SPRINKLERS & FIRE VENTING – CONTROVERSY RESOLVED

SUSAN OLEG [1]
PANAITESCU VALERIU [2]

[1] *Eng, PhD Std at University "Politehnica" of Bucharest, Romania and at Technical University of Chişinău, Moldova*
[2] *Prof., Power Engineering Department, University "Politehnica" of Bucharest, Romania*

Resume: The studies of smoke and heat venting used in conjunction with sprinklers show clearly that venting does not have a negative effect on sprinkler performance. Successful performance of sprinklers does not rely upon reduced oxygen concentrations. Venting has been shown to have no effect on the activation times of early sprinklers and does not affect the total number of sprinklers activated. If the fire is directly beneath a vent, activations of the first sprinklers may be delayed slightly, but there is no evidence that this will have a significant impact on sprinkler performance.

Keywords: fire, smoke, sprinklers, venting, heat, curtains

1. INTRODUCTION

The practice of providing automatic smoke and heat (roof) vents in industrial and storage buildings protected by a sprinkler system has been the subject of intense debate in the fire protection field for more than 30 years. The principal reason for the debate is centered on the concern that roof vents, which open automatically, will have an adverse impact on the ability of sprinklers to control a fire. Despite this concern, provisions that require roof vents in sprinklered storage buildings were included in the Uniform Fire Code (UFC) in the 1980s. When the three regional code groups merged and developed a single model building code and fire code, the provisions for roof vents in sprinklered buildings contained in the UFC (and also the Standard Fire Prevention Code) were included in the new codes, the International Building Code (IBC) and the International Fire Code (IFC).

Just prior to the publication of the first edition of the International Codes, new research on the use of roof vents and draft curtains in sprinklered buildings, sponsored by the National Fire Protection Research Foundation (NFPRF), was conducted at Underwriters Laboratories (UL). The results were published in September 1998. As a result, code changes to delete the requirements for roof vents in sprinklered buildings have been introduced into the code change process at least four times since 1999.

The American Architectural Metals Association (AAMA) announced a research project on the interaction of sprinklers and roof vents in the summer of 2006, apparently in response to the CTC's (International Code Council's Code Technology Committee) discussions of the sprinkler/vent issue.

The announcement of the new research project on roof vent/sprinkler interaction appeared in the summer 2006 issue of the AAMA newsletter, AAMAnet.work. This announcement included the following excerpt:

"Smoke and Heat Vents (S&HV) on building roofs not only improve fire protection, but also improve the level of safety for firefighters. Prompt venting has been proven to reduce dangerous heat, vision-obscuring smoke, and toxic or potentially explosive products of combustion. And, by preventing heat from mushrooming over the fire

area and heating other materials to the point of ignition, fire venting has a marked effect on reducing the lateral spread of fire."

Do automatic roof vents actually perform as indicated in the AAMA's announcement of their new research project? The results of the NFPRF research on the interaction of sprinklers, roof vents and draft curtains conducted in 1997-98 seem to challenge the AAMA's assertions. The following excerpts are from a 1998 report titled, "Sprinkler, Smoke and Heat Vent, Draft Curtain Interaction: Large Scale Experiments and Model Development" by Kevin B. McGrattan, Anthony Hamins and David Stroup. To download the full report, visit www.nist.gov and reference NISTIR 6196-1 [1].
"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." (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." (Executive Summary)

"The tests and model simulations showed that when draft curtains were installed, up to twice as many sprinklers activated compared to tests performed without curtains." (Executive Summary)

"In one rack storage test where the ignition of the fire took place near a draft curtain and the fuel array extended underneath the curtain, disruption of the sprinkler spray and delay in sprinkler operation caused by the draft curtain led to a fire that consumed more commodity compared to the other tests where the fires were ignited away from the draft curtains. This result was demonstrated by the model simulation, as well." (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." (Executive Summary)

"Model simulations showed how the activation times of 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 1 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. It had been suggested that these different outcomes were due to the presence of draft curtains in the tests with the sprinkler delay, but the simulations showed that the curtains had no effect because they were over 9 m (30 ft.) away from the ignition point." (Executive Summary)

"The objective of the project 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." (Introduction)

"In all, 39 tests were specified by the committee. All 39 tests were conducted in the Large Scale Fire Test Facility at Underwriters Laboratories (UL) in Northbrook, Illinois." (Introduction)

However, there are ongoing controversies regarding the use of these two well established fire protection technologies together. The goal of this paper is to assess our current state of knowledge regarding the interactions of sprinklers and smoke/heat vents (Fig. 1) through a review of the experimental research that has been performed.

