COMPARISON OF VARIOUS SINGLE PLY ROOF COVERS FOR FIRE RESISTANCE

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As Civilization Harnesses Fire, New Risks Threaten Lives and Property

The use of controlled fire in domestic applications began approximately 500,000 years ago. This ability to use fire allowed humans to move from the warm tropical areas of the world to the colder climates of Europe, Asia and the western hemisphere. Fire provided a means to warm the living areas, cook food, and provide light. Fire was instrumental in the development of everyday tools and goods from metals to pottery, which allowed for quicker advancement of mankind. As civilization moved forward, people started to develop densely populated cities, mostly for security reasons, often with individual buildings being connected or sharing common walls. Typically these structures had beams made from wood, and the roofs were thatch or similar organic material. Chimneys were often generally short with large openings that allowed burning embers to travel to adjacent roofs, igniting the roofing and other materials. As one can imagine, with the lack of equipment or firefighting methods, fires in ancient cities were catastrophic, often resulting in complete destruction of the city.

History has a record of major fires devastating cities from ancient Rome to Western Europe during the medieval times. In 1666, the Great Fire of London burned for five days destroying approximately 2/3 of the city and leaving over 200,000 people homeless. From this event, the first fire departments and fire insurance companies were founded. The fire led to the first recorded use of pumps to fight fires, ladders to be used for fire suppression and rescue as well as fire insurance. New building laws stopped the use of timber, required brick, stone or masonry construction, and widened the streets to limit the damage from flying burning embers. In essence, London enacted the first Fire Code for buildings.

Fires were also very common in the early days of settlement in North America. In 1631 Boston banned the use of thatch roofs and wood chimneys after a serious fire; New York followed suit in 1648. After a devastating fire in 1653 where a third of the families in Boston were left homeless, the city required every house to have a ladder and a 12 foot long pole with a wet swab to extinguish burning embers on the roofs. There were additional requirements and restrictions enacted by the city but to no avail as the city was devastated at least five more times by massive fires. Throughout the 1700's and 1800's and into the first third of the 1900's, massive, devastating fires continued to plague cities causing a tremendous loss of life as well as extremely costly property damage.

Insurance Industry and Fire Codes

The insurance industry, after massive fires and economic losses, was instrumental in the development of fire codes. One of the first fire codes that was used as a type of model code was developed by the

National Board of Fire Underwriters, later renamed the American Insurance Association. After a number of fires with large loss of life, such as the infamous Triangle Building fire, the National Fire Protection Association (NFPA) began issuing pamphlets in the early 1900's describing the basic requirements for evacuating or exiting buildings safely. These pamphlets led to the development of the NFPA Building Exit Code, later renamed the Life Safety Code. The safety codes along with the insurance driven codes eventually became the foundation for what is currently used in the International Building Code (IBC), the model code developed by the International Code Council (ICC), which has been adopted throughout the country. The International Building Code covers in great detail fire prevention in regard to building construction and design, while the International Fire Code addresses fire issues from the operations of a completed and occupied building.

While fire, safety, and building codes in general have greatly improved over the years, losses from fire are still an ongoing issue. The following is taken from the NFPA Journal Sept/Oct 2011, by Mr. Michael J. Karter, Jr. ...

> *In 2010, public fire departments responded to 1,331,500 fires in the United States, according to estimates based on data NFPA received from fire departments responding to its 2010 National Fire Experience Survey. An estimated 482,000 structure fires were reported to fire departments in 2010.*
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> *The NFPA estimates that the 1,331,500 fires to which the fire service responded last year caused nearly $11.6 billion in property damage. Fires in structures resulted in $9.7 billion in property damage. Of the reported fires, the NFPA estimates there were 3,120 civilian deaths with the vast majority in residential fires. In addition to the civilian deaths, an estimated 17,700 people were injured in fires during 2010. This is approximately a 3.9% increase from 2009 and the highest total since 2005.*

The information noted above from the NFPA reinforces the fact that while the frequencies of fires may be declining, there is still a tremendous impact due to losses from fires. Building codes and insurance requirements have been developed and implemented with the intention of minimizing fire loss.

Roof Systems and Fire

One of the most vulnerable components of a building when exposed to fire is the roof. Roof systems can burn either from fires from within the building or from the top side down. Fires from within are more complex with a multitude of building systems that may influence the fire. External fires affecting the roof are generally simpler as there are fewer components within the roof system. Codes require that roofing systems are tested and classified to meet certain requirements, depending on the building use and occupancy.

