Incident Summary #II-1889584-2025 (#57150) (FINAL)

SUPPORTING INFORMATION	Incident Date		April 4, 2025
	Location		Surrey
	Regulated industry sector		Gas - Natural gas system
	Impact – Injury	Qty injuries	2
		Injury description	Two children in the home were exposed to carbon monoxide (CO) and experienced symptoms including nausea and vomiting. They were evaluated by emergency medical responders and transported by ambulance to hospital for treatment.
		Injury rating	Moderate
	Impact – Damage	Damage description	A residential gas furnace heat exchanger failed resulting in high levels of CO being produced by the furnace. Redundant safety features (flame rollout switch, air proving switch) failed to control the hazard. This resulted in CO exposure to the occupants inside the home.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		A natural gas furnace in a residential townhome produced high levels of CO in the flue gas. The flue gas containing CO migrated into the occupied indoor space. Built-in automatic safety devices within the furnace did not reliably detect the conditions produced by the corroded secondary heat exchanger. Two children in the home became ill and the CO detectors in the home alarmed. First responders identified CO indoors and a responding gas utility technician measured 125ppm CO in the home. The two children were taken to hospital via ambulance and treated for CO poisoning.

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INVESTIGATION CONCLUSIONS

Site, system and components

Residential gas furnaces use the heat produced from the combustion of a gas/air mixture to heat the home. The combustion occurs at the entrance to a heat exchanger. The flue gases produced by combustion pass through the inside passages of the heat exchanger and are carried safely to the outdoors through a venting system connected to the furnace. A blower draws air from inside the home and passes it around the outside of the heat exchanger. Heat transfers through the heat exchanger shell to the air on the outside which is then distributed throughout the home through a ducting system to heat the home (Diagram 1).

High efficiency furnaces incorporate a secondary heat exchanger in addition to the primary heat exchanger. A draft inducer fan first draws the flue products through the primary heat exchanger then through the secondary heat exchanger before forcing them through positive pressure to the outdoors through the venting system. The secondary heat exchanger allows additional heat to transfer to the heating air, reducing the amount of heat lost through the exhaust to the outdoors and increasing the appliances heating efficiency.

A by-product of removing more heat from the flue products is the generation of condensation, which accumulates inside the venting system and secondary heat exchanger. High efficiency furnaces are designed to allow for the condensate to drain back through the furnace and be piped to a separate drain in the home.

The condensate created in a high efficiency furnace is acidic and corrosive to most metals. The venting systems, condensate drains, and secondary heat exchangers are required to be made of materials that are not affected by the corrosive properties of the condensate.

The design of the furnace involved in this incident uses carbon steel secondary heat exchanger tubes lined with thermoplastic polypropylene on the inside to protect the steel from the corrosive condensate.

Residential gas furnaces incorporate electrical safety circuits designed to shut the furnace off in unsafe conditions. The electrical safety circuits have switches which monitor aspects of the furnaces performance and will open the electrical circuit if any of the monitored values go outside the switches set parameters. When the electrical safety circuit is interrupted, the furnace will stop operating.

PVC vent materials are connected by means of solvent welding with the use of approved primers and cements identified by the manufacturer. Solvent welding involves the use of a solvent cement to create a permanent leak-proof connection by softening the surfaces and allowing the molecules to fuse together.

Natural gas requires a minimum amount of air to burn completely. When the minimum amount of air is not present, the result is incomplete combustion. One of the by-products of incomplete combustion is carbon monoxide (CO). 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 information on carbon monoxide check out "CO Safety Tips ").