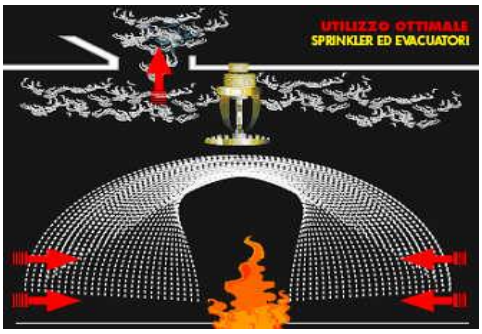

Fig. 1. Interactions of sprinklers and smoke/heat vents

2. EVALUATING CLAIMS IN FAVOR OF SMOKE AND HEAT VENTS IN SPRINKLERED FACILITIES

It is claimed in the literature that, when used with sprinklers, vents lead to enhanced fire safety over that attained by sprinklers alone in the following ways:

Positive Claim: Smoke and heat vents improve visibility: The benefit of *improved visibility* is a result of the fundamental action of the venting. Smoke that is vented from the building does not contribute to the reduction of visibility within the building.

Because the buoyancy and smoke concentration is greatest in the curtained area of the fire, smoke and heat vents provided within the draft curtain area of fire origin will most effectively vent the smoke and heat of the fire, hence improving visibility with the building. The enhanced visibility benefits escaping occupants of the building and firefighters who need to locate the fire to complete fire extinguishment.

Positive Claim: Smoke and Heat vents reduce temperatures and hazardous gas concentration: The above explanation for *improved visibility*, i. e., removal through vents of the smoke, and replacement with cool, uncontaminated air, also explains how vents generally lead to reduced temperatures and reduced toxic and combustible gas concentrations within the space. The reduction in temperatures and hazardous gas concentrations benefit escaping occupants of the building and firefighters who need to locate the fire to complete fire extinguishment.

Positive Claim: Smoke and heat vents contain damage to the curtained space: The combined action of draft curtains and smoke vents not only allows for the removal of smoke and heat from the building but also acts to limit the spread of heat and smoke outside the curtained area. The smoke and heat are trapped within the curtained area and are directly vented to the outside. In the absence of the curtains and vents, the smoke would spread throughout the facility, causing additional damage to the building contents.

Positive Claim: Smoke and heat vents assist the fire department identify the location of the fire within the facility and reduce the need for hazardous manual roof venting: The opening of the vents will lead to a flow of smoke through the roof of the facility, but only within the bounds of this curtained compartment of fire origin. Thus, the location of the fire *inside* the facility is revealed to the fire department, from *outside* the facility. In the absence of the curtain/vent system, the smoke would spread through the volume of the entire facility and flow to the outside through all randomly spaced leaks in the upper building envelope. These smoke leaks would not reveal the fire's location, requiring the fire department to search throughout the building to find the fire

before completing the extinguishment of the fire. In addition, deployment of a curtain/vent system provides additional assistance in locating the fire once the fire department is *inside* the facility by virtue of the above-discussed benefit, *improved visibility.*

The second of the fire department benefits are related to manual venting, i.e., the common firefighter practice of venting the fire by manually cutting holes in the roof of a facility. This is well known to be a particularly dangerous activity. With ceiling vents in place and available for firefighter use, the need for manual venting may be eliminated altogether. If additional venting is required, the practice is accomplished more quickly and safely than it would be possible in the absence of automatic roof vents, which can be easily and quickly operated manually.

Positive Claim: Smoke and heat vents provide protection even if the sprinklers do not work: It is generally recognized that sprinkler systems are operational and effective in 90 to 95 percent of the fires, depending on the statistical source used and the definitions and qualifications applied. If the sprinkler system is not operational or effective, then manual firefighting needs to be relied upon for fire control. The smoke and heat vents will be effective in limiting damage to the building, providing firefighter access to the fire, and aiding in the escape of building occupants. In short, the benefits of heat and smoke vents can be realized in the absence of an effective sprinkler system.

