# Incident Summary #II-997950-2020 (#16924) (FINAL)

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| SUPPORTING INFORMATION | Incident Date | | February 29, 2020 |
| | Location | | Surrey |
| | Regulated industry sector | | Gas - Natural gas system |
| | Impact – Injury | Qty injuries | 0 |
| | | Injury description | None |
| | | Injury rating | None |
| | Impact – Damage | Damage description | A residential furnace heat exchanger failed, and produced of high levels of carbon monoxide (CO), and failed to isolate the products of combustion from the home. Redundant safety features (flame rollout switch, air proving switch) failed to control the hazard.<br><br>High level of carbon monoxide produced in the furnace flue gas and 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. A safety switch was intentionally bypassed on the appliance allowing its continued operation and allowing carbon monoxide to enter the occupied space. |
| 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 thought-out the home through a ducting system, (Diagram 1).<br><br>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.<br><br>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.<br><br>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. |

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| | 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.<br><br>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.<br><br>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.<br><br>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 "CO Safety Tips") |
| Failure scenario(s) | A natural gas furnace operating in a residential townhome quit working. A gas technician inspected the furnace, identified a carbon monoxide hazard, shut off the furnace and informed the occupants not to use it. At a later time another individual then bypassed a safety switch and put the furnace back into operation.<br><br>The furnaces secondary heat exchanger had corroded. The corrosion created holes in the heat exchanger and restricted the airflow of the combustion products through it. The restricted airflow led to incomplete combustion and the production of carbon monoxide. Carbon monoxide produced by the furnace was able to enter the home. |
| Facts and evidence | A Carrier model 58MCB060 (Image 2) high efficiency natural gas furnace had been installed in a residential townhome. The original installation permit indicates the furnace was installed in the home in December 2009. The furnace had been operating in the home for just over 10 years prior to the incident.<br><br>The occupants of the home stated they were tenants and rented the townhome. When the furnace quit working, the tenants hired a heating company to troubleshoot the non-operational furnace. A gas technician working for the heating company went to the home and inspected the furnace. The technician stated that staining on the metal under the main blower was observed which indicated condensate leakage. Upon further examination burn marks were found inside the burner box indicating flame rollout from a blockage in the heat exchanger. Corrosion and signs of leaking condensate were observed on the exterior of the secondary heat exchanger tube |

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inlets (Image 6). The technician then notified the occupants of the findings and informed them not to use the furnace until it could be repaired or replaced.

The tenants of the townhome stated they informed the townhome owner of the issue with the furnace and the findings of the gas technician. The owner sent over another individual to inspect the furnace. The individual removed the flame rollout switch and informed the owners that he believed was faulty and a new one would be purchased to replace it. The individual then installed two carbon monoxide detectors in the home and put the furnace back into operation.

Technical Safety BC received a notification from a heating company. The notification stated that after their technician identified a faulty furnace at this location and informed the tenants not to use it, the heating company was unable to contact the tenants to give them a quote to replace it. The heating company was concerned the furnace might have been put back into operation and that if it was it could create an unsafe condition by exposing the occupants to carbon monoxide.

A Gas Safety Officer with Technical Safety BC went to the home to investigate the potential hazard. The Safety Office stated that It was a cold day outside and upon entering the home noticed that it was warm. The tenant was asked how the home was being heated and they stated that the furnace was being used to heat the house and that somebody came by and fixed it. While examining the furnace, the Safety Officer observed that the flame rollout switch was missing and had been removed from the burner box (Image 3) and a wire was installed bypassing the safety circuit.(Image 4) The Safety Officer zeroed his carbon monoxide meter outdoors, eliminated any other potential sources of carbon monoxide and had the occupants turn up the thermostat to start the furnace. He began to measure for carbon monoxide in the ambient air around the entrance to the mechanical room. After the furnace's main blower came on the meter began to indicate carbon monoxide in the heating air from the overhead register just outside the mechanical room door. The measurement was increasing approximately 1 ppm (part per million) every 1-2 seconds. After reaching 8 ppm the furnace was shut down and the readings returned to zero. The Safety Officer stated that the furnace was shut down at this point during the testing because there was a newborn baby in the home that he did not want be exposed to any higher levels of carbon monoxide. The Gas Safety Officer then instructed the tenants not to use the furnace until it could be repaired or replaced. When the Gas Safety Officer asked the tenants who put the furnace back into operation they stated that they believe the individual was a family friend of the owner and were unaware if they held any gas qualifications or were associated with a heating company.

