Performance of New Smoke Alarms to a Range of Nuisance Cooking Sources in a Mock Kitchen

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Abstract

New smoke alarms that have passed the new broiling hamburger nuisance test introduced in ANSI/UL 217 Standard for Safety Smoke Alarms 8th Edition have reached the market. This cooking scenario was selected to be representative of cooking nuisance sources generally. The current study aims to compare the nuisance alarm resistance between older designs and new smoke alarms to a variety of cooking scenarios. A series of cooking experiments are conducted with an electric-coil cooktop and oven surrounded by mock cabinets and the smoke alarms mounted on ceiling panels in the mock-kitchen. A variety of smoke alarm types and models are tested, including four smoke alarm models that have passed ANSI/UL 217 8th Edition or later and six ionization, photoelectric, or dual-type models certified to the previous Edition. The results showed that the new alarms as a group were not clearly superior in nuisance alarm resistance to the selected cooking scenarios compared to the older designs. While the broiling hamburger nuisance test added in the 8th Edition may not be sufficient to represent a range of nuisance cooking scenarios, it does provide a performance baseline to ensure newer alarms that need to meet the more stringent flaming and smoldering fire tests are not overly sensitive to nuisance sources.

Keywords: Cooking sources; nuisance alarms; smoke alarms; ANSI/UL 217

Introduction

New smoke alarms that have passed the new flaming and smoldering fire tests and cooking nuisance test in ANSI/UL 217 Standard for Safety Smoke Alarms 8th Edition [1] have begun to reach the market as the effective date for implementation was June 2024 when all smoke alarms must be certified to the current Edition. Two new fire tests and a nuisance test were added to the 8th edition in 2015 to address concerns about smoke alarm response. Flaming and smoldering polyurethane foam tests were added to represent a common fuel component in residential fires. An additional nuisance test was included to ensure new alarms did not activate for a representative cooking scenario, for which broiling hamburgers was chosen. A wider range of cooking scenarios was included for nuisance sources in a 2016 report by Cleary [2], which evaluated the performance of smoke alarms that were on the market at the time and had been tested to the previous edition of ANSI/UL 217. Cleary concluded that no smoke alarm models available at the time would meet all the new performance tests [2]. Cleary also reported significant variations across the different nuisance cooking sources in measurements of aerosol production rates, beam obscuration, and ionization response [2]. Although the broiling hamburger nuisance test seemed to be one of the most conservative scenarios, it was an open question whether this single nuisance cooking test was sufficient to prevent nuisance alarms for a wide range of cooking activities. The current study aims to compare the nuisance resistance between old and new smoke alarms for a variety of nuisance cooking scenarios.

Experimental Methods

A series of experiments were conducted in a mock kitchen depicted in Figure 1, with an electric-coil cooktop and electric oven surrounded by mock cabinets and countertop constructed from gypsum board, with dimensions given in Fig. 1. A range hood was located 77 cm above the cooktop and used in half of the tests on the highest setting. The range hood pulled effluent through a grease filter and directed it back toward the center of the room through a vent. The flow velocity measured by an anemometer 5 cm below the grease filter was 1.6 m/s ± 0.7 m/s for the highest range hood setting. The cooktop burners were designed with a temperature sensor to meet the new Coil Surface Unit Cooking Oil Ignition Test in UL858 Standard for Household Electric Ranges [3]. This safety system automatically shut off the burner before the food was well-done in some cooking scenarios. Therefore, an additional standalone electric-coil burner, with a heat output of 1.1 kW, was placed in the center of the cooktop and used for most of the cooktop scenarios. The front left 0.86 kW burner on the cooktop was used for frying bacon, since this scenario generally produced enough aerosol to trigger some smoke alarms before the automatic shut-off. A toaster was placed on the countertop, 8 cm to the right of the cooktop and 8 cm from the front edge of the countertop for toasting bread and toaster pastries.

A variety of smoke alarm types and models were tested, including four smoke alarm models that have passed ANSI/UL 217 8th Edition (N1, N2, N3, N4) and six models that have not, referred to hereafter as “legacy” alarms. The six legacy alarm models included two ionization models (I1, I2), two photoelectric models (P1, P2), and two dual ionization and photoelectric models (D1, D2). Twelve smoke alarms were mounted across three ceiling panels that were 189 cm from the front of the cooktop as shown in Fig. 1. The 12 alarms consisted of one of each smoke alarm model, plus an additional D1 and D2. The three panels, which each had four alarms, were rotated in repeat tests to average out location effects.