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Failure scenario(s)	A natural gas furnace was installed in the new residential townhouse in 2008. The furnace was a Carrier brand high efficiency furnace model 58MCB060-0-8 manufactured in April of 2007. It was designed and manufactured with a polypropylene lined secondary heat exchanger. The furnace was installed in the townhome with a single pipe venting system that vented the furnaces flue gasses out through a continuous PVC vent pipe which terminated out the sidewall at the back of the townhome. Two of the vent pipe joints in the mechanical room were never properly solvent welded together and only had primer installed on them. The joints did not come apart but were easily separated by hand when they were being replaced after the incident. Combustion air for the furnace was ducted using a metal air duct which draws air from a grill installed at the underside of the patio at the rear of the home and supplied it, through natural ventilation means, into the sealed mechanical room housing the gas fired water heater and furnace located in the garage of the home. At some point a 90-degree elbow was placed on the outdoor termination of the furnace vent pipe outdoors. The elbow directing the flue gas straight down was non-compliant to the furnace and vent manufacture's required installation. It was not glued in place but was held in place by friction only. The 90-degree elbow directed the warm flue gasses from the furnace straight down beside the outdoor patio. While the furnace was operating, the flue gases exited the pipe and rose due to natural convection and recirculated back into the mechanical room through the combustion air ducting (Image 5). Over the furnaces 16 years of operation the polypropylene liner in the secondary heat exchanger failed creating a restriction of the flow through it and allowing the condensate to create corrosion and holes in the secondary heat exchanger tubes. The furnace safeties including the air pressure switch and flame rollout switch were ineffective at shutting down the operation of the furnace as the degradation progressed to the point of the furnace producing very high concentrations of CO in the flue gases. The very high concentrations of CO in the flue gas resulted in hazardous levels of CO to be recirculated back into the home even after being diluted with clean outdoor air. The furnace was shut off when the occupants went on vacation. After returning home from vacation the furnace was turned back on. The furnace operated for longer than usual period of time. During that time, flue gasses containing hazardous levels of CO recirculated into the mechanical room through the non-compliant venting system and combustion air ducting. The prolonged operation of the furnace combined with the leaking of flue gases into the home eventually raised the levels of CO in the home to concentrations that made two children in the home feel nauseous with one of them vomiting and eventually triggered CO detectors in the home alerting the occupants. 911 was called and the first responders personal CO alarms activated indicating the presence of carbon monoxide.

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Facts and evidence

Interview statements

- The townhouse was built in 2007-2008.
- New additional plug-in CO detectors were installed in the home after a recommendation from the strata counsel after another recent CO incident in the same townhouse complex (https://www.technicalsafetybc.ca/regulatory-resources/incident-investigations/failed-heat-exchanger-leads-to-carbon-monoxide-poisoning-in-home).
- After arriving home from vacation, they turned the furnace back on.
- A short time later their two children began feeling ill and one of them vomited.
- The CO detectors began alarming in the home.
- 911 was called and the fire department arrived and detected CO indoors
- A gas utility technician arrived who confirmed measurements of 125ppm CO on all indoors floors.
- The two children were taken by ambulance to the hospital for treatment of CO poisoning.

Site observations

- The furnace was a single pipe vented with a combustion air pipe ducted to the underside of the middle floor patio. The furnace vent termination was beside and slightly above the combustion air intake with a downward pointing elbow installed but not glued.
- New plug-in CO detectors had been installed in the home.
- The furnace was a Carrier brand high efficiency furnace model 58MCB060-0-8 manufactured in June of 2007 and manufactured with a polypropylene line secondary heat exchanger.
- An independent contractor was hired to replace the furnace and when they were disassembling the furnace venting in the mechanical room, they discovered that two of the pipe joints had not been properly solvent welded together and only had primer installed in the joints. Both pipe joints where held together by friction only and were able to be pulled apart by hand (Image 4).

<u>Furnace manufactures instructions</u>

Installation

The installation and operating instructions provided by the manufacturer for the furnace identify that all acceptable side-wall vent piping for the furnaces terminate horizontally and not vertically up or down.

Service and maintenance

The service and maintenance instruction provided by the manufacturer for the furnace state that it is essential that maintenance beyond basic cleaning and filter replacement is performed annually by trained and qualified personnel. Annual maintenance is detailed in the instructions including several actions of inspection and cleaning. The annual maintenance instructions identify that the inside of the secondary heat exchangers "CANNOT be serviced or inspected" and do not include a suggestion for burner combustion analysis.

CO detector manufacturer literature

The CO detectors in the home have manufactures literature that indicate the CO sensors meet the alarm response time requirements of the applicable product standards for Canada. The CO sensor will not alarm to levels of CO below 30 ppm and will alarm in the following time range when exposed to the corresponding levels of CO:

- At 70ppm CO the alarm must not activate before 60 minutes but must activate before 240 minutes.
- At 150ppm CO, the alarm must not activate before 10 minutes but must activate before 50 minutes.
- At 400ppm CO the alarm must not activate before 4 minutes but must activate before 15 minutes.

