

Incident Summary #II-1624613-2023 (#40659) (FINAL)

SUPPORTING INFORMATION	Incident Date	August 18, 2023	
	Location	Surrey	
	Regulated industry sector	Gas - Natural gas system	
	Impact	Qty injuries	1
		Injury description	One occupant reported experiencing nausea
		Injury rating	Minor
	Damage	Damage description	Carbon monoxide (CO) release from dislodged boiler venting system
		Damage rating	Moderate
Incident rating	Moderate		
Incident overview	The natural gas fired boiler's exhaust venting system was dislodged from a delayed ignition detonation. The boiler continued to run releasing CO into an interior space through the exhaust vent connection opening. One occupant reported feeling nausea, the CO alarm was going off repeatedly, the building was exited, and 911 was called.		
INVESTIGATION CONCLUSIONS	Site, system and components	<p>Site and system</p> <p>The residential home utilizes one natural gas Viessmann Vitodens 100 B1HA 26 hydronic boiler for water heating with a rated output of 87,000 BTU. The heating system includes the boiler, the hydronic water plumbing system, the gas system, and exhaust venting system.</p> <p>Boiler system</p> <ul style="list-style-type: none"> - The boiler has an electrical ignition system to ignite natural gas from the burner. - On a call for heat from thermostat(s), the boiler fires and heats the water in the boiler for the heating systems. - The boiler's heat exchanger transfers heat from the combustion to the water heating chamber. - The heat exchanger requires cleaning as sediments can clog the heat exchanger and cause excessive heat. - The condition of the ignitor is an important factor in ensuring complete and timely ignition. - Under normal operation, the products of combustion from a boiler are exhausted to the exterior of the building through the vent system. - The venting system is required to be sloped downwards towards the boiler so any condensation in the vent will drain into the boiler's condensation drain. - Cleaning of the condensation drain is required to keep the drain from clogging. If clogged, condensate can accumulate in the bottom of the combustion chamber leading to ignition problems as referenced in the boiler's certified manual. - The direct ignition system must ignite the main burner gas within 4 seconds after gas reaches the main burner point. - During operation of a boiler, delayed ignition can occur for various reasons including foreign debris, electrical shorting of the ignition means, gas pressure issues, or condensate backup. 	

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	<ul style="list-style-type: none"> - Depending on the length of time of the ignition delay and the ratio of gas to air mixture, delayed ignition may result in detonation also known as hard light off that can create high pressure on the boiler and the venting system. <p>Vent system</p> <ul style="list-style-type: none"> - The vent system for the boiler consists of PP (polypropylene) vent pipe, with clipped and gasketed vent couplings, and metal strapping style support. - System 636 PP vent system manufacturer's requirements include that the venting needs horizontal supports every 1.0 meter and at changes in direction such as 90-degree elbows. - The venting manufacturer recommends clam shell vent supports from threaded rod. - The PP manufacturer requirements include that the vent pipe must be free to expand and contract. <p>Certification</p> <ul style="list-style-type: none"> - The operational and testing requirements for this type of boiler are defined in the ANSI Z21.13-CSA4.9 boiler product standard. - The boiler standard requires the boiler and its ignition system not to cause excessive flame flash-out or damage to the boiler if there is a delay of ignition of the main burner gas. - In response to delayed ignition, the boiler standard includes delayed ignition testing, in which the boiler must be run through full ignition cycles with a control circuit to delay the arcing ignitor at varying intervals while gas enters the chamber. The boiler must be monitored for flame flash out or damage to the boiler during the tests. - The operational and testing requirements for PP vent pipe and fittings are defined in the ULC-S636 product standard. <p>Carbon monoxide</p> <p>Carbon monoxide is a colourless, odourless, tasteless gas that is toxic to humans and animals (Chart 1). Exposure to carbon monoxide interferes with the body's ability to absorb oxygen, which can result in serious illness or death. Symptoms of carbon monoxide poisoning can present similar to flu symptoms: headaches, nausea, dizziness, or vomiting. For more information on carbon monoxide, visit Carbon Monoxide Safety Tips.</p>
<p>Failure scenario(s)</p>	<p>The hot water boiler was installed in the crawl space of a residential home in 2017-2018. The venting system connects to the top of the boiler in a rubber boot or gasket that uses friction to keep the vent in place. The venting system had wrapped metal strapping in place as a securing means leaving the vent vulnerable to upward motion. The boiler continued in operation over the next five-to-six-year period. It was stated that maintenance was performed on the boiler 1-2 years before the August 2023 incident. The boiler was found to have a fouled heat exchanger, a degraded ignitor rod, and a clogged condensate drain. These conditions contributed to the boiler experiencing delayed ignition detonation. The detonation blew the partially supported vent out of the friction fit connector on the top of the boiler (Image 1). With the venting system dislodged, the boiler continued to run emitting products of combustion and CO into interior spaces. The CO alarm in the house was triggered, an occupant was nauseous, and the occupants exited. The homeowner called 911 and the fire department attended. The gas utility attended the site a half hour after the fire department arrived and even with the doors having been left open in the house by fire crews there was still roughly 60-70PPM (parts per million) of CO in the crawl space and a low CO reading in the home. The gas utility technician noticed a strong aldehyde and sulphur smell inside the home while moving towards the crawl</p>

