

## Incident Summary #II-1020945-2020 (#18073) (FINAL)

SUPPORTING INFORMATION	Incident Date	May 29, 2020	
	Location	Surrey	
	Regulated industry sector	Gas - Natural gas system	
	Impact	Qty injuries	0
		Injury description	NA
		Injury rating	None
	Damage	Damage description	A residential furnace heat exchanger failed, and produced of high levels of carbon monoxide (CO). Redundant safety features (flame rollout switch, air proving switch) failed to control the hazard. This resulted in carbon monoxide exposure inside the home.
		Damage rating	Moderate
	Incident rating	Moderate	
Incident overview	A natural gas furnace in a residential home produced elevated levels of carbon monoxide. Measurable amounts of carbon monoxide were detected inside the home.		
INVESTIGATION CONCLUSIONS	Site, system and components	<p>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 thought-out the home through a ducting system, (Diagram 1).</p> <p>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 one before forcing them 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.</p> <p>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 the condensate to drain back through the furnace and be piped to a separate drain in the home.</p> <p>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.</p>	

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	<p>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.</p> <p>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.</p> <p>A flame rollout switch is one component of a safety circuit and is installed just upstream of the gas burners. A blockage of the flue passages or venting system can cause the burner flames to roll out the front of the burners. If flames rollout from the burner tubes, the switch will overheat and open the electrical circuit to shut off the furnace. A flame rollout switch must be manually reset if it trips by pressing a button on the outside of the switch. The switches are designed this way because flame rollout is evidence of a serious problem with a furnace or venting system and examination should be done by a qualified individual to identify the issue and not allow the furnace to operate until it is repaired.</p> <p>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 (Chart 1). 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 "<a href="#">CO Safety Tips</a>")</p> <p>Another by-product of incomplete combustion are organic compounds know as aldehydes. While carbon monoxide is odorless, aldehydes have a sharp penetrating odor. The odor of aldehydes differs from odorants added to natural gas for detection. Aldehydes, much like carbon monoxide, are toxic to humans and animals.</p>
<p>Failure scenario(s)</p>	<p>A natural gas furnace was operating in a residential home. The furnaces secondary heat exchanger had corroded creating holes in the heat exchanger and restricted the airflow of the combustion products through the furnace. The restricted airflow led to incomplete combustion and the production high levels of carbon monoxide and aldehydes. The carbon monoxide and aldehydes were able to enter the home.</p>
<p>Facts and evidence</p>	<p>A Carrier model 58MVB100 (Image 2) high efficiency natural gas furnace had been installed in a residential home. The original gas installation permit indicates the furnace was installed in the home in March 2008. The furnace had been operating in the home for just over 12 years prior to the incident.</p> <p>The owner stated that the furnace never stopped working but started producing a strong smell around the furnace and at the vent outlet on the side of the house. They called a gas technician to investigate the furnace.</p> <p>The gas technician stated that when he investigated the furnace he found evidence of staining in the bottom of the furnace cabinet indicating leaking condensate. He started the furnace and measured for carbon monoxide in the home. Once the furnace had run for approximately 15-20 minutes he measured 23 parts per million (ppm) in the heating air supplied to the home and noticed a strong smell of</p>

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aldehydes from the furnace exhaust. The components of the safety circuit were intact and operational including the pressure switches and flame rollout switch however the flame rollout switch failed to stop the operation of the furnace. The hot water tank was electric and no other gas appliances were operating in the home at the time, no other sources of carbon monoxide were identified other than the furnace. The technician determined that the furnace had sufficient combustion air provided to the mechanical room and the venting system was intact without any cracks, holes or other openings that may have allowed carbon monoxide to enter the home. The technician determined that the only way for carbon monoxide to enter the heating air would be from passing through holes in the heat exchanger. The furnace was found to be installed slightly low on the right hand side but level front to back on both sides. This would allow for proper drainage of the condensate from the secondary heat exchanger.

The technician returned to replace both the primary and secondary heat exchangers under the manufacturers enhanced heat exchanger warranty. The replacement components were of the same design and materials as the originals they were replacing.

Investigation of the removed furnace heat exchanger assembly showed the primary heat exchanger did not have any holes, cracks or signs of corrosion. While removing the secondary heat exchanger, corrosion and holes were observed on the inlet side to the heat exchanger tubes. Photos show light shining through the holes in the heat exchanger (Image 4).

