SCHULTE & ASSOCIATES

Building Code Consultants
880D Forest Avenue
Evanston, IL 60202
fpeschulte@aol.com
504/220-7475

AN ANALYSIS
HUGHES ASSOCIATES INC.'S PAPER 21
INTERACTION OF SPRINKLERS WITH SMOKE AND HEAT VENTS
CRAIG BEYLER/LEONARD COOPER

The Hughes Associates, Inc.'s website includes a number of papers on various fire protection and fire safety related topics. Paper 21 is titled "**Interaction of Sprinklers with Smoke and Heat Vents**" written by Craig L. Beyler and Leonard Y. Cooper. This paper is dated February 1999 and appears to be a response to the publication of a report on research on this subject sponsored by the National Fire Protection Research Foundation (NFPRF) conducted at Underwriters Laboratories (UL) in 1997 and 1998.

The report on the NFPRF research project at UL is titled "**Sprinkler, Smoke & Heat Vent, Draft Curtain Interaction -- Large Scale Experiments and Model Development**" written by Kevin B. McGrattan, Anthony Hamins and David Stroup and is dated September 1998. The report is published by the National Institute of Standards and Technology (NIST) and can be downloaded from the NIST website. (The report is referred to as NISTIR 6196-1.)

The following is an analysis of various passages from the Beyler/Cooper paper.

Executive Summary, Page 1

> "*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 that assure early operation of vents, and vent operation should be ganged so that the benefit of roof vents is fully realized.*"

Commentary:

It should be noted that Beyler and Cooper specifically state that roof vents may not operate in sprinklered buildings (where the sprinkler system is operational) when the roof vent installation complies with current design practices, such as those reflected in section 910 of the International Building Code (IBC) and section 910 of the International Fire Code. This statement by Beyler and Cooper is based upon the research sponsored by the NFPRF.

It should further be noted that Beyler and Cooper state that, if roof vents operate in a building protected by sprinklers, the number of vents which will operate will be limited to a single vent.

Given the statement that the number of roof vents which will operate will be limited to a maximum of one (due to the operation of the sprinkler system), it can be concluded that automatic roof vents (as presently required to be designed by the IBC/IFC) will only be useful in building where the sprinkler system fails to discharge water (i.e. due to a closed water supply valve) or where the sprinkler system is completely overwhelmed by the fire (i.e due to a deficient design or broken system supply piping).

Page 2

> "***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.*"

Commentary:

Beyler and Cooper stated in the Executive Summary of their paper that roof vents may not operate or that the number of roof vents which operate may be limited to a single vent. Given this, the statement that smoke/heat vents improve visibility within the building due to venting of combustion products is only true in the case where the sprinkler system fails to discharge water or where the sprinkler system is completely overwhelmed. In the case where the sprinkler system functions properly, the roof vents will have little or no effect on the visibility within the building due to the fact that, at most, only one vent will operate. Hence, the statement above is misleading because the statement made is a "blanket statement" which does not address the most probable case where either only one or no vents operate.

Page 3

> "*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.*"

Commentary:

This comment addresses the use of draft curtains. A review of the requirements for roof vents contained in the IBC/IFC indicates that draft curtains are only required to be provided in industrial and storage buildings which do not contain high-piled storage. Further, the provisions for draft curtains contained in the IBC/IFC permit draft curtains to enclose a maximum area of 50,000 SF. Given the IBC/IFC provisions for draft curtains (or more accurately, lack of draft curtains), it can be concluded that the statement above does not reflect the requirements for roof vents/draft curtains contained in the IBC/IFC.

Given the fact that the IBC/IFC does not require draft curtains and the fact that the number of roof vents which will operate will be limited to a maximum of one in the most probable scenario where sprinkler protection successfully controls the fire, the combination of roof vents and draft curtains will have little, if any, impact on the visibility of both the building occupants and firefighters in most cases.

Page 3

> *"**Positive Claim: Smoke and heat vents reduce temperatures and hazardous gas concentrations:** 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.*"

Commentary:

See the previous comments. If vents do not operate as indicated by Beyler and Cooper in the Executive Summary, then vents will have no impact on either the temperatures within the building or the concentrations of combustion products in the building. Again, the statement excerpted above is misleading because the statement does not indicate the scenarios to which the statement is applicable.

