Incident Summary (Reference# 5613743)

SUPPORTING INFORMATION	Incident Date			*March 24, 2017*
	Location			*Surrey, BC*
	Regulated industry sector			Gas
	Impact	Injury	Qty Injuries	*0*
			Injury description	*N/A*
			Injury rating	*N/A*
		Damage	Damage description	*Fire damage to floor and boiler, smoke damage to house*
			Damage rating	*Minor*
	Incident rating			*Minor*
	Incident overview			The household residents awoke to their smoke detectors going off, and got out of the house. The fire department found that a fire had started on the wood flooring beneath the house's boiler.
INVESTIGATION CONCLUSIONS	Site, system and components			*In residential applications gas is either supplied to the house at 14 inches water column (Herein referred to as "WC) or 2 psi. In a 2 psi system a regulator must be installed in the piping before any appliances to regulate pressure down to an acceptable working pressure for the appliances. Most appliances have a maximum supply pressure of 14"WC. If gas is supplied to your average appliance at 2psi it will cause the appliance to overfire (Operate with an input above what the appliance is rated for.) and run much hotter than designed.* *When a boiler system receives a call for heat, the pump starts running, the boiler's gas valve opens, the boiler lights off, and the "run cycle" begins until the water in the system comes up to temperature and satisfies the operating aquastat (herein referred to as the operator). Once the operator is satisfied the boiler cycles off until the system temperature drops below set point, and the boiler once again cycles on, this is referred to as a heating cycle.* *While the boiler is in its "run cycle" the gas valve's internal regulator lowers the gas pressure supplied by the system (Usually 7-14" WC depending on what else is running in the system.) to a lower pressure for delivery to the burners this is referred to as the boiler's "manifold pressure." The manifold pressure is specified by the appliance manufacturer and must be checked and set anytime a gas valve is changed, otherwise the appliance may overfire or underfire. It must also be noted that the gas system in this house is a 2 psi system, which means gas is supplied to the boiler room at 2 psi, then a line pressure regulator in the mechanical room then regulates the 2PSI gas pressure down to a 7" WC which is then further reduced down to a 3.5" WC by the gas valve.* *The boiler in question on this site is a low mass fin tube boiler, which means the heating water is run through a series of tubes with extruded fins on them to increase heat transfer (see Figure In pictures. These fins are often very tightly spaced so that they pick up as much heat as possible from the products of combustion. However this design may be susceptible to plugging up with soot if not properly maintained, especially if the water returning to the boiler is colder than the temperature the boiler is designed to receive. If water returns to the boiler at too cold of a temperature, the products of combustion passing through the heat exchanger condense into soot in the fins on the tubes and begin plugging up the boiler. This soot often glows orange and radiates heat to the surrounding surfaces.*

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		To further understand what happened here one must also be aware that on the water side of the system there is a safety device called a "Pressure Relief Valve" which is installed to limit the amount of pressure in the water system so that system components cannot be damaged by high water pressures. When the relief valve is subjected to high system pressures it opens and releases water from the system to drop the pressure within safe operating limits. However if the relief valve lets out too much water the system pressure may drop, and the boiler system's "make-up water" supply will allow water from the house's plumbing system into the boiler system to try and make up for any water that is lost. This water is often much cooler than the temperature the operator is looking for so the boiler will fire to heat this water.
	Failure scenario(s)	*In January, the line pressure regulator serving the mechanical room failed, causing 2 psi gas to be supplied to the boiler. This damaged the gas valve and caused the boiler to stop working, however it is not known how long the boiler was overfiring on 2 psi gas before the gas valve failed and caused the boiler to stop working. A service technician attended and replaced the line pressure regulator, damaged gas valve, and a few other components which do not apply to the failure scenario. However in this process the technician did not check or set up the manifold pressure to the appliance causing it to overfire by roughly 30% (based on an orifice flow calculation of (1658.5 x K x A) x (√Δp/sg)). Later, at an unknown time, the pressure relief valve began to leak causing cool water to be drawn into the system to make up for the water that was leaking out of the relief valve. This constant supply of cool water caused the boiler to fire more frequently and for longer periods of time, as well as contributed to sooting of the heat exchanger. In a normally operating boiler system this would lead to high gas usage and reduced efficiency. But given the additional factors that the boiler was overfired for an unknown amount of time when the line pressure regulator failed, that it was possibly overfired by an incorrectly adjusted gas valve (see facts and evidence), and that a partially plugged heat exchanger was radiating heat to the floor below; pyrolysis of the floor below occurred until it ignited.*
	Facts and Evidence	*- Burn marks and fire trails were all localized to the floor below the boiler, with the most significantly burnt areas centralized to directly below the middle of the boiler.* *- An invoice from the service contractor states that the gas valve and 2lb regulator were replaced, and that "[The] Gas regulator had damaged original gas valve on [The] boiler causing failure"* *-A test performed by the gas fitter who was on site at the time of investigation found that the boiler was operating with a manifold pressure of 5.5-5.6" WC. Where the manufacturers rating plate called for a manifold pressure of 3.5"WC. however the gas valve may have been exposed to fire damage which may have put this reading off.* *-Inspection of the boiler found the heat exchanger to be partially plugged with soot.* *-Interviewed the service technician who performed the work. When asked what work he performed, he stated exactly what was done, he also added that he checked and adjusted the gas valve to manufacturer's specifications at 3.5" WC. However this is not noted on the invoice.* *- Upon inspection it was found that the boiler's pressure relief valve had failed and was leaking into the drain for the water heater. Furthermore the boiler's make-up water was piped into the cold line (which is a normal practice) which after time would have caused very cold water to be introduced into the system.*

