Revised on May 15, 2025

Incident Summary #II-1865169-2025 (#56294) (FINAL)

SUPPORTING INFORMATION	Incident Date		February 6, 2025
	Location		Surrey
	Regulated industry sector		Gas - Natural gas system
	Impact – Injury	Qty injuries	3
		Injury description	One adult and two children in the home were exposed to carbon monoxide (CO) and experienced symptoms including headaches and dizziness. 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 very high levels (10,000 ppm) of CO in the flue gas. During a cold spell with temperature below the seasonal average, prolonged operation of the furnace created high levels of CO which migrated into the occupied indoor space and triggered multiple CO detectors. Built-in automatic safety devices did not reliably detect the conditions produced by the corroded secondary heat exchanger. Three occupants including two children (aged 7 and 11) were taken to hospital via ambulance and treated for CO poisoning.
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.

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	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 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. 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 ")
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 June 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 sealed and continuous PVC vent pipe which terminated out the sidewall at the back of the townhome. 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, though 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 manufactures 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 gasses exited the pipe and rose due to natural convection and recirculated back into the mechanical room through the combustion air ducting (Image 3). The current owners moved into the townhome in 2012. Since that time, no regular maintenance was conducted by qualified technicians. The home was equipped with three wired combination smoke/CO detectors with one on each of the three floors. 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 in excess of 10,000 parts per million

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	(ppm) in the flue gas while it was operating. 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. During a cold snap with prolonged outdoor temperature below the seasonal average. The furnace operated for longer that usual periods of time. During those times the flue gasses containing very hazardous levels of CO leaked through holes in the secondary heat exchanger that were located upstream of the internal blockages and where being recirculated into the mechanical room thought the non-compliant venting system and combustion air ducting. The prolonged operation of the furnace combined with the leaking of flue gasses into the home eventually raised the concentration of CO in the home to levels that triggers multiple CO detectors in the home alerting the occupants.
Facts and evidence	**Homeowner statements** • The townhouse was built in 2007/8. • They had purchased it and lived there since 2012. • There had been no repairs or professional maintenance conducted since 2012 other than a condensate pipe leak repair in January 2025. • The furnace operated without the need for repair since they moved in 2012. • Their spouse and two children had experienced headaches, dizziness off and on over the past few years primarily in the winter. The spouse homeschools the kids, so they spend a lot of time in the home each day. • A contractor who was hired to repair a broken condensate drain line outside of the furnace suggested getting additional plug in CO detectors in when he was there in January. • Three new additional plug-in CO detectors were installed in the home. • On the evening of February 6th during a cold weather snap, multiple CO detectors began alarming in the home. To confirm the plug-in detectors were swapped from the upper floor to the middle floor and alarmed as well. • 911 was called and the fire department arrived and detected CO indoors and had a gas utility technician arrive who confirmed measurements of 40-50ppm CO on all three indoors floors. • The only other gas appliance was a gas fireplace that was completely shut off and did not have the pilot light on. • There were no automobiles running outside the home at the time. **Site observations** • The furnace was 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. • There were three built-in wired combination smoke/CO detectors with battery backups on the ceiling of each floor. • Three new plug-in CO detectors were installed in the home (One on each floor). • 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.

- Disassembly of the furnace after testing was conducted showed that the secondary heat exchanger had failed, restricting the flue passages inside and causing corrosion including several holes in the heat exchanger tube inlets (Images 5-12).

Furnace manufactures instructions

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.

Equipment testing

An independent gas contractor conducted testing of the equipment under the guidance of Technical Safety BC for the purpose of the investigation. The testing found:

- The furnace was tested and flue gas analyzer readings exceeded 10,000 ppm within seconds of initial operation at the sidewall vent termination.
- Flue gases containing very high concentrations of CO were recirculating into the combustion air duct for the small mechanical room located in the garage housing the furnace and an electric hot water tank.
- During a few minutes of furnace operation, the combustion analyzer measured 10ppm of CO in the ambient air in the mechanical room which has the air supplied by the combustion air duct near the vent termination.
- CO was also measured in the warm supply air through a compromised heat exchanger and during a short time of operation (approx. 5-10 minutes) CO was measured in the warm supply air ducting on all three floors of up to 22 ppm.
- The tests did not continue past this time frame due to the concentrations of CO being detected in a short time within the dwelling unit in the multi-unit townhouse complex.

