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June 6, 2011 **_Via e-mail:_** *kevin.reinertson@fire.ca.gov*

California State Fire Marshal's Office
P.O. Box 944246
Sacramento, CA 94244-2460

and

California Building Standards Commission
2525 Natomas Drive, Suite 130
Sacramento, CA 95833-2936

Re: Proposed Amendments to 2010 Edition of the CFC

Ladies and Gentlemen:

We have reviewed the proposed amendments to Chapter 9 and Chapter 10 of the 2010 California Fire Code (CFC) intended to address limitations and/or inadequacies of the adopted reference model code and SFM regulations relating to exit access travel distance and fire fighter operations in Group F-1 and S-1 occupancies. We agree that a modification is needed to allow exit access travel distances up to 400 feet in these occupancies. However, we have a number of concerns with the current proposal and wish to offer further modifications.

I have been intimately involved in the subject of smoke and heat venting since about 1975 and have served on the NFPA 204 Technical Committee for many years, although I resigned some time ago and before it was put under the scope of the NFPA 92A/92B TC. Also, I have been a member of the ICC's Code Technology Committee (CTC) since its inception in 2005 and currently serve as its Chair. One of the topics assigned to the CTC has been smoke and heat vents and, until recently, I chaired the CTC Study Group on this topic. In the CTC over the last several years, we conducted a number of discussions, conference calls and literature reviews which led to the change proposed for the IBC and IFC in the last cycle. The proposal was amended as a "compromise" and nearly was adopted last year. I believe we are close to achieving a consensus on a way to move the technology forward in the upcoming cycle, and also note that NFPA 204 will likely be amended in the June meeting, removing its confusing and misleading language.

I look forward to working with representatives from your office to achieve a consensus in the model code which addresses both the use of vents in sprinklered buildings and provisions to allow a 400 feet exit access travel distance.

As you may know, RJA is an international consulting engineering firm specializing in fire protection engineering and security. RJA has no financial or client interest in this matter. This proposal is simply intended to provide a better level of life safety and fire protection. Also, please note that I am not speaking on behalf of the ICC CTC, but rather as a professional engineer who has studied this topic for more than 35 years.

My concerns with the current proposal are summarized as follows:

1. **Allowing the increased travel distance should be based on other mitigating factors rather than smoke/heat vents.**

   Experience and full-scale tests show that fusible link-operated vents in a sprinklered building will not likely operate. Furthermore, in the event that the vents operate either automatically or manually, the efficacy of the vents in moving cold smoke out of the building is highly questionable.

   The report prepared by Aon Fire Protection Engineering and included in the "Report to the California State Fire marshal on Exit Access Travel Distance of 400 Feet," by Task Group 400, December 20, 2010, shows that a 400-foot exit access travel distance in large Group F-1 and S-1 occupancies provides a reasonable level of safety for the occupants without other special provisions.

2. **For firefighting purposes, mechanical smoke exhaust should be recognized as an acceptable, if not superior, method of exhausting smoke in lieu of smoke and heat vents.**

   The referenced standards allow the design of a mechanical system in lieu of providing smoke and heat vents. However, the current language puts this superior method of exhausting smoke at a major disadvantage of being utilized.

   Furthermore, the use of smoke and heat vents with sprinkler systems, especially those employing ESFR sprinklers, is questionable and may lead to excessive damage and a risk to life safety. Allowing the use of mechanical systems gives designers an option to meet the goal of the exhausting smoke in these large buildings while not mixing the use of vents and sprinklers.

3. **The mechanical smoke exhaust system only needs to replace the smoke/heat vents, therefore, the ventilation rate specified in the code is excessive.**

   The ventilation rate included in the current edition of the CFC, 300 cfm for every square foot of vent area, is based upon calculations derived for uncontrolled fires in unsprinklered buildings. The physics are much different when compared to that associated with fires in sprinklered buildings and are not appropriate to be used.

Attached to this letter are: (1) proposed revisions to Section 910 of the CFC/CBC which address the above concerns, and (2) typical smoke production and exhaust rate calculations approved for use on actual projects in the State of California where mechanical exhaust systems have been used in lieu of smoke and heat vents. The second attachment provides the technical substantiation for the recommended exhaust rate to be used with the mechanical exhaust option.