Page 3

> *"**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.*"

Commentary:

The statement above assumes that draft curtains will be provided. As previously indicated, the IBC/IFC does not require draft curtains to be provided in buildings which contain high-piled storage. Industrial and storage buildings which do not contain high-piled storage are still required to be provided with draft curtains, however, both the IBC/IFC allow the curtained area to be a maximum of 50,000 SF. Hence, the statement that draft curtains will contain smoke to the curtained area is incorrect since, in many cases where roof vents are required, draft curtains are not required.

The statement "*in absence of curtains and vents, the smoke would spread throughout the facility, causing additional damage to the building contents*" reflects a scenario which could potentially occur if the requirements for roof vents and draft curtains contained in the IBC/IFC are utilized in the design of a roof vent/draft curtain system.

Page 3

> *"**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. . . .*"

Commentary:

As previously noted, the IBC/IFC does not require that draft curtains be provided in many cases where roof vents are required. Given this, the statement indicating the smoke will be confined to the curtained area doesn't reflect the provisions for roof vents/draft curtains contained in the IBC/IFC.

In addition, also as previously noted, Beyler and Cooper have indicated that the activation of sprinklers will limit the number of vents which operate to either one or none if the sprinkler system is reasonably successful in controlling the fire. If no roof vents operate due to the activation of sprinklers, then smoke flow through a vent will not occur. Hence, the claim that roof vents will assist the fire department in locating the fire is misleading because this statement implies that this benefit will occur under all conditions, rather than the limited conditions of where a vent actually operates.

Pages 3 and 4

> *"**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.*"

Commentary:

The fire which occurred in the bulk retail store in Tempe, Arizona on March 19, 1998 at least partially refutes the statement that roof vents/draft curtains will provide benefits in the event that the sprinkler system is ineffective. In this fire, roof vents failed to operate even though the sprinkler system was ineffective in controlling the fire.

It also appears that one of the causes of the ineffectiveness of the sprinkler system was that a draft curtain located in the aisle between two racks prevented sprinklers on the opposite side of the draft curtain from operating and prewetting the combustibles on the opposite side of the draft curtain. This allowed the fire to spread between racks separated by an aisle which was 10 feet in width.

Based upon the results of the fire in the bulk retail store in Tempe, it appears that the only time that roof vents/draft curtains may be of benefit is in the event of the total failure of the sprinkler system. Given that the performance which will result from compliance with the IBC/IFC provisions for roof vents/draft curtains has never been determined, no conclusions can be made as to whether or not the IBC/IFC provisions are adequate in the event of the total failure of the sprinkler system.

Page 4

> ***"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.*"

Commentary:

The above statement is based upon the assumption that draft curtains will be provided. As previously noted, the IBC/IFC provisions for roof vents/draft curtains only require draft curtains in industrial and storage buildings which do not contain high-piled storage. Hence, the spread of both heat and smoke will not be contained by draft curtains in many cases were roof vents are required.

The above statement also assumes that a reduction in the number of sprinklers which operates will assist the sprinkler system in controlling the fire. In some cases, reducing the number of operating sprinklers may assist in the control of the fire, however, in other cases, preventing the operation of sprinklers not located directly over the fire may be detrimental. The statement discounts the value of prewetting of combustibles located adjacent to the fire. In many cases, prewetting is necessary to prevent the spread of fire to adjacent combustibles.

Page 5

> *"**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.*"

Commentary:

There is general agreement that reduced temperatures of the smoke layer will reduce the flow of smoke through vents which have opened. In addition, there is general agreement based upon the NFPRF research that sprinkler operation will prevent the operation of roof vents. Both the reduced temperature differential and the non-operation of roof vents will reduce the quantity of smoke actually vented. Of course, if no roof vents operate, then no smoke will be vented through the roof vents.

Pages 13 and 14

"*The FMRC fire test facility at West Gloucester was used for a full-scale test program to determine if existing or new technology fire sprinkler systems are capable of providing acceptable protection for storage found in warehouses and warehouse-type retail stores. . . . The authors indicated that neither of the two tests with draft curtains met the above criteria.*"

Commentary:

It has been stated that the FMRC research regarding the interaction of sprinklers and draft curtains is not applicable to designs which include roof vents. Later research sponsored by the NFPRF demonstrated that sprinkler activation will limit the number of vents to either one or none. Hence, tests on the interaction of sprinklers and draft curtains without roof vents is essentially the same as tests on the interaction of sprinklers, roof vents and draft curtains. Given this, the FMRC conclusion that draft curtains interfere with the operation of sprinklers is a valid conclusion, regardless of whether or not roof vents are provided (except in the case where the sprinkler system fails to discharge water due to a closed water supply control valve or broken pipe).

