



# **Findings from CPSC's 2014 Carbon Monoxide/Combustion Sensor Forum and Request for Information**

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# Report on the Findings from CPSC's 2014 Carbon Monoxide/Combustion Sensor Forum and Request for Information

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## EXECUTIVE SUMMARY

In April 2014, CPSC staff published a *Federal Register* Notice that announced a Carbon Monoxide (CO)/Combustion Sensor Forum and issued a Request for Information (RFI) to help staff gain a broader understanding of the availability and capabilities of gas sensor technologies currently available or under development, as well as barriers to using these technologies in vented gas heating appliances. The Forum was held on June 3, 2014 at the CPSC's National Product Testing and Evaluation Center (NPTEC) and was attended by 22 stakeholders, including 14 gas appliance industry representatives, one standards development organization representative, and one sensor manufacturing representative.

The forum was divided into two panel presentations. Panel 1 provided an overview of the Gas Appliance CO Sensor Project by CPSC staff from the Directorate for Engineering Sciences and the Directorate for Health Sciences, including discussions on:

- Hazard patterns,
- Annual CO death estimates,
- Physiology of carbon monoxide poisoning,
- CPSC's CO-related activities,
- History of CPSC's participation in the American National Standards Institute (ANSI) Z21 standards which govern gas appliances, and
- Applicable current and proposed international standards and regulatory schemes.

Panel 2 included presentations by a sensor manufacturing representative and a U.S.-based gas industry research organization. The first of the Panel 2 presentations was given by the U.S. distributor of CarboSen combustion sensing devices manufactured by Lamtec, GmbH. The CarboSen sensors have been under development and field testing since 2001 for energy efficiency applications within the combustion chambers of residential gas boilers in the European market.

The second Panel 2 presentation was given by a representative of the Gas Technology Institute (GTI) on their findings from a 2011 study they conducted on the technical feasibility of using CO sensors in gas appliances. The study was conducted for and funded by the Air-Conditioning, Heating and Refrigeration Institute (AHRI) and consisted of a literature survey on sensor technologies and a survey of gas appliance manufacturers. The study did not include any sensor testing conducted by GTI. GTI concluded the following from the literature search and manufacturers survey:

- Sensor range, maximum sensor value, accuracy and voltage were not limitations for the usage of CO sensors in gas appliances.
- Temperature and humidity operating limits prevent the use of current CO sensor technology in the flue or combustion chamber of gas-fired appliance.
- The existing life span of CO sensors studied is currently less than 6 years, short of the 20-year life expectancy of some gas-fired appliances.
- Based on the available literature and testing data, extensive research is required before current designs of CO sensors would be able to operate in the combustion chamber or flue of a gas-fired appliance long enough to be used for safety or combustion control.

CPSC staff believes that the CarboSen sensors and other combustion product sensing devices certified to the European standard, EN 16340, *Safety and control devices for burners and appliances burning gaseous or liquid fuels— Combustion product sensing*, show promise as possible technological means of implementing staff's CO shutoff proposal. EN 16340 has not yet been fully incorporated into European gas appliance standards. Staff believes that the standard's endurance and other performance requirements address the concerns about the durability and

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longevity of a sensor operating in a gas appliance raised by the ANSI Z21/83 Technical Committee, as well as those raised in the second Panel 2 presentation.

Finally, this memorandum summarizes comments on the RFI received from 2 stakeholders and includes CPSC staff response to those comments. CPSC staff concludes that it is important to continue the dialogue with national and international standards development organizations, and continue to seek out U.S. and international sensor manufacturers and information that demonstrate their product capabilities for long-term, in-flue application within gas furnaces and boilers.

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## I. INTRODUCTION

On April 16, 2014, the U.S. Consumer Product Safety Commission (“CPSC” or “Commission”) published a *Federal Register* notice with docket number CPSC-2014-0009, announcing that a Carbon Monoxide/Combustion Sensor Forum would be held at the CPSC’s National Product Testing and Evaluation Center (“NPTEC”) on June 3, 2014.<sup>1</sup> The *Federal Register* notice also included a Request for Information (“RFI”) on carbon monoxide (“CO”) and combustion sensors and their applicability for use in vented gas appliances.

Both the Carbon Monoxide/Combustion Sensor Forum and the RFI are in support of the CPSC’s Gas Appliance CO Sensor Project. The purpose of the forum and the RFI was to help staff obtain a broader understanding of the sensor technologies currently available and under development, as well as any barriers to using these technologies in a vented gas appliance as a shutoff device if excessive CO is being produced.

This report documents the information shared during the forum, in addition to the findings from the RFI.

## II. BACKGROUND AND PURPOSE OF THE GAS APPLIANCE CO SENSOR PROJECT

The Gas Appliance CO Sensor Project is designed to reduce the occurrence of CO deaths, injuries, and exposures associated with known failure modes or conditions in vented gas heating appliances. The scope of this project includes vented residential gas heating appliances, such as gas furnaces, boilers, floor furnaces, and wall furnaces that use natural gas or liquefied petroleum gas (“LP-gas”) for fuel. If these products are not installed or maintained properly, or if they experience component malfunction or defect, they may not burn their fuel completely, potentially resulting in the production of dangerous levels of CO. Gas furnaces and boilers are two of the leading causes of CO poisoning among all consumer products. For the 12-year period from 1999 to 2010, there were a total estimated 369 non-fire CO poisoning deaths associated with central gas furnaces/boilers, wall furnaces, and floor furnaces.<sup>2</sup>

The focus of the project, to date, has been to find a way to address the CO hazard at the source, through participation in the relevant voluntary standards organizations. Staff continues to:

- research the viability of using CO sensors in vented gas appliances<sup>3</sup>;

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<sup>1</sup> <http://www.cpsc.gov/en/Regulations-Laws--Standards/Federal-Register-Notices/2014/Carbon-MonoxideCombustion-Sensor-Forum-and-Request-for-Information/>.

