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STANDARD ENGINEERING PRACTICE OR JUNK SCIENCE? PART 4

The Executive Summary of a research study by Hughes Associates, Inc. on the concept of the "ganged" operation of smoke/heat vents in single-story buildings protected by standard spray sprinklers titled "*Analysis of the Performance of Ganged Operation of Smoke and Heat Vents with Sprinklers and Draft Curtains*" (dated February 18, 2008) contains the following excerpts:

> "*The gang operation concept involves opening all the* [smoke/heat] *vents within the coverage area of the sprinkler system in which the fire originates one minute after the first sprinkler has operated.*" (Page 11)
>
> "*Comparison of sprinkler operations between vented and unvented cases clearly shows that the operation of sprinklers was not affected by smoke and heat vents or by smoke and heat vents with draft curtains. The time to first sprinkler operation, the number of sprinkler operations and the pattern of operation were not impacted by the venting system.*" (Page 11)
>
> "*The operation of the smoke and heat vent system had no effect on the operation of sprinklers and as such maintained the operational effectiveness of the sprinkler system while improving the conditions within the building in support of fire department operations.*" (Page 12)

A completely opposite point of view is expressed as part of a letter to the editor written by Gunnar Heskestad of FM Global Research published in the 3rd quarter 2002 issue of Fire *Technology*. Heskestad's letter addressing a paper titled "*Interaction of Sprinklers With Smoke and Heat Vents*" authored by Craig L. Beyler and Leonard Y. Cooper which had previously been published in *Fire Technology* contains the following excerpt:

> “*In opposition to these must be added the conclusions of N.E. Gustafsson (“Smoke Ventilation and Sprinklers-A Sprinkler Specialist’s View,” Seminar at Fire Research Station, Borehamwood, Herts, 1992). Gustafsson discovered from the sprinkler operation maps in the report (authors’ ref.24) that, in vented tests, sprinklers near the fire source often were delayed or did not operate altogether. He makes the point very strongly: “It is clearly seen that the effect of ventilation on the operation of sprinklers was strong and detrimental in all cases. It must be appreciated that prevented or substantially delayed operation of any sprinkler close to, or directly above, the fire must be avoided.”* ”

Who’s correct, Gustafsson or Hughes Associates, Inc.?

After studying this issue for 26 years (beginning while I was with the San Jose Fire Department representing the Northern California Fire Prevention Officers at meetings of the Uniform Fire Code ad hoc committee on high-piled storage in 1982), it is my opinion that traditional automatic venting (were the temperature rating of the vent activating mechanism is equal to or higher than the temperature rating of the sprinklers) does not significantly interfere with the operation of sprinklers. At the same time, it is also my opinion that Gustafsson’s opinion regarding venting excerpted above is correct. These viewpoints appear to be diametrically opposed to one another, so an explanation is in order.

The testing on the interaction of sprinklers, vents and draft curtains sponsored by the National Fire Protection Research Foundation (NFPRF) in 1997/1998 concluded that the operation of standard spray sprinklers interferes with the opening of automatic (individually-controlled) roof vents. The large scale tests included in the NFPRF research clearly demonstrated that automatic vents will likely not open in sprinklered buildings and, if vents do open, the operation of the vents will be significantly delayed with no more than a few vents, typically only one vent, opening. Given this, the installation of vents should not adversely affect the operation of standard spray sprinklers. This means that automatic vents are essentially useless in sprinklered buildings.

With regard to the “ganged” operation of roof vents, the impact on the operation of standard spray sprinklers will depend on the time when multiple vents are opened. Based upon the sprinkler activation times recorded in the NFPRF large-scale plastic commodity tests, it should be obvious that the simultaneous opening of thirty vents with a dimension of 8 feet by 4 feet will have an adverse impact on the operation of the sprinkler system if the vents are opened 60 seconds after the sprinkler system water flow is detected. However, if the opening of multiple vents is delayed for 30 minutes or more after the sprinkler water flow alarm is activated, then the “ganged” opening of vents will likely not have much affect upon the operation of the sprinkler system. If the opening of multiple vents is delayed for 30 minutes, the vents are also likely to be pretty much useless.

In summary, the above means that it's my opinion that automatic vents, whether individually operated or "ganged", are a useless fire protection feature in a sprinklered single-story building, at best, and, at worst, the "ganged" operation of vents will have a significant adverse effect on the operation of the sprinkler system (i.e. potential sprinkler system failure).

