UNVENTED ATTIC ASSEMBLY TEST PROTOCOL – A CRITICAL REVIEW OF THE PROTOCOL

Prepared For

AMERICAN CHEMISTRY COUNCIL'S SPRAY FOAM COALITION

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1. FORWARD

The International Building Code (IBC) and the International Residential Code (IRC) require foam plastic insulation to be protected by a thermal barrier[1] with specific and limited uses where this thermal barrier is not required. One of these uses is when the foam plastic is installed within attic spaces meeting certain prescribed conditions whereby the code requires protection of the foam plastic from becoming involved in the fire (i.e., protected by an ignition barrier[2]). In these attics, the ceiling assembly separating the interior occupied (IBC) or habitable spaces (IRC) from the attic space must contain a prescribed thermal barrier. The Special Approval (2021 IBC Section 2603.9[3]) and Specific Approval (2021 IRC Section R316.6[4]) sections allow for the approval of uses without the prescribed thermal barrier or ignition barrier materials based on large scale fire testing that is representative of the actual end use configurations. In simple language, the code contains provisions to qualify uses of foam plastic with alternative protective materials or with no protective covering based on large scale performance testing of the actual end use. Two ANSI reference standards developed for spray polyurethane foam (spray foam) insulation products, ICC-1100[5] and IAPMO/ANSI ES1000[6], refer to uses qualified by end use configuration testing under the Special or Special Approval sections as "alternative thermal barrier assemblies" and "alternative ignition barrier assemblies" depending on the protection required prescribed for the use. This report will use the "alternative ignition barrier assembly" term.

The 2021 and earlier editions of the IBC and IRC reference several standard large scale test methods as examples to use for Special or Specific Approval qualification testing, but the Code does not limit the code to the four referenced standard test methods. Although Special or Specific Approval sections of the IBC and IRC do not provide specific test requirements for ignition barriers or alternative ignition barrier assemblies, the Code does provide guidance to qualify ignition barriers through the requirement that testing is "related to actual end use conditions."

In 2008-2009, a task group of the Spray Polyurethane Foam Alliance (SPFA) sought to develop a test procedure for adoption by the ICC Evaluation Service (ICC-ES) to qualify alternate ignition barrier assemblies for uses of spray foam under ICC-ES Acceptance Criteria for Spray-applied Foam Plastic Insulation (AC377). The task group performed a series of multiple large-scale fire tests (NFPA 286) comparing fire performance of alternative assemblies against that of assemblies with selected ignition barriers materials prescribed in the IBC and IRC. This comparative testing led to the development of what became Appendix X of ICC-ES AC377, a modified NFPA 286 test with acceptance criteria and limitations for uses in attics and crawl spaces meeting certain conditions. The task group determined

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[1] Thermal barrier requirements are found in IBC Section 2603.4 and IRC Section R316.4 and require foam plastics to be separated from interior spaces except as provided for in IBC Section 2603.4.1 Thermal barrier not required, IBC Section 2603.9 Special approval, IRC Section R316.5 Specific requirements, and IRC Section R316.6 Specific approval.

[2] Ignition barrier is not a phrase defined in the IBC or IRC but refers to a barrier required to protect foam plastic in unoccupied attics and crawl spaces to increase the time it takes for the foam to become involved in the fire. (See IBC Section 2603.4.1.6 and IRC Sections R316.5.3 and R316.5.4)

[3] Section numbers may differ for previous editions of the IBC.

[4] Section numbers may differ for previous editions of the IRC.

[5] ICC-ES 1100-2019 Standard for Spray-applied Polyurethane Foam Plastic

[6] IAPMO/ANSI ES1000-2020 Standard for Building Code Compliance of Spray-Applied Polyurethane Foam

that the full room size performance of an ignition barrier was adequately evaluated using Appendix X. After the development of Appendix X, several spray foam system manufacturers worked individually to continue to study how unvented attics perform in a fire. This research led to the development of an alternative means to evaluate the need for ignition barrier assemblies in unoccupied attics and crawl spaces.

In 2011, the ICC-ES announced a program whereby building product manufacturers could collaborate with and access enhanced fire testing expertise of ICC-ES's designated fire consultant, Priest & Associates.[7] This relationship provided an opportunity for manufacturers to explore additional approaches to evaluate alternative ignition barrier assemblies and the fire performance of unvented (or unventilated) attics and crawl spaces. Before the development of Appendix X, manufacturers had qualified foam products for use in attics without ignition barriers using other test methods. The results differed from the results yielded by Appendix X. Thus, given the difference in test methods and results obtained, there was significant interest in answering questions as to what fundamental factors were truly important in terms of fire performance of foam in attic end uses. This research led to the development of a series of tests to qualify alternative ignition barrier assemblies for unvented attics and crawl spaces. This series of tests is known as the Unvented Assembly Test Protocol (UVAATP).[8] The series of tests is described in Section 4. The relationship between ICC-ES and Priest & Associates was sunset in the mid-2010s.

The development of the UVAATP is, in part, a response to information from the Federal Emergency Management Agency's (FEMA) National Fire Incident Reporting System (NFIRS). The FEMA data identified a variety of causes of attic fires providing a basis for developing a test procedure based upon the specific fire risks in such spaces.