<sup>2</sup> Hnatov, M., Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products. 2010 Annual Estimates, U.S. Consumer Product Safety Commission. January 2014. <http://www.cpsc.gov//Global/Research-and-Statistics/Injury-Statistics/Carbon-Monoxide-Posioning/2010NonFireCODeathsFINAL.pdf>.

<sup>3</sup> Jordan, R., and Butturini, R., Evaluation of the Durability and Longevity of Chemical Sensors Used *In-Situ* for Carbon Monoxide Safety Shutdown of Gas Furnaces, U.S. Consumer Product Safety Commission. September 2012. [http://www.cpsc.gov/PageFiles/129834/CO\\_sensor\\_durability\\_and\\_longevity\\_testing.pdf](http://www.cpsc.gov/PageFiles/129834/CO_sensor_durability_and_longevity_testing.pdf).

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- investigate international voluntary standards and regulatory schemes for the use of CO sensors in vented gas appliances to reduce the CO hazard and their applicability to the U.S. market for residential vented gas appliances; and
- participate in voluntary standards activities of the governing ANSI Z21 committee.

CPSC staff actively participates in voluntary standards activities to address CO hazards associated with vented gas heating appliances, such as furnaces and boilers. The Canadian Standards Association (“CSA”) and CSA America, Inc. (operating as “CSA Group”) develop voluntary standards for gas appliances and gas appliance accessories sold in the United States and Canada. The U.S. versions of these standards are accredited by ANSI, while the Canadian versions are accredited by the Standards Council of Canada.

Staff previously worked with the ANSI Z21/83 Technical Committee (“TC”), from 2002 to 2004, to develop a test criterion to evaluate the use of CO and combustion sensor technology to implement CPSC staff’s proposed performance requirement that appliances shut down, or exhibit some other preemptive response, when dangerous levels of CO within the appliance are detected. In 2005, TC Z21/83 decided not to pursue evaluation of sensor technology.

In addition, staff has investigated international voluntary standards and regulatory schemes, including the development of European standards in CEN Technical Committee 58 (“TC 58”) *Safety and Control Devices for Burners and Appliances Burning Gaseous or Liquid Fuels* and the Japanese Standards Association (JIS) and continues to explore their applicability to the U.S. market.

### III. FINDINGS FROM CPSC’S 2014 CARBON MONOXIDE/COMBUSTION SENSOR FORUM

The CPSC Carbon Monoxide/CO Sensor public forum held on June 3, 2014, focused on technological means of reducing the risk of carbon monoxide exposure from vented gas appliances under a variety of conditions. The forum’s purpose was to help CPSC staff gain a broader understanding of the scope, state of the art, and availability of current or prototype sensor technologies being used to shut off gas heating appliances when incomplete combustion or dangerous levels of CO are detected.

As seen in Table 1, the 22 external attendees at the Carbon Monoxide/CO Sensor Forum included industry representatives and other stakeholders. The breakdown of attendees from outside of CPSC is segmented as follows:

<b>Table 1. Stakeholder</b>	<b>Number</b>
Gas industry	14
Standards development organization	1
Gas monitor manufacturer or distributor	3
Sensor manufacturer	1
Academia	1
Consultant	1
Unknown	1

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The 14 representatives from the gas industry were comprised of six appliance manufacturers, six gas appliance trade or research organizations, and two gas appliance component suppliers. A complete list of the attendees' names and contact information is provided in Appendix A.

## **a. SUMMARY OF INFORMATION PRESENTED AT THE FORUM**

Presenters included CPSC staff, a sensor distributor, and a representative of GTI. The forum was videotaped and is available for viewing on the CPSC's website.<sup>4</sup>

*Panel 1: Mr. Ronald Jordan, CPSC Project Manager and Dr. Sandra Inkster, CPSC Physiologist*

Mr. Jordan and Dr. Inkster presented an overview of the project, including:

- hazard patterns,
- annual CO death estimates,
- physiology of carbon monoxide poisoning,
- CPSC's CO-related activities,
- history of CPSC's participation in the ANSI Z21 standards that govern gas appliances, and
- applicable current and proposed international standards and regulatory schemes.

The CPSC staff presentations are available at:

<http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0006>

*Panel 2: Mr. Steven Craig, Vice-President, Hayes Cleveland (North America Distributor for Lamtec, a sensor manufacturer) and Mr. Larry Brand, Gas Technology Institute*

### Presentation by Mr. Steven Craig (Lamtec GmbH & Company)

Lamtec is a German-based developer and manufacturer of sensors and systems for combustion management technologies used in commercial and residential gas- and oil-fired equipment and appliances. Lamtec was founded in Germany in 1995, after a management buyout from ABB-Deutschland. The Hays Cleveland Division of UniControl Inc. is a Cleveland-based manufacturer of combustion controls for commercial and industrial gas equipment and a maker of air proving switches for residential gas furnaces and boilers. Hays Cleveland recently partnered with control and instrumentation manufacturer, Lamtec, to support their combustion control markets in the United States and Canada.

