Incident Summary #II-1000866-2020 (#16972) (FINAL)

SUPPORTING INFORMATION	Incident Date		April 6, 2020
	Location		Campbell river
	Regulated industry sector		Gas - Natural gas system
	Impact – Injury	Qty injuries	0
		Injury description	N/A
		Injury rating	None
	Impact – Damage	Damage description	Products of combustion including carbon monoxide (CO) were exhausted into the mechanical room of a middle school. 6 of the 8 boilers had blown pressure vessel gaskets and 3 of the 8 boilers had disengaged venting systems.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		Multiple natural gas fired boilers in a school building experienced delayed ignition detonations and emitted products of combustion including CO from dislodged vents into the boiler room.
INVESTIGATION CONCLUSIONS	Site, system and components		**Site and system** • The school building utilizes natural gas boilers with electronic spark ignition for water heating. • The hydronic boiler uses the combustion of natural gas to heat water which is circulated to heaters in the school. **Boiler components** • The boiler's ignitor applies an electrical arc to natural gas from 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. • 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. • Whether a single or double prong ignitor is utilized, the distance of the gap is a critical factor in ensuring proper ignition. • Boiler venting consists of chlorinated polyvinyl chloride (CPVC) supported by threaded metal rod and hangers.

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	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)	Delayed ignition occurred on multiple boilers as the arc gaps between the ignitor prong and the metal burner mesh increased beyond the manufacturer's recommended gap distance. The residual stress in the metal offset bend of the single prong ignitors (Image 1) released from advanced wear and tear with the gap widening until the ignitors were no longer initially igniting the natural gas. This delayed ignition led to build up of unburnt gas and explosive detonations when ignitions would finally occur. The boiler chamber gaskets for 6 of the 8 boilers were blown out (Image 5-8) and the venting systems for 3 of the 8 boilers separated (Image 2-4) at the tops of the boilers from the force of the boiler detonations. Products of combustion including CO were released into the space.
Facts and evidence	**School gas fitter statements:** • The school gas fitter and a colleague randomly came across the boilers and noticed a smell of products of combustion and found boiler venting systems disengaged from at least two running boilers. • The 636 <PVC venting> was not clamped in anymore and was popped right off. • When they <the boilers> would go down to low fire, the regulator would hunt. • Ignitors that were in use were single prong but since then all of the ignitors across the school district have been changed to dual prong. • The boiler room is approximately 20 x 28 <feet> and has a supply fan. • There are no CO detectors in the room. **Contractor gas fitter statements:** • Initial install was completed around late September of 2019 including the scope of placement and piping of the product. This included assembling of the racking system, placement of the boilers on to the racking, and hydronic and gas piping up to the units but excluding commissioning. • The boilers were commissioned by the manufacturer in 2019. • Was called to site after the incident by maintenance staff to investigate disconnected venting related to the 8 boilers originally installed by the contractor. • On site, they found three vents were disconnected, and internal to the boilers, the heat exchanger gaskets had blown out of installation position on six boilers. • Upon investigation, concluded that the boilers had a combustion failure. • The top venting was connected with a gear clamp, so there was quite a bit of force holding that in place. To dislodge that, was something significant. • They were advised by the manufacturer representative, that the boilers were experiencing a 'lifting' situation and the fix for this was to go from single prong to dual prong ignitors.

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Manufacturers representative statements - June 2021

- Has been to a few sites where there were detonations, they go through the boilers from tip to toe, gas pressures, adjust the gas valves. Its always just one visit and then off we go.
- There have been a few where there are detonations, we had a school in Campbell River and there is a full report there.
- In that case, it was a mix of ignitors and gas supply pressure that was pulsating 6 inches either side of normal as the gas regulators were hunting and then as boilers come online and drop off.
- It is an 8 boiler system that had some issues, went up and did a full redo on those, dual prongs, every gas valve.

Manufacturer's site report

- When the boilers were fired <during post incident troubleshooting> at 300MBTU, the gas regulators on both banks of boilers (B1-B4 and B5-B8) were hunting with gas manifold pressure fluctuation 1-1.5" Wc. <water column>.
- There was an auditable <audible> hunting noise observed from both the gas regulators.
- A hunting gas regulator would exacerbate a poor ignition condition in the boiler set.
- The DDC established a call for heat with a set-point of 82C.
- With all the boilers at 399MBTU, the call for heat from the DDC dropped away and was then re-established 2 minutes later with a lower setpoint of 74C. If this operation is normal it can lead to a very high boiler ignition cycle count.
- B1-B8 <boiler 1 through 8> were fitted with a new dual prong igniter part number P-111 <after the incident>.
- Suggest that the CPVC exhaust pipes be clamped to the first support cross piece on each exhaust run as added protection against the exhaust being able to lift up if a delayed ignition event were to occur in the future.

