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INCIDENT INVESTIGATION REPORT

Type of occurrence
Explosion

Notice of incident number	Incident outcome	Date of incident
2014140710119	**INJURY × 3**	**October 9, 2014**
Location of incident **Pinnacle Pellet Plant** **22075 Hwy 16 East** **Burns Lake, B.C.**	Lead investigator **Brent Farnsworth**	Investigation file number **2014-0109**
Approved by manager, Fatal and Serious Injury Investigations **Kenneth Bradley**	Signature K Bradley	Date October 24, 2015

PARTIES INVOLVED IN INCIDENT

Employer	Name and address **Black Fox Enterprises Ltd.** **20053 Farewell Creek Road** **Telkwa BC V0J 2X2**	Employer ID **769543**	Industry classification **764028** **Heavy Equipment, Machinery, or Parts Sales, Rental, Service, or Repair**
Workers	[redacted]	**Injured**	Occupation **Labourer**
	[redacted]	**Injured**	Occupation **Labourer**
	[redacted]	**Injured**	Occupation **Labourer**
Employer	Name and address **Pinnacle Renewable Energy Inc.** **Unit 350 3600 Lysander Lane** **Richmond BC V7B 1C3**	Employer ID **867025**	Industry classification **714019** **Pressed Board Manufacture**
Employer	Name and address **Advanced Millwright Services Ltd.** **PO Box 1743** **Vanderhoof BC V0J 3A0**	Employer ID **769803**	Industry classification **764028** **Heavy Equipment, Machinery, or Parts Sales, Rental, Service, or Repair**

Persons mentioned in report

Name	Known in the report as	Role in the incident/investigation
	Labourer 1	Assisted Pinnacle Renewable Energy Inc. (Pinnacle) labourers with cleaning burner no. 1. Employed by Black Fox Enterprises Ltd.
	Labourer 2	Assisted Pinnacle labourers with cleaning burner no. 1. Employed by Black Fox Enterprises.
	Labourer 3	Assisted Pinnacle labourers with cleaning burner no. 1. Employed by Black Fox Enterprises.
	Night Shift Operator	Was the control room operator during the night shift before the incident. Employed by Pinnacle.
	Day Shift Operator	Was the control room operator at the time of the incident. Was assigned to clean the burner in the no. 2 dryer system. Employed by Pinnacle.
	Production Superintendent	Was in charge of the cleanup crew, consisting of Pinnacle and Black Fox Enterprises workers. Employed by Pinnacle.
	Welder	Was assigned to repair the discharge pipe on the no. 1 dryer system. Employed by Advanced Millwright Services Ltd.
	Lead Hand	Showed the Welder where the main switch for the induced draft fan was located. Employed by Black Fox Enterprises.
	Cleanup Worker 1	Provided information about Pinnacle's burner cleanout process to WorkSafeBC investigators. Employed by Pinnacle.
	Cleanup Worker 2	Provided information about Pinnacle's burner cleanout process to WorkSafeBC investigators. Employed by Pinnacle.

Scope

This incident investigation report sets out WorkSafeBC's findings with respect to the cause and underlying factors leading to the workplace incident that occurred on October 9, 2014, at Pinnacle Renewable Energy Inc.'s pellet plant in Burns Lake, British Columbia. The purpose of this report is to identify and communicate the findings of this incident investigation to support future preventive actions by industry and WorkSafeBC.

This investigation report includes some of the enforcement action taken under the *Workers Compensation Act* and the Occupational Health and Safety Regulation as a result of the investigation and in response to the incident. Regulatory compliance activities may be summarized here but will be documented separately.

How the Investigation Was Conducted

WorkSafeBC's Investigations Department conducts health and safety investigations using a methodology that involves collecting information from various sources to understand the facts and circumstances of the incident and analyzing that information to identify causal and underlying factors that led to the incident.

The field investigation generally includes the following:

- Securing and examining the incident site, including any equipment involved
- Taking notes and photographs
- Interviewing people with relevant information, such as employer representatives, supervisors, workers, and witnesses
- Collecting documents such as equipment operating manuals, written procedures, and training records
- Conducting tests of materials or equipment, if necessary

The analysis of the information usually includes the following:

- Determining a sequence of events
- Examining significant events for unsafe acts and conditions
- Exploring the underlying factors that made the unsafe act or condition possible
- Identifying health and safety deficiencies

Table of Contents

1 Incident details

1.1 Incident synopsis

On October 9, 2014, during maintenance shutdown at a wood pellet plant, three workers were standing at the opening of a burner door when an explosion occurred in the dryer system. The three workers were knocked backwards by the force of the explosion and suffered burn injuries.

1.2 Firms

1.2.1 Pinnacle Renewable Energy Inc.

Pinnacle Renewable Energy Inc. (Pinnacle) produces softwood pellet fuel at six mill locations around the province. All of these mills operate 24 hours a day, 7 days a week, in two 12-hour shifts. The incident occurred at the Burns Lake mill site, which shuts down once a week for maintenance and cleanup.

1.2.2 Black Fox Enterprises Ltd.

Black Fox Enterprises Ltd. is a local mill-servicing firm that Pinnacle contracted to provide labourers and tradespeople to assist with the maintenance and cleanup work. The three injured workers were labourers employed by Black Fox Enterprises. Labourer 1, Labourer 2, and Labourer 3 all had previous experience doing this type of cleanup work. They were being supervised at the time by the Production Superintendent, who was employed by Pinnacle.