There have been various forms of fire codes and insurance requirements for fire protection since the colonial times. What was lacking for construction materials, specifically roofing products, was a method to test products when exposed to fire. It is believed that the first fire test for roofing products was developed by Underwriters Laboratories, Inc. (UL) in 1903. This UL test protocol standardized the evaluation of roof coverings based on their ability to withstand ignition, flame spread, and fire penetration from external fires. In 1910, a new standard developed by the NFPA was adopted which set classifications for roof covers. This standard had three tests — flame exposure, burning brand, and a radiation exposure. The standard also included an investigation to determine the quality of the raw material, weathering and repairability of the roof coverings as applied to the roof system.

There were continuing adjustments and refinements to the fire test standards and reporting up to 1955 when the ASTM Standard E-108, Standard Test Methods for Fire Tests of Roof Coverings was adopted. The last major changes were made to the Standard between 1970 and 1975, mostly with regard to format and test criteria, which is the basis for the current version.

ASTM E-108 Testing – Class A, B, and C Fire Classifications for Roof Coverings

ASTM E-108, which is essentially the same as UL 790 and NFPA 256, evaluates the relative fire characteristics of roof coverings when exposed to external fire sources. There are three classifications defined in the standard, Class A, Class B, and Class C.

The Class A rating is for roof coverings that can withstand severe test exposure, afford a high degree of protection to the roof deck, will not slip, and do not generate any flying brand or embers. Class B ratings are for roof covers that can withstand moderate test exposures, affording a moderate degree of protection to the roof deck, will not slip, and do not generate any flying brand or embers. Class C ratings cover light test exposures and afford a light degree of protection to the roof deck, will not slip, and do not generate any flying brand or embers.

This test standard measures the ability of the roof covering to protect or resist fire from penetrating from the top side of the test deck to the underside. The roof fire penetration tests include the burning brand test (Photo 1) and the intermittent flame exposure test (Photo 2). The standard also measures distance a flame can spread along the top surface, the spread of flame test (Photo 3, a non-penetrating test).

If the intent is to test a roof covering over a combustible type roof deck, then all three tests are done. When the roof deck is noncombustible, such as concrete or steel, or if a combustible deck assembly uses a specific type of gypsum board or similar approved thermal barrier, then only the spread of flame test is conducted.

The spread of flame test uses a constant flame source and a steady air movement to determine the potential for fire to spread across the surface of the roof cover. The maximum length allowed that still achieves a class A rating is six feet, class B is eight feet, and class C is thirteen feet. In all cases the fire cannot spread laterally to either edge of the test sample.

Photo 1 – Burning Brand

Photo 2 – Intermittent Flame


Photo 2 – Spread of Flame

Roof Covering Buildup and Deck Slope

The main variables in the E-108 test method are the components of the roof covering buildup and the slope of the deck. This test method provides a means for comparing roof covering materials as tested according to the standard. There was some concern with the fire test standard as noted in the MRCA and NRCA report dated January 2006. Prior to this report, the MRCA and NRCA did a series of aging evaluations on 109 polymer modified bitumen roof systems. During the study, beginning in 1991, they realized fire resistance is an important attribute for roof covers. In 1996, the MRCA did a limited fire test program following the spread of flame method from ASTM E-108. Four of the roof systems from the study were tested, with half passing.

Based on the results, the MRCA conducted additional fire tests on aged materials in 2001, again to see if aged roof systems maintained their listed fire classification or rating. In this study ten samples were taken from five different roof covering categories: coated modified bitumen, granular surfaced modified bitumen, PVC, TPO, and EPDM. All systems were believed to have been installed as classified fire rated systems. From this round of testing, five of the test decks passed the spread of flame tests; both PVC systems, one from each of the modified bitumen and one EPDM.

In an effort to better understand the failure of the rated EPDM and TPO materials, the MRCA and NRCA conducted additional fire test evaluations, this time with new and aged systems using these membranes. They wanted see if the aged roof cover systems would maintain the listed fire classification as well as verifying that new roof cover systems would meet the listed ratings. This round of testing evaluated thirty-four assemblies, eight new and ten existing EPDM membranes and ten new and six aged TPO membranes. This round of testing also used four different certified testing laboratories, who were instructed to test for spread of flame. Of the thirty-four test assemblies, only thirteen passed, or met the listed classification. Of the test assemblies that passed, nearly all (12 of the 13) included a cover board.