Lamtec manufactures, among other products, ceramic gas sensors used to optimize the combustion process and energy efficiency in gas appliances sold in Europe. Of particular

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<sup>4</sup> <http://www.cpsc.gov/en/Newsroom/Multimedia/?vid=70087>.  
<http://www.cpsc.gov/en/Newsroom/Multimedia/?vid=70094>.  
<http://www.cpsc.gov/en/Newsroom/Multimedia/?vid=70213>.



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relevance to the CO Shutoff discussion is Lamtec's CarboSen series sensors for residential gas boilers (and other gas and oil heating appliances). According to Lamtec, the CarboSen sensors are used to detect the combustion gases produced within the combustion chamber of oil and gas-fired appliances, including CO, hydrogen (H<sub>2</sub>), and hydrocarbons (C<sub>x</sub>H<sub>y</sub>). The aggregate of these combustion gases are referred to by Lamtec as CO equivalent (CO<sub>e</sub>). The sensor is comprised of the sensing element, sensor housing, and electronics and signal cable, and is used to detect the CO<sub>e</sub>. The sensor electronics enable temperature compensation during operation of the sensor, flexible control of the sensor, and the acquisition of all sensor signals. The CarboSen 1000 has a CO<sub>e</sub> detection range of 0–3,000 ppm but operates ideally at CO<sub>e</sub> concentrations of up to 1,000 ppm.

The technology used for this detection principle is similar to the technique used for lambda oxygen sensors. However, varying the sensing element's geometry, material and electrical wiring allows the sensor to detect other gases, such as CO, H<sub>2</sub>, and C<sub>x</sub>H<sub>y</sub>; although the sensor is non-selective and can detect all kinds of oxidizable gaseous substances. To operate, the sensor is heated to a temperature of 630°C using a heating component mounted to the back of the sensing element. This temperature is set automatically and kept constant during operation by the sensor electronics.

A potential drawback with the Lamtec sensor is that the sensor does not isolate CO from the other combustion gases, but instead, measures the total of the combustion gases, aggregating them as a measure known as CO<sub>e</sub>. The U.S. distributor indicated that CO is, by far, the largest constituent being measured.

The Lamtec presentation, titled "*Ceramic Gas Sensors for Optimisation of Combustion Processes*," is available at <http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0005>.

### Presentation by Mr. Larry Brand (Gas Technology Institute)

The Gas Technology Institute ("GTI") is an independent, not-for-profit technology organization that provides the natural gas industry with research, development, and training for the transmission, distribution, and end use of natural gas in the United States, and globally. Particularly in the area of end use of natural gas, GTI provides research that supports the residential gas appliance safety and standards development efforts of the Canadian Standards Association (CSA)/ANSI Z21 Gas Appliance Standards and the Air-Conditioning, Heating, and Refrigeration Institute ("AHRI").

GTI was formed in April 2000 by the merger of the Gas Research Institute ("GRI") and the Institute of Gas Technology ("IGT"). Functionally, GTI's support and involvement with the gas appliance industry was provided by GRI before the merger. GTI presented the findings of a study they conducted from 2009 through 2010 on the technical feasibility of using CO sensors in gas appliances. The study was conducted for and funded by AHRI. GTI's stated objectives were to:

- understand the types of CO sensor technologies available;
- establish a technical baseline for integrating CO sensors into appliances; and



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- identify critical areas needing further investigation.

Their approach to accomplishing these objectives consisted of conducting: (1) a literature survey on sensor technologies, and (2) a survey of gas appliance manufacturers. They did not conduct any sensor testing.

GTI's literature survey spanned the years from 1996 through 2003, and 2006 through 2010. The 1996 through 2003 survey segment only referenced a 1996 GRI report and a 2003 GTI report. The 1996 GRI report concluded that there were no CO sensors available that met all the technical requirements. The 2003 GTI report was a survey on available technologies, including the following sensor technologies:

- Solid state ceramic
- Copper oxide with alkaline metal
- Tin oxide in a sensor array
- Tin oxide with platinum or palladium doping
- Catalytic bead sensor
- Gallium lead diode laser absorption sensor
- Zirconia sensor

GTI's 2003 survey concluded that metal oxide semiconductor ("MOS"), electrochemical, and catalytic technologies were widely available, but not suitable for gas appliance safety circuits. GTI's 2006 through 2010 literature search referenced a 2008 Galatsis report that identified electrochemical ("EC"), metal oxide ("MOS")/semiconductor ("SMO"), and infrared ("IR") sensors as the predominant sensor technologies available.

From the literature search GTI concluded:

1. Sensor range, maximum sensor value, accuracy, and voltage are not limitations for the usage of CO sensors in gas appliances.
2. Temperature and humidity operating limits prevent the use of current CO sensor technology in the flue or combustion chamber of a gas-fired appliance.
3. The existing life span of CO sensors studied is currently less than 6 years, short of the 20-year life expectancy of some gas-fired appliances.
4. Based on the available literature and testing data, extensive research is required before current designs of CO sensors would be able to operate long enough in the combustion chamber or flue of a gas-fired appliance to be used for safety or combustion control.