Beginning in 2010, third-party certification agencies started to recognize the use of spray polyurethane foam insulation in unventilated attic assemblies qualified using the UVAATP. By the early 2020s, a majority of the spray foam industry had obtained recognitions for this use, based on the UVAATP, from ISO/IEC 17065 accredited organizations such as ICC-ES, Intertek, and DrJ Engineering. The use of the UVAATP has been used extensively since that time without any adverse fire experience reported by NFIRS.

Through the end of 2020, the research and test data has been treated as proprietary information since manufacturers performed the testing and evaluation independently. Koffel Associates, Inc. was asked to examine the work carried out by eight manufacturers and assess the rigor of the method and any identifiable trends in the data to increase transparency and build public confidence in the UVAATP and the approaches it uses.

The UVVATP demonstrates, through full-scale testing and computer modeling, that should ignition of the insulation occur in the attic, the assembly reaches a condition that does not support combustion very quickly (on the order of 1 minute or less) followed by cooling and remains resistant to subsequent re-ignition.

[7] https://icc-es.org/announcement/icc-es-expands-its-expertise-in-fire-resistance-and-flammability-requirements/

[8] The method has also been referred to as the "End Use Configuration Test" or "Oxygen Depletion Test."

2. INTRODUCTION

Eight spray foam manufacturers and subsequently the American Chemistry Council's Spray Foam Coalition retained Koffel Associates, Inc. to perform an independent, third-party analysis of their respective end-use configuration testing, under the UVAATP, used to qualify the products as complying with the alternate ignition barrier assembly requirements of the *International Building Code* (IBC) and the *International Residential Code* (IRC), using the Special Approvals sections. In each case, the manufacturers had previously retained Priest & Associates Consulting, LLC, hereinafter referred to as "Priest," to propose the fire testing plan, review the fire test results, perform computer modeling, and prepare a summary evaluation report. For purposes of this analysis, the series of tests and the Priest reports for the following products were reviewed. To the extent that similar testing and modeling may have been performed by Priest for other manufacturers, the reports for those manufacturers were not reviewed. The reports that were reviewed are:

- BASF Enertite NM, Open Cell for Unvented Attics
- Demilec Selection 500 ½ lb Open Cell SPF
- GACO F4500 oc SPF
- Icynene LD-C-50 Spray Foam for Unvented Attics
- Johns Manville Corbond® Open Cell
- NCFI Polyurethanes InsulStar® Light
- Carlisle SealTite™ Pro Open Cell
- SWD Urethane Quik-Shield I 106.5 lb Open Cell

3. BACKGROUND

The purpose of the testing and evaluations was to review end-use configuration tests developed in consultation with various evaluation agencies to recognize alternative assemblies for Code Evaluation Reports, in accordance with the provisions of the IBC, IRC, and ICC-ES AC 377, ICC-1100, and IAPMO-1000. More specifically, IRC Section R316.6 and IBC Section 2603.9 clearly state that foam plastic insulation can be qualified for use in assemblies without requiring an ignition barrier where the assembly is approved, by one of the following tests: NFPA 286 with the acceptable criteria of sections in the code, FM 4880, UL 1040 or UL 1715 or other acceptable (large scale) test. The specific approval shall be based on an actual end-use configuration and shall be performed on the finished foam plastic assembly in the maximum thickness intended for use. Additionally, ICC-ES AC377 (April 2020, editorially revised July 2020) Section 3.3.9 states:

> **3.3.9 Alternative Qualification Methods:** Recognition of specific products or systems may be based on end use, quantity, location and similar considerations, where testing described in Section 3 of these criteria is not applicable or practical. In accordance with Section 2.7, alternative qualification methods shall be submitted to and approved by ICC-ES staff prior to any testing being conducted.

4. THE UNVENTED ATTIC ASSEMBLY TEST PROTOCOL

The Priest evaluations considered a number of full-scale end-use configurations of attics, large- and small-scale testing, modeling and analysis. The testing and fire modeling protocol was intended to demonstrate whether a fire initiated in an insulated, unvented attic with an exposed foam plastic performs equal to or better than a fire in an attic with a foam plastic that has been qualified by another method (e.g., a prescriptive ignition barrier or an alternative ignition barrier assembly qualified under ICC-ES AC377 Appendix X). The evaluations were intended to validate acceptable performance of the foam plastic qualified as an alternative ignition barrier assembly. Testing, modeling and analysis considered the following:

- Minimum and maximum thickness of foam plastic.
- Room geometry, including volume (minimum and maximum), shape and roof slope.
- Potential ignition and fire sources.
- Effect of openings to the attic space, including, but not limited to, the attic entry, direct venting for appliances and unintended openings.
- Comparable performance with systems that meet the requirements of ICC-ES AC377, Appendix X.

