Incident Investigation Report

Houston BC Pellet Dryer Explosion

Technical Safety BC

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OVERVIEW

November 25, 2020, an explosion and fire occurred at an industrial facility in Houston BC. The facility utilizes a system incorporating a large natural gas fired air heater to dry wood fibre material for the purpose of wood pellet production. The facility had recently been experiencing issues with operating conditions with the dryer system. The system was producing abnormal temperature spikes, irregular responses to operator controls and pulses of positive pressure in areas automated to maintain negative pressure conditions. The issues were communicated within the operations team and were being investigated by facility staff and management. Plant operators made decisions to stop and restart the gas burner 3 times within an 18-hour period to alleviate the upset system conditions. During the third burner restart an explosion occurred approximately 5 minutes after main burner ignition. The explosion originated at the natural gas fueled air heater and created a secondary explosion and fireball in the dust collection equipment. Three employees were injured, and the facility sustained major damage during the explosion.

Technical Safety BC conducted an investigation in coordination with WorkSafeBC and other parties

CONCLUSIONS

Incorrect governing of the air and fuel volumes led to upset pressure conditions and an unbalanced air/fuel ratio in the combustion chamber. Unburnt natural gas may have collected in the system and ignited causing an explosion. The initial explosion disturbed combustible dust downstream causing a secondary dust explosion and fireball.

Failure to have the gas train, air control components and combustion inspected, tested, and maintained on a regular basis, along with the operator and management decisions to repeatedly restart and continue operation of the air heater when known upset conditions continued to occur were the cause of the incident.

1.0 SYSTEM DESCRIPTION

The wood fibre drying system used a large (50,000,000 btu/hr) variable input natural gas fueled burner to produce heat. A combustion air blower supplies the air required for combustion while the gas train supplies the fuel. Precise amounts of air and fuel are mixed at the burner to provide a balanced air/fuel ratio (AFR) that is automatically adjusted according to the variable input of the burner which allows for complete and efficient combustion. The air and fuel volumes are independently controlled through the adjustment of fan speeds, air dampers and fuel valves operated by actuators controlled by the burner management system (BMS), programmable logic controller (PLC) or human-machine interface (HMI) control panel.

- A BMS is a safety system used to assure safe start-up, operation and shut down of gas burners.
- A PLC is a computer adapted for the control of a system. It will make decisions and control equipment based on set parameters and input signals.
- An HMI is a dashboard or interface that connects a person to a machine or system. It allows monitoring and control of system data, operation and performance.

The diagram below (Image 1) illustrates the major components of the wood fibre dryer system.

