Application of FDS 5 to PRISME DIVA Test, PRS_D3

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1. Introduction

Risk-informed and performance-based analyses are being introduced into fire protection engineering practice. Reliance on fire modeling will play a key role in this practice.

NUREG-1824[1] based on ASTM E 1355 describes 4 steps in the evaluation process for a given model. These are (1) definition of the model and scenarios, (2) assessment of the appropriateness of the model's theoretical basis and assumptions, (3) assessment of the model's mathematical and numerical robustness (verification), and (4) quantification of the uncertainty and accuracy of the model results in predicting events in similar fire scenarios (validation). Validation entails comparing model predictions with full-scale fire experiments and quantifying the results.

The objectives of this study, focused on the model validation, are to compare PRISME DOOR program (PRS_D3) result with FDS 5 prediction and to validate FDS 5.

2. PRISME DIVA tests

The aims of the OECD/NEA PRISME project are firstly to understand and quantify, by means of an analytical approach, the propagation mechanisms of smoke and heat as they spread from a source room towards one or several adjacent rooms, then, to provide the elements necessary for assessing the propagation mechanisms in configurations typically found in the nuclear industry.

The PRISME project consists of a set of DIVA experiments and is designed to produce valuable data for code development and validation. DIVA facility owned by French *Institut de radioprotection et de sûreté nucléaire* (IRSN) is specifically dedicated to carrying out tests involving fires in configurations with several confined and ventilated premises. It comprises three 120 m^3 rooms, one 150 m^3 corridor, one 170 m^3 room on the second floor and a ventilation network. DIVA test facility is briefly described in Figure 1.

Phase 1 of DIVA test consist of DOOR programs and LEAK programs. Figure 2 shows the brief description of DOOR test. PRS_D3 test as part of DOOR program consists of studying the thermal transfer of hot gases and smoke from the source room, containing fire, towards a target room through a fully opened door. The fire source is a liquid hydrogenated tetra-propylene (TPH) pool fire with a surface area of 0.4 m^2. The mean initial air renewal rate used in this test was 4.7/h.

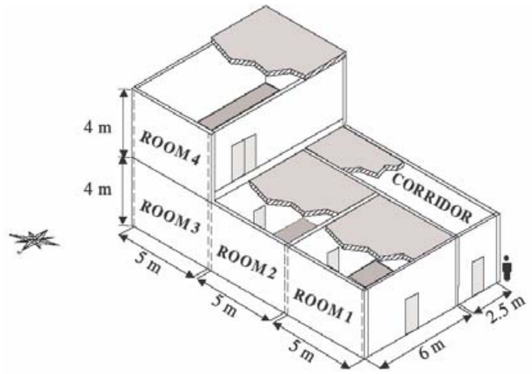

Figure 1 Perspective view of PRISME DIVA test facility

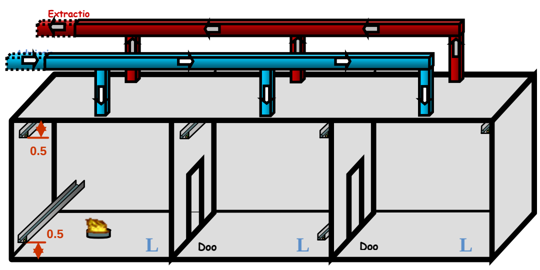

Figure 2 Brief description of PRISME DOOR program

Ventilation flow rates are 570 m^3/h of fire room and 560 m^3/h of target room.

3. FDS code description

Fire Dynamic Simulator (FDS) has been developed at the NIST to study fire behavior and to evaluate the performance of fire protection systems in building.

FDS is a CFD code that solves the Navier-Stokes equations in low Mach number, or thermally expandable form. Transport algorism is based on large eddy simulation techniques, radiation is modeled using a gray gas approximation and a finite volume method is used to solve the radiation transport equation. Combustion is modeled using a mixture faction approach, in which a single transport equation is solved for a scalar variable representing the fraction of gas originating in the fuel stream.

4. Fire modeling of PRS_D3 using FDS 5

The cell size used in this study is 5 cm x 10 cm x 10 cm and the dimensions of cell are 324 by 94 by 43. FDS 5 fire model of PRS_D3 is shown in Figure 3.

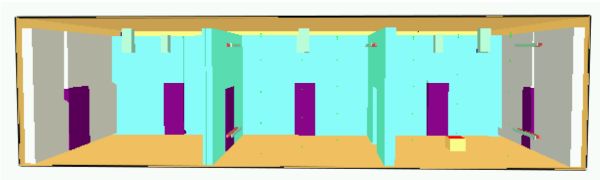

Figure 3 FDS 5 fire modeling for PRS_D3 test facility

Heat release rate (HRR) is one of the most important factors in the analysis of a fire.[2] From PRS_D3 test report[3], initial HRR is estimated as 402.4 kW. HRR as a fire characteristic of PRS_D3 test is shown in Figure 4. The predicted HRR as shown in Figure 5 rises very quickly to about 400 kW following 3 second after ignition. But measured HRRs are gradually increasing at a rate comparable to the predictions.

