Incident Summary #II-1124951-2021 (#20341) (FINAL)

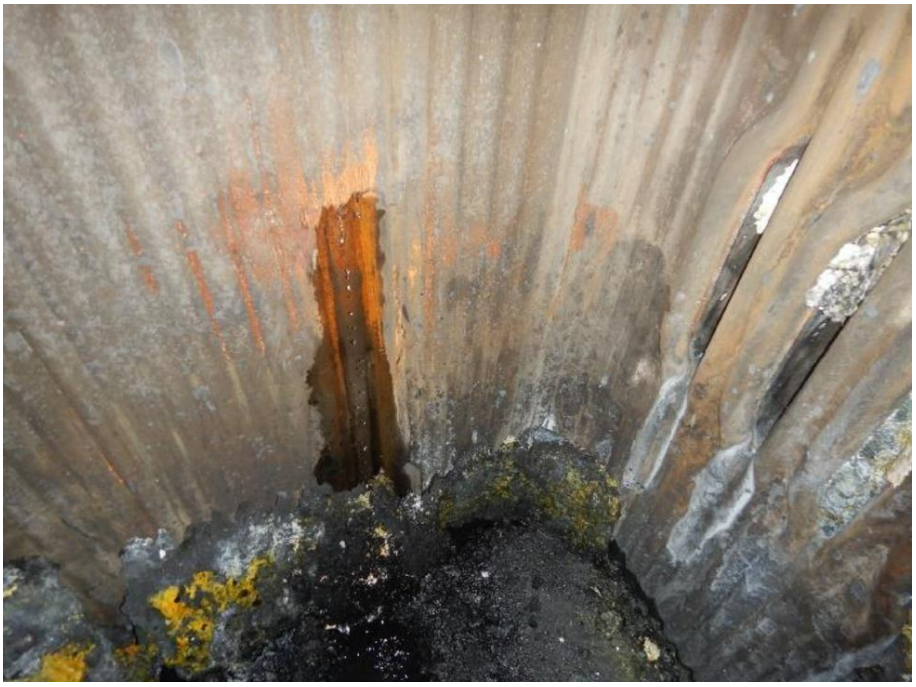
SUPPORTING INFORMATION	Incident Date		December 31, 2020
	Location		Prince George
	Regulated industry sector		Boilers, PV & refrigeration - Refrigeration system
	Impact – Injury	Qty injuries	0
		Injury description	NA
		Injury rating	None
	Impact – Damage	Damage description	A boiler wall tube section was damaged and replaced.
		Damage rating	Minor
	Incident rating		Minor
	Incident overview		A leak was identified in the lower furnace of a Recovery Boiler. The tube leak discharged directly above the smelt bed. The potential for a smelt water explosion was created. An emergency shut down of the Recovery Boiler was employed.
INVESTIGATION CONCLUSIONS	Site, system and components		This industrial site utilizes the KRAFT Pulp manufacturing process. The “Recovery Boiler” is a high pressure steam boiler which is heated by the combustion of black liquor within the furnace. The intense heat in the boiler furnace fuses the inorganic elements of black liquor (mainly sodium carbonate and sodium sulphide) to form what is known as smelt. The boiler furnace is constructed of tangential tubes containing water and steam. One of the main hazards in operation of a recovery boilers is a smelt-water reaction, an explosion can happen if even a small amount of water is mixed with the high temperature smelt. This incident resulted in water/steam being discharge directly over the smelt bed.
	Failure scenario(s)		The appearance of high levels of copper distributed within voids in the wall of the leak opening and the finding of extremely localized changes to the microstructure (localized overheating) suggests the tube was “scarred” by a stray welding arc. The tube may have suffered an inadvertent “arc strike” from a gouging rod brief enough that it did not blow through the tube during work conducted in 2005. Gouging rods typically have a copper sheath which would explain the high levels of copper that appear fused with the surfaces of the voids. The net result was a small area that was melted and then cooled rapidly. Such intense local heating, melting and cooling at the point of contact generated high levels of residual stress that were sufficient to initiate stress assisted corrosion attack. The subsequent metal spray application of the corrosion coating hid the defect from view until it precipitated the failure.
	Facts and evidence		The recovery boiler tube failure was located in the lower furnace rear wall about 4ft above the floor tubes. The boiler tube leak was in the hot side crown of the tube. The area around leak thinned from the outside with significant roughness at leak area. The boiler tube is made from A192 seamless carbon steel. In 2005 work was performed to convert the boiler furnace to a “tube and membrane” configuration by welding round bar in place to provide a seal between tubes. Once the “membrane” installation was complete, the lower furnace had a metal spray coating applied to protect the hot side from further corrosion damage and appears to have been effective in preventing fireside corrosion of the tubes. The leaking tube was removed and a failure analysis report (photos 4-6) was prepared for the owner by an independent materials testing and analysis laboratory. The report identified a number of findings, including:

Incident Summary #II-1124951-2021 (#20341) (FINAL)

	• Pits with cracking typical of stress assisted corrosion (SAC) were present on the inner surface of the tube. The SAC damage was confined to an area an inch or less in diameter at the leak location. • Overheating in a highly localized area around the failure was evident by the degraded pearlite microstructure of the metal. • Tube microstructure near the inside diameter surface and directly below the leak area consisted of well-defined pearlite grains not indicative of overheating. • There was no evidence of bulk overheating of the rest of the tube. • The SAC mechanism requires the presence of imposed tensile stress such as may occur at welded attachments, there was no evidence of any attachment welds or repairs having been made on the hot side surface of the leaking tube. • Examination of the failed tube found no metallurgical deficiencies that could have contributed to the failure. • An unusual copper coloured material was found within rounded voids at the leak location, analysis identified abnormally high concentrations of copper.
Causes and contributing factors	It is highly likely that the tube failure occurred as a result of highly localized stress assisted corrosion attack associated with an inadvertent “arc strike” from a welding rod.

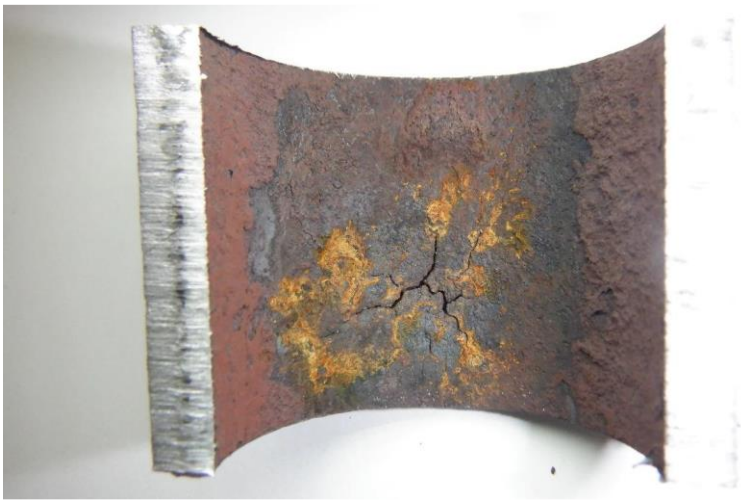
1. Lower Furnace picture of live tube leak

2. Tube leak with static head pressure during lower furnace inspection

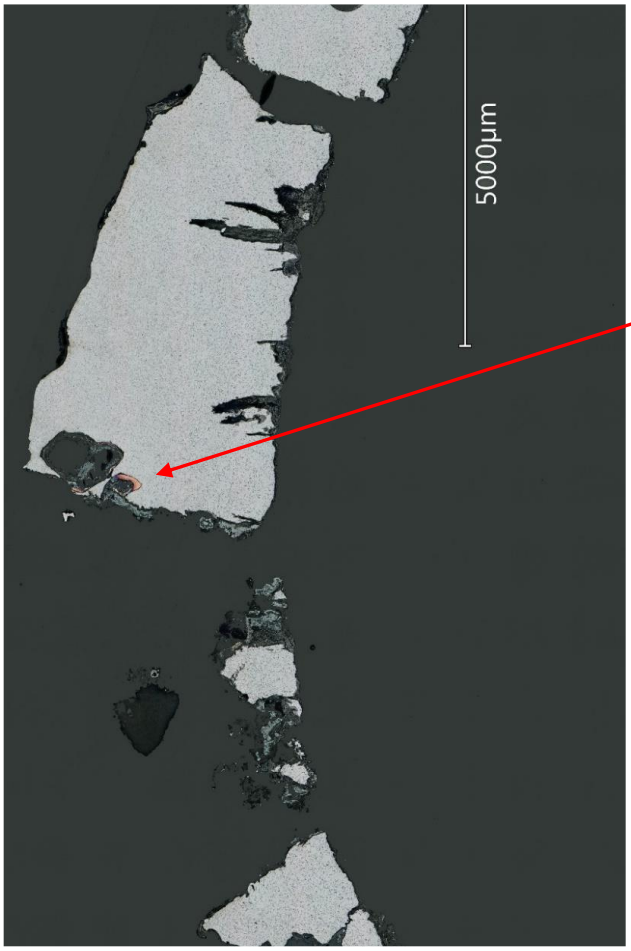


3. Tube Leak Location

4. Close up view of the failure showing the raised material on outer surface of tube.



5. View of the interior of the tube at the failure location showing an unusual network of cracks or fissures in the surface.



6. Low magnification view of cross section prepared through tube at the leak point. Pits with cracking typical of SAC extending from them are present at the leak site, several of which in this view have perforated the tube. Also present are rounded intrusions into the OD surface. The arrow indicates an unusual copper coloured material lining the rounded void in the wall of the leak.