The UVAATP includes a number of small- and large-scale tests that exhaustively consider a wide variety of fire issues related to the attic end-use application of the subject foam:

1. Small scale behavior and material testing:

    a) ASTM E-84 - Standard Test Method for Surface Burning Characteristics of Building Materials
    b) ASTM E-970 - Standard Test Method for Critical Radiant Flux of Exposed Attic Floor Insulation Using a Radiant Heat Energy Source
    c) Ignition Sources (or Other Small-Scale Testing)– typically a variety of tests were used to assess risks for workers doing maintenance in attics. Risks could include inadvertent ignition of foam with torches, cigarettes, malfunctioning electrical work etc. These tests were typically videotaped and reviewed. Some of the reports expanded this to a broader set of tests of differing ignition sources including cigarettes and various types of torches with varying exposures.

2. Room Size testing (768 ft3): The room size tests generally used room geometry taken from existing thermal barrier tests and modified the rooms so that entry was from a standard code compliant attic hatch (See. IRC 2018 Section 807.1) versus the entry door. There were some deviations noted in the room and representative assembly tests that were performed as referenced in each Priest Report, but they typically included a) through d) below. The total smoke release was determined for several of the room fire tests to address the specific requirement in the IBC for meeting the requirements of Section 803.1.1.1 when NFPA 286 is the test that is used. Pressures and temperature measurements were taken throughout the duration of the tests as an indication of combustion and cool down within the rooms.

    a) Performance with an open attic hatch and poorly sealed attic floor assembly simulated the likely scenario that if the primary air barrier for the building was at the roof level, then the floor of the attic was likely to be leaky as a result of electrical, plumbing and other penetrations. The attic hatch would then add to this leakage if left open for the purposes of the test(s).

b) Performance with a sealed hatch / sealed floor assembly; this testing was carried out to simulate the impact of inadvertently sealing the floor of the attic.
c) Performance with different thicknesses of foam.
d) Performance with a variety of penetrations (plumbing, vent pipes etc.) in the attic floor and/or roof assembly.
e) Comparative performance to a Code accepted foam product qualified by other means – It should be noted that at least one product was approved without this comparative test.

3. Large-Scale Testing and Computer modeling:

   a) Large scale (at least 3x volume) tests.
   b) Computer modeling with NUREG model.
   c) Computer modeling with CFAST model.
   d) Calibration of the modeling with room size and large volume (3x volume) attic fire tests.

Room Size and Large-Scale Testing

The UVAATP consists of several large-scale tests. In each room fire test, several basic performance parameters were measured. Measurements of attic leakage, hatch opening force, heat flux, room pressure and temperatures were carried out. Smoke release was only measured in Test #1 since that information is needed to compare to the IBC code - 1000 m2 allowed for NFPA 286 volume.

For each test, the burner temperature was monitored with a thermocouple 12 inches above the burner surface.

For this analysis, the following parameters were measured: time until the fire dissipated and the conditions in the space no longer supported combustion; observation of room temperatures to monitor re-ignition for at least 5 hours; char depths, and wood or structural damage due to charring.

The thermocouple map for each test is shown below:

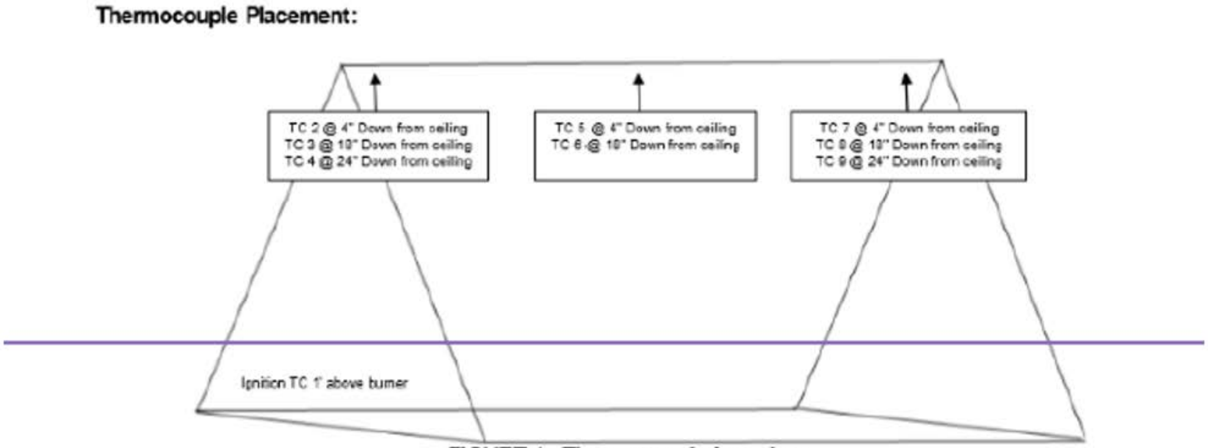

FIGURE 1. Thermocouple Locations

TC 1 – 1 ft above burner

TC 2, 3, 4 – ¼ distance of room length (4", 18", 24" below ceiling)

TC 5, 6 – ½ distance of room length (4", 18" below ceiling)

TC 7, 8, 9 – ¾ distance of room length (4", 18", 24" below ceiling)

The time until the fire dissipates and no longer supports combustion is defined as the time after ignition of the foam at which the room temperatures reached a peak and began to drop dramatically as determined by the upper layer temperatures. This determined the fire growth rate to determine the T2 constant for modeling from Test #1. Since the burner was ignited with a ball of newspaper (approx. 10 to 15 kW), the start of the fire growth rate is defined as the time at which the slope of the upper layer temperature increased at a rate much faster than the temperature slope during the burning of the newspaper ball.