Technical Safety BC Investigation and public safety notice

In 2021 Technical Safety BC released a public safety notice and recommendations following an Investigation into multiple incidents involving a common product line of residential gas-burning furnaces manufactured between 1989-2001 by Carrier Corporation. Public safety - Gas furnace carbon monoxide safety risk. Technical Safety BC's investigation found that incidents resulted from furnaces that had a common design feature that contributed to the failures, specifically, polypropylene lined secondary heat exchangers. This component was found to be susceptible to corrosion, which interfered with combustion air flow, producing CO. CO was found in occupied living spaces, having escaped the furnaces due to corrosion holes in the heat exchangers or due to corrosion blockage that allowed CO gases to circulate back into the home in certain venting configurations. It was further determined that built-in automatic safety devices did not reliably detect the conditions produced by the corroded secondary heat exchangers.

Carrier Corporation manufactured these furnaces under the brand names Carrier, Bryant, Payne and Day & Night. Homeowners can determine whether their furnace is one of the affected models by locating the furnace tag on their unit and comparing their model number with the model numbers listed in Appendix B of the report.

The full investigation report can be downloaded here: Technical Safety BC - Investigation Report Failure of Gas Furnaces.

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Causes and contributing factors	The cause of the incident was the furnace secondary heat exchanger design which used polypropylene laminated steel materials. Rapid and excessive corrosion of these materials restricted airflow through the furnace resulting in production of carbon monoxide due to incomplete combustion, which then entered the home. Contributing factors to the incident include: • The incorrectly installed 90-degree elbow placed on the end of the vent termination allowed the flue gasses containing hazardous concentrations of CO to be drawn back into the home through the combustion air grill located under the exterior patio. • The failure of the furnace safeties to stop the operation of the furnace allowed the furnace to continue operating in a hazardous state. • The non-solvent welded vent pipe joints created a high hazard for CO poisoning by potentially separating indoors while there were very high concentrations of CO in the furnace flue gases.

