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Impact of UL 268 and UL 217 Fire and Nuisance Tests

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Foreword

This document will explain the context that led to the development of the new requirements, details about the new tests, and the consequences of the new products for designers, installers, end-users, and authorities having jurisdiction.

This document was developed by the Building Systems—Fire, Life Safety, Security and Emergency Communications Section.

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1 Scope

The addition of new polyurethane foam fire tests and a cooking nuisance smoke test were the largest changes ever to UL 217 and UL 268. These new tests required that all smoke alarms and detectors be redesigned to operate completely differently, that is, detect fires more quickly and reject cooking nuisances. This document will explain the context that led to the development of the new requirements, details about the new tests, and the consequences of the new products for designers, installers, end-users, and authorities having jurisdiction.

2 History of Smoke Detection Standard Requirements

One of the key moments for the development of modern smoke detector requirements was the so-called Dunes Studies that took place in 1975. The research was conducted by Underwriters Laboratories and the Illinois Institute of Technology for the National Bureau of Standards (now called the National Institute of Standards and Technology (NIST)). The testing was conducted on what is now the Indiana Dune National Park, which is located along the southern tip of Lake Michigan. The testing involved setting fires in actual homes that were slated for demolition as part of the development of the park. Controlled fires were set in the homes, and detailed data was collected in order to establish detector activation criteria based on measured tenability criteria such as temperature and obscuration (visibility). These tests directly affected smoke detector requirements in UL and NFPA standards. The tests are known as NBS GCR 75-51 and NBS GCR 77-82 and can be located on the NIST website.

In terms of performance requirements, UL standards remained relatively static for several years. However, there were minor fire test changes in order to eliminate gasoline (in favor of heptane), eliminate the polystyrene (packing peanuts) test, and modify smoldering smoke limits for increased nuisance immunity. By the early 2000s, concern was growing in the fire protection community that detectors set to limits established by testing in the 1970s were no longer adequate for the 21st century.

A research study was begun that sought to update the research that was done in the original Dunes test. This new testing was conducted by NIST and was completed in 2004. The report was called, Performance of Home Smoke Alarms—Analysis of the Response of Several Available Technologies in Residential Fire Settings (NIST TN 1455). The testing was done in an actual home in much the same way as the original Dunes testing with some updated fire scenarios. The key finding in the research was that while both photoelectric and ionization detection technologies provided adequate escape time, the amount of time had decreased since the 1970s. This decrease in escape time from 17 minutes to 3 minutes, in some cases, was attributed to the increased use of synthetic materials in furnishings.

The decrease in escape time was alarming to the fire protection community, and it was decided that more data was needed in order to potentially update fire detection standards. To fill this knowledge gap, the Fire Protection Research Foundation commissioned a research project that was funded by an array of companies and institutions in the industry. Underwriters Laboratories was selected as the contractor for the project, called the Smoke Characterization Project. The project consisted of the careful characterization of dozens of different types of materials. The parameters measured included particle size and color, detector response, and gas effluent composition, among others. The conclusion of this work was that additional test-fires should be added to the UL smoke alarm and smoke detector standards that would expand the range of smoke types that detectors are required to react to. Specifically, it was recommended that polyurethane foam should be added as a fuel type.

Upon the conclusion of the Smoke Characterization project, a task group was formed to provide recommendations on new tests that could be added to the smoke alarm and smoke detector standards to enable products to be more responsive to modern furnishings and building materials. The task group was led by UL and quickly focused its efforts on the development of a smoldering polyurethane foam fire and a flaming polyurethane foam fire as these tests would create smoke of a type outside that of the existing fire tests. The development of these new fire tests proved to be a massive undertaking. Even deciding upon the type of polyurethane foam that is most typical of furnishings was challenging. After the selection of the material, a method had to be developed that would produce the desired amount and type of smoke in a repeatable and reproducible manner. Finally, the task group had to decide on the detector activation criteria (when they should alarm), and they were aided in that effort by yet another NIST study (TN 1837 Improving Smoke Alarm Performance—Justification for New Smoldering and Flaming Test Performance Criteria). The goal was to improve escape time, and the result was very aggressive activation criteria and, therefore, very sensitive detectors.