GTI also conducted a survey of selected AHRI appliance manufacturers to establish the environmental and operating criteria under which a CO safety sensor must operate in a gas-fired appliance. The following operating criteria were reported in that survey:

- Temperature Range: -40 to 500°F

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- Humidity Range: 0% to 100% RH
- Normal CO Sensor Range: 0 to 400 ppm
- Maximum CO Sensor Value: 3000 ppm
- Lifespan: 20 years
- Accuracy: ±5%
- Electrical Voltage: 24 VAC.

The GTI presentation, titled “*Technical Feasibility Study CO Sensing Safety Systems for Appliances,*” is available at: <http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0004>.

### Relevance of the Lamtec sensor technology to the Gas Appliance CO Sensor Project

It is unclear at this time whether their sensor could be used for the precise measurement of CO in combustion products or whether a correction factor is available, or even possible to develop, within the expected operating window of applicable appliances to allow for an approximate measurement of CO.

As summarized in Table 2 below, Lamtec has conducted field and life testing of the sensing element, housing, and electronics subassemblies of the CarboSen units, dating back to 1999. It wasn’t clear from their presentation if the field testing included the full sensor assembly as well, or just the subassemblies listed (*i.e.*, sensing element, housing, and electronics). Staff believes that the performance of the sensing element is most critical because it relates to the longevity and durability concerns raised by the ANSI Z21/83 Technical Committee and the U.S. residential gas appliance industry. This partial test summary demonstrates sensor technologies whose lifespans are approaching the 15 to 20-year threshold sought by the ANSI Z21/83 Technical Committee and the U.S. residential gas appliance industry.

	<b>Sensor element</b>	<b>Housing</b>	<b>Electronics</b>
<b>Function</b>	Tested in oil, gas, and solid fuel firings since 1999	Approximately 2,000 housings in operation (three different types)	Approximately 1,000 units in operation since May 2003
<b>Production</b>	More than 20,000 pieces since 2002	Experiences with series: Integration-without problems Standard-up to 200°C, condensing atmospheres High temp.-up to 450°C, condensing atmospheres	n/a
<b>Development</b>	n/a	n/a	Feb. 2003: prototype May 2003: pre-series Oct. 2003: redesign pre-series March 2004: zero series
<b>Field tests</b>	No blackouts of the sensor element since March 2002	n/a	n/a
<b>Life time</b>	Tests in oil and gas since	Tests in gas and oil since May 2003, two	No blackout since Oct. 2003

<sup>5</sup> “Ceramic Gas Sensors for Optimisation of Combustion Processes,” Dr. –Ing Frank Hammer, Power Point presentation by Steve Craig at CPSC’s Carbon Monoxide/Combustion Sensor Forum, June 3, 2014.

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<b>tests</b>	May 2003, two peripheral blackouts, tests go on	blackouts, problems solved, tests go on	
<b>Price</b>	Now: 250 € (\$272) per piece; Goal: 5-10 € (\$5-\$11) per 100.000 pieces	Now: 250 € (\$272) per piece; Goal: 3-6 € (\$3-\$7) per 100.000 pieces	500 € (\$544) per piece

The performance characteristics of Lamtec’s sensor technology appear to address many of the durability and longevity concerns of a sensor operating in a gas appliance that were raised by the ANSI Z21/83 Technical Committee.<sup>6</sup> Lamtec’s sensor technology also demonstrates:

1. that gas sensors exist that are used to monitor directly the combustion products, including CO (by non-selectively measuring all kinds of oxidizable, gaseous substances present), inside the combustion chamber of residential gas boilers;
2. that a type of gas sensor exists that is durable enough to operate within the harsh environments (*e.g.*, temperatures up to 600°C (1112 °F), relative humidity up to 100 percent) of gas appliance combustion chambers and flue passageways; and
3. that the lifespan and potential lifespan (*i.e.*, 11 years +) of this type of sensor, operating in gas appliance environments, is similar to the lifespan of gas appliances sold in the United States and Canada.

The information presented on behalf of Lamtec raises the following questions:

1. Was field testing performed on the sensor element alone, or was field testing performed on the sensor element, housing, and electronics integrated into a single assembly?
2. Would Lamtec be willing to share information on the life test setup and duration or the life test procedure or standard they used/referenced?
3. What type of failure mode does “blackout” refer to?
4. Of the “more than 20,000 pieces produced since 2002,” how many sensor elements were field or life tested?
5. Of the approximately 2,000 housings in operation (three different types), how many were field or lifetime tested?
6. Of the approximately 1,000 units in operation since May 2003, how many of the electronics units were Field or Life Time tested?
7. Are there other field test results for the sensor elements and the housings?
8. How many units were field tested separately as subassemblies (*i.e.*, separately as sensor elements, housings, or electronics), or as a single, assembled unit, including the sensor element, housing, and electronics?
9. To what extent would variations in unburned hydrocarbons, oxygen, or impurities in combustion products impact the performance of the sensor? Could this lead to false positives and/or false negatives?

