

FIRE MODEL VALIDATION: PREDICTING ACTIVATION TIMES OF MULTIPLE SPRINKLERS AND THE EFFECTS OF SPRINKLER SPRAY DISCHARGE

By Richard Schulte

The issue of the use of smoke/heat (roof) vents in buildings protected by a sprinkler system has been rattling around the fire protection field since, at least, the mid-1970's, if not longer.

In order to demonstrate that roof vents will not have an adverse impact on the capability of a sprinkler system to control a fire and that smoke/heat vents will perform their intended function in buildings provided with sprinkler protection, Dr. Craig Beyler/Hughes Associates has performed research on these two issues utilizing fire modeling.

In March 2007, Dr. Beyler submitted a document titled "*AAMA Smoke and Heat Vent [S&HV] Modeling Plan Summary for the CTC Study Group*" to the International Code Council (ICC) Code Technology Committee (CTC) study group on roof vents. The following are excerpts from this document:

"The goal is to provide a credible method for design of S&HV systems in sprinklered buildings. At the time the test plan was initiated in 1999, NIST and HAI had used fire modeling to gain insights into sprinkler/S&HV interactions. However, at that time the technology was sufficiently new that it was deemed necessary to conduct large scale fire tests to provide results that would be widely accepted as credible and valid. Much has changed in the past 5-6 years."

"The NIST large eddy simulation model of 1999 was Industrial Fire Simulator. This model has continued to be developed and today is known as Fire Dynamic Simulator (FDS) V4. While some improvements in the model relevant to sprinkler/vent interactions have been made over the years, more importantly FDS has been developed to allow simulation of a wider class of fire problems which has resulted in its widespread use in the fire community and its wide acceptance as a valid modeling tool. In addition there has been a series of additional validation studies published in the fire science literature that have contributed to the wide acceptance of FDS."

“ . . . While FDS formally has fire suppression algorithms, validated predictions of fire suppression remain beyond the capabilities of FDS. As such the prior test strategy of using fire heat release histories that span the actual performance of sprinkler systems will be maintained. . . ”

The statement regarding the “validation” of the capabilities of the Fire Dynamics Simulator (FDS) indicated above is straight-forward and couldn’t be any clearer.

On March 21, 1996, a high bay warehouse in New Orleans, known as McFrugal’s Warehouse, was completely destroyed by fire. The warehouse was roughly one million square feet in floor area and the roof height in the center one-third of the building was approximately 70 feet.

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In the litigation which followed the fire at McFrugal’s, a case known as *Ian David McAuslin, et al v. Grinnell Corporation, et al*, Dr. Craig Beyler acted as an expert for the plaintiffs. Dr. Beyler produced his expert report in February 1999 and subsequently testified in deposition a few months afterwards.

In his expert report, Dr. Beyler utilized the results of fire modeling as his basis for concluding that the sprinkler protection provided for the building was improperly designed. The following are excerpts from Beyler’s expert report and sworn deposition testimony:

“In a recent study sponsored by the NFPA Research Foundation, LES3D was used to predict the interaction between sprinklers and heptane spray fires. The sprinkler activation times predicted by LES3D compared well against the heptane spray fire experiments done at Underwriters Laboratories for the same study. First ring sprinkler activation times were predicted to within about 15 percent, and second ring sprinklers activation times were predicted to within about 25 percent. Predictions of the total number of sprinklers activated by the spray fires were generally very good with most predictions within 25 percent with greater deviations in three of the 21 tests.” (Expert Report)

“The standard clearance fire caused activation of four sprinklers over a period of 100 to 350 seconds. The McFrugal’s NODC clearance resulted in a fire that activated nearly 70 sprinklers during the simulation and clearly did not control the fire.” (Expert Report)

“ . . . LES3D was used to predict the interaction between sprinklers and heptane spray fires.”

“The graphs on this page indicate the estimated operating times of sprinklers for a fire in a Class II commodity which is three tiers high with top of storage to ceiling clearances of 10 feet and 50 feet.” (Expert Report)

“The graph for the 10 feet clearance indicates that the first operating sprinkler will activate in approximately 100 seconds and that the fire will be controlled by a total 4 operating sprinklers.” (Expert Report)

“The graph for the 50 feet clearance indicates that the first operating sprinkler will activate in approximately 215 seconds and that the fire will not be controlled and will continue to grow.” (Expert Report)

“The computational domain does not include the racks themselves. That does not mean that we aren’t predicting or otherwise know what’s going on within the racks, but that is done as a sub-model as opposed to being a part of the - - fluid mechanics domain. What has been done is the fluid mechanics domain starts at the top of the racks up to the ceiling, of course. We predict using the LES model how much water arrives at the top of the racks and we use other models to establish, one, how the fire grows within the racks, and two, what the effect of that water is. So they are - - they are modeled, but they are not modeled in the fluid dynamical part of the LES 3D.” (Deposition Testimony)

“We predict using the LES model how much water arrives at the top of the racks and we use other models to establish, one, how the fire grows within the racks, and two, what the effect of that water is.”

