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THE ICC CODE DEVELOPMENT HEARINGS: ROOF VENTS IN SPRINKLERED BUILDINGS

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The installation of automatic roof vents and draft curtains in large single story industrial and storage buildings protected by standard spray sprinklers has been the subject of controversy since the 1970's. Despite this fact, the International Building Code (IBC) and the International Fire Code (IFC) continue to mandate that roof vents be installed in sprinklered buildings. Since the publication of the 2000 edition of the IBC and IFC, there have been three code change proposals to delete the provisions which require roof vents in sprinklered buildings. Each of these code change proposals has been rejected by the code committee responsible for reviewing the proposals. In the most recent code change cycle for the IBC and the IFC, the 2007/2008 code change cycle, four code changes to substantially modify the requirements for roof vents were proposed.

Code change F192, submitted by the Rick Thornberry of The Code Consortium representing the American Architectural Manufacturers Association (AAMA) Smoke Vent Task Group, proposed to allow smoke/heat vent systems to be an engineered design per the requirements contained in NFPA 204 as an alternative to the specification-oriented design provisions presently included in the code. Code change F196, submitted by Robert Davidson of Davidson Code Concepts, LLC, proposed to allow the installation of manually operated roof vents in sprinklered buildings as an alternative to automatic roof vents presently required. Code change F197, also submitted by Rick Thornberry representing the AAMA Smoke Vent Task Group, proposed to include specific provisions for the design of "ganged" automatic operation of roof vents. Code change F200, submitted by Schulte & Associates, proposed to allow five alternative methods of providing ventilation for smoke removal purposes (intended to be utilized after the fire is controlled and extinguished). Three of the four proposals outlined above were rejected by the code committee, while the fourth proposal, code change F196, was withdrawn from consideration.

The basis for the rejection of code change F192 was the fact that neither the current edition, nor previous editions of NFPA 204 contain specific guidelines for an engineered design of roof vents and draft curtains in buildings protected by a sprinkler system. The basis for the rejection of code change F197 was that sufficient research on the "ganged" roof vent concept has not been conducted at present (and that the research which has been conducted has not been peer-reviewed). Code change F200 was rejected because the code committee did not accept the premise that the ventilation provided for smoke removal should only be designed for conditions after the fire has been controlled and extinguished.

In order to better understand the combined operation of standard spray sprinklers and automatic roof vents, along with draft curtains, it is helpful to review statements made by Dr. Craig Beyler of Hughes Associates, Inc., a consultant retained by the AAMA Smoke Vent Task Group, from various sources and also by a prominent fire research engineer working for Factory Mutual Global Research.

The following are excerpts from a proposal to amend the 2002 edition of the NFPA 204, the standard for Smoke and Heat Venting, submitted by Dr. Beyler and Paul Compton of Colt International, Ltd. (The text which is underlined is new text which was proposed to be added to the standard.)

> "**204-26 Log #21 Final Action: Accept in Principle (F.3)**
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> Add new text as follows:
>
> **F.3** *Recent research (7) In tests where the vents were opened by fusible link a number of the vents failed to open, attributed to either the cooling effects of the sprinklers on the smoke layer or direct spray cooling of the fusible links.*
>
> *Design considerations (5) Determination of the smoke layer temperature should take into account the operation of the sprinkler system. Sprinklers operate when a temperature rated fusible bulb breaks in each individual sprinkler head. Since in most fires only a small number of sprinkler heads close to the seat of the fire operate it follows that the bulk temperature of the smoke layer and/or the ceiling jet beyond the operating sprinklers cannot be significantly higher than the sprinkler bulb temperature, due to the cooling effect on the smoke of the operating sprinklers.*
>
> *Therefore once the first sprinkler has operated, if calculations show the smoke layer temperature to be above the sprinkler bulb operating temperature, the smoke layer temperature should be modified to reflect this effect. A possible approach when vents are used would be to set the smoke layer temperature equal to the sprinkler bulb operating temperature, this being a reasonably conservative design solution.(7) The effect of sprinkler cooling may limit the number of vents opening if control is only by fusible link or if drop out panels are used. If the fusible link or drop out panel operating temperature is equal to or higher than the sprinkler bulb operating temperature then vents outside the outer ring of operating sprinklers are unlikely to open. This could significantly limit the effectiveness of the smoke vent system. Use of ganged vents operated from detectors or a sprinkler flow switch is a way to avoid this situation.*"

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."