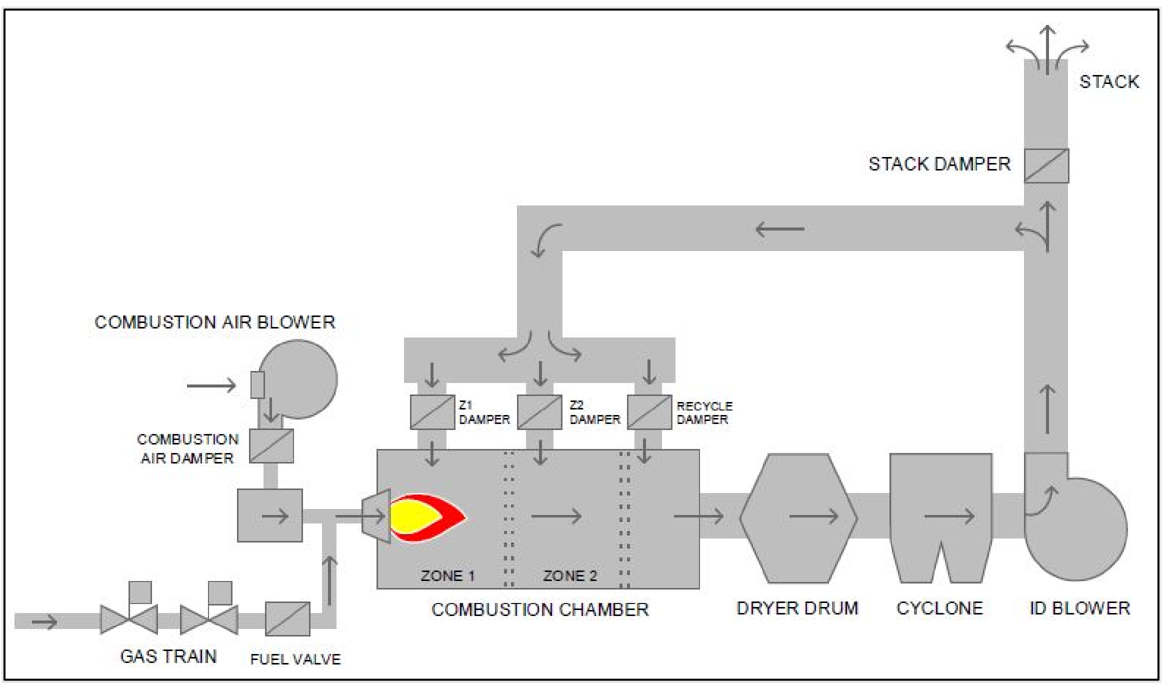


Image 1 – Diagram of the dryer system and component orientation and airflow

Air is drawn through the system and exhausted to the atmosphere by a large, blower (ID blower). The air is first heated by the burner then passes through a rotating dryer drum where wet wood fibre is introduced and heated to remove moisture. Downstream of the dryer drum the air is drawn through to a cyclone which separates and collects the airborne wood dust fibers before it is exhausted to atmosphere though the stack. A duct from the stack allows a portion of the warm exhaust air to be recycled back into the combustion chamber for the purposes of temperature control of the combustion chamber zones and to maintain a set negative pressure in the system upstream of the ID blower.

1.1 System Operation

System control operating components shown in Image 1 include:

- Dilution Zone dampers (Z1, Z2) modulate airflow in the combustion chamber to control temperatures for their zones.
- Recycle zone damper modulates airflow to maintain a set negative system pressure upstream of the ID blower. Automated modulation of this damper is controlled by the PLC.
- Stack damper is located downstream of the ID blower and controls the positive pressure in the stack and recycle ducting system.

When the operator initiates a burner start, the BMS issues a purge command to set the dampers and fan speeds to predetermined values and purges the entire system with air for eight minutes to exhaust any combustible gases that may be in the system. After the eight-minute purge, the BMS starts a 30 second delay then a 10 second trial for pilot flame ignition during which time an attempt is made to ignite the pilot burner and prove its presence. After the flame detection system detects the pilot flame for five seconds, it will attempt to ignite the main burner. If the main burner ignites and is detected it will initiate a ten second delay for stabilization, then release to modulate (RTM) which will allow the PLC and HMI to adjust the burner inputs.

The PLC controls the amount of air and fuel delivered to the burner by adjusting the combustion air blower speed and two separate actuators controlling the combustion air damper and fuel control valve. The AFR is not measured or monitored by the system and should be setup during commissioning and future inspections of the burner system by a qualified technician. Setup is achieved through the adjustment of mechanical linkages to provide a safe AFR throughout the varying burner input rates. Any changes to the operation of the PLC control signals, actuator performance, linkage setup, damper and valve operation, fan speed or gas pressure will affect the AFR and could lead to incomplete combustion and possible accumulation of unburnt gas in the system. It is therefore important that any process control changes are determined and implemented by qualified personnel and documented.

1.2 Combustible Dust

Part of the wood fibre drying process includes the separation and collection of fine combustible wood dust. The collection system uses separators that remove the fine dust in the air before exhausting it to the atmosphere.

Combustible dust can cause flash fire or explosion hazards. The facility has a dust control program in place to minimize these hazards including inspections, cleaning intervals and a spark detection and water deluge system inside the dryer and exhaust. Documents show a "Safety Tour" on November 3rd with "good" selected for dust accumulation and weekly dust audits that took place November 4th and November 12th. (The incident occurred on the 25th). It is evident that the facilities dust control program was not effective in identifying and/or preventing conditions that could lead to a dust explosion.

The concussion from the gas explosion is believed to have traveled through the dryer system causing a large amount or dust to become airborne which likely contacted the gas burner resulting in an ancillary explosion and fireball at the dust collection equipment location.

2.0 INVESTIGATION

A detailed investigation was conducted to determine the causal and contributing factors to the incident. Technical systems were examined including the gas system, system controls, inspection and maintenance processes, and operational factors.

System controls

Mechanical actuators controlling the air and fuel flow through the system were inspected and tested after the incident. An independent instrumentation and automation service provider conducted an evaluation and the following was noted on their service report:

a) Some actuators were found to be in poor condition with heavy corrosion.
b) One actuator had damaged internal sensors.
c) One was found with a field repair circumventing a missing connector.
d) The actuator controlling the recycle damper failed to determine its position and respond to automated signals.