Two additional D2 smoke alarms were mounted closer to the cooking sources, in positions 13 and 14, as a check for test consistency. Two tests were conducted for each configuration, for a total of at least six tests at each cooking scenario. The test series was repeated with the range hood off and on at full power. Almost all smoke alarm models were hardwired, and the time when the alarm signal was produced was determined through the electrical signal. For models where a hardwired version was not available, the alarm time was obtained visually. Data on smoke alarm activation was collected during the cooking scenario and for two minutes after the cooking was complete.

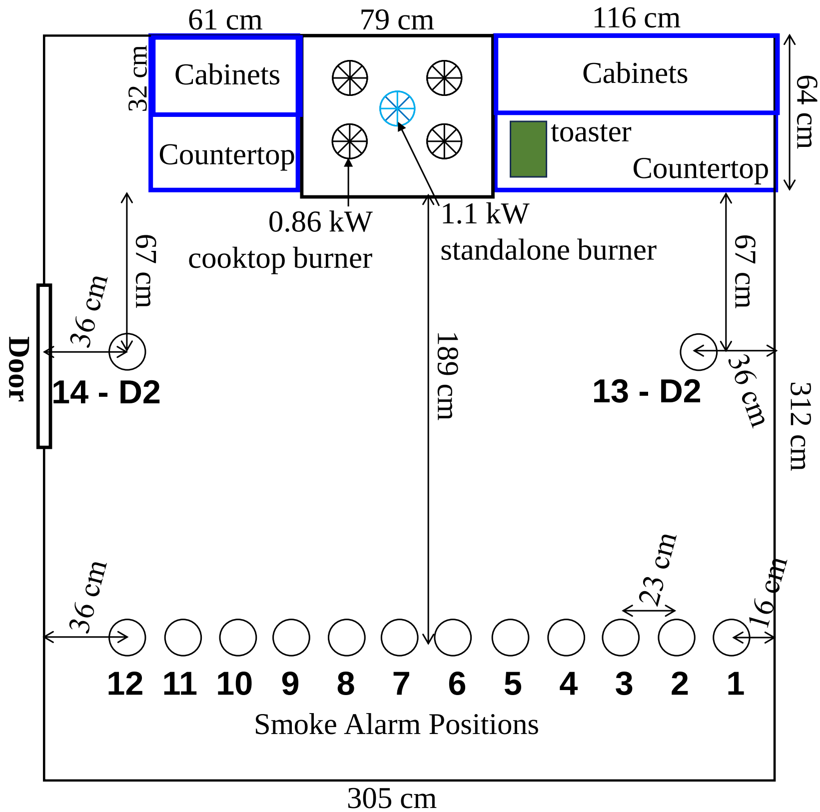

Figure 1. Top view of the mock kitchen experimental setup.

The nuisance cooking sources tested in this study include broiling hamburgers plus a wider range of foods, including broiling frozen pizza, toasting bread and toaster pastries, and frying various foods in a 20 cm (8 in) diameter pan or pot on an electric-coil burner (bacon, hamburger, frozen potato fries, stir-fried vegetables, and grilled cheese sandwiches). Overall, the test series consisted of 10 cooking scenarios that were representative of normal cooking. The cooked foods could be considered well-done, but without excessive charring, and no ignition of the foods.

The first scenario was broiling hamburgers, similar to the nuisance test in ANSI/UL 217 8th Edition. Two frozen 80 % lean hamburgers were placed in the oven on a broiler pan on the shelf 14 cm below the upper heating elements, and the oven door remained opened about 8 cm. The oven was set to high broil mode for 1200 s (20 min). An individual-sized frozen pizza was also broiled on high for 840 s (14 min) on a sheet of aluminum foil on the same oven shelf with the oven door open 8 cm. There were two toasting bread scenarios conducted using a toaster hardwired to apply heat whenever connected to power. For regular toast, two slices of white bread were toasted on the highest setting for 180 s, which was roughly the toasting time before the toaster was hardwired. A dark toast scenario extended the toasting time to 240 s to achieve dark brown, but not black, toast. Toaster pastries were also toasted for 180 s. The frying bacon scenario heated two slices of bacon (approximately 61 g) in four pieces on the highest burner setting in the stainless steel pan on the 0.86 kW cooktop burner. The bacon was cooked for 300 s, flipped, and then cooked until the automatic shut-off (115 s to 215 s more). All other frying scenarios used the 1.1 kW standalone burner. The frying hamburger scenario began by heating 30 mL of soybean oil in the stainless steel pan on the highest setting for 100 s. Then the one frozen hamburger was placed on the oil and cooked on high for 180 s, cooked on half-power for 150 s, flipped, and cooked on half-power for 180 s. The frozen potato fries scenario began by heating 45 mL of soybean oil on high for 120 s in a 2.8 L saucepan, then spreading about 167 g of frozen fries in a single layer over the oil. The fries were heated on high for 900 s and flipped every 300 s. The stir-fried vegetable scenario also began by heating 45 mL of soybean oil for 120 s in the stainless steel pan, then spreading the chopped, raw vegetables (approximately 67 g onion, 68 g celery, and 36 g carrot) across the oil. The vegetables were heated on high for 720 s and stirred every 60 s. The final scenario was a grilled cheese sandwich made with two slices of processed cheese inside two slices of white bread, coated on the outside with a total of about 15 g of vegetable oil spread. The sandwich was heated in the stainless steel pan on high for 180 s, flipped, heated on high for 100 s, flipped again, and heated on high another 35 s.

