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Technical Bulletin **No. 0899-2**

MODELING GAS STRATIFICATION IN SMALL BREAK LOCA CONTAINMENT ANALYSES

PART II: MODEL VALIDATION

RETROSPECTIVE

Technical Bulletin 0899-1, *"Modeling Gas Stratification in Small Break Loca Containment Analyses – Part I: State of the Art Modeling Techniques,"* pointed out that accurate prediction of the containment gas mixing and distribution is essential for reliable small break LOCA containment analysis. The distribution and possible stratification of the low momentum, high buoyancy gases discharged to containment determines the potential for flammability and may influence the effectiveness of passive heat sinks, which, in turn, affect the containment pressure response.

Technical Bulletin 0889-1 also pointed out that the gas stratification that may occur during small break LOCA sequences is not readily modeled with traditional lumped parameter methods found in most state of the art containment analysis codes. However, when lumped parameter methods are enhanced with sub-nodal physics models, provided uniquely in the MAAP4 Generalized Containment Model, the deficiencies of the lumped parameter methods can be overcome.

The current Technical Bulletin presents benchmark results found in the open literature that demonstrate the shortcomings of standard lumped parameter methods and the efficacy of the MAAP4 sub-nodal physics models, when applied to small break LOCA containment analyses.

HDR 11.2 TEST

In test E11.2, a small break LOCA was simulated by sequentially injecting steam then a hydrogen/helium mixture over a 16-hour time period. Following the gas injection phase, the containment was allowed to cool naturally for 15 minutes before an external spray system was actuated to cool the steel containment dome. The sprays were finally turned off at 19.8 hours. See part I of this Technical Bulletin (TB 0899-1) for a detailed description of the HDR facility.

MAAP4 CALCULATIONS (Ref. 1)

Figures 1 and 2 compare the results of the MAAP4 calculations against the E11.2 test data. Figure 1 shows the H_2/He gas concentration in the upper dome region and provides a good indication of the effectiveness of the MAAP4 sub-nodal physics models. When the H_2/He gas mixture is injected at 44,00 sec, the light gases quickly enter the upper dome region.

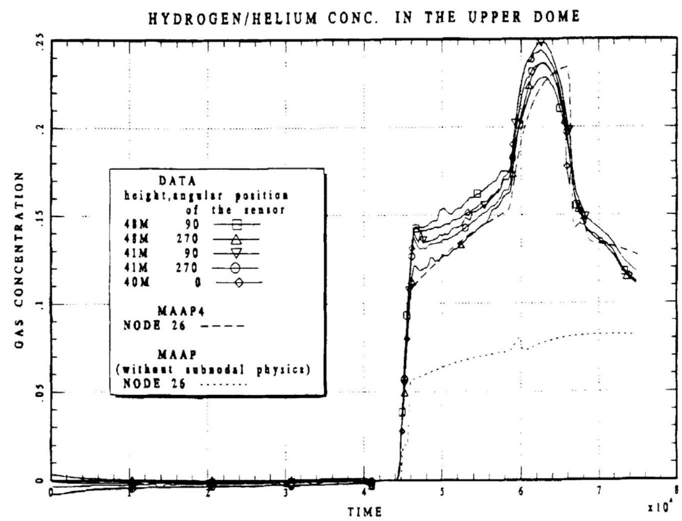

Figure 1 MAAP4 and HDR E11.2 H_2/He concentrations in the upper dome (taken from Ref. 1).

At 57,600 sec, the external dome spray is initiated resulting in rapid condensation of steam in the upper dome region, effectively increasing the dome H_2/He gas concentration. The external sprays also have the effect of cooling non-condensible gases, causing the non-condensible gas to become progressively more dense until it becomes heavier than the gas below the dome region. This unstable configuration resulted in a rapid gas turn over at ~ 65,000 sec at which time the H_2/He-rich gas in the dome was exchanged with oxygen-rich gas from the regions below the dome.

The dotted line in Figure 1 represents the MAAP4 calculations without sub-nodal physics. As shown, the accumulation, or stratification, of the H_2/He gas in the upper dome is not predicted, nor is the rapid gas turn over predicted.

The dashed line in Figure 1 shows the MAAP4 results when sub-nodal physics models are activated. With sub-nodal physics added to the MAAP4 lumped parameter model, the initial gas stratification and gas turnover are both predicted remarkably well.

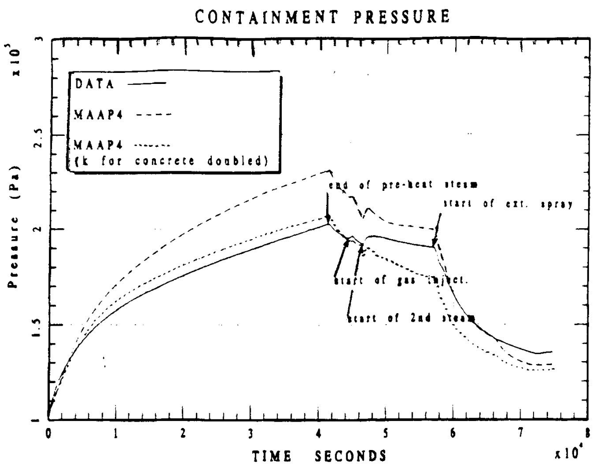

Figure 2 MAAP4 and HDR E11.2 Containment Pressure (taken from Ref. 1).