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:

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- 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.

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.

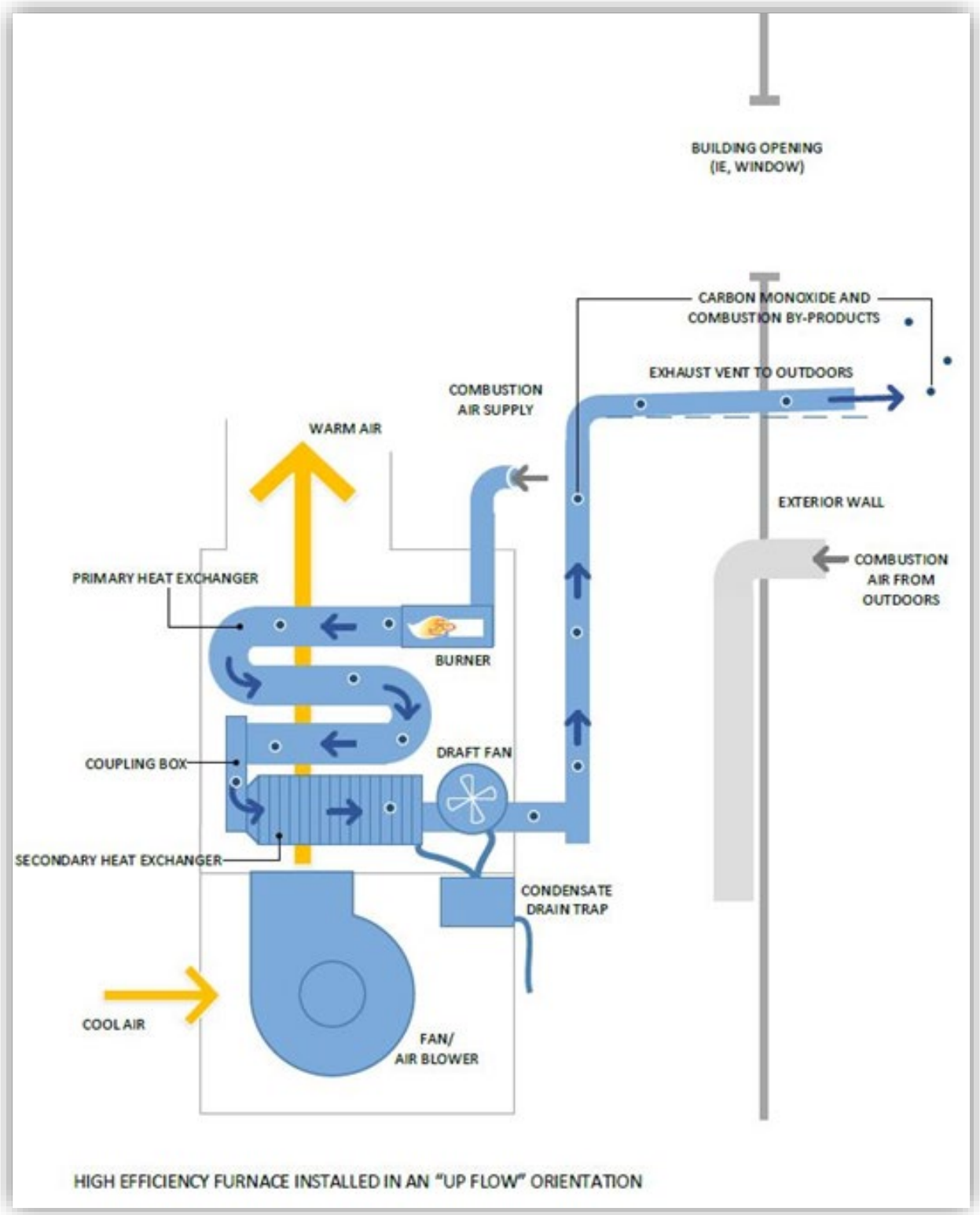

Diagram 1 – Typical furnace operation. Arrows are in the direction of flue gas flow and dark coloured dots represent carbon monoxide.