Both the Hughes study of the "ganged" vent operation concept and my opinions regarding this concept are based upon the NFPRF tests conducted in 1997/1998 so it is worth revisiting the NFPRF tests. The report on these tests is titled "*Sprinkler, Smoke & Heat Vent, Draft Curtain Interaction -- Large Scale Experiments and Model Development*" authored by Kevin B. McGrattan, Anthony Hamins and David Stroup and is dated September 1998. This report is referred to as NISTIR 6196-1. The following are excerpts this report:

> "*This study was the result of a coordinated public-private research effort to gain insight into the interaction of sprinklers, roof vents and draft curtains through fire experiments and numerical modeling. The work was conducted over a period of two years.*" (Page *i*, Executive Summary)

> "*A Technical Advisory Committee consisting of representatives from the sponsoring organizations, the National Institute of Standards and Technology (NIST), and other interested parties planned 39 large scale fire tests that were conducted in the Large Scale Fire Test Facility at Underwriters Laboratories (UL) in Northbrook, Illinois.*" (Page *i*, Executive Summary)

> "*Funding for the large scale tests, although substantial, permitted only five high rack storage commodity fire tests to be conducted. In order to best prepare for these tests and to add to the information available for model development and verification, 34 easily conducted and controlled heptane spray burner tests were also performed.*" (Page *i*, Executive Summary)

> "*In parallel with the large scale fire tests, a program was conducted at NIST to develop a numerical field model, Industrial Fire Simulator (IFS), that incorporated the physical phenomena of the experiments*. . . .*Simulations were first performed for the heptane spray burner tests, where they were shown to be in good quantitative agreement in terms of both predicting sprinkler activation times and near-ceiling gas temperature rise. The sprinkler activation times were predicted to within about 15% of the experiments for the first ring* [of sprinklers]*, 25% for the second* [ring of sprinklers]*. The gas temperatures near the ceiling were predicted to within about 15%. Next, simulations were performed and compared with unsprinklered calorimetry burns of the cartoned plastic commodity. The heat release rates of the growing fires were predicted to within about 20%. Simulations of the 5 cartoned plastic commodity fire tests were then performed.*" (Page *i*, Executive Summary)

"*The overall goal of the testing and modeling program was to investigate the effect of roof vents and draft curtains on the time, number, and location of sprinkler activations; and also the effect of sprinklers and draft curtains on the activation time, number, and discharge rates of roof vents.*" (Page *ii*, Executive Summary)

"*The tests and model simulations showed that when the fire was not ignited directly under a roof vent, venting had no significant effect on the sprinkler activation times, the number of activated sprinklers, the near-ceiling gas temperatures, or the quantity of combustibles consumed.*" (Page *ii*, Executive Summary)

"*The tests and model simulations showed that when the fire was ignited directly under a roof vent, automatic vent activation usually occurred at about the same time as the first sprinkler activation, but the average activation time of the first ring of sprinklers was delayed. The length of the delay depended on the difference in activation times between the vent and the first sprinkler.*" (Page *ii*, Executive Summary)

"*The tests and model simulations showed that when the fire was ignited directly under a roof vent that activated either before or at about the same time as the first sprinkler, the number of sprinkler activations decreased by as much as 50% compared to tests performed with the vent closed.*" (Page *ii*, Executive Summary)

"*The significant cooling effect of sprinkler sprays on the near-ceiling gas flow often prevented the automatic operation of vents. This conclusion is based on thermocouple measurements within the vent cavity, the presence of drips of solder on the fusible links recovered from unopened vents, and several tests where vents remote from the fire and the sprinkler spray activated. In one cartoned plastic commodity experiment, a vent did not open when the fire was ignited directly beneath it. The model simulations could not predict this phenomenon.*" (Page *ii*, Executive Summary)

"*Model simulations showed how the activation times of the the first and second sprinklers had a substantial impact on the overall number of activations in the plastic commodity tests. In the simulation of one test, it was shown that a delay of approximately one minute in the activation of the second sprinkler led to the activation of four times as many sprinklers as in a simulation of a test with no delay.*" (Page *ii*, Executive Summary)

