Secondhand Smoke: Preliminary Investigation into the Effects of Canned Smoke Aerosol Testers on Carbon Monoxide Sensors Used in Combination Alarms

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Maintenance Requirements for Smoke Alarms and Detectors

- NFPA 72-13 requires annual functional testing of smoke alarms (i.e. hotels, commercial facilities, apartment buildings) with the exception of those used in one- and two-family dwellings.

- Functional testing for smoke alarms and detectors typically incorporate the use of simulated smoke aerosols.

- The availability of canned smoke aerosols makes testing easy and affordable.

- For combination smoke/CO alarms, following annual smoke alarm tests, it is unknown if there are any adverse effects of smoke aerosols on CO sensors.
Concerns

Potential *unintended* outcomes of canned smoke aerosol use:

- Adverse effects on CO sensors within combination alarms
  - CO sensitivity may change
  - CO sensor may be temporarily blinded and unable to detect sudden high concentrations of CO
  - Residual chemical buildup that may attract dust over extended periods of testing, causing CO sensitivity drift.
Agenda

- Project Objective and Overview
- Combination Smoke/CO Alarms
- Canned Aerosols
- Test Plan
- Test Setup
- Test Results
- Findings
- Recommendations
**Project**

**Objective** - Determine whether the use of commercially available canned smoke aerosols affects the sensitivity of CO sensors in combination smoke/CO alarms

**Overview**
- Two-phase investigation (short-term and long-term effects)
- Commercially available off-the-shelf (COTS) combination smoke/CO alarms
- COTS smoke aerosols
Combination Smoke/CO Alarms

- Three combination smoke alarms from three separate manufacturers (A, B, and C)
- Biomimetic sensors were unavailable in the market at time of testing
- All alarms are AC-powered with battery back-up

<table>
<thead>
<tr>
<th>Model</th>
<th>CO Sensor</th>
<th>Smoke Sensor</th>
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<tbody>
<tr>
<td>A</td>
<td>Electrochemical</td>
<td>Photoelectric</td>
</tr>
<tr>
<td>B</td>
<td>Electrochemical</td>
<td>Ionization</td>
</tr>
<tr>
<td>C</td>
<td>Metal Oxide</td>
<td>Ionization</td>
</tr>
<tr>
<td></td>
<td>Semiconductor (MOS)</td>
<td></td>
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</table>
Canned Aerosols

- Five brands of canned smoke aerosols with different chemical formulations were selected for testing.

- The following chemicals may adversely affect the sensitivity of CO sensors:
  - Silicones, Hydrocarbons, and Alcohol.

- A combination of these compounds may be found in canned smoke aerosol testers available on the market.
Test Plan

- **Baseline Test**
  - Before aerosol spraying or exposure

- **Normal Spray Test**
  - Manufacturers’ instructions

- **Abnormal Spray Test**
  - Over spraying and spraying too close to the alarms

- **Baseline 2 Test**
  - After normal and abnormal testing

- **Modified Second Abnormal Spray Test**
  - Reduce time from expose to chamber
Test Setup

- Each model (A, B, and C) of combination alarms were tested at the same time; 18 alarms total.

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- The remaining three alarms of each model served as control samples and were not exposed to aerosol spray.
Test Setup Continued

- Normal Spray (manufacturers instructions)
  - 10 seconds until alarm from a distance of 2 feet

- Abnormal Spray (overspray and spraying too close)
  - 1 minute from a distance of 1 feet

- After spraying, the alarms are placed in the chamber and connected to the directional microphones and ASD system
CO sensitivity testing in accordance with ANSI/UL 2034, Section 39, 400 ppm

CO alarm test point is 400+-10 ppm with alarm activation required from 4 to 15 minutes of establishing test level

Why 400 ppm?
– Simulate the worst-case scenario associated with a compromised refresh signal or adverse effects on CO sensor sensitivity directly after being sprayed
Data Acquisition

- Audible Signal Detection System
  - Multiple alarms
  - Detects normal and trouble signals
  - Independent channels
  - Each alarm detected independently

- Microphones
  - Directional audio pickup

- Data Acquisition Software
  - Allows time synchronization of alarm activations
  - Activation times - time to alarm after achieving 400 ppm CO concentration in the chamber
Results: Aerosol A1
Alcohol mixture with HFC 134a refrigerant
Baseline, Normal Spray and Abnormal Spray

