Incident Summary #II-1540107-2023 (#34754) (FINAL)

SUPPORTING INFORMATION	Incident Date		April 24, 2023
	Location		Peace River Region
	Regulated industry sector		Boilers, PV & refrigeration - Boiler and pressure vessel system
	Impact – Injury	Qty injuries	0
		Injury description	N/A
		Injury rating	None
	Impact – Damage	Damage description	Extreme heat from an oil fire permanently deformed sheet metal, metal tubing, disintegrated fire-resistant materials, and melted sections of metal cladding of a wood waste fired thermal oil heater.
		Damage rating	Major
	Incident rating		Major
	Incident overview		The S-tube heat exchanger tube in a lumber mill's wood waste fired thermal oil heater failed, causing a leak. This leaked several hundred liters of thermal oil throughout the heater's convection section. The oil caught fire damaging a S-tube heat exchanger, industrial convection ducting, and a flue gas dust separator.
INVESTIGATION CONCLUSIONS	Site, system and components		This lumber mill's wood waste fired thermal oil heater is a type of indirect heating system used to transfer heat from a heat source to a thermal oil, which then transfers heat to generate electricity. There are seven components relevant to this incident and how this heater is supposed to work are: • Wood waste, commonly referred to as hog, is comprised of sawdust, wood chips, or bark. • Induced draft system includes a fan or blower that creates a negative pressure within the combustion chamber or system. This negative pressure helps to draw the combustion gases out. • Convection chamber in this heater is like an elevator shaft. • Flue gas reversion section resembles a hallway where flue gases from the vertical radiant heat exchanger travel horizontally into the convection chamber. • S-tube heat exchanger is made up of a series of horizontal tubes arranged in a zigzag or S-shaped pattern to form a cube. • Shot drop cleaning system utilizes an abrasive material, often referred to as shot, that is dropped onto a surface to clean it. Shot is small steel balls. • Flue gas dust separator captures and removes solid particles, such as ash, soot, and other particulate matter, from the flue gases generated during combustion processes. During normal operation wood waste is fed into the furnace at a controlled rate. Once in the furnace, the wood waste undergoes combustion releasing flue gas. Flue gas primarily consists of heat, nitrogen, carbon dioxide, water vapor, oxygen, carbon monoxide, sulfur dioxide, nitrogen oxide, and particulate matter.

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To ensure complete combustion, outside air is drawn into the furnace to provide the required oxygen via an induced draft system. This draft system will increase or decrease the amount of supplied air depending on demand for heat. Sometimes over supply of wood waste, poor quality wood waste, or insufficient supply of combustible air will cause incomplete combustion. Incomplete combustion will increase the amount of particulate matter, also known as soot, in the flue gas. Soot is a black, powdery or flaky substance composed primarily of carbon particles resulting from the incomplete combustion of wood.

As flue gases are released from the furnace, they are drawn up through the center of radiant heater, turn 90 degrees traveling horizontally through a flue gas reversion section, then turn 90 degrees dropping vertically into the first of three S-tube heat exchangers in the convection chamber. While the flue gases travel through the convection chamber, heat is transferred to thermal oil flowing through each S-tube heat exchanger. That heat energy is transferred out by the thermal oil to be used in the generation of electricity. Once most of the heat energy is drawn out of the flue gases, cooled flue gases continue out of the convection chamber into a flue gas dust separator, where soot is removed from the heater (Image 1).

Over time, flue gases with moderate to high soot content will release soot throughout the flue gases path. Heavy or bonded soot will accumulate on the flue gas reversion floor or in low velocity areas of the convection chamber. Light or unbonded soot will accumulate on the ceiling and walls of the convection chamber since the S-Tube heat exchanger presents a partial barrier. Heavy and light soot typically will accumulate on or between the tubes (Image 2).

The design of this heater made allowances for the removal of accumulated soot from the S-tube heat exchangers tubes with a shot drop cleaning system. The shot drop cleaning system has three primary components, the shot, shot collection pot, and two shot disbursement nozzles. Shot is made of several hundred small soft metal balls 3mm in diameter. A shot collection pot is a chamber located just above the convection chamber that stores shot until it is released. Shot disbursement nozzles are made up of two 2” pipes, connected to the shot collection pot, that drop vertically into the convection chamber just above the S-tube heat exchangers. At the end of each disbursement nozzle there is a deflector plate that ensure shot is distributed throughout the convection chamber.

Periodically the shot is released into the convection chamber, deflecting up and away from the disbursement nozzle’s deflector plate. Then gravity and induced draft pull the small metal balls down through the convection chamber. As each small metal ball falls, they hit S-tube heat exchanger tubes, bouncing off towards another tube. This hit and bounce is repeated several times for each small metal ball as they fall to the end of the convection chamber. Each hit loosens soot deposits, which is then drawn downstream to a flue gas dust separator. The shot is collected by the shot cleaning system and propelled back to the shot collection pot.

