United States
Consumer Product Safety Commission

Stationary Generators:

The Carbon Monoxide Poisoning Hazard and Recommendations for Mitigation

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This report was prepared by the CPSC staff. It has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

Executive Summary

This report characterizes the carbon monoxide (CO) poisoning hazard associated with stationary generators. A stationary generator, alternatively referred to as a home standby or whole home generator, among many other names, is a product permanently installed outside a consumer's home to provide power in the event of a loss of utility power. It has an engine that converts the chemical energy of the fuel powering the engine into rotational energy, which, in turn, is converted into electrical power. The engines in stationary generators for the residential market are fueled by either natural gas or liquid propane and, like all combustion engines, their exhaust contains carbon monoxide (CO), a toxic gas.

CO is called the "invisible killer" because it is colorless and odorless. When CO is inhaled, it preferentially binds with hemoglobin in the bloodstream, effectively displacing oxygen from red blood cells, causing hypoxia. Mild CO poisoning may manifest as nonspecific flu-like symptoms; worsening symptoms are headache, lightheadedness, nausea, and fatigue; and more severe symptoms are vomiting, confusion, loss of consciousness, coma, and ultimately, death.

Stationary generators typically are installed by licensed tradesmen in accordance with the *National Electrical Code* for connection to the residential electrical distribution system and according to the manufacturers' installation instructions. Manufacturers' installation instructions specify the minimum allowable distances between the stationary generator enclosure and the home as well as openings into the home, to mitigate the risk of fire that the generator poses to the home. These distances are obtained from NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

After Hurricane Ida caused widespread power outages in the greater New Orleans area in Fall of 2021, staff learned from the Louisiana State Fire Marshal's office that CO from the exhaust of stationary generators had infiltrated into many homes in dangerous concentrations. Fire departments were inundated with 911 calls and were responding to these incidents in rapid succession. CPSC received information on 256 homes that reported at least one incident of CO exposure within the home. Staff's investigations into many of these incidents revealed 105 homes in which the home's stationary generator was identified specifically as the source of CO. Field investigators obtained information from residents at 57 affected homes about their incident and their stationary generator. The data show incidents in which the exhaust had traveled at least 25 feet away from the enclosure, spread laterally by at least 6 feet, and rose vertically more than 10 feet, and even higher when there was an obstruction that deflected the exhaust upward, causing the CO to infiltrate indoors in high enough concentrations to result in the homes' CO alarms activating. These findings clearly demonstrate that the 5 ft. enclosure-to-opening clearance allowed in NFPA 37 is inadequate to prevent infiltration of dangerous concentrations of CO into the dwelling. Past attempts to have requirements addressing the CO hazard adopted into NFPA 37 have been unsuccessful. There are no codes or standards that address the CO poisoning hazard associated with stationary generators.

Of the 105 homes known to involve a stationary generator, twelve had one or more residents with CO poisoning symptoms. One of these homes had nine residents, one of whom was transported to the hospital and admitted for one night; the other eight transported themselves to the hospital where they were held for observation and released. At another of these 12 homes, one resident was transported to the hospital and was treated and released. At the other 10 homes, no one sought medical evaluation or treatment. Eight-five of the 105 homes had a CO alarm activate; 20 homes did not mention the presence of a CO alarm or a CO alarm activation, but in 14 of these homes, the fire department detected CO.

Staff finds that addressing the CO poisoning hazard associated with stationary generators is urgently needed. Staff recommends that the technical committee for UL 2200 *Standard for Safety: Stationary Generator Assemblies* consider the following recommendations for approaches to address the hazard and develop requirements for adoption into UL 2200: (1) develop installation requirements that will minimize risk of exhaust infiltration through openings into structures that can be entered or occupied, and (2) develop a requirement that stationary generators must have engines with substantially reduced CO emission rates. Both approaches should include requirements for on-product markings and comprehensive information about the CO poisoning hazard in manufacturers' product literature and packaging. In addition, staff recommends that the technical committee for NFPA 37 increase the separation distance between the stationary generator and openings into structures from the current 5 feet to at least 25 feet.

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I. Introduction

This report characterizes the carbon monoxide (CO) poisoning hazard associated with stationary generators, using incidents that occurred in the aftermath of Hurricane Ida to illustrate this hazard.

CO is called the "invisible killer" because it is colorless and odorless. When CO is inhaled, it preferentially binds with hemoglobin in the bloodstream, effectively displacing oxygen from red blood cells, and forms carboxyhemoglobin (COHb), which causes hypoxia. COHb formation depends on various factors such as the exposed person's breathing rate, activity level, and health status as well as the CO concentration the person is exposed to and the duration of the exposure. Mild CO poisoning may manifest as nonspecific flu-like symptoms; worsening symptoms are headache, lightheadedness, nausea, and fatigue, and more severe symptoms are vomiting, confusion, loss of consciousness, coma, and ultimately, death. If COHb levels of exposed individuals rise suddenly and steeply, the persons will likely experience rapid onset of confusion, loss of muscular coordination, and loss of consciousness without having experienced the milder CO poisoning symptoms associated with a low, or slowly rising, CO level. People who have been exposed to CO may choose not to seek medical treatment and initially may even seem to recover without any ill effects; however, depending on the severity of their exposure, the exposure can cause delayed yet lasting and adverse health effects after apparent initial recovery.[1,2]

Hurricane Ida caused widespread power outages in Louisiana in August and September 2021, and the Louisiana State Fire Marshal's office reported that fire departments were inundated with 911 calls from homeowners about CO in their home. Staff received information on 256 homes that reported at least one incident of CO exposure within the home. A stationary generator was the source of CO for at least 105 of these homes. Of the 105 homes known to involve a stationary generator, twelve had one or more residents with CO poisoning symptoms. One of these homes had nine residents, one of whom was transported to the hospital and admitted for one night; the other eight transported themselves to the hospital where they were held for observation and then released. At another of these 12 homes, one resident was transported to the hospital and was treated and released. At the other 10 homes, no one sought medical evaluation or treatment. Eight-five of the 105 homes had a CO alarm activate; 20 homes did not mention a CO alarm activation, but for 14 of these homes, the fire department detected CO.

This report provides staff's analysis of these incidents of CO exposures inside homes resulting from stationary generators operating outside homes and provides recommendations to address the CO hazard.

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[1] Inkster, Sandra, PhD, CPSC Memorandum, *"Health Hazard Assessment of CO Poisoning Associated with Emissions from a Portable, 5.5 Kilowatt, Gasoline-Powered Generator*", September 21, 2004.

[2] UpToDate "Carbon Monoxide Poisoning", last updated November 26, 2024. https://www.uptodate.com/contents/carbon-monoxide-poisoning/print

II. Background on Stationary Generators

Stationary generators are products permanently installed outside the home to provide power in the event of a loss of utility power. Stationary generators are alternatively referred to as residential, home, whole-home, house, backup, standby, home standby (HSB), emergency, fixed, or permanent generators. A stationary generator has an engine that converts the chemical energy of the fuel powering the engine into rotational energy, which, in turn, is converted into electrical power. The engines in residential stationary generators are fueled by either natural gas (NG) or liquid propane (LP), and like all combustion engines, their exhaust contains CO, a toxic gas.

Stationary generators are housed within an enclosure and installed at a fixed location outside the home with the fuel supply and power output connected via hard connections. The fuel to run a stationary generator is supplied to the engine either through tubing connected to an external tank (propane or natural gas) adjacent to the generator, or via a connection to a utility-supplied natural gas supply. The generator's power is connected to a sub-panel to the home's main electrical panel by way of a transfer switch, which can be either automatic or manual. An automatic transfer switch (ATS) detects when utility power to the home's electrical panel has been interrupted, automatically switches off the main breaker that brings the utility's power to the panel, and switches on the breaker to the sub-panel of selected circuits that the homeowner wants to power during the grid outage. This action sends a signal to the generator's battery to start the generator's engine, which after a brief period to allow the generator output to stabilize, provides power from the generator to the sub-panel. The ATS is intended to provide a smooth transition between power sources without consumer involvement. An ATS may have a built-in maintenance routine that periodically starts the generator's engine automatically and allows it to run for some period of time to help ensure that it is ready and capable of running when a power outage occurs. For example, the ATS may run the cycle once a week, with the engine running for 15 minutes. The ATS also detects when utility power has been restored and responds by switching the panel's main breaker back on and stopping the generator. A manual transfer switch (MTS), in contrast, relies on the consumer to detect the power outage, start the generator, and switch the MTS to the sub-panel, and then reverse the process when utility power is restored.