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	<p>space. The boiler was shut down and red tagged. During servicing the day after the incident, the boiler had an F4 error in the controller (Image 5), which the boiler manual associates with ignition issues.</p>
<p>Facts and evidence</p>	<p>Repair gas fitter statements</p> <ul style="list-style-type: none"> - The boiler's venting gasket [boot] was worn out and needed replacing. - Ignitor was worn at the end. - Condensation was not going down properly. - Heat exchanger was filled with dirt and debris. - Boiler had an F4 error. <p>Utility gas technician statements</p> <ul style="list-style-type: none"> - The venting 90 was popped of the top of the boiler. - Was told by an occupant that the CO alarm had been reset over a period of a couple days as they thought it was faulty. - Upon walking in the house, could smell aldehydes quite a bit, down the landing it smelled sulphury. - Read 60-70 PPM on their gas detector in the crawl space, 30 minutes after the fire crews had arrived and started airing the place out. - In the house there was a low reading of CO at that time. - Shut power and gas off. <p>Fire fighter</p> <ul style="list-style-type: none"> - Fire crew CO monitor activated when close to the crawl space. - One occupant reported feeling nauseous. <p>Homeowner statements</p> <ul style="list-style-type: none"> - Heard the CO alarm keep ringing and ringing for 10-15 minutes, so called 911. - Occupants' younger child was nauseous when the incident occurred. - The boiler had been serviced 1-2 years before the incident by a gas fitter, but the owner couldn't recall the name of the gas fitter. - That maintenance service reportedly included general inspection, cleaning the heat exchanger, and changing the ignitor. - Boiler was installed when the house was built in 2017-2018.
<p>Causes and contributing factors</p>	<p>The vent was most likely dislodged by delayed ignition detonation leading to CO release into interior spaces. The venting system not having the required support may have contributed to the vent being able to move upwards and dislodging.</p> <p>Contributing factors to the detonation may have included the:</p> <ul style="list-style-type: none"> - Degraded arcing ignitor. - Heat exchanger filled with dirt and debris. - Clogged condensate drain. <p>A contributing factor to the CO release into interior spaces was the ability of the boiler to run with a dislodged vent.</p>



Image 1 – Dislodged vent.



Image 2 – Boiler after servicing.



Image 3 – Exhaust venting to exterior.

