

Preliminary Applicability Assessment of MELTSPREAD to SAEUL Units 3&4

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1. Introduction

During a severe accident, lower-head failure can discharge high-temperature corium into a flooded reactor cavity. The submerged jet may fragment and form a quenched particle bed, while the remaining coherent melt spreads over the floor. This partition controls the local debris depth, contact area, and initial conditions for subsequent Molten Core-Concrete Interaction (MCCI). MAAP5 is efficient for integral plant analysis, but local ex-vessel behaviour is necessarily represented by simplified models. MELTSPREAD solves transient mass, momentum, and energy balances along a user-defined equivalent spreading path and can therefore supplement system-level analysis with a mechanistic evaluation of jet fragmentation and early spreading [1,2].

The code was enhanced through the OECD/NEA Reduction of Severe Accident Uncertainties (ROSAU) Project. The improvements include up to 999 time-dependent source points, friction based on the current local melt depth, extended water and steam properties, and options for side walls, gates, non-central injection, and jet impingement [2]. This study assesses whether the improved code reproduces experimental trends relevant to plant application, accepts a MAAP5-derived large loss-of-coolant accident (LLOCA) source term and an APR1400 cavity representation, and provides interpretable indicators of the initial spreading process. Long-term debris coolability and downstream MCCI consequences are outside the scope.

2. Model Basis and Plant Application

MELTSPREAD represents ex-vessel debris as a transient layer distributed over a prescribed nodal path. Heat transfer, solidification, friction, and geometric restrictions control melt-front advance. The approach is practical for a plant cavity reduced to an equivalent flow path, provided that the consequences of the one-dimensional idealisation are assessed separately. For submerged discharge, fragmented material in the SAEUL calculation was assumed to quench and accumulate as a separate particle bed above the coherent melt without remixing. This treatment provides distinct mass histories, although the predicted morphology depends directly on the breakup model and particle-bed porosity.

The experimental comparisons provide a limited basis for the preliminary assessment. For five selected FARO tests, four calculated fragmented fractions differed from measurements by 3.8-11.1 percentage points. For the

initially saturated L-28 test, however, MELTSPREAD predicted 79.4% fragmentation compared with 52% measured, an overprediction of 27.4 percentage points [2,4]. This case is relevant because the SAEUL pool was also modelled at saturation, although the discrepancy cannot be transferred quantitatively across different scales, compositions, and jet conditions. In the MST-2 comparison, replacing a constant average pour with a transient gravity-driven history improved the predicted initial front velocity, while jet-impingement momentum provided a smaller additional improvement. The result remained strongly sensitive to the viscosity model. Because breakup was disabled for MST-2, the comparison does not validate fragmentation and spreading as a coupled process [2,4].

The LLOCA sequence was selected because it was the assessed SAEUL Units 3 and 4 scenario that proceeded to reactor pressure vessel failure [3,4]. The MAAP5 source begins at approximately 14,746 s, peaks near 14,760 s, and decreases to nearly zero by 14,800 s. The lower-head material temperature is approximately 2,820 K, and specific decay heat decreases from approximately 137 to 52 W/kg. The APR1400 cavity was reduced to a 155-node one-dimensional path from the main room to the auxiliary room, retaining the floor slope. The cavity-to-sump opening was represented by an effective width of 1.9 m, and limestone-common-sand concrete was specified. The flooded boundary was held at 0.44 MPa, a water depth of 6.47 m, and the corresponding saturation temperature. The fall height, breach diameter, and particle-bed porosity were 7.4 m, 0.3 m, and 0.4, respectively. The reported MELTSPREAD transient covers 0-50 s, while the corresponding MAAP5 release window spans about 54 s; the source report does not explicitly document the mapping between the two time origins.