Manufacturer correspondence

- IBC has been using the same double prong (electrode) ignitor design since 2010. In this design the spark is generated in the spark gap between two electrodes. The double electrode design has the advantage of having an easily controlled and verifiable spark gap.
- In 2017 IBC began testing a single electrode ignitor design. In this design the spark is generated between the ignitor electrode and the burner. The disadvantage is that the spark gap is not simple to control since it will vary with manufacturing tolerances and the gap is not easy to visually verify.
- The manufacturers manual includes diagnosis and remedy for the maximum ignition trails error as adjusting to a spark gap setting of between 3.2 and 4.7mm (Image 9).

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, including 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

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	• 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 models on their website on January 22, 2021, including 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
Causes and contributing factors	The gap between the single prong ignitor and the burner very likely exceeded the maximum recommended gap leading to the delayed ignition detonations causing the boilers venting to become dislodged.

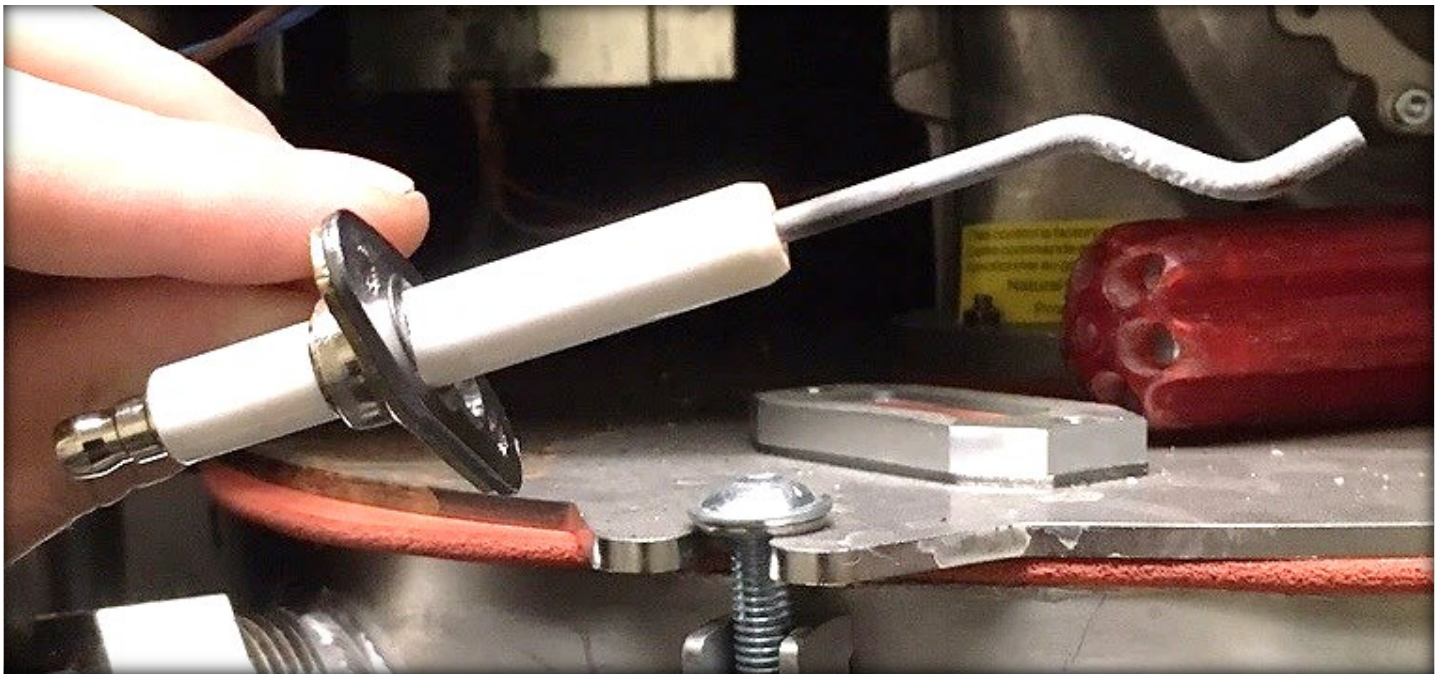

Image 1 – Single prong ignitor in use at time of the incident.