Image 1 – Furnace installed in a sealed mechanical room located in the garage of the townhome.

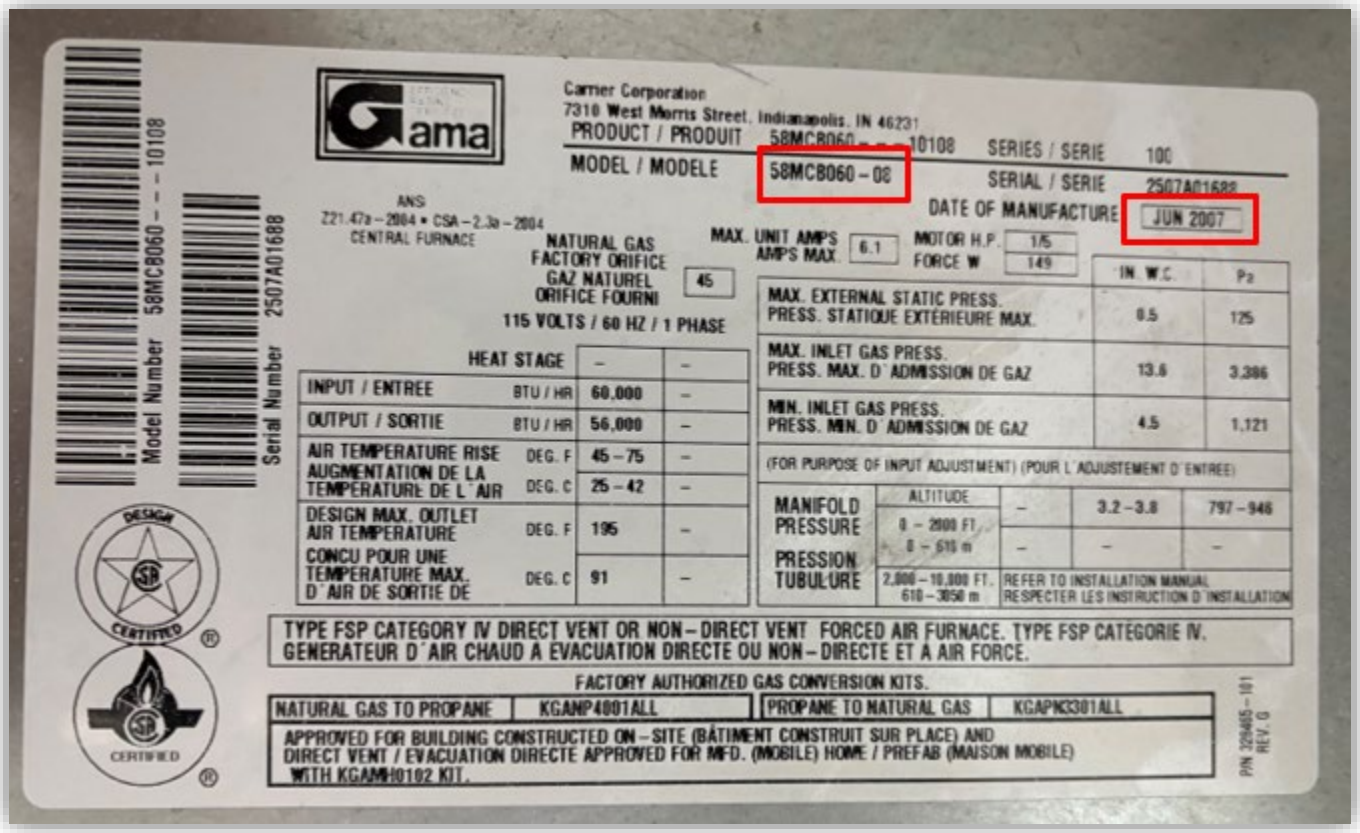

Image 2 – Data tag of furnace with the model number and manufacture date.