Stationary generators typically are installed by licensed tradesmen. Retail outlets and dealers of stationary generators commonly offer to arrange their installation for the consumer, but having an installer under contract is not necessarily a precondition for the consumer to purchase the generator and to have it delivered to the consumer's home. The authority having jurisdiction (AHJ) may require a permit before a generator can be installed and, as part of the permitting process, may require an approved inspection of the electrical and fuel connections after installation, before the consumer can use the generator. Any permitting and inspection processes for stationary generators that an AHJ may require will be specific to the applicable codes and standards adopted by that jurisdiction. Many states, cities, and local jurisdictions

adopt National Fire Protection Association (NFPA) 70: *The National Electrical Code (NEC)*,[3] which covers the connection of the generator output to the electrical distribution system.

Codes and Standards

A voluntary industry consensus safety standard for stationary generators, UL 2200 *Standard for Safety: Stationary Generator Assemblies*,[4] addresses "electrical (energy, shock, explosion, and fire), mechanical (enclosures and moving parts), fuel related (containment and flow control for liquid and gaseous fuels including purge / dilution functions), and prime mover related hazards." The Scope of UL 2200 covers generators intended for installation and use with, among other codes and standards, NFPA 37 *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.[5] Neither UL 2200 nor NFPA 37, nor any other standard or code, address the CO hazard associated with stationary generators.

Section 4.1.4 of NFPA 37, which pertains to engines located outdoors, requires engines and their enclosures to be at least 5 feet from any openings in the walls of structures and from any structures having combustible walls, to mitigate the risk of fire that these products pose to those structures. However, the standard includes exceptions that allow for generators to be installed less than 5 feet from a wall if (1) the wall has a fire rating of at least one hour, (2) a fire test demonstrates that a fire originating at the engine will not ignite combustible structures, or (3) calculations performed under engineering supervision demonstrate that a fire originating at the engine will not ignite combustible structures.

UL 2200 does not require installation instructions to state that the generator must be installed according to NFPA 37; however, manufacturers' installation manuals typically reference the clearances from the generator enclosure to nearby structures in NFPA 37. For example, Figure 1, below, is from an installation manual that states: "The installation of the generator must comply strictly with NFPA 37, [and other standards]." Importantly, Figure 1 illustrates an example that allows for a distance of only 18 inches from a combustible wall. Although the generator manufacturer's installation manual may list certain building codes and standards that must or should be followed or consulted, the installation ultimately must comply with codes and standards adopted by the local jurisdiction, as well as any applicable state or local laws.

[3] Free digital access to NFPA 70 is available at https://link.nfpa.org/free-access/publications/70/2023

[4] UL offers free access to UL 2200 and all its standards; follow instructions at https://www.ul.com/news/qa-complimentary-online-access-ul-standards

[5] Free digital access to NFPA 37 is available at https://link.nfpa.org/free-access/publications/37/2024

Figure 1. Illustration from a Stationary Generator Manufacturer's Installation Manual, Depicting Clearances from Home and Openings in the Home

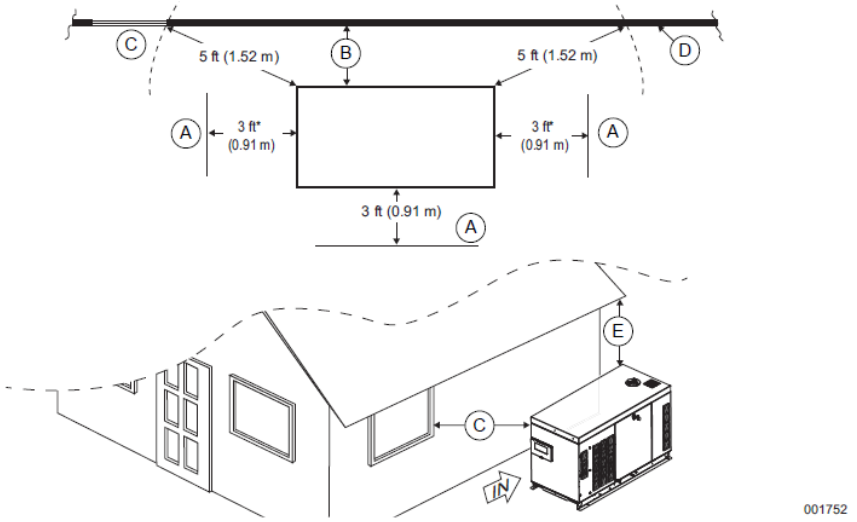


Figure 3-1. Installation Clearances

ID	Description	Comments
A	Surround Clearance	• Minimum clear distances cannot include shrubs, bushes, removable fence panels, or trees. • Removable fence panels for servicing cannot be placed less than 3 ft (0.91 m) in front of the generator (if **one hour fire rated**); no less than 5 ft (1.52 m) in front of the generator if the fence is **not** fire rated.
B	Side Clearance	**For products NOT showing SWRI on the data plate:** • 5 ft (1.52 m) minimum distance if the wall is **not** fire rated • 3 ft (0.91 m) minimum distance if the wall is **one hour fire rated**. **If the data plate indicates the product is SWRI rated:** • 18 in. (47.7 cm) minimum distance from a combustible wall
C	Windows and Openings	No operable windows, doors, or openings in the wall are permitted within 5 ft (1.52 m) from any point of the generator.
D	Existing Wall	—
E	Overhead Clearance (including wooden decks)	5 ft (1.52 m) minimum distance from any structure, overhang, or projections from the wall. DO NOT install under wooden decks or structures unless this distance is maintained.
IN	Air intake	Air intake end of unit. Opposite end is discharge.

Note: SwRI rating means the enclosure has been approved for an 18" installation minimum from the rear panel of the generator to an adjacent structure for fire protection

Staff and other stakeholders submitted proposals, referred to as public inputs (PI), to the NEC in 2014, and to NFPA 37 in 2015 and 2018, to address the CO hazard by way of increasing clearances and other installation requirements to minimize the risk of CO infiltrating into

dwellings. All the PI's were rejected as out of scope, though both the NEC and NFPA added related informational notes.[6, 7,8]

III. Case Study of CO Poisoning Incidents Involving Stationary Generators: Hurricane Ida (2021)

Background

On the morning of August 29, 2021, Hurricane Ida made landfall as a category-4 hurricane in Grand Isle, Louisiana, causing power outages to more than a million people in the greater New Orleans area. In early September 2021, a senior engineer from NFPA copied CPSC staff on an email to an Administrator on the LA State Uniform Construction Code Council that was responding to the Administrator's email about numerous instances where CO was found in dangerous concentrations in homes where stationary generators were being used after the

[6] Staff's PI submitted in 2014 for the first draft revision of the 2017 edition of the NEC, the technical committee's resolution of the PI, and the informational note can be viewed online at https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70 under the "Current & Prior Editions" tab with the 2017 edition selected, below "Archived Revision Information," in the "First Draft Report." They are located in Public Input No. 4587-NFPA 70-2014 [Section No. 445.10] and First Revision No. 7502-NFPA 70-2015 [Detail].

[7] The three PIs that staff submitted in 2015 for the first draft revision of the 2018 edition of NFPA 37, the technical committee's resolution of each, and the revised paragraph A.8.2.3.1 containing the added information can be viewed online at https://www.nfpa.org/codes-and-standards/nfpa-37-standard-development/37 under the "Current & Prior Editions" tab, with the 2018 edition selected, below "Archived Revision Information," in the "First Draft Report." They are located in the following:
Public Input No. 13-NFPA 37-2015 [New Section after 4.1.4],
Public Input No. 16-NFPA 37-2015 [Section No. 8.2.3.1],
Public Input No. 17-NFPA 37-2015 [Section No. A.8.2.3.1], and
First Revision No. 8-NFPA 37-2015 [Section No. A.8.2.3.1].

