex-vessel Modeling Analyses;

6. Asserting the risk-based information for all quantification codes like SAPHIA- PSA, MELCORE, STCP, PST, and XSOR have been treated consistently with the same baseline information for assigning system/component reliability value;

7. Quantifying the fractions of Radionuclides Release and Source Terms input for MACCS2 code, matching them with the results of specific PDS or severe accident information. The data should be verifiable and traceable to becoming parts of PSA Levels 1, 2 and 3 qualification.

8. Establishing and computing a new Nuclear Consequence Measure (NCM), to be incorporated with λ-indexes (Cho's Weighted Factors), for assessing the degradation process in SSCs, equipment, and/or man-made error/faults. Those information (PDS) must be defined at a certain time instant, while making risk assessments, so that it will reflect an equivalent discrete state of time history failure progression. Then the process can inter-relate with the evaluations of SAPHIA-PSA, MELCOR and MACCS2 respectively. This NCM algorithm can be serve as a practical working procedure, easily implemented by both the PRA and non-PRA practitioners.

To summarize, the essence of this paper is to derive the necessary input information for the CHRONC part of MACCS2 code, which will, at least, cover the following items:

1. Water pathway nuclide definition
2. Food pathway definition data
3. Transfer factor from soil to plant by soil ingestion
4. Radioactive retention factors, affected to humans
5. Retention factor for nuclides in crops
6. Time consumption of meat-producing animals
7. Crop processing & preparation retention factors
8. Define the direct deposition to crops transfer function

As can be seen, these areas deal with physical states of volatile and uncertain natures. It is imperative to find realistic values of Radionuclides Release Fraction and its Source Terms inputs for MACCS2. We are realizing that MACCS2 quantification needs some pertinent results of PSA Levels 1, 2 and 3, MELCORE, XSOR and PST, and we can conceive that this recommended algorithm of NCM can help not only expediting the quantification process of MACCS2, and also serving as an efficient and viable LINK among those inter-related codes for resolving many uncertainties in the physical states and man-made problems.