Incident Summary #II-1199310-2021 (#22131) (FINAL)

SUPPORTING INFORMATION	Incident Date		May 23, 2021
	Location		Maple Ridge
	Regulated industry sector		Gas - Natural gas system
	Impact – Injury	Qty injuries	3
		Injury description	Multiple occupants reported symptoms of carbon monoxide (CO) exposure including headaches, nausea, vomiting, loss of focus, and drowsiness at various times over a period of 3 plus years. One occupant sought medical attention for the CO symptoms.
		Injury rating	Moderate
	Impact – Damage	Damage description	Products of combustion including CO and corrosive condensate spilled into multiple interior spaces; corrosion to electrical distribution equipment; disintegration of the electrical room ceiling from condensate moisture; bowing and splitting of the flooring in the dwelling above from moisture.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		A natural gas fired boiler used for hydronic heating in a multi-dwelling residential building exhausted products of combustion including carbon monoxide (CO) from it's exhaust venting system into interior areas of the building. Multiple occupants experienced symptoms associated with CO exposure at various times over the three plus years of operation of the boiler.
INVESTIGATION CONCLUSIONS	Site, system and components		**Site and system** - The multi unit residential building utilizes a natural gas boiler with electronic spark ignition as the main source of heat. - The hydronic boiler uses the combustion of natural gas to heat water which is circulated to radiators within the homes that are individually controlled by thermostats to provide heat for areas within each home. **Boiler components** - The boiler's ignitor applies an electrical arc to natural gas in the burner. - The produced heat transfers to the water by way of a heat exchanger. This is done at intervals determined by the electronic controls of the boiler based on settings and demand. - The heat exchanger transfers heat to the water system without direct contact. - There are single prong and double prong ignitors that have been provided by the manufacturer for this type of boiler depending on the date of manufacture. - The single prong ignitor operates by creating an electrical arc between the prong and a grounded metal burner mesh. - The double prong ignitor creates an electrical arc between the ignitor's energized prong and the ignitor's grounded prong.

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	- Whether a single or double prong ignitor is utilized, the distance of the gap is a critical factor in ensuring proper ignition. - Short cycling can occur when a boiler turns on and off too often. A boiler that is oversized for the loads it feeds turns on and off more frequently. **Boiler venting system** - The boiler's exhaust venting system is required to be sealed at all joints and connections. - The venting consists of polypropylene ducting with gasketed connections and clipped couplings that is supported by metal rod hangers and clamps. - The venting system manufacturer's instructions include requirements for supporting the venting at specified interval distances. **Carbon monoxide** - 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.
Failure scenario(s)	The boiler (Image 3) was installed in a system where it was oversized and as a result would repeatedly take short amounts of time to meet the heating demand (known as short cycling). The boiler used a single prong ignitor that had residual stress in the metal offset bend (Image 1). The ignitor experienced advanced wear and tear from the short cycling occurrences. From this wear and tear the residual stress was very likely released and the arc gap between the ignitor prong and the metal burner mesh increased beyond the manufacturer's recommended gap distance (Image 5). On multiple occasions, the boiler was not initially igniting the natural gas. This delayed ignition led to a build up of unburnt gas and explosive detonations when ignition would finally occur. The venting system on multiple occasions separated within the interior space from the force of the boiler's detonations (Image 4). This released products of combustion including moisture and CO into the ground floor rooms that then infiltrated the above dwelling through its floor (Image 7).
Facts and evidence	**Manufacturer representative's statements:** - The boiler was sent from the manufacturer with a single prong ignitor given the manufacture date (prior to the Jan 2018 installation). - After reports from the installer of delayed ignition and explosive detonation, the manufacturer went to site to commission the boiler. - The boiler was oversized for the loads, and it was difficult to get sufficient load or run time for the boiler. The result was short cycling, on and off, which increases the chance of delayed ignition (*from the increased ignitor gap*). - The commissioning included substantial time adjusting the boiler's time over temperature algorithm. This was in an attempt to find a setting where the boiler would run for a decent amount of time and then shut off. - The ignitor can jump a maximum 5mm gap, with a typical gap of 3.5mm. - Some single prong ignitors installed at other sites, would drift away from the burner due to release of residual stress in the metal from heat exposure. That would cause the gap to grow, leading to detonations. - Their process for re-gapping ignitors was to heat them with a torch and adjust the gap distance. - They have had other issues with ignitors and these model of boilers at other sites. These have been resolved when a dual prong ignitor is installed.

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- There are no records available from the manufacturer of a dual prong ignitor being installed at this site.
- Both ignitors from (Image 1) look to be of the Kanthal advanced powder metallurgy (APM). The unmarked one, is a new vendor who only produced Kanthal APM. The Sapco ones looks like the newer style and is expected to be Kanthal APM as well.