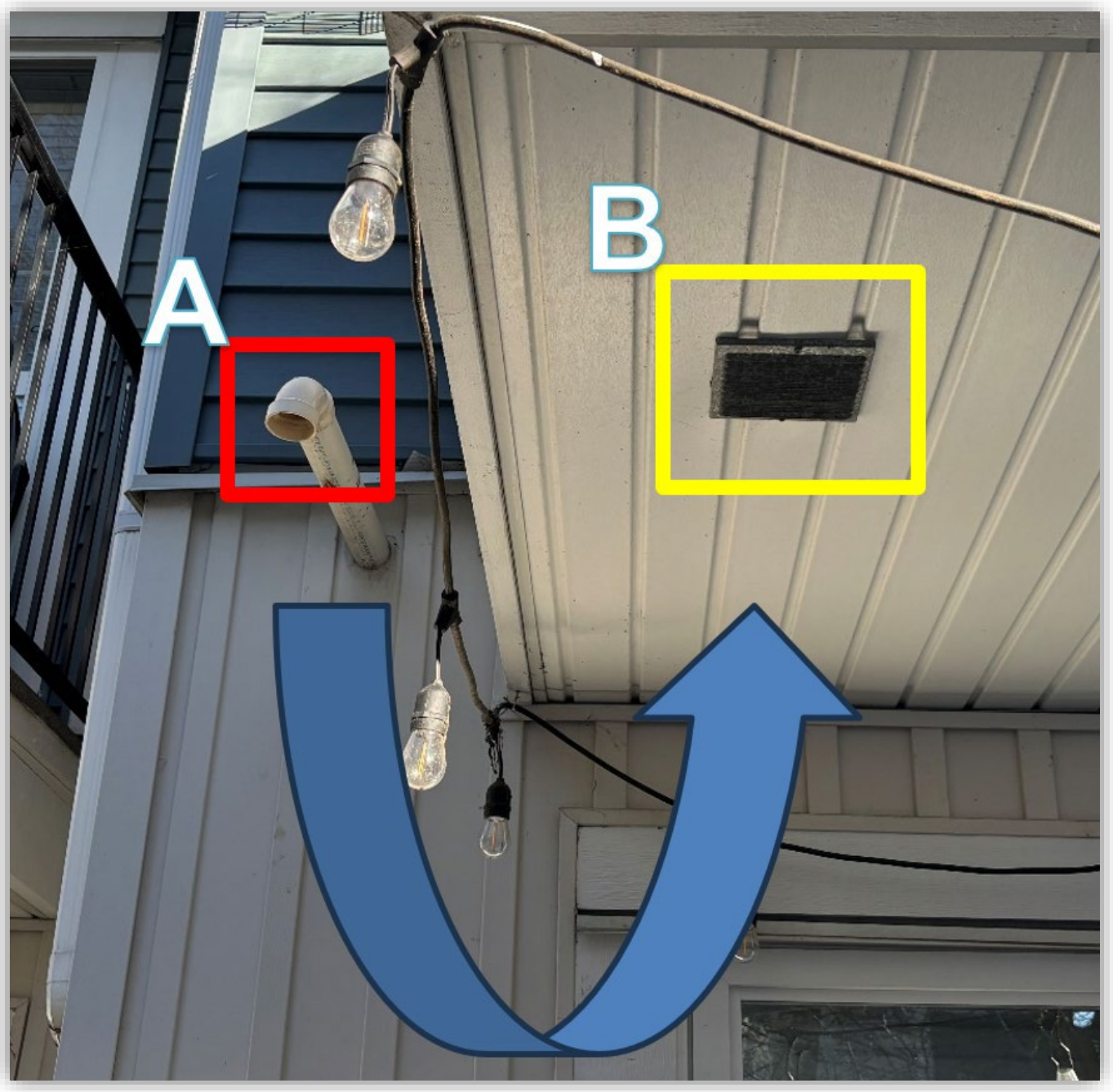

Image 3 – Sidewall vent termination at the rear of townhome. [A] The furnace vent termination with 90 deg elbow installed pointing down and [B] is the intake grill for the combustion air pipe for the mechanical room. Arrow is the path of the warm flue gases going into the combustion air intake.