"*There were three objectives of the study. First, there was a need to understand how sprinklers, vents and draft curtains interact. Second, there was a need to develop a numerical model capable of predicting multiple sprinkler activations and the heat release rate from a burning fuel array both before and after sprinkler activation with sufficient accuracy to reliably differentiate between fire scenarios that would produce a large versus small number of sprinkler activations. Third, there was a desire to look beyond current building practices and generate experimental data, along with a numerical modeling capability, that could be used to evaluate proposed changes to codes and standards*." (Page 1)

"*The experiments were divided into three series: an initial set of 22 heptane spray burner tests (Heptane Series I) [1], 5 cartoned plastic commodity tests (Plastic Series) [2], and 12 additional heptane spray burner tests (Heptane Series II) [2]. Many of the test parameters did not change throughout the entire project. The ceiling heights were set at either 7.6 m (25 ft) or 8.2 m (27 ft), the storage height was nominally 6.1 m (20 ft) in the cartoned plastic tests, the sprinkler system consisted of 0.64 in orifice upright sprinklers spaced 3 m (10 ft) apart delivering a 0.34 L/(sm) (0.50 gpm/ft) discharge density, and the 1.2 m by 2.4 m (4 ft by 8 ft) vents used were of the same design, from the same manufacturer, and UL listed. The parameters that did change were fire size, fire/ignition position, mode of vent operation, and draft curtain placement*." (Page 1)

"*A large effort was made to develop numerical techniques that could be used to interpret and potentially supplement the physical experiments. This work is a major undertaking by NIST. The Large Eddy Simulation (LES) Fire Model [3, 4] is a computational fluid dynamics (CFD) code that solves the differential equations that govern the transport of smoke and hot gases from a fire. The model being developed and applied in this project is referred to as the Industrial Fire Simulator (IFS).*" (Page 1)

"*There is no nationally recognized standard for the combined installation of sprinklers and roof vents.*" (Page 3)

"*Even though the practice of installing vents in sprinklered buildings has been debated for decades, and in spite of several projects involving large scale tests and numerical modeling, there is still disagreement about how roof vents and draft curtains affect the time, number and location of sprinkler activations; and how sprinklers and draft curtains affect the activation time, number and discharge rates of roof vents. As a result, there is a great disparity among building codes as to the proper treatment of these fire protection devices*." (Page 3)

"*However, a position paper by N.E. Gustafsson of Industrial Mutual, Helsinki, interprets the results of the Ghent tests completely differently [19]. He argues that for the rapidly growing fires, a significant delay in sprinkler activation was caused by the presence of vents. Even though the delay was about 10 to 20 s in most cases, this allowed the fire to grow from 10.2 MW in the unvented case to as much as 14.2 MW in one of the vented cases. He also cites the inability of the sprinkler system to surround the fire* [pre-wetting] *in the vented cases.*" (Page 4)

"*In January, 1997, a series of 22 heptane spray burner experiments was conducted at the Large Scale Fire Test Facility at Underwriters Laboratories (UL) in Northbrook, Illinois [1]. The objective of the experiments was to characterize the temperature and flow field for fire scenarios with a controlled heat release rate in the presence of sprinklers, draft curtains and a single vent. The results of the experiments were used to evaluate the predictive capability of the IFS model, and also to provide guidance as to the interaction of vents and draft curtains with sprinklers for planning the cartoned plastic commodity fires.*" (Page 6)

"*Preliminary calculations indicated that the first sprinkler in most cases would activate 60 to 70 s after ignition.*" (Page 9)

Note: The actual activation times of the first sprinkler in the five plastic commodity tests, Tests P-1 through P-5, were 76 seconds, 100 seconds, 67 seconds, 93 seconds and 74 seconds. The average operating time of the first sprinkler in these tests was 82.0 seconds.

