TECHNICAL SAFETY BC

Incident Summary #II-1484979-2022 (#30753) (FINAL)

SUPPORTING INFORMATION	Incident Date			December 13, 2022
	Location			Prince George
	Regulated industry sector			Boilers, PV & refrigeration - Boiler and pressure vessel system
	Impact	Injury	Qty injuries	0
			Injury description	N/A
			Injury rating	None
		Damage	Damage description	Boiler, building, and elevator cladding broke free. There was extensive damage to the dissolving tank roof and support beam. A smelt spout and nearby small-bore piping were damaged. The spout hood disconnected and dropped into dissolving tank.
			Damage rating	Moderate
	Incident rating			Moderate
	Incident overview			A Kraft pulp mill recovery boiler had been firing on natural gas only for an extended period. An operator opened one of the 4 plugged spouts and a sudden release of accumulated molten smelt resulted in heavy runoff into the dissolving tank. Water and smelt came into contact and smelt-water explosions occurred resulting in damage to surrounding equipment and structures.
INVESTIGATION CONCLUSIONS	Site, system and components			The Kraft pulping process generates a liquid waste called black liquor which is a by-product of the pulping process that contains the residual chemicals and lignin. The recovery boiler is used to recover the inorganic chemicals as smelt, burn the organic chemicals, and recover the heat of combustion in the form of steam. Incoming black liquor is burned in the boiler and is converted to a mixture of molten salts. This molten salt mixture, called smelt, accumulates on the boiler hearth, and drains into a tank where it is dissolved in water. In addition to the molten smelt a char bed consisting of partially pyrolyzed solids will accumulate on the hearth. The smelt flows out furnace openings through water cooled troughs or spouts located near the hearth. Steam shatter sprays are used to break up the smelt stream leaving the spouts to aid in effective dissolution in the dissolving tank. The dissolving tank is equipped with a vent to remove the steam and other gases released during the dissolving process. The firing process is supervised by operators and is visually monitored, both directly and by remote infrared camera. The smelt spout area of a recovery boiler can be a hazardous area to work in. However, essential regular tasks need to be carried out for efficient operation of the boiler. Smelt can cause issues in the spout area as it tends to coagulate and plug the spouts and needs regular manual cleaning. The spouts are managed by an operator who utilizes a torch or rod to manually clear plugged spouts and ensure enough spouts are open to accommodate the smelt flow. The recovery boiler may also be fired using natural gas as an auxiliary fuel source. This is typically used during start up, shut down and when there is low heat input to the furnace.

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Failure scenario(s)	Due to the mill operational needs, heating load requirements due to extreme cold weather and frozen conveyers, and to keep the boiler in a ready to go state; the recovery boiler was operated at a high rate of gas firing for approximately 20 hours, with no black liquor. During the dayshift after the firing of black liquor ceased, the spouts were opened numerous times with no flow. When the day shift assessed the hearth condition, it was reported that there was nothing to see but a bare bed. All spouts were closed. Visual inspection of the boiler bed may have been partially obscured by a crust on top of the smelt and possible distortion of direct vision by the gas flames. It was reported that there was no thought that there was smelt in the boiler as it had been firing without liquor for approximately 20 hours, and typically all molten smelt is gone within 6 hours of firing on gas alone. Under the heat of extended natural gas firing at a high rate, the accumulation of un-melted char bed material likely formed into molten smelt. In addition, material accumulated on the superheaters above likely shed deposits and dropped into the front area of the bed. The sloped boiler floor concentrated the height of any accumulation at the front wall behind the plugged spouts. The evidence of a clean boiler floor after the event suggests that any char bed accumulations on the boiler floor had melted. On the morning of the incident, night shift operators identified and cleared two plugged spouts at around 3am. The dayshift crew took over at 6am and at 7am an operator observed four plugged spouts. Based on an incorrect understanding that there was no molten smelt accumulation, the operator proceeded to open one of the four plugged spouts with a propane torch. When the spout opened, a heavy molten smelt runoff condition occurred flowing into the dissolving tank. The molten smelt entering the dissolving tank created a smelt/water reaction, resulting in rapid water vaporization. The instant volume expansion of the water vapor then caused concussive forces and damage to the surroundings.
Facts and evidence	This recovery boiler has a sloped hearth with spouts on the front wall (bottom of slope). A review of industry incident reporting finds that the boiler geometry of the lower furnace plays a significant role in runoff events. Sloped floor units are more vulnerable to smelt buildup and heavy runoff incidents because the spouts may plug more easily and they rapidly develop hydrostatic head, which is the driving force for smelt flow. The location of this boiler's spouts relative to the nose arch can affect the likelihood of spouts plugging when material sheds from the upper furnace. The geometry of the "bullnose" or "nose arch" being on the back wall does not provide protection from material shedding from the upper furnace superheaters. Mill operational cycling resulted in fluctuation in black liquor chemistry. The liquor chemistry was stated as being conducive to forming "jelly roll" smelt, which is more prone to plugging of spouts. The 4 boiler spouts were reported to have been plugging up periodically and spouts were opened several times. Prior to the incident, deposits were stated to have been noticed on the superheaters and a char bed on the floor was observed. After the event, it was observed that the hearth was very clean, this suggests that any char bed build up had been since been consumed.

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	It was stated that liquor firing was stopped the previous day and the boiler was fired at a high rate on natural gas for 20 hours leading up to the incident; it is abnormal to fire for such an extended period in this manner. The mill procedure for stopping liquor firing and smelt bed burn down does not address extended firing on natural gas.
Causes and contributing factors	The primary contributing factor to the incident was the boilers sloped hearth design and operational fluctuations contributing to likelihood of smelt build up and heavy runoff. Additional contributing factors include: - A lack of effective procedures in place to address extended periods off liquor and on auxiliary fuel firing. - The abnormal situation of extended natural gas firing without black liquor likely contributed to a degree of complacency and incorrect understanding of the presence of molten smelt in the boiler.