The following are excerpts from a document written by Dr. Beyler and provided to the International Code Council (ICC) Code Technology Committee (CTC) at a meeting held in Kansas City in October 2006 titled "*Smoke and Heat Vents: A review of the technology and the way forward to the next generation*":

"*The primary means of controlling the production of smoke and heat is to suppress the fire by automatic means or by manual firefighting. Even when automatic suppression systems are employed, manual firefighting by the fire department is an integral part of the process of fire suppression.*"

"*The specific benefits of smoke and heat venting include:*

1. *Facilitate safe egress of building occupants by restricting spread of smoke and hot gases into escape routes*

2. *Facilitate firefighting operations by enabling firefighters to enter the building and to see the seat of the fire without the delay and hazards of manual roof venting*

3. *Limit damage to the building and contents due to smoke and heat by removing smoke and heat from the building*

Each of these is achieved by preventing smoke logging of the building down to occupied levels of the building where people require adequate visibility to escape and where adequate visibility facilitates the firefighters finding and extinguishing the fire. Limiting smoke damage to the building and contents is achieved by removing the smoke. This limits the exposure of the building interior and contents to smoke deposition."

“*In 1982, NFPA 204 set aside the issues with the use of smoke and heat venting in sprinklered buildings and embraced the mathematical modeling approaches that had been developing since the late 1950's for nonsprinklered buildings*”.

“*In the case of NFPA 204, the standard has not been put forward for consideration by IBC pending the development of a design methodology for sprinklered facilities.*”

“*The findings of the review* [referring to a paper titled “*Interaction of Sprinklers With Smoke and Heat Vents*” authored by Beyler and Leonard Y. Cooper] *were that smoke and heat venting does not negatively impact sprinkler performance. The review also found that smoke and heat venting did limit the spread of smoke and heat so as to benefit building occupants and firefighters and reduce smoke and heat damage. At the same time, the review identified that the design methods currently employed may limit the number of vents operating during successful sprinkler operation to one or, possibly none, in very successful sprinkler operations. The review found that additional work is needed to develop more effective design methods. In a Letter to the Editor in the following year, Gunnar Heskestad concurred that additional research is required to develop design methods for smoke and heat venting in sprinklered facilities. He indicated concern that adequate attention be paid to assuring that vents and draft curtains do not interfere with the operation of sprinklers which deliver water to the fire.*”

“*HAI performed modeling studies using LES 3D (now FDS 4)* [model] *for a 140' x 140' x 27'* [19,600 SF] *sprinklered facility, divided into four draft curtained areas* [4,900 SF per curtained area]*, with four 8' x 4' vents per curtained area* [1:38 vent/floor area ratio]*.* [The required vent/floor area ratios contained in the IBC range from 1:50 to 1:100 depending on height and classification of combustibles being protected.] *The fire modeled was a t-squared fire reaching 10 MW in 75 s, and was controlled at that rate for 600 seconds. The number of vents simulated to open was parametrically varied from zero to four. For all cases modeled visibility was lost within the sprinkler discharge area, but outside the area of sprinkler operation, increasing the number of vents operating improved visibility. . . .In this case, the venting clearly changed the conditions for occupants and firefighters from near black-out conditions to navigable smoke conditions*.”

[**Note:** It should be noted that the IBC does not require that draft curtains be provided. Hence, the results of the modeling study presented above are based upon a design which exceeds the requirements contained in the IBC. It should also be noted that Beyler's proposal to amend NFPA 204 excerpted above indicates that the maximum number of vents which will operate will be limited to one. No explanation was provided on why more than one vent was assumed to open in the modeling study discussed above.]

