WHITE PAPER

Nest Protect Carbon Monoxide Field Study: Results from November 2013 to May 2014

Nest Labs, Inc.
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Introduction

This white paper shares field data on the incidence and characteristics of carbon monoxide (CO) events detected by the Nest Protect: Smoke + Carbon Monoxide™ alarm.[1]

Carbon monoxide is a serious public health issue: it's the leading cause of accidental poisoning deaths in North America[2], accounting for approximately 472 fatalities[3,4], and over 36,000 medical visits per year.[5] In the United Kingdom (UK), carbon monoxide poisoning accounts for approximately 50 fatalities and 4,000 medical visits per year.[6] These CO-related medical visits not only represent a high cost to individuals but to society at large as well. According to the Consumer Product Safety Commission, each carbon monoxide incident that requires medical attention costs nearly $16,000[7].

In October 2013, Nest launched Nest Protect, a combination smoke and carbon monoxide alarm designed to give people the information they need to stay safe. As an Internet-connected alarm installed in hundreds of thousands of homes, Nest Protect is able to report detailed, anonymous information on the CO events that it detects. This connectivity enables us to understand CO events in real homes on a scale that's never been available before. This provides a collaboration opportunity with the fire services community, safety experts, scientists, and consumers.

While carbon monoxide poisoning has been studied extensively, until now, the fire services community has had to rely primarily on self-reported data to estimate how many people are exposed to high levels of carbon monoxide, as well as the level of CO exposure in each incidence. Another research challenge that Nest Protect addresses is the difficulty in catching CO events because of the relative low number of incidents. For example, Nest Protect detected high levels of CO in 0.15% of homes per month. In the past, researchers would need to install and monitor more than 10,000 devices for a month just to observe 15 natural occurrences of high CO levels.

In this white paper, Nest is sharing its first summary of field data on carbon monoxide events from November 2013 to May 2014 in the US, Canada and the UK. All field data is anonymous, and no information about individual users is disclosed or discussed. Highlights from this report include:

- 0.15% of Nest homes experienced a CO event per month between November 2013 and May 2014.
- Peak CO levels during CO alarms ranged from 70 parts per million (ppm) to 1,964 ppm, with a median of 142 ppm.
- The length of CO events ranged from 3 minutes to over 24 hours, with a median of 1 hour and 17 minutes.
- Nest Protect data suggests that at least one million households across the US, UK and Canada are exposed to high levels of carbon monoxide each year.

How Nest Protect responds to carbon monoxide events

Nest Protect has been tested to comply with safety standards in the US, Canada and the UK set out by:

- Underwriters Laboratories Inc. (UL)
- California State Fire Marshal
- Canadian Standards Association
- British Standards Institution (BSI)

For the purpose of this white paper, a carbon monoxide event is defined as any situation in which Nest Protect sounded a carbon monoxide alarm. The sensitivity of a carbon monoxide alarm is based on two factors: the concentration of carbon monoxide in the air, measured in parts per million (ppm), and the amount of time that carbon monoxide has been detected.

As a UL and BSI certified device, Nest Protect's carbon monoxide algorithm performs within the ranges as specified in Appendix A and B, respectively, and complies with specifications set by the California State Fire Marshal and the Canadian Standards Association.

When Nest Protect detects high levels of carbon monoxide, as specified by the standards in Appendix A and B, it provides information in multiple ways:

- **Visual**: The light ring will glow yellow or red, giving occupants an emergency visual cue.
- **Audible**: All Nest Protects in the building will sound an 85 decibel alarm and speak the type and location of the danger. For example, "Emergency: there's carbon monoxide in the living room. Move to fresh air."
- **Mobile**: The Nest app will notify users about the type and location of the emergency.

When smoke or carbon monoxide nears emergency levels, Nest Protect also provides a "Heads-Up" alert, so occupants can address potential issues before they reach critical levels. A Heads-Up only notifies users of high levels of carbon monoxide, as specified by UL and BSI standards. Heads-Up is not a low-level CO alert.