From this round of testing more questions were raised, including the reproducibility of the test method between labs and within the same laboratory, the methods for constructing the test assembles (how the edges are addressed), and how different labs interpret the results (lateral failure to just one or both sides).

ASTM Committee E05 is addressing the issues regarding test method E-108, specifically with the construction of the test decks, interpreting the results, and adding a precision and bias statement to the document.

Sika Sarnafil Tests EPDM, PVC, and TPO

Given the results from the various fire test investigations by the MRCA and NRCA, Sika Sarnafil decided to conduct its own test program to compare the fire test properties of fire retardant EPDM, PVC, and TPO membranes.

We chose two of the most common substrates used with single ply roof membranes; an ASTM C 1289 Type II, Class 1 Grade 2 isocyanurate insulation board (organic black facer, 20 psi compressive strength) and glass faced gypsum board. The slope for the test program was determined after reviewing the classifications for each membrane type and substrate found in the UL Fire Directory. The highest slope for each type of membrane and board combination was charted. From this information we chose the lowest slope for the membrane and board combination. For example ...

With gypsum board as the substrate, the greatest slope found in UL's directory for the TPO membrane that achieves a Class A rating is 3 in 12; for PVC it is a 5 in 12 at the time of the study. Similarly, the EPDM membrane over the Dens Deck has a Class A rating of 5 in 12 for unreinforced adhered membrane, and 4 in 12 for reinforced mechanically attached membranes. Based on this information, all fire testing with the Dens Deck substrate was conducted at a slope of 3 in 12.

Comparing UL Class A fire ratings with isocyanurate insulation as the substrate, the TPO membrane has a maximum slope of 0.5 inch in 12, the PVC is at a 2 in 12 and the EPDM achieves a Class A at a 0.5 inch in 12 for unreinforced adhered membranes and 0.75 inch in 12 for reinforced mechanically attached membranes.

U. L Fire Ratings, Class A Assemblies

	EPDM FR rated membrane	TPO	PVC	Test Slope
Isocyanurate	0.5/12 to 0.75/12	0.5/12	2/12	0.5/12
Gypsum board	4/12 to 5/12	3/12	5/12	3/12

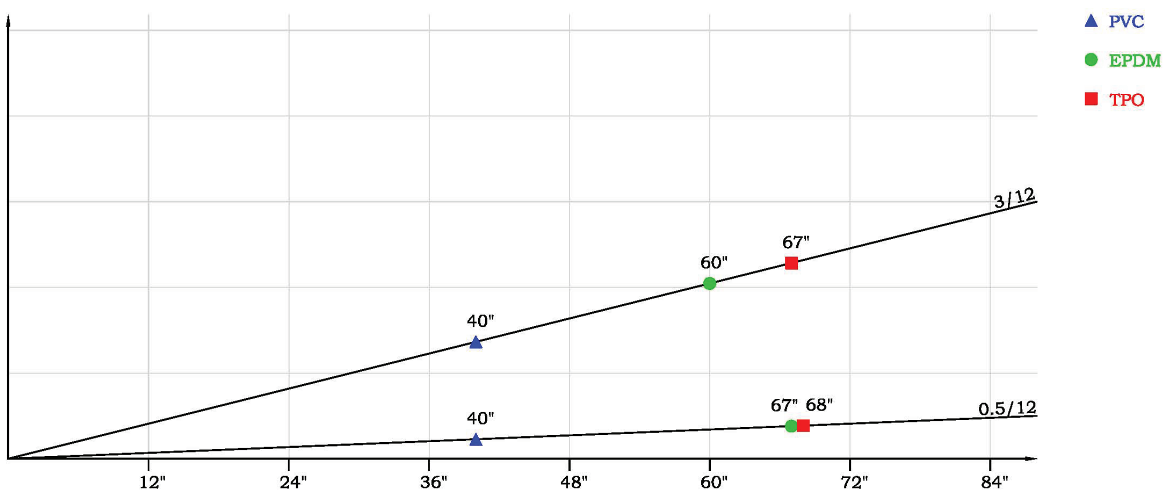
Testing the three membranes to the noted slope per substrate allows for a direct comparison between the membranes and the specific board substrate, providing comparative information on how each membrane burns.