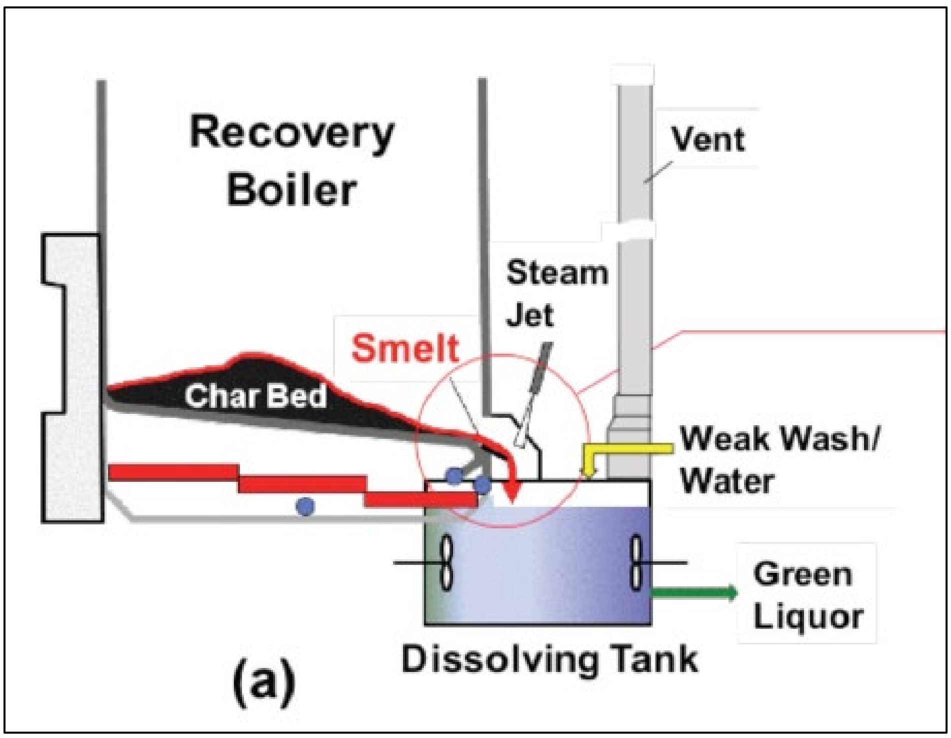
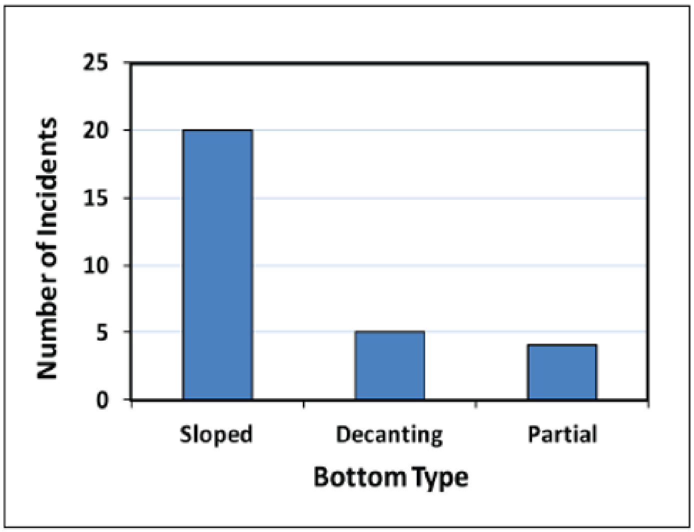
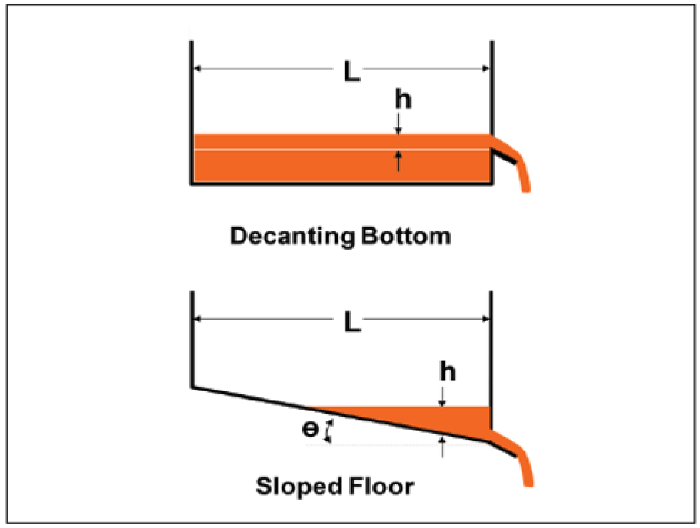


Figure 1 - Explanatory diagram of system.
Source*: Understanding recovery boiler smelt runoff phenomena – Honghi Tran, Andrew K. Jones and Thomas M. Grace*



2. Summary of heavy runoff incidents in recovery boilers with different bottom types.



10. Smelt pools in sloped and decanting bottom units.

Figure 2 - Boiler geometry affects likelihood of dissolving tank explosions.
Source*: Understanding recovery boiler smelt runoff phenomena – Honghi Tran, Andrew K. Jones and Thomas M. Grace*

Photo 1 – Location of recovery boiler smelt spouts and dissolving tank.

Photo 2 – **RED**: Smelt spout and opening to dissolving tank. Note that the shatter spray cover is missing and was later found inside the tank.