Page 18

"*. . . . 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. 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. Similarly, there have been many studies of portions of the problem through experimentation and analysis. None of that work is sufficiently comprehensive to rise to the level of insight provided by the experimental studies in the prior section. . . . . It is notable that in the time since the 1974 FMRC model study, FMRC has conducted hundreds of full-scale sprinkler tests and have published no additional modeling studies of the type used in the 1974 report.*"

Commentary:

The American Architectural Manufacturers Association (AAMA) recently announced that the AAMA has retained Hughes Associates, Inc. to do a modeling study of roof vents. While the statement above is more than 6 years and the state-of-the-art with respect to modeling has advanced, the above statement questions a modeling approach for research on the interaction of sprinklers, roof vents and draft curtains. In effect, Beyler and Cooper are questioning the modeling study which Hughes Associates, Inc. is now working on for the AAMA.

Page 19

> "*None of the testing programs reviewed used a test building of sufficient size to fully evaluate the interactions of sprinklers and roof vents. As large as some of the test facilities were, they are dwarfs beside the buildings in which sprinklers and vents are used. The FMRC facility (4650 m^2 (50,000 ft^2)) has no capabilities to include roof vents, and as such, FMRC has never performed a full-scale sprinklered test with roof vents. The UL facility has a test area of only 1393 m^2 (15,000 ft^2), only about three times a typical curtained area, and that facility cannot be operated without ventilation due to environmental concerns. As such, we must realize that the data available to us at this time are not complete and require great care in assessing our understanding of the issues.*"

Commentary:

Although the two research facilities discussed above may not be large enough to conduct full-scale testing, Beyler and Cooper appear to have ignored the full-scale test of the interaction between standard sprinklers, roof vents and draft curtains which occurred on March 19, 1998 at a bulk retail store in Tempe, Arizona.

The building in which this real world test was conducted had dimensions of 400 feet by 250 feet (100,000 SF). The ceiling height of the building varied from 24 feet to 29 feet. The building was protected by large orifice high temperature standard sprinklers (17/32 inch orifice; 286°F temperature rating). The sprinkler system was designed for a Class IV commodity with a maximum height of 20 feet. The hydraulic design criteria utilized in the design of the sprinkler system was a density of 0.495 gpm/SF applied over an area of 2,000 SF. The hydraulic calculations assumed that 29 sprinklers would operate.

At the time of the fire, the combustibles in the area of origin were predominantly both expanded and unexpanded Group A plastics, rather than a Class IV commodity. It was also noted that the spray patterns of a number of operating sprinklers were obstructed by ceiling insulation which became detached from the underside of the roof. A total of 66 sprinklers (protecting an area slightly in excess of 5,000 SF) operated in the fire.

The building was constructed with a roof vent/draft curtain system. The building was provided with 29 roof vents activated by fusible links with a temperature rating of 165°F. Each roof vent had dimensions of 4 feet by 8 feet. (The total area of the roof vents provided was 928 SF. Based upon this, the ratio of floor area to vent area was approximately 108:1.) The draft curtains provided were 6 feet, 6 inches in depth. The dimensions of the areas formed by the draft curtains was 96 feet by 80 feet (7,680 SF). It should be noted that the floor area to vent area ratio slightly exceeds the maximum ratio permitted by the IBC/IFC (100:1), however, the IBC/IFC does not require that draft curtains be provided.

Firefighters arriving at the scene of the fire reported that the entire building was filled with smoke from the floor to the underside of the roof and the visibility in the building was zero. A ladder company assigned to ventilate the roof reported that only three roof vents had automatically opened and that one plastic skylight in the roof had burned through. (It should be noted that the roof vent fusible link temperature rating was 165°F, while the sprinkler temperature rating was 286°F.) Based upon this, it can be concluded that a roof vent/draft curtain system complying with (actually exceeding) the requirements contained in the IBC/IFC (and the recommendations of Beyler and Cooper regarding the temperature rating of the fusible links provided for the vents with respect to the sprinkler temperature rating) had failed to perform its intended function.

It was noted that a draft curtain was located in an aisle near the area of origin (as recommended by Beyler and Cooper). This aisle was reported to be 10 feet in width. It was reported that the fire spread across this aisle and destroyed the contents of the rack across the aisle from floor to the top of the rack for a distance of 32 feet.

This fire appears to confirm a number of conclusions reached in the NFPRF research. The first is that the operation of sprinklers limits the number of automatic roof vents which will operate (despite the fact that the temperature rating of the vent fusible links was 121°F less than the temperature rating of the sprinklers). The second is that draft curtains will interfere with the operation of the sprinkler system. It appears that the draft curtains interfered with the prewetting that normally occurs with the operation of a sprinkler system and allowed the fire to spread across a 10 foot wide aisle.