Thank you for your consideration on this important matter. Please contact me if you have any questions. I also look forward to working with you as we proceed with modifications of the IBC/IFC on this topic.

Very truly yours,
THE RJA GROUP, INC.

Carl F. Baldassarra, P.E.
Executive Vice President
cfb (r/cfb0

Licensed in IL, KS, NM

Attachments (2)

ATTACHMENT 1
PROPOSED REVISIONS

1. Amend Section 910.1 of the proposed revision to 2010 CFC/CBC as follows:

910.1 General. Where required by this code or otherwise installed, smoke and heat vents or mechanical smoke exhaust systems and draft curtains shall conform to the requirements of this section.

Exceptions:

1. Frozen food warehouses used solely for storage of Class I and II commodities where protected by an approved automatic sprinkler system.
2. *Automatic smoke and heat vents or mechanical smoke exhaust systems are not required within areas of buildings equipped with early suppression fast-response (ESFR) sprinklers unless any of the following conditions exist:*
   2.1. The building is a state institution,
   2.2. The building is a state-owned or state-occupied building,
   2.3. The building is any of the applications listed in Section 1.11 regulated by the Office of the State Fire Marshal, or
   2.4. The area of a Group F-1 or S-1 occupancy protected with the ESFR sprinklers has an exit access travel distance of more than 250 feet (76 200 mm).

2. Amend Section 910.2 of the 2010 CFC/CBC as follows:

910.2 Where required. Smoke and heat vents or mechanical smoke exhaust systems shall be installed in the roofs of one-story buildings or portions thereof occupied for the uses set forth in Sections 910.2.1 and 910.2.2.

3. Amend Section 910.4 of the 2010 CFC/CBC as follows:

910.4 Mechanical smoke exhaust. ~~Where *approved* by the *fire code official*,~~ engineered mechanical smoke exhaust systems shall be an acceptable alternative to smoke and heat vents.

4. Amend Section 910.4.1 of the 2010 CFC/CBC as follows:

910.4.1 Location. Exhaust fans shall be uniformly spaced ~~within each draft-curtained area~~ and the maximum distance between fans shall not be greater than 100 feet (30480 mm).

5. Amend Section 910.4.2 of the 2010 CFC/CBC as follows:

910.4.2 Size. Fans shall have a maximum individual capacity of 30,000 cfm (14.2 m^3/s). The aggregate capacity of smoke exhaust fans shall provide a minimum of ~~be determined by the equation:~~

~~$C = A \times 300$ **(Equation 9-4)**~~

~~where:~~

~~C = Capacity of mechanical ventilation required, in cubic feet per minute (ft^3/min).~~

~~A = Area of roof vents provided in square feet (m^2) in accordance with Table 910.3.~~
two complete air changes per hour based on the volume of the building or portions thereof without deduction for any commodity storage.

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ATTACHMENT 2

TYPICAL SMOKE PRODUCTION AND EXHAUST RATE CALCULATION

INTRODUCTION

This paper provides an example of the calculation of the capacity of a mechanical smoke exhaust system proposed in lieu of smoke and heat vents for a hypothetical facility. This analysis is based upon an actual project completed by Schirmer (Aon Fire Protection) Engineering. The mechanical exhaust system eliminates the need to have fire fighters going on the roof or entering the building to release smoke and heat vents. In addition, the proposed mechanical smoke removal system provides an effective method of removing products of combustion without compromising the superior performance of the sprinkler system.

MECHANICAL SMOKE REMOVAL SYSTEM CAPACITY REQUIREMENTS

The current design criterion for mechanical smoke removal systems of 300 cfm per square foot of vent area, which first appeared in the 1985 Uniform Fire Code, is believed to have originated from the 1982 edition of NFPA 204M, *Guide for Smoke and Heat Venting*, the current edition at that time. This standard was intended to offer guidance in the design of facilities for the emergency venting of combustion products from *uncontrolled fires* in *non-sprinklered* single story buildings.