Results and Discussion

Overall, 120 cooking tests were conducted, 60 with the range hood off and 60 with the range hood on. Smoke alarm performance was evaluated by tracking the fraction of tests where an alarm signal was produced up to a certain percentage of the cooking time. A value of 1 means the smoke alarm was activated for all tests, and a value of 0 means the smoke alarm was not activated in any tests. Three performance levels were defined according to the percentage of the cooking time, 75 %, 100 %, and 100 % plus an additional 120 s. Table 1 lists each smoke alarm model and the fraction of tests for all cooking scenarios that activated alarms. Since there are two of each dual-type model in each experiment, the values reported for D1 and D2 are each an average of two smoke alarms. The last two rows report the fractions for the two reference alarms that were closer to the cooking sources, in positions 13 and 14. With the range hood off, the legacy photoelectric model, P2, had the lowest fraction of alarm signals at all three levels. Other alarms that produced an alarm for less than 20 % of the hood off tests were N3, P1, and D1. N2 and N3 did not contain radioactive material and were presumably light-scattering sensor designs. Of the new alarms, N2 and N3 performed best with the range hood off and performed better than the legacy ionization alarms. With the range hood on, performance improved for almost all the models, suggesting that the mixing from the range hood tended to dilute the concentration of cooking aerosols on average. Models that produced alarm signals for less than 10 % of the tests with the range hood on were N1, N3, I1, P1, P2, and D1.

Table 1. Overall Fraction of Cooking Tests Where a Smoke Alarm Signal Was Produced

Model	Range Hood Off (60 tests)			Range Hood On (60 tests)		
	75 % time	100 % time	100 % time + 120 s	75 % time	100 % time	100 % time + 120 s
N1	0.05	0.22	0.32	0	0	0.02
N2	0.03	0.17	0.25	0.05	0.05	0.13
N3	0.13	0.13	0.17	0.03	0.03	0.05
N4	0.12	0.37	0.52	0.02	0.08	0.10
I1	0.07	0.20	0.37	0.03	0.03	0.08
I2	0.15	0.40	0.50	0.07	0.08	0.10
P1	0.03	0.07	0.17	0.02	0.03	0.08
P2	0	0.02	0.07	0.02	0.03	0.08
D1 (2)	0.02	0.04	0.11	0.01	0.04	0.07
D2 (2)	0.02	0.16	0.32	0.03	0.11	0.18
13-D2	0.37	0.72	0.83	0.12	0.40	0.58
14-D2	0.57	0.75	0.93	0.25	0.63	0.70

While Table 1 reported the overall performance across all cooking scenarios, some scenarios consistently produced alarm signals, while other scenarios generated almost none. Therefore, test fraction data was further broken down for the scenarios with the most alarm signals: broiling hamburgers, frying hamburger, frying bacon, and dark toast, in Table 2. Because the alarm performance tended to be similar among the same alarm types, the data in Table 2 is grouped by alarm type.

Both hamburger scenarios caused many alarm signals to be produced. The broiling hamburgers scenario was similar to the ANSI/UL 217 cooking nuisance test, which all the new alarms have passed, with the most significant difference being this study is conducted in a much smaller room and with the alarms closer to the cooking sources [1]. While the new alarms performed better on average than legacy ionization or dual-type alarms, the new alarms performed worse or the same as the legacy photoelectric alarms. Not unexpectedly, the range hood did not have a consistent effect, and the fraction of alarm activations actually increased when the range hood was turned on for legacy photoelectric and dual alarm types. When the same food was cooked instead in a pan on the standalone burner, the results varied substantially. There were significant fractions of tests with the range hood off to produce an alarm signal before 75 % of the cooking time. The tests with the range hood on had noticeably fewer alarm signals. Turning on the range hood had an especially significant effect for the new alarms and the legacy ionization alarms, both of which were triggered in a high fraction of the frying hamburger tests with the hood off.