### Evidence Examination

The inlets to the furnace's secondary heat exchanger tubes had corroded and the interior polypropylene lining had delaminated which restricted the airflow through them. The restricted airflow reduced the amount of air at the point of combustion in the burner box. The unbalanced air/fuel ratio produced elevated levels of carbon monoxide in the flue products.

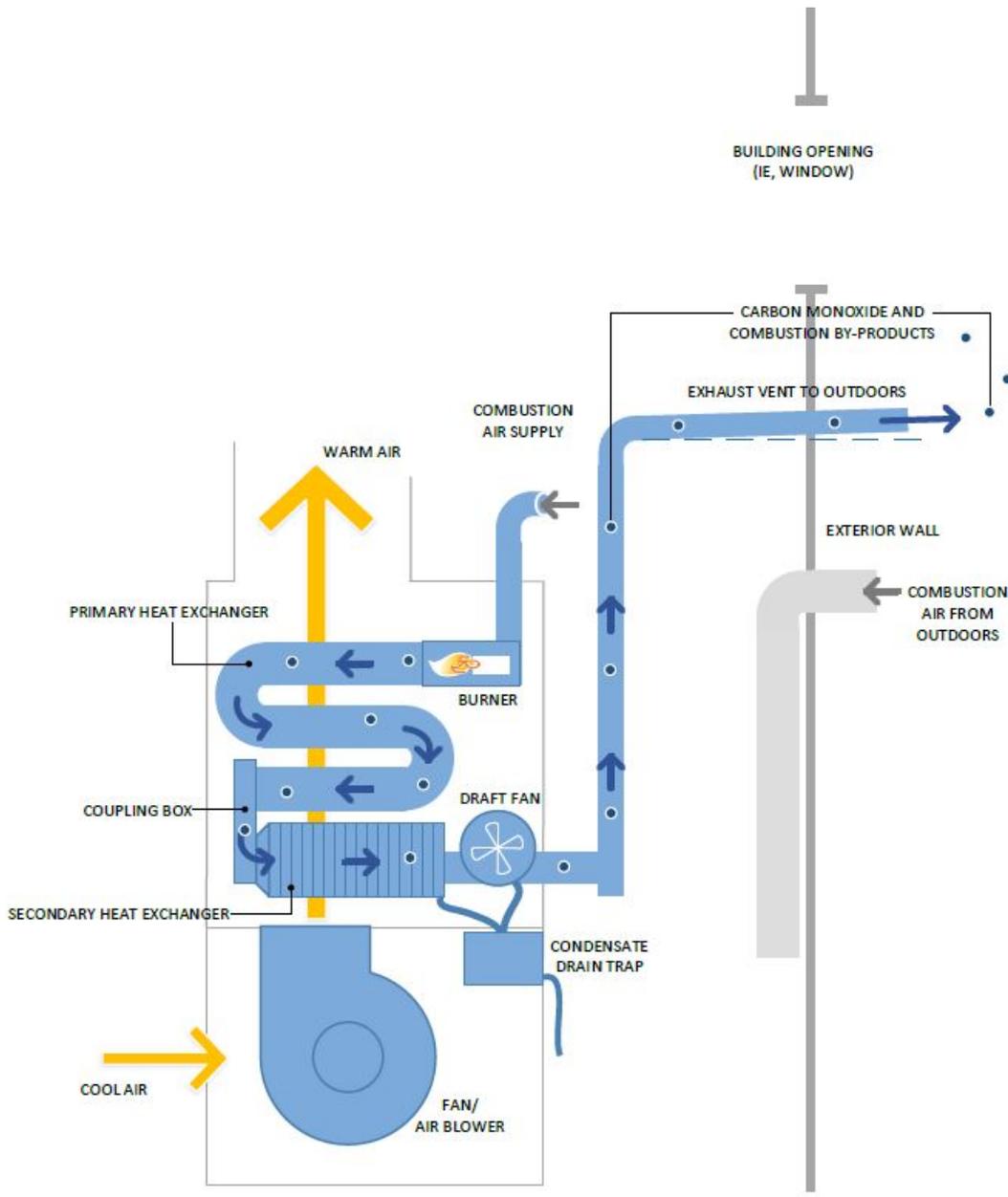
During operation of the furnace, the restricted flue passages caused the flames to slightly roll out of the burner tubes inside of the burner box. Flame rollout did not sufficiently occur to cause the safety switch to overheat and allowed the furnace to continue to operate in an unsafe condition.