The inspection findings indicated that the conditions described had existed prior to the explosion incident and were therefore evaluated to determine if they had a contributing influence on the explosion events.

The actuator for the recycle damper was not performing as required to safely control and maintain a set negative pressure in the system upstream of the ID blower. It is likely that this contributed to the abnormal pressure fluctuations observed in the system.

Gas System

Investigation of the gas system by an independent industrial gas contractor determined that some critical operating conditions did not meet specified values (Table 1). For example:

- Natural gas pressure was set exceeding the maximum allowable working pressures (MAWP) of multiple components in the gas valve train by 30%.
- High and low gas pressure safety switches were set outside their required settings.
- Natural gas supplied from the utility was 10 psi lower than typical supply pressure.

Component	Expected operating condition (range or value)	Actual
Gas Safety shut off valves	MAWP= 10 psi	13 psi
High pressure safety switch	Proper setpoint - 3.75 psi	Setpoint 9 psi
Low pressure safety switch	Proper setpoint - 6.5psi	Setpoint 1.5 psi
Natural gas supply from utility	Typical pressure - 60 psi	Delivered pressure - 50 psi

Table 1 – Gas pressure and component setpoints

The gas system settings had not been set or maintained to correct setpoints and the gas supply pressure from the utility was lower than normal. These factors may have contributed to issues with combustion and flame stability that may have allowed unburnt gas to accumulate in the system when it was experiencing abnormal pressure fluctuations.

Inspection and Maintenance

Review of documentation and interviews with personnel regarding inspection and maintenance practices found the following issues:

- Access to the burner management system parameters were not locked and undocumented changes were reported to have taken place since installation.
- There were no established reoccurring gas system inspection or combustion testing processes in place.
- Maintenance and repair work was contracted to qualified gas contractors on an irregular basis.
- No documentation of gas systems installation, setup, maintenance or repair history could be produced for examination after the incident.

Control of burner management system parameters is critical to the efficient and safe operation of the wood fibre drying process. Routine inspection, maintenance and records that document this work is a standard requirement in industries that operate large scale combustion equipment. Review of the inspection and maintenance program at this facility found a low level of control and monitoring of the gas system and combustion characteristics, which may have contributed to the production of hazardous conditions in the system.

Operation and Management

Review of operations and management practices found the following issues:

- Decisions were made to continually restart and operate the gas burner while monitoring system parameters and investigating possible causes without a qualified and knowledgeable gas technician on site.
- The upset system conditions were not communicated to employees who were clearing dust in the close vicinity of the equipment which resulted in injuries from the explosion.

There are risks to attempting to resume operation or continue operating a combustion system when the cause of process interruptions or failures have not been fully diagnosed, evaluated and rectified.

The lack of communication to all employees involved and the decisions to continue operating the gas burner likely contributed to the incident and associated injuries. The decisions to continue operating contributed by allowing operation of the system without a thorough and comprehensive investigation into the warning signs given by the upset system operating conditions. The lack of communication to all employees resulted in some employees performing tasks in the immediate area of the equipment that was under observation.

2.1 Employee Statements

Several employees of the facility were interviewed during the course of this investigation. Information provided during these discussions is summarized below.

The plant operated 24 hours a day 365 days a year only stopping during scheduled shutdowns for maintenance or if immediate repairs were required. October 28, 2020 was the last full shutdown of the system for maintenance and cleanout.

A sound described as “clinking” and loud banging noises were heard around the burner when it was operating and steam was seen puffing out of the seals on the ends of the rotating drum. The noises and steam coincided with measured pressure and fan amperage fluctuations.

- This was found to be caused by pressure pulsations in the system typically regulated by the automated controls to maintain a negative pressure (-1.5” WC). The pulses in pressure were forcing steam out of the drum seals and causing large metal plates held in place by gravity to bounce resulting in the “clinking” and loud banging noises heard.

When the burner was stopped but the main ID fan was still operating and moving air through the system the pressure pulsations and banging noises stopped.

- This identifies the burner operation as the main contributing factor to the pressure pulsations.