In addition to these alerts, Nest Protect offers additional features to help users both before and during an emergency:

Wireless interconnect

In case of an event, all Nest Protects in the home speak the type (smoke or CO) and location (room name) of the emergency. Wireless interconnect works independently of Wi-Fi, so it will continue to function even if the home network is down.

Heating Shutoff

If a Nest Protect owner also has a Nest Learning Thermostat, Nest Protect will tell the Nest Thermostat to turn off fossil fuel heating during a CO emergency.[8]

What To Do

Nest Protect users can use the Nest app to prepare for emergencies. The What To Do section provides information on how to react during smoke and carbon monoxide emergencies. Customers can also enter the phone number of their local fire department, police department or a neighbor in the Nest app, which displays this information during emergencies.

Results of the study

Overall incidence of carbon monoxide events

From November 2013 to May 2014, Nest Protect reported that 0.15% of homes per month experienced a carbon monoxide event. Over the entire duration, 0.65% of homes experienced a carbon monoxide event.

Seasonal variation

Figure 1 shows the percentage of homes that experienced CO events for each month starting December 2013, the first full month that Nest Protect was gathering data in the field.

There was seasonal variation in the rate of CO events observed. There are higher incident rates during the colder months than warmer months, which is often attributed to increased use of heating systems. During the same period, Nest Protect reported events 3.0 times as often in December as it did in April. In comparison, the National Fire Protection Agency (NFPA) reports 2.3 times as many non-fire carbon monoxide calls to fire departments in January as in April.[9]

Figure 1: Incidence rate of CO events by month

Differences between Nest Protects in North America vs. the UK

Nest Protects in the UK experienced 1.64 times more CO events than Nest Protects in North America during the study period. BSI standards have lower CO thresholds which may account for the higher number of events in the UK.

Average number of events per household

On average, homes that experience a CO event have more than one event that month. The Nest homes that experienced CO events had on average 1.53 events in the same month.

Peak carbon monoxide levels during CO events

Figure 2 shows peak carbon monoxide levels during CO events, the highest level of CO observed over the source of the event. Health officials in the US consider 70 ppm the minimum threshold at which an alarm can sound. At 70 ppm symptoms such as headache, fatigue and nausea may begin to appear.[10]

For the majority of carbon monoxide events, carbon monoxide levels did not exceed 200 ppm at any point during the event. Over a third of events (34%) peaked below 100 ppm, while 29% of events peaked between 100 and 200 ppm. The maximum level of CO recorded during an event was 1,964 ppm, and the median event peaked at 142 ppm.

In the UK, the median peak CO level reached during events was 452 ppm, significantly higher than the median value across all Nest devices.