The corrosion on the secondary heat exchanger created holes which allowed some of the flue products containing carbon monoxide to pass into the heating air for the home instead of being safely removed to the outdoors through the furnace's venting system.

### Causes and contributing factors

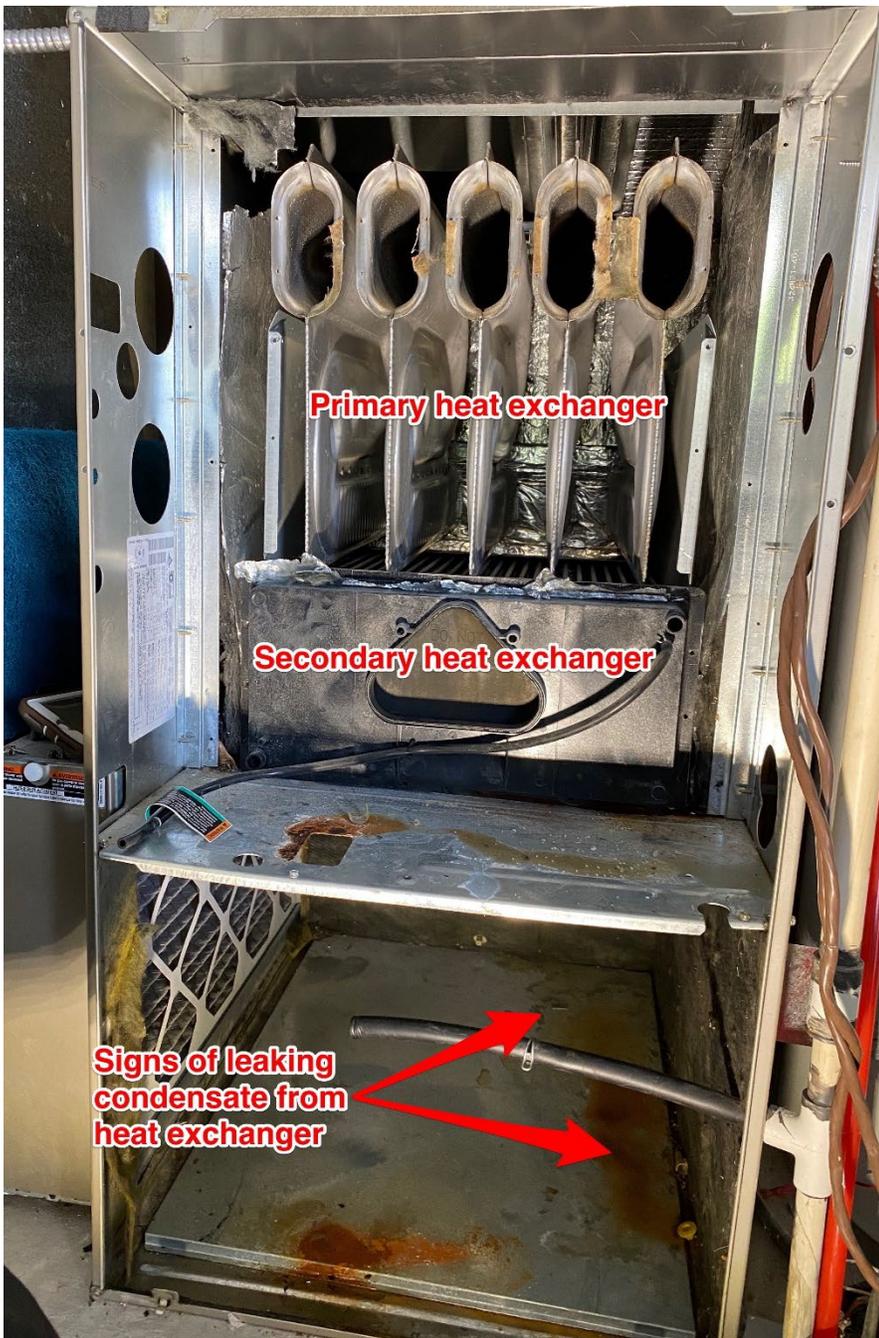
The cause of the incident was the furnace secondary heat exchanger design and use of polypropylene laminated steel materials. Rapid and excessive corrosion of these materials restricted airflow through the furnace resulting in production of carbon monoxide due to incomplete combustion.