"*The fire modeled was a t-squared fire reaching 10 MW in 75 s, and was controlled at that rate for 600 seconds, just as before. Calculations were done without vents or draft curtains, with vents and no draft curtains, and with both vents and draft curtains.* [Multiple] *Vents were* [simultaneously] *opened at least 30 seconds after the first sprinkler operated. At this time all the sprinklers which could contribute to fire suppression had already operated. In the unvented case, smoke was distributed throughout the facility, leading to widespread loss of visibility. The vent cases limited the spread of smoke and visibility was maintained outside the area of sprinkler operation. While performance was better with draft curtains, the results without draft curtains were quite promising.*"

"*While great strides have been made in fire modeling in recent years, it is not yet possible to predict fire suppression by sprinklers. Fortunately, this is not required to solve the design problem. . . . Enough is known from the available testing to simulate the nature of the heat release rate curves associated with the range of possible performance levels so that smoke and heat venting in fires controlled by as few as four sprinklers and up to the number of sprinklers that constitute the full design area can be simulated.*"

"*Indeed, it has been recognized that full scale sprinkler tests are not very reproducible and this makes studying the venting problem with sprinklers very difficult.*"

"*Because of the difficulties with performing a full scale fire test series and because of the advancement of fire modeling capabilities, it is now considered feasible to develop the design methodology using fire modeling methods.*"

The following are excerpts from a letter-to-the-editor written by Gunnar Heskestad of FM Global Research addressing a paper titled "*Interaction of Sprinklers With Smoke and Heat Vents*" authored by Craig L. Beyler and Leonard Y. Cooper and referenced by Dr. Beyler in the excerpts above. This letter was published in the 3rd quarter 2002 issue of *"Fire Technology"*.

"*. . . .With respect to the third conclusion* [referring to the conclusion in the Beyler/Cooper paper that roof vents are a valuable tool in the event sprinklers fail to operate (i.e. a closed water supply valve)]*, it is our* [FM Global Research's] *position that venting, installed as backup to an automatic sprinkler system which is inadequate or impaired, is not cost effective because it is unlikely a large loss will be averted solely due to the presence of vents.*"

"*To justify our* [FM Global Research's] *views we may first recall the results of the main test series of FMRC's Model Study, reported in 1974 (authors' ref. 18). . . . In fires operating fewer than approximately 20 sprinklers did not activate the fusible-link actuated vents spaced at 50 ft. Larger fires, operating approximately 50 sprinklers (without venting), activated 4 vents. Among these, averaged over the number of fires for each test condition, vents alone (no draft curtains) had essentially no effect on the total number of operating sprinklers (52 versus 51 sprinklers), but delayed loss in visibility from 13.1 to 15.7 min, increased minimum recorded O_2 concentration (at scaled eye level, 37 ft from the ignition point) from 18.2 to 20.5%, and increased fuel consumption from 13,100 to 18,900 lb. Vents and draft curtains increased the number of operating sprinklers from 51 to 69, delayed loss in visibility from 13.1 to 20.2 min, increased minimum recorded O_2 concentration from 18.2 to 20.2%, and increased fuel consumption from 13,100 to 21,400 lb. Unambiguous benefits of venting cannot be read into these results.*"

"*Loss of visibility was associated with the smoke being dragged down by the sprinkler sprays when buoyancy was lost in the smoke layer, following control of the fire, which occurred later in the vented fire than in the unvented fire. Adding the draft curtain made the vents more effective, bringing in more fresh air than without them, causing a further increase in burning activity. Due to the increased burning rate and confining effect of the draft curtains, gas temperatures in the smoke layer increased and caused additional sprinkler operations. The increased burning activity delayed further the loss in buoyancy in the smoke layer and drag down of the smoke layer to the floor, leading to loss of visibility. With these explanations we may interpret the delay in loss of visibility to be associated with increased fire activity. Do we count this delay as a benefit of venting?*"

"*When vents are installed in the absence of draft curtains we may see no change in the number of sprinkler operations relative to the unvented building, or at best there will only be a small reduction, and only a marginal improvement in visibility conditions can be expected. These minor effects are predicted since the open vents will influence so little of the smoke under the ceiling, now mostly confined to the ceiling jet and not accumulated in a layer underneath. With vents and draft curtains installed, we may still see an increase in the number of sprinkler operations because of the heat confining effect* [of the draft curtains]*. In addition, increased floor-level smoke densities can be expected in the curtained/surrounding area as a result of the deep smoke layer at the moment the fire is controlled by the sprinklers.*"

