Incident Summary (Reference # 5603269) (Final)

SUPPORTING INFORMATION	Incident Date			July 26, 2016
	Location			West Vancouver
	Regulated industry sector			Natural Gas System
	Impact	Injury	Qty injuries	4
			Injury description	One person deceased, one person was found unconscious and was taken to hospital in critical condition and two other individuals were transported to hospital for further treatment.
			Injury rating	Fatal
		Damage	Damage description	N/A
			Damage rating	None
	Incident rating			Severe
	Incident overview			The fire department responded to a 911 call and discovered four individuals who had suffered various degrees of carbon monoxide poisoning. The fire department measured up to 900 parts per million of carbon monoxide in the ambient air within the home. No carbon monoxide detectors were found to be installed within the home so the residents were not alerted to the presence of carbon monoxide.
INVESTIGATION	Site, system and components			The mechanical system within the home is comprised of two main components, a low mass fin tube hot water boiler which provides heat for the domestic hot water, fan coil, pool and spa and an air handling unit which moves air throughout the home to be either heated in the winter by the boiler water or cooled in the summer by the outdoor condensing unit. The basic configuration of the mechanical system is illustrated below in Figure 1, and the components are discussed following the illustration.

Incident Summary (Reference # 5603269) (Final)

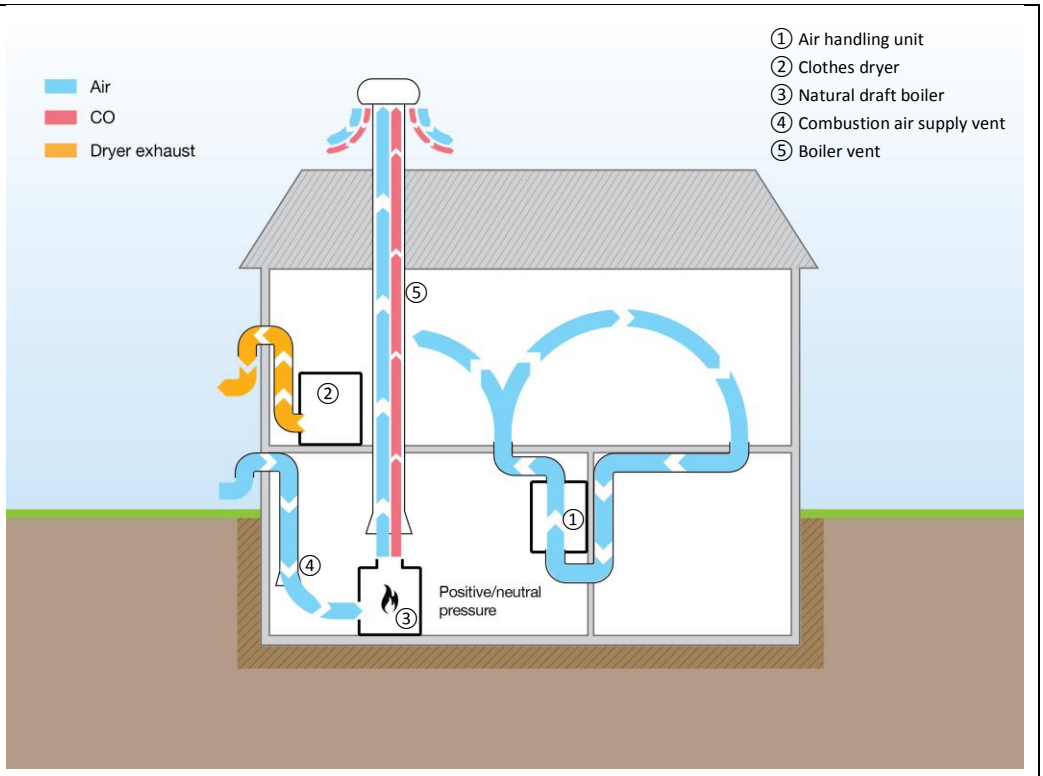

Figure 1: Intended air flow and combustion air flow

Figure 1 is a basic illustration of the mechanical system. This illustration is not to scale and is included for illustrative purposes only.