Alongside the desire for detectors with increased sensitivity was the very real impact of nuisance alarms. Cooking nuisances account for the vast majority of unwanted smoke alarm and smoke detector activations. And these unwanted activations often result in the disablement of the smoke detection device. In order to better understand the cooking nuisance issue, a number of research studies were conducted including:

- NIST TN 1784: Smoke Alarm Performance in Kitchen Fires and Nuisance Alarm Scenarios (2013)
- NFPA/FPRF: Smoke Alarm Nuisance Source Characterization (Jensen Hughes 2015)
- UL: Characterization of Smoke Alarm Nuisance Sources from Cooking Scenarios (2015)

The task of assimilating all of the data from the various fire and nuisance research studies fell to the Standards Technical Panel (STP) for smoke alarms and smoke detectors. The STP is convened and managed by the standards developing organization (SDO), in this case, Underwriters Laboratories. UL LLC, the product certifier, is a separate organization from the SDO. STP 217, the committee responsible for UL 217 and UL 268, is composed of approximately 40 members. The committee has a balance of interest groups to ensure that everyone’s viewpoint is considered. UL LLC is a member of the STP and gets one vote, like the other members. It is also important to point out that while the standards are called UL 217 and UL 268, any approved nationally recognized test laboratory (NRTL) can certify products.

3 New Fire Tests

The goal of the new fire tests was to force a change in the performance of all smoke alarms and smoke detectors. That is, regardless of technology, detectors that were previously on the market would need to be redesigned in order to meet the new requirements. A new flaming polyurethane foam fire would challenge existing photoelectric smoke detector technology, and a new smoldering polyurethane fire would challenge existing ionization smoke detectors. The ultimate goal of the new tests would be to regain the escape time that had eroded over the years since the original Dunes testing.

General-purpose smoke alarms and smoke detectors have a challenging task, which is to respond to every type of fire while ignoring nuisance conditions. During product certification, rather than expose the product to every possible type of fire, the standard exposes them to a variety of smoke particle sizes and colors. The previously existing fire tests in the standard consisted of newspaper, wood, and a flammable liquid (n-heptane). While the STP knew they wanted polyurethane foam, they had to decide on what type. Ultimately, an ordinary foam of the type that would be used in US furniture was selected. It has a density of about 1.8 pounds per cubic foot. Early on in development, a piece of foam wrapped in synthetic fabric (like a cushion) was used, but while realistic, it proved to not be repeatable in a test environment.

Developing a smoldering fire test with a repeatable smoke build-up rate is very challenging, and this step took many years of research. Foam can be heated by many methods, and most of them tend to cause the foam to burst into flames rather than continue to smolder. Ultimately, UL chose a method of holding the foam in a vertical orientation and exposing it to radiant heaters, although other methods will also produce similar results. For example, foam could be put on an industrial hot plate, similar to the wood smoke test. The resultant smoke profile is one that takes quite a while to produce smoke, but once it starts, the test is over within 5 to 6 minutes.

Once the smoldering smoke could be generated in a repeatable manner, the committee had to decide on when the detector was required to alarm. Ultimately, a limit of 12%/ft. obscuration was determined to be the limit. In order to set this limit, a tenability limit must be determined. In other words, what are the conditions that must be present in order for a person to escape successfully? This is a topic of considerable research in the fire protection industry. It turns out that the most important factor in escape is not heat or gas build-up but visibility – one must be able to see clearly to escape. The criteria that was chosen was 15 ft. of visibility or 0.25 OD/m. To support the selection of the activation criteria, NIST performed calculations based on actual fires done in a full-scale test house. They calculated the required egress time based on a range of walking speeds and exit routes. The NIST researchers wanted to achieve an 85% rate of successful escape (prior to the tenability criteria) across all of the different scenarios. While NIST calculated an activation criteria of 14%/ft., the more conservative limit of 12%/ft. was ultimately chosen.