All of the membranes were wrapped over the edges and secured to the wood side rails with roofing staples. The test method followed the ASTM E-108 and UL 790 standard for spread of flame. The distance of the flame spread was recorded as well as the lateral distance every twelve inches beginning from the leading edge. The time of ignition as well as the time to reach the maximum flame spread was recorded. All testing was completed in the same day and done by the same technician at the same laboratory.

	Gypsum Board – Slope 3/12			ISOCYANURATE – Slope 0.5/12		
Membrane	Max Flame Spread	Time to Max Flame	Class	Max Flame Spread	Time to Max Flame	Class
EPDM FR rated membrane	67"	4:03	A	60"	2:30	No rating **
PVC	40"	0:54	A	40"	1:35	A
TPO	68"	8:18	A	67"	8:02	A

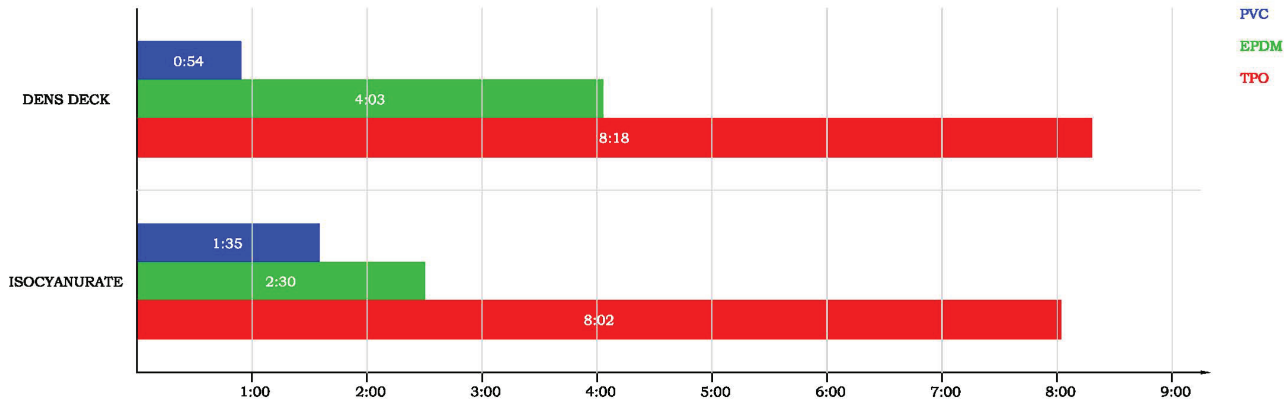
** Lateral spread of flame both to the right and left sides, starting 18 inches from the leading edge and proceeding for 24 inches. Smoke generation was similar for all test frames.

The graph below shows the comparison between the three membranes flame spread for each substrate and tested slope combination (Iso at 0.5" and DD at 3"). The results show that the PVC membrane with a significantly lower flame spread indicating that the membrane has a much greater resistance to spread of flame than the other membranes tested at the same conditions.



MAX. SPREAD OF FLAME

The time duration for the fire to reach the maximum flame spread was significantly shorter for the PVC membrane than either of the other membrane types, for both substrates. Of important note, the flame on the PVC membrane did not sustain the fire, in essence the membrane self-extinguished. The EPDM membrane burned four times as long and the TPO membrane eight times as long as the PVC membrane with the gypsum substrate. The following graph illustrates the time differences between the membranes over each substrate. The shorter the bar on the graph the better the fire performance of the roof cover, as the system is not sustaining the fire.



TIME TO MAX. FLAME

The burn patterns for the PVC show a very uniform triangular shape for both substrates (Photos 6 and 9). The TPO membrane has an elongated triangular shape with the gypsum substrate (Photo 5) and an irregular burn pattern for the isocyanurate (Photo 8). The EPDM membrane has a very irregular burn pattern for both substrates, including a lateral spread off the test deck, (Photo 4 with gypsum board and Photo 7 with Iso).