[8] The nine PIs that three stakeholders submitted in 2018 for the first draft revision of the 2021 edition of NFPA 27 and the technical committee's resolution of each can be viewed online at https://www.nfpa.org/codes-and-standards/nfpa-37-standard-development/37 under the "Current & Prior Editions" tab, with "2021 edition" selected, below "Archived Revision Information", in the "First Draft Report." They are located in the following:
Public Input No. 32-NFPA 37-2018 [New Section after 4.1.1.5],
Public Input No. 35-NFPA 37-2018 [Section No. 4.1.2.1.3],
Public Input No. 44-NFPA 37-2018 [Section No. 4.1.2.2.2],
Public Input No. 38-NFPA 37-2018 [Section No. 4.1.2.2.3],
Public Input No. 39-NFPA 37-2018 [Section No. 4.1.3.1 [Excluding any Sub-Sections]],
Public Input No. 33-NFPA 37-2018 [Section No. 4.1.4.1 [Excluding any Sub-Sections]],
Public Input No. 31-NFPA 37-2018 [Section No. 4.1.4],
Public Input No. 34-NFPA 37-2018 [New Section after 4.1.4.1.2], and
Public Input No. 40-NFPA 37-2018 [New Section after 8.2.5.2.1].

Note: A presentation on these PIs made by a stationary generator manufacturer's representative at the technical committee meeting for the first draft is included in "The First Draft Meeting Minutes," which can be found below "First Draft Committee Information."

hurricane. This official was alarmed about the number of 911 calls to which fire departments were responding to address these incidents. The official said that the State Fire Marshal's office also received calls on the same issue from master code professionals, certified building officials, electrical contractors, and a major retailer of stationary generators. CPSC staff contacted this official, and having learned of additional details on what his office had been tracking as well as news articles on the matter,[9,10,11] staff decided to initiate an independent effort to investigate these incidents. CPSC's Field staff then contacted the State Fire Marshal, who in turn requested all fire departments in areas with power outages caused by Hurricane Ida to send to CPSC information on any stationary generator-related CO incidents to which they responded. In the information from several fire departments, staff also learned of CO incidents involving portable generators operating outside, but whose exhaust was migrating inside homes in dangerous concentrations; therefore, staff requested through the State Fire Marshal that all LA fire departments in the affected localities send information on portable generator-related CO incidents as well. Staff ultimately received information on 256 homes that reported at least one incident of CO exposure within the home, including from fire departments, consumers via www.saferproducts.gov, and via a news article. Two hundred fifty of the 256 homes involved 276 fire department responses (23 homes called 911 two or more times; 6 homes did not call 911.).

From June through October 2022, CPSC field staff initiated investigations into the first 200 homes for which staff received information to (1) request the fire department report, in case one was written but not initially provided to CPSC, and (2) obtain more details from the consumer on the incident, including the generator that was involved.

The following information pertains to all 256 homes:[12]

- For 105 homes, a stationary generator was identified as the source of CO.
- For 65 homes, a portable generator was identified as the source of CO.
- For 35 homes, the fire department's documentation did not contain sufficient detail for staff to ascertain whether the generator was a stationary or a portable generator, and staff was unable to reach a resident to find out; however, for many of these homes, the

[9] "Carbon monoxide worries post-Ida prompt officials to take action" by Meg Gatto, 11/1/2021, available online https://www.fox8live.com/2021/11/02/carbon-monoxide-worries-post-ida-prompt-officials-take-action/

[10] "St. Tammany official wants law changed pertaining to generator placement" by Meg Gatto, 11/12/2021, available online at https://www.fox8live.com/2021/11/12/st-tammany-official-wants-law-changed-pertaining-generator-placement/

[11] "Lawmaker drafting legislation to address placement of whole home generators" by Meg Gatto, 11/23/2021, available online at https://www.fox8live.com/2021/11/24/lawmaker-drafting-legislation-address-placement-whole-home-generators/

[12] One home called 911 twice, the first time due to the neighbor's portable generator, the second time due to their own stationary generator, which explains why the total number of homes in the bulleted list sums to 257, not 256.

fire department documented in their write-up that the homeowner should turn the generator off and have the generator moved because it was too close to the house.
- For 52 homes, the fire department's documentation did not identify the source of CO and staff was not able to reach a resident to obtain more information.

The information for the last three subsets (describing 65, 35, and 52 homes, totaling 152 homes) mentioned above is used in this report for the sole purpose of discussing homes with and without CO alarms with respect to residents experiencing CO poisoning symptoms. These data are discussed in the next subsection and within section IV.

In 57 of the 105 homes known to have involved a stationary generator, a CPSC Field Investigator was able to obtain additional information from someone at the home. This additional information, along with information obtained from the documents the fire departments provided to CPSC, is discussed in further detail below.

CO Alarms and CO Poisoning Symptoms Among Homes Involving a Known or Possible Stationary Generator

Of the 105 homes with incidents known to have involved a stationary generator:

- 85 homes (81%) had the CO alarm activate.[13]
    - Five of these homes had one or more residents with CO poisoning symptoms.
        - One of these homes had nine residents, one of whom was transported to the hospital and admitted for one night; the other eight transported themselves to the hospital where they were held for observation and released.
        - At another of the five homes, one resident was transported to the hospital and was treated and released.
        - At the other three homes, no one sought medical evaluation or treatment.
- 20 homes (19%) did not report the presence of a CO alarm in the home or a CO alarm activation, but for 14 of them, the fire department detected CO in the home.
    - Seven of these homes had one or more residents with CO poisoning symptoms, but no one sought medical evaluation or treatment.

[13] The CO concentrations that are required in UL 2034, *Standard for Safety, Single and Multiple Station Carbon Monoxide Alarm*s (the U.S. voluntary standard for residential CO alarms) for alarm activation to alert occupants of dangerous CO concentrations are: the alarm shall activate for 70 ppmv CO between 60 to 240 min, 150 ppmv CO between 10 to 50 min, and 400 ppmv CO between 4 to 15 min. In each of these, the CO alarm must activate before the upper time limit is reached and must not activate before the lower time limit is reached. The upper time limit of these activation points is based on 10 percent COHb, which is the level commonly associated with the point at which one might begin to experience the onset of mild CO poisoning symptoms, such as a headache.

Of the 152 homes in which a CO incident occurred but the documentation either specified a portable generator, did not specify the type of generator involved (stationary or portable), or did not identify the CO source:

- 80 homes (53%) involved a CO alarm activation.
    - Six homes had residents with CO poisoning symptoms, but there is no indication that any of these residents sought medical evaluation or treatment.
- 72 homes (47%) did not report the presence of a CO alarm in the home or a CO alarm activation.
    - Ten of these homes had one or more residents with CO poisoning symptoms.
        - At 4 of these homes, there is no indication that anyone sought medical evaluation or treatment.
        - At another home, where the fire department measured CO concentrations of 100 parts per million by volume (ppmv),[14] a resident reportedly was incoherent and needed assistance with getting out of the house but refused aid from the ambulance.
        - At another home, a resident was transported to the hospital and was admitted for one night.
        - At the other four homes, a total of seventeen residents were transported by ambulances to the hospital. Because staff was unable to reach residents at these homes, their level of treatment or hospitalization is unknown.

Staff notes that residents at several homes told CPSC Field investigators they had extended family members staying at their house during the power outage specifically because a stationary generator was providing power to the home.

Generator Characteristics

Among the 105 homes with incidents known to have involved a stationary generator, the stationary generator manufacturer was provided for 56 homes; 54 of the 56 generators were made by the same manufacturer. Two other manufacturers were identified, each reported at one home. The manufacturer of the stationary generator at the other 49 homes was not identified.[15]

The stationary generator's fuel type was reported for 53 of the generators: 49 were fueled by natural gas and 4 were fueled by propane.

[14] Parts per million by volume is a measurement of concentration on a volume basis. This is commonly used to measure the concentration of gas.

[15] When the manufacturer was identified, CPSC's Clearinghouse sent a letter with the incident's documents to the manufacturer to notify them of the incident and allow them the opportunity to provide a written response.

The rated power was reported for 45 stationary generators and ranged from 10 kilowatts (kW) to 24 kW. The most common size, reported for 27 of the generators, was 22 kW.

Fifty-seven homes with a stationary generator, and for which a field investigator was able to reach someone at the home, reported the following details about the generator installation:

- 32 homes reported that the stationary generator was installed by a company authorized by the generator manufacturer;
- 3 reported that the installer was arranged by the retailer or dealer;
- 3 reported that the generator was installed by an "authorized installer;"
- 2 reported that the generator was installed by the homebuilder;
- 12 reported that they did not know who installed it or did not know if the installer was authorized by the generator manufacturer;
- 2 reported that the generator was installed by a contractor not authorized by the generator manufacturer;
- 2 reported that the generator was a do-it-yourself installation; and
- 1 reported that the generator was installed by a plumber.