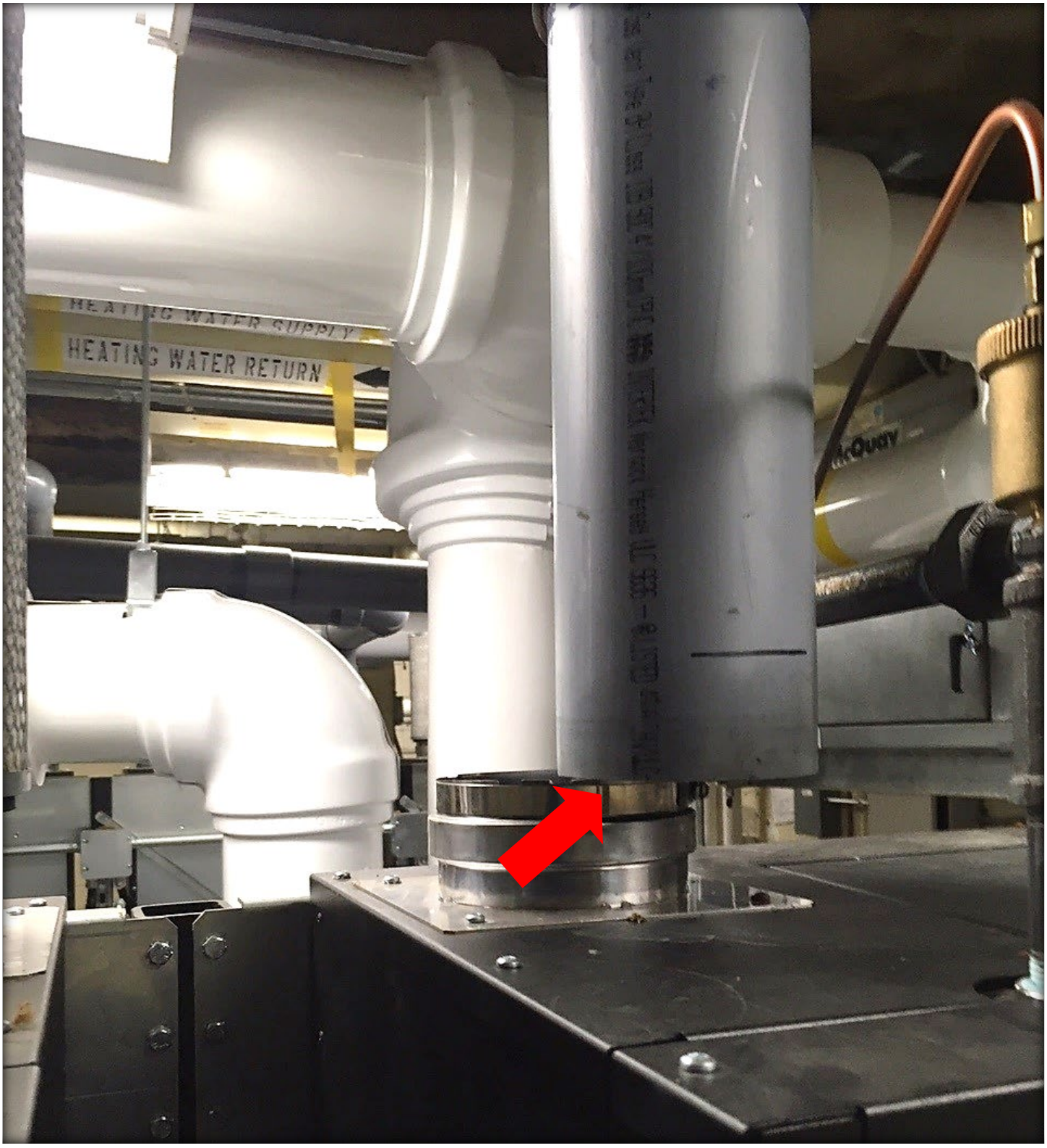

Image 2 – Venting dislodged from boiler due to delayed ignition detonation (example 1 of 3).