"*Following the analysis of the results of the first series of heptane spray burner tests, a series of high rack storage cartoned plastic commodity fire experiments was performed at the Large Scale Fire Test facility at UL, the same space that was used for the heptane burner tests described in Sections 3 and 4.*" (Page 33)

"*The Factory Mutual Research Corporation (FMRC) Standard Plastic test commodity, a Cartoned Group A Unexpanded Plastic, served as the fuel for this test series [21]. This commodity has been used extensively for testing since 1971 [29]. The complete fuel package consists of a combination of the cartoned plastic commodity and Class II commodity.*" (Page 33)

"*A commodity storage height of 6 m (20 ft) with a ceiling height of 8.2 m (27 ft) represents one of the most severe arrangements allowable under NFPA 231C without requiring in-rack sprinklers.*" (Page 33)

"*Even though UL listing and FM approval of this sprinkler with this type of storage arrangement are based on a minimum density requirement of 0.6 gpm/ft, the lower density of 0.5 gpm/ftwas used to allow for more challenging, but still controllable, fires and more sprinkler activations.*" (Page 34)

"*When the fire was ignited 3 m (10 ft) from the vent center, the only discernible affect of the vent opening on sprinkler activation was for those sprinklers immediately downstream of the vent. For example, consider the sprinkler activation times for Tests I-4, I-5, I-6 and I-7 (Fig. 6). The two sprinklers to the west of the vent did not activate in Tests I-5 and I-6 when the vent was manually operated at 40 and 90 s. However, in Test I-7 when the vent did not open, both sprinklers activated, and in Test I-4 when the vent was held closed, one of the two sprinklers activated. Consider the peak gas temperatures near the two sprinklers in Tests I-4 and I-7 compared with those in Tests I-5 and I-6 (Figs. 88-91). Compared to the unopened tests, the temperatures were 25C (45F) lower when the vent was opened at 40 s, and 5C (9F) lower when the vent was opened at 90 s.*" (Page 60)

"*In tests where the fire was ignited directly beneath a vent, vent openings prior to the activation of the nearest sprinklers had an effect on the sprinkler activation times. The earlier the vent opening, the more noticeable the effect. . . . This data suggests that the earlier the vent activation, the longer the delay in activation of the first ring of sprinklers.*" (Page 60)

"*Test I-16 was performed with a different fire growth curve, and cannot be directly compared with any other test. In that test, the first sprinkler activated at the same time that the vent opened (1:46), followed by the next two sprinklers at 2:06 and 2:08. One of the four sprinklers nearest the fire did not activate at all. The temperature near this sprinkler was 140C (284F) at the time of the vent opening, but it decreased to about 80C (176F) over the next few minutes. A similar effect was seen in Test I-20 (Fig. 8). Following a vent opening at 1:20, one of the four sprinklers nearest the fire did not open until 3:16. The first sprinkler activation was at 0:54.*" (Pages 60 and 62)

"*During the second series of heptane spray burner tests, two tests were performed with the burner directly under a vent (Fig. 14). In Test II-7, where the vent was held closed, the average activation times of the nearest two sprinklers was 1:14 and the nearest six 1:24. In Test II-3, where the vent opened automatically at 1:15, the average of the nearest two sprinklers was 1:17 and the nearest six 1:32.*" (Page 62)

"*What effect did the vents have on the number of activations? When the fire was ignited directly under a vent (Position A), the number of activations was reduced. Consider Test I-12 versus Tests I-13, I-14, I-15 and I-16. The number of activations was roughly halved due to the opening of the vent directly above the fire. Tests II-3 and II-7 show the number of activations reduced from 18 to 12. However, when the fire was not ignited under a vent, there was either a small decrease or no decrease at all in the number of sprinkler activations. . . .Thus, unless the ignition took place under or very near a vent, there was no evidence in this data set that venting reduced the number of sprinkler activations.*" (Page 62)

"*To see why vents had little effect on the number of sprinkler activations, consider the average peak temperatures in the curtained area in Tests II-1, II-2, II-5, II-6, II-11 and II-12. In Tests II-1 and II-5 where the fire was located at Position D and no vents operated, the average peak temperatures were 129.4C and 130.0C, respectively. In Tests II-2 and II-6 where the fires were at Position D but all the vents were opened at the start of the tests, the average peak temperatures were 128.8C and 127.5C, respectively. Similarly, in Test II-11 where the fire was at Position C and the vent did not operate, the average peak temperature was 123.4C, whereas in Test II-12, where all the vents were opened at the start, the temperature was 119.0C.*" (Page 63)