Natural Gas Boiler

Under normal operation the boiler is designed to turn on when there is a call for water in the boiler piping system to be heated. The gas is ignited in the combustion chamber which heats the water passing through the fin tube coils. Once past the heat exchanger the flue gases are designed to vent out of the boiler and home through the process of natural draft (the natural process of hot air rising and cold air falling).

Combustion Air

In a typical installation of naturally drafted appliances, combustion air is supplied to the mechanical room either through an opening in an exterior wall entering the mechanical room or through ductwork which allows for a flow of outside air into the mechanical room. This combustion air is provided to replenish the air which is used in the combustion and venting processes.

Ambient Pressure

Ambient pressure refers to the force which is exerted on an object by its surrounding medium, at sea level the ambient pressure exerting force on a person or object is approximately 14.7 pounds per square inch. Under normal operation the ambient pressure within a mechanical room housing a natural draft appliance should be equal to the ambient pressure outside of the building.

Air Handling Unit

Under normal operation the air handling unit is designed to draw “return” air through a sealed ducting system from various different locations within the home. This air then passes

Incident Summary (Reference # 5603269) (Final)

		through two coils, one coil will heat the air in the winter and one will cool the air in the summer. The heated or cooled air is then distributed throughout the home through a separate sealed “supply” air ducting system. Any area within a home which has return air drawn from it will also have supply air provided to it to ensure a balanced system.
	Failure scenario(s)	A negative ambient pressure condition was created within the homes mechanical room due to a large unrestricted opening in the return air ductwork serving an air handling unit installed within the room. The opening in the return air ductwork allowed the air handling unit to draw large amounts of air from the mechanical room without supplying any air back into the room, lowering the ambient pressure in the room. Additionally it was identified that the combustion air supply to the mechanical room was fully blocked. The negative pressure within the room caused air to be drawn from the outdoors down through the boilers venting system and into the mechanical room. When the boiler was energized, due to the flow of air down through the venting system, it was not able to vent the flue gases (containing carbon monoxide) to the outdoors and they began to fill the mechanical room. As the boiler continued to operate and the flue gases continued to fill the mechanical room the oxygen content within the air in the mechanical room would begin to deplete causing the boiler to create excessive levels of carbon monoxide due to incomplete combustion. Due to the air handling unit continually drawing air from the mechanical room, the flue gases containing carbon monoxide were drawn into the return air ducting system and distributed throughout the home. Since the majority of the windows and doors within the home were closed the flue gases within the home were contained and continued to increase as the boiler operated. Figure 2 illustrates the configuration observed and measured air flow. The residents within the home were not alerted to the increasing levels of carbon monoxide within the home due to the fact that there were no carbon monoxide detectors installed within the home.