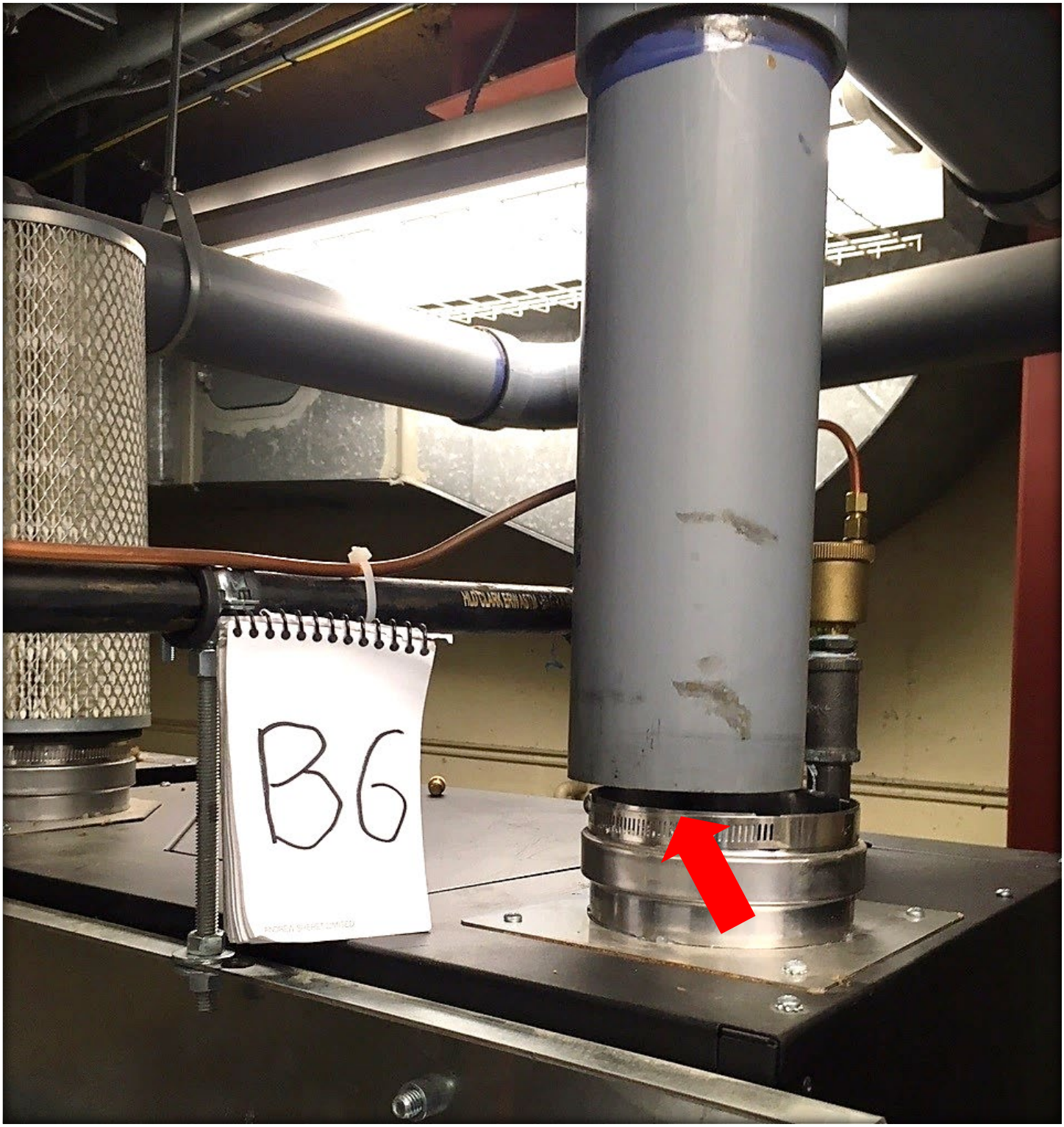

Image 3 – Venting dislodged from boiler due to delayed ignition detonation (example 2 of 3).

