Fire Death in a Sprinklered Rest Home

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Structural fire deaths in New Zealand are comparatively rare events (New Zealand Fire Service statistics[1] from 2002 to 2007 show an average of 22 deaths per year). Some might argue that the rate of fire death in New Zealand is at, or below, the level of statistical noise however, records from jurisdictions in North America shows that the automatic fire sprinkler protection can further-reduce fatalities from fire. Indeed, fire deaths are almost unheard of in buildings protected with compliant sprinkler protection.

All unintentional fires provide an important learning opportunity for the fire engineering community, particularly those fires where the outcome was in some way unexpected or unusual. It is only through post incident analysis that we can gain an understanding of how fire safety systems performed (what went wrong and, of equal importance, what worked). The results of such analysis allow us to reinforce those aspects of regulations and Standards that were proven, and in some instances improve the design basis for fire safety systems.

In October 2009 a fire occurred in a bedroom suite of a sprinkler protected aged care home (refer to Figure 1). The fire resulted in the subsequent death of the occupant in hospital. Consequently the New Zealand Fire Service (NZFS) conducted an Post-Incident Analysis (PIA) into this fire of interest.

The analysis included a review of NZFS, Police, and Hospital records, compliance documentation, facility emergency procedures and witness statements. Two items of coroner's evidence were visually examined and a scene examination was completed (although much of the evidence had been disturbed by this time).

Examination of the room of fire origin, sprinkler system and compliance documentation identified a number of issues that might have contributed to the fatal outcome of this fire. These included sprinkler Response Time Index (RTI), sprinkler head placement relative to the ceiling and apex of the unusually high-pitched ceiling, and potentially obstructing exposed beams.

The fire sprinkler contractor reported that three sprinkler heads had operated. This was considered unusual for what was essentially a fire in a small room with a fire load considered to be typical for this type of occupancy. Was the cause rapid fire growth, delayed sprinkler operation, shielding of discharge, or a combination of these?

The extent of combusted material was limited due to operation of the automatic sprinklers which fully extinguished the fire. It was not immediately apparent how the fire had spread from the probable first point of ignition, a pillow on the floor in immediate proximity to a portable fan heater, to involve upholstered furniture.

The fire was modelled using Fire Dynamics Simulator[2] (FDS5) to study the probable rate of fire growth, the mechanism of fire spread, gas temperatures and smoke toxicology. Modelling allowed examination of various aspects of the sprinkler system and smoke detection in order to ascertain if any installation aspects had contributed to the fatal outcome of this fire.

It should be remembered that modelling is just that, involving a simplification of what we know and can reasonably assume, in order to develop an understanding of what may or may not have occurred. A significant advantage of modelling after-the-fact is that the model can be developed to be consistent with the available evidence, providing a somewhat higher degree of confidence in the results than might be warranted in the investigation of hypothetical design fire scenarios (this latter use of modelling being the more common fire engineering design challenge).

The room geometry was modelled from actual measurements using appropriate literature data for the thermal properties of the materials of construction as shown in Figure 2. The model mesh cell size was initially selected to be a 50 mm cube with a grid of 1.7 million cells to permit realistic physical modelling of the high pitched skillion ceiling, exposed beams, the fan heater and pillow. The stair-stepping construction limitations of the FDS model results in eddy effects at sharp corners and edges. This is a computational efficiency that results in Lego type construction of inclined planes and curves. Sensitivity analysis of the grid and eddy effects on the inclined planes (the latter using the FDS SAWTOOTH parameter) was completed to validate the selected grid dimensions.

The model was developed by initially considering only the fan heater and the pillow in the room of fire origin. The fan heater was modelled as a ***rectangular*** parallelepiped with an induction vent on the top surface and a heated air discharge

Figure 1. Fire Scene

vent on one side. Air flow and temperature data on the heater were not available so these parameters were estimated based on similar physically sized and power-rated appliances.

Data on combustion of latex foam rubber pillows is somewhat limited and the literature[3] suggests that latex pillows can be difficult to ignite. Had time and resources been available it would have been useful to conduct experimental work on the likely source of ignition and initial fire growth under the effects of fan-forced hot air. In the absence of other data the latex pillow Heat Release Rate (HRR) from the Kransy et al. was used as the basis for initial combustion in the model.

The only other significant contributors to the combustion process were the bedding and mattress and an upholstered foam chair. These were incorporated in the model using combustion data from experimental values cited in the CBUF Report[4] with time to ignition and fire spread determined by material properties and fire growth within the model. It should be noted that this aspect of FDS fire modelling is considered to be in the realm of research, although it can produce intuitively realistic fire growth.

A wood veneered chest of draws and a bookcase had also been burnt, but the extent of fire damage to these items was limited suggesting late involvement in the fire and a minimal HRR contribution. A section of the floor covering had been melted and partially burnt but the physical evidence at the fire scene indicated that this was not a significant contributor to fire spread. The structure of the building was not involved in the fire.