<sup>6</sup> ANSI Z21/83 Technical Committee meeting on September 22, 2005.  
[http://www.cpsc.gov/PageFiles/179887/ANSI-Z21\\_83-TC-mtg-log.pdf](http://www.cpsc.gov/PageFiles/179887/ANSI-Z21_83-TC-mtg-log.pdf)

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## Relevance of GTI's Presentation to the Gas Appliance CO Sensor Project

GTI's findings are consistent with the gas appliance industry's position dating back to 2005, when the Z21/83 Technical Committee opted not to pursue sensor testing. Recently, use of similar technologies in water heaters in Japan, and developments of combustion sensors for European standards for fuel efficiency, which are beginning to be phased in, indicate that it might be possible to operate combustion sensors within a range similar to GTI's recommended criteria.

## **IV. RESPONSES TO CPSC'S 2014 RFI ON CARBON MONOXIDE/COMBUSTION SENSORS**

Staff did not receive any responses to the RFI from sensor manufacturers. However, two industry associations provided written comments.

### Air-Conditioning, Heating, and Refrigeration Institute comments

The AHRI provided comments to CPSC through electronic submission of a letter dated July 7, 2014. As stated in their comments, AHRI is a trade association that represents air-conditioning, heating, water heating, and refrigeration equipment manufacturers and whose members make up more than 90 percent of the residential gas-fired heating equipment sold in the United States. AHRI was formed in 2008, through a merger between the Gas Appliance Manufacturer's Association ("GAMA") and the Air Conditioning and Refrigeration Institute ("ARI"). All of the support and involvement in CSA standards development activities for gas appliances currently provided by AHRI were previously provided by GAMA. Although their identity has changed, their position on CO shutdown of gas appliances has not.

AHRI provided the following general comments:

1. Based on the information presented at the June 3, 2014, forum, *in situ* CO sensor use on residential gas-fired heating equipment continues to be in the experimental development phase.

**CPSC staff response:** *Staff disagrees with the statement that in situ CO sensor use on residential gas-fired heating equipment continue to be in the experimental development phase. These sensors are in widespread commercial use in Japan, where they are required in residential water heaters (JIS S 2109, Gas-burning water heaters for domestic use).*

2. Consumers must not be given a false sense of confidence by CO or combustion sensors used to shutoff gas appliances when elevated CO concentrations are present. CO safety shutoff system sensitivity must not degrade appreciably over time.

**CPSC staff response:** *CPSC staff agrees with AHRI that consumers should not be given a false sense of confidence when CO or combustion sensors are in use. CPSC staff does believe that a consumer would be given a false sense of security because a CO or*

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*combustion sensor was added to the appliance. CPSC staff also agrees that the sensitivity of a CO safety shutoff system should not degrade appreciably over time. Adherence to this would require a performance standard or the qualifications specified by the OEM appliance manufacturer and met by the sensor manufacturer.*

3. Nuisance shutdowns or system breakdowns could lead consumers to attempt to override or disable the system.

**CPSC staff response:** *CPSC staff agrees with AHRI on this matter. CPSC staff would expect that the potential for and occurrence of nuisance shut-downs would be addressed by appliance and component manufacturers, as well as the Z21 standards, in the same manner that nuisance shutdowns caused by existing shutoff or control devices, required by existing standards, are already addressed.*

4. CO safety shutoff system must fail safely and render the appliance inoperative.

**CPSC staff response:** *CPSC staff agrees with AHRI on this matter. Adherence to this would require a performance standard or the qualifications specified by the OEM appliance manufacturer and met by the sensor manufacturer.*

5. CO safety shutdown of an appliance would be a significant change in the consumer's experience with gas-fired heating appliances. Some consumers needing heat when the appliance shuts down may call a service technician. However, other consumers will not call a service technician or the technician may not be available immediately. In these cases, consumers will seek their own solution to address loss of heat.

**CPSC staff response:** *CPSC staff acknowledges that these scenarios may occur. However, staff believes this scenario is no different from scenarios in which appliance shutdown is caused by a pressure switch or any other safety shutoff device currently required by gas appliance standards.*

6. Although not a completely analogous situation, consumer misuse of portable generators during power outages illustrates the risks that consumers create when trying to resolve the loss of a basic need for their home.

**CPSC staff response:** *CPSC staff agrees the two situations are not analogous. The vast majority of CO incidents involving gas furnaces and boilers reported to CPSC do not involve consumers misusing the appliance after losing heat. Gas heating appliances currently shut down for a variety of reasons other than CO safety. Staff does not believe that a consumer is any more likely to tamper with an appliance that has shutdown, regardless of whether the shutdown is for CO safety or some other operational problem with the appliance.*

AHRI made the following recommendations to CPSC:



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1. When estimating the benefit of a CO safety shutoff system to reduce CO deaths and injuries, CPSC should compare this to the baseline of a residence with a functioning CO alarm. This is a code requirement in many parts of the United States. Although the CO alarm does not directly address the generation of CO, the alarm's function is to alert the occupants before a hazardous concentration of CO develops. By causing the occupants to act (e.g., leave the residence or turn off any operating combustion equipment), the CO alarm prevents a CO death or injury. The result, in terms of the consumer's safety, is the same.

