

SUPPORTING INFORMATION	Incident Date		April 22, 2019
	Location		Delta BC
	Regulated industry sector		Gas - Natural gas system
	ıpact Injury	Qty injuries	0
		Injury description	N/A
		Injury rating	None
	ln nage	Damage description	Burner, access door, and venting detached from boiler. Boiler is a total loss.
	Dan	Damage rating	Major
	Incident rating		Major
	Incident overview		While a service technician was working on a boiler that had been experiencing issues with lighting off or establishing a main burner flame. The boiler had a hard light off, meaning the main burner flame did not establish smoothly, this can be the equivalent of a small explosion in the boiler, and is caused by delayed ignition of the main burner flame. This hard light off blew off the burner, access door, and venting on the rear of the appliance. (Figure 1-2)
INVESTIGATION CONCLUSIONS	Site, system and components		 This is a forced draft appliance which relies on a fan on the inlet of the appliance to push and mix an air fuel mixture through the appliance, where the air fuel mixture is burnt and the products of combustion are then vented outdoors. Due to their nature, forced draft appliances (especially appliances with inputs over 409,000 btu's) employ a specific start up sequence to ensure safe light off of the appliance before operation of the appliance is handed off to the appliance's firing rate controls in what is referred to as the "run cycle". The start-up sequence is controlled by the appliance flame safeguard, which ensures the appliance is safe to light off, initiates and stages the light off-sequence, and once the appliance does not operate. Flame safeguards are designed so that any unexpected conditions during the operation of the appliance, or loss of flame, result in a lock out of the appliance. When an appliance locks out all ignition and fuel sources are extinguished, the boiler attempts to purge any gas that was introduced into the combustion chamber. It then shuts down and will not re-activate until somebody resets the flame safeguard. The light off sequence generally follows the following sequence: First the boiler receives a call for heat from a sensor in the system. Next the flame safeguard preforms a safe start check where it checks to ensure that all operating conditions are as required, and that there is no flame present in the appliance.



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	 where an end switch within the input control makes to prove the input control is in "high fire" position. The flame safeguard then begins the pre-purge sequence, at this point air is passed through the boiler to exhaust any gas that may have accumulated in the burner chamber while the appliance was in standby mode. Code requires that at least four air changes happen within the appliance at a firing rate of not less than 60% of the maximum firing rate. After the pre purge has completed, the appliance drives the input controller down to its "low fire" position for what is known as a "low fire start", this is done so that a main flame can be established without too much turbulence in the air, and ensures a smooth light off (imagine lighting a lighter in the wind, vs no wind). When the boiler drives to low fire start the input control motor of the appliance drives the combustion air damper to a position where it is nearly closed, limiting the air flow that is going through the boiler, once the boiler reaches this position an end switch is made in the input control motor and the boiler attempts to ignite. Once the flame is established and the flame safeguard senses the flame, the safeguard will drive the input controller up to its required firing position, supervise the flame to ensure that it is stable, and allow the boiler to enter
	 This boiler uses direct spark ignition, this means that there is no pilot flame, and the main flame is established using a spark ignition rod, which when energized causes a spark to continuously jump from the rod to the burner head, creating a source of ignition. The flame safeguard was a mechanical type flame safeguard, as opposed to some which are entirely microprocessor based. This means that a rotating cam within the flame safeguard opens and closes sets of contacts which activate the various functions of the boiler through the pre-purge, ignition, and run cycles. At the top of this cam is a dial indicator which shows what stage of operation the
	boiler is in, and is a handy way to identify at what stage a lockout is happening. Outside of the flame safeguard's control there are other factors which could cause a hard light off within the boiler. One example would be, if the supply gas pressure is too high there could be an incorrect gas-air ratio at the burner head which could make ignition difficult. Another example would be if the end switch in the input control motor was incorrectly adjusted and the low fire start was occurring before the burner had completely driven to low fire start position, in which case the boiler would be attempting to ignite while the velocity of air and gas across the burner head is too high (again imagining the lighter in the wind) allowing for some air-gas mixture to accumulate in the boiler before it ignites.
	Both of these setting are generally set to manufacturers specifications when the boiler is first commissioned and only ever adjusted to bring the appliance back to these settings should something go out of adjustment. The venting system employed a barometric draft control device, which operates
	Similar to a draft nood but instead uses a weighted damper to allow dilution air into the draft system so that it does not pull too hard of a draft which could pull the flame off the burner head. The ignition and operation sequence of this type of appliance is complex. The intent of the system it to use a series of redundant safeties to ensure safe and proper ignition and operation of the appliance to prevent the type of failure that