Much of the theory for the smoke venting requirements in the 1982 edition of NFPA 204M is based on the work by Dr. Gunnar Heskestad. The recommended mechanical exhaust capacity per square foot of vent area prescribed in NFPA 204M is 354 scfm per square foot for curtained compartments up to 6 feet in depth. The recommended mechanical smoke exhaust rate increases for corresponding increases in curtain depth. It is important to note that the calculations used to derive this relationship were based upon uncontrolled fires in unsprinklered buildings with the resulting temperatures and buoyancy needed to drive smoke and heat out of the vents.

The 2010 California Fire Code (CFC) and California Building Code (CBC) includes the ratio of 300 cfm per square foot of vent area in Section 910.4.2. In addition, the CFC requires that individual fans shall not exceed a capacity of 30,000 cfm and shall be uniformly spaced with not more than 100 feet between fans. For 20 foot high storage of high-hazard commodities (Group A plastics), the required ratio of smoke/heat vents to floor area is 1 square foot of vent area per 50 square feet of floor area (1:50). For the 104,279 square foot floor area of a hypothetical facility, the required smoke/heat vent area is 2,086 square feet. Applying the design of 300 cfm per square foot of venting area results in a total required exhaust capacity of 625,800 cfm, requiring a minimum of 21 exhaust fans. For this 25.5 foot high building, this ventilation rate would exceed an incredible *14 air changes* per hour.

As was previously discussed, the calculation of the mechanical ventilation rate prescribed by the CFC is for the removal of combustion products from uncontrolled fires in large industrial and storage facilities. This design has merit when applied to such cases. However, Section 910 is applicable to storage areas of facilities protected with automatic sprinklers. The proposed smoke removal system will be used for overhaul of the building after the fire has been suppressed, rather than removal of combustion products from an uncontrolled fire. As such, the smoke and heat removal requirements of 300 cfm per square foot of venting area are considered to be inappropriate for the intended application to facilities which are sprinklered.

DESIGN JUSTIFICATION

The conditions that could occur within a building during a fire situation can be simulated by conducting appropriate fire testing. A series of nine large scale fire tests were conducted at the Underwriter's Laboratories Fire Test Center in Northbrook, Illinois, between June and August, 1998. The purpose of these tests was to investigate the performance of the Grinnell Corporation's Model ESFR-25 pendent sprinkler which has a nominal discharge coefficient (K factor) of 25. Test No. 6 consisted of Group A unexpanded plastic stored to a maximum height of 20 feet, protected with ESFR K-25 sprinklers with a design pressure of 15 psi.

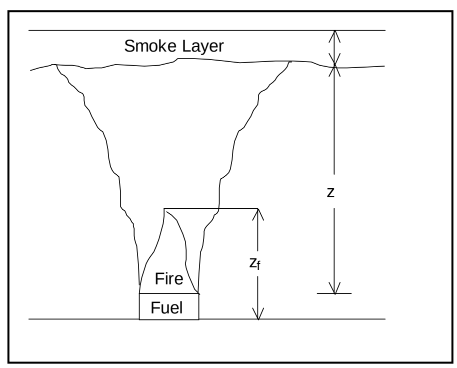
Only one ESFR sprinkler was needed to suppress the fire. The gas temperature above the ignition source peaked at 203ºF and returned to ambient temperature approximately two minutes after operation of the sprinkler. The peak steel temperature was measured at 102ºF. Steel temperatures returned to ambient levels approximately fifteen minutes after operation of the sprinklers. These steel temperatures are well below the critical temperature of 1,000ºF.

Smoke Production Calculations

The mass rate of smoke production can be estimated as the mass rate of air entrained along the height of the smoke plume up to the lower boundary of the smoke layer. Correlations have been developed to calculate the mass rate of smoke production based upon the heat release rate of the fire and height of the fuel surface to the lower boundary of the smoke layer[1]. Utilizing these correlations, the amount of smoke produced by the selected fire scenario will be calculated. An axisymmetric plume was assumed as a worst case situation. The amount of smoke produced will be compared to the capacity of the smoke removal system to determine if the design objective has been met.