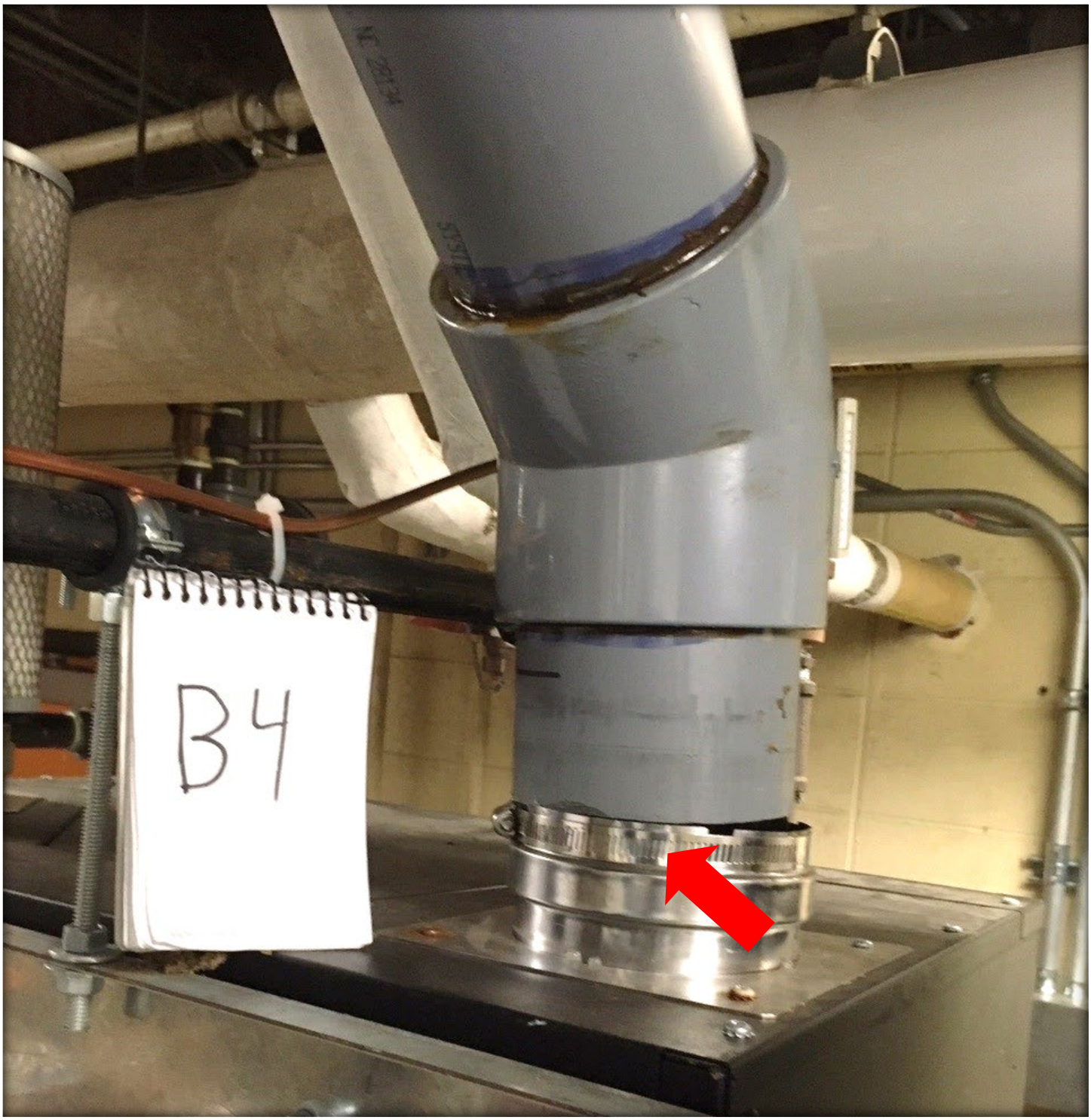

Image 4 – Venting dislodged from boiler due to delayed ignition detonation (example 3 of 3).