The above fire clearly calls into question the effectiveness of roof vents/draft curtain systems designed to comply with the IBC/IFC provisions for roof vents and draft curtains.

Source: NFPA fire investigation report.

Page 19

"*Limiting the extent of smoke spread is the key physical process that allows emergency egress, firefighter access, and limits spatial extent of smoke and heat damage.*"

Commentary:

In order to limit the extent of smoke spread and assist the venting process, it is necessary to provide both roof vents and draft curtains. As has been previously noted, the IBC/IFC does not require that draft curtains be provided, except in industrial and storage buildings which do not contain high-piled storage. The code provisions which require draft curtains in industrial and storage buildings (without high-piled storage) allow the curtained areas to be as large as 50,000 square feet. Given this, it can be stated that the provisions for roof vents and draft curtains presently contained in the IBC/IFC will not prevent the spread of smoke throughout the building. Hence, as indicated above, the installation of roof vents (without draft curtains) will not perform the function of "limiting the extent os smoke spread" discussed above. Hence, roof vents (without draft curtains) may not enhance "emergency egress, firefighter access or limit smoke and heat damage as implied by the statement a-bove.

Page 20

> "*The claim that venting assists the fire department in locating the fire and reduces the need for manual venting relates to operational characteristics of vents. That automatically operated vents or even manually operable vents reduce the demands on firefighters venting the building are not matters for fire research. Similarly, that fire plumes are visible from roof vents is not a matter for research.*"

Commentary:

The statement above assumes that automatic or manual roof venting will reduce firefigh-ting demands in large single story buildings, however, this statement does not address whether roof venting, whether automatic or manual, is the optimal means of reducing de-mands on firefighters.

The use of either automatic or manual roof venting assumes that firefighters will perform active interior firefighting. An alternative strategy which can be employed is for firefighters to assume a supporting role and permit the sprinkler system protecting the building to first control, then extinguish the fire.

This alternative strategy is based upon the following statements in NFPA 13:

> "*Sprinkler protection installed as required in this standard is expected to protect the building occupancy without supplemental fire department activity. Fires that occur in rack storage occupancies are likely to be controlled within the limits outlined in B-1.1, since no significant building damage is expected. The first fire department pumper arriving at a rack storage-type fire should connect immediately to the sprinkler siamese fire department connection and start pumping operations.*"

"*During the testing program, the installed automatic extinguishing system was capable of controlling the fire and reducing all temperatures to ambient within 30 minutes of ignition. Ventilation operations and mop-up were not started until this point.*"

The effectiveness of sprinkler operation in controlling and eventually extinguishing the fire can be monitored simply by watching the pressure gauge on the pumper supplying the fire department connection. If the pressure at the pumper remains steady (constant), this is an indication that additional sprinklers are not be activated and that the sprinkler system is controlling the fire. If the pressure at the pumper decreases, then this is an indication that additional sprinklers are being activated.

Avoiding entering the building until the sprinkler system gains control of the fire and extinguishes the fire is a means to ensure the safety of firefighters. This approach complies with the recommendations of NIOSH publication 2005-132. The following are excerpts from NIOSH publication 2005-132:

"*Steel trusses are also prone to failure under fire conditions and may fail in less time than a wooden truss under the same conditions.*" (Page 7)

"*The number of fire fighter fatalities related to structural collapse could be significantly reduced through proper education and information concerning truss construction. Fire fighters should be discouraged from risking their lives solely for property protection activities.*" (Page 7)

"*Lives will continue to be lost unless fire departments make appropriate fundamental changes in fire-fighting tactics involving trusses.*" (Page 8)

"*NIOSH recommends that fire departments, fire fighters, building owners, and managers take steps to minimize the risk of injury and death to fire fighters during fire fighting operations involving structures with truss roof and floor systems. . . .*" (Page 8)

"*Use defensive strategies whenever trusses have been exposed to fire or structural integrity cannot be verified. Unless life-saving operations are under way, evacuate fire fighters and use an exterior attack [Brannigan 1999; Dunn 2001].*" (Page 9)