The original heating company that identified the faulty furnace was hired to replace it after the Safety Officer visited the home. The technician for the heating company stated that upon furnace removal and disassembly, they observed holes and blockage at the inlets of the secondary heat exchanger fin tubes due to corrosion and delamination of the polypropylene liner. One of the heat exchanger fin tubes was able to be removed by hand by the technician, without disassembly of the heat exchanger frame. This was likely due to the amount of corrosion at the fin tubes inlet resulting in an insecure mechanical connection. The technician also stated that they did not observe any installation characteristics with the furnace, ducting or venting system which they believe may have contributed to an premature failure of the secondary heat exchanger. The manufacturer of the furnace advertises a twenty year limited warranty on the secondary heat exchangers for this model of furnace which had been in service in this townhouse for approximately 10 years.

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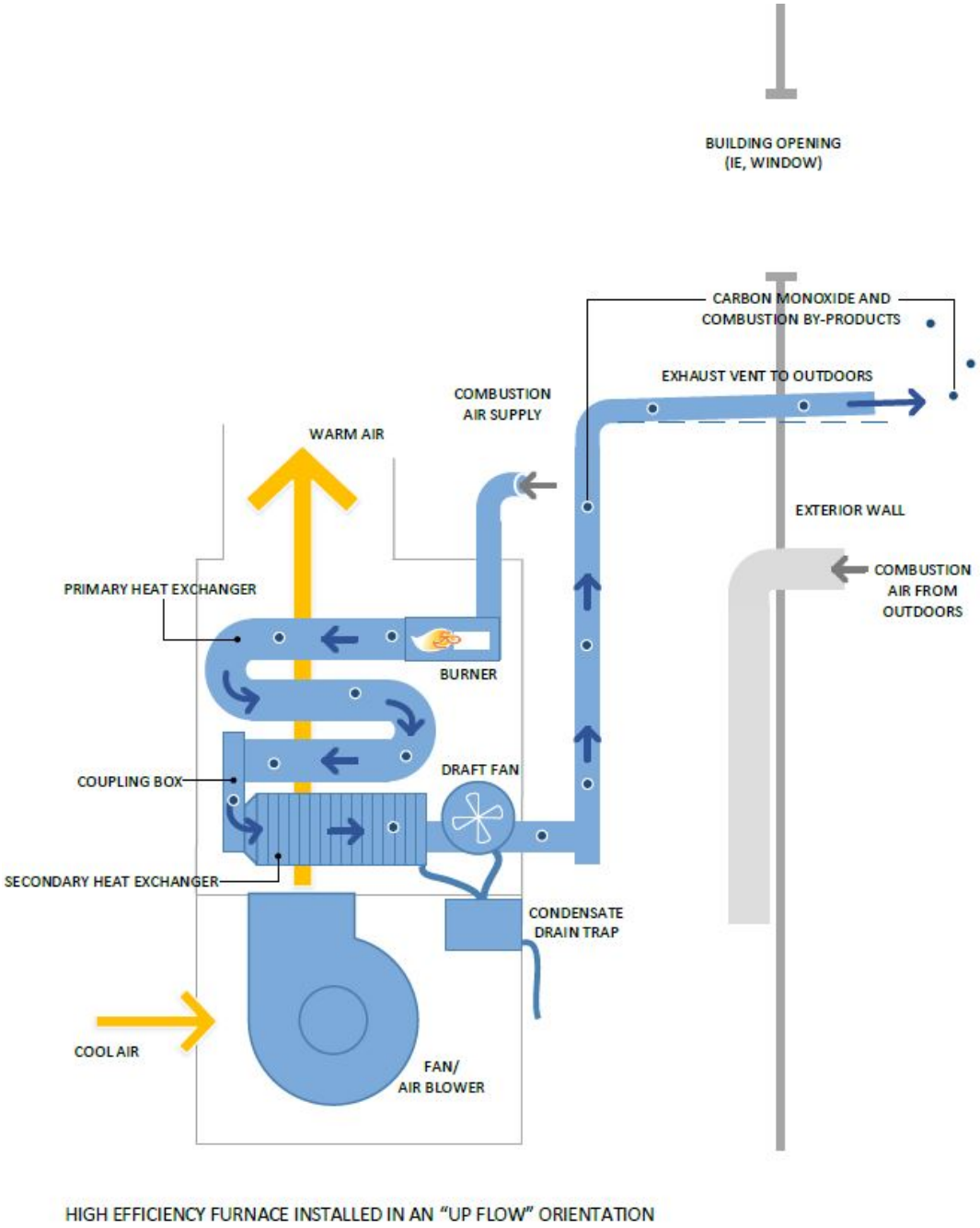
| | **Evidence Examination**<br><br>The inlets to the furnace's secondary heat exchanger fin tubes had corroded and the interior polypropylene lining had delaminated which restricted the airflow through them. The restricted airflow reduced the amount of air at the point of combustion in the burner box. The unbalanced air/fuel ratio produced elevated levels of carbon monoxide in the flue products.<br><br>During operation of the furnace, the restricted flue passages caused the flames to roll out of the burner tubes inside of the burner box. The flame rollout caused an increased temperature at the flame rollout safety switch installed on the side of the burner box. The temperature eventually increased to the point the flame rollout safety switch opened the electrical circuit and shut the furnace off.<br><br>Failure analysis of the heat exchanger was conducted by an independent laboratory, which concluded that the secondary heat exchanger failed due to corrosion caused by rapid degradation of the polypropylene lining. |
| Causes and contributing factors | The cause of the incident was due to furnaces secondary heat exchanger design and use of polypropylene laminated mild steel material that contributed to rapid and excessive corrosion which restricted airflow allowing for the production of carbon monoxide due to incomplete combustion.<br><br>A contributing factor to the incident was the furnaces flame rollout switch being bypassed and the furnace being put back into operation. |