"*In the cartoned plastic commodity Test P-3, the draft curtain to the north of the ignition point delayed the operation of sprinklers further north and blocked the spray of sprinklers on either side of it. . . . The fire spread to the north side of the main array because the commodity there was unwetted due to a delay in sprinkler activation on the north side of the curtain and blockage of the sprinkler spray from the south side. The results of Test P-3 reinforced evidence provided by two similar tests performed by Factory Mutual [21]. In the FMRC tests, the fires spread underneath the curtains, resulting in the development of a more severe fire, a greater number of sprinkler operations, an atypical sprinkler opening pattern, distorted sprinkler discharge patterns which affected prewetting of commodity, and more smoke production.*" (Page 63)

"*However, it appears from the data below that the sprinkler spray influenced the thermal response characteristics of this particular vent, and it is believed that sprinklers could have a similar influence on similar vent designs.*" (Page 64)

"*In the one unsprinklered test of the study (Test I-11), the vent opened at 4:48. The heptane spray burner was 8.6 m (28 ft) from the vent center. Six other tests were performed with the fire at this distance from the vent when the vent was equipped with a fusible link, and in none of these tests did the vent open. In the unsprinklered Test I-11, the temperature near the vent was about 170C (338F), whereas in Test I-10, with the fire at the same location, the temperature near the vent was about 90C (194F) after the sprinklers had activated around the fire (Figs. 94 and 95). Examination of the near-ceiling temperatures from all the tests indicates that sprinklers of this type have a significant cooling effect, and this will certainly have an effect on thermally-responsive, independently-controlled vents.*" (Page 64)

"*In Plastic Test P-2, the fire was ignited directly under a vent. In the experiment, flames reached the top of the central array at about 65 s and the vent cavity at about 70 s. The first sprinkler activated at 100 s. The vent did not open at any time during the 30 min test even though another vent 6 m (20 ft) to the west of the unopened vent opened at 6:04.*" (Page 64)

"*The cooling of the near-ceiling gases due to the operation of sprinklers will affect the rate of discharge through a vent. . . . An indirect effect of sprinklers on vent performance is that sprinkler sprays entrain smoke and hot gases, cool them, and transport them towards the floor.*" (Page 65)

"*The first series of heptane spray burner tests provided a rich set of data with which to validate the hydrodynamics and sprinkler spray algorithm of the model.*" (Page 81)

"*The most obvious check of the numerical model is how well it predicted sprinkler activation times. Examination of the activation times of nearby sprinklers was also important, especially in cases where several sprinklers were at equal distances from the fire and, in theory, should have activated at the same time.*" (Page 81)

"*In most of the tests, the numerical model predicted the activation of the first four sprinklers surrounding the fire to within about 5 or 10 s. For the next ring of sprinklers, the model underpredicted the activation times by 15 to 30 s, on average*." (Page 81)

"*Experimental burns of the cartoned plastic commodity were performed at UL. Two, three and four tier configurations were tested. The ignition method was the same as the large scale commodity burns. . . .For the period of time before water application, the simulation heat release rate is within 20% of the experiment*." (Page 83)

"*The model in its present form can be used to analyze the cartoned plastic commodity experiments for the first few minutes. For longer times, a better characterization of the burning and extinguishment processes need to be developed and incorporated into the model.*" (Page 86)

"*A drawback of large scale testing is that this type of sensitivity analysis usually requires more tests than can be afforded. If a sufficient number of replicates cannot be performed, then the outcomes of the experiments are often subject to debate as to whether differences in test results were due to changes in test parameters or due to random variations.*" (Page 90)

"*Consider, for example, the different outcomes of Tests P-1 and P-4 in which the only difference in test parameters was that draft curtains were installed for Test P-4, but not for Test P-1. Twenty sprinklers activated in Test P-1, five in Test P-4. . . .The model demonstrated the effect of delaying the second sprinkler. The difference in outcomes of Tests P-1 and P-4 of the cartoned plastic test series was not due to the draft curtains, but rather to the sprinkler delay in Test P-1.*" (Page 90)

"*Less clear, however, is why so many sprinklers activated in Test P-2. The simulation of Test P-1 with no manipulation of the sprinkler activation times produced only 4 activations.*" (Page 93)

Note: As indicated in the previous excerpt, 20 sprinklers actually activated in Test P-1.