Work by Heskestad (1989)[2] has developed the following equation for the calculation of smoke production:

$$\dot{m} = 0.022\,(Ec)^{1/3}\; z^{5/3} + 0.0042\,(Ec)$$



where:

$\dot{m}$ =   mass rate of smoke production, lb/sec
Ec = convection heat release rate of the fire, btu/sec
Z =   height from top of the fuel surface to the bottom of the smoke layer, feet

The above equation is appropriate for clear heights, *z*, that are greater than the limiting height, *zf*, where $zf = 0.533\, Ec^{2/5}$. A discussion of the input data used in the calculation follows.

[1] Design of Smoke Management Systems, John Klote and James A. Milke
[2] Design of Smoke Management Systems, John Klote and James A. Milke.

Heat Release Rate

The type and form of the commodity are the most influential factors in determining the heat release rate of a storage fire[3]. The heat content of the material, the burning rate, the exposed surface area, and how the commodity reacts to the application of water determine the protection requirements. Rack storage fires are generally more severe than solid-piled storage because of better air access and stability of the burning product. Storage height is a key determinant of heat release rate. As more material is exposed vertically, the burning rate increases with increasing storage height.

For this analysis, assume a storage commodity consisting of a mixture of products, ranging from Class I commodities to Group A plastic. As a conservative approach, Factory Mutual Research Corporation (FMRC) Standard Plastic Commodity (polystyrene cups in compartmented cartons) was selected. This commodity is recognized to represent the most severe fire hazard of the high density plastics tested[4].

Heat release rate data for unsprinklered rack storage fires are almost non-existent due to the obvious hazard of conducting such tests. However, convective heat release data were documented for 20 foot rack storage of FMRC Standard Plastic Commodity by Yu[5]. The storage array used to develop the data consisted of two-pallet loads wide and two-pallet loads deep of FMRC Standard Plastic Commodity in rack storage array. Test Nos. 5 and 6 utilized four tiers of storage stacked in such an array. Total storage height was approximately 20 feet. Heat release data from Test No. 6 was selected as the data is somewhat higher. This testing data is considered a conservative representation of the predicted fire scenario as the amount of product consumed in the ESFR fire testing was much less, the storage array is similar, and the commodity utilized is the same.

The convective heat release rate reaches 5,000 kw (4,742 btu/sec) at approximately one minute, six seconds, which is conservative since the first ESFR sprinkler activated at 50 seconds. The convective heat release rate will then decrease as fire suppression is achieved. Suppression is achieved not later than two minutes as shown by air temperatures above ignition.

For calculation purposes, the convective heat release rate is assumed to be a constant 4,742 btu/sec from ignition to two minutes after ignition. This is very conservative as the convective heat release rate increases to a peak of 4,742 btu/sec at one minute, and then rapidly decreases until fire suppression is achieved at two minutes. The convective heat release rate is approximately 70 percent of the total heat release, thus it is noted the total heat release rate is 7,150 kw.

Heat release rate data for the rack storage of aerosols, flammable liquids, and combustible liquids are non-existent. The use of a constant convective heat release rate for Group A plastic is very conservative and the best available data. The axisymmetric plume equation is primarily dependent on the variable clear height. Moderate increases in the convective heat release rate will not significantly affect the smoke production rate or the overall results.

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[3] Factory Mutual Loss Prevention Data Sheet 8-9R *"Storage of Class I, 2, 3, ,4 and Plastic Commodities"*.
[4] An Engineering Approach to Industrial Fire Protection, Robert Zalosh, January 1994.
[5] Yu, H-Z, *The Transient Ceiling Flows of Growing Rack Storage Fires,"* FMRC JION1JO.RA(3).

Clear Height

To determine the clear height (z), the height of the top of the fuel surface and the depth of the smoke layer must be determined. The height of the proposed storage array is 20 feet. As shown in the fire test data, the fire actually consumed product to an elevation of 5 feet. As a conservative approach (the greater the clear height the greater the smoke production rate), the top of the fuel surface will be considered at the floor.

The depth of the upper layer is dependent upon the ceiling to fire source height. The upper layer thickness can be estimated as 5 to12 percent of the ceiling to fire source height[6]. An upper layer thickness of 3 feet (25.5 foot ceiling height - 0 foot fire source height x 12 percent) was utilized.