During the night shift before the incident the inlet temperature in the system was not responding to the operators control inputs. The temperatures stayed high and even increased as the operator attempted to lower them by continually reducing the burner input level. The operator had never experienced this before and made the decision to shut the burner down. The operator reported being quite shaken and “very concerned that they nearly had a critical incident” he contacted the Plant Coordinator, and they made the decision to restart the burner. The operator felt like they shouldn’t continue operation of the burner but after the phone conversation with a supervisor they made the decision to restart the burner and monitor its operation. After the burner was restarted the plant operated as expected until it was handed over to the morning shift.

- The inability to control the temperature by reducing the burning inputs suggests actuators controlling air and fuel flow were not operating correctly.

Shutting down the main blower (ID blower) for the system is a lengthy extensive procedure requiring 6.5 hours of operation with the burner off before they can shut it down.

Moments before the incident a Millwright was sent to inspect the flame characteristics through a 6” peep hole at the end of the burner. The millwright was suspicious of the way the plant was operating and walked wide around the dryer drum instead of taking the shortest route alongside the drum. The millwright did not make it to the burner peephole when the explosion occurred.

- The long-term employee with 14 years’ experience took actions while walking by the equipment due to their suspicion of high risks associated with the issues the system was experiencing. This shows employee acknowledgement to the severity of the issue.

Similar pressure fluctuations and pulses in the system had been observed in the past when pressure sensing lines had accumulated with water and failed to transmit proper pressure signals to the PLC that controlled the automated airflow damper actuators. Removal of the water on the lines had remedied the situation in the past occurrences. Incorrect pressure sensing resulted in improper damper positions which produced similar pressure pulsations in the system. During the upset conditions in the days prior to the incident the pressure sensing lines were checked for water or blockages and no amounts of concern were found.

- This suggests that the cause of the air and gas flow dampers not acting as intended leading up to the incident was irregular and not a result of a malfunctioning pressure sensor line.

The Plant Manager stated he was only aware of one upset condition in the past week. Evidence shows three separated upset conditions in the 18 hours prior to the incident that resulted in burner shutdowns and restarts.

A gas contractor had been contacted to investigate the burner issues after the second burner shutdown and restart. He had not attended the scene before the decision was made and the burner was shut down and restarted for the third time in 18 hours.

2.2 Human Machine Interface (HMI) Data

Process operators use the human-machine interface (HMI) system control panel to monitor and control the pellet drying operation. The HMI is an integral part of the process management system which monitors and logs several data points within the system. The captured data from the days leading up to and the time of the incident were analyzed.

Data from the temperature sensors show that during the last two burner restarts temperatures in dilution zones 1 and 2 spiked unexpectedly before main burner input was increased from its low fire position. The temperatures were reduced by the operator by opening other airflow dampers to cool the temperatures down. During the last burner restart before the incident the temperature in the zone farthest away from the burner (Zone 2) exceeded that in the zone closer to the burner (Zone 1) before being controlled by manual airflow adjustments in the burner dilution zones (Graphs 2 and 3). This could indicate incomplete combustion at the burner throat with combustion occurring farther down the combustion chamber. This could result from an over rich air fuel ratio produced by either insufficient combustion air or an excess of natural gas.