"*What was the difference between the simulation of Test P-1 and Test P-2? Only the presence of a 1.2 m by 2.4 m by 0.3 m deep (4 ft by 8 ft by 1 ft deep) cavity in the ceiling formed by the vent in Test P-2. This cavity led to a 14 s delay in the first sprinkler activation in the simulation of Test P-2. The significance of this delay is shown in Fig. 56, in which the heat release rate histories for the simulations of the two versions of Test P-2 are plotted on the same graph as the heat release rate curves for the 2 by 2 by 4 tier cartoned plastic calorimetry experiment and the simulation of Test P-1 with no second sprinkler delay. The growth of the fire during the time period 60 to 100 s after ignition was very fast, and it was demonstrated that even a 14 s delay in sprinkler activation could significantly alter the number of sprinkler activations.*" (Page 93)

"*Clearly, the draft curtains had an effect on the performance of the sprinkler system. The draft curtains delayed the opening of the two sprinklers directly north of the first two sprinklers to activate. Less obvious, the draft curtains changed the near-ceiling flow pattern of both the sprinkler spray and the fire plume. Regardless of the submodel used to simulate the burning of the cartoned plastic commodity, the calculation showed that less water reached the north side of the central array when the draft curtains were installed.*" (Page 95)

"*Hinkley points out in the SFPE Handbook [50] that for temperature rises less than about 75C (167F) there is a serious decrease in the mass flow rate through a vent.*" (Page 97)

"*The numerical model was used to estimate the mass flow rates through the vent nearest the fire. Figure 61 presents the rates of three typical calculations compared to the rate predicted by Eq. 47. The mass flow rates for Test I-10 and P-5 are relatively low compared with the theoretical maximum because the near-ceiling gas temperatures are greatly reduced by the sprinklers. The flow rate for Test II-2 is much higher because the ceiling layer temperatures are significantly higher for the 10 MW fire. The simulation of Test II-2 was rerun with the draft curtains removed. The computed mass flow from the numerical simulation dropped into a range of 1.5 kg/s to 2.0 kg/s. In terms of Eq. (47), this reduction in mass flow rate is due to the decrease in the smoke layer depth, d, but another contribution is the change in ceiling jet dynamics caused by the draft curtain removal. This latter effect is not accounted for in Eq. (47), but it is in the numerical model.*" (Page 100)

"*Model simulations showed how the activation times of the the first and second sprinklers had a substantial impact on the overall number of activations in the plastic commodity tests. In the simulation of one test, it was shown that a delay of approximately one minute in the activation of the second sprinkler led to the activation of four times as many sprinklers as in a simulation of a test with no delay.*" (Page 102)

"*The Industrial Fire Simulator (IFS) developed in conjunction with the test program was shown to be in good quantitative agreement with the heptane spray burner tests in terms of both predicting sprinkler activation times and near-ceiling gas temperatures. The sprinkler activation times were predicted to within about 15% of the experiments for the first ring, 25% for the second* [ring]*. The gas temperatures near the ceiling were predicted to within about 15%.*" (Page 102)

Discussion

Do open roof vents affect the activation time of standard spray sprinklers? With a little study of the excerpts from NIST 6196-1 above, the answer to this question becomes rather obvious. The answer is yes, open vents can cause a delay in the activation of sprinklers. That's actually just a common sense conclusion.

More importantly, is the delay in sprinkler activation caused by open vents significant? Again, based upon the information from excerpts above, it becomes obvious that Gustafsson's observations on the Ghent tests have been confirmed in the NFPRF research. Even small delays in the operation of sprinklers caused by open vents can have a significant adverse effect on sprinkler system operation (i.e. Test P-1 vs. Test P-4; Test P-2).

If open vents cause a significant delay in sprinkler activation and this delay can adversely affect the capability of sprinkler systems to control a fire, how is it that sprinkler system failures are seldom observed in buildings which are provided with (individually-operated) automatic roof vents? There are many answers to that question, however, Test P-4 and P-5 in the NFPRF tests are good illustrations of one of the answers to that question.

In Test P-4, only 5 sprinklers operated, while in Test P-5 only 7 sprinklers operated, despite the fact that the density utilized in these tests was 0.50 gpm/SF, rather than 0.60 gpm/SF as required by the sprinkler installation standard. Given the uncertainties associated with the testing used to determine the sprinkler system design criteria for rack storage, the sprinkler system design criteria is necessarily conservative. (Another reason is that the density of the first sprinklers to activate typically far exceeds the minimum design density. Of course, a third reason is that individually-activated vents typically don't open in sprinklered buildings. There are other reasons too, but due to space limitations, further discussion of this will have to wait for another column.)