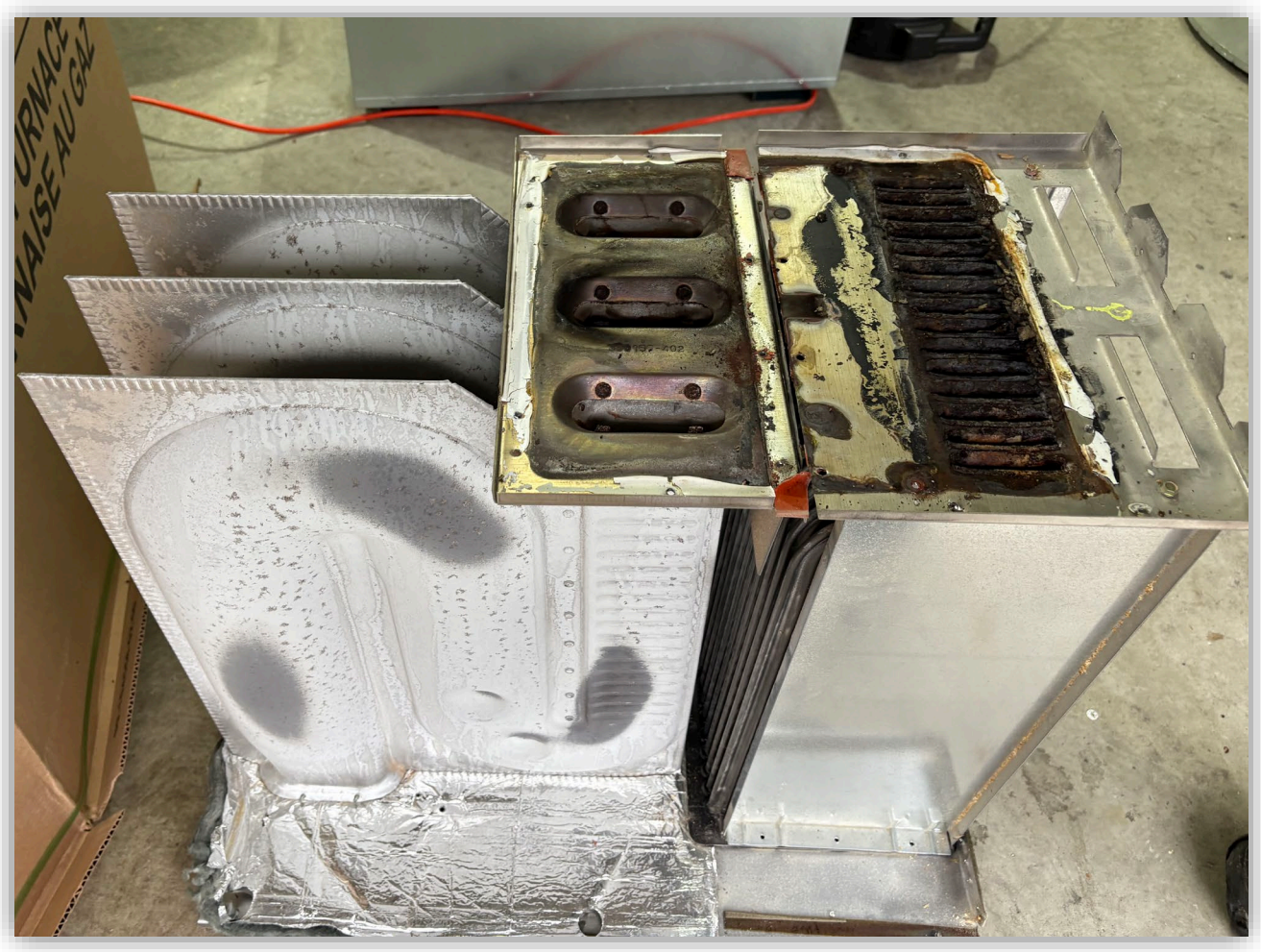

Image 4 – Primary (left) and secondary (right) heat exchangers removed from furnace during examination.

Image 5 – Exit of primary heat exchanger and inlet to secondar heat exchanger.

