In 1953, the 14 ha (34 acre) General Motors (GM) transmission plant in Livonia, Michigan, was destroyed by a localized internal fire, which was fueled by the roof covering assembly and eventually engulfed the entire building. Although memory of the original fire has faded, insurance carriers and building codes continue to address the potential involvement of roof covering assemblies in building fires. The extent to which such involvement contributes to the spread of fire within a building is a major factor in the assessment of life safety and insurance risks.

**What Happened in Livonia?**

The roof covering on the GM Livonia plant consisted of a large, continuous expanse of steel roof deck, insulated with mineral fiber board that was adhered with asphalt and topped with a BUR heavily laden with asphalt. An internal fire accidentally started. Fueled by the contents of the building, heat from the developing fire collected under the roof covering assembly. Percolation of the combustibles in the roofing assembly caused hot gas pressure to build and force its way through joints in the steel deck, where it was ignited by the fire already working inside the building. Asphalt materials were also forced through the joints in the metal deck, spreading the fire across the entire facility.

Most roof covering systems contain some combustible materials such as vapor retarders, adhesives, insulations, and membranes, though most are not close to the fuel level of the Livonia roof. Heat from an internal fire is readily transmitted to combustibles above the metal deck, making fire spread under the steel deck a possibility.

After the Livonia fire, building codes did
Fire Spread Under Steel Roof Decks
not generally adopt rules addressing potential contribution of combustible roof coverings to underdeck fire spread. Control of this phenomenon was left to property insurers. In the mid 1970s, when foam plastic roof insulation entered the market, the only test standards available to building codes to address this concern were standards developed after Livonia.

It is interesting to note that, although foam plastics are subject to the standards developed after Livonia, there were no foam plastics in the Livonia roof, and there is nothing in today’s model building codes that prohibits the use of the same BUR/mineral fiberboard roof covering laboratories, Inc. (UL) participation, conducted a series of tests at the FM facility in Norwood, Massachusetts. The fire test structure, painted white and now known as the “white house,” was a masonry structure 6 m wide, 30 m long, and 3 m high (20 ft wide, 100 ft long, and 10 ft high). One 6 m end was left open.

The additional UL test method uses a collection hood and duct system prescribed under various nationally recognized fire test procedures, including the standard Fire Test of Interior Finish Material, UL 1715.

An ignition source consisting of two nozzles that atomized heptane fuel was provided at the closed end. Blowers were used to introduce combustion air. Five test roofs over steel decking were separately tested on top of the white house. Five tests were conducted to establish the limits of acceptable and unacceptable fire performance. A reconstruction of the Livonia roof deck assembly spread fireing, but the insulation was mechanically fastened to the steel deck.

**White House Research**

After the GM fire, Factory Mutual Research Corp. (FM), with Underwriters Laboratories, Inc. (UL) participation, conducted a series of tests at the FM facility in Norwood, Massachusetts. The fire test structure, painted white and now known as the "white house," was a masonry structure 6 m wide, 30 m long, and 3 m high (20 ft wide, 100 ft long, and 10 ft high). One 6 m end was left open.

The additional UL test method uses a collection hood and duct system prescribed under various nationally recognized fire test procedures, including the standard Fire Test of Interior Finish Material, UL 1715.

**Evolution of FM 4450 and UL 1256**

The large-scale white house fire test was very expensive to conduct. In response, FM and UL investigated the use of smaller scale fire test methods. From these investigations, two methods, differing in concept and technique, were develop-
veloped. The methods, developed in the late 1950s, are still in use today, and are described in the Approval Standard for Class I Insulated Roof Decks, FM 4450, and Fire Test of Roof Deck Constructions, ANSI/UL 1256.

The FM test method uses a construction materials calorimeter 1.5 m wide, 5.3 m long, and 1.14 m deep (5 ft wide, 17 ft 6 in. long, and 3 ft 9 in. deep). It will accept a 1.2 x 1.2 m (4 x 4 ft) sample of the roof covering assembly including the steel deck. Pass/fail is judged by applying limits on fuel contribution from the roof covering expressed in BTUs per unit of time.

The UL method uses the tunnel furnace described in ASTM E-84 (UL 723). The tunnel is most often used to determine the surface burning characteristics of building materials. The sample roof assembly, including steel deck, is covered with a refractory lid that completely encapsulates the top side of the roof covering assembly. Pass/fail is determined by measuring fire spread rate along the tunnel's length.

UL and FM determined acceptable levels of performance in their respective small-scale tests by testing various assemblies and comparing results to the identical assembly results acquired in the white house test series. Unlike fiberboard or mineral insulation, foam plastic insulation was considered a source for potential contribution to an interior fire. According to Ken Rhodes, associate managing engineer at UL, “Early recommendations for all foam plastics required their separation from the steel deck by a thermal barrier, typically gypsum board, to delay the time at which the lowest critical temperatures for the foam plastic would be reached.”

The white house is now being used to validate the additional UL test method intended to assess roof deck constructions that contain polyurethane directly over steel decks.

