HRR Influence Analysis of FDS 5 using PRISME DOOR Test Data

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1. Introduction

The heat release rate (HRR) of a burning material is important parameter to quantify the growth and spread of a compartment fire.[1] To predict HRR, the mass loss rate and burning area must be estimated first. Flame spread rate is necessary to estimate the burning area. As a consequence, fire models usually require a HRR profile as input.[2]

Risk-informed and performance-based appraches are being introduced into fire protection engineering practice. Reliance on fire modeling will play a key role in this practice. Validation in NUREG-1824[3] 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 understand the HRR influence to Fire Dynamic Simulator (FDS) Ver. 5 predictions using PRISME DOOR test (PRS_D3) data and to validate FDS 5.

2. PRISME DIVA Facility

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 fire modeling development and validation. DIVA facility owned by French *Institut de radioprotection et de sûreté nucléaire* (IRSN) 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 consists of DOOR programs and LEAK programs. Figure 2 shows the brief description of DOOR test facility. 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 air renewal rate used in this test is 4.7/h.

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

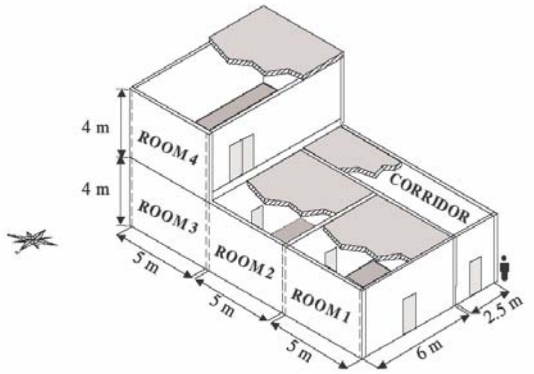

Figure 1 Perspective view of PRISME DIVA test facility

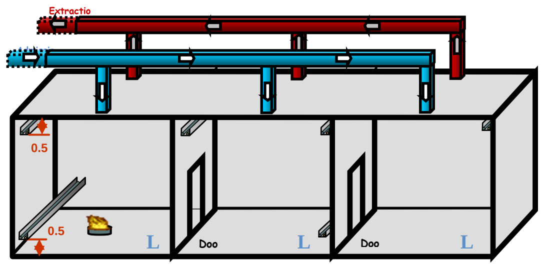

Figure 2 Brief description of PRISME DOOR program

3. FDS code description

FDS is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow developed at the NIST to study fire behavior and to evaluate the performance of fire protection systems in building. A detail description of the FDS model is given in Ref. [4].

FDS solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow with an emphasis on smoke and heat transport from fires.

The partial derivatives of the conservation equations of mass, momentum and energy are approximated as finite differences, and the solution is updated in time on a three-dimensional, rectilinear grid. Thermal radiation is computed using a finite volume technique on the same grid as the flow solver.

Transport algorithm is based on large eddy simulation techniques. Radiation is modeled using a gray gas approximation. 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.