CO Concentrations and Migration into the Home

When recorded by the fire departments, CO concentrations within homes of residences with a stationary generator were as high as 170 ppmv. One consumer stated that the fire department measured concentrations higher than this, with 300 ppmv in the attic (and 100 ppmv in his son's bedroom), but these measurements were not recorded in the fire department's report. In some homes, the fire department documented that the residents had started ventilation by opening windows and doors before the fire department arrived.

For homes in which it was documented how the stationary generator's exhaust came into the house, most reported that it entered through vents in the attic. In 46 of the 105 homes with incidents involving a stationary generator, either the fire department documented, or the consumer told a CPSC investigator, that at least one path the exhaust took to enter the house was through vents into the attic; 45 referred to the path as soffit vents in the eaves[16] and one referred to a gable vent. For 17 homes, it was surmised that at least some of the exhaust entered through a closed door, a closed window, an exhaust fan vent, a dryer vent, the space around a window air conditioning unit, or from underneath the house.

[16] Soffit vents, located on the underside of a roof's eaves, serve to draw outside air into the attic. When present in combination with other roof vents like ridge vents or gable vents, they provide ventilation to prevent buildup of heat, moisture, and mold, which provides healthier indoor air quality and helps prevent potential structural damage.

Fire Department Responses and Recommendations

Fire departments started responding to 911 calls for the 105 homes with a stationary generator the day after the power outage began and continued to do so every day for 10 days, with two additional 911 calls four days after that 10-day period.

For those incidents for which a fire department report was provided to staff, the fire department reportedly was on-scene for approximately 30 minutes, on average. The actions of the fire department, when reported by the fire department or the consumer, typically included the following:

- evacuating residents from the house;
- taking readings with their gas meter to measure CO concentrations throughout the house's living spaces and attic;
- opening windows and doors, when not already done by the residents, and ventilating the house naturally or with fan(s) to remove the CO;
- taking subsequent CO readings before allowing the residents back in the house;
- asking the residents if they felt ill with any CO poisoning symptoms, and assessing them as needed; and
- offering care from, or transport by, an ambulance.

For many homes, information from the fire departments included one or more recommendations to the residents, or observations regarding the generator's location. These included the following:

- have the generator moved further away from the home;
- the generator is too close to the home;
- have the installer or code enforcement look at the installation;
- have the generator looked at because something may be wrong with it;
- do not turn on the generator until the generator has "properly ventilation;"
- do not turn on the generator and stay elsewhere until utility power is restored or "the issue is addressed;" and
- shut off the generator and ventilate, either daily or until their CO alarm shows no CO.

Consumer Responses

Among the same 57 homes mentioned above, 17 reported that they contacted the installer about the incident, 4 reported that they attempted to contact the installer but didn't receive a response, 2 said they did not know if anyone contacted the installer, 31 said they did not contact the installer, one did not answer the question, and 2 were do-it-yourself installations, so the question did not apply to them. Ten of the 57 homes reported that someone at the home contacted the generator manufacturer about their incident, and 4 homes were not sure if someone in the home had reported the incident to the generator manufacturer. For the remaining 43 homes, the consumer said that no one at the home contacted the generator

manufacturer; however, one of these homes reported that they contacted the dealer rather than the manufacturer.

Consumers at 15 homes reported that, after the incident, they had the stationary generator either moved further from their home, rotated so the exhaust was oriented away from their home, or both moved and rotated. At six homes, consumers reported the specific distance it was moved: one moved it 20 feet, one moved it 25 feet, one moved it 30 feet, two moved it 50 feet, and one moved it 60 feet. Four had it moved some unspecified distance further away from their home.

Other actions taken by consumers in response to the incidents, either during or after the grid outage, included sealing soffit vents, attempting to keep the exhaust away using a fan or some other means to deflect it or create a barrier, sealing cracks around a window air conditioning unit, replacing single-pane second floor windows with double-pane windows, and turning the generator off at night. Others left the home to stay elsewhere until utility power was restored.

Generator Installation

The distance of the stationary generator enclosure from the house was provided for 56 of the 105 homes; for 51 homes this was reported to be 6 feet or less, for 3 homes it was reported to be 8 to 10 feet,[17] for one home it was reported to be 26 feet away with exhaust side of the generator facing the house, and for one home that was raised 4 feet above the ground it was reported to be under the house.

For 49 of those 56 homes, the distance between the enclosure and the opening that served as the CO entry point into the home was reported by the consumer and/or was estimated by CPSC Engineering staff based on one or more photos provided by the consumer. For 29 homes, one or more photos were provided; these also revealed the orientation of the exhaust side of the enclosure relative to the home.[18] Twenty-six of the homes had the enclosure's exhaust side perpendicular to the home's adjacent wall at the time of the CO incident, indicating that the exhaust largely flowed parallel to the adjacent wall. For two of the other three homes, the exhaust side of the enclosure faced the home, and for the other one, the exhaust side of the enclosure faced directly away from the home. Table 1 provides a summary for these 49 homes of the enclosure-to-opening clearances, along with the enclosure-to-home clearances, the identified path into the homes, the rated power and fuel type of the generators, and the dates when the CO incidents occurred. For ease of characterizing the clearances, staff categorized them into the ranges of distances shown in Table 1, but more specific distances are provided in Appendix A, Tables A.1 through A.3, for 42 of the homes. Figures 2 through 5 show photos of 9

[17] This includes 2 homes that specified 10 feet and one home that specified 8 to 10 feet with its exhaust pointing towards the home.

[18] Field staff conducted their investigations 10 to 14 months after Hurricane Ida struck. For the homes that had their generator moved and/or rotated after the hurricane and provided one or more photos, most photos reflected the generator's new location/orientation. The information provided here is that of the generator's location during the power outage caused by Hurricane Ida.

stationary generators, referred to in Tables 1, and A.1. through A.3, that exemplify enclosure-to-opening clearances in which the path the CO took to enter the home exceeded NFPA 37 minimum distance requirements resulted in high enough concentrations to activate the home's CO alarm.

Table 1. 49 Homes' Range of Distances between the Stationary Generator Enclosure and the Home, and the Opening Identified as Path for CO to Enter the Home, the Generator's Rated Power and Fuel Type, and Dates of CO Incidents

Number of Homes	Range Category for Distance Between Enclosure and Openings Identified as Path of CO into Home	Range Category for Distance Between Enclosure and Home	Identified Path	Generator Rated Power and Fuel	Dates of CO Incidents (Grid outage began on 8/29)
5	Less than 5 feet	under the house (1 home) see note 1	through the floor (house raised 4 feet off the ground)	Unknown	~9/1
		2 feet or less (3 homes) see note 2	through the floor (2 homes not sitting on the ground) around window A/C unit and soffit vents (1 home)	All 3 generators were 22 kW, NG	8/31, 9/1
		3-4 feet (1 home) see note 3	under house raised several inches off the ground	22 kW, NG	8/30
31 see Appendix A Table A.1 for details	5 feet up to 10 feet	2 feet or less (14 homes)	soffit vents for 13 homes window in addition to soffit vents (1 home) unsure but maybe window A/C (1 home)	6 were 22 kW, NG 1 was 22 kW, LP 1 was 22 kW, fuel not specified 1 was 24 kW, NG 3 were 16 kW, NG 1 was 20 kW, NG 1 was unknown rating, LP	8/29 - 9/6
		~2-3 feet (11 homes)	soffit vents (9 homes) hole in roof (1 home) maybe window (1 home)	3 were 22 kW, NG 1 was 24 kW, NG 1 was 20 kW, NG 1 was 19.5 kW, NG 1 was 18 kW, NG 2 were 16 kW, NG 1 was 12 kW, LP 1 was 10 kW, NG	8/31 - 9/6, 9/12
		5-6 feet (6 homes)	soffit vents (5 homes) window (1 home)	4 were 22 kW, NG 1 was 22 kW, LP 1 was 18 kW, NG	8/31, 9/1, 9/7
7 see Appendix A Table A.2 for details	10 feet up to 15 feet	2 feet or less (1 home)	soffit vents	22 kW, NG	9/6
		~2-3 feet (2 homes)	soffit vents	1 was 22 kW, NG 1 was unknown rating, NG	8/31, 9/1
		5-6 feet (3 homes)	door to sunroom on exhaust side of enclosure (1 home) soffit vents (1 home) soffit vents 12 feet horizotally away from exhaust side of enclosure (1 home)	2 were 22 kW, NG 1 was 16 kW, NG	9/1, 9/3, 9/4
		10 feet (1 home)	door	unknown rating, NG	8/30
4 see Appendix A Table A.3 for details	15 feet to 20 feet	2 feet or less (1 home)	2nd floor windows and soffit vents	22 kW, NG	8/31
		~2-3 feet (2 homes)	soffit vents	1 was 22 kW, NG 1 was unknown rating, NG	9/4
		5-6 feet (1 home)	soffit vents	unknown rating, NG	9/6
2	About 25 feet	3-4 feet (1 home) see note 1	2nd floor bathroom exhaust fan vent about 25 from the exhaust side of the enclosure and 10 feet above it	22 kW, NG	9/8
		26 feet	soffit vents see photo in Figure 2.	18 kW, NG	~9/4