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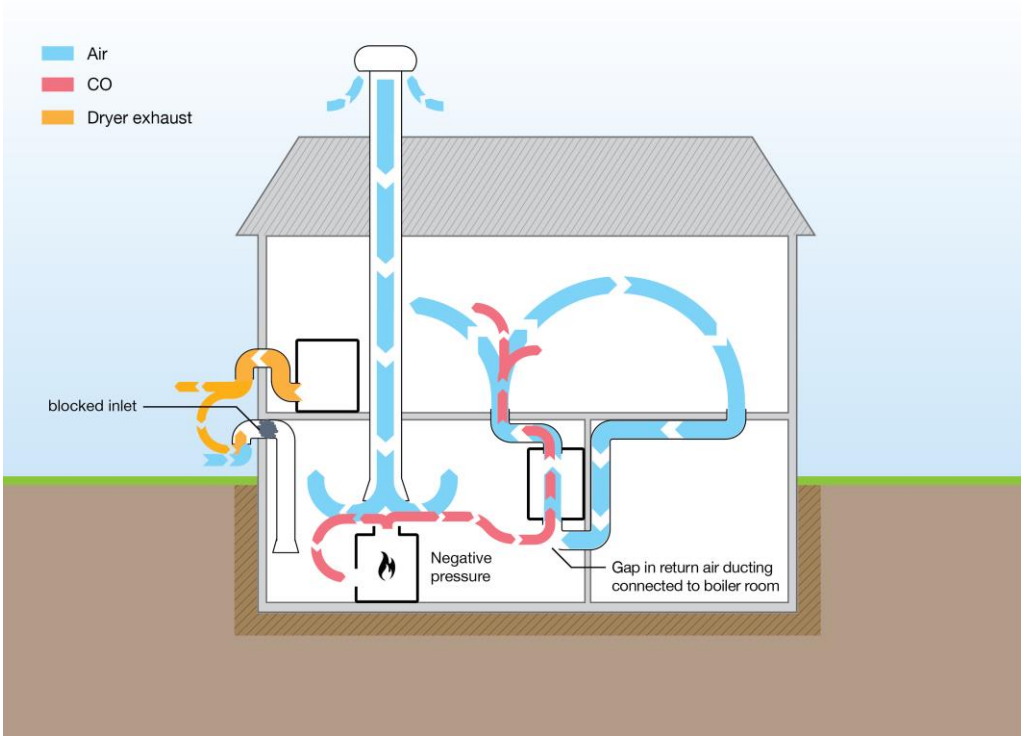

Figure 2: Measured Air Flow and Combustion Venting

Facts and evidence	• The fire department reported having measured up to 900ppm of carbon monoxide in the ambient air within the home. • The residents of the home reported that the day before the incident the pool system had been energized to bring it up to a comfortable temperature for use which created an elongated boiler run time. • The residents of the home reported that almost all of the windows and doors within the home had been kept closed to allow the air conditioning system to keep the house cool. • The combustion air supply grill on the exterior of the home was found to be fully blocked with dryer lint. Additionally when the combustion air supply ducting was dismantled it was found to be significantly obstructed due to the installation configuration (see photos #2, #3 & #4). • Multiple operational tests were performed on the boiler during the investigation which found that; with the mechanical room door closed and the air handling unit running, when the boiler was energized products of combustion immediately began to spill out through the draft hood of the boiler. Additionally as soon as either the mechanical room door was opened or the air handling unit was de-energized the draft in the venting system would immediately re-correct and flow up through the venting system to the outdoors (see photo #5). • Ambient pressure tests within the boiler mechanical room with the door closed and air handling unit running found that the ambient pressure within the mechanical room was approximately -0.0290” water column below ambient atmospheric pressure outdoors.

		• Multiple smoke tests were performed within the mechanical room which found that the air within the mechanical room was being drawn with force into a large unrestricted opening in the return air ductwork.
	Causes and contributing factors	It is highly probable that the main cause of the incident can be attributed to the large unrestricted opening in the return air duct work creating a reduced ambient pressure condition in the mechanical room. Multiple contributing factors which were identified were: • A blocked/inadequate combustion air supply into the mechanical room. • An elongated boiler run time. • A lack of carbon monoxide detectors within the home which would have alerted the residents to the presence of carbon monoxide.

Figure 3: Natural gas boiler (green arrow) and Air handling unit (red arrow)

Figure 4: Proximity of dryer vent (red arrow) to combustion air supply intake (blue arrow)

Figure 5: Blocked combustion air supply (outdoor termination)

Figure 6: Obstructed combustion air supply ductwork (mechanical room ceiling)

Figure 7: Match flame being forced downward
(The red arrow represents the flow of air down and out through the draft hood)