The reason for this discrepancy is FDS 5 uses a mixture fraction model of combustion. Briefly, the evaporated fuel burns readily with oxygen when mixed to the appropriate ratio, regardless of temperature. Thus, FDS does not simulate properly the spreading of the fire across the fuel pan; rather it predicts an almost instantaneous involvement of the entire fuel surface.

The measured HRRs as shown in Figure 4 increase steadily about 600 kW until 200 sec. after ignition and then decrease to 400 kW at 500 sec. This phenomenon is due to ignite fire on fuel pan using pilot gas burner.

Figure 6 and 7 show the gas temperatures in the center of target room at 3.9 m above the floor. The temperatures are generally slightly overestimated until 150 sec. after ignition. But overall gas temperatures could be reasonably well simulated by FDS 5.

5. Conclusion

PRS-D3 test, performed in DIVA test facility, had been included in validation exercises using FDS 5 for PRISME project covering deterministic fire hazard analysis. Through the application of FDS 5 to DIVA tests, following insights were derived.

- FDS does not simulate properly the spreading of the fire across the fuel pan; rather it predicts an almost instantaneous involvement of the entire fuel surface.
- The overall gas temperatures could be reasonably well simulated by FDS 5.

REFERENCES

[1] M. H. Salley, “Verification & Validation of Selected Fire Models for Nuclear Power Plant Applications”, NUREG 1824, USNRC, May 2007

[2] P. G. Holborn, P. F. Nolan and J. Golt, “An analysis of fire sizes, fire growth rates and times between events using data from fire investigations”, Fire Safety Journal, Vol. 39, Issue 6, Sep. 2004, p481-524.

[3] W. Le Saux, “PRISME DOOR programme – PRS_D3 test report”, PRISME-014, Nov. 2007.

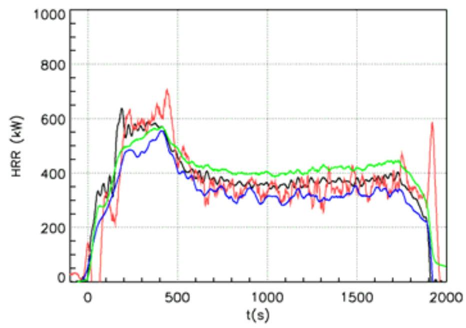

Figure 4 Heat release rate of PRS_D3 test

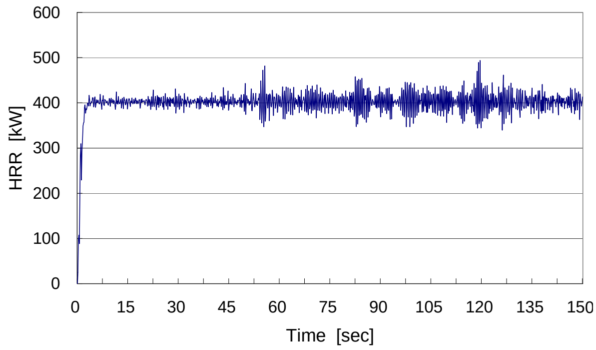

Figure 5 Predicted HRR of PRS_D3 t

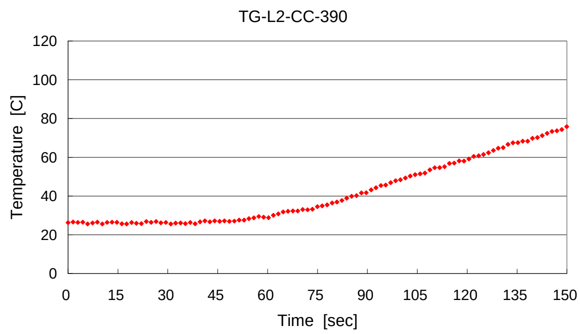

Figure 6. Measured gas temp. in the center of target room

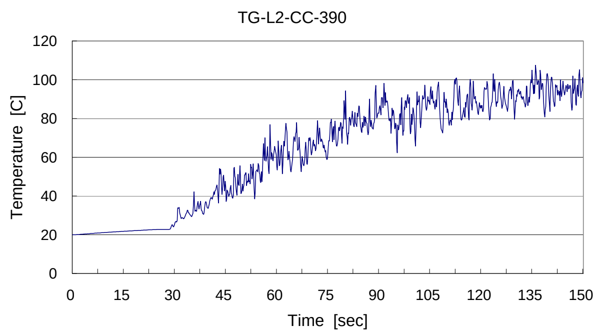

Figure 7. FDS prediction of gas temp. in the center of target room