The fact that the sprinkler system design criteria are conservative means that sprinkler systems are typically over-designed for the hazard being protected. This intentional over-design (factor of safety) compensates for adversities a system might face when a fire occurs perhaps 30, 40 or 50 years after the system installation is completed, including sprinkler "skipping", sprinkler orifice obstructions by gravel, or obstruction of flue spaces in rack storage.

Simply because the hydraulic design criteria for sprinkler systems protecting "high challenge" storage arrays is conservative and intended to address the operation of systems under adverse conditions, should venting which potentially adversely affects sprinkler system operation be permitted without altering the system design criteria? Apparently, the vent manufacturers and Hughes Associates, Inc. think that the answer to that question is yes, but, according to testimony by William Koffel at the ICC code development hearings in Palm Springs, California in February 2008, the NFPA 13 committee voted to specifically indicate that the design criteria for high-piled storage only applies to buildings without automatic vents.

One last question which needs to be dealt with regarding the Hughes' study on the concept of "ganged" roof vent operation is whether the Fire Dynamics Simulator (FDS) can accurately predict the activation times of multiple sprinklers. To some extent, this issue is addressed in NISTIR 6196-1. As indicated in the excerpts above, "*the sprinkler activation times were predicted to within about 15% of the* [heptane spray] *experiments for the first ring, 25% for the second* [ring] *"* and *"the simulation of Test P-1 with no manipulation of the sprinkler activation times produced only 4 activations".* Twenty sprinklers actually activated in Test P-1.

While the Industrial Fire Simulator predicted the sprinkler activation times in the heptane spray tests reasonably well, attempts to utilize the Industrial Fire Simulator (now referred to as the FDS) to predict multiple sprinkler activation times in the full-scale tests with the Group A plastic commodity (Tests P-1 through P-5) was not discussed at length in the report. The reason for this becomes obvious when the activation times in the full-scale tests are reviewed. The activation times of first four sprinklers (and subsequent sprinklers) are quite different from the sprinkler activation times in the heptane spray tests. (See Table 1.) In other words, fires which occur in rack storage in the real world are not as predictable as the heptane spray fire experiments.

The Hughes' study evaluated the FDS's capability to predict the activation times of sprinklers based upon the tests which utilized heptane spray as the fire source. Where differences of a few seconds in sprinkler activating times determines whether only 5 sprinklers activate (Test P-4) or whether 20 sprinklers activate (Test P-1), is predicting sprinkler activation times to within 15 percent or 25 percent precise enough to draw any conclusions regarding the effect of the "ganged" opening of vents on the capabilities of a sprinkler system to control a fire? The answer to that question is obvious.

Table 1. Comparison of Sprinkler Activating Times-NFPRF Full-Scale Tests vs. Hughes Associates, Inc. Model Runs

	Total # of Activations	1st A.S. Activations	1st Four A.S. Activations	1st Five A.S. Activations	1st Six A.S. Activations	1st Seven A.S. Activations
Test P-1	20 A.S.	76 sec.	303 sec.	511 sec.	515 sec.	562 sec.
Test P-2	23+ A.S.	100 sec.	121 sec.	150 sec.	152 sec.	154 sec.
Test P-3	19+ A.S.	67 sec.	123 sec.	131 sec.	242 sec.	307 sec.
Test P-4	5 A.S.	93 sec.	199 sec.	200 sec.	-----	-----
Test P-5	7 A.S.	74 sec.	147 sec.	201 sec.	213 sec.	304 sec.
Average		**82.0 sec.**	**178.6 sec.**	**238.6 sec.**	**280.5 sec.**	**331.8 sec.**
Range		**67-100 sec.**	**121-303 sec.**	**131-511 sec.**	**152-515 sec.**	**154-562 sec.**

Note: The "+" sign indicates that sprinklers immediately adjacent to the edge of the "mock-up" operated and that it is possible that additional sprinklers may have operated had the "mock-up" extended further.