A contributing factor to the incident was the failure of the flame rollout switch to stop the operation of the furnace.



HIGH EFFICIENCY FURNACE INSTALLED IN AN "UP FLOW" ORIENTATION

**Diagram 1** – Showing typical furnace operation. Arrows show direction of flue gas flow and dots represent CO.



**Image 1** – Furnace after blower and burner components removed to access heat exchanger for warranty replacement.



CERTIFIED



ANSI  
Z21.47b-2006 • CSA-2.36-2006  
CENTRAL FURNACE

Carrier Corporation  
7310 West Morris Street  
Indianapolis, IN 46231

PRODUCT / PRODUIT: 58MVB10L-F-11120

DATE OF MANUFACTURE / DATE DE FABRICATION: JAN 2008

MODEL / MODELE: 58MVB100-20

SERIES / SERIE: [REDACTED]

NATURAL GAS FACTORY ORIFICE / GAZ NATUREL ORIFICE FOURNI: 45

115 VOLTS / 60 HZ / 1 PHASE

MAX. UNIT AMPS: 13

MOTOR H.P.: 1

FORCE W: 746

MAX. EXTERNAL STATIC PRESS. / PRESS. STATIQUE EXTERIEURE MAX. IN WC/POGE: 0.5 kPa

MAX. INLET GAS PRESS. / PRESS. MAX. D'ADMISSION DE GAZ: 13.6 3.206

MIN. INLET GAS PRESS. / PRESS. MIN. D'ADMISSION DE GAZ: 4.5 1.121

HEAT STAGE		HIGH		LOW	
		BTU / HR	DEG. F	BTU / HR	DEG. C
INPUT / ENTREE	See Note Below	100,000	45-75	65,000	50-80
OUTPUT / SORTIE	See Note Below	93,000	25-42	61,000	28-44
AIR TEMPERATURE RISE / AUGMENTATION DE LA TEMPERATURE DE L'AIR	DEG. F	45-75	25-42	50-80	28-44
DESIGN MAX. OUTLET AIR TEMPERATURE / CONCU POUR UNE TEMPERATURE MAX. D'AIR DE SORTIE DE	DEG. F	195	91	195	91

(FOR PURPOSE OF INPUT ADJUSTMENT) (POUR L'ADJUSTEMENT D'ENTREE)

MANIFOLD PRESSURE / PRESSION TUBULURE	ALTITUDE		HIGH		LOW	
	0-2000 FT. / 0-610 m	610-3050 m	3.2-3.8	1.3-1.7	.797- .946	.324- .423

REFER TO INSTALLATION MANUAL / RESPECTER LES INSTRUCTION D'INSTALLATION

TYPE FSP CATEGORY IV DIRECT VENT OR NON-DIRECT VENT FORCED AIR FURNACE. TYPE FSP CATEGORIE IV. GENERATEUR D'AIR CHAUD A EVACUATION DIRECTE OU NON-DIRECTE ET A AIR FORCE.

FACTORY AUTHORIZED GAS CONVERSION KITS/ENSEMBLES DE CONVERSION AU GAZ AUTORISES PAR L'USINE

NATURAL GAS TO PROPANE	KGAMP410TALL	PROPANE TO NATURAL GAS	KGAPM350TALL
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APPROVED FOR BUILDING CONSTRUCTED ON-SITE (BATIMENT CONSTRUIT SUR PLACE).