HIGH EFFICIENCY FURNACE INSTALLED IN AN "UP FLOW" ORIENTATION

**Diagram 1** – Showing typical furnace operation

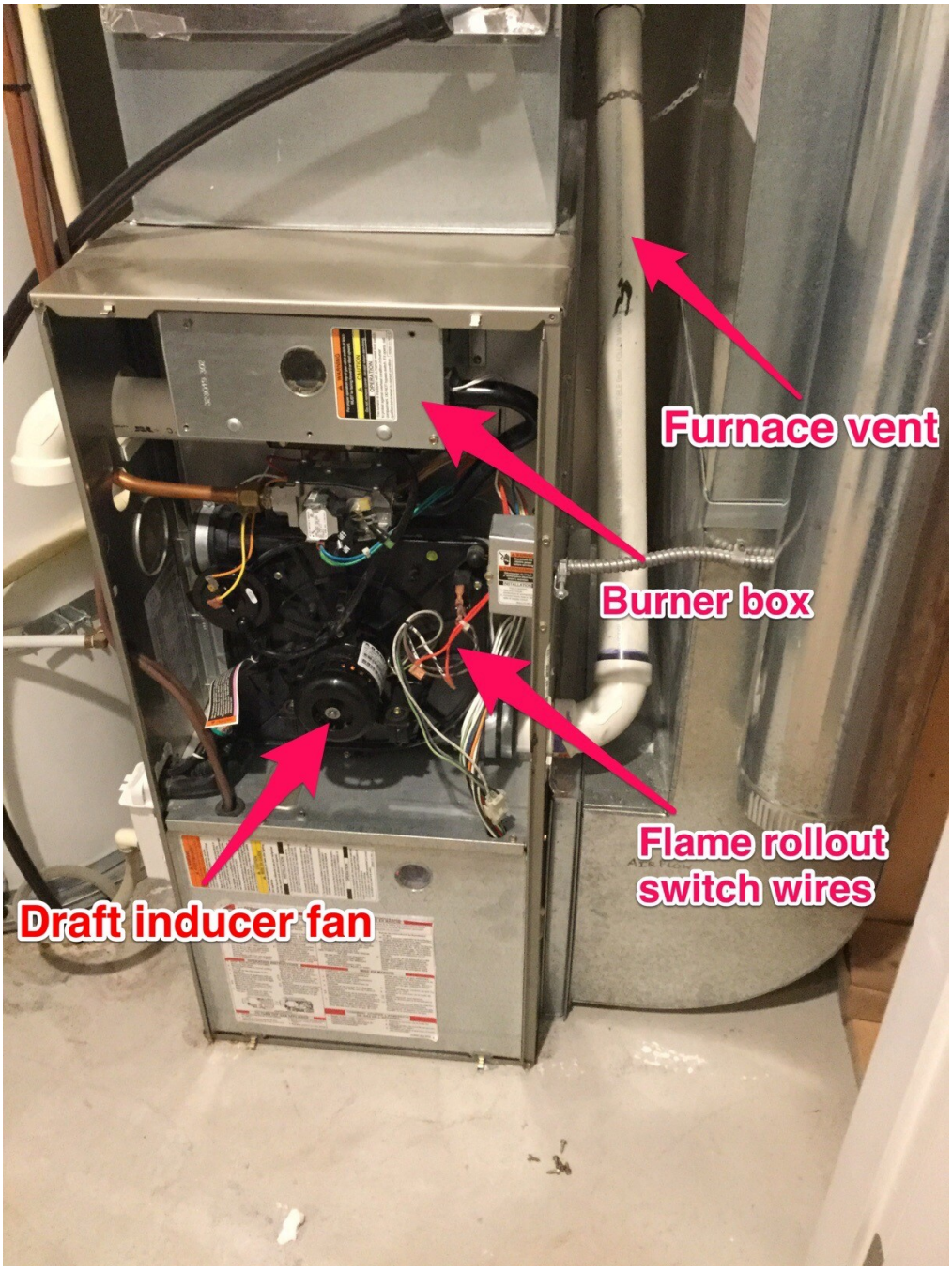