	Total # of Activations	1st A.S. Activations	1st Four A.S. Activations	1st Five A.S. Activations	1st Six A.S. Activations	1st Seven A.S. Activations
Run #1	5 A.S.	69 sec.	74 sec.	88 sec.	-----	-----
Run #2	6 A.S.	70 sec.	74 sec.	92 sec.	92 sec.	-----
Run #3	6 A.S.	70 sec.	74 sec.	86 sec.	90 sec.	-----
Run #4	19 A.S.	71 sec.	74 sec.	82 sec.	84 sec.	96 sec.
Run #5	18 A.S.	71 sec.	74 sec.	83 sec.	84 sec.	97 sec.
Run #6	20 A.S.	71 sec.	74 sec.	83 sec.	84 sec.	96 sec.
Run #7	21 A.S.	70 sec.	74 sec.	83 sec.	84 sec.	98 sec.
Run #8	19 A.S.	70 sec.	74 sec.	82 sec.	82 sec.	99 sec.
Run #9	20 A.S.	70 sec.	73 sec.	83 sec.	84 sec.	99 sec.
Run #10	20 A.S.	64 sec.	75 sec.	90 sec.	92 sec.	92 sec.
Run #11	18 A.S.	70 sec.	74 sec.	84 sec.	84 sec.	98 sec.
Run #12	17 A.S.	69 sec.	74 sec.	85 sec.	86 sec.	98 sec.
Run #13	19 A.S.	68 sec.	79 sec.	79 sec.	85 sec.	92 sec.
Run #14	22 A.S.	63 sec.	76 sec.	87 sec.	93 sec.	93 sec.
Run #15	20 A.S.	65 sec.	81 sec.	84 sec.	90 sec.	97 sec.
Run #16	21 A.S.	65 sec.	79 sec.	85 sec.	86 sec.	92 sec.
Average		**68.5 sec.**	**75.2 sec.**	**84.8 sec.**	**86.7 sec.**	**95.9 sec.**
Range		**64-71 sec.**	**73-81 sec.**	**79-92 sec.**	**82-93 sec.**	**92-99 sec.**

Conclusion

To paraphrase Abraham Lincoln, "*you can fool some of the people some of the time, but you can't fool all of the people all of the time*". After reviewing NISTIR 6196-1 in detail and reviewing the sprinkler activation times predicted in the Hughes study to actual sprinkler activation times determined in NFPRF Tests P-1 through P-5, it is very apparent that something is amiss with the Hughes' study. Is the Hughes' study an attempt to fool us into thinking that the "ganged" roof vent concept is actually a viable concept or did the "fire scientists" at Hughes simply fool themselves into thinking that the predictions of the FDS are infallible? That's a question worth asking. My guess is that it's the latter.

To conclude this series of columns on the Hughes' study of the "ganged" operation of vents concept, the following is an e-mail note dated June 10, 2008 from Dr. Shyam Sunder, the director of the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST), regarding the issue of whether or not the FDS is capable of accurately predicting the activation times of multiple sprinklers:

> "*We (NIST) do a considerable amount of validation work, as evidenced by such documents as NISTIR 6196-1, the WTC reports, and NUREG 1824 -- the very extensive Verification and Validation study we participated in with the US NRC. We do validation work as a routine part of improving our models. However, model validation is technically the responsibility of the end user.*
>
> *For example, the US NRC performed the model evaluation study of not just FDS and CFAST, but 5 fires models that are used throughout the nuclear industry. We participated in the study, as did the other developers, but at the end of the day the US NRC decided whether or not the models were sufficiently accurate for their own applications. They, and EPRI (who also participated), are the "end users."*
>
> [**Note:** Page 3-2 of Volume 7 (Fire Dynamics Simulator) of "*Verification & Validation of Selected Fire Models for Nuclear Power Plant Applications*" (NUREG-1824) dated May 2007 indicates that the RTI/C-Factor Algorithm (estimating sprinkler activation) in Version 4 of the FDS has not been adequately "verified and validated" for use on work regulated by the Nuclear Regulatory Commission (NRC). The Hughes' study utilizes Version 4 of the FDS.]
>
> *Craig Beyler* [of Hughes Associates, Inc.]*, in his study of roof vents, references NIST validation work, but it is he and his sponsors who have decided that the model is appropriate for their application, and that is an argument that he, and any other users of FDS, must make.*

Organizations like the US NRC, NFPA Research Foundation, and the SFPE have all cited NIST validation reports, but also have done validation work on their own to determine if FDS and CFAST are appropriate for various applications of interest. They decide, not us, whether or not the model is appropriate for their application."

* * * * *