Incident Summary #II-1708402-2024 (#46057) (FINAL)

SUPPORTING INFORMATION	Incident Date		May 8, 2024
	Location		Burnaby BC
	Regulated industry sector		Boilers, PV & refrigeration - Boiler and pressure vessel system
	Impact – Injury	Qty injuries	0
		Injury description	N/A
		Injury rating	None
	Impact – Damage	Damage description	Explosion damage in a mechanical room including pushed out walls, broken drywall, minor fire damage at the ceiling level and disengagement of the vent piping at multiple locations for boiler #1.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		A commercial water heating boiler in a retail shopping mall had operational issues that allowed natural gas to accumulate in the mechanical room leading to an explosion.
INVESTIGATION CONCLUSIONS	Site, system and components		The facility is a large retail shopping mall that uses hot water boilers to heat common indoor spaces. There are two natural gas fired 2,500,000 btu boilers used for the heating. One boiler is typically set as the primary boiler and the second acts as a standby and both are controlled by a remote direct digital control (DDC) system. The boilers are Category IV forced draft boilers that use a fan to supply a mixture of air and fuel into a combustion chamber where it is ignited. Category IV gas appliances are condensing appliances that operate with a positive vent pressure. The fan provides a slight positive pressure to push the combustion gasses out a venting system safely to the outdoors. The heat is transferred from the combustion to the water as the flue gasses pass through a heat exchanger made up of a series of copper finned tubes containing the water. The boiler is equipped with a number of safety features that are incorporated into the boiler's control system to ensure conditions are safe for the boiler to start and to monitor for continued safe operation. These safeties include: 1. Water flow switch 2. High & low gas pressure switches 3. High temperature limit 4. High stack temperature switch 5. High exhaust back pressure switch The high exhaust back pressure switch is connected to the boiler's combustion chamber using a combination of black iron and stainless-steel piping. The pressure it senses from the combustion chamber acts on an internal diaphragm which opens or closes a microswitch on an electrical circuit at a predetermined pressure setpoint. The switch's intended use for the boiler application is to sense the pressure inside the combustion chamber and open the "normally closed" electrical circuit stopping operation of the boiler when the pressure inside the combustion chamber exceeds a factory setting of 4" water column (WC) (0.145 psi) due to a blockage in the boiler or venting system.

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	### Maintenance The boiler manufacture's installation and operation manual outlines recommended maintenance which includes annual inspection of the heat exchanger, venting system, and inspection and cleaning of the burner and heat exchanger tubes. ### Carbon monoxide Natural gas requires a minimum amount of oxygen for complete combustion. When the minimum amount of required oxygen is not supplied to a gas burner or engine, the result is incomplete combustion. A by-product of incomplete combustion is carbon monoxide. Carbon monoxide is a colourless, odourless, tasteless gas that is toxic to humans and animals. Exposure to carbon monoxide interferes with the body's ability to absorb oxygen, which can result in serious illness or death. For more carbon monoxide information, visit Carbon monoxide safety tips.
Failure scenario(s)	Two boilers were installed in the mechanical room of the retail shopping mall in 2014. Initial setup of the boilers was completed by qualified technicians and proper operation at the time of installation was confirmed through testing and combustion analysis. The boilers were included in a preventative maintenance program which consisted of qualified technicians observing and inspecting the boilers operation at regular intervals. The preventative maintenance program did not include all of the manufactures recommended semi-annual and annual maintenance procedures. The boilers did not receive the manufactures recommended "Strip and Clean" service on an annual basis which consists of an internal burner, combustion chamber and heat exchanger inspection and cleaning. They only received this service once after 5 years of operation. 5 years after they had last received the strip and clean service, boiler #1 accumulated a substantial buildup of deposits on the internal finned tube heat exchanger. The buildup of deposits restricted the ability for the flue gasses in the combustion chamber to flow through the heat exchanger and out the attached venting system safety to the outdoors. The restriction in flow led to improper air-fuel ratios and incomplete combustion of the natural gas inside the combustion chamber along with the production of very high levels of CO. On April 9th, 2024, a technician working for a service contractor was conducting routine preventative maintenance on Boiler #1 and found that was producing in excess of 5000 parts per million (ppm) of CO in the flue gas during operation. The technician sent in a request for an urgent quote to be sent to the facility management to address the issue but did not identify a potential hazard with the finding and allowed the boiler to remain in operation. The facility management was not informed of the operating issue with the boiler until a quote for repair work was sent on April 22, 2024. At no time was the facility management ever notified of any potential hazards with the operation of Boiler #1 after it was identified by the technician. On May 1st, 2024, seven days before the incident, the facility operating management switched boiler #1 from standby operation to the primary operating boiler. The heat exchanger blockage caused incomplete combustion and the production of high levels of CO (>5000ppm). Corrosion debris and deposits plugged the piping elbow and inlet port to the boiler's high exhaust back pressure switch rendering it ineffective at shutting the boiler off when the pressure inside the combustion chamber increased due to the restricted heat exchanger. The heat exchanger blockage eventually caused the back drafting of a gas/air mixture into the room, likely