Photo 4 – FR rated EPDM over Dens Deck, very irregular flame pattern

Photo 5 – TPO over Dens Deck

Photo 6 – PVC over Dens Deck

Photo 7 – FR rated EPDM over Iso, excessive lateral flame spread

Photo 8 – TPO over Iso

Photo 9 – PVC over Iso, side view

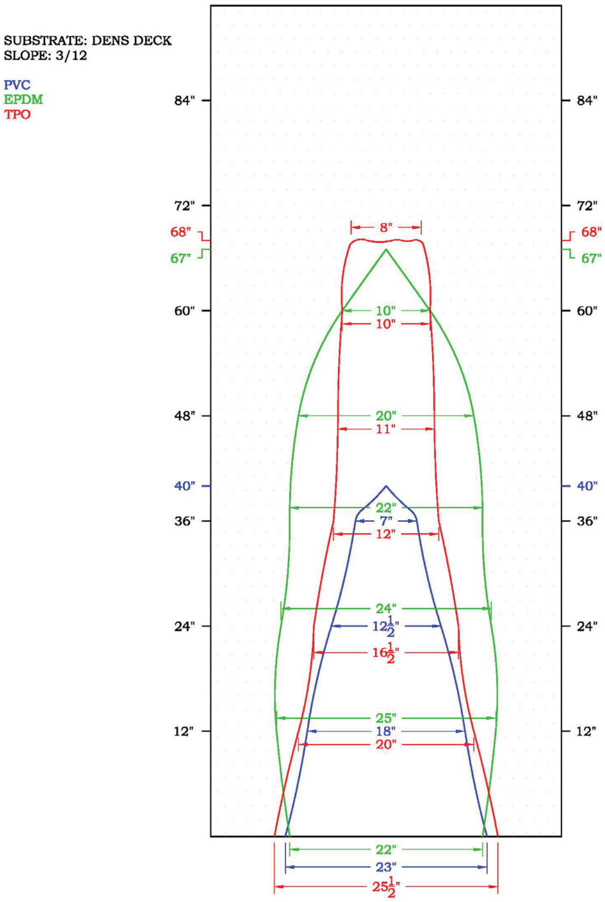


Figure 1

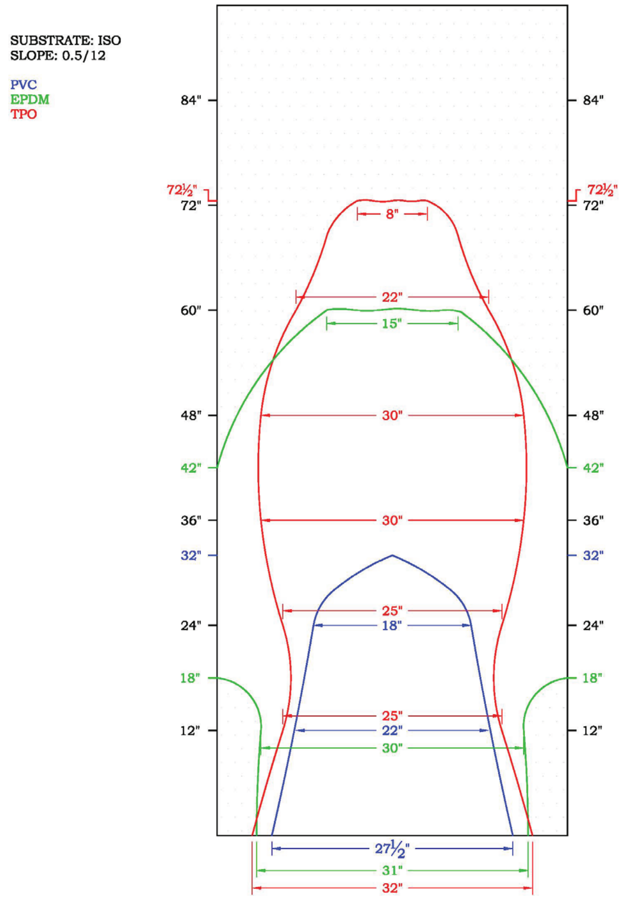


Figure 2

Figures 1 and 2 illustrate the measured patterns for the three membranes over the two substrates. The PVC has a very compact burn pattern for both substrates, especially when compared to the other membrane types. The ASTM E-108 spread of flame test, while basically a system test, does offer an opportunity to see how different roof covers burn. The isocyanurate does provide fuel to the test construction, which allows the fire to propagate as shown by the additional lateral spread of flame for all three membranes. When the roof covers are placed on the fire resistant gypsum board, little to no fuel is added to the fire. This assembly provides a good idea on how well the roof membranes resist the spread of fire. The PVC roof cover has almost 60 percent better spread of flame resistance than the other membranes.