Page 21

"*The claim that smoke and heat vents operate effectively when sprinklers do not operate is clearly a valid one. The smoke venting studies reviewed in this paper and others clearly provide the basis for the claim. The real question here is how relevant is the claim, i.e., how reliable are sprinkler systems. While it is outside the scope of this paper to review sprinkler system reliability studies, sprinkler systems are widely reported to be 90-95 percent reliable, with strong indications that the actual reliability is even lower. In the remaining cases, manual firefighting must be relied upon, and the support of an automatic venting system has clear value in these cases.*"

Commentary:

Typically, large single story industrial and storage buildings are constructed using Type 2B (unprotected noncombustible) construction with the roof supported by steel bar joists. Based upon the recommendations contained in NIOSH 2005-32, firefighters should avoid entering buildings with unprotected truss construction if the trusses have been exposed to fire for any significant length of time (more than 5 minutes). Based upon the NIOSH recommendations, it can be stated that firefighters should avoid entering large industrial or storage buildings if the sprinkler system fails. Given this recommendation by NIOSH, providing roof vents provides no additional protection for the building since NIOSH recommends that firefighters not enter the building.

Page 21

"*The claim that the use of smoke and heat vents will enhance burning rates has been actively made by Factory Mutual (e.g., Battrick 1986; Ward 1985]. This view has also been the basis for advising firefighters to not enter or vent a building protected by sprinklers, but rather the building should be "buttoned up," and the sprinkler system should be left to do its work. Entry should only be attempted after the fire is clearly controlled though guidance on how this is to be determined is not clearly given. This guidance clearly contradicts normal fire service practices, and the FM guidance does not seem to be followed in general.*"

Commentary:

The FM recommendation regarding firefighters entering a large industrial or storage building protected by sprinklers has little to do with burning rates. The recommendation has to do with the capability of the sprinkler system to control and extinguish fires in these buildings without the assistance of fire department. FM's primary concern is that firefighters will utilize the water supply for large hose streams and deplete the water supply for the sprinkler system. FM's recommendation is a recognition that sprinkler system discharge is far more effective means of controlling a fire in a large single story building than the use of hose streams by the fire department.

Page 22

> "*The claim that smoke and heat vents will delay sprinkler activation is not supported by the available data except when the fire is directly below the vent. Tests in which vents were manually operated at the start of the test by FMRC [Heskestad 1974], IITRI [Waterman et al. 1982; Waterman 1984], Ghent [Hinkley et al. 1992a], 1998 UL [McGrattan, Hamins, and Stroup 1998] all showed no effect on the activation of early sprinklers. Similarly, the 1998 UL rack tests, where vents were opened at the first sprinkler activation, showed no effect on the timing of subsequent sprinkler operations. Where the fire is not directly beneath the vent, there are no data which indicate this claim is valid. When the fire is directly beneath the vent, the FMRC tests [Heskestad 1974] found no notable effect of the vent on sprinkler activations. In the 1998 UL heptane tests, some delays in early sprinkler activations were noted. No serious effects were noted. The 1998 UL rack tests intended to explore this phenomenon, but the vent fusible link failed to operate the vent due to cold soldering. The overwhelming evidence is that vents do not affect sprinkler operations even if opened at the start of the test. This is consistent with the European practice of ganging the vents and operating them by smoke detector or first sprinkler activation [Heselden 1985]. This result relates to the concerns over the reliable operation of smoke vents. Current U.S. practice is to impede the operation of vents to assure that sprinklers operate first. This concern is unwarranted based on the data. Early activation of vents and ganging vents are viable strategies which should be employed to improve venting reliability.*"

Commentary:

The issue of whether or not open vents affect the operation of sprinklers is still the subject of debate despite the assertions in the statement above.

What is not subject to debate is the fact that draft curtains will interfere with the operation of sprinklers and that the effectiveness of locating draft curtains over aisles to address this issue is dependent upon the width of the aisles.

To gain an understanding of the effect of both roof vents and draft curtains on the operation of standard sprinklers, it is necessary to understand how standard sprinklers control and extinguish a fire. The following describes the operation of standard sprinklers in a fire in a storage occupancy:

> "*Cooling takes place at the roof/ceiling, where relatively small drops are lifted by the fire plume and cool the gas layer at the ceiling. This has the positive effect of preventing collapse of the building structure and sprinkler piping, but also can delay operation of adjacent sprinklers (commonly known as "skipping")*."
>
> "*Prewetting takes place away from the actual fire area, where discharge from sprinklers falls onto unburned combustibles, preventing ignition.*"
>
> "*Penetration of the fire plume by water is the only one of the three mechanisms that actually reduces the heat release rate (HRR) of a fire and, if sufficient, can completely extinguish a fire. Penetration is a function of the momentum of water discharge from sprinklers and drop size, as well as the intensity of the fire plume.*"
>
> "*Control mode (CM)* [standard] *sprinklers are designed to rely on cooling and prewetting, allowing the fire to continue to burn in the area of ignition while controlling roof/ceiling temperatures and preventing fire spread until firefighters arrive or until the fire burns itself out. Control mode sprinkler protection is characterized by a relatively large area of sprinkler operation (15 – 50 sprinklers)* [in storage occupancies]."