Also of interest in a discussion of the need to provide roof vents in large one-story buildings protected by a sprinkler system is the capability of standard sprinklers to control and extinguish a high challenge fire. The following excerpts are included in explanatory material contained in NFPA 13, the standard for the Installation of Sprinkler Systems:

"*Sprinkler protection* [for storage arrays which will generate high challenge fires] *installed as required in this standard is expected to protect the building occupancy without supplemental fire department activity.*"

"*During the testing program* [for sprinkler protection for storage arrays which will generate high challenge fires]*, the installed automatic extinguishing system was capable of controlling the fire and reducing all temperatures to ambient within 30 minutes of ignition."*

Discussion

In the testimony on code change F200 at the ICC code development hearings held in Palm Springs, California in the last two weeks of February of this year, Jesse Beitel of Hughes Associates, Inc. (HAI) stated that HAI has done a modeling study of a building which was 80,000 square feet in floor area and that the study demonstrates that "vents work". Beitel has also made this same statement in his testimony on code changes relating to roof vents at the ICC code development hearings held in Cincinnati in February 2005 and in Lake Buena Vista, Florida in September/October 2006. What Beitel never indicates in his testimony however, is how HAI determined how many automatic roof vents would operate and at what time the vents would operate.

The testing program sponsored by the National Fire Protection Research Foundation (NFPRF) in 1997/1998 clearly demonstrated that modeling cannot accurately predict whether or not a roof vent will actually operate or determine at what time a roof vent will open simply because we don't have the capability to model the interaction of water spray droplets and heat. Even with advances in fire modeling in the 10 years since the NFPRF-funded testing program, predicting the activating time of an automatic roof vent is still beyond our modeling capabilities. Of course, we wouldn't have known this were it not for large scale testing which Beyler dismisses as not being reproducible.

Clearly, Dr. Beyler is now on record indicating that the number of automatic roof vents which will operate in a building protected by standard spray sprinklers will be limited to a maximum of one (assuming that the sprinkler system is operational and is adequate for the hazard protected), if any roof vents operate at all. Based upon Dr. Beyler's recent statements (which are based upon the 1997/1998 research sponsored by NFPRF and also the modeling study conducted by FMRC in 1974), it is quite probable that no roof vents will operate automatically in many fires. What neither Beyler or Beitel have yet to explain is how the installation of automatic roof vents will prevent a building from becoming "smoke-logged" if no vents open due to the interaction between operating sprinklers and roof vents.

Given the recognition that automatic roof vents will likely not function as intended in buildings where both standard sprinklers and vents are installed, the roof vent manufacturers and their consultant, HAI, are now proposing that roof vents be "ganged" together so that multiple roof vents automatically open when water flow in the sprinkler system is detected. In the excerpts above, Beyler proposes opening the "ganged" roof vents at least 30 seconds after the first sprinkler operates, while in other forums (testimony at the ICC code development hearings), it has been suggested that the delay in opening the "ganged" vents be 60 seconds after the sprinkler system water flow indicating device is activated.

Note: It should be noted that water flow indicating devices in wet sprinkler systems typically incorporate a delay (of up to 60 seconds) in order to prevent activation of the water flow alarm when surges occur in the water supply. Given this, it is highly unlikely that the activation of the water flow device represents the time at which water discharges from the first operating sprinkler. In dry sprinkler systems, the tripping of the dry valve is only indicative of water flow occurring at the dry valve itself. There will be a delay after the dry valve trips before water is actually discharged from sprinklers that have operated in a dry sprinkler system.