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		- The roof cap of the venting system showed signs of sooting beyond what would be expected from a normally operating gas appliance. This would suggest that it may have been conducting smoke from the fire for a while before the fire was noticed.
	Causes and Contributing Factors	The most likely cause of the fire was pyrolysis of the floor due to excess heat from the boiler. A partially blocked heat exchanger most likely contributed to this fire by radiating excess heat to the floor, coupled with increased run time due to the failed pressure relief valve, speeding up pyrolysis. If the boiler were firing with a 2PSIG supply pressure for an extended period of time before damage to the gas valve occurred and was noticed, this may have contributed to pyrolysis of the floor prior to any repairs being performed. The possibility exists that the service tech may have incorrectly adjusted the manifold pressure of the gas valve. If this were the case and the boiler was firing with excessive manifold pressure it certainly would have contributed to pyrolysis and ignition of the floor. However a conflict between the service tech's statement and onsite findings makes it impossible to rule this in or out.

Figure 1: Front of boiler after fire.

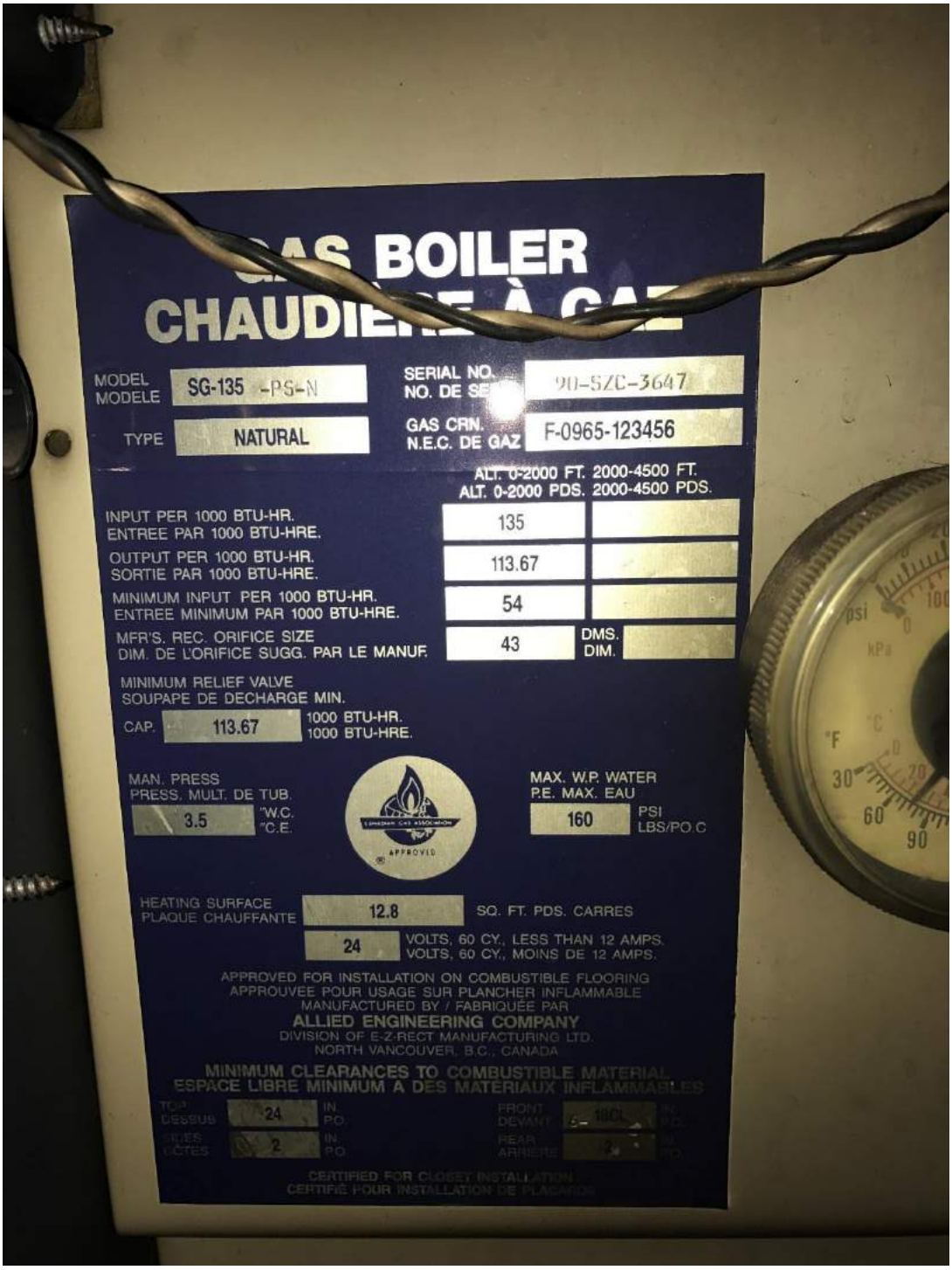

Figure 2: Boiler rating plate.