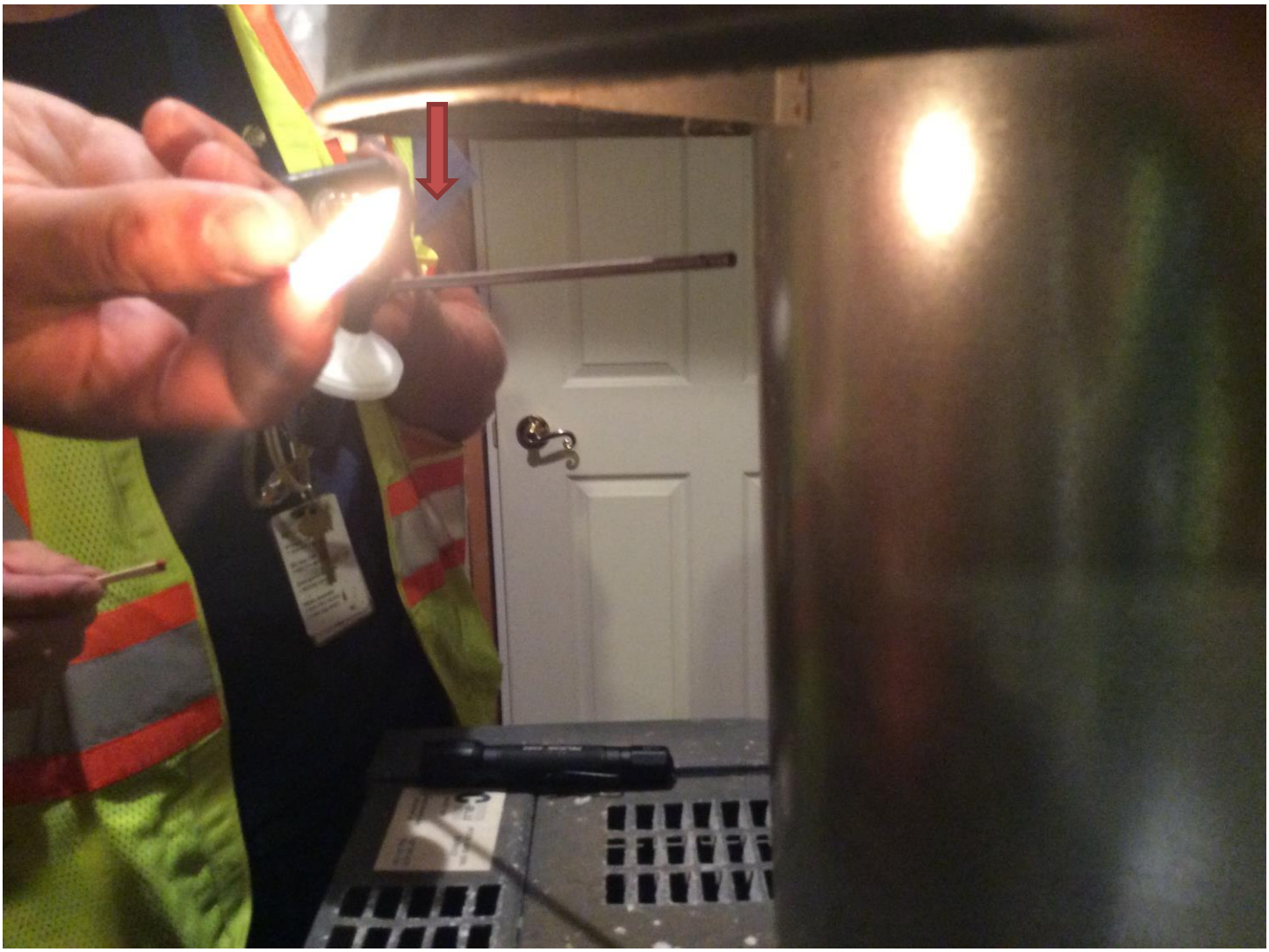

Figure 8: Open ceiling space housing return air ductwork drawing air from the mechanical room