**Image 1** – Furnace prior to removal

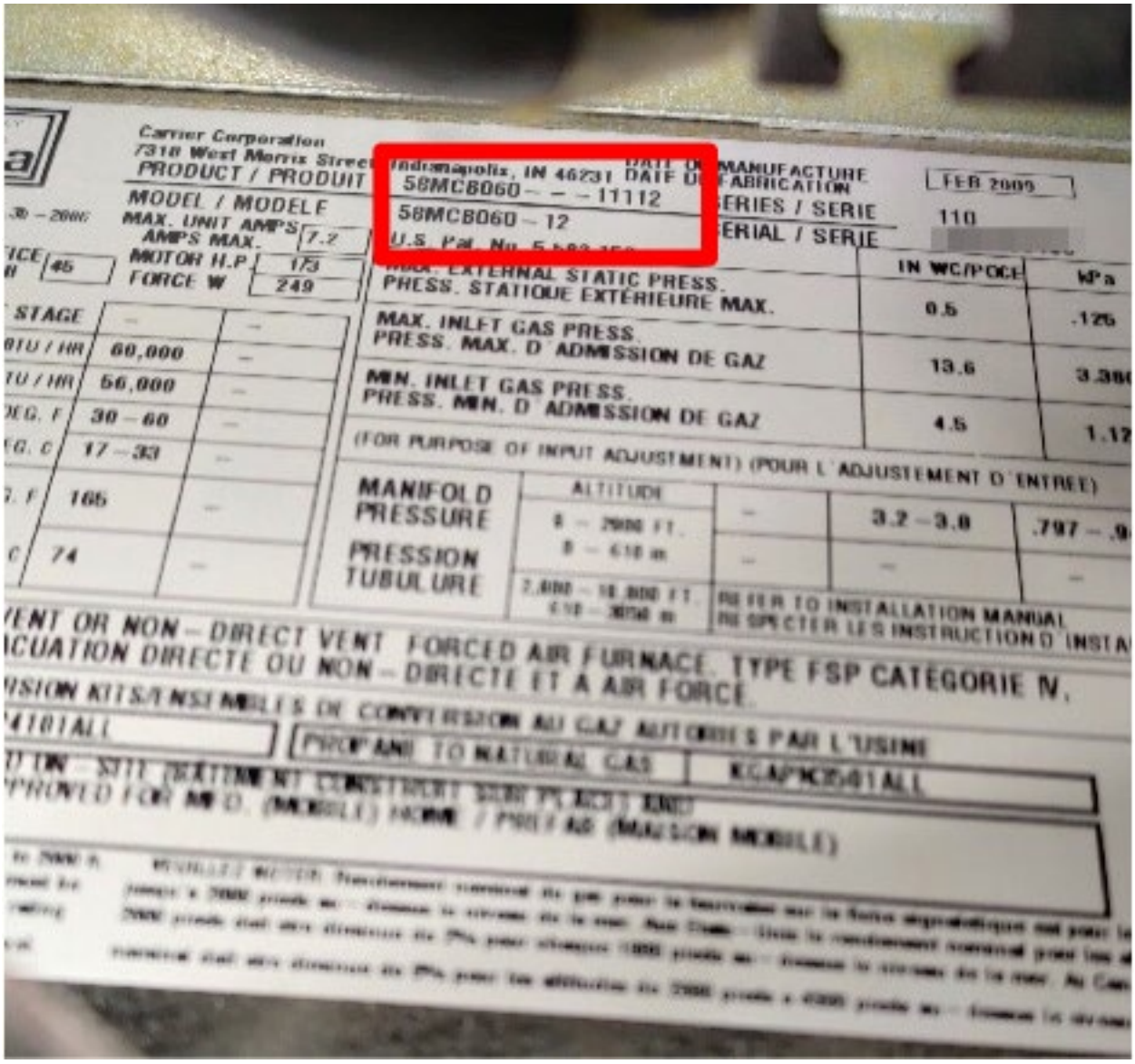



**Image 2** – Furnace data tag identifying it as a Carrier model # 58MCB060

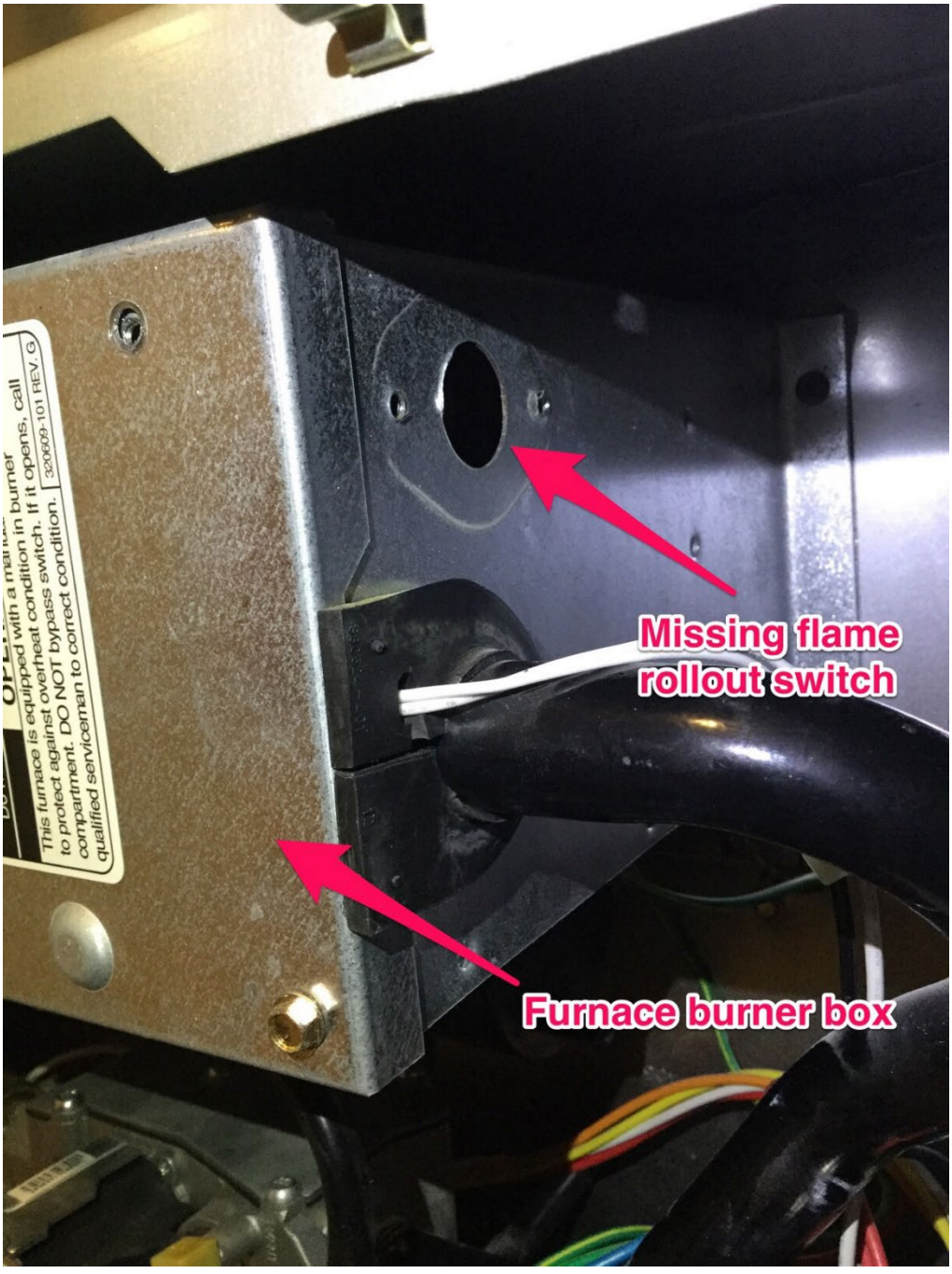