Ignitor product changes:

- The boiler manufacturer issued a change to single prong and double prong ignitors (that applies to the SL G3 boiler at this site) on their website on July 30, 2020, that included the following wording:
  "During the 2018 heating season, a fraction of IBC's ignitors showed signs of rod distortion. The rod material in the ignitors has since been changed to a Kanthal APM (advanced powder-metallurgical) material to fortify the structure of the ignitor. The improved ignitors sell in the following kits: P-111B for the double-prong offset ignitor and P-340B for the single-prong offset."
  Link: Fortified Ignitors

- The boiler manufacturer identified issues with the original ignitors and issued a discontinuation of P-340 single prong ignitors (that applies to the SL G3 boiler at this site as well as other indicated models) on January 22, 2021, that included the following wording:
  "Effective immediately, the P-111B double-prong ignitor (Figure 1) replaces the P-340 single-prong ignitor. The P-111B is the new standard for the SL-series boilers as it combines an improved metallurgic formula for longevity with the convenience of a factory-set spark gap."
  Link: P-111B change

Ignitor info
A gas contractor representative stated that the boiler was utilizing a single prong ignitor (Image 1) as of May 23, 2021. A second previously used single prong ignitor was found inside the boiler cabinet. There is no evidence that an ignitor other than a single prong type had been utilized at any time for this boiler.
The manufacturers manual specifies a spark gap setting of between 3.2 and 4.7mm.

Timeline
Early January 2018 - A gas contractor stated they installed the hydronic boiler.

January 2018 - The original gas contractor and the boiler manufacturer both confirmed by statement that they performed on site commissioning to address delayed ignition issues with the boiler.

Jan 29, 2018 - The utility gas technician stated that they shut off the gas to the boiler as delayed ignition of the boiler was reported and confirmed.

May 12, 2018 - The unit 5 occupant stated that they had reported to the utility that they had been experiencing headaches and a smell of gas in their unit that is directly above the mechanical room. The utility gas technician attended the site and found a piece of the boiler venting had blown off and fallen to the floor. They noted that boiler exhaust was spilling into the ground floor room below unit 5, that the ceiling drywall was wet and that there were large amounts of water on the floor. They noted that the exhaust had been making its way to unit 5 through the damaged ceiling and floor.

Nov 01, 2020 - A building occupant stated that the fire alarm was triggered in the middle of the night from boiler exhaust in the basement. The boiler vent had

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	disengaged in the electrical room from delayed ignition detonations. Boiler exhaust and condensate was damaging the ceiling. May 23, 2021 - The utility gas technician stated they had reports from multiple tenants of large booms (sounding like a shotgun) leading up to May 23rd and gas smells in the building. The fire department stated that they noted a gas smell, measured 14 parts per million of carbon monoxide and decreased oxygen levels in the mechanical room. The utility gas technician confirmed that they shut the gas to the boiler off.
Causes and contributing factors	The incident was very likely caused by the use of an inadequate single prong ignitor. The appliance venting system repeatedly disengaging in multiple locations from the delayed ignition detonations was a contributing factor.

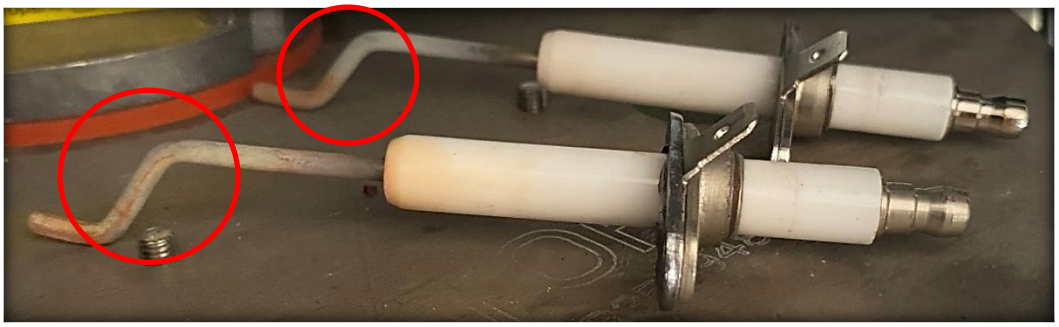

Image 1 - Single prong ignitors used with the boiler. Offsets indicated in the circles.

Image 2 - Dual prong type ignitor indicated in boiler manufacturers product change.

Image 3 - Hydronic boiler. Note the extra used single prong ignitor in the red rectangle.

Image 4a, b, c – Boiler venting disengaged from delayed ignition detonations and with improper tape repairs.

Image 5 - Single prong ignitor configuration and direction of warping away from the burner mesh due to release of stress in the metal (arrow). This warping would cause an increased arc gap.

Image 6 - Photo from Nov 2020 showing damage from products of combustion and condensate to the electrical room ceiling/electrical equipment and the corner vent piece fallen from explosive detonations.

Image 7a, b, c, d – Residence flooring bowed from rising products of combustion and condensate moisture; condensation drops on the ceiling of the residence above the electrical room.

Properties of Carbon Monoxide

Colourless	Cannot be seen.
Tasteless	Cannot be detected through the sense of taste.
Odourless	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.
Non-irritating	Carbon Monoxide will not cause irritation. However, aldehydes usually present with higher levels of CO will irritate the eyes, nose, and mucous membranes.
Specific gravity	Slightly lighter than air (Sg 0.975). It may, but not always collect near the ceiling, and mixes freely with air.
Flammable (explosive) limits	CO is flammable between concentrations of 12.5% to 74% when mixed with air. Its ignition temperature is 609ºC (1128ºF).
Toxic	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"