For lab safety reasons, the gas supply was shut off as soon as the burner temperature began to drop dramatically (below 900°F) due to oxygen depletion (to avoid filling the room with propane gas). In some cases, the fire dissipated and conditions in the space no longer supported combustion before the burner was extinguished due to localized oxygen availability at the floor level of the room.

The more important parameters (the time for the fire to dissipate and the conditions in the space no longer supported combustion, Re-Ignition, Char Depths, and Wood Structural Damage) are reported and analyzed.

Large-Scale Fire Test #1 - 1X Volume

The purpose of this test is to prove whether the fire in the unvented attic assembly will dissipate until conditions in the space will no longer support combustion and remain extinguished. The attic is constructed to have the same volume as an NFPA 286 test (1X volume), except the plan view size is different to accommodate a pitched roof (20/12). The construction utilizes real construction details such as plywood decking, wood trusses (20/12 pitch), gypsum wallboard floor deck (i.e., ceiling of living area), and a real attic hatch (ladder-type, wood construction with aluminum ladder that opens toward the living space). The hatch was closed at the start of this test. Smoke release, attic leakage, hatch opening force, heat flux, room pressure and temperatures were monitored. Smoke release was measured since that information is needed to compare to the IBC code – 1000 m^2 – allowed for NFPA 286 volume. This test also serves as the baseline for the modeling calculations.

Large-Scale Fire Test #2 – 1X Volume **–** small ignition source on flat gable surface – (not in corner)

The purpose of this test is to evaluate the flame spread properties of small ignition sources not in the test corner. The room was the same as Test #1. The Ignition tests indicate that uncontrolled flame spread can only occur if a fire of sufficient size persists at the test corner. This test uses a premixed gas burner producing a 4-to-6-inch flame directed at the bottom of the vertical gable near the hatch opening. The burner is angled slightly toward the foam for direct flame impingement.

Large-Scale Fire Test #3 - 1X Volume – but hatch open

The purpose of this test is to determine the extent of potential damage to the roof deck. The attic is constructed to have the same volume as an NFPA 286 test (1X Volume), except the plan view size is different to accommodate a pitched roof (20/12). The construction utilizes real construction details such as plywood decking, wood trusses, gypsum wallboard floor deck (i.e., ceiling of living area), and a real attic hatch (ladder-type, wood construction with aluminum ladder that opens toward the living space). The hatch is open at the start of this test. This test is designed to show the effect of product thickness in unvented attics and the effect of the attic hatch being open.

Large-Scale Fire Test # 4 –3X Volume (2,304 ft^3)

The purpose of this test is to show the effect of attic shape/size/volume/pitch in unvented attics, and to show that the fire model results for larger structures is reasonably accurate. The design is similar to Test #1 except the attic is larger by a factor of 3X the volume and of a different shape and pitch (12/12). Attic leakage, hatch opening force, heat flux, and temperatures are monitored.

Large-Scale Fire Test #5 - 1X Volume

The purpose of this test is to determine what happens if a homeowner creates a ventilated condition in the unvented attic. This test represents a worst-case scenario, allowing a fire to exhaust upward and intake air from the bottom. Computer modeling is conducted on this scenario. The test is designed to show the effect of unintended ventilation in unvented attics. The design is similar to fire test #1, except that the attic contains a hole in the roof (6 in. x 6 in. at topmost location where foam peaked internally) and the attic hatch was open during the test. The roof vent dimension was chosen based on mathematical fire modeling. The opening depicts the maximum size for which the fire remains controlled (i.e., not a continuous flashover). Attic leakage, hatch opening force, heat flux, and temperatures were monitored.

In all of the testing, the containment of the fire was reviewed. In the larger tests, the fire would typically reach a point where the environment in the unvented attic would not support further combustion. In smaller tests, removal of the fire source, generally meant that combustion would not be sustained. In some of the testing, where the attic walls, roof and floor were tightly built, combination of a tight attic and a closed attic hatch was found to be sufficient enough to allow pressures to build up. The creation of by-products of combustion and elevated temperatures caused gasses to expand. An outward opening attic hatch was added to the design criteria to account for this possibility. Similarly, in tests where the attic hatch did not open (usually because the floor of the attic was sufficiently leaky to avoid pressure build-up) or where the attic hatch opened and then closed, the attic hatch was manually opened to simulate the effect of additional oxygen entering the room after the fire was contained.

Attic fire tests specimens were typically left for at least 5 hours untouched to verify that fires did not spontaneously re-ignite.

The UVVATP demonstrates, through full-scale testing and computer modeling, that should ignition of the insulation occur in the attic, the assembly reaches a condition that does not support combustion very quickly (on the order of 1 minute or less) followed by cooling and remains resistant to subsequent re-ignition.