**Image 3** – Burner box after flame rollout switch was removed and bypassed

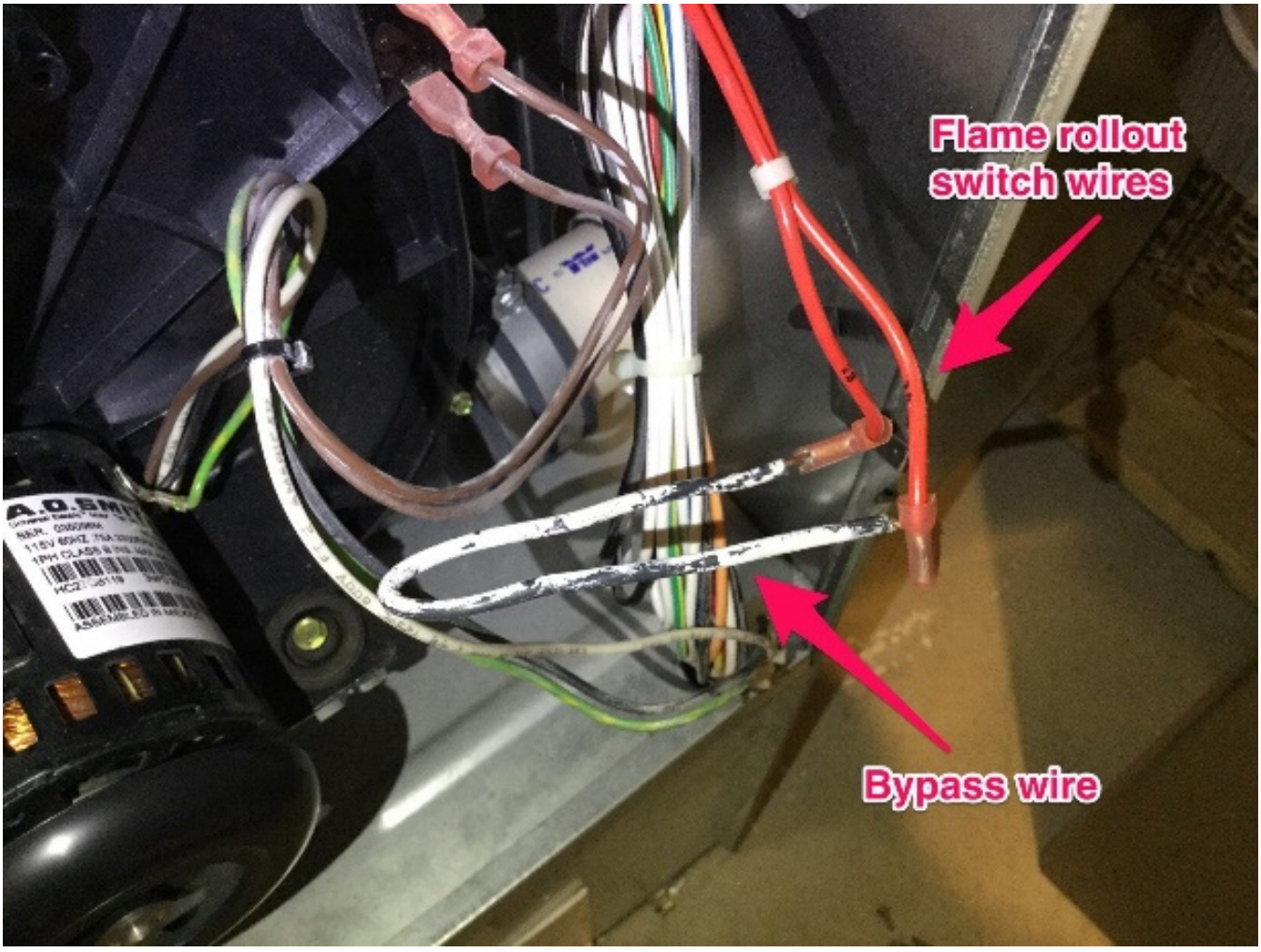



**Image 4** – Bypass wire allowing the operation of the furnace