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Failure scenario(s)	With the shot drop cleaning system inoperable since commissioning in 2014, manual cleaning occurred every six-months for the convection chamber. Since cleaning happened only every six-months, soot would accumulate in low velocity areas. The areas most susceptible to accumulation of soot are the floor and ceiling at the end of the flue gas reversion section, the walls just before the first S-tube heat exchanger, and on or between the tubes of the first S-tube heat exchanger. Each six-month cleaning cycle allowed soot to accumulate or form blockages within the first S-tube heat exchanger, which likely resulted in incremental heat damage to the tubes of the first S-tube heat exchanger. In 2019, two tubes adjacent to the 2023 tube failure leaked, and these tubes were abandoned by capping the tubes at the thermal oil supply and return headers and plugging each end of the two S-tubes. Over time, soot continued to accumulate or form blockages every six months within the first S-tube heat exchanger until April 2023, when the induced draft broke through a weak point in the soot blockage igniting a secondary fire. Extreme heat from this fire eroded the microstructure of the metal tube until it failed, releasing several hundred liters of thermal oil.
Facts and evidence	Witness statements • The shot drop cleaning system was not operational since 2014. • In lieu of shot drop cleaning system, manual cleaning is scheduled to occur every six months. Documents • The last convection chamber cleaning occurred 161 days prior to incident. 19 days before its next scheduled cleaning. Site observations • Area surrounding the failed tube was packed with soot and appeared to have a tunnel passing the point of failure (Image 4). • Photographic evidence of the failed tube (Image 5 and image 6).
Causes and contributing factors	It is possible that secondary fire within the soot blockage overheated the metal tube causing it to fail, releasing thermal oil into the convection chamber which ignited and burned. Contributing factors to the soot accumulation and overheating include: • The shot drop cleaning system not being operational. • The insufficient cleaning cycle maintenance interval of 6 months.

