

Development of New Flaming and Smoldering Polyurethane Foam Test Protocols for UL 217 Standard on Smoke Alarms

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Smoke alarms provide a vital warning to occupants within residential settings that there is a presence of smoke, and possibly a fire. Over the last four decades, several studies have been conducted to determine the response of smoke alarms and to assist in establishing performance criteria for their use in residential settings. These studies have led to the development and subsequent revisions of UL Standard 217 *Single and Multiple Station Smoke Alarms*, as well as a National Fire Alarm Code (NFPA 72) that addresses smoke alarm installation requirements. A study completed by NIST in 2004 reflected that smoke alarms were working but there was a reduction in the margin between available and safe egress times from an earlier study in 1975.

Fires in either a flaming or a smoldering phase provide several cues for smoke alarms. These include smoke particulates, heat, and gas effluents (*e.g.*, carbon monoxide and carbon dioxide). Current smoke alarms primarily utilize two types of detection technologies: photoelectric or ionization. The photoelectric type detects changes in light scattering or obscuration caused by smoke particulates; the ionization type detects changes in local ionization field within the detection chamber resulting from the presence of smoke. Both types of alarms activate when a set threshold is reached. While current technology smoke alarms utilized in the UL-FPRF Smoke Characterization Project study operated within the performance criteria specified in UL 217, there was a difference in activation times for the different technologies depending upon the combustion mode (flaming vs. non-flaming).

Some of the key findings in the UL-FPRF Smoke Characterization Project study were:

1. Flaming combustion creates smaller smoke particles than non-flaming combustion.
 2. Non-flaming combustion tends to generate greater volumes of smoke particles for a given consumed mass than flaming combustion.
 3. Polyurethane foams in the flaming mode produced the smallest particle sizes of all materials tested.
 4. Ionization alarms responded quicker to flaming fires while photoelectric alarms responded quicker to non-flaming fires.
 5. Smoke settling and stratification were observed for the longer, low energy, non-flaming tests.
- Based on these key findings, it was proposed that the addition of other test materials, such as polyurethane foam, in the flaming and non-flaming combustion modes, to UL 217 be considered.

The UL Standards Technical Panel responsible for UL 217 and UL 268 convened a specialized Work Group consisting of UL and industry experts for the purpose of developing a flaming and a smoldering polyurethane foam test. The project is divided into six tasks to investigate the smoke particle size and count distributions, effluent gases, and smoke accumulation profiles produced by various foam samples under different exposure conditions:

- Task 1 - Select PU foam test samples
- Task 2 - Perform analytical and small-scale tests to determine decomposition and smoke generation characteristics
- Task 3 - Develop flaming and smoldering mode scenarios using intermediate-scale testing
- Task 4 - Develop smoke data in UL's Fire Test Room
- Task 5 - Develop Task Group Proposal
- Task 6 - Establish Representative Smoke Profile Data

Preliminary findings of smoke accumulation profiles for flaming and smoldering combustion of various sample geometries of the targeted foams were previously presented¹. This presentation provides an update on the current status of the study in which additional combustion characteristics (*e.g.* particle size and count distribution, effluent gas) were measured for the previously presented scenarios as well as for a newly developed self-sustained smoldering scenario.

Task 1 - Select PU foam test samples

The foam types selected for this study include four polyurethane foams and one viscoelastic foam. The four polyurethane foams cover a range of densities typically used in the construction of residential mattresses and upholstered furniture. The selected polyurethane foams include foams meeting the requirements for EN 54-7 smoke detector testing, upholstered furniture component testing, and UL 1626 residential sprinkler testing.

Task 2 - Perform analytical and small-scale tests to determine decomposition and smoke generation characteristics

The five foam materials have been characterized for density, chemistry by Fourier Transform Infrared Spectroscopy (FTIR), thermal degradation by Thermogravimetric Analysis (TGA), smoke production as a function of decomposition temperature (TGA-Smoke), combustibility under non-flaming and flaming conditions by cone calorimeter (Cone), and smoke and effluent gas developed under non-flaming and flaming conditions (Cone-Smoke-FTIR).

Task 3 & 4 - Develop flaming and smoldering mode scenarios

Flaming foam tests were conducted on various shapes of the different foams so that a 10 %/ft obscuration level was achieved in as short as 85 seconds to in excess of 1500 seconds. The EN 54-7 foam test arrangement was also evaluated.

Smoldering scenarios for the various foams were based on two different approaches: (1) heating from underneath via a custom programmable hot plate, and (2) heating from above via radiant heaters. The evaluated heating rates for the hot plate included the UL 217 profile and two other profiles based on thermogravimetric analysis degradation data obtained in Task 2. For the hot plate tests, 1 %/ft obscuration was generally achieved in 1200 to 1600 seconds and the additional time necessary to achieve 10 %/ft ranged from 500 to 1250 seconds. With the radiant panel heating system 1 %/ft obscuration was generally achieved in 100 to 400 seconds; the additional time necessary to achieve 10 %/ft obscuration level varied from as short as 250 seconds to as long as 2650 seconds depending on the foam density, size, type and heater output.

¹T Fabian, G Hunter, PE Patty, PD Gandhi, "Development of Test Protocols for UL 217 Standard on Smoke Alarms", SUPDET 2008.

Smoldering combustion was also evaluated for a polyester microsuede covered polyurethane foam mock-up to simulate smoldering upholstered furniture. Combustion was induced under two scenarios: (1) cigarette heating, and (2) electric element heating. Combustion of the mock-up cover fabric and foam was achieved in the cigarette scenarios as evidenced by charring; however, combustion of the mock-up assembly components ceased upon extinction of the cigarette. Self-sustained combustion of the mock-up assembly was achieved using the electric heating element. Smoke obscuration of 10 %/ft was achieved approximately 30 minutes after disabling the heating element.