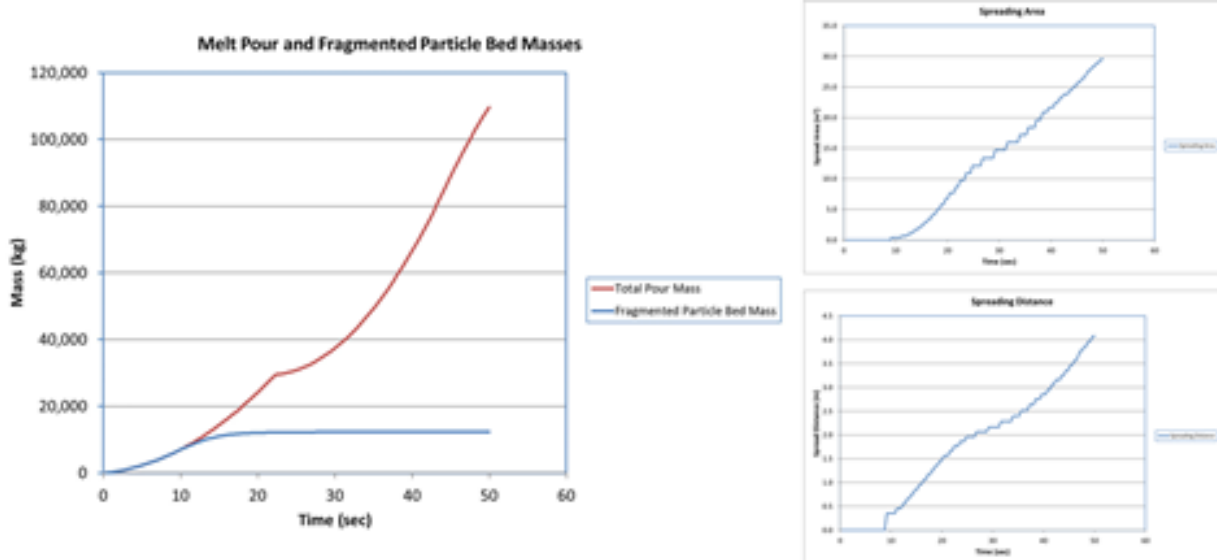


Figure 1. Calculated mass partition and early spreading indicators for SAEUL Units 3 and 4

3. Results and Discussion

Figure 1 summarises the calculated mass partition and spreading indicators. The source report states that approximately 120 t of corium was discharged and 10 t fragmented, whereas the plotted endpoints indicate approximately 109-110 t of total poured mass and 12-13 t in the particle bed. The difference may reflect integration limits or reporting conventions, but it should be reconciled against the raw output before a definitive mass partition is assigned. Coherent spreading begins at approximately 9.2 s, while particle-bed mass continues to increase until approximately 20-22 s; fragmentation and floor spreading therefore coexist for a finite interval.

At 50 s, the spreading area is approximately 29.5 m² and the leading-edge distance is approximately 4.1 m. Both curves are still increasing, so these values represent an evolving early transient rather than the terminal area or stopping distance. Nevertheless, the plant calculation demonstrates that MELTSPREAD can accept a MAAP5-derived transient source, represent the APR1400 cavity through a practical equivalent path, and produce interpretable histories of fragmentation, area, and front location.

The present evidence does not establish a validated terminal-spreading prediction. The FARO results show non-uniform fragmentation accuracy under initially saturated conditions, MST-2 shows strong viscosity sensitivity without coupled breakup, the plant calculation ends before physical arrest, and the source-term time alignment and mass inventory remain unresolved. Verification should therefore include extension to a documented stopping criterion, time-step and nodal refinement studies, and sensitivities to water state, viscosity correlation, particle-bed porosity, effective opening width, and equivalent-path geometry. The L-28 discrepancy should be treated as evidence of model-form sensitivity rather than as a direct plant uncertainty multiplier.

4. Conclusions

MELTSPREAD was applied to the SAEUL Units 3 and 4 LLOCA using a MAAP5 source term and a 155-node APR1400 cavity path. Coherent spreading began at approximately 9.2 s, and the calculated area and front distance reached approximately 29.5 m² and 4.1 m at 50 s. Because fragmentation continued after spreading began and the indicators were still increasing at the endpoint, the results describe early debris evolution rather than the final extent. The study supports preliminary use of MELTSPREAD as a mechanistic supplement to system-level severe-accident analysis. Use in final design or safety judgements requires reconciliation of the source term and mass inventory, extension to physical arrest, documented numerical convergence, and quantified model and geometry sensitivities.

REFERENCES

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