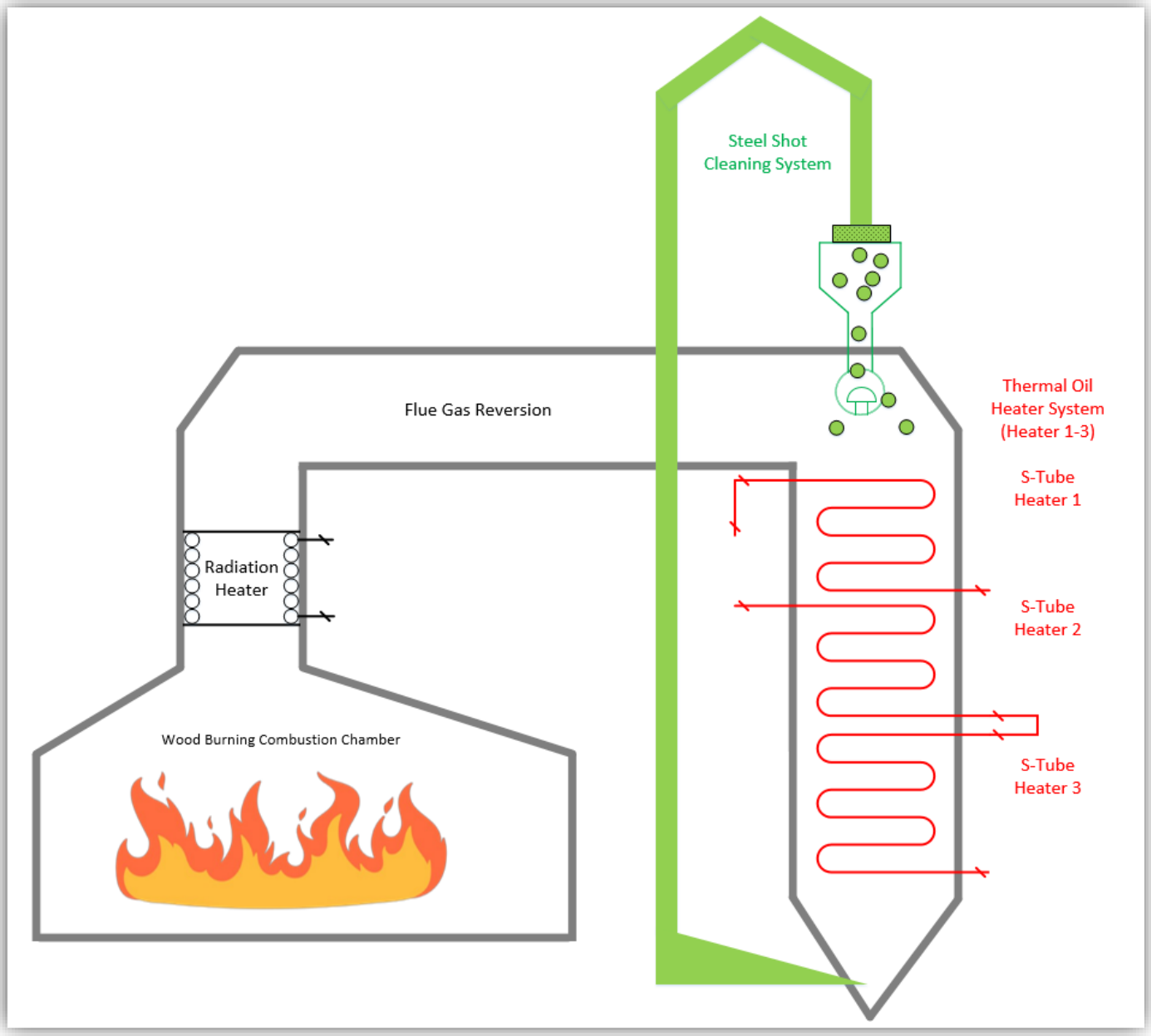

Image 1 – Diagram of heater.

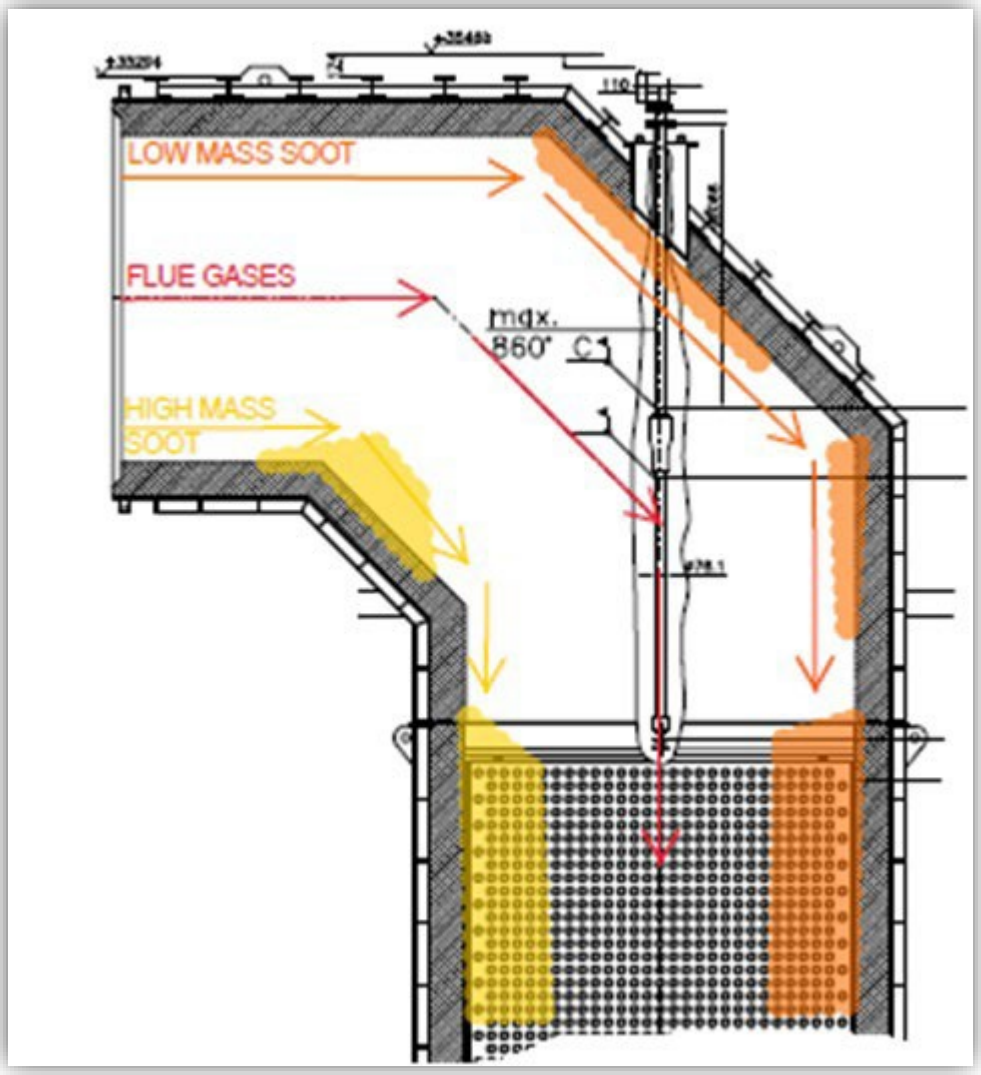

Image 2 – Diagram of soot accumulation and low velocity area.

Image 3 – East side of failed S-tube heat exchanger.

Image 4 - Location of tube failure.

Image 5 - Face of failed tube.

Image 6 – Side view of failed tube.

Image 7 – Damaged convection ducting.