Serial No. [REDACTED]

PN 330221-2011 REV. B

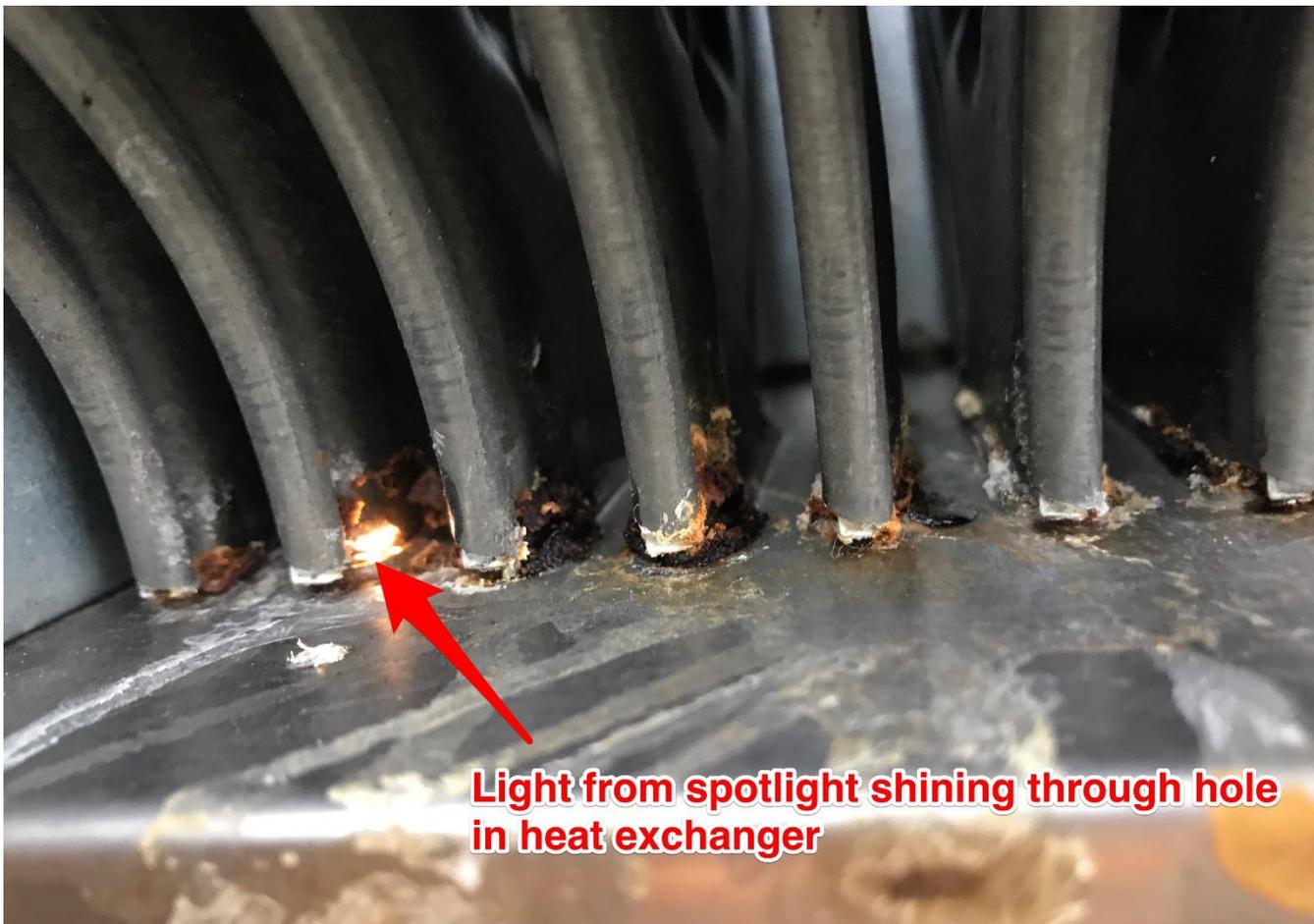
NOTE: Furnace gas input rate on rating plate is for installation up to 2000 ft. above sea level. In USA the input rating for altitudes above 2000 ft. must be derated by 2% for each 1000 ft. above sea level. In Canada the input rating must be derated by 5% for altitudes of 2000 ft. to 4500 ft. above sea level.

VEUILLEZ NOTER: Rendement nominal du gaz pour la fourniture sur la fiche signalétique est pour les installations jusqu'à 2000 pieds au-dessus le niveau de la mer. Aux Etats-Unis le rendement nominal pour les altitudes au-dessus 2000 pieds doit être diminué de 2% pour chaque 1000 pieds au-dessus le niveau de la mer. Au Canada le rendement nominal doit être diminué de 5% pour les altitudes de 2000 pieds à 4500 pieds au-dessus le niveau de la mer.