Vertical Strip Fire Test

Another test method to show how different roof membranes perform when exposed to fire is a vertical strip fire test. With this test, samples of roof membrane cut at 75 mm (3 inches) wide by 170 mm (6.7 inches) long strips are fixed to a hanging device. A gas flame is placed in contact with the sample and left in place for 15 seconds, at which time the flame is removed. The test records the time for either the flame to extinguish or consume the sample. An example of this test can be seen at **www.vinylroofs.org/durability/vinyl-fire-performance/index.html**. The test recorded on this web site was conducted by

Southwest Research Laboratories (SwRI) in San Antonio TX. This test shows that the PVC membrane will self-extinguish within seconds of having the gas flame removed. Both the EPDM and TPO membranes will burn until fully consumed. Similar to the spread of flame test deck with the gypsum substrate, this test shows how the different roof membranes react when ignited.

PVC and Fire Resistance – Real World Examples

One of the strengths of a PVC roof membrane is the ability to "self-extinguish" and resist spreading the fire. There are documented events where the PVC roof membrane helped contain a fire and limit the amount of damage to the building, its occupants, and equipment. One example is the Ballantyne facility in Omaha, NE. The fire started at a heat stack and moved upward to the roof surface. The PVC roof membrane resisted spreading the fire, according to Mike Connolly of D.C.Taylor company, the installing roofing contractor, thus limiting damage to the exterior in the immediate vicinity of the stack, as seen in Photo 10.

Photo 10 – Heat stack, Ballantyne facility

A PVC roof is credited for protecting a number of businesses from being destroyed following a fire in North Bay, Ontario. The fire started in the Motion Canada building and began spreading to other sections. The building owner, who acknowledged that their fire hydrants were not operative, and the fire department, who had little to no water to battle the fire, credit the PVC roof membrane with preventing the fire from spreading.

In yet another example, a roof mounted lighting system at the Toyota Center, Houston TX short-circuited on a number of occasions, causing fires. The fires were never able to propagate across the surface of the PVC roof membrane, thereby limiting the damage and preventing a potentially dangerous situation from developing (see Photos 11 and 12, next page).

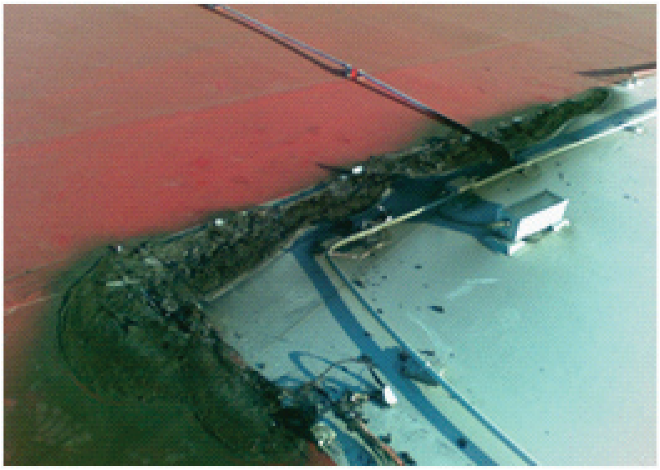


Photo 11

Photo 12

With the increased use of the rooftop as a platform for installing solar photovoltaic systems, there is also an increased possibility of a rooftop electrical fire. Fires that may be a result from a rooftop PV installation present unique and dangerous challenges to fire fighters due to the fact that the PV panels continue to generate electricity as long as they are exposed to sunlight, increasing the risk of rapid fire spread across the underlying roof surfaces. With their superior ability to minimize the spread of flame and to self-extinguish, PVC membranes provide important life safety benefits on roofs upon which PV arrays are to be installed.

Summary

Building codes including fire safety codes continue to evolve and provide additional security for building occupants. While tremendous strides have been made in reducing fires and the resultant property damage, injuries and deaths, the construction industry should work to continuously improve through better construction practices. As part of the building industry, roofing specifiers and contractors must take fire safety seriously in design and specifications. Specified roof systems should at a minimum be a tested and listed assembly with one of the certified testing agencies approved by the building code. However, they must be mindful that specifying to a minimum standard is not necessarily in the best interest of the building owner. Testing by various sources has shown that there is a significant performance difference among various roof membrane types.

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About the Author

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He has 30 years of experience in the roofing industry and previously held managerial positions with JM and BondCote.

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