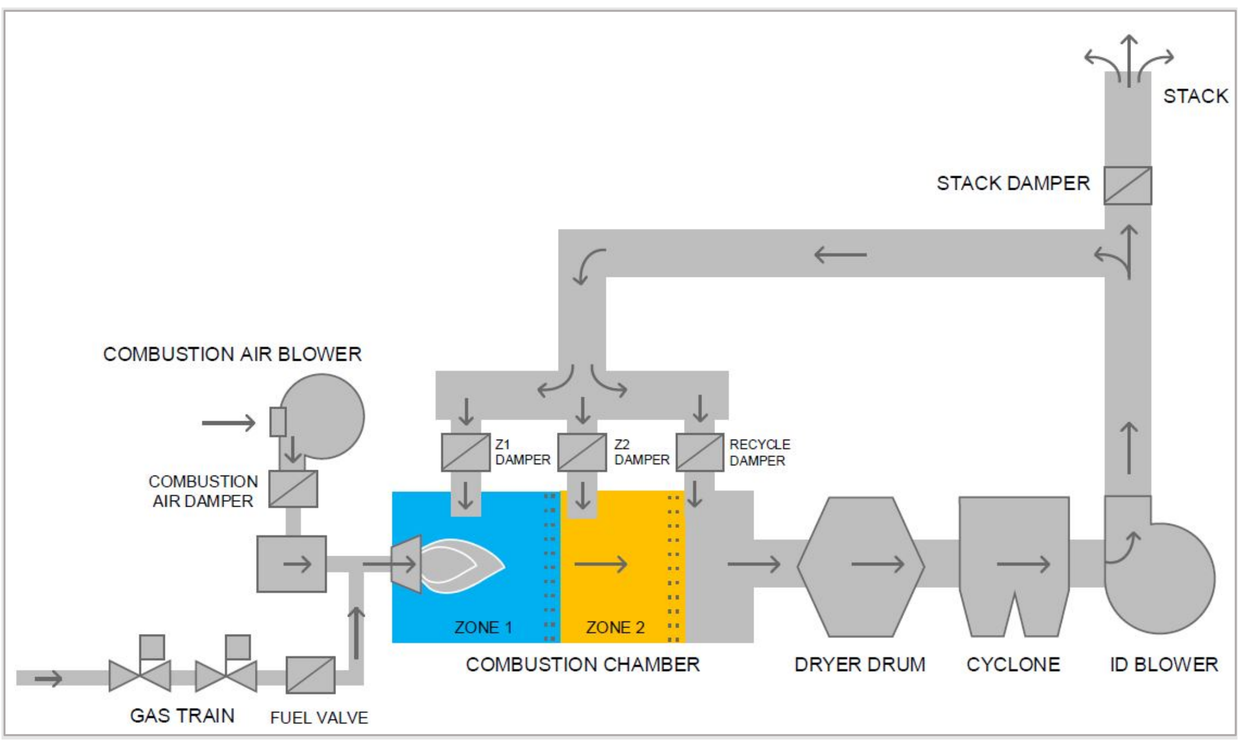
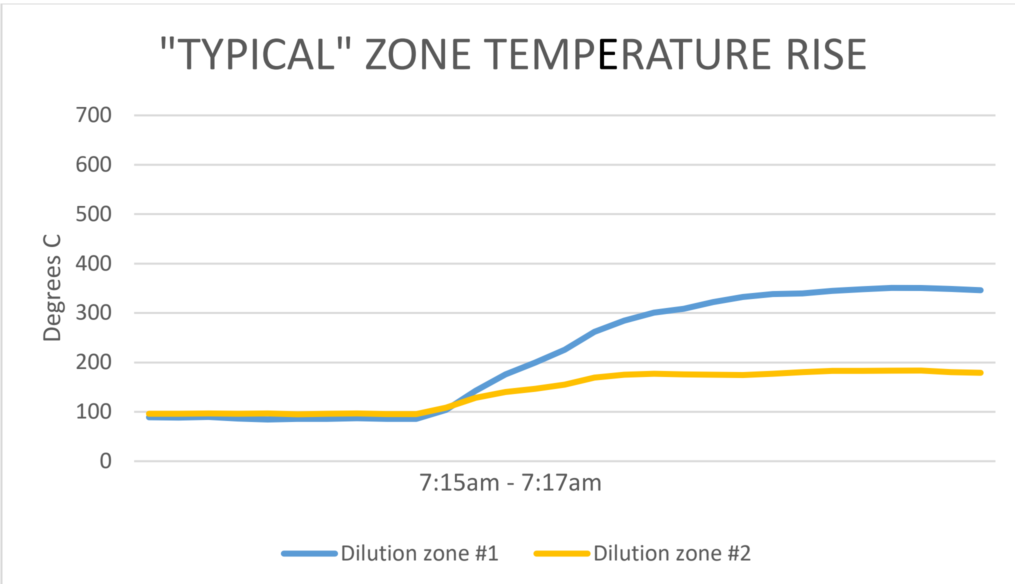