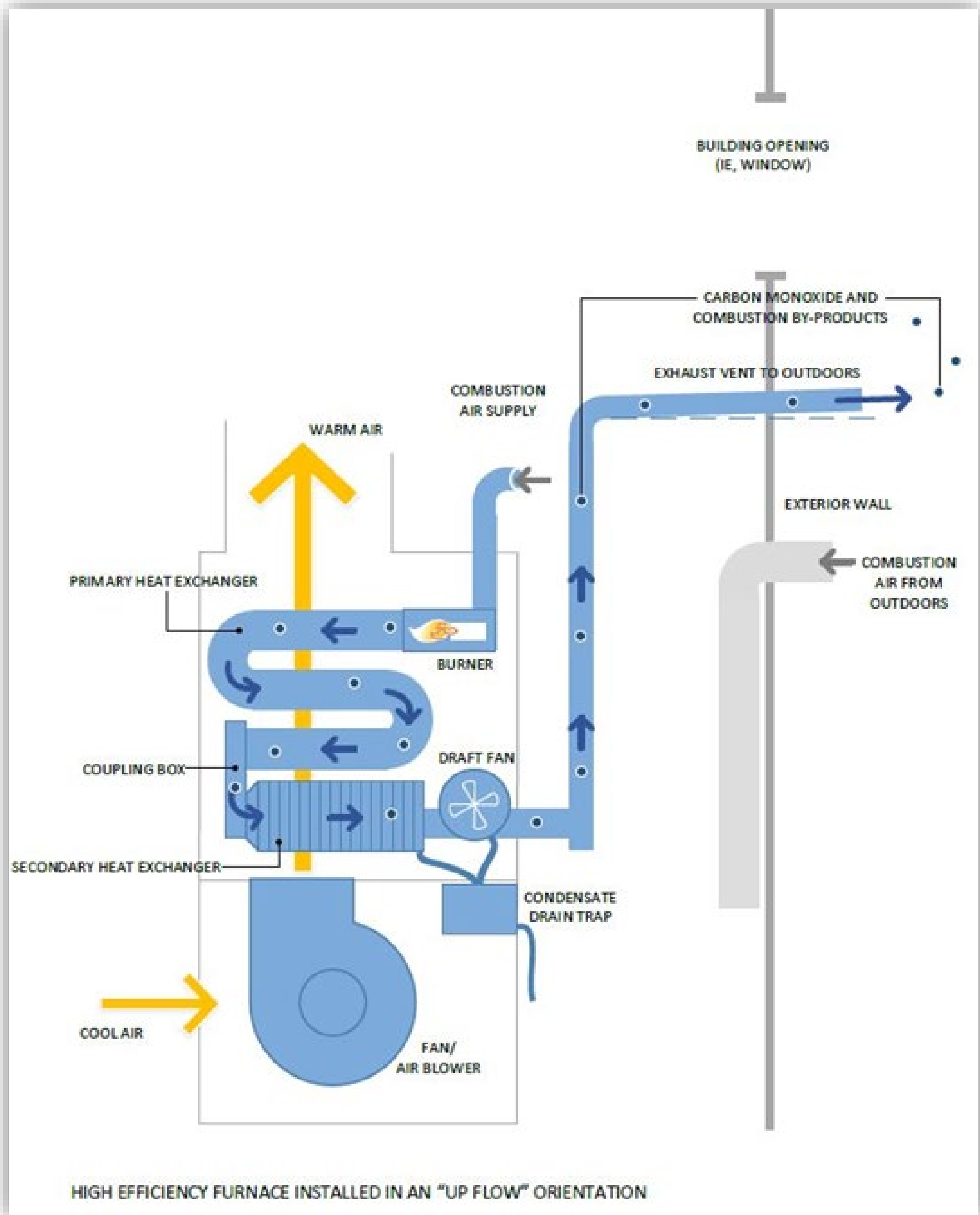

Diagram 1 – Typical furnace operation. Arrows represents the direction of flue gas flow and dots represent carbon monoxide.

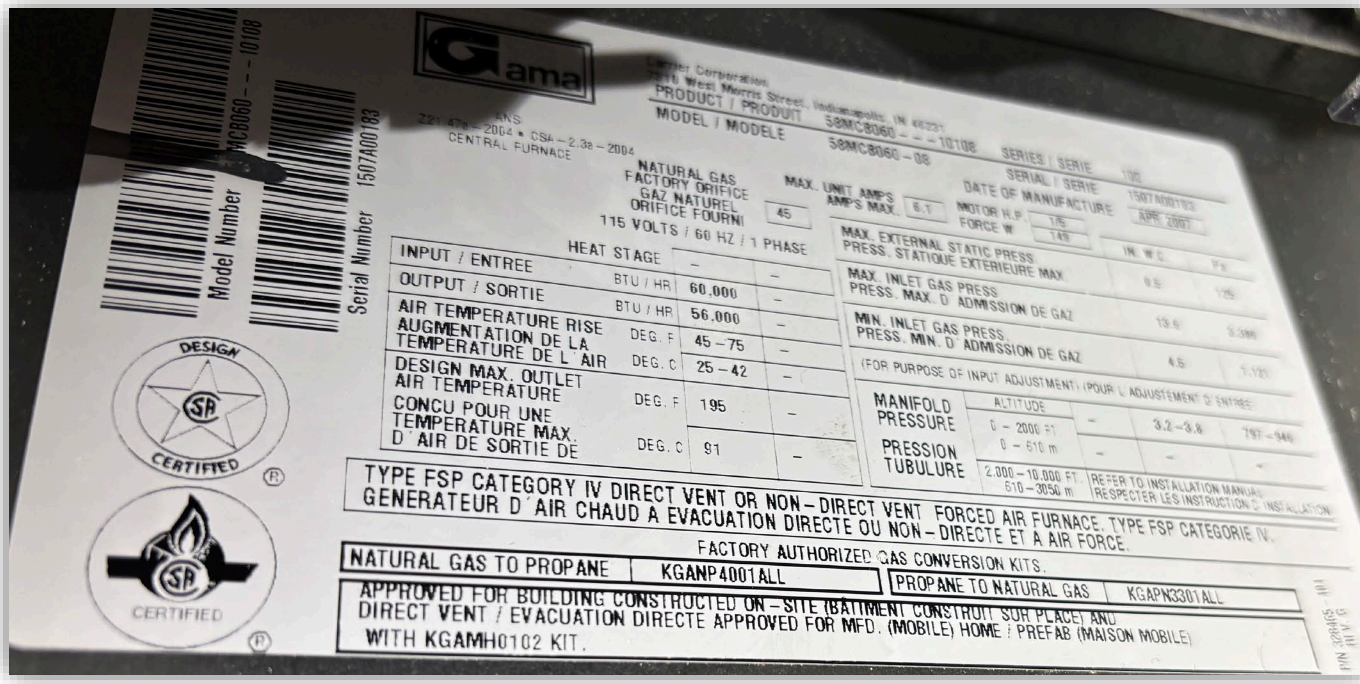

Image 1 – Data tag of furnace installed in a sealed mechanical room located in the garage of the townhome.