without the flame rollout switch

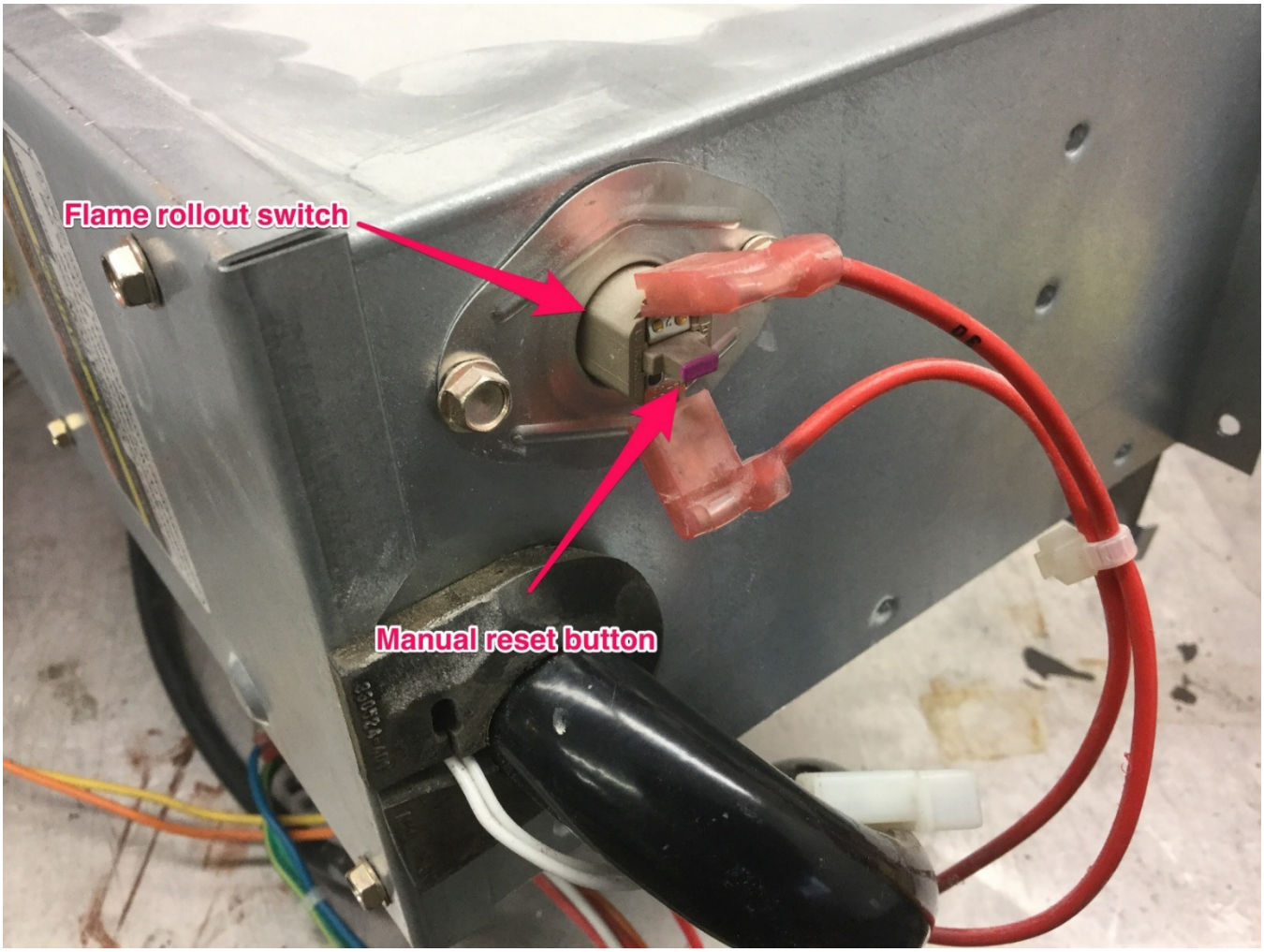



**Image 5** - Exemplar switch from a separate furnace of the same make and model

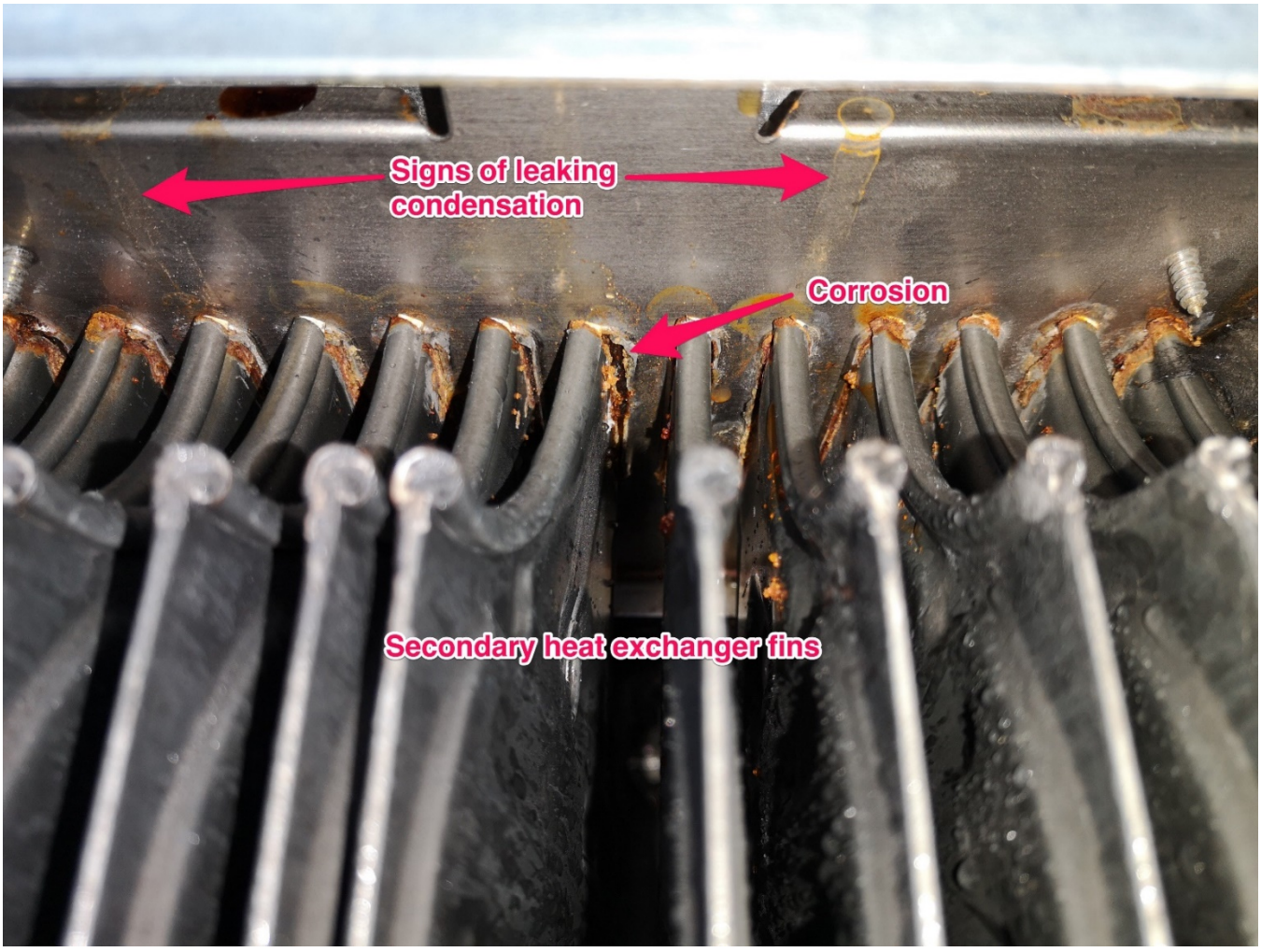



**Image 6** – Secondary heat exchanger fin tube inlets attached to coupling box

**Image 7** - Example of corroded secondary heat exchanger fin inlets from similar make, model and age of furnace

## *Properties of Carbon Monoxide*

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| *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"