5. ANALYSIS OF THE UNVENTED ATTIC ASSEMBLY TEST PROTCOL

As stated above, the Special Approval sections of the IBC and IRC that allow for the qualification of alternative ignition barrier assemblies specifically do not limit the code user to only the four standard test methods identified. In fact, none of the four tests are intended to address the requirements for an ignition barrier. In practice, Evaluation Services collaborate with industry and review testing protocols to answer the fundamental performance questions they have. A summary of the discussion between ICC-ES and Priest is included in Appendix A. Frequently tests are redone or are reanalyzed if fundamental concerns arise. Based on Code requirements the testing had to include large-scale tests. Ultimately, the IBC and IRC require that the code official approve the use of the UVAATP or any other alternative test procedure that:

- Include large-scale test
- Relate to the end-use configuration of the foam plastic.
- Be performed on the finished assembly in the maximum thickness intended for use.
- Be reviewed by a fire scientist
- Be qualified by the listing agency, such as ICC-ES and Intertek before a listing is issued.

The Authority Having Jurisdiction or code official always has the option of accepting or rejecting the findings of an Evaluation Report. Years of experience has indicated that most code officials have accepted the UVAATP as an appropriate analysis consisting of various fire tests and computer modeling.

Our analysis used the above criteria and we determined that the criteria contained in the codes has been followed in the development and use of the UVAATP. This was done by reviewing the test protocols used in the reports of the eight manufacturers. The results documented in the reports were also analyzed to verify that consistent acceptance criteria were being applied in all eight of the reports. In addition, consideration was given to the fact that an ignition barrier is intended to limit the extent of fire in an unoccupied attic or crawl space by increasing the time it takes for the foam to become involved in the fire.

An important aspect of the analysis is the validation that has been done for the room size testing and full-scale testing. The computer modeling was calibrated or validated using full-scale fire tests. The modeling was used to predict performance in actual end-use configurations that may deviate from the standard attic fire test. The modeling allowed consideration of many attic sizes, shapes and geometries as well as imperfections in construction. This is in accordance with generally accepted practice regarding the validation of fire modeling activities.

6. ANALYSIS OF THE QUALIFCATION OF ALTERNATIVE IGNITION BARRIER ASSEMBLIES

Beyond the material methods used in standardized tests there have been questions raised about why the end use configuration testing approach, such as the UVAATP, should be considered acceptable. As an example, none of the four thermal barrier test procedures identified in codes (i.e., NFPA 286, FM 4880, UL 1715 or UL 1040) provide testing procedures for testing ignition barriers. The elegance of end-use configuration testing is that it requires manufacturers and designers to demonstrate solutions using actual configurations and by showing answers to specific issues and concerns. Of necessity, an end-use configuration test approach is generally more comprehensive than a single test to address the range of concerns that might be reasonably anticipated in an evaluation by an Evaluation Source.

Innovative testing protocols, like UVAATP, are based experience with repetitive testing and adjustments made as determined to be appropriate. In this case, the protocol was developed and subsequently revised by Priest and refined after discussions with the various evaluation service entities involved and reviewed by engineers – as intended by the IBC and IRC.

All of the test plans provided for this report were reviewed by accredited agencies (ICC-ES, Intertek or DrJ Engineering, LLC) before recognitions were given to demonstrate appropriate due diligence was used. At least one report notes that the Test Plan used was submitted to ICC-ES for evaluation prior to performing the tests and modeling. The plan submitted was approved by ICC-ES on May 6, 2013. Whereas the Test Plan is intended to be a specific approval, the protocol is not required to be developed using a consensus process. However, as required by the IBC and IRC, the code official has the responsibility to approve the use of the test protocol for the specific application.

Over time, experience gained through the execution of multiple testing projects naturally led to greater inter-project consistency of testing performed. Initially tests were performed to respond to specific ICC-ES questions until ICC-ES was satisfied that the relevant issues and concerns were addressed. The final set of tests from the first project essentially came to serve as a “test plan” template for subsequent projects, including those that used Intertek or DrJ Engineering, LLC.

Any variation between test plans is identified therein. When testing under a test plan did vary, it was generally due to differing requirements between the three evaluation services and research concerns addressed by the various manufacturers. For example, in at least one case Intertek required one of the attic assembly tests to include a small ignition source for 20 minutes and an additional attic assembly test with an open hole in the roof to monitor the performance of an unintended opening.

However, the core group of fire tests as determined to be necessary by ICC-ES were performed and are documented in each subsequent test plan. Some test plans reference additional fire tests that the manufacturer may have performed to further document the performance of a specific product.

7. CONCLUSIONS

The Priest evaluations considered a number of end-use configuration tests of attics using large- and small-scale testing, modeling and analysis to address concerns. In each case, the testing and fire modeling demonstrated that a fire initiated in an insulated, unvented attic in which a specific spray foam assembly was used performs equal to or better than one that has been qualified by alternate means (e.g., as a prescriptive ignition barrier or by testing under ICC-ES AC377 Appendix X), thereby validating acceptable performance of the foam plastic as an alternative ignition barrier assembly.

The UVAATP is representative of how an unvented attic performs in a real fire. In the event of fire, unvented attics typically contain combustion by-products and heat, and these factors can alter how the fire spreads and other performance characteristics. Passing a particular test does not eliminate risk, it merely indicates the comparative risk is the same. It is very common to use a comparative risk analysis to demonstrate that an alternative method or product has a performance equivalent to another code complying product or method.