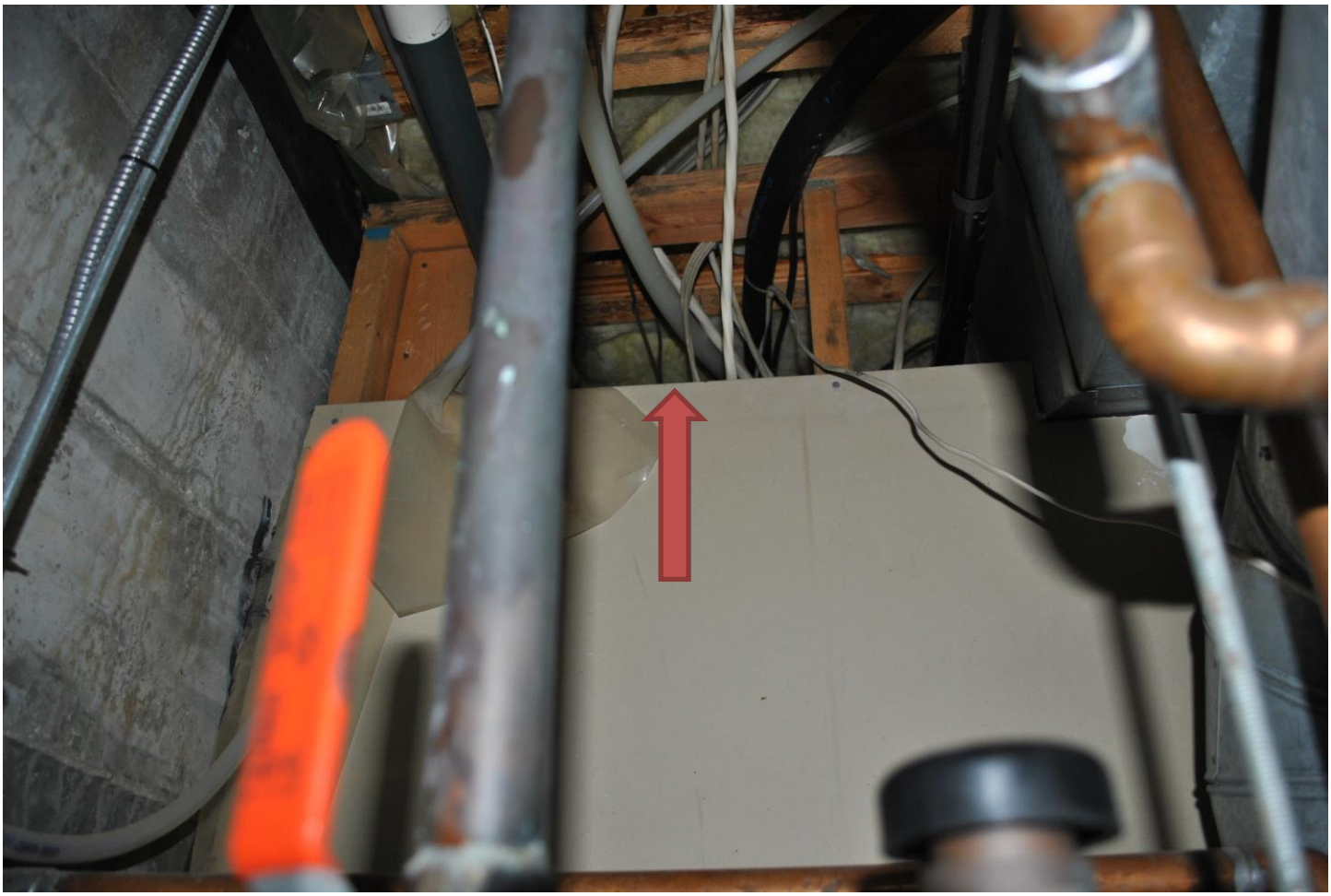

Figure 9: Return air ductwork in ceiling space and large unrestricted opening into ductwork
(The red arrow represents the path of airflow into the return air ducting system)