Notes referred to in the third column of Table 1:

1. No photos of this home's generator were provided.
2. A resident at one of these 3 homes provided a photo, which shows that the exhaust side of the enclosure was perpendicular to the adjacent wall of the home.
3. A resident at this home provided several photos, which show that the exhaust side of the enclosure was perpendicular to the adjacent wall of the home.

Figure 2. Photo of Stationary Generator Referred to in Table 1.

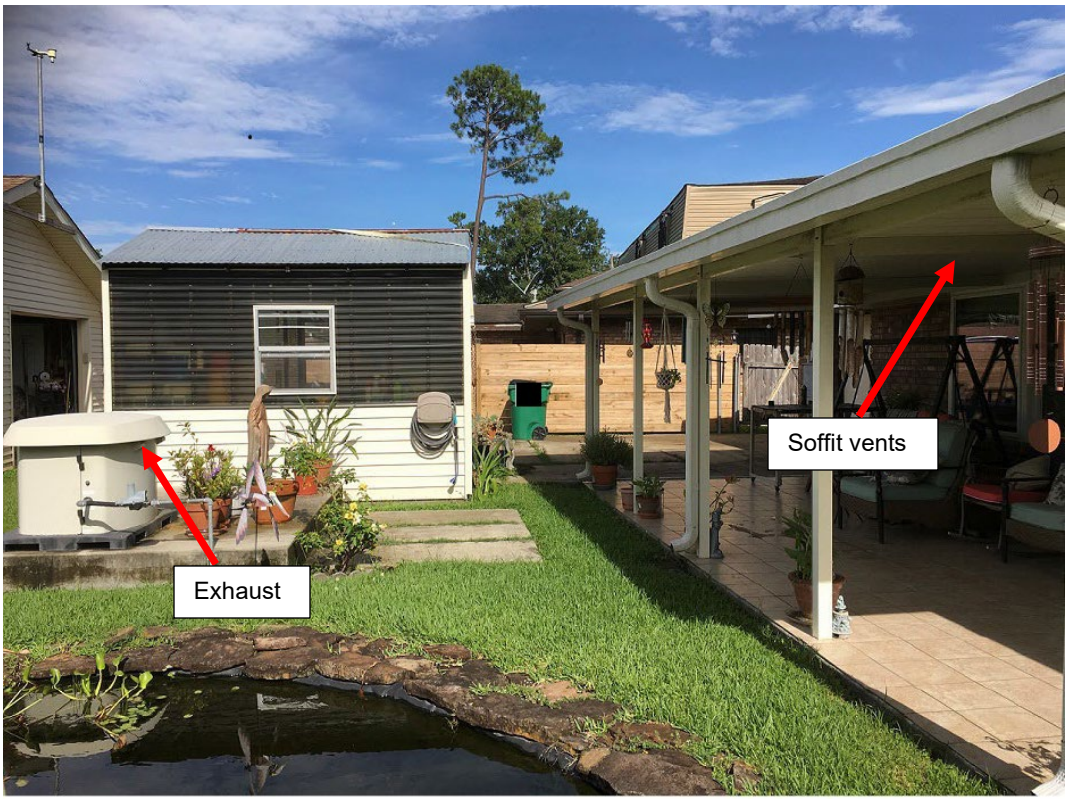


Figure 3. Photos of Four Stationary Generators Referred to in Table A.1.

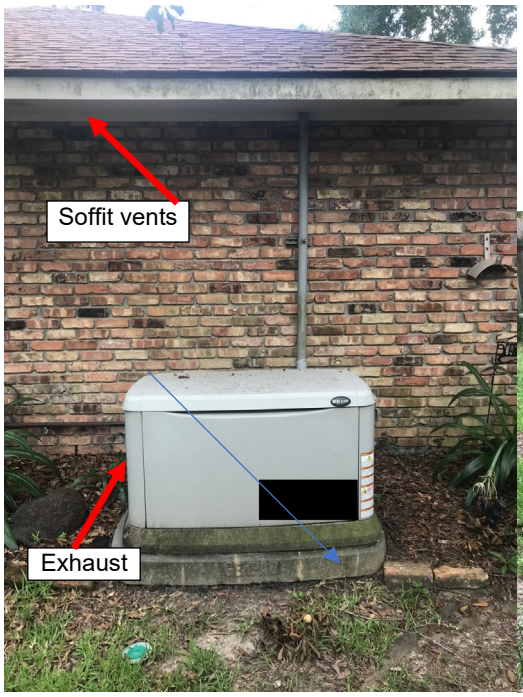
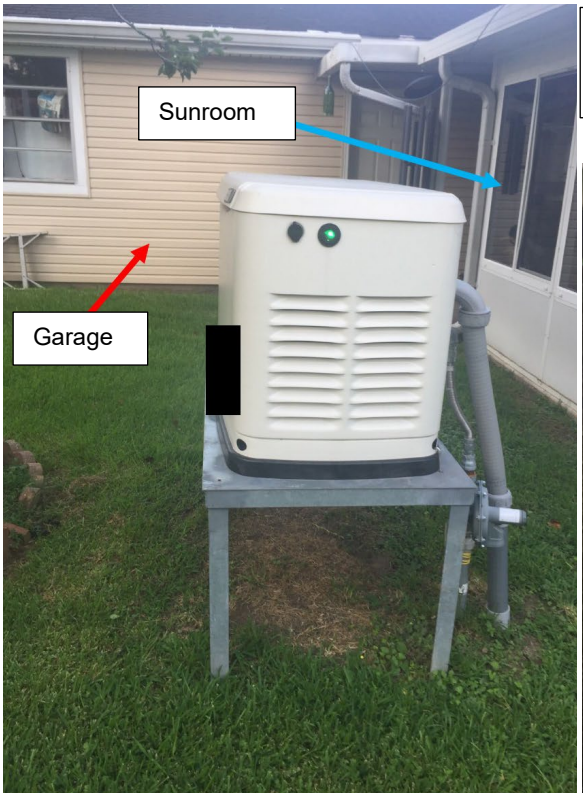