The UVAATP analysis considered the following:

- Minimum and maximum thickness of foam plastic.
- Room geometry, including volume (minimum and maximum), shape and roof slope.
- Potential fire sources.
- Effect of openings to the attic space, including, but not limited to, the attic entry, direct venting for appliances and unintended openings. Intent of the requirements for prescription ignition barriers.

The testing and evaluation methodology is consistent with the Code requirement that allows testing consistent with end-use configuration testing for qualifying alternative uses without prescriptive thermal barriers or prescriptive ignition barriers. The methodology is a result of an original proposed methodology refined in response to questions raised by ICC-ES. To date, each code report recognition of uses qualified the UVAATP provided by ICC-ES, Intertek or DrJ Engineering, LLC have included review by these agencies of the test plan, test data, modeling, and final engineering evaluation. The ultimate approval of the alternative use and qualification method rests with the Authority Having Jurisdiction.

In summary, it is our opinion that the UVAATP offers a Code compliant method to qualify the use of foam plastics in certain unvented attic assemblies using actual end-use configuration where the prescriptive code requires an ignition barrier. It is our opinion that the UVAATP is both well considered and comprehensive in its evaluation of the use and configuration under fire condition considered. While some projects [or test plans] contained slightly different or additional fire testing, there is a demonstrated consistency in terms of approach, core testing, modeling, and subsequent evaluation of the results. The development of this research has also helped further the understanding of fire performance to facilitate the evolution of the Code requirements. A key driver for this work clearly is the Code requirement for full scale testing of end use conditions as set out in IRC Section R316.6 or IBC Section 2603.9.

Appendix A

A Summary of the Conversation between Priest and ICC-ES

As indicated in the Priest test reports, an extensive list of questions submitted by ICC-ES were addressed in tests and modeling as part of the evaluations. It should be noted that the Priest Responses have been editorially modified to delete any reference to a specific product. In the individual test reports, more specific product information is provided. Some of the questions asked include the following:

> **Koffel Analysis Note**: The following discussion between ICC-ES and Priest & Associates uses the term "self-extinguished" several times. It should be understood that the use of "self-extinguished" in the Priest Reports refers to the fact that room temperatures drop dramatically and the conditions in the space will no longer support combustion. The use of "self-extinguished" in the Priest Reports does not relate to spray foam, but the full attic assembly.

1. What effect would a 4-in. diameter hole (ventilation for furnace) have, or a 12- to 20-in. diameter tubular skylight passing through the attic space?

   Priest Response: *In a finished construction, the furnace ventilation is a closed loop system. The intake and vent penetrations will be sealed. We recommend that skylight wells or skylight tubes be protected and the protection is identified in each test report. The fire tests contained in the analysis have shown that there is some quantity of good foam remaining after the fire has self-extinguished*[i] *Therefore, covering tubes or holes will have the same protective effect.*

2. Prove out the extended room theory (CFAST study or additional testing).

   Priest Response: *We used CFAST to model the actual test scenario and the model predicted the measured time to self-extinguishment*[i] *within 4 seconds of the actual test. When we expanded the model to larger volumes, the CFAST results were in good agreement with our initial estimates using the simplified method. Also, a 3x volume test was conducted and the time resulting in the room self- extinguishing*[i] *is documented in each report. This measurement agrees with the hand calculation model that was used. CFAST was used to predict a time to self-extinguishment*[i] *and that time is documented in each report. The room measured 16 ft x 18 ft x 8 ft high and was covered on the walls and ceiling with a specified type and thickness of spray foam. Due to the size of the room, calorimetric measurements (HRR, Smoke) were not possible. However, room temperatures and heat flux were monitored. The test results are documented in each report providing a time to self-extinguishment,*[i] *the peak upper layer temperature and the peak heat flux. The peak upper layer temperature was compared to the NUREG prediction and the peak heat flux was less than the NFPA 286 volume room test result.*

   After the test, the room was allowed to cool naturally while monitoring the room for re-ignitions. It must be noted that the attic hatch was closed at the start of the test. The room pressure opened the hatch and the hatch remained opened for the extended fire-watch period (5+ hours without external fire suppression). The room was left overnight without fire suppression. During this period, no re-ignitions occurred even with the hatch left wide open allowing fresh air to infiltrate the room. The 5-hour room thermocouple data shows a monotonically reducing room *temperature with no spurious spikes which would indicate smoldering. The following day a damage assessment was made with the following results*

*(**Koffel Analysis Note**: these results are from one specific test report and are provided for illustrative purposes. Other reports included similar information but in a more qualitative manner):*