Image 2 – Secondary heat exchanger tubes with exterior corrosion.

Image 3 – Secondary heat exchanger tubes with exterior corrosion.

Image 4 – Venting joints originally installed with primer only and without glue. Both joints were able to be pulled apart by hand.

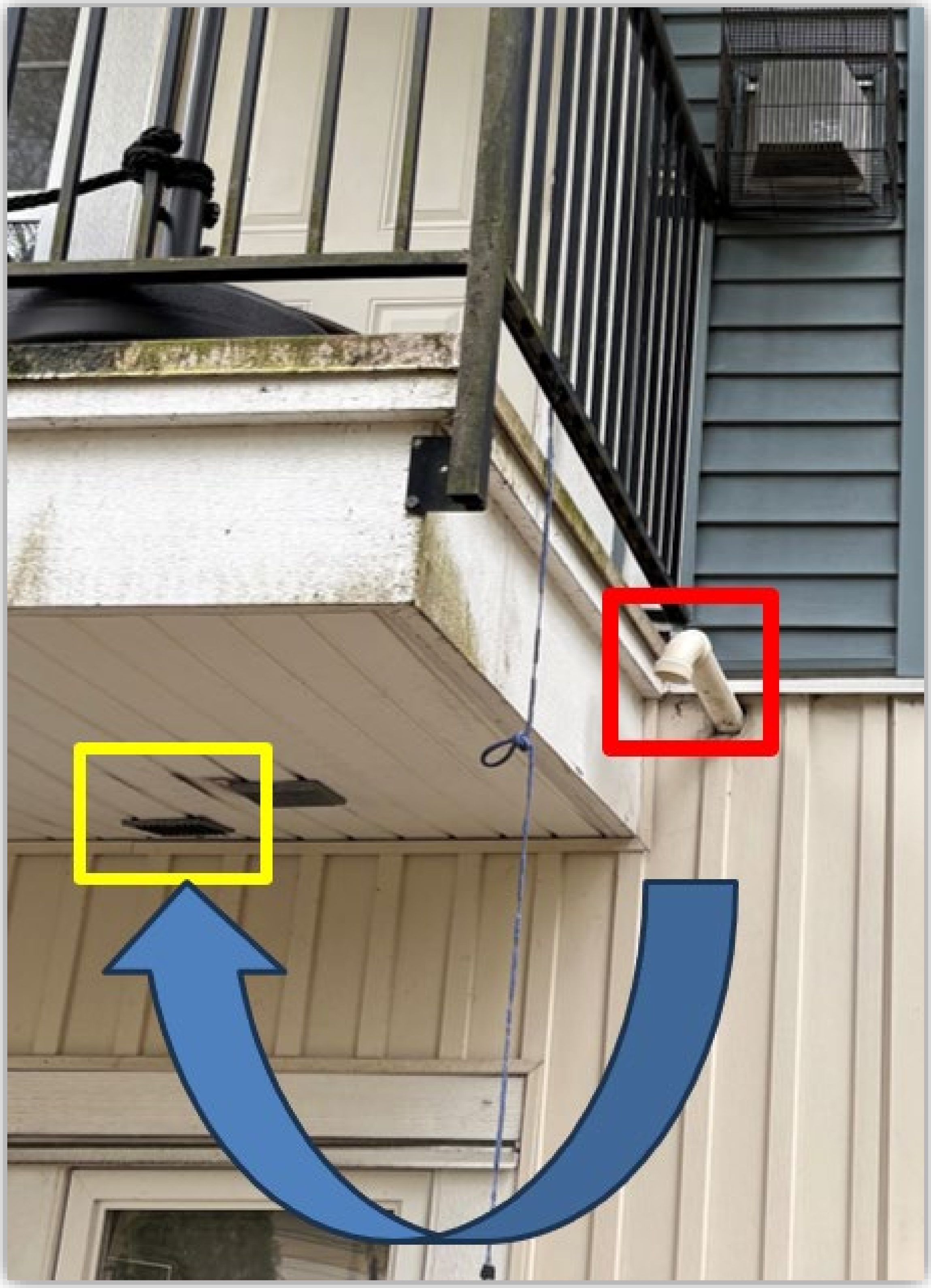

Image 5 – Horizontal furnace vent termination with 90-degree elbow pointing down.