Image 2 - Highlighting the location of combustion chamber dilution zones # 1&2

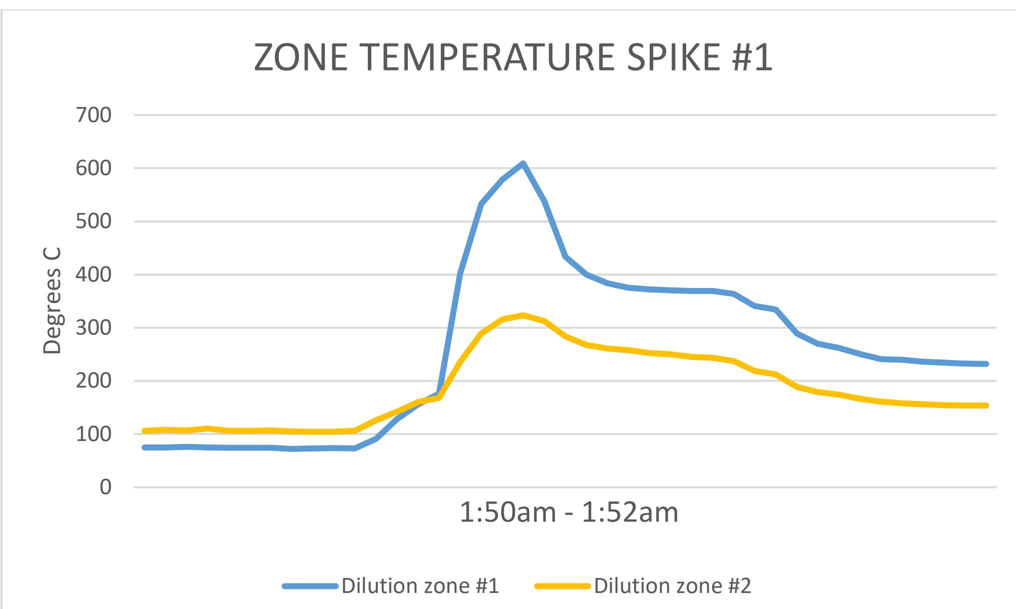
The data in graphs 1 through 3 show the temperatures in the combustion chamber during a typical burner restart cycle, compared to the atypical conditions prior to the explosion incident.

The data in Graph 1 represents the ignition of the main burner but before burner input is increased above 0% (low fire start).



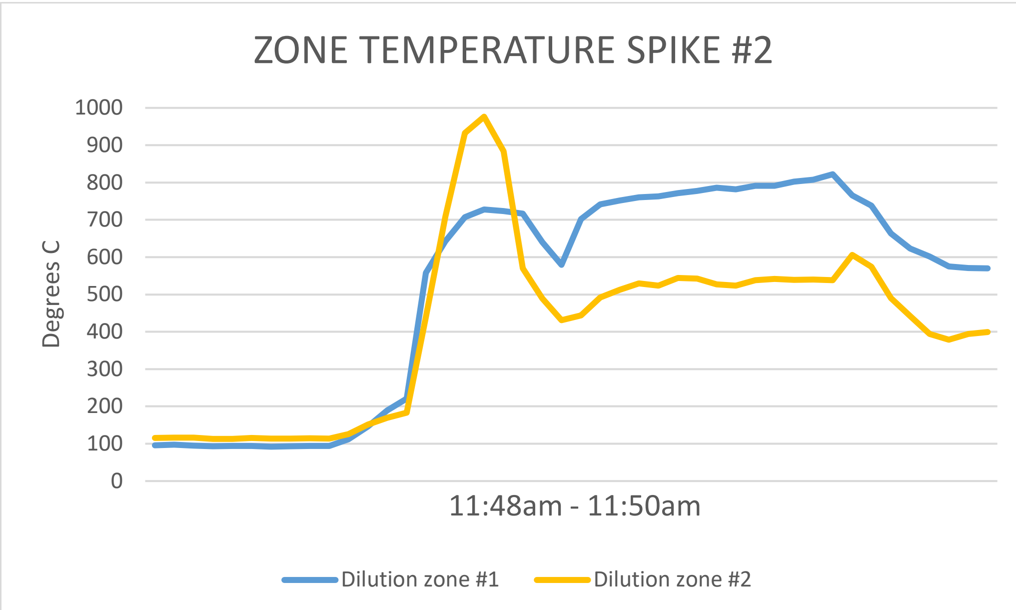
Graph 1 - 11/24/2020 Temperature rise in the combustion chamber dilution zones during a “typical” burner restart.

The data in Graph 2 represents the ignition of the main burner but before burner input is increased above 0% (low fire start). The temperature in zone #1 spiked abnormally high and needed to be controlled by manual airflow adjustments by the plant operator in the burner dilution zones.



Graph 2 – 11/25/2020 Temperature rise in the combustion chamber dilution zones during the burner restart that occurred during the night shift before the incident.

The data in Graph 3 represents the ignition of the main burner but before burner input is increased above 0% (low fire start). The temperature in zone #1 spiked abnormally high and the temperature in zone #2 exceeded the zone #1 temperature and needed to be controlled by manual airflow adjustments by the plant operator in the burner dilution zones.