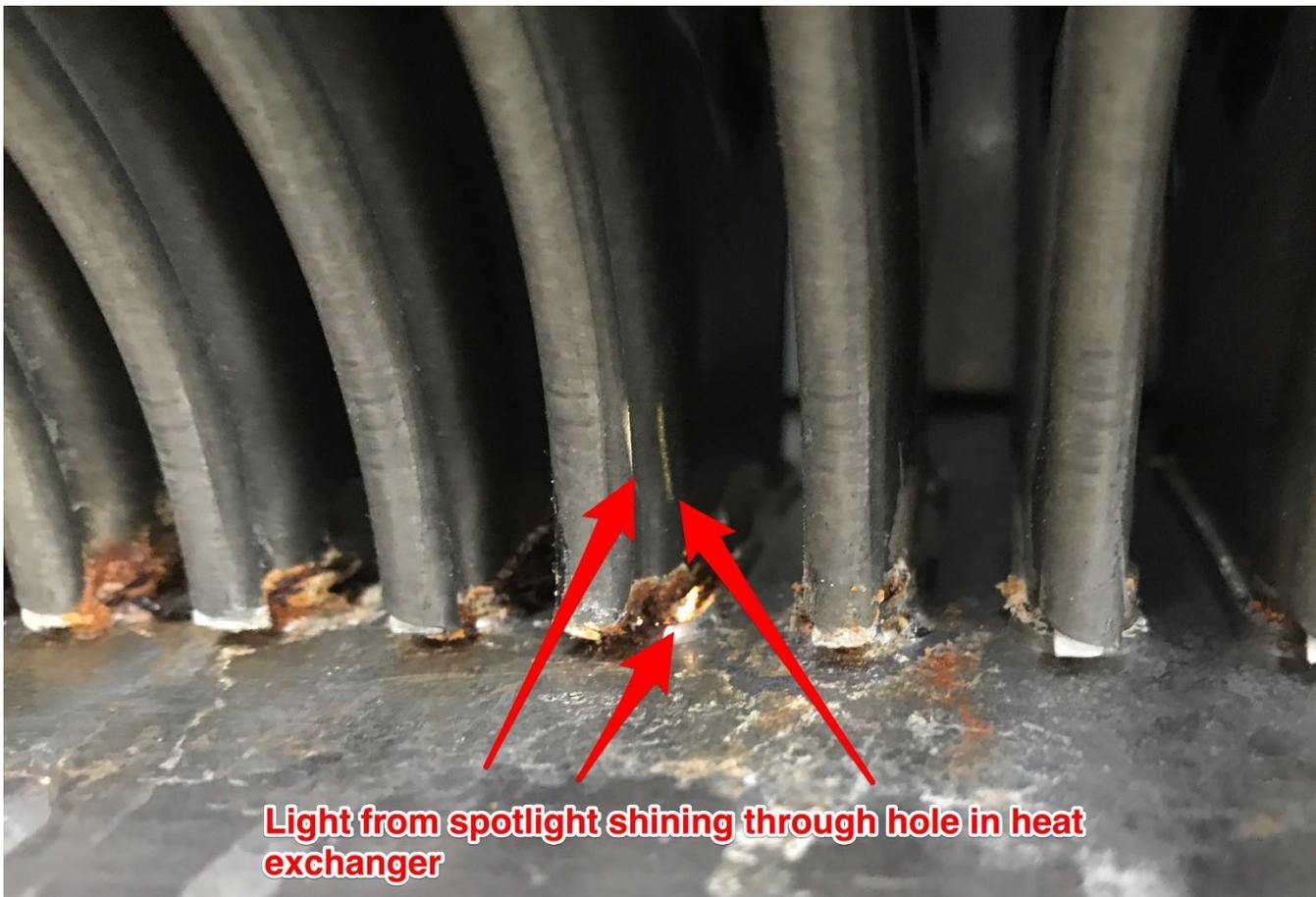
Image 2 – furnace data tag identifying it as a Carrier model # 58MVB100.



**Image 3** – Removed heat exchanger assembly (upside down from installed orientation) showing the path the flue gasses travel through the heat exchangers.