Calculation Results

As shown in the attached calculation (Appendix A), a maximum of 68,960 cfm of smoke will be generated by the design fire. Based upon an empty building volume of 2.659 million cubic feet, the exhaust rate required to achieve two air changes per hour is 88,637 cfm. Because no single fan can exceed 30,000 cfm and fans cannot be spaced more than 100 feet apart, this project required five fans, each exhausting 25,570 cfm for a total of 127,850 cfm. This exceeds the minimum two air changes per hour by more than 40 percent. Even at the minimum required rate of two air changes per hour, the calculation results show that the mechanical smoke removal system proposed will be capable of removing the smoke from the building faster than it will be generated, ultimately removing smoke from the building once the fire is extinguished. A degree of conservatism is added to this by the calculation using an empty building volume.

DISCUSSION

The design goal of the smoke removal system is to remove smoke from the building without compromising the performance of the sprinkler system and to facilitate fire fighting operations. An ESFR sprinkler system will activate very quickly, at approximately one minute, and suppress the fire, thereby minimizing smoke production. The smoke that is produced will be exhausted from the building by activation of the smoke removal system, thus making it unnecessary for fire department personnel to access the roof. At the time the fire department begins manual overhaul, the visibility should be improved, facilitating operations. A superior level of performance is likely when compared to that expected from the performance of the building having heat-activated smoke and heat vents which rely upon the natural buoyancy of cold smoke. The design goal has therefore been achieved.

APPENDIX A
SMOKE PRODUCTION CALCULATIONS

$$\dot{m} = 0.022\,(Ec)^{1/3}\,z^{5/3} + 0.0042\,(Ec)$$ [7]

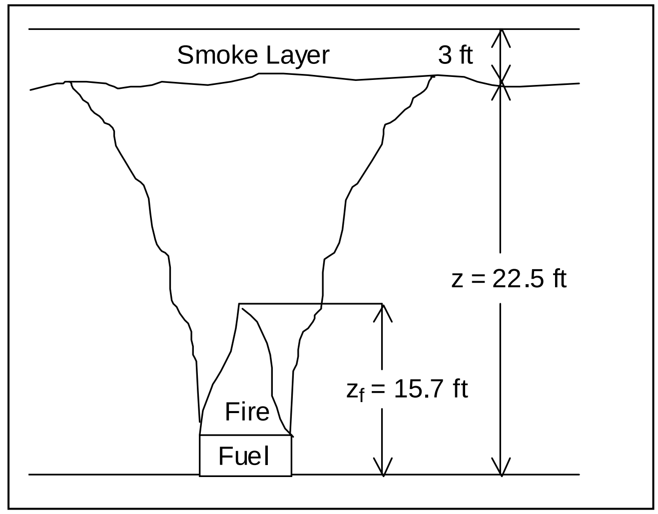
$$z = (25.5\ ft - 3\ ft) - 0\ ft = 22.5\ ft$$

$$Ec = 5000\ KW\ x\ \frac{56.90\ BTU/\min}{1\ KW}\ x\ \frac{1\ \min}{60\ \sec}$$

$$= 4742\ BTU/\sec$$

$$zf = 0.533\,(4742\ BTU/\sec)^{2/5} = 15.7\ ft$$

$z \rangle zf$, *therefore the equation is valid*



$$\dot{m} = 0.022\,(4742\ BTU/\sec)^{1/3}\ 22.5\ ft^{5/3} + 0.0042\,(4742\ BTU/\sec)$$
$$= 86.2\ lb/\sec$$

$$Q = C\,\frac{\dot{m}}{p}$$ [8]

Q = *volumetric smoke production rate, cfm*

$C = 60$ *(constant)*

p = *density of plume gases,* $lb/ft^3 = 0.075\ lb/ft^3$ *(at* $68^\circ F$ *and one atmosphere)*

$$Q = 60\,\frac{86.2\ lb/\sec}{0.075\ lb/ft^3} = 68{,}960\ cfm$$

Approximate Building Dimensions:
104,279 ft^2 x 25.5 ft high
Building volume = 2.659 million ft^3

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[7] Design of Smoke Management Systems, John Klote and James A. Milke, Equation 10.8
[8] Design of Smoke Management Systems, John Klote and James A. Milke, Equation 10.12