In the document which discusses “ganged” roof vent operation (excerpted above), Beyler states that the model indicates that “*all* [of] *the sprinklers which could contribute to fire suppression had already operated*” within 30 seconds after the first sprinkler activates. Obviously, this statement shows a less than adequate knowledge of how standard spray sprinklers operate to control and extinguish a fire on the part of Beyler. Not only is the operation of spray sprinklers directly over the fire important, but, just as important in controlling “high challenge” fires is the operation of sprinklers over unignited combustibles located adjacent to area of fire origin. The operation of sprinklers over combustibles adjacent to the fire is referred to as “pre-wetting”.

The “pre-wetting” of combustibles adjacent to the fire serves to contain the spread of the fire to the area of origin. Once the fire is contained by “pre-wetting”, the fire will consume all of the combustibles in the area of origin and the rate of heat released by the fire will diminish with time. The reduction in heat release by the fire eventually allows the water spray from the sprinklers located directly over the fire to reach the surface of the burning combustibles to effect final extinguishment of the fire (without the need for supplemental fire department activity). Without “pre-wetting” of unignited combustibles adjacent to the area of fire origin, a “high challenge” fire may continue to spread, which in turn will cause the operation of additional sprinklers. If more and more sprinklers continue to operate, eventually this will result in the failure of the sprinkler system.

There is little doubt that the opening of a number of roof vents in close proximity to the fire within 60 seconds of the activation of the water flow alarm will have a significant impact on the capabilities of standard spray sprinklers to control a fire. NFPA 13 contains requirements for the location of sprinklers with respect to ceiling. The reason for these requirements is that the location of the sprinkler operating element with respect to the ceiling affects the operating time of sprinklers. Similarly, an open roof vent located between a fire and a sprinkler which has not operated will have a significant impact on the operating time of the sprinkler.

Given that our present modeling capabilities cannot predict the operating times of sprinklers which operate subsequent to the first operating sprinkler without open vents, we certainly cannot accurately predict the effect that open vents will have on the operating times of sprinklers where vents are located between the fire and sprinklers which has not yet operated. Hence, neither Beyler or anyone else can predict the precise impact of multiple open vents on sprinklers which may be involved in performing a “pre-wetting” function using modeling. Presently, the only way that we can address the impact of open vents on sprinklers which may be involved in “pre-wetting” is through large-scale testing which has yet to be performed by the manufacturers of roof vents. In other words, the “ganged” roof vent concept being promoted by Beyler and the AAMA Smoke Vent Task Group is simply not ready for prime time yet.

Conclusions

With studies (FMRC 1974; NFPRF 1998) that indicate that automatic roof vents are not likely to operate in buildings protected by standard spray sprinklers (and studies (FMRC-1974; FMRC 1994; NFPRF 1998) which conclude that draft curtains interfere with the operation of standard spray sprinklers), even the proponents of automatic roof vents can no longer claim that automatic roof vents work as intended in sprinklered buildings. Yet, that's exactly what Beyler, Beitel and the AAMA Smoke Vent Task Group continue to claim both at the ICC code development hearings and in ICC CTC study group meetings.

With the limited time for testimony allowed at the ICC code development hearings, the AAMA Smoke Vent Task Group and their consultants have succeeded in preventing major modifications to the provisions which require roof vents to be installed in buildings protected by standard spray sprinklers. Fortunately, at the insistence of the Alliance for Fire and Smoke Containment and Control (AFSCC), the ICC has developed a second forum for code development, the Code Technology Committee (CTC). A 90 minute debate on the proposed code changes to the roof vent provisions contained in the IBC/IFC before the CTC is scheduled for the next meeting of the CTC (May 21-22, 2008).

With 90 minutes to discuss the issue of the provisions which require roof vents to be installed in sprinklered buildings perhaps common sense and reason will triumph over emotion. In any event, the proponents of roof vents in sprinklered buildings will have plenty of time to present their studies on the reduction in property losses which occur when roof vents are utilized in sprinklered buildings. Oops, sorry, I forgot that the manufacturers of roof vents don't have any studies which support their claim that roof vents actually reduce property losses in sprinklered buildings. This claim is just one in a long string of unsubstantiated claims made by those who profit from the manufacturer of roof vents. Unlike sprinkler protection, there would be no market for roof vents in the United States if the installation of vents were not mandated in sprinklered buildings by the IBC/IFC.

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