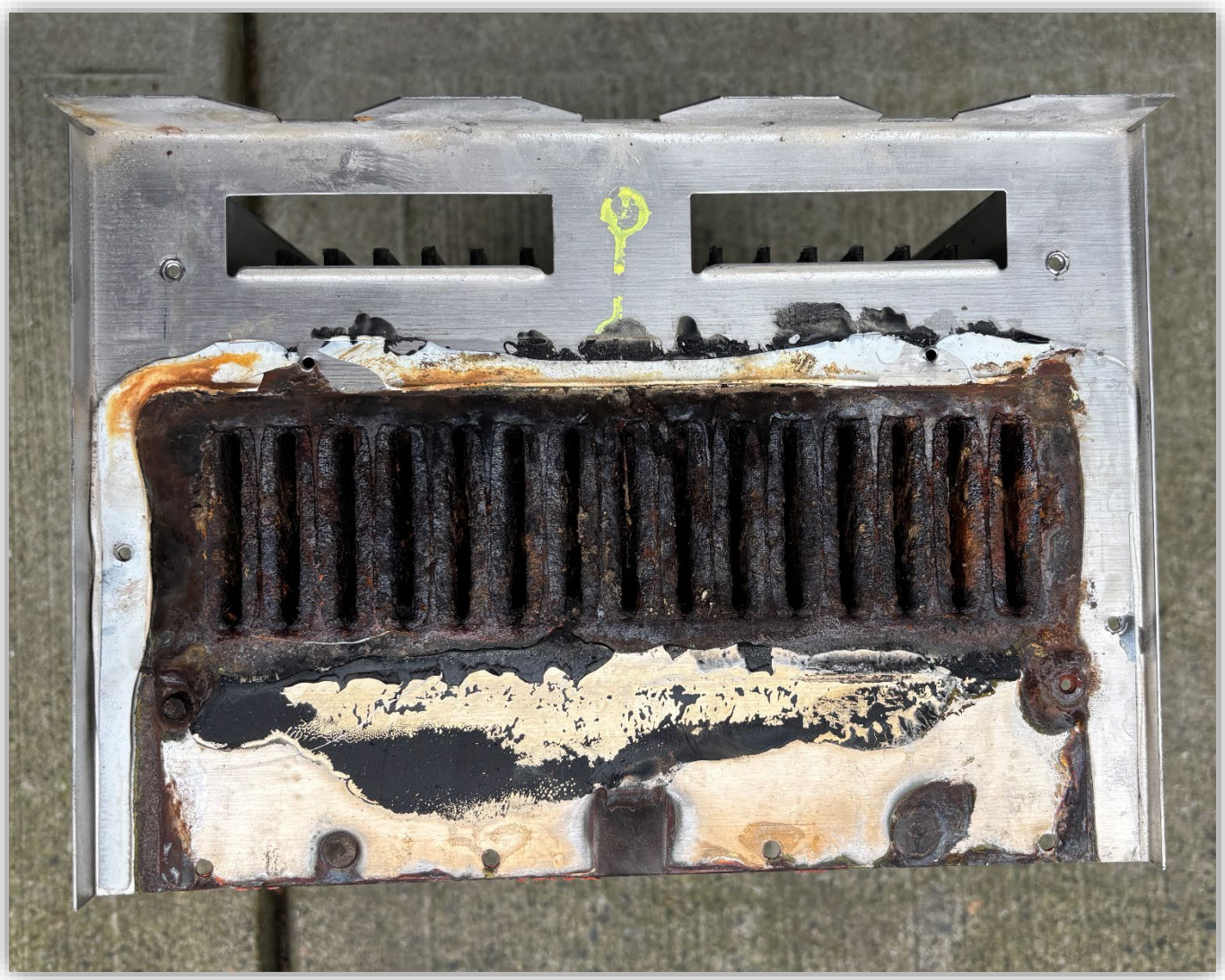

Image 6 – Inlet to secondar heat exchanger showing corrosion and blockages.