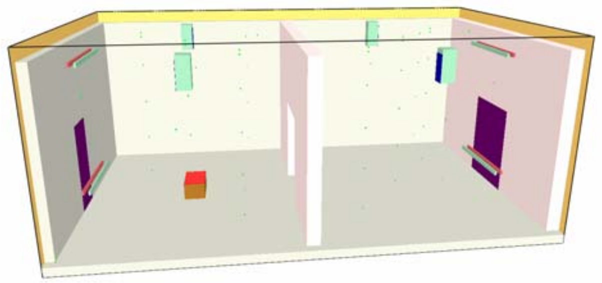

Figure 3 FDS 5 fire modeling for PRS_D3 test facility

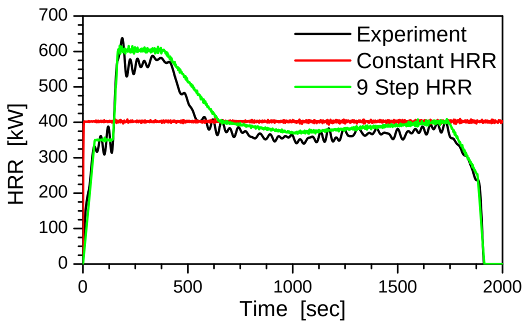

Figure 4 HRR profiles of PRS_D3 test

4. Fire modeling of PRS_D3

The cell size used in this study is 10 cm x 10 cm x 10 cm and the dimensions of cell are 108 by 64 by 45. FDS 5 fire model of PRS_D3 is shown in Figure 3.

Initial HRR is estimated as 402.4 kW from PRS_D3 test report [5]. 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 fuel on fuel pan using pilot gas burner.

2 different types of HRR as a input of FDS 5 are applied to understand the HRR influence of FDS 5. As shown in Figure 4, first one is the curve of constant value and second one is the curve with 9 step values

5. Discussion

The most important factor to consider when modeling compartment fire using fire field model is the prescribed HRR in order to predict temperature profiles within the compartment.

HRR curve is established from mass loss data taken during the experiments and it is used as fire model input. HRR profile for experiment relies on the value of pyrolysis rate of combustion for the fuel provided in the test report and that the accuracy of this value was difficult to identify.

Figure 5 and 6 show the gas temperatures in the fire room at 3.4 m and 2.15 m above the fire source. The temperatures are generally underestimated and the temperature difference between the predictions and the experiment data is increased with elevation.

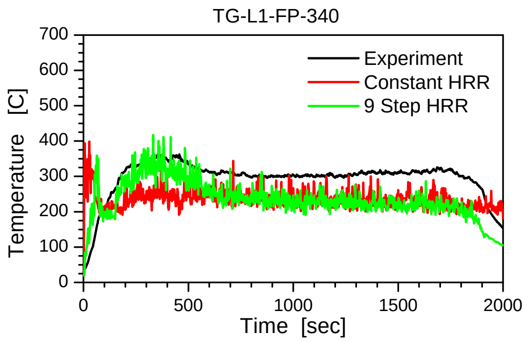

Figure 5. Gas temp in fire room at 3.4 m above fire source

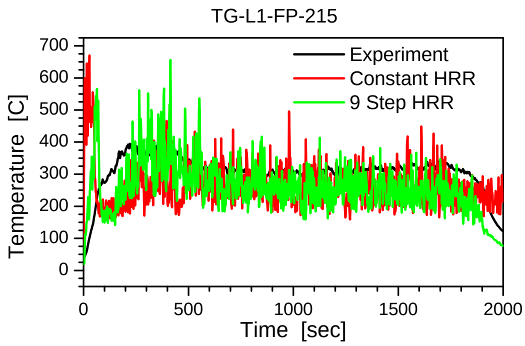

Figure 6. Gas temp in fire room at 2.15 m above fire source

Gas temperature profiles as shown in Figure 5 and 6 are similar to each HRR profiles. That means HRR profile is a critical factor to accurately predict the compartment fire phenomena.

6. Conclusions

Through HRR influence analysis of FDS 5 using PRISME DOOR test data, following insights were derived.

- HRR profile is a critical factor to accurately predict the compartment fire phenomena.
- The overall gas temperatures are underestimated but could be reasonably well simulated by FDS 5.

REFERENCES

[1] V. Babrauskas, R.D. Peacock, “Heat release rate – the single most important variable in fire hazard”, Fire Safety Journal, Vol. 18, Issue 3, 1992, pp 255-272.

[2] R. Kassawara, “Fire Modeling Guide for Nuclear Power Plant Applications”, EPRI TR-1002981, Aug. 2002.

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

[4] K. McGrattan, et al., “Fire Dynamics Simulator (version5) – Technical Reference Guide”, NIST Special Publication 1018-5, BNFL, NIST, July 30, 2008

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