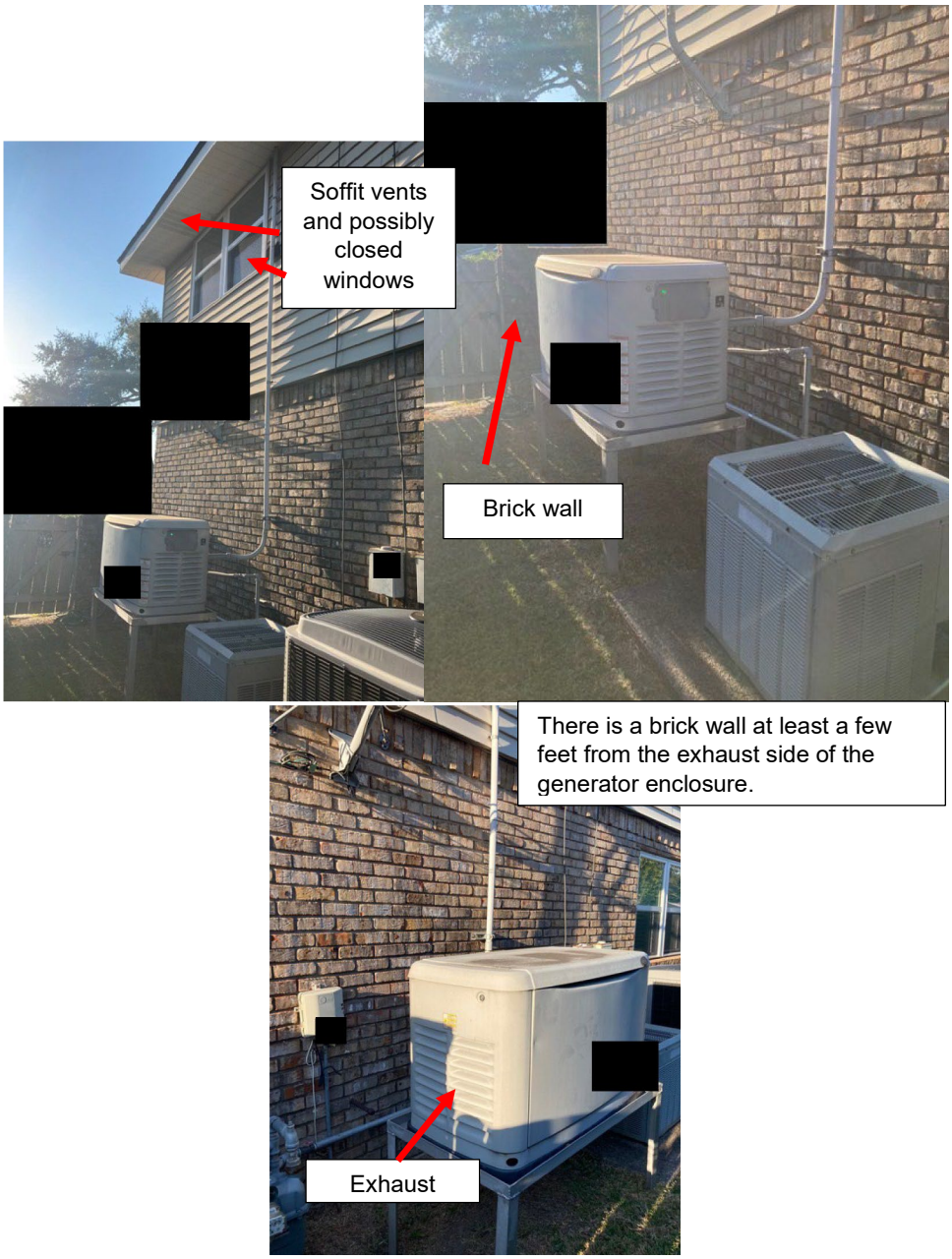
Figure 4. Photos of Three Stationary Generators Referred to in Table A.2.



The fire department found elevated CO readings in the sunroom, which was closed during the incident.

During the incident, the generator's exhaust was facing the house. Before the incident, the consumer had covered the soffit vents near the generator and thinks that the CO entered the soffit vents under his patio cover. After the incident, the consumer had the generator rotated 180 degrees, as shown in the photo on the left.

Figure 5. Photo of Stationary Generator Referred to in Table A.3.



IV. Discussion

The Hurricane Ida CO incidents documented in this report highlight significant problems related to the safety of stationary generators. Moreover, because stationary generators can run for days without consumer action, potential consumer exposures to CO are exacerbated.

Current Codes and Standards Do Not Address the CO Hazard

As noted earlier, the most commonly identified type of stationary generator involved in the Hurricane Ida incidents is a 22 kW residential generator fueled by natural gas. Staff estimates this generator emits CO at a rate that exceeds the CO emission rate of all but the highest rated-power gasoline-fueled portable generators on the market.[19] Since 2013, CPSC has been recommending that all portable generators be operated at least 20 feet from openings in homes and other structures that could be entered or occupied, with the exhaust pointed away from these structures, to reduce the risk of CO infiltrating into these structures.[20] Portable generator manufacturers also recommend 20 feet or greater in their on-product label, in their owner's manual, or both,[21] and many other manufacturers recommend "far away."

Staff is unaware of any code or standard that includes requirements to address the CO poisoning hazard posed by stationary generators. As described earlier, staff and other stakeholders unsuccessfully attempted to add CO mitigation requirements to NFPA 37 and the NEC, and although both technical committees added non-enforceable information, they reaffirmed that CO mitigation is outside the scope of both codes. Also stated earlier, UL 2200 addresses other hazards but not the CO hazard. Furthermore, UL 2200 does not require any

[19] Staff's estimate for stationary generators is based on the following assumptions: the engine has a weighted CO certification level of 127 grams per kilowatt-hour (g/kW-h) (per the U.S. Environmental Protection Agency (EPA) annual certification data for small nonroad spark-ignition engines, found at https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment under the heading "Small Nonroad Spark-Ignition (NRSI) Engines."); the typical load profile of a residential stationary generator is the same as the weighted profile that industry developed to replicate typical in-use operation of small utility engines when used in all types of engine-driven products; the engine's weighted CO rate is the same as the generator's weighted CO rate; and the generator's weighted CO rate is the same as the CO rate when the generator is delivering approximately half of the generator's rated power. The resulting stationary generator's CO emission rate is estimated by staff to be 1678 grams per hour (g/h). For mid-size portable generators up to about 9 kW of rated power, staff estimates their CO rate to be an average of 1550 g/h. To put these rates into perspective relative to that of a car, idling mid-size late 1990s model cars emit 2.4 to 5.4 g/h of CO (ref: Frey, H., et al., *On-Road Measurement of Vehicle Tailpipe Emissions Using a Portable Instrument*, Journal of the Air & Waste Management Association, Vol.53, August 2003).

[20] https://www.cpsc.gov/Safety-Education/Safety-Education-Centers/Carbon-Monoxide-Information-Center

[21] For example, the on-product label and the warning in the owner's manual for a Firman generator recommend 20 feet, as shown in https://firmanpowerequipment.com/products/t07571, as do the instructions in the owner's manual for a Ryobi generator as shown in https://www.ryobitools.com/help-plus/search?Search=Submit&query=RY906522. A Mech Marvels generator warning recommends 25 feet in https://www.homedepot.com/p/Mech-Marvels-3200-Running-Watt-4000-Surge-Recoil-Start-Gasoline-Powered-Portable-Generator-with-RV-Outlet-CARB-Approved-MM4350C/317458282.

instructions or on-product markings that warn consumers or installers that a stationary generator produces unsafe levels of CO. Staff has not previously been involved in UL 2200.

Manufacturers' Installation Instructions are Inadequate

In stationary generator installation manuals examined by staff, warnings about the production of CO in the generator's engine exhaust typically were found in a section with other "general hazards." Also, the manuals' installation instructions specify clearances that are from NFPA 37, which, as stated earlier, are intended to address the risk of fire to nearby structures, not the infiltration of CO into these structures. Predictably, installers use the distances provided in the installation manual.

The incidents resulting from Hurricane Ida clearly demonstrate that the minimum enclosure-to-opening clearance in the installation instructions is inadequate to prevent infiltration of dangerous concentrations of CO into the dwelling. Out of the 56 homes that reported the location of the enclosure relative to the house, nearly all reported it being within 6 feet, and of the 49 homes that reported the location of the enclosure relative to the openings that allowed CO to infiltrate the home, 3 were 5 feet away and 41 were more than 5 feet away, which is the minimum distance from openings in NFPA 37.

As for the orientation of the exhaust side of the enclosure relative to the home, most enclosures were installed with the exhaust side perpendicular to the house, meaning that the exhaust largely flowed along the adjacent wall of the home. Of enclosures with this orientation, at least five were 5 or 6 feet away from the home, with the exhaust entering into the home through soffit vents that were 8 feet to up to 15 feet away from the enclosure (See the 4th generator in figure 3 and the first 2 generators in figure 4); at one home the exhaust traveled 25 feet horizontally along the house to enter through a second-floor bathroom exhaust fan vent; and at another home in which the exhaust side of the enclosure faced a brick wall at least a few feet away, the exhaust was deflected upward, rising 15 to 20 feet to second-floor windows and the soffit vents above them (See figure 5). However, even at a home where the enclosure's exhaust side was 6 to 7 feet from the home and pointed *directly away* from the home, CO still entered the home (See 2nd generator in figure 3). At another home, the exhaust side of the enclosure was facing the house but was *26 feet away* (See figure 2), yet CO still infiltrated indoors. Thus, the incident data show that that the stationary generator exhaust can spread linearly from the generator's enclosure by at least 25 feet, spread laterally at least 6 feet, and rise vertically to 10 feet or higher, particularly if an obstruction is present that deflects the exhaust upward towards openings, and result in dangerous CO concentrations indoors.