**CPSC staff response:** *CPSC staff advocates the use of residential CO alarms. However, CO alarms do not detect an underlying fault condition within a gas appliance that leads to the production and release of CO into the living space. If such a fault condition exists and progresses to the point that CO is produced and released into a living space, then a level of safety and protection has been lost. Staff believes that a device that stops CO production and release at the source would have similar effects as devices, such as vent safety shutoff switches (VSSS) and oxygen depletion sensors (ODS) have had on vented and unvented gas space heaters in practically eliminating CO deaths associated with that group of products and failure modes. A CO alarm does not directly impact the safe operation of a gas furnace or boiler. A VSSS and ODS do have a direct impact on the safe operation of vented and unvented gas space heaters.*

2. As CPSC continues to consider the concept of CO/combustion sensors on gas-fired heating equipment, it should conduct a study to establish the baseline and trend of the cumulative effect of measures that have been implemented to address the CO hazard in residences in the U.S.

**CPSC staff response:** *CPSC has conducted a similar analysis and presented the findings at the sensor forum.<sup>7</sup> (Ref. Slides 18-22) The analysis compared the relative effects that standards changes in the late 1980s/early 1990s had on vented and unvented gas space heaters versus gas furnaces and boilers.) CPSC staff also relies on the staff's annual report of Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products<sup>8</sup> to determine trends that relate to the risk of death associated with the CO hazard in the United States.*

3. When analyzing the potential benefit of CO/combustion sensors, CPSC should consider the possibility that the use of CO alarms may decline, because occupants may misconstrue that a safety device on the gas-fired furnace, boiler or wall furnace prevents any CO hazard, rather than only the potential for a CO hazard from that product.

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<sup>7</sup><http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0006>

<sup>8</sup> <http://www.cpsc.gov/Global/Research-and-Statistics/Injury-Statistics/Carbon-Monoxide-Posioning/NonFireCarbonMonoxideDeathsAssociatedwiththeUseofConsumerProducts2011AnnualEstimatesSept2014.pdf>

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**CPSC staff response:** *When analyzing the benefits of CO/combustion sensors, CPSC staff would consider a variety of factors impacted by such a change, including the impact on CO alarm usage. CPSC staff believes that as regional building codes that require residential CO alarms increase, the likelihood of occupants purposefully removing CO alarms would decrease. CPSC staff is not aware of any analogous decline in the use of smoke alarms as standards addressing appliance fires have been developed.*

AHRI's comments are available at: <http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0002>.

### American Gas Association Comments

The American Gas Association (“AGA”) provided comments to CPSC through electronic submission of a letter, dated July 7, 2014. AGA represents more than 200 local energy companies that deliver natural gas throughout the United States. There are more than 71 million residential, commercial, and industrial natural gas customers in the United States. Of that number, 94 percent of the customers (68 million) receive their gas from AGA members.

AGA's comments are summarized as follows:

1. CPSC's focus should be not only on CO sensors and other onboard approaches, but also should be more flexible in reducing risks of CO poisonings, whether they include onboard sensors, onboard combustion analysis approaches (sensor-based or alternatives), or external ambient air monitoring approaches.

**CPSC staff response:** *CPSC staff is open to approaches that would significantly reduce the CO hazard. However, staff strongly believes that reducing the hazard at the source is often the most effective approach. CPSC staff's original proposal was for a new performance requirement to be added to the standards, not a design requirement for an onboard CO sensor. The onboard CO sensor approach was intended to demonstrate a technological means of implementing the proposed standard. The Japanese Industrial Standard (JIS) for domestic gas water heaters, JIS-S-2109, requires gas water heaters to be equipped with incomplete combustion-preventive devices that shutoff the appliance in response to 0.03 percent CO in the room, based on the CO concentration in the combustion gas.*

2. CO sensors are not always the most efficient and effective means of approaching appliance shutdown in the event that CO emissions rates exceed “safe” levels. The often-cited experience with CO shutoff functions of appliances in Japan notes, “there are different types of incomplete combustion prevention devices [incorporated in appliances], including those which detect a change in the flame condition by a temperature sensor and those which use a sensor that directly monitors the carbon monoxide concentrations.” In addition, activation of shutdown of appliances based on CO thresholds in combustion gases may not be sufficiently protective where appliances are installed and operated in situations outside of design standard performance test specifications. Use of air-free CO



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emissions thresholds implemented in certification standards; for example, assume operating conditions that may be overly liberal with respect to installation conditions of free air exchange in the structure. In such cases, shutdown of the gas-fired appliance may not occur within intended safe limits.

**CPSC staff response:** *CPSC staff is open to other approaches to accomplish the goal of reducing or eliminating CO exposure risks. Use of an air-free, CO emissions threshold in CPSC staff's "CO Shutoff" proposal would be subject to discussion and debate within the standards development process to reach consensus on this or any other standards proposal.*

3. Furthermore, with respect to the Japanese experience, an estimated "98% of water heaters" have incorporated CO-preventative shutdown systems; but in the case of Japanese water heaters, this includes "water heaters for indoor installation (indoor intake and indoor exhaust)." United States and Canadian water heaters do not incorporate "indoor exhaust" (*i.e.*, unvented) operation as an option under existing product and installation codes. This suggests that the Japanese prevalence of CO shutoff systems on appliances may not be logically extended to U. S. design certification or installation requirements without considerable additional investigation.