The other two scenarios that produced many alarm signals were frying bacon and dark toast. Notably, many of the alarm signals recorded for frying bacon occurred in the 120 s after the end of cooking. Without the range hood, both new alarms and legacy ionization alarms produced some signals before the end of cooking, and often many of the rest of the alarms were eventually activated. With the range hood on, the new alarms and legacy ionization alarms actually had a lower fraction of tests producing a signal compared to the legacy photoelectric and dual-type alarms. The dark toast scenario was challenging for the legacy ionization alarms, as expected from Cleary [2]. Both legacy ionization alarms were activated in all dark toast tests with the range hood off. The new alarms and legacy dual-type alarms produced an alarm in about half of the tests. With the range hood on, the fractions of tests with an alarm signal were significantly lower, suggesting the additional airflow was effective at diluting the toasting bread aerosols. The legacy photoelectric alarms never produced a signal in any of the dark toast tests.

The overall performance, averaged across all cooking scenarios and grouped by alarm type, is given at the bottom of Table 2. The new alarms, as a group, show slightly better performance than legacy ionization alarms, but not legacy photoelectric or dual-type alarms. With the range hood off, the legacy photoelectric alarms were activated in the lowest fraction of tests. With the range hood on, the new alarm and legacy photoelectric alarm groups were activated in the same fraction of tests.

Table 2. Fraction of Cooking Tests Where a Smoke Alarm Signal Was Produced, for Select Cooking Scenarios and Overall, by Smoke Alarm Type

Model Type	Range Hood Off			Range Hood On		
	75 % time	100 % time	100 % time + 120 s	75 % time	100 % time	100 % time + 120 s
	Broiling Hamburgers (1200 s cooking time)					
New	0	0.33	0.46	0.04	0.13	0.25
Ion	0.08	0.67	0.75	0	0.25	0.50
Photo	0	0.17	0.17	0	0.17	0.25
Dual	0	0.38	0.50	0	0.25	0.54
	Frying Hamburger (610 s cooking time)					
New	0.46	0.71	0.71	0.08	0.08	0.08
Ion	0.58	0.58	0.58	0	0	0
Photo	0.17	0.25	0.25	0.17	0.17	0.17
Dual	0.17	0.25	0.25	0.21	0.21	0.21
	Frying Bacon (~450 s cooking time)					
New	0	0.50	0.83	0	0.04	0.25
Ion	0	0.33	0.92	0	0	0.08
Photo	0	0	0.75	0	0	0.42
Dual	0	0	0.67	0	0.17	0.33
	Dark Toast (240 s cooking time)					
New	0.08	0.42	0.50	0	0.08	0.11
Ion	0.25	0.83	1.00	0.08	0.17	0.21
Photo	0	0	0	0	0	0
Dual	0	0.29	0.58	0	0.13	0.14
	Overall					
New	0.06	0.22	0.31	0.01	0.04	0.08
Ion	0.11	0.30	0.43	0.02	0.05	0.09
Photo	0.02	0.04	0.12	0.02	0.03	0.08
Dual	0.02	0.10	0.21	0.02	0.08	0.12

Conclusions

This study exposed new and legacy smoke alarms of different types to a variety of selected cooking scenarios in a mock kitchen. The smoke alarm activation times were tracked, and the results were used to compare the nuisance resistance of new alarms compared to legacy alarms for a much wider range of cooking sources than just the broiling hamburger nuisance test that was added to the 8th Edition ANSI/UL 217. The fraction of tests that activated each smoke alarm was tabulated for tests with the range hood off and the range hood on.

While the mock-up kitchen was relatively small, there were significant differences in alarm activation between the D2 alarm models at different distances from the cooking sources. This observation, along with the overall reduction propensity to alarm in experiments with the range hood on, both reinforce the recommendation to maximizing the distance from the nuisance source while still providing adequate coverage for smoke detection. While the best performing alarm with the range hood off was a legacy photoelectric-type (P2), one of the new alarms, N3, along with P1 and D1, also performed well. All alarms showed marked improvement in performance when the range hood was turned on. Two of the new alarms that presumably relied either ionization chamber (N1) or light-scattering sensor (N3) designs, performed better than all other alarms when the range hood was on.

When grouping the data by alarm type, it was observed that the new alarm group tended to behave similarly to, but slightly better than, legacy ionization alarms. However, the legacy photoelectric alarm group performed the best overall across all tests. Given that the new alarms also need to meet the more stringent flaming and smoldering fire tests, it does appear that the cooking nuisance test provides a baseline performance level such that newer alarms do not perform worse than legacy alarms.

References

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