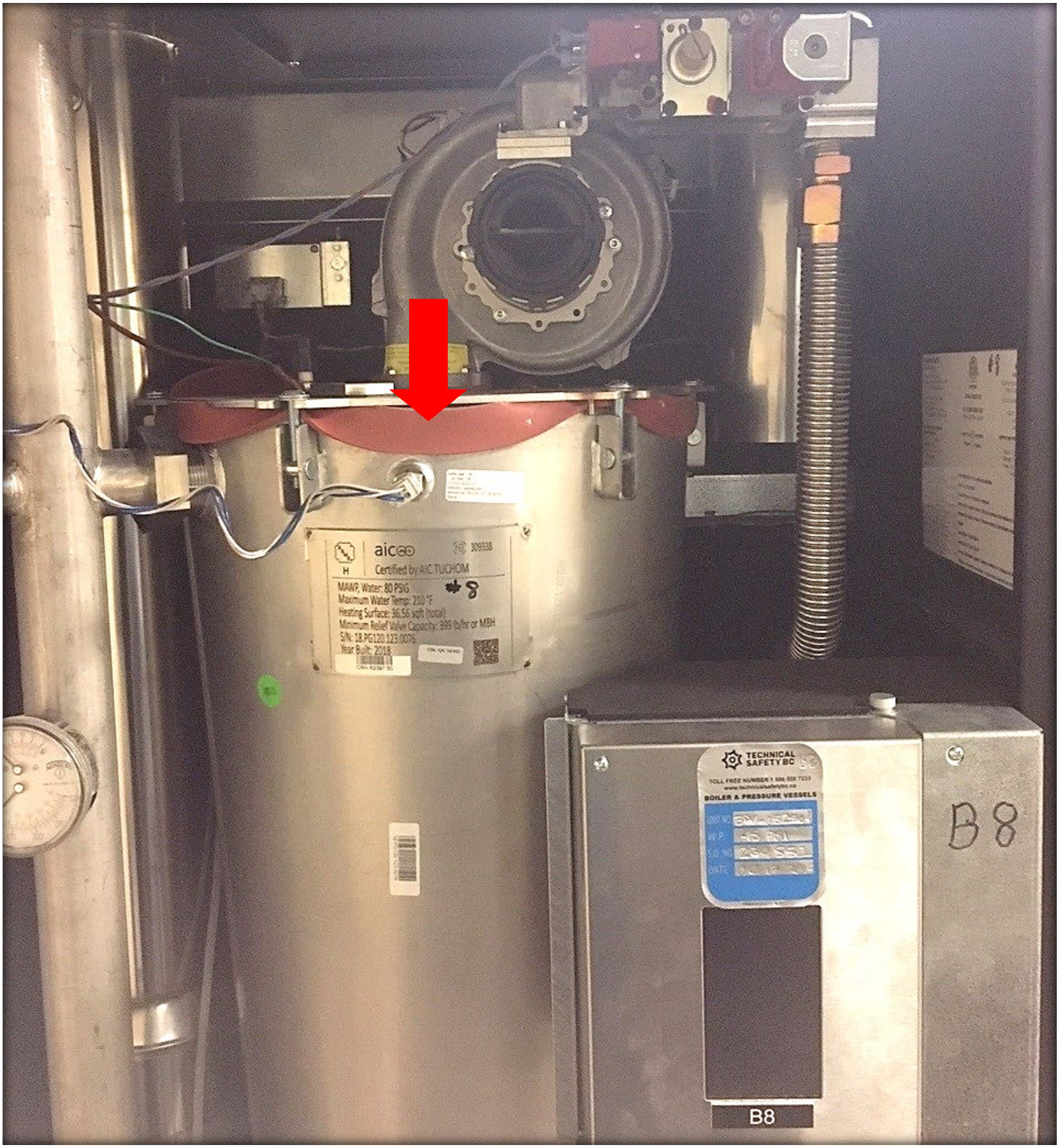

Image 5 – Pressure vessel gasket blown out from delayed ignition on Boiler 8 (example 1 of 4)

Image 6 – Pressure vessel gasket blown out from delayed ignition on Boiler 1 (example 2 of 4)

Image 7 – Pressure vessel gasket blown out from delayed ignition on Boiler 4 (example 3 of 4)

Image 8 – Pressure vessel gasket blown out from delayed ignition on Boiler 3 (example 4 of 4)

SYMPTOM	DIAGNOSIS	REMEDY
MAXIMUM IGNITION TRIALS ERROR **Touchscreen Message:** **Error – Ignition Failure after 3 tries** **Boiler has failed to ignite on 3 successive attempts. Boiler in lockout for 1 hour, then repeats 3-try seq. Consult service technician if error recurs.**	**Gap between igniter probe rods is too large or too small.**	Adjust ignitor probe rod gap between 1/8th and 3/16th (3.2-4.7 mm)

Image 9 – Troubleshooting guide (Control module display errors) - Manufacturers installation & operating instructions

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"