Positive Claim: Smoke and heat vents prevent an excessive number of sprinklers from operating: By limiting the spread of heat and smoke to the curtained area of fire origin, the operation of sprinklers remote from the fire is prevented. While sprinkler systems are designed to perform adequately without the benefit of smoke vents and draft curtains, in marginal fire control situations, the prevention of the activation of remote sprinklers can allow successful fire control by the sprinklers where control might otherwise not be achieved.

For purposes of evaluation, the claims can be simplified to the following four claims:

1. Smoke and heat vents limit the distribution of products of combustion in the facility;
2. Smoke and heat vents decrease the number of discharged sprinklers;
3. Smoke and heat vents assist the fire department identify of the location of the fire within the facility and reduce the need for hazardous manual roof venting; and
4. Smoke and heat vents limit the distribution of products of combustion in the facility if the sprinklers are inoperative.

3. EVALUATING CLAIMS AGAINST THE USE OF SMOKE AND HEAT VENTS IN SPRINKLERED FACILITIES

When used with sprinklers, it is claimed in the literature that vents lead to reduced fire safety over that attained by sprinklers alone in the following ways:

Negative Claim: Smoke and heat vents will cause enhanced burning rates: By definition, successful venting requires that the smoke that flows through the vents and out of the facility be continuously replaced *via* low-level supply-air vents. Therefore, with successful venting, virtually all the gases entrained into the combustion zone of the threatening fire will be fresh air, and the burning rate will be maintained at "free-burn" levels. In contrast, without roof vents or other natural or forced fresh air ventilation, a threatening fire in a facility will continuously consume the available oxygen in the entire space. The reduction in burning rate caused by the

reduced oxygen concentration will reduce the burning rate of the fire. Thus, relative to the closed compartment fire scenario, the use of smoke and heat vents will lead to enhanced burning rates.

Negative Claim: Smoke and heat vents will delay sprinkler activation: The venting of heat and smoke through roof vents will result in lower gas temperatures at ceiling level and will cause the early sprinkler activations to be delayed. This will result in a larger fire at the time of the early sprinkler activations, which could cause the fire to not be controlled by the sprinkler system.

Negative Claim: Smoke and heat vents increase the number of activated sprinklers: The claim that vents cause an increased number of discharged sprinklers, in a way that is deleterious to success of sprinkler control of the fire, can be explained in two different ways, both of which are invoked in the position papers.

The first explanation is that the delay in the activation of the first sprinklers will cause the fire size at first sprinkler activation to be larger. This in turn causes more sprinklers to be activated during fire control. In effect, fire control may not be realized and the number of sprinklers activated will exceed the design area.

The second explanation is that the confinement of heat and smoke by the draft curtains will increase the temperatures at remote sprinklers within the curtain area, and this will increase the number of sprinklers activated.

Negative Claim: Smoke and heat vent flow rates are insufficient to realize any benefit: The claim here is that the action of discharging sprinklers is so effective in cooling the smoke that the remaining forces of buoyancy will not be strong enough to successfully drive a significant amount of smoke out of the roof vents. As such, the benefits posed for smoke and heat venting will not be realized.

Negative Claim: Smoke and heat vents are not cost effective: This claim is that smoke and heat vents are not sufficiently effective to justify the additional costs. It is sometimes suggested that the money would be better spent on other fire protection measures.

The list is reproduced here for reference.

1. Smoke and heat vents will delay sprinkler activation;
2. Smoke and heat vents increase the number of operated sprinklers;
3. Smoke and heat vent flow rates are insufficient to realize any benefit;
4. Smoke and heat vents are not cost effective.

4. DISCUSSION

Based on the NFPRF research published in 1998, it appears that many of the AAMA's "proven" assertions of "improved fire protection" provided by roof vents and draft curtains simply do not occur in buildings protected by standard (control mode) sprinklers. While the NFPRF research did not completely resolve the long-standing debate over whether automatic vents have a detrimental impact on the operation of sprinklers, the research clearly demonstrated that the operation of sprinklers has a significant adverse impact on the operation and effectiveness of smoke/heat vents and that draft curtains can have a significant adverse impact on the operation of a sprinkler system.