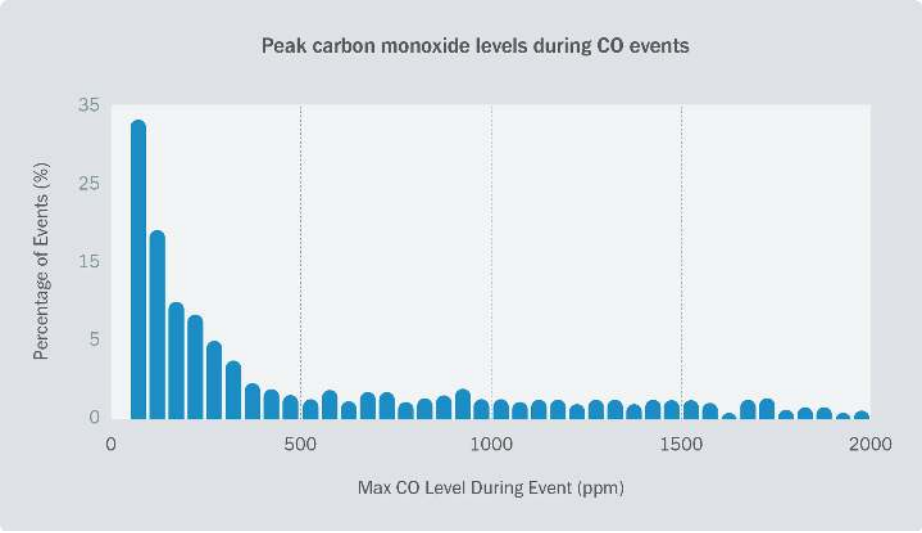

Figure 2: Peak carbon monoxide levels during CO events

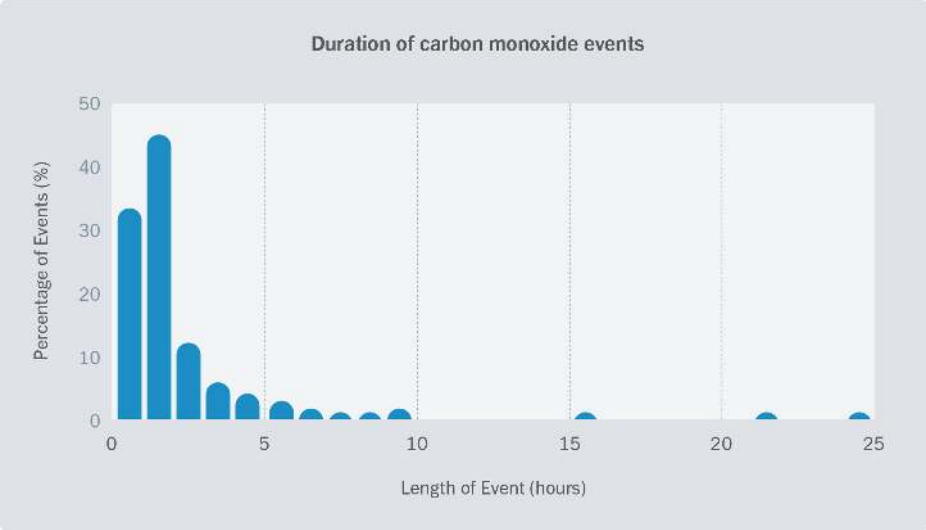

Figure 3: Duration of carbon monoxide events

Duration of carbon monoxide events

For the same set of CO events observed in Figure 2, Figure 3 shows the duration of those events when CO levels were above 50 ppm. The duration of the event is defined as the length of time that CO levels were about 50 ppm, from the first sample that crossed the 50 ppm threshold to the last sample above 50 ppm in the event.

The median length of a carbon monoxide event across the sample population was 1 hour, 17 minutes. Nearly all events ended within four hours: 78% of events lasted two hours or less, and 33% of events ended in under one hour. Three events extended over ten hours, with the longest event extending over for 24 hours.

Sample CO event profiles

Because Nest Protect records data from a large and diverse scale of homes and environments, it's able to observe different patterns of CO behavior. Here are case studies of two carbon monoxide events. During each event, Nest Protect did not detect any smoke.

Event Profile 1

Figure 4 shows one typical example CO profile. During this event, CO built up over 30 minutes to reach a peak level of 325 ppm. Then, CO levels began to drop steadily for 45 minutes. The rate of dispersal was slightly below the rate of build up.