In contrast to the smoldering polyurethane fire test, the flaming test was much easier to develop. The test is conducted by laying the foam horizontally in a foil pan and lighting the corner. It turns out that the test is very repeatable in terms of the build-up rate of the smoke. For activation criteria, the NIST research data was again used by the STP to select a limit of 5%/ft. obscuration, slightly less conservative than the NIST recommendation. Since the foam is ignited in the corner, it starts slowly but quickly builds and is over within about 3 minutes. As a practical matter, the new requirement means perhaps an extra minute of escape time in a flame fire scenario.

4 New Nuisance Smoke Test

Initially, the new smoldering and flaming fire tests were developed as a proposal and balloted as a change to the UL 217 and UL 268 standards. But, the Standards Technical Panel voted against the new tests, concerned that the resulting devices would be too sensitive, exacerbating the existing nuisance alarm activations. Drawing upon previous research, UL LLC developed a method of generating cooking nuisance smoke in a repeatable fashion. By also requiring a nuisance test, unwanted alarms might be avoided.

By examining cooking nuisance data from various sources such as frozen pizzas, frying vegetables, frying meat, etc., UL was able to determine that broiling a hamburger in an oven from a frozen state produces a range of smoke particle sizes that encompasses many of the other food sources. The test would consist of using two hamburger patties in an American style electric cooking range on the broil setting. The hamburgers produce particles from 30 to 110 nanometers in size over the course of the test, evolving to the larger size as the test progresses. The test spans a period of 14 to 22 minutes.

The cooking nuisance smoke test setup consists of mounting smoke alarms or detectors set to their most sensitive setting within 10 feet of the cooking range. The ceiling height is reduced to 8 feet for the nuisance test to simulate a worst-case condition. The requirement is that the devices ignore the cooking smoke to a level of 1.5%/ft. obscuration and then are still able to alarm when a piece of polyurethane foam is ignited at the end of the test.

The question that does arise in the minds of fire alarm system designers when the cooking nuisance smoke test is described is whether these new detectors are suitable for use in kitchens. The guidance on installation of detectors in the proximity of cooking appliances remains the same. That is, stay as far away from the kitchen as possible (see NFPA 72 for requirements). While the detectors are designed to be immune to this particular type of smoke that builds up in this way, it is not a guarantee against all nuisances. Furthermore, devices near the kitchen will inevitably get dirtier than they would in other areas, potentially creating a false alarm.

Adding the combination of the two new fire tests and the new cooking nuisance smoke test allowed the STP to achieve the goal of detectors that activate more quickly but are not prone to false alarms due to cooking. Ultimately, the goal is for these new tests to not only be used in the UL standards but also in the Canadian ULC standards as well.

5 Effect on Performance

Other than the obvious effect of increased escape time in the case of burning of synthetic materials, there are a number of other effects that these new tests have on performance. System designers, installers, and authorities having jurisdiction need to be aware of the consequences that these changes will have.

One effect that these new requirements have had on smoke detector manufacturers is the narrowing of the production sensitivity window. The production sensitivity window is the range of smoke alarm or smoke detector sensitivities that arise from normal production variation. The manufacturer must ensure that all devices that are produced will pass all of the UL performance tests regardless of where their production sensitivity falls. With the new tests, the concept of a “window” all but vanishes since the devices are required to ignore nuisance smoke beyond where they are required to detect an actual fire. System designers may notice that there are fewer sensitivity levels available on the control panel than in the past.

When the new fire and nuisance tests were being devised, the general assumption was that only multi-criteria smoke alarms or smoke detectors would be able to pass. But, as manufacturers began to design products to meet the new requirements, it was determined that multiple sensors were not strictly necessary to meet the requirements of the standard. In fact, in the new flaming polyurethane foam fire, for example, the additional sensors do not tend to help all that much. There is only a small amount of carbon monoxide and heat produced in addition to the small amount of smoke. Using microprocessors and advanced algorithms, manufacturers have been able to sense and distinguish different fire and nuisance scenarios, often without additional sensors.