If you compare the requirements for roof vents and draft curtains contained in the Uniform Building and Fire Codes with the provisions for vents and draft curtains in the International Codes, you will note one striking

difference -- the requirements for draft curtains have essentially been removed in the International Codes. It appears that the reason why the requirements for draft curtains was eliminated in the IBC/IFC is the NFPRF (and also 1994 FMRC) research findings regarding draft curtains and the operation of sprinkler systems. What may not be clear, however, is that the elimination of the requirements for draft curtains has a negative impact on the operation of smoke/heat vents.

The combined effect of not providing draft curtains and the activation of sprinklers means that automatic smoke/heat vents will provide little, if any, automatic venting in a fire where the sprinkler system is operational. In other words, automatic vents will likely have to be opened manually in order for venting to occur and that the venting which will be provided by the manually opened vents will be significantly impaired by both the lack of the draft curtains and also by the cooling effects of operating sprinklers. Of course, once the sprinklers begin to gain control of the fire, the smoke will lose its buoyancy, and roof vents will be of little use. Given the above, it would appear that the only case where providing smoke/heat vents in a building is actually beneficial is where the sprinkler system fails to discharge water due to a closed water supply valve, broken supply piping or a pump which doesn't start. In this case, smoke/heat vents may indeed prove effective in venting smoke and heat from the building, but will smoke/heat vents installed per the requirements contained the IBC and IFC be adequate to reduce the ceiling temperatures sufficiently to prevent the collapse of a non-rated roof structure? (A roof deck supported on non-rated steel bar joists or steel trusses only provides a nominal fire resistance rating.) Given that the roof vent-to-floor area ratios presently required in the IBC are the same as the ratios contained in the 1970's versions of the UBC, it certainly seems reasonable to at least question whether or not firefighters can safely operate in buildings provided with smoke/heat vents per the IBC when there is a complete failure of the sprinkler system.

5. CONCLUSIONS

The studies of smoke and heat venting used in conjunction with sprinklers show clearly that venting does not have a negative effect on sprinkler performance. Successful performance of sprinklers does not rely upon reduced oxygen concentrations. Venting has been shown to have no effect on the activation times of early sprinklers and does not affect the total number of sprinklers activated. If the fire is directly beneath a vent, activations of the first sprinklers may be delayed slightly, but there is no evidence that this will have a significant impact on sprinkler performance.

Experimental studies have shown that venting does limit the spread of products of combustion by releasing them from the building within the curtained compartment of fire origin. This improves visibility for building occupants and firefighters who need to find the seat of the fire to complete fire extinguishment. Limiting the spread of smoke and heat also reduces smoke and heat damage to the building. In the event that sprinklers do not operate, venting remains a valuable aid to manual control of the fire.

The experimental studies have shown that early vent activation has no detrimental effects on sprinkler performance and have also shown that current design practices are likely to limit the number of vents operated to one and vents may in fact not operate at all in very successful sprinkler operations. Design practices should move to methods which assure early operation of vents, and vent operation should be ganged so that the benefit of roof vents is fully realized. Sprinkler design with vents and draft curtains needs to take full account of draft curtains as obstructions. Curtains should be placed in aisles rather than over storage.

REFERENCE:

[1]. McGrattan, K.B. Hamins, A., and Stroup, D.W. (1998), "*International Fire Sprinkler; Smoke and Heat; Draft Curtain Fire Test Project - Large Scale Experiments and Model Development*", Technical Report prepared by the National Institute of Standards and Technology for the National Fire Protection Research Foundation, Quincy MA, NISTIR 6196-1, September 1998.

[2]. Miller, E.E., Waterman, T.E., and Ward, EJ. (1997), "*Automatic Heat and Smoke Venting in Sprinklered Buildings*" Addendum to Section 7/Chapter 7, *Fire Protection Handbook*, Eighteenth Edition, Cote, A.E., Ed., National Fire Protection Association, Quincy MA, 1997.

[3]. NFPA 204 (1975), "*Guide for Smoke and Heat Venting*" First Edition, National Fire Protection Association, Quincy, MA, 1975.

[4] Battrick, P. (1986), "*Venting Plus Sprinklers-The Case Against*," *Fire International*, October/November 1986.

[5] Hinkley, P.L. (1989), "*The Effect of Smoke Venting on the Operation of Sprinklers Subsequent to the First*" *Fire Safety Journal*, 14, 1989.

[6] Morgan, H.P. (1998a), "*Sprinklers and Smoke Exhaust Ventilation: When They Can Be Used Together?"*, To be Presented in Fire Asia '98, Hong Kong, China.