A total of twelve 240 second simulations were completed. These tested aspects of model sensitivity, fire growth rate, and the effects of varying the sprinklers' RTI and location with respect to the ceiling in accordance with the Standards of the day. While the simulation time was typically 24 hours to model 240 seconds from ignition, the model preparation and subsequent analysis required several months to complete outside of the time and resource limitations that exist within the NZFS. The model was run on a Microsoft Windows 7 64 bit platform with a 3.2 GHz Intel Core 2 Quad processor with 8 GB of RAM running FDS5 using Open Multi-Processor (OpenMP) simulation.

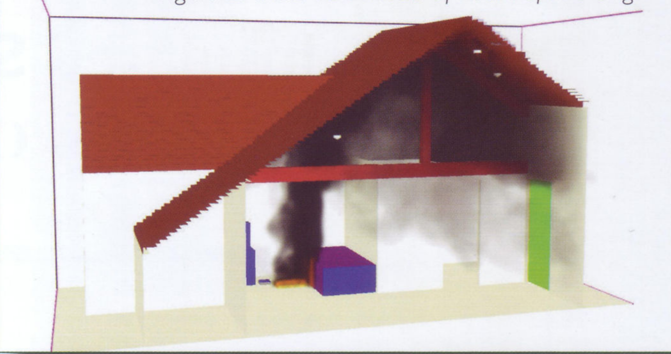
The qualitative modelling results were consistent with the post-fire evidence, witness statements and estimated time-lines. The quantitative modelling results gave weight to the assumed mode of fire spread. From the probable ignition of the pillow the fire spread to the bedding through continuity of combustibles aided by forced air flow from the fan heater. Subsequent involvement of the upholstered chair appears to have been through radiative ignition, an aspect of the fire not readily discernable from the physical evidence.

Modelled smoke alarm and sprinkler activation times are summarised in Table 1 below.

From the modelling it is apparent that:

- the delay in sprinkler activation due to response rate and location in relation to the ceiling would have had minimal impact on the fatal outcome of this fire.

Figure 2. Initial FDS Model of Room of Fire Origin



- tenability criteria in the room were maintained away from the seat of the fire to the time of sprinkler operation.
- the rapid development of the fire could reasonably have activated three sprinklers.

It has been established as a matter of fact that the victim was aware of the fire very early in its development, certainly some tens of seconds before the activation of the smoke alarm and in the order of a minute before the operation of the sprinkler system. It is also apparent that the occupant's intimacy with the fire early in its growth and secondary factors including age and heath were the significant contributing factors to the fatal outcome. This is in agreement with the literature[5] that indicates even limited fire exposure for the very young or very old is likely to have fatal consequences.

The NZFS report concluded that:

> *"On the basis of the information available at the time of the investigation it can be concluded that the cause of this fire was the result of an unfortunate and improbable sequence of events and that, but for the wisdom of hindsight, the fatal outcome could not have reasonably been anticipated."*

The full PIA report makes eight significant recommendations that extend beyond the material presented in this article, including matters relating to sprinkler system compliance and the investigation process. The full report can be requested from the NZFS with reference to Incident Number F0524664.

[1] New Zealand Fire Service Emergency Incident Statistics. 1 July 2006 - 30 June 2007. http://www.fire.org.nz/Facts-and-Figures/Statistic-Reports/Statistics-reports-from-2005-onwards/Documents/ce561f469cb477546c1715d6e0bf107f.pdf

[2] National Institute of Standards and Technology (NIST), 'Fire Dynamics Simulator Version 5.4.2 (FDS5)', US Department of Commerce, 2009

[3] Kransy, F.K., Parker, W.J. & Babrauskas, V., 'Fire Behaviour of Upholstered Furniture and Mattresses', Noyes.

[4] Publications, 2001, pp 287 et seq. Sundstrom, B. (Ed.), 'CBUF Fire Safety of Upholstered Furniture – the final report on CBUF research programme', EU Commission, Measurements and Testing Report, EUR 16477 EN

[5] Purser D.A., 'Assessment of Hazards to Occupants from Smoke, Toxic Gases and Heat', Sect. 2, Ch. 6, Figure 2-6.30, National Fire Protection Association, 'SFPE Handbook of Fire Protection Engineering', 4th Ed., Mass, 2002

		Sprinkler		Device Activation Time (s)			
Simulation	Design Fire	Response	Location	Smoke Det.	Sprinkler 1	Sprinkler 3	Sprinkler 5
Molly7.fds	Minimal	Standard	Actual	29.2	-	213.9	223.3
Molly8.fds	Credible	Standard	Actual	29.8	75.8	74.0	68.2
Molly9.fds	Credible	Fast	Compliant	29.8	69.5	62.9	65.3

Table 1. Response Time of Smoke and Heat Detectors