Graph 3 - Temperature rise in the combustion chamber dilution zones during the burner restart that occurred 4 minutes before the explosion.

2.3 Burner Operation Timeline

Data extracted from the HMI system provided a chronological account of burner operational settings, Table 2.

The Timeline shows the steps taken during the three shutdown and restarts of the burner which occurred in the 19 hours leading up to the incident

11/24 6:28am	Burner turndown (2% input)
11/24 6:53am	Burner shutdown
11/24 7:06am	Burner purge initiated
11/24 7:15am	Burner restart
11/24 7:20am	Burner RTM (Start of incremental warmup)
11/24 9:04am	Burner input modulation (production)

11/25 1:04am	Burner shutdown (Input from 40% to 0%)
11/25 1:40am	Burner purge initiated
11/25 1:49am	Burner restart
11/25 1:54am	Burner RTM (Start of incremental warmup)
11/25 2:25am	Burner input modulation (production)
11/25 11:15am	Burner shutdown (Input from 40% to 0%)
11/25 11:39am	Burner purge initiated
11/25 11:48am	Burner restart
11/25 11:50am	Burner RTM start of incremental warmup (Burner 5% input)
11/25 11:54am	Explosion

Table 2: BURNER OPERATION TIMELINE (HMI Data uncorrected time setting)

Image 3 showing locations of dilution zone and recycle air dampers. (TE) represents the location of the temperature probes for dilution zones 1&2.

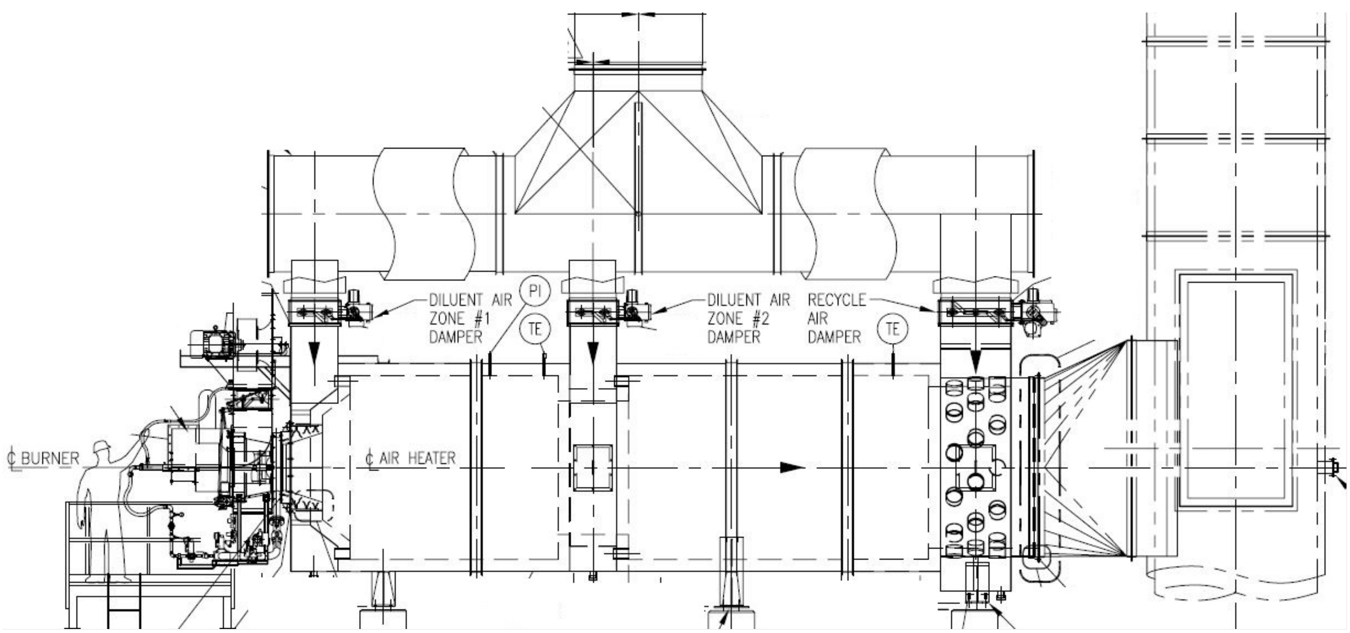


Image 3 - Burner and combustion chamber detail (From drawing CAN06-DM-101 provided by manufacturer)

Video surveillance footage of the equipment involved was reviewed. Still images from the video show that the initial explosion originated between the burner and the dryer drum, (Image 4). A secondary explosion and fireball occurred at the cyclone dust collection system.