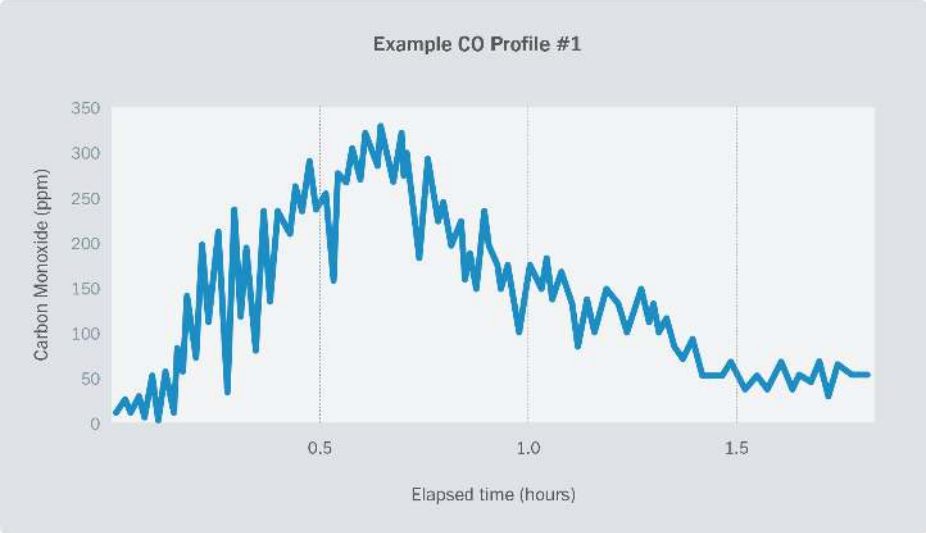

Figure 4: Example CO Profile #1

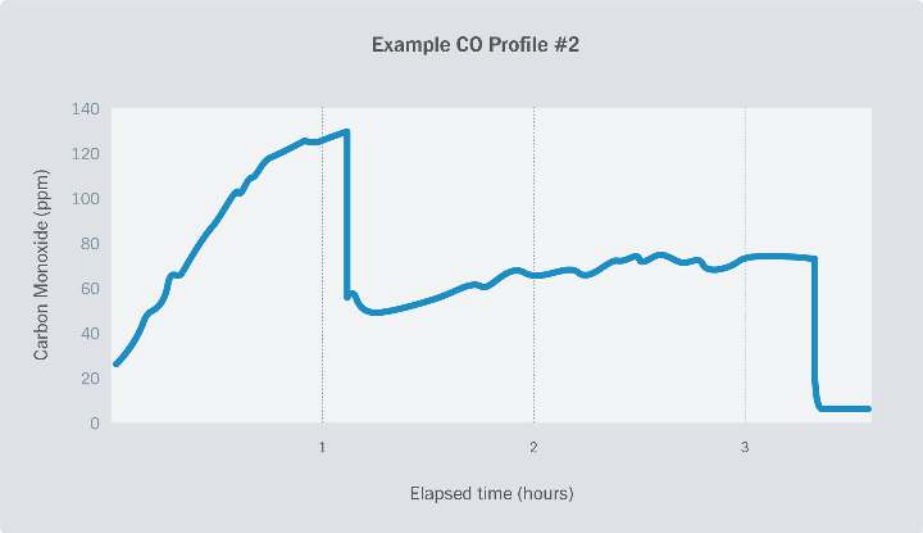

Figure 5: Example CO Profile #2

Event Profile 2

Figure 5 provides a profile of human intervention addressing carbon monoxide in the building. The CO level rose steadily for an hour, eventually reaching 120 ppm. At 120 ppm, the carbon monoxide alarm was manually hushed at the device and CO levels quickly dropped to ~60 ppm. The alarm sounded again soon after the hushing and continued sounding while the CO level remained high. About 2.5 hours after the first intervention, the alarm was hushed again, coinciding with another rapid decrease of CO to finally stop the alarm.

Conclusion

Because Nest Protects are connected to Wi-Fi, Nest can provide insight into the incidence of high CO levels among homes that have CO alarms - without requiring people to (a) be home and (b) report the event. This provides a new layer of data about residential carbon monoxide (see Figure 6). Also, Nest Protect's built-in sensors provide the ability to detect additional pieces of environmental data, run algorithms to determine the level of danger, and report that data in real time to further enhance our understanding of these events.

Based on the seven months of data collected, Nest modeled a projection of the annual exposure level. Taking seasonality into account, this projection shows that approximately 0.9% of households are exposed to high CO levels, or about 1.4 million households across the US, Canada, and the UK.