Some manufacturers have begun to offer photoelectric smoke alarms or detectors with two different LED colors for their smoke sensors. Or, in some cases, they will use different scattering angles. Regardless of how it is described or designed, these solutions offer the ability of the smoke detection device to measure the size of the particulate. This, in addition to other factors, enables the detector to discern different fire or nuisance scenarios. These enhancements provide some additional information to the alarm decision process, often increasing accuracy.

Finally, to provide a formal assessment of the performance of smoke alarms and smoke detectors that meet the new requirements, research was performed by NIST and presented at the AUBE-SUPDET 2020 conference. The research consisted of modeling the performance of the new devices to see if they would achieve the intended egress objectives. The results showed that the new devices did achieve better escape outcomes over a range of scenarios.

6 Special Application Detectors

Once the new fire and nuisance tests were added to the UL 268 product standard, a question arose. That is, what does a designer do if a higher sensitivity detector is required for a specialty application such as in a data center, where nuisance conditions are unlikely? The STP had intentionally made the fire and nuisance test requirements the same for both UL 217 and UL 268. This was because many UL 268 smoke detectors wind up in residential-type occupancies as a part of monitored fire alarm systems (typically UL 985 listed panels). To address the need for higher sensitivity detectors without creating a loophole that would allow disreputable manufacturers to incorrectly claim their products are exempt from the nuisance test, a task group was formed to create a new category of smoke detectors in UL 268.

The new smoke detector category is called “special application” detectors. These requirements allow a detector to have a special mode or configuration that is more sensitive than would normally be allowed. This mode may not be the default mode of the detector and must be enabled by a deliberate action by the installer of the device. So, in default mode, the detector would meet all of the requirements of UL 268, including the nuisance test. A perfect example of why this special application mode is necessary is because of air sampling-type (or aspirated) smoke detectors. These detectors are designed to operate at sensitivities hundreds of times more sensitive than ordinary detectors but are rarely in environments where cooking takes place. Designers should use caution when employing a detector's special application mode, so that nuisance alarms do not occur.

Detectors that are listed for special application are clearly marked on their product nameplate. Typically, there will be two sensitivity ranges listed. There will be an "open area" sensitivity range that indicates the range that allows the product to meet all of the requirements of the standard. The second "special application" sensitivity range is a higher sensitivity that results from not having to meet the requirements of the cooking nuisance smoke test. These sensitivity ranges are also indicated in product literature or, in the case of aspirated smoke detectors (ASD), in the pipe network configuration tool.

The new smoke detector requirements have also created further clarity around the sensitivity of aspirated smoke detectors. Inexperienced designers of ASD systems in the past have had confusion around the sensitivity of the smoke detector vs. the sensitivity of a particular sampling point/hole. Very simply, if an aspirated smoke detector is set to 0.1%/ft. and there are ten holes, then the effective hole sensitivity is 1%/ft. Now, when ASD products are certified, they are required to show that their hole sensitivity meets the requirements of the standard, including air transport time from the hole to the detector.

7 Retrofits and older systems

It is important to note that these new requirements in the UL product standards are not retroactive. The older product that is already installed and maintained in the field may remain throughout its lifespan. The best defense against fire is a working smoke alarm or smoke detector, regardless of whether it meets these new fire and nuisance test requirements. Going forward, once the effective date of these changes has passed, manufacturers are no longer allowed to make the older product, even for retrofits. Each manufacturer may meet the need for older systems in their own way. In some cases, for smoke detectors, control panel firmware might need to be updated. Or newer products will simply work on older systems but with a reduced number of available sensitivity levels. It is important for designers and installers to check the manufacturer's published instructions for key information on how to handle retrofits.

8 Summary

The changes in the latest editions of UL 217 and UL 268 with respect to fire and nuisance tests have received much publicity as manufacturers develop and launch new products. But it is not often the case that the reasoning behind the changes is explained to those in the fire protection industry. This document seeks to explain the evolution of these new requirements.

The new polyurethane fires are specifically designed in order to expand the responsiveness of smoke alarms and smoke detectors to the threats of the 21st century. Products that meet these new requirements will provide better escape time and immunity to nuisance alarms than previous generations.

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