Figure 3: Front of boiler annotated to show components and fire damage.

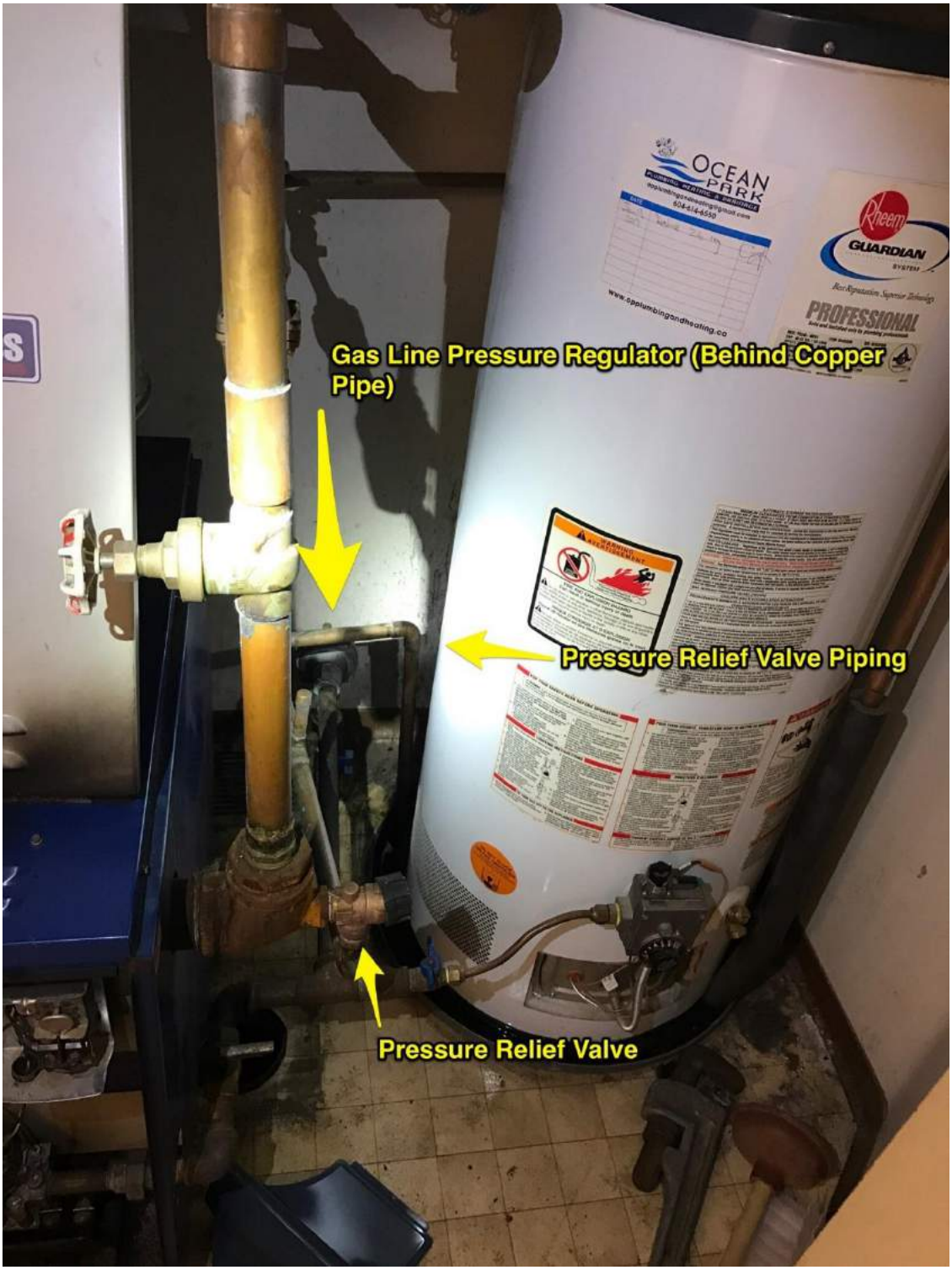

Figure 4: Pressure relief piping, and gas line pressure regulator.

Figure 5: Discharge of relief piping showing leakage.

Figure 6: Boiler heat exchanger showing heavy sooting. (Please note: Some of this black soot may be from the fire)

Figure 7: Roof termination for boiler, showing sooting beyond what would be expected from this type of appliance if it were burning properly.

Figure 8: Fire damage below boiler.