CO Alarms Are Critical, But Not Enough

In the aftermath of Hurricane Ida and its associated CO poisoning incidents, several Louisiana state and local officials expressed eagerness to find a safe installation distance for stationary generators from both the victims' homes and neighbors' homes, so that a state law requiring

such distances could be drafted.[22] Staff is not aware of what progress has been made on that effort; however, in 2022, the Louisiana State Legislature passed a state law requiring any house sold or leased after January 1, 2023, to have at least one CO alarm. Also, the Louisiana Uniform Construction Code Council adopted an amendment to the state's residential building code requiring CO alarms to be installed at the same time any whole-home, standby generator is installed. This change also went into effect on January 1, 2023.

The data from the Hurricane Ida incidents are further proof that CO alarms help prevent injuries. Only 7 percent of the homes in which a 911 call was placed because a CO alarm activated (11 of 165[23]) had one or more residents who experienced CO poisoning symptoms; yet 18 percent of the homes that did *not* mention the presence of a CO alarm or a CO alarm activation (17 of 92[24]) had residents with CO poisoning symptoms. Staff commends the Louisiana officials' swift action to have their law and amendment to the state's residential building code, both requiring CO alarms, in effect only 16 months after Hurricane Ida struck. However, these data also demonstrate that CO alarms should not be relied on as the only means to address the hazard, because such reliance still leaves consumers exposed to dangerous CO levels and having to find ways to contend with the CO hazard presented by their stationary generator until utility power is restored. Furthermore, these incidents put an undue burden on the community resources, such as fire departments and emergency medical services, which must be available to respond to a myriad of emergencies, particularly when a community has been severely impacted by a widespread disaster. As some fire department representatives told CPSC Field staff, and as mentioned earlier in this report, the fire departments were responding to numerous CO incidents in rapid succession during Hurricane Ida.

Establishing requirements that will minimize the risk of dangerous CO concentrations infiltrating indoors, as discussed in the next section, will help to minimize residents' exposure to CO and the incidence of CO poisonings.

Staff considers the Hurricane Ida incidents to have sufficiently demonstrated the need to address the CO poisoning hazard associated with stationary generators; however, other widespread power outages may provide additional examples of the pressing need for a solution. As a more recent example, Hurricane Beryl made landfall near Matagorda, Texas, on July 8, 2024, as a category-1 hurricane that caused 2.8 million electricity customers in the Houston area to lose power, and even 8 days later approximately 226,000 homes were still without

[22] These officials included a Louisiana state representative, a parish councilman, the State Fire Marshal, a fire protection chief, and a parish director of permitting and inspections, per the news article in footnote 11.

[23] 85 homes that had a stationary generator and 80 homes that had a portable generator, an unidentified generator type, or an unidentified CO source.

[24] 20 homes that had a stationary generator and 72 homes that had a portable generator, an unidentified generator type, or unidentified CO source.

power.[25] Calls to 911 about CO alarm incidents were reported to be spiking.[26] CPSC Field staff is in the process of acquiring reports from fire departments in the affected areas that responded to 911 calls about CO during just the first 5 days of the power outage. As of the end of May 2025, staff has received the following:

- 153 reports in which a stationary generator was identified as the CO source
  - for 128 of these, the report stated that the home's CO alarm activated. For 23 of the other 25 reports, the report did not mention the presence of a CO alarm or a CO alarm activation but stated that the fire department detected CO in the home.
  - At 10 homes, residents were experiencing CO poisoning symptoms and at 2 of these homes, emergency medical services provided on-site care to 4 people before transporting 3 of them to the hospital (the 4th person refused transport).
- 162 reports in which a portable generator was identified as the CO source
  - For 131 of these, the report stated that the home's CO alarm activated; out of the other 31 reports which did not mention the presence of a CO alarm or a CO alarm activation, 22 stated that the fire department detected CO in the home.
  - At 11 homes, residents were experiencing CO poisoning symptoms. At 3 of these homes, occupants were transported to the hospital.
- 103 reports identified a generator as the CO source without providing sufficient information for staff to determine whether it was a stationary generator or a portable generator.
- 66 reports did not identify the CO source but the home's CO alarm had activated and/or the fire department detected CO in the home.

Staff notes that stationary generator sales are predicted to continue to increase in future years,[27] which further underscores the urgency for action to address this hazard.

V. Recommendations

Staff recommends two approaches to mitigating the CO hazard posed by stationary generators: (1) develop installation requirements for UL 2200 that will minimize the risk of exhaust infiltration through openings into structures that can be entered or occupied, and (2) develop a requirement for UL 2200 that stationary generators must have engines with substantially

[25] "Beryl Outages: Thousand Enter Week Two Without Power" by Jaden Edison and Pooja Salhotra, The Texas Tribune, July 15, 2024, available online at https://www.texastribune.org/2024/07/15/texans-power-outages-hurricane-beryl/

[26] "Heat, Carbon Monoxide Poisoning Spike 911 Calls in Montgomery County" by Catherine Dominguez, The Houston Chronicle, July 11, 2024, available online at https://www.houstonchronicle.com/neighborhood/conroe/article/power-outage-montgomery-county-911-19567066.php

[27] https://www.fortunebusinessinsights.com/u-s-generator-sales-market-106160

reduced CO emission rates. Both approaches should include requirements for on-product markings and comprehensive consumer-targeted information about the CO poisoning hazard in manufacturers' product literature and packaging.

In addition, staff recommends, for NFPA 37, that the separation distance between the stationary generator and openings into structures be revised from the current 5 feet to at least 25 feet.

Develop Installation Requirements to Minimize the Risk of CO Infiltration into Structures

Staff recommends the development of installation requirements related to minimum allowable clearances between the exhaust side of the generator enclosure and openings into structures that can be entered or occupied, to minimize the risk of exhaust infiltration. Structures that can be entered or occupied include, but should not be limited to, dwellings, garages, and sheds. The requirements should be based on the incident data and should take into account the orientation of the exhaust side of the generator enclosure relative to the structure's openings, as well as any obstructions that might impact the flow of exhaust between the enclosure and the structure. Staff also recommends on-product markings that identify the exhaust side of the generator enclosure and that indicate the required distance from that side of the enclosure at which obstructions should not be placed. Obstructions include, but should not be limited to, fences, walls, shrubbery, and air conditioning condensing units. Structure openings include, but should not be limited to, operable windows and doors, exhaust fan vents, dryer vents, furnace air intakes and exhaust vents, and soffit vents.

As part of this, staff also recommends that stationary generator manufacturers provide consumers with comprehensive information about the CO poisoning hazard, including the clearance requirements, in their product advertising, marketing, on-product packaging, and installation manuals. Providing consumers with this information would allow them to make an informed decision *before* purchasing the generator.

Develop a Requirement for Stationary Generator Engines to Have Substantially Reduced CO Emission Rates

Another approach to addressing the CO poisoning hazard is to require stationary generators to have engines with a substantially reduced CO emission rate. There are several natural gas and propane-fueled engines made by different engine manufacturers in the EPA's annual engine emissions certification database that have very low CO emission rates.[28] If such reduced CO emission rate engines were used in stationary generators, the increased clearances established

[28] These are air-cooled, horizontal crankshaft engines that have a maximum power rating of 10 kW up to 25 kW with maximum rated useful life of 1000 hours, all of which are attributes of engines used in stationary generators. They have CO emission rates below 20 g/kW-h. (Reference: https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment under the heading "Small Nonroad Spark-Ignition (NRSI) Engines".)

in the first approach likely could be substantially reduced, or possibly may not apply. Comprehensive information about the CO hazard should still be required in product literature as well as on-product markings, as discussed above.

Staff cautions, however, that regardless of which approach is chosen, it should never be assumed that CO from a stationary generator cannot infiltrate the home. Therefore, staff continues to advocate that all homes have CO alarms.

VI. Conclusions

This report demonstrates that addressing the CO poisoning hazard associated with stationary generators is both necessary and long overdue. Staff recommends that the technical committee for UL 2200 consider staff's recommendations for two approaches to address the hazard and develop requirements for adoption into UL 2200. In addition, staff recommends that the technical committee for NFPA 37 increase the separation distance between the stationary generator and openings into structures from the current 5 feet to at least 25 feet.

Appendix A

Table A.1. Details of 31 Homes in Table 1.