Aerosol A1

Baseline
Normal
Abnormal

Alarm A
UL 2034, 400 ppm
Required Activation Window

Alarm B

Alarm C

Activation Time (minutes)

Combination Smoke/CO Alarm

Model A1 Model A2 Model A3 Model B1 Model B2 Model B3 Model C1 Model C2 Model C3

Baseline Normal Spray Abnormal
Results: Aerosol A2
Butane/propane hydrocarbon blend
Baseline, Normal Spray and Abnormal Spray

Normal Spray – C1 activated 15 seconds before the 4 minute mark
Results: Aerosol A3
HFO 1234ze(E) refrigerant and a proprietary chemical
Baseline, Normal Spray and Abnormal Spray

Normal Spray - C3 activated 25 seconds before the 4 minute mark
Results: Aerosol A4
Alcohol (ethanol and glycerin) based
Baseline, Normal Spray and Abnormal Spray
Results: Aerosol A5
Butane/propane hydrocarbon blend with alcohol
Baseline, Normal Spray and Abnormal Spray

Aerosol A5

Baseline
Normal
Abnormal

UL 2034, 400 ppm
Required Activation Window

Activation Time (minutes)

Combination Smoke/CO Alarm

Model A1  Model A2  Model A3  Model B1  Model B2  Model B3  Model C1  Model C2  Model C3

Baselinet
Normal Spray
Abnormal
Results: Control Alarms
Baseline, Normal Spray and Abnormal Spray

Control alarms were not sprayed with canned aerosol; they were subject to UL 2034 tests at the same time as the other alarms during all test sequences.
Baseline Comparisons

Comparison between Alarms before normal and abnormal spraying (Baseline) to Alarms after normal and abnormal spraying (Baseline 2)
Model A Smoke /CO Alarm
Baseline vs. Baseline 2

UL 2034, 400 ppm
Required Activation Window

Aerosol A  Aerosol B  Aerosol C  Aerosol D  Aerosol E  Control

Activation Time (minutes)

Combination Smoke/CO Alarm

Baseline  Baseline 2

AA1  AA2  AA3  BA1  BA2  BA3  CA1  CA2  CA3  DA1  DA2  DA3  EA1  EA2  EA3  FA1  FA2  FA3
Model C Smoke/CO Alarm
Baseline vs. Baseline 2

UL 2034, 400 ppm
Required Activation Window

Model C Alarms
Baseline
Baseline 2
Findings

- Following a normal spray application, two units of Alarm C activated slightly prematurely and thus were not within the specified time frame in UL 2034, table 39.1, 400 ppm CO concentration.

- The two units that activated slightly prematurely following the normal spray testing, activated within the required time frame following the more severe abnormal spray test.

- All other alarms activated within the required time frame throughout baseline, normal and abnormal testing.
Findings Cont’d

- Overall, the performance of Alarm C was erratic with 50% of testing resulting in a standard deviation greater than 1; Alarm C contains a MOS CO sensor, whereas alarms A and B have electrochemical CO sensors.

- Throughout testing, the average time to chamber from start of spray (normal and abnormal) to exposure of the required 400 ppm CO concentration was 33.72 minutes.

- Approximately 30 minutes after exposure to canned smoke aerosols, the test results showed no obvious discernible pattern of effect on CO sensor sensitivity.
Second Abnormal Spray
Reducing Time to Chamber

Objective: To determine the effects on the CO sensor immediately after exposure to canned smoke aerosols

- Five tests (one per aerosol); 30 alarms total
- Each test consists of three alarms (Model A, B, and C) and three control alarms (Model A, B, and C); 6 alarms total per test
- The alarms used in these tests were used in the previous tests
- Alarms were pre-wired with a microphone prior to test spray
Second Abnormal Test Results

The average time to chamber from start of spray to exposure of the required 400 ppm CO concentration was 6.44 minutes.
Conclusions and Recommendations

- The test data did not appear to show any immediate effects to the CO sensors from the canned smoke aerosols tested.

- Based on the limited results, it appears that the MOS CO sensor used in this investigation was less consistent than the electrochemical CO sensors; additional testing of other MOS CO sensors may provide more data.

- Conduct long-term, Phase II testing of alarms that allows for accumulation of potential dust and residue build-up.
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