The incidence of high CO levels reaffirms the importance of CO alarms - yet, studies have shown that less than half of consumers in the US[11] and the UK[12] have these alarms. CO alarms are not mandated everywhere in the US, UK and Canada, and existing requirements often only cover new construction or renovations. The information shared in this white paper, combined with other research results, can help inform relevant decision-makers whether CO alarms are necessary more widely to improve life safety for consumers.

To contact Nest about the results of this white paper, please email firesafety@nest.com.

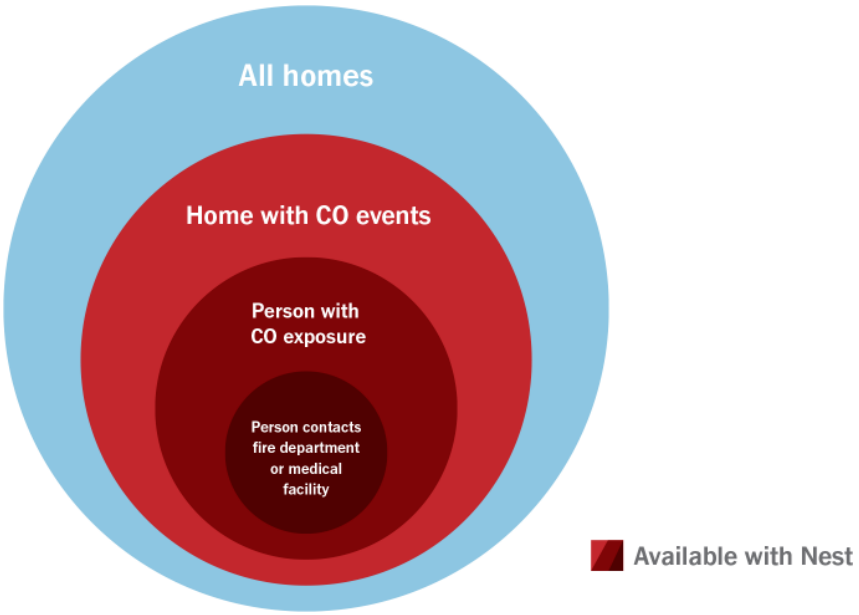

Figure 6: Sources of data related to the ability to observe residential carbon monoxide events.
Note: figure not to scale

References

1. This white paper does not guarantee or promise any specific level of performance or benefit from the use of Nest Protect or any of its features. Actual performance of Nest Protect varies with factors beyond Nest's control or knowledge. This white paper is solely intended to present findings about the Nest Protect during a field test that occurred during a limited period of time under specified conditions.
2. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6030a2.htm
3. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6303a6.htm
4. http://www.winnipegfreepress.com/canada/key-facts-about-carbon-monoxide-250675231.html
5. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6030a2.htm#tab1
6. http://www.co-bealarmed.co.uk/about/
7. https://www.cpsc.gov//Global/Research-and-Statistics/Injury-Statistics/Carbon-Monoxide-Posioning/IncidenceandCostofCarbonMonoxidePoisoningPoolandSpaSubmersionandLeadPosioning.pdf
8. This feature relies on the Internet and requires working Internet and Wi-Fi connections to the thermostat and CO alarm at the time of an emergency.
9. http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Non%20fire%20Incidents/osnonfirecarbonmonoxide.pdf
10. https://www.cpsc.gov/en/Safety-Education/Safety-Education-Centers/Carbon-Monoxide-Information-Center/Carbon-Monoxide-Questions-and-Answers-/
11. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6030a2.htm#tab1
12. http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Non%20fire%20Incidents/osnonfirecarbonmonoxide.pdf

Appendix A

UL 2034 alarm standards

UL specified ranges

CO concentration (+/- 5 ppm)	Alarm response time in minutes
70 ppm	60 - 240
150 ppm	10 - 50
400 ppm	4 - 15

Appendix B

BSI EN50291 alarm standards

British Standards Institution specifications

Underwriters Laboratories guidelines	
CO concentration	Alarm response time in minutes
30 ppm	after 120
50 ppm	60 - 90
100 ppm	10 - 40
300 ppm	0 - 3