Number of Homes	Range Category for Distance Between Enclosure and Openings Identified as Path of CO into Home	Distance between Enclosure and Openings	Range Cateogry for Distance Between Enclosure and Home	Distance between Enclosure and Home	Identified Path	Information relevant to exhaust side of enclosure Exhaust orientation: A - exhaust side of the enclosure was perpendicular to the adjacent wall of the home;	Generator Rated Power and Fuel	Date of CO Incident (Grid outage began on 8/29)
31	5 feet up to 10 feet	5 feet	2 feet or less	18 inches	soffit vents	Exhaust orientation A. Photo shows only about 5 feet from exhaust side of enclosure, with no obstructions in that space.	22 kW, NG	9/5
		6.5 feet		20 inches	soffit vents	No photos provided. Wooden fence between yards reported by consumer.	22 kW, NG	8/31
		8 feet		2 feet	soffit vents	No photos provided. Chainlink fence reported by consumer.	unknown rating, LP	9/2
		8 up to 10 feet		2 feet	soffit vents	Exhaust orientation A. 2 sheds appear to be 15 to 20 feet away.	22 kW, NG	9/1
		6 feet		19 inches	soffit vents	Exhaust orientation A. Fence about 20 feet away.	16 kW, NG	9/1
		8 up to 10 feet		2 feet	soffit vents	Exhaust orientation A. A/C condensing unit about 10-15 feet away.	22 kW, LP	~8/29
		7 to 10 feet		2 feet	soffit vents	No photos provided. Fence nearby reported by consumer.	22 kW, NG	8/29
		6 to 8 feet		2 feet	soffit vents	Exhaust orientation A. Neighbor's house 6 feet from enclosure.	22 kW, fuel unspecified	9/4
		8 feet		2 feet	soffit vents	Exhaust orientation A. A/C condensing unit 8 feet away.	24 kW, NG	9/4
		7 feet		2 feet	soffit vents	Exhaust orientation A but exhaust side was beyond back wall of house so exhaust was not under the eaves. Fence 7 feet from exhaust side of generator. **See photos in Figure 3.**	22 kW, NG	9/6
		8 feet		1 foot	soffit vents	Exhaust orientation A. Fence a few feet away.	16 kW, NG	9/4
		up to 10 feet		1 to 2 feet	soffit vents	Exhaust orientation A. Photo shows only only a few feet away from exhaust side.	16 kW, NG	8/30
		6 to 7 feet		1 to 2 feet	window, soffit vents	Exhaust side of enclosure was parallel to the adjacent wall of the home with the exhaust blowing away from the house. The exhaust side of generator was 6-7 feet from the house. Consumer reported a sheet metal fence approximately 6-7 feet from the generator (not visible in photo, but online photos show fence on property line, parallel to long side of enclosure.) **See photo in Figure 3.**	22 kW, NG	8/31 and 9/5
		6 to 8 feet		1 to 2 feet	unsure but maybe window A/C	Exhaust orientation A. A/C condensing unit about 2 feet away.	20 kW, NG	9/3
		6 feet	~2-3 feet	3 feet	soffit vents	Exhaust orientation A. Photo shows A/C condensing unit and fence many feet away. **See photos in Figure 3.**	22 kW, NG	9/1
		8 up to 10 feet		2+ feet	soffit vents	Exhaust orientation A. Photo doesn't show to left of exhaust side of enclosure.	19.5 kW, NG	9/5
		9 feet		3 feet	soffit vents	Exhaust orientation A. Photo shows 5 feet to left of exhaust side of enclosure, with no obstructions in that area.	20 KW, NG	9/2
		5 feet		3 feet	soffit vents	No photos provided. Fence 5 feet away reported by consumer	10 kW, NG	9/3
		up to 10 feet		3 feet	soffit vents	Exhaust orientation A. Photo shows A/C condensing unit and fence about 10 and 15 feet away.	24 kW, NG	8/31
		8 to 9 feet		3 feet	soffit vents	Exhaust orientation A. Photo shows nothing within about 15 feet from exhaust.	18 kW, NG	9/1
		8 feet		3 feet	soffit vents	No photos provided.	16 kW, NG	9/6
		6 feet		3 feet	hole in roof (soffit vent near generator had been removed when generator was installed)	Exhaust orientation A. Photo shows nothing within about 10 feet of exhaust side.	12 kW, LP	9/12
		8 feet		3 feet	soffit vents	No photos provided. Fence with neighbor 5 feet away that fell reported by consumer.	22 kW, NG	9/4
		up to 10 feet		3 feet	soffit vents	Exhaust orientation A. Bushes appear to be at least several feet away.	22 kW, NG	9/2
		5 feet		2 to 3 feet	maybe window	No photos provided. Nothing nearby reported by consumer.	16 kW, NG	9/4
		8 up to 10 feet	5-6 feet	5 feet	soffit vents	Exhaust orientation A. Nothing on exhaust side shown in photo. **See photos in Figure 3.**	22 kW, NG	9/1
		6 feet		5-6 feet	soffit vents	No photos provided.	18 kW, NG	9/7
		6 feet		5 feet	soffit vents	No photos provided.	22 kW, NG	9/7
		up to 10 feet		5 feet	soffit vents	Exhaust orientation A. A/C condensing unit about 5 feet away.	22 kW, NG	~9/1
		8 feet		5 feet	soffit vents	Exhaust orientation A. A/C condensing unit about 15 feet away but closer to the house than the gen enclosure.	22 kW, NG	~8/31
		6 feet		6 feet	maybe window; consumer said that the soffit vents on the generator's side of house were sealed	Exhaust orientation A. Distance away from exhaust side not visible in photo	22 kW, LP	~9/1

Table A.2. Details of 7 Homes in Table 1.

Number of Homes	Range Category for Distance Between Enclosure and Openings Identified as Path of CO into Home	Distance between Enclosure and Openings	Range Catogory for Distance Between Enclosure and Home	Distance Between Enclosure and Home	Identified Path	Information relevant to exhaust side of enclosure Exhaust orientation: A - exhaust side of the enclosure was perpendicular to the adjacent wall of the home;	Generator Rated Power and Fuel	Dates of CO Incidents (Grid outage began on 8/29)
7	10 feet up to 15 feet	10 to 15 feet	2 feet or less	2 feet	soffit vents	No photos provided.	22 kW, NG	9/6
		10 feet	~2-3 feet	3 feet	soffit vents	No photos provided.	unknown rating, NG	9/1
		10 to 15 feet		2 to 3 feet	soffit vents	No photos provided.	22 kW, NG	8/31
		less than 15 feet	5-6 feet	5 feet	closed door to sunroom on exhaust side of enclosure	Exhaust orientation A. Garage wall about 15 feet from exhaust side of enclosure. **See photos in Figure 4.**	16 kW, NG	9/4
		11 feet		6 feet	soffit vents	Exhaust orientation A. Photo shows a few feet beside the exhaust side of the enclosure, with no obstructions shown. **See photos in Figure 4.**	22 kW, NG	9/1
		12 feet		6 feet	soffit vents 12 feet horizotally away from exhaust side of enclosure	Exhaust side of enclosure was parallel to the adjacent wall of the home with the exhaust blowing toward the house. **See photos in Figure 4.**	22 kW, NG	9/3
		10 feet	10 feet	10 feet	door	No photos provided.	unknown rating, NG	8/30

Table A.3. Details of 4 Homes in Table 1.

Number of Homes	Range Category for Distance Between Enclosure and Openings Identified as Path of CO into Home	Distance Between Enclosure and Openings	Range Category for Distance Between Enclosure and Home	Distance Between Enclosure and Home	Identified Path	Information relevant to exhaust side of enclosure Exhaust orientation: A - exhaust side of the enclosure was perpendicular to the adjacent wall of the home;	Generator Rated Power and Fuel	Dates of CO Incidents (Grid outage began on 8/29)
4	15 feet to 20 feet	15 to 20 feet	2 feet or less	1 foot	2nd floor windows and soffit vents	Exhaust orientation A. Brick wall a few feet from exhaust side of gen. **See photos in Figure 5.**	22 kW, NG	8/31
		20 feet	~2-3 feet	3 feet	soffit vents	No photos provided.	unknown rating, NG	9/4
		20 feet		3 feet	soffit vents	No photos provided.	22 kW, NG	9/4
		15 to 20 feet	5-6 feet	6 feet	soffit vents	No photos provided.	unknown rating, NG	9/6