Manufacturers of polyurethane insula-

The limits established for both the UL and FM test procedures were based on measurement of the level of combustibles, primarily asphalt, felts, and insulation materials that will not contribute to unacceptable underdeck fire spread, based on the white house test series.

**Foam Plastic Insulation**

With the introduction of combustible foam plastic roof insulation in the mid-1970s, questions were raised regarding the behavior of the insulation when exposed to understeel-deck interior fires. UL performed the white house tests under separately sponsored programs. In conjunction with these tests, UL 1256 small-scale tests were also conducted. From the data developed, it was determined that the criteria established under the UL 1256 standard were viable for
subsequent evaluation and classification of polyurethane systems without thermal barrier protection. FM also considered the use of its calorimeter procedure viable for these types of systems.

When polystyrene manufacturers sought a direct-to-steel-deck listing, UL again considered a large-scale white house fire test to be necessary, as with polyurethane. UL did, however, recognize a significant difference in the behavior of thermoplastic polystyrene. It melts when subjected to the heat of a developed and working internal fire source. Unlike the charring exhibited by mineral and vegetable fiberboard and thermoset foam plastics, polystyrene board soon diminishes to molten material. This behavior permits an early fire breakthrough of the roof covering, releasing the hot gases that drive fire spread, thereby limiting spread.

It was this unproven theory of performance that led to a large-scale white house fire test in 1986. Data from the test showed that polystyrene insulation combined with a single-ply roofing membrane not only met previously acceptable standards for large-scale performance, but was under the acceptable standard by 25 percent. Based on this data, a classification was promulgated under UL's Roof Deck Construction category and detailed under Construction No. 260.

Another Test Method

As with polyurethane, small-scale test procedures for polystyrene were desirable to evaluate systems without incurring the expense of the large-scale white house fire test. However, ANSI/UL 1256 testing, conducted under the sponsorship of various manufacturers, showed that polystyrene insulation often approached that used successfully in the 1986 large-scale white house test, unacceptable flame spread occurred. According to Rhodes of UL, “It was concluded that the release of hot gases, inherent in the performance of polyurethane and polystyrene in the large-scale white house structure, cannot occur in the tunnel furnace where test specimens are backed with a refractory lid assembly.”

Based on the observed inconsistencies between the large-scale white house results, the foundation of all underdeck testing, and the UL 1256 method, it was concluded that another, smaller scale fire test method was needed. Therefore, UL developed a test procedure that permits the release of heat energy to the atmosphere, an occurrence in every large-scale white house test.

It is not necessary to quantify the heat energy released harmlessly to the sky, much as smoke developed in roofing assemblies is not quantified or regulated in current building codes. However, it is necessary to verify that a given assembly allows energy to be released. Testing has shown that different insulation thickness and cover board combinations produce differing results with regard to energy release.

The additional UL test method uses a collection hood and duct system prescribed under various nationally recognized fire test procedures including the standard, Fire Test of Interior Finish Material, UL 1715. The test structure is a masonry room 2.4 m wide by 3.7 m long by 2.4 m high (8 ft wide by 12 ft long by 8 ft high), with one 2.4 m wide end opening. Bepane fuel burners are used to provide the internal fire source.

The test method uses oxygen consumption calorimetry to quantify the roof covering material's contribution to the underdeck fire source by capturing effluent from beneath the roof assembly and recording the rate of heat production in kW per minute. Acceptance is based on comparison of data with that developed under this procedure for the original polystyrene directly on deck assembly that was successfully tested in the large-scale white house test.

Standardization of the Test Method

Since 1953, UL has used the large-scale white house test procedure in approximately 10 client-sponsored investigations. The white house test procedure is now being used to validate the additional UL test method intended to assess roof deck constructions that contain polystyrene directly over steel decks.

To complete validation and acceptance of the test, several new white house tests are being conducted by Omega Point Laboratories under the supervision of UL, and sponsored by the Foamed Polystyrene Alliance (Resin Supplier Council and Extruder Council) of the Society of the Plastics Industry. Once the planned testing is completed, UL will document the white house test and the additional UL smaller scale fire test procedure and acceptance criteria.

The methods will be reviewed under the UL standards revision process and, upon completion, will be submitted to the ANSI approvals process as an incorporation into ANSI/UL 1256.

As the additional UL test is validated to the satisfaction of all industry interests, the standardization process will facilitate adoption by regulatory authorities of the historical large-scale white house test, and the additional small-scale test procedure.

In the meantime, two of the U.S. model code agencies, BOCA ES and SBCCI PST and ES1, have reviewed and accepted the additional UL test method as a valid measure of underdeck fire spread performance and have issued technical reports to that effect. The reports were released under typical building code evaluations that allow the introduction of new methods and materials when proper engineering and life safety justification is provided by the applicant. A third U.S. model code agency, ICBO ES, is reviewing the matter.

Note

To ensure an understanding that foam plastic insulation is combustible; many manufacturers print in their literature notes that it will ignite if exposed to fire of sufficient heat and intensity. See individual manufacturers’ literature for specific statements and instructions regarding its proper use in construction assemblies.

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