**CPSC staff response:** *CPSC staff agrees that incorporation of any new technology, including the CO shutoff systems required on Japanese water heaters since 2001, should first undergo an appropriate amount of investigation before being extended to U.S. design certification and installation requirements for gas appliances in the United States.*

4. If it is CPSC's intention to promulgate CO prevention technology through the gas-fired appliance standards (*e.g.*, the ANSI-recognized Z21/Z83 standards), CPSC should describe a clear strategy or proposal for design standards language that would meet its needs. In most cases, the combustion performance and methods of test implemented through these standards specify only combustion emissions thresholds and test conditions to achieve the targeted performance, not the specific technologies for preventing exceeding thresholds. For example, CPSC might propose time-weighted average exposure(s) for CO concentrations and the operating characteristics of the gas-fired appliances in a test chamber simulating installation local conditions. This would allow the greatest flexibility for appliance manufacturers in identifying effective and reliable shutdown approaches, whether or not they would employ CO sensor technologies.

**CPSC staff response:** *It is not CPSC staff's intention to "... promulgate CO prevention technology. ..."* Rather, CPSC's intention and actions have been, and continue to be, to work with stakeholders to develop voluntary consensus performance standards that provide a greater level of protection from many of the appliance failure modes and mechanisms associated with CO exposure incidents reported to CPSC. In support of developing a performance standard, CPSC staff has demonstrated a possible technological means of implementing a performance standard. Staff has also learned of international SDOs for domestic gas heating appliances that have taken a similar path to

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*address CO exposure or energy efficiency. However, if AGA is aware of other, more effective means of addressing CO exposure risks from appliances, CPSC staff invites AGA to share those approaches with the Z21/83 Technical Committee and with CPSC staff. CPSC staff intends to continue actively participate in the standards development process with the Z21/83 Technical Committee, the Z21.47 Central Furnace TAG, and the Z21.13 Boiler TAG to improve the safety of gas appliances.*

*The purpose of the Ad Hoc Working Group for CO/Combustion Sensors (established in 2002 by the Z21/83 Technical Committee) was to (1) develop a test criterion to evaluate the use of sensors for the shutoff of gas appliances in response to elevated levels of CO, and (2) to develop a RFP to solicit testing agencies to conduct the work. Both of these objectives were accomplished by the Working Group in 2004, and approved by the Technical Committee the same year. The ultimate goal of these activities was to develop a performance standard, if warranted. CPSC staff's 2000 "CO Shutoff" proposal<sup>9</sup> did not specify any specific technologies to prevent exceeding thresholds. CPSC staff's "proof-of-concept" testing was used to demonstrate a technological means for implementing the standard. Staff has always emphasized this point whenever the shutoff proposal or proof-of-concept test results were discussed at standards meetings or presented at industry conferences.*

5. CPSC staff's CO Shutoff proposal and related activities typically reference Air-Free Concentrations of CO. However, air-free measurements require simultaneous measurement of either carbon dioxide (CO<sub>2</sub>) or oxygen from excess air in the sample to perform an air-free CO calculation. Air-free CO performance, then, requires two measurements of gases in the flue gases to subtract out the dilution air contribution to as-measured CO performances. CPSC must consider both CO sensor and second gas sensor simultaneous measurement performance (including response ranges, accuracy, and drift) to assess technical feasibility of an air-free based CO shutoff system. To date, it does not appear that CPSC has addressed this additional complexity.

**CPSC staff response:** *CPSC staff agrees with AGA on this matter. In fact, CPSC staff's original CO Shutoff proposal did not specify "air-free CO," but instead made reference to "... CO emissions that exceed the standard limits."<sup>10</sup> CPSC staff continues to support development of a performance standard that would provide appropriate protection to consumers in shutting down appliances at an appropriate level of CO production.*

6. If CPSC would prefer using as-measured CO performance in lieu of calculating air-free CO emissions, it would need to perform a detailed analysis of air-free CO/as-measured emission factors across the appliance products for which it proposed a CO-based shutoff system. Appliance types differ significantly in the use of dilution air, and so general rules

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<sup>9</sup> CPSC staff letter to CSA International dated November 14, 2000.

[http://www.cpsc.gov/PageFiles/106498/Letter\\_ANSI\\_Z21.47\\_COemissions\\_furnace2\\_to\\_5\\_CO\\_shutoff\\_proposal.pdf](http://www.cpsc.gov/PageFiles/106498/Letter_ANSI_Z21.47_COemissions_furnace2_to_5_CO_shutoff_proposal.pdf)

<sup>10</sup> Ibid.

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of thumb for approximating air-free measurements from as-measured measurements of CO do not hold. Additionally, many appliances within a type may have different dilution air performance integral to their design. Unless and until CPSC assesses these relationships in detail, use of as-measured CO thresholds (presuming a relationship to the air-free CO performance used in design certification) would be ill-advised.