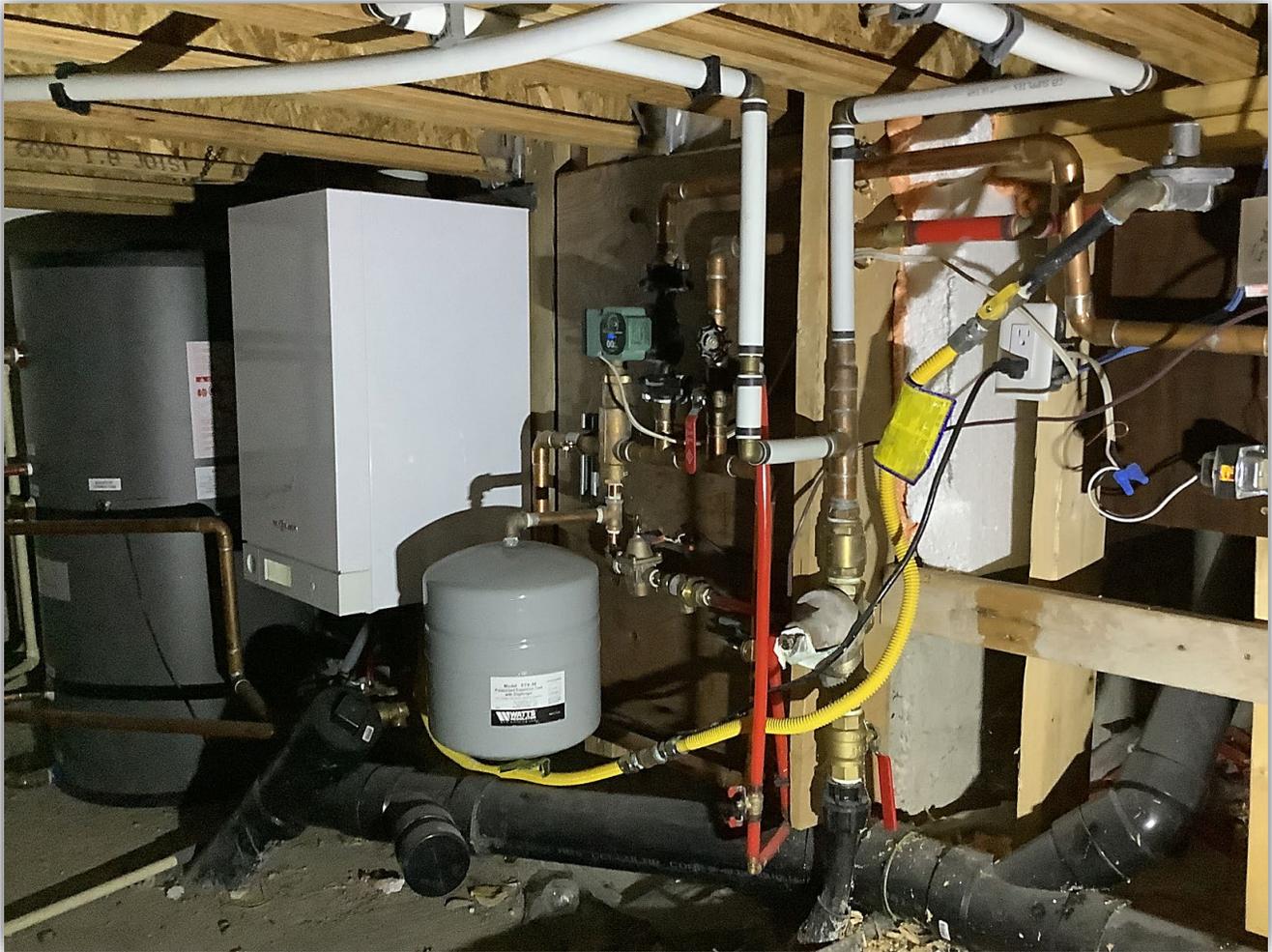


Image 4 – Boiler overall system.

F4	Burner in fault mode	No flame signal is present	Check ignition electrodes and wires. Measure the ionization current, check the gas pressure, check the gas valve, ignition, ignition module and condensate drain. Reset control. Check ignition cable resistance (4.5K to 5K ohms).
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Image 5 – Boiler F4 fault code information.

Properties of Carbon Monoxide

<i>Colourless</i>	Cannot be seen.
<i>Tasteless</i>	Cannot be detected through the sense of taste.
<i>Odourless</i>	Cannot be detected by sense of smell, However, CO can also be accompanied by aldehydes. Aldehydes' odour can somewhat resemble vinegar, which can be detected by the sense of smell, and may also result in a metallic taste in the mouth.
<i>Non-irritating</i>	Carbon Monoxide will not cause irritation. However, aldehydes usually present with higher levels of CO will irritate the eyes, nose, and mucous membranes.
<i>Specific gravity</i>	Slightly lighter than air (Sg 0.975). It may, but not always collect near the ceiling, and mixes freely with air.
<i>Flammable (explosive) limits</i>	CO is flammable between concentrations of 12.5% to 74% when mixed with air. Its ignition temperature is 609°C (1128°F).
<i>Toxic</i>	Can cause death if enough is absorbed into the bloodstream.

Chart 1 - Properties of Carbon Monoxide – From Technical Safety BC's "[Carbon Monoxide Handbook](#)".

Concentrations (*ppm) Observations and Health Effects

1 to 3	Normal.
25	Occupational exposure limit averaged over 8 hour period.
30 to 60	Exercise tolerance reduced.
100	15-minute short-term exposure limit (STEL).
60 to 150	Frontal headache. Shortness of breath on exertion.
150 to 300	Throbbing headache, dizziness, nausea, and impaired manual dexterity.
300 to 650	Severe headache; nausea and vomiting; confusion and collapse.
700 to 1000	Coma and convulsions.
1200	Immediately dangerous to life and health (IDLH).
1000 to 2000	Heart and lungs depressed. Fatal if not treated.
Above 2000	Rapidly fatal.

*1 ppm = 1 part of gas per million parts air by volume

Chart 2 - Carbon Monoxide concentrations and health effects – From Technical Safety BC's "[Carbon Monoxide Handbook](#)".