	occurred in this situation. Alteration or by-passing any of the safety devices or start/run sequence components can cause the equipment to operate unpredictably and in some cases fail causing damage to the equipment and potentially the surrounding area. It is very important to ensure that only qualified and knowledgeable personnel operate and maintain this type of equipment due to the complexity of the systems and potential hazards associated with failure.
Failure scenario(s)	The heating contractor had been experiencing nuisance lock-outs of the appliance for roughly a week leading up to the incident. Several technicians had attended site and worked on the appliance depending on who was available when the appliance locked out. During an after hour's call a service technician adjusted the flame sensor and ignition rod, replaced some weights that appeared to have fallen off the barometric damper, and reset the appliance. He said it appeared to be operating fine when he left site, however he was called back to site the next day for another lockout. At this point he again adjusted the flame sensor and spark rod, and reset the appliance. He monitored the appliance through three cycles, however on the fourth cycle the appliance had a very hard light off which damaged the appliance, and venting system.
Facts and evidence	 Site Observations -When I attended site the service contractor had already cleaned up most of the damage, and altered the scene during the repair process. (Figure 3) -The interior of the boiler was clean and showed no signs of sooting or incomplete combustion that would indicate the boiler was having ignition or flame issues prior to the incident. (Figure 4) -The burner head for the boiler was examined and determined to be free of cracks or defects which may have caused poor mixing and possibly a hard light off. (Figure 5) - The safety shut off valves for the appliance were leak tested and holding tight, disassembly of the safety shut off valves found no damage to the sealing surfacesThe input controller appeared in good shape, and an interview with the service technician indicated that no adjustments were made to the end switch camsThe dial for the flame safeguard indicated that it had entered the trial for ignition phase when the hard light off happened, so a spark would have been present in the boiler at the time of failure. (Figures 6-8) - The flame safeguard was examined and found to have a pitted contact on the ignition contact. However, testing of the flame safeguard contacts determined that this would have only affected when the ignition spark would have poned. Therefore reducing the possibility that the flame safeguard was at fault. (Figures 9-11) -The weights having been knocked off the barometric damper would indicate that other hard light offs may have occurred during the lock outs during the previous weeks.



	Interview with service technician -Interviews with the service technician who was on site indicated that adjustments were made to the spark and flame rods to adjust them within manufacturers specs. -When asked if any safeties were bypassed during his troubleshooting process, the technician told me that none were observed by him. -When asked if any adjustments were made to the low fire start cam on the input control motor, he told me none were observed by him. -When asked if any adjustments were made to the supply pressure regulator, he told me that none were observed by him. - He also told me that he was not the only technician to make adjustments to the boiler while it was having problems.
Causes and contributing factors	 It is highly probable that a hard light off resulted in an explosion within the combustion chamber and the detachment of the burner, access door, and appliance venting from the boiler. It is possible that adjustments were made to the boiler by someone other than the technician who was on site that may have caused the hard light off. Something may have also failed within the flame safeguard system that allowed the boiler to light off before the "low fire start" was achieved causing gas to build up within the boiler and ignite.





Photo taken from the scene the day of the incident, showing detached burner and damage to the boiler breeching. The red oval shows the burner unit and controller. The yellow arrow shows the separation between the burner unit and the boiler frame as a result of the explosion.

Components visible in picture:

Green Arrow: Flame Safeguard

Blue Arrow: Double block safety shut off valves





Detached boiler venting, yellow arrow shows the separation between the boiler and the venting.





Photo of the scene from the day I attended site. This photo shows the equipment was altered and partially disassembled as the equipment was being worked on in an effort to determine if the equipment was salvageable.





Interior of the boiler, no evidence of sooting or poor combustion. This shows that operation of the boiler while in the run cycle was correct and is not suspected as a potential cause.





Burner head, with no signs of apparent damage, cracking or warping. This rules out any damage to the burner as being a cause of hard light off in this appliance.





The position of the indicator dial on the flame safeguard at the time of failure. Interpretation of this position in the photos below.





Diagram showing the different positions of the flame safeguard indicator dial. The flame safeguard always begins and ends operation at the start position arrow. When a call for heat is received the dial, and attached cam begin to rotate clockwise to the various points indicated above. At the purge interlock, the appliance is looking for airflow through the boiler before it continues to the pre-purge stage. Between the purge interlock and the low fire interlock is where the pre-purge occurs. When the dial reaches the low fire interlock the low fire start begins. Once the low fire cam is made, the ignition sequence begins, and once a flame is proven the run cycle (release to modulate) begins.



Figure 8

Diagram showing interpretation of the point when the failure occurred. Green text indicates an output that has been energized, blue text indicates an input which is being monitored by the flame safeguard. So in this situation the boiler had energized the spark rod and attempted to light the boiler when the failure occurred.





Picture of top contact for ignition output, while photo does not clearly show there is a pit on the contact where metal was removed and welded to the bottom contact. This enforces the possibility that perhaps a fault in the flame safeguard caused the failure.





Photo of bottom ignition contact, while it is difficult to see there is a small raised piece of metal on the contact.

The red circle shows the surface area of the ignition contact, and the red arrow shows the raised piece of metal on the contact surface.





A continuity test was performed to determine if the damaged contact in question served the ignition output #16 for the flame safeguard. This test determined that the lower contact with the welded piece of metal did in fact serve the ignition output for the flame safeguard. However further tests determined that this contact did not also energize the safety shut off valves for the appliance, reducing the possibility that a fault in the flame safeguard was the cause.