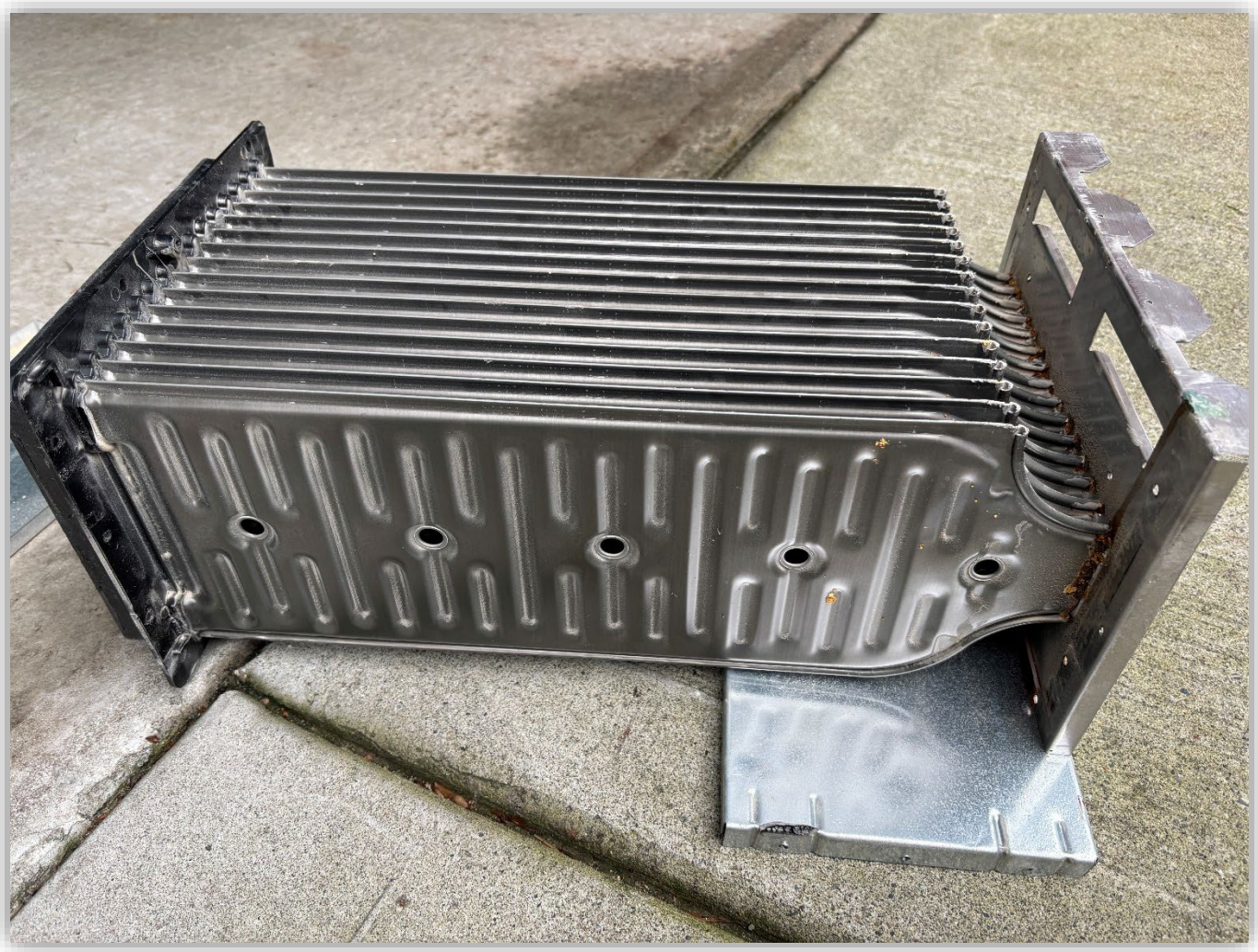

Image 7 – Exterior of secondary heat exchanger tubes.

Image 8 – Closeup of secondary heat exchanger tube inlets showing corrosion.

Image 9 – Secondary heat exchanger tube inlets showing corrosion and blockages.

Image 10 – 5-6mm corrosion hole in secondary heat exchanger tube.

Image 11 – Corrosion hole in secondary heat exchanger tube.

Image 12 – Corrosion hole in secondary heat exchanger tube.