“Those sub-models are a fire growth model that’s described subsequently in the report as well as the effect of water is. There’s a sub-model for that that we added for that. Both of those are - - We’ll talk about them in detail, I’m sure. Both of those come out of work done at Factory Mutual.” (Deposition Testimony)

“Those sub-models are a fire growth model that’s described subsequently in the report as well as the effect of water is.”

“Yes. Basically the modeling approach that we adopted that I just described in terms of dealing with the domain only above the commodity is the same approach that’s inherent in the ADD-RDD or RDD-ADD concept that Factory Mutual has been using I’m going to say a couple of decades, but I’m not absolutely sure, in terms of how they have conducted experimental programs to understand the interaction of sprinklers and fires. They in fact have reduced it, I don’t mean reduced in the sense of diminish, but reduced it that is, developed it to the point where it’s actually a standard type of a test that they use to establish the commodity classification of some commodity that may not have been tested previously or for whatever reason they have some doubt as to how it’s expected to burn. So the intention of including these here is simply to indicate that this is not an approach without precedent. It is the underlying basis for a whole body of research that Factory Mutual has done over the years. . .” (Deposition Testimony)

“Yeah. What we’re doing in this part is describing how we’re going to model the commodities in terms of surface areas and then we’ll go on in the subsequent page to burning rate per unit areas and then subsequently into flame spread rates, which are the things that are needed to - - that’s the fire growth model. And, you know, which are coming out, as we’re seeing here, as out of data in correlations of data provided by various authors at Factory Mutual.” (Deposition Testimony)

“Sure. Bert did experiments in which he looked at a range of sprinklers and looked at the drop size distributions that were produced and correlated those drop size distributions. This is a report of that work. And you will find that equation 13 is included in Bert Yu’s work as a means of correlating the mean droplet diameter to the flow rate and we are using this correlation. So as the flow rate from the sprinkler diminishes, as more sprinklers are activated, not only does the flow rate change, which we have produced in our modeling input, but also the mean droplet size changes, and that is also reflected through the use of this correlation developed by Bert Yu in Exhibit 42.” (Deposition Testimony)

“I mean the substance of the meaty, you know, the meaty part, the central portion of this, our report, are the modifications that we made to LES to allow the modeling of the effect of sprinkler sprays on the burning of the commodities.”

“I mean the substance of the meaty, you know, the meaty part, the central portion of this, our report, are the modifications that we made to LES to allow the modeling of the effect of sprinkler sprays on the burning of the commodities. We added that, we used that. What we did would be - - is applicable to ceiling sprinkler systems, and as indicated yesterday and again today, that I don’t know how to expand that to in-rack sprinklers.” (Deposition Testimony)

“And so I mean you have the question there of does the source code do what you want it to do, and that’s error checking, which was done. And then there’s the question of given the - - you know, a correct implementation of the model, how well does that model do relative to data. Those comparisons of model to available experimental data are included in the references we cited, which I believe are all exhibits to my deposition. I mean they exist.” (Deposition Testimony)

It seems clear from the excerpts above that Dr. Beyler utilized fire modeling in *McAuslin v. Grinnell* to not only predict the activation times of multiple sprinklers, but also to predict the effect of sprinkler spray discharge on a fire in storage racks.

Interestingly enough, also in February 1999, Dr. Beyler, along with Leonard Y. Cooper, published a paper titled “*Interaction of Sprinklers With Smoke and Heat Vents*”. This paper, also referred to as Paper 21, contains the following excerpt:

“. . . While there have been many attempts to model all or part of the interactions of sprinklers and vents, the issues are more complex than can be dealt with using even the most sophisticated modeling methods available today [1999]. The most clear indication of this is the recent NFPRF research project. While modeling of the fluid mechanical aspects of the problem were quite successful in predicting aspects of sprinkler activation in the first heptane spray fire series, the model was unable to predict the corresponding results in the rack storage tests beyond first sprinkler activation. . .”

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In other words, Dr. Beyler contradicted his expert report from February 1999 and expert testimony in 1999 in both February 1999 and also March 2007.

Can the Fire Dynamics Simulator accurately predict the activation times of multiple sprinklers and the effects of sprinkler spray discharge on a fire in rack storage? Dr. Beyler was correct in both February 1999 and March 2007-the answer to this question was no in both 1999 and in 2007. In other words, the analysis contained expert report produced by Dr. Beyler in *McAuslin v. Grinnell* was “junk science”.

Given the timing of Dr. Beyler's statement regarding the capabilities of fire modeling in his paper written with Leonard Cooper, it is my opinion that Beyler was well aware that his work as an expert in *McAuslin v. Grinnell* was "junk science".

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Editor's Note: Richard Schulte is a 1976 graduate of the fire protection and safety engineering program at the Illinois Institute of Technology (IIT) in Chicago. Schulte worked as the fire protection engineer for the San Jose (California) Fire Department from 1980-1982. Schulte was named as one of ENR's "Top 25 Newsmakers of 2004" by Engineering News-Record for his work on critiquing the National Institute of Standards and Technology (NIST) investigation into the collapse of the World Trade Center towers on 9/11.