Video still images also show the progression of the explosion and subsequent fireball due to ignition of combustible dust, (Image 5).

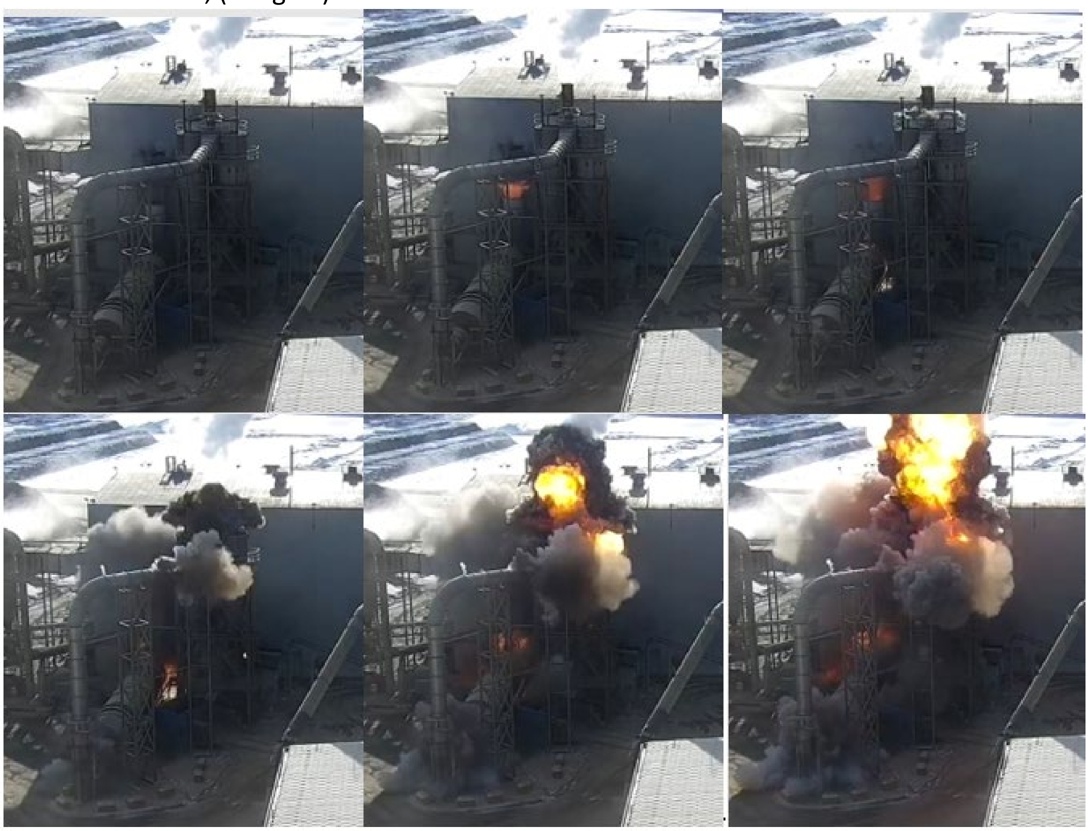


Image 4 – Video still images show origin of initial explosion (burner/dryer drum) and secondary explosion/fireball at the cyclone dust collection system.

Image 5 – Video still images show progression of explosion and subsequent combustible dust fireball.

3.0 SUMMARY

Major findings identified by this investigation are summarized below

A. The incident was found to be due to ignition of natural gas that collected in the system due to incorrect governing of air and fuel volumes and pressure conditions in the combustion chamber.

B. The cause of the incident was found to be due to the following:
   i. Failure to conduct routine inspection, testing and maintenance of the gas train, air control components and combustion systems, and
   ii. Management decisions to repeatedly restart and continue operation of the air heater when known upset conditions continued to occur were the cause of the incident.

C. Combustible dust is present in the ductwork and collection system. The initial explosion disturbed the combustible dust causing it to be airborne within the duct. The airborne dust then ignited causing a secondary dust explosion and fireball. The ancillary dust explosion and fireball may have been prevented through the use of explosion isolation systems including isolation dampers, valves or barriers.