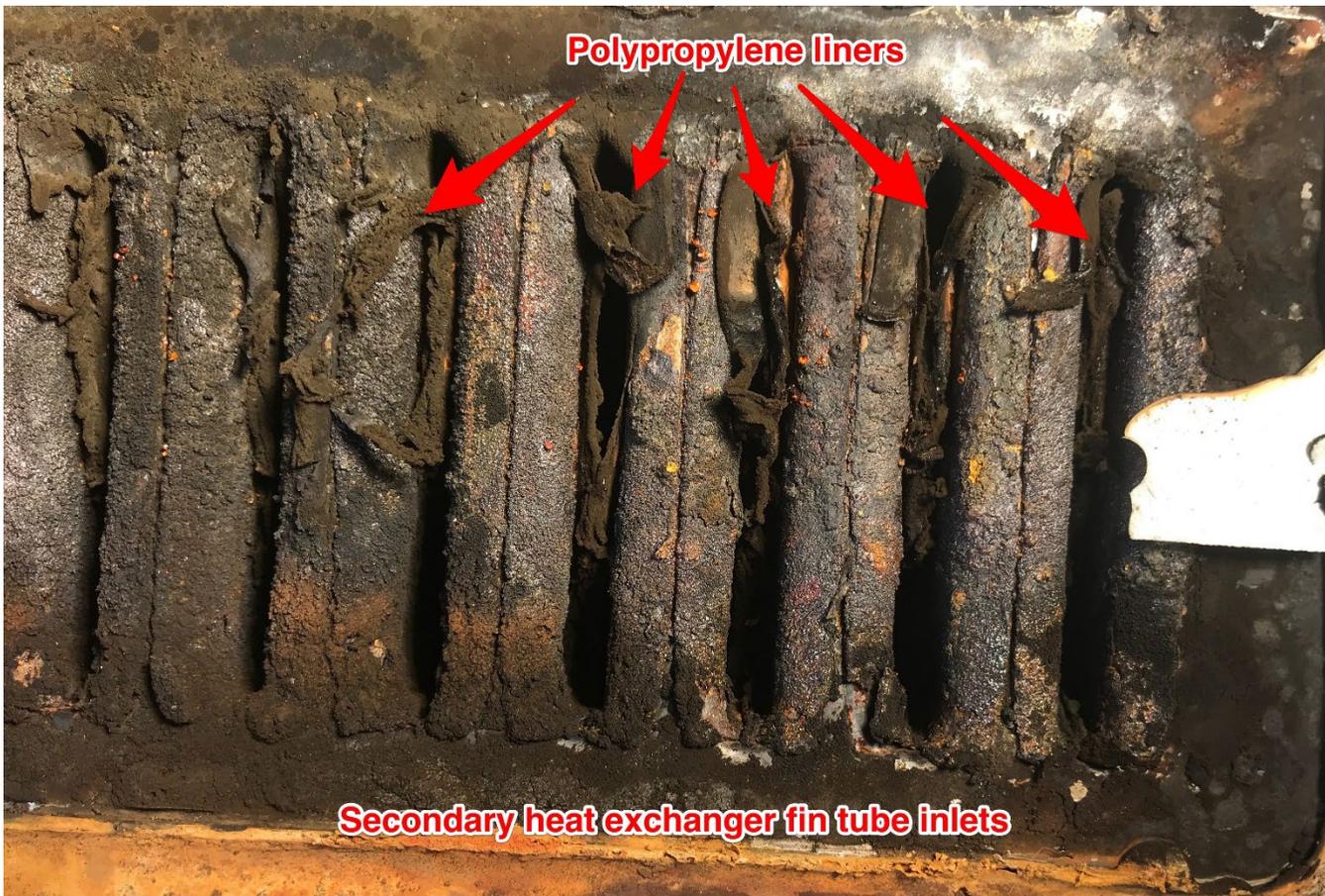
**Image 4** – Image taken with a bright spotlight shining in the corroded and blocked secondary heat exchanger inlets. The light is passing through a hole from corrosion where the tube connects to the coupling box.