Figure 2 compares the MAAP4 containment pressure calculation to the E11.2 test data. As shown, the MAAP4 calculations overestimate the actual containment pressure, however better predictions are obtained in the sensitivity run where the concrete thermal conductivity is doubled. This is an indication of the importance of accurate modeling of the passive heat sinks during small LOCA containment analyses.

LUMPED PARAMETER CALCULATIONS (Ref. 2)

The lumped parameter model found in the GOTHIC code does not incorporate the aforementioned sub-nodal physics models, thus it has difficulty predicting the small break LOCA gas stratification phenomena. This is evident in the GOTHIC calculations of gas concentration in the upper dome of the HDR facility during test E11.2, as depicted in Figure 3.

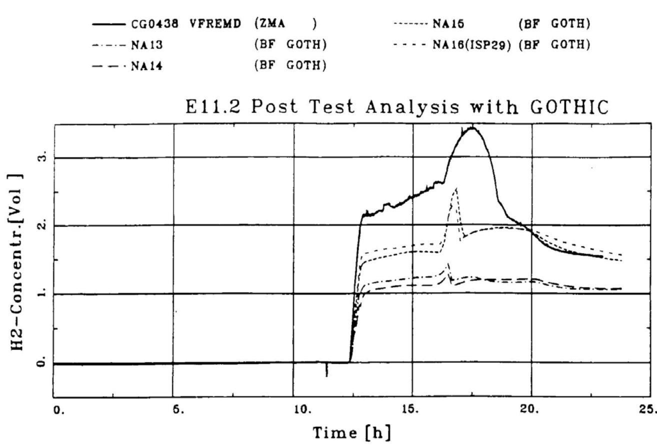

Figure 3 GOTHIC and HDR E11.2 H_2/He concentrations in the upper dome (from Ref. 2).

When the junction areas in the GOTHIC model are artificially reduced by a factor of 10 (GOTHIC runs NA15 and NA16), some gas stratification is predicted, however code calculations do not closely follow the significant gas stratification and gas turnover observed experimentally. Furthermore, as shown in Figure 4, calculations relying on the artificial restrictions on flow path area overestimate the containment pressure. This may be due to a resulting underestimate in heat transfer to the passive heat sinks.

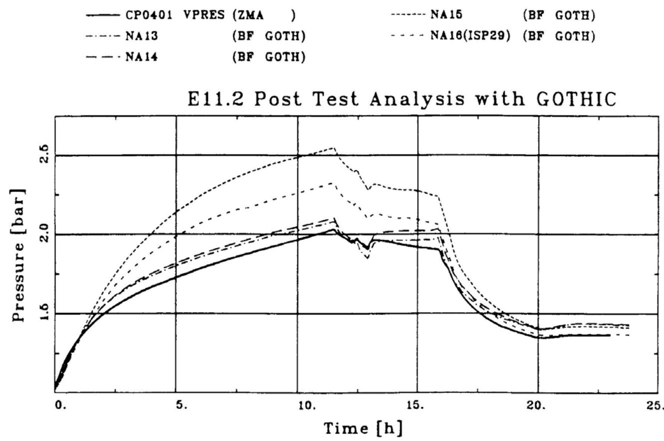

Figure 4 GOTHIC and HDR E11.2 containment pressure (taken from Ref. 2).

CONCLUSIONS

The MAAP4 Generalized Containment Model with sub-nodal physics predicted the intricate transients of the HDR E11.2 test remarkably well. MAAP4 predicted initial stratification of the gas concentration in containment as well as the intricate gas turnover phenomena in the dome region during the external spray time period. This benchmark indicates that,

1. lumped parameter codes enhanced by sub-nodal physics models, such as those found in MAAP4, are quite capable of predicting the gas mixing and stratification phenomena as well as the overall containment pressure expected during small break LOCA accidents.
2. Coarse nodalization schemes are adequate if sub-nodal physics models are employed to model gas stratification and plume behavior.
3. Accurate modeling of passive heat sinks is an important aspect of small LOCA containment calculations.

REFERENCES

1. S. J. LEE, C. Y. PAIK, R. E. HENRY, M. E, EPSTEIN, and M. G. PLYS, "Benchmark of the Heiss Dampf Reaktor E11.2 Containment hydrogen-Mixing Experiment using the MAAP4 Code, " *Nucl. Technol.*, **125**, 182 (1999).

2. H. HOLZBAUER, and L. WOLF, "GOTHIC Verification on Behalf of the Heiss Dampf Reaktor Hydrogen-Mixing Experiments," *Nucl. Technol.*, **125**, 166 (1999).

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