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	from the combustion fan air inlet. The gas/air was contained within the mechanical room and when it reached a flammable level it ignited causing an explosion that separated boiler 1's venting system in multiple places, pushed out the upper portion of the mechanical room walls and melted and burned multiple plastic and paper materials in the top half of the room.
Facts and evidence	**Gas technician Statement** • During routine checks on the boilers, they found that boiler 1 had high levels of CO measured in the flue gasses. • They did not equate the high CO readings to hazardous operation of the boiler. • They sent an urgent recommendation for a quote to repair the boiler to their foreman, management and dispatch but did not directly inform the facility management. • This was the first time they had ever worked on that boiler. **Facility manager statement** • They had not been made aware of an issue with the boiler until a quote for repair was received 13 days after the technician discovered the issue. • The quoted repair did not identify and hazards with the boilers continued operation and did not recommend removing the boiler from operation. **Manufacturer statements** • The exhaust backpressure switch is factory set to actuate at 4" WC positive pressure from the combustion chamber. • The exhaust backpressure switch is tested during factory fire testing of the appliances. • The appliance involved in the incident had been tested at the factory on 9/13/2013. • The exhaust backpressure switch does not have an in-field recommended test. • To complete a test validation on an exhaust backpressure switch on an installed unit requires removal of the switch from the unit, and a pressure source to activate it. • Given the risk of damage to the unit, it is not recommended to complete the test in the field. **Boiler manufactures Installation and Owners manual** • Safety checks that must be made before putting the boiler into normal operation or after all repairs or maintenance include testing of the ignition safety system, Low water cut-off, high limit control, and the low and high gas pressure switches. (No inclusion of the High exhaust back pressure switch) • Semi annual maintenance includes the inspection and cleaning of the main burner. • Annual maintenance includes inspection of the combustion chamber and inspection and cleaning of the heat exchanger. **Site observations** • A plug in CO detector in the mechanical room had a max CO reading recall of 999 ppm CO which was the highest reading the detector would display.

	• The explosion damaged the interior and exterior walls of the mechanical room. The force pushed the walls outward and damaged the drywall and exterior stucco. • The venting for boiler 1 was found disconnected in multiple locations and a pipe plug for a testing port on the vent adapter was found blown out and laying on the floor. Testing and measurements • The low and high gas pressure switches were tested and found to be set correctly and operational. • The gas lines and regulators between the shutoff valves and the appliance gas valves were pressure tested with a digital manometer and a digital combustible gas leak detector with no leaks found. • The gas valves on boilers were tested for tightness and no leaks were found. • The low and high gas pressure switches were tested with a digital multimeter and the HGP switch on boiler 1 was in the closed position and the low gas pressure switch was found in the open position. • The blocked flue switch was tested with a digital multimeter and found to be in the closed positions. • Pressure was applied to both switches with a hand bulb and neither of the switches operated. The first one was supplied with up to 8”wc connected to a manometer and the second, without the manometer, by squishing the hand bulb as hard as possible.
Causes and contributing factors	The restricted heat exchanger allowed unburnt gas to backdraft into the mechanical room space, accumulate and contact a source of ignition causing an explosion. Contributing factors to the incident include: • The high exhaust back pressure switch becoming ineffective at safely stopping the operation of the boiler due to corrosion and debris plugging the sensor inlet. • The high exhaust back pressure switch not being part of manufactures recommended routine maintenance, inspection or testing failed to identify it’s ineffectiveness prior to the incident occurring. • The continued operation of the boiler after high levels of CO were measured in the flue gas provided more opportunities for an incident to occur. • Ineffective communication and understanding of the hazards associated with the continued operation of the boiler failed to inform decisions to halt the operation of the boiler.

Image 1 – Boilers in mechanical room. Boiler #1 in the foreground Boiler #2 in the background.