a) *Unburned foam remaining Back Wall (Burner wall) – 0 to ½ in. depending on location (upper vs lower area of wall)*
b) *Unburned foam remaining RHS Wall (Burner wall) – ¼ in. to ½ in. depending on location (upper vs lower area of wall)*
c) *Unburned foam remaining LHS Wall (opposite of burner wall) – 0 to 1-1/4 in. depending on location (upper vs lower area of wall)*
d) *Unburned foam remaining Front Wall (opposite burner wall) – 0 to 3/4 in. depending on location (upper vs lower area of wall)*
e) *Note: For areas marked as 0 in., there remained a thin (1/8 in.) discolored layer of foam. The gypsum wallboard underneath this layer was intact, white and in our expert opinion - completely undamaged.*
f) *Unburned foam remaining ceiling – 1/8 in. to ½ in. depending on location (front vs rear area of ceiling)*
g) *The wood studs on the walls remained intact and only discolored due to scraping charred or discolored foam from the wood. Only one area near the burner did there appear to be a thin crust of soot easily scraped with a fingernail exposing undamaged wood.*
h) *The wood ceiling joists were mainly discolored after scraping off charred or discolored foam except one area in which a thin crust of char was apparent but was easily scraped with a fingernail exposing undamaged wood.*
i) *The floor joists which were left unprotected during the test showed a thin layer of sooty char which was easily removed by rubbing with a bare finger exposing undamaged but discolored wood.*
j) *The wood on the attic hatch showed the same layer of soot which was also easily removed with light rubbing with a bare finder leaving undamaged but slightly discolored wood.*
k) *Overall damage assessment: It is our opinion that this room could easily be scraped to remove charred foam exposing an intact substrate which could be re-sprayed with foam. Effectively, the foam protects the materials over which it is sprayed.*

3. What happens if a fire-fighter punches a hole in the roof before the fire has self-extinguished?[i] What is the likelihood of that occurring?

Priest Response: *The reports indicate that a fire would self-extinguish[i] before firefighters arrive. Test results and modeling indicate self-extinguishment[i] occurs between 20 seconds and 1.3 minutes. The foam is protected by a layer of surface char and all testing indicates re-ignition of the foam does not occur.*

(***Koffel Analysis Note**: The times in this response have been modified to include the range of values obtained in the different test reports).*

By the time firefighters arrive at a scene, the room has cooled significantly as documented by cool-down curves in the test reports. However, in the tests conducted which opened the hatch, fresh oxygen was allowed to enter the room immediately after the fire self-extinguished.[i] In neither of the two cases, did the room re-ignite. Also, charred foam is more difficult to ignite. The char layer provides an effective ignition barrier to the fresh foam underneath.

4. What are the potential fire sources? Will a slower growth fire create a worse or better fire scenario than the standard room corner crib or burners?

   Priest Response: *Our torch flame test indicated that small, short lived ignition sources cannot ignite the foam to cause a runaway fire. If the ignition source is not small and short lived, ignition will occur and the result will be behavior as demonstrated in the testing. The main difference between a small ignition source and a 40-kW burner or crib is a delay in the time to flashover. Small fire sources also may never spread to the point of flashover. Potential fire sources are documented in the FEMA section of each report.*

   (***Koffel Analysis Note**: Some reports addressed a broader range of potential fire scenarios other than a torch flame test. Examples include cigarettes and an arc-welder. There are also instances in which different torch sources with differing exposure times were used.)*

5. Why use a specific foam material as the comparison? What would be the scenario if ¼ inch plywood was used (i.e., the code assembly)?

   Priest Response: *The Foam is an AC 377 Appendix X approved foam determined compliant in attics without the need for a prescriptive ignition barrier or an alternative ignition barrier coating. We wanted to compare with an AC 377 Appendix X approved product. Comparing to plywood is a known result. Plywood test would likely result in a slow flashover – then taking longer to self-extinguish.[i] One fact we have proven is that the foam does not smolder in these scenarios, while wood is known to smolder under low oxygen conditions. If there is enough oxygen remaining for wood smoldering, then plywood may perform worse. Wood has the potential to smolder (and re-ignite if additional O_2 is allowed back into the room) and it can potentially burn through the roof deck resulting in a vented attic fire.*

   (***Koffel Analysis Note:** This response to this question has been revised editorially for clarification of the actual Priest Response in any single report.)*

6. Is there a minimum thickness of material for the scenario to work?

   Priest Response: *We have shown that different thicknesses perform the same. The reports indicated a thickness that is the minimum thickness that has been tested and the foam provided adequate protection. Fire science theory and modeling indicates there does not appear to be a maximum thickness beyond which this behavior does not occur.*

7. The scope of the review is the spray-applied foam plastic insulation; with a minimum thickness, no maximum; applied to vertical surfaces and the underside of roof decks and does not include application to attic floors; and is limited to recognition under the IRC and more recent editions of the IBC in which unvented roof attics were specifically permitted.

   Priest Response: *Other evaluation reports currently accept the use of products tested on attic floors based on the ASTM E970 test. That approval is not the subject of this application.*

8. We need you to provide an engineering analysis outlining the following:

   a) The fire tests conducted. The analysis should identify the critical performance measures of the test, the effect of the attic access door being open or closed; and the effect of attic geometry (volume, shape, and roof slope).
   b) The fire modeling used to justify the extension of test results beyond the conditions of the tested assembly.
   c) An analysis of the data concluding that the product/assembly complies with IRC Section R316.6.

   Priest Response: *The reports meet the requirements of items a and b. In item c, R316.6 allows a foam plastic to be tested in an end-use-configuration test with acceptable results. This evaluation meets this requirement when evaluated as per "Public Notification of Alternate Methods for Qualifying Spray- applied Foam Plastic Insulation Used in Attics without a Prescriptive Ignition Barrier, Subject AC377-1012-R1 (MB/CA)".*

9. We believe an additional modified NFPA 286 test is needed to correlate actual test performance with the predictions of the CFAST model. The room size should be the largest that is practical to test. This will give us a second data point to compare with the CFAST model.