Source: "*Meeting the Challenges of an Ever-Changing Storage Industry*", *James Golinveaux and Joe Hankins*

The NFPRF research on the interaction of sprinklers, roof vents and draft curtains, as well as the fire in the bulk retail store in Tempe, Arizona, clearly illustrates the fact that draft curtains can interfere with the prewetting of combustibles surrounding the fire. A lack of prewetting of adjacent combustibles can cause a fire to spread activating additional sprinklers, thereby reducing the ability of sprinklers to control and eventually extinguish the fire.

Page 22

> "*The negative claim is that smoke and heat vent flow rates are insufficient to realize any benefit. . . . It is well known that vent flow rate is reduced at temperatures below 200˚C (392˚F) [Hinkley 1995] and that sprinklers can cause cooling of upper layer smoke to well below this level. For example, in sprinklered fires, it would not be unreasonable for smoke layer temperatures to be 70˚C (158˚F). At such a temperature, the theoretical flow rate relative to the maximum possible high temperature flow rate would be halved.*"

Commentary:

In addition to the reduced flow rates through open roof vents caused by cooling as a result of sprinkler operation, reduced flow rates from vents are also caused by not providing draft curtains (as permitted by the IBC/IFC) (and also by the fact that sprinkler operation reduces the number of roof vents that operate).

Page 23

> "*The final negative claim that smoke and heat vents are not cost effective has never been seriously studied. Any such study would need to consider the cost of installation, the energy/lighting savings which may be realized through natural lighting, and the reduction in heat, smoke, and fire damage which results from the use of vents. While the first two are reasonably well known, the latter has not been studied in any investigation reported in the fire literature. As such, this claim has no clear basis and must be regarded as mere speculation*."

Commentary:

The cost effectiveness of providing roof vents has been questioned for at least 30 years. While the statement that this issue has never been researched is correct, it would seem that the manufacturers of roof vents would initiate such a study to demonstrate that the use of roof vents is indeed cost effective. It appears apparent that roof vent manufacturers have not initiated a study of the cost effectiveness of roof vent/draft curtain installations because the results of the study appear to be obvious (based upon the discussion which follows).

While no formal research has been conducted on the cost effectiveness of roof vent/draft curtain installations, it is a known fact that no property insurer requires the installation of roof vents and draft curtains. This would appear to be an obvious indication that property insurers do not believe that roof vents and draft curtains reduce fire losses in large storage and industrial occupancies.

In addition to the factors listed in the Beyler/Cooper paper affecting the total cost of a roof vent/draft curtain design, factors such as roof leakage, heating/cooling losses, inspection costs and fusible link replacement costs should be considered.

Given the fact that the IBC/IFC permit roof vent installations without draft curtains, the reductions due to both fire and smoke damage should also be assessed both with and without draft curtains. In the case of successful sprinkler operations, the damage due to fire and smoke will be the same in buildings without draft curtains since research indicates that the roof vents will not operate.

Page 23

> "*First, it is clear that the current focus on assuring that vent operation is delayed has an adverse effect on system performance. It is important that design attention be paid to causing vents to operate more rapidly and in greater numbers. The data indicate that the European approach of ganged operation of vents based on early detection is a viable and desirable strategy. Second, it has been noted that draft curtains represent obstructions and should be dealt with in sprinkler design as obstructions. Draft curtains should be provided in the center of aisles and not directly over the storage. Dealing with these issues will improve fire protection design.*"

Commentary:

The statement above is tantamount to an admission that the provisions for roof vents/ draft curtains presently contained in the IBC/IFC are seriously flawed. This admission would appear to support the proposal that the provisions for roof vents/draft curtains be removed from the IBC/IFC.

It should be noted that the paper written by Beyler/Cooper is dated February 1999. To date, no proposal to revise the roof vent/draft curtain provisions contained in the IBC/IFC has been submitted.

In should be noted that representatives from Hughes Associates, Inc. have testified against the proposals to delete the provisions for roof vents/draft curtains contained in the IBC/IFC several times.

* * * * *