**CPSC staff response:** *CPSC staff agrees with AGA that gas appliances have design differences that may not allow for a one-size fits all design for a CO or combustion sensor. Staff does not agree with AGA's suggestion that CPSC should somehow account for the design considerations of sensors that have to operate in appliances with a wide variety of dilution air requirements. This is somewhat analogous to appliances that have different static pressures in their flue passageways, heat exchangers, or inducer motor intakes or exhausts. The ANSI Z21 standards require that gas furnaces and boilers be equipped with pressure switches to respond to blockages within these compartments. There is no one-size-fits-all pressure switch that can meet all of the design differences of gas furnaces and boilers. Rather, staff would expect any standard developed to be a performance standard and would anticipate for this issue of product-specific design parameters to be addressed by the design specifications provided to pressure switch suppliers from OEM furnace and boiler manufacturers. The appliance manufacturer would provide their design specifications, including dilution air requirements, to the sensor manufacturer, and the sensor manufacturer would have to build products to meet those specifications.*

7. At the Forum, CPSC did not cite cracked furnace heat exchangers as a significant source of CO poisonings. The gas utility industry would agree with this observation and add that private sector emphasis of furnace inspection procedures may be largely associated with this outcome. Inspection of furnaces for cracked heat exchangers may be a major success story for addressing gas-fired appliances and reduced incidence of CO poisonings over the past three decades. CPSC should redouble its efforts on promoting annual appliance inspections as a first-order effort for reducing CO poisonings while it continues to develop technical recommendations for appliance control approaches.

**CPSC staff response:** *CPSC staff agrees with AGA on this matter.*

8. In approaching appliance shutoff based on CO emissions performance, CPSC should directly and intensively assess potential unintended consequences of failures of CO shutoff approaches and technologies. While shutoff systems may "fail safe," consumer responses in the event of a loss of heat due to furnace shutdown may elicit unsafe emergency heating practices such as operation of kerosene heaters as a primary source of heat indoors or other potentially dangerous behaviors.

**CPSC staff response:** *CPSC staff acknowledges that this scenario may occur. However, staff believes that this scenario is no different from when an appliance with a pressure switch, required by various gas appliance standards, actuates and shuts down the appliance when the vent pipe is totally blocked. There are a variety of devices on gas*

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*appliances that will cause the shutdown of the appliance for a number of reasons. Staff does not believe that any one reason the appliance shuts down (e.g., elevated CO, blocked vented, over temperature, low water) will make a consumer any more or less likely to use an emergency/alternative heating source. Therefore, staff expects that this concern would be addressed in the same manner as any other type of appliance shutdown.*

AGA's comments are available at:

<http://www.regulations.gov/#!documentDetail;D=CPSC-2014-0009-0003>

### V. NEXT STEPS

#### **CPSC staff identified a number of follow-on actions as a result of the Forum and the RFI:**

- Continue to seek out U.S. and international sensor manufacturers and information that demonstrate their products' capabilities for long-term, in-flue application.
  - Follow-up with Lamtec to determine whether CO measurement can be isolated with their sensor or whether a correction factor can be developed for an approximate CO measurement; and whether the non-selectivity of this sensor type and the dependence of the sensor voltage on oxygen content can be overcome to develop means for its practical use, directly or indirectly, for CO-shutoff.
  - Follow-up with other combustion product sensor device manufacturers.
- Continue the dialog with International SDOs, particularly CEN and JSA.
- Share findings with the ANSI Z21/83 Technical Committee and subordinate TAGs.
- Evaluate whether the CEN and JSA requirements are suitable for CSA Z21 standards for gas furnaces and boilers.
- Share findings with the Commission.

### VI. CONCLUSION

Staff believes that it is important to continue to seek out U.S. and international sensor manufacturers and information that demonstrate their product capabilities for long-term, in-flue application within gas furnaces and boilers. Staff believes that it is important to continue the dialog with national and international SDOs, to reduce deaths and injuries associated with these products by reducing the CO poisoning hazard at the source.

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## APPENDIX A. CPSC CARBON MONOXIDE/COMBUSTION SENSOR FORUM ATTENDEES LIST

<b>FIRST NAME</b>	<b>LAST NAME</b>	<b>ORGANIZATION</b>
Eric	Cho	Dexen Industries
Henry	Xue	California State Polytechnic University, Pomona
Roy	Deppa	Marchica & Deppa LLC
Bill	Spohn	TruTech Tools, LTD
Larry	Brand	Gas Technology Institute
Jeff	Arensmeier	Emerson Climate Technologies
Steven	Craig	UniControl/Hays Cleveland /Cleveland Controls/ Lamtec's U.S. Distributor
Charles	Adams	A. O. Smith Corporation
Kurt	Bauer	Boiler Manufacture
Doug	Keeports	Bacharach Inc.
James	York	Rinnai America Corporation
Brian	Cothroll	A. O. Smith Corporation
Jeff	Kleiss	Lochinvar, LLC.
Frank	Stanonik	Air-Conditioning, Heating, and Refrigeration Institute
Aleksandr	Kovalenko	Heat Transfer Products, engineering manager
Rachel	Feinstein	Hearth, Patio & Barbecue Association
John	Crouch	HPBA
Greg	Orloff	CSA Group
Rehan	Ehsan	AHAM
Ted	Williams	AGA
David	Wheaton	UET
Marko	Bruinsmc	Testo, Inc.
Sandy	Inkster	CPSC/HSPP
Ron	Jordan	CPSC/ESFS
Han	Lim	CPSC/ESFS
Robert	Franklin	CPSC/EC
Andy	Kameros	CPSC/OGC
Patty	Davis	CPSC/OCM
Matt	Brookman	CPSC/LSME
Joel	Recht	CPSC/ES
John	McGoogan	CPSC/OCM
Matthew	Hnatov	CPSC/EPHA
Dominic	Vedder	CPSC/ESFS
Tim	Smith	CPSC/ESHF
Richard	Wright	CPSC/CDI