   Priest Response: *A 3x volume test was conducted. Also see the answer to Question 2 above.*

10. Acceptable performance depends on a quick flash-over, followed by immediate self- extinguishing[i] of the foam plastic due to limited oxygen in the attic space. The analysis should comment on whether it is reasonable to assume the attic will always be sealed and how to prevent alteration of the attic conditions (i.e., venting) without first considering the conditions of installation. Is typical fire-blocking required by IRC Section R302.11 sufficient to address draft openings in framed construction?

    Priest Response: *The reports were submitted by the manufacturers seeking approval of the product in unvented attics. If an end user decides to occupy the attic, then the foam shall be protected with a thermal barrier (per the applicable ESR) or removed. While this is difficult to* *control, it is no different to any other foam used in a limited access space. Other factors that have been considered are as follows:*

a) *It has been shown that a torch fire applied to the foam (for short durations) does self-extinguish[i] and that most attic ignitions are caused by small ignition sources.*

b) *The likelihood of a lightning strike on a house with an unintentional vented attic sprayed with foam is even smaller. However, evidence shows that lightning strikes on attics insulated with spray foam tend to self-extinguish.[i]*

c) *Appliances within the attic space are closed loop systems and contain fire sources much smaller than the 40-kW fire used to test the product. Also, when such sources are in close proximity to combustibles, those materials must be protected according to the Mechanical Code.*

d) *The tendency in the field is to go from vented to unvented attics. Venting an attic in some climates causes negative effects (moisture control, etc.) and it is relatively costly to negate these effects. Also, when converting from unvented to vented, it is recommended to move HVAC ductwork into the attic space.*

e) *The SWRI 99-02 tests submitted showed that product performs better than bare plywood. The SWRI 99-02 test is a ventilated test, therefore data exists that the products evaluated perform better than bare plywood and kraft face fiberglass batts.*

f) *The ESR or Code Report which covers the use of the product in unvented attics is a legal document. If an end user decides to change the use of the attic as with any change in a building, it is incumbent on that individual to ensure that a safe, code compliant assembly is maintained.*

   *(**Koffel Analysis Note**: While the initial report dealt with ICC-ES, it should be noted that some subsequent reports have dealt with other accredited evaluation service agencies including Intertek's CCRR's, DrJ's LLC, TER's, and IAPMO ER's. The ESR or Code Report, as is commonly done with product listings, have a set of conditions that must be met as additional safeguards for this exact scenario.)*

Fire-blocking of draft openings as required by IRC R302.11 lists various materials which are intended to stop flames from traversing from one space to the next. The leakage rate of the fire-blocking is likely much smaller than the leakage rate of the hatch opening – therefore fire-blocking of draft openings does provide sufficient control of leakage into the attic space.

11. The burner was turned off after self-extinguishment.[i] I understand from our conversations that it was done for safety reasons, however, can you respond to what would happen in the attic if the fire source were not extinguished?

    Priest Response: *The gas would not have enough oxygen to support combustion. During the test, the temperature directly above the burner (approximately 1 ft) was monitored. As soon as the temperature dropped by several hundred degrees, the gas was shut off. This decrease in temperature is an indication that the fuel did not have enough oxygen to support combustion. Also, most listed gas appliances have a safety shutoff valve if the pilot light is extinguished. Additionally, standard practice by firefighters is to shut off gas supplies upon arriving at a house fire.*

12. How will the attic environment respond if oxygen is introduced to the attic after self- extinguishment[i] of the foam plastic?

    Priest Response: *See Answer 3.*

13. Tape was used to seal the surrounding construction. Since that likely will not be done in the field, and we cannot reasonably expect attics in standard construction to be completely sealed, will the attic environment respond differently if limited oxygen is allowed into the attic during the test? If the safety of this system depends on having no openings, how will that be ensured after final inspection; how will the information be transmitted to subsequent owners of the home?

    Priest Response: *The leakage of the attic hatch far surpassed the leakage of the edges of the room. During the setup, the flow rate change was monitored as the room was sealed, and it effectively did not change. However, even if the room edge leaks were not sealed, a test was conducted with an open hatch. This test performed the same as the closed hatch tests. This test was not allowed to cool and was quenched with water for safety reasons. During the closed hatch tests the hatch remained open allowing oxygen into the room. The 5-hour cool-down period indicated that no spurious re-ignitions occurred. Additionally, one test was conducted with the attic hatch completely open and a leaky floor assembly with the same time to self-extinguishment[i] result occurring*

14. The Priest report contains a reference that indicates that the effect of sloped roofs should be addressed.

    Priest Response: *A vertical wall spreads flame faster than a horizontal roof. As the slope of a wall is rotated towards the horizontal (i.e., a sloped roof), the flame spread behaves more and more like a ceiling (lower flame spread). Therefore, the vertical wall testing we have conducted represents worst case for these scenarios.*

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[i] **Koffel Analysis Note:** Meaning, the fire in the assembly dissipated until the conditions no longer supported combustion.