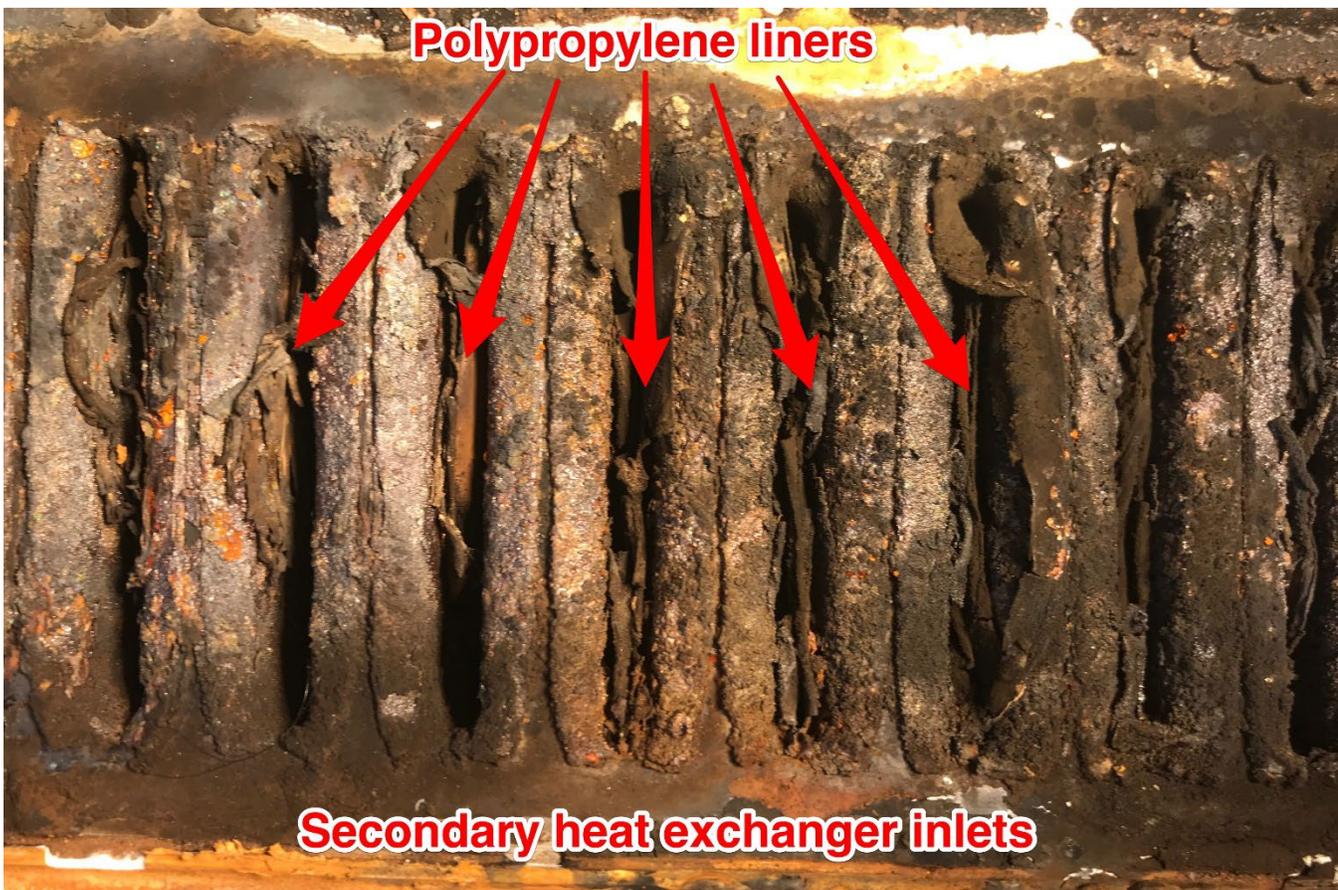
**Image 5** -. The light is passing through another hole from corrosion where the tube connects to the coupling box.



**Image 6** – Plugged and blocked tube inlets from corrosion and delaminated polypropylene liners.



**Image 7** – Close up photo shows delaminated polypropylene liners.



**Image 8** – Another photo showing excessive restriction to gas flow from plugged and blocked tube inlets due to corrosion and delaminated polypropylene liners

## Properties of Carbon Monoxide

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

**Chart 1** Properties of Carbon Monoxide – From Technical Safety BC's "[Carbon Monoxide Handbook](#)"