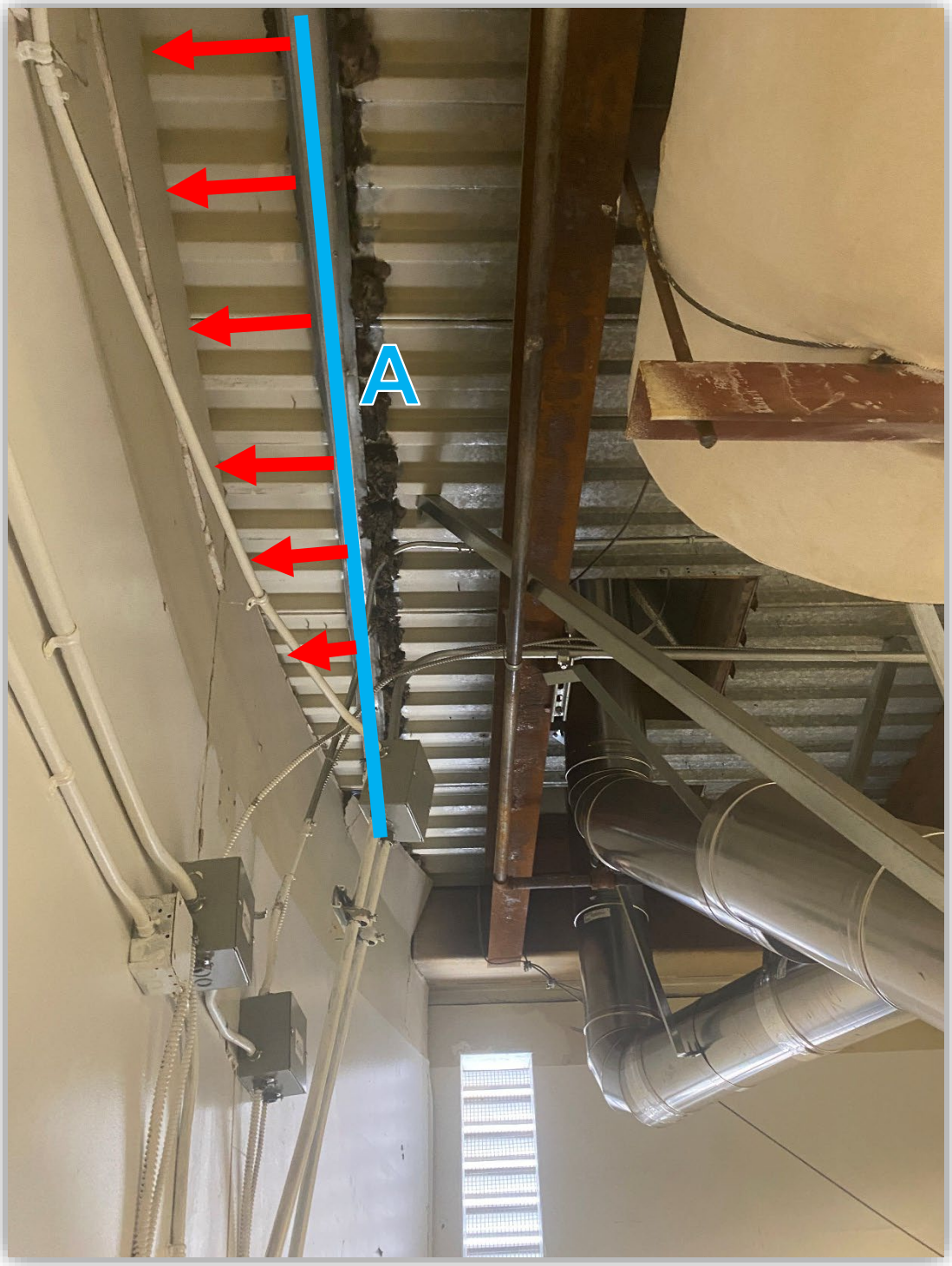

Image 2 – Damaged wall of mechanical room. [**A**] line indicated original location of the wall and the arrows show the amount the wall was pushed in by the explosion.

Image 3 – Damaged drywall at ceiling of mechanical room.

Image 4 – Dislodged venting components from Boiler #1 after explosion.

Image 5 – Comparison of the dirty and plugged heat exchanger of Boiler #1 (Left) to relatively clean heat exchanger of Boiler #2 (Right).

Image 6 – A second comparison of the dirty and plugged heat exchanger of Boiler #1 (Left) to relatively clean heat exchanger of Boiler #2 (Right).

Image 7 – Deformed burner mesh from Boiler #1.

Image 8 – High exhaust backpressure switch installed on boiler with a black iron street elbow. *(Image taken during disassembly with other components and wiring removed).*

Image 9 – Corrosion debris inside ¼” outlet housing the black iron street elbow for the high exhaust backpressure switch.

Image 10 – Corrosion debris from inside black iron street elbow housing the high exhaust backpressure switch.

Image 11 – Corrosion plugged inlet to the high exhaust backpressure switch for Boiler #1.