1.2.3 Advanced Millwright Services Ltd.

Advanced Millwright Services Ltd. is a local firm that provided Pinnacle and other wood products manufacturing plants with millwright servicing. One worker from the firm was directly involved in the incident: the Welder, who was familiar with the maintenance work he was performing. Advanced Millwright Services had supervision on site for its own workers.

1.3 Production of fuel pellets

To produce the fuel pellets, the wood waste (which includes chips and other debris) first has to be dried. The wet wood waste is fed into a large rotary dryer drum, where it is separated, agitated, and moved through the drum by internal vanes and airflow. The dry wood waste is carried out of the dryer by the airflow through ducting to a cyclone, where the heavier material is separated. This wood waste is then conveyed back into another area of the mill for grinding to size and processing into pellets.

The Pinnacle mill uses two dryer systems (or streams). The incident occurred at dryer no. 1, and this report will deal only with the associated equipment at that location (see Figure 1).

The burner in the no. 1 dryer system was an M-E-C TherMec pressurized shell burner located at one end of the rotary drum. This burner comprises two combustion chambers — primary and secondary — where other wood waste (fuel) is burnt to produce heat. Combustion is initiated by propane, which then remains running at a low level, like a pilot light. The combustion in the burner and the heat that enters the dryer system are controlled by regulating the airflow and the feed rate of the wood fuel.

Unbalanced airflow either lowers or increases combustion temperature. With higher temperatures, there is a greater risk of fire throughout the system. With lower temperatures, the wood waste will not dry adequately. The airflow through the dryer is controlled by the speed of the induced draft (I.D.) fan and duct damper position.

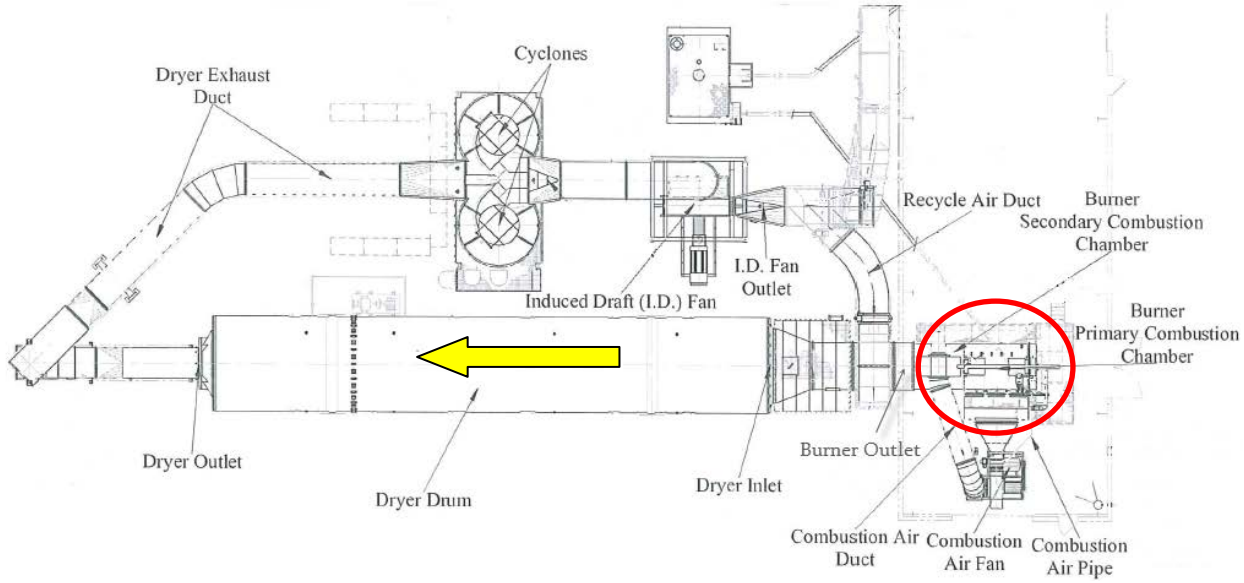

Figure 1: *Plan view of the no. 1 dryer system. The burner is circled. The yellow arrow indicates the direction of the flow of the wood waste. (Source: Pinnacle Renewable Energy Inc.)*

The entire dryer system is controlled by a computer system that interacts with personnel in the mill's control room with a display known as the human-machine interface (HMI). Temperatures at the burner outlet and dryer are read from the HMI monitor in the control room. Multiple safety devices including spark detection and water deluge nozzles are installed throughout the system.

A buildup of slag and ash occurs in the combustion chambers as a result of the burning process. This slag and ash must be removed on a weekly basis, which is what was occurring on the day of the incident. The removal process requires workers to enter both the primary and secondary combustion chambers to remove the slag and ash.

1.4 Sequence of events

On the morning of the incident, the Night Shift Operator, who works in the control room monitoring all production and alarm conditions on the HMI monitors, was preparing for the weekly shutdown. At approximately 04:30, the HMI indicated an alarm condition (equipment breakdown, high temperature, or some other upset condition) at dryer no. 2. The Night Shift Operator shut down the no. 2 dryer system. Some remaining wet wood waste from this system was then sent over to dryer no. 1. This caused the shutdown process for dryer no. 1 to be delayed.

At 04:39 and again at 05:08, the HMI system recorded a high temperature spike in dryer no. 1, which triggered an automatic water deluge process to cool the temperature in the dryer. The I.D. fan continued to circulate air through the no. 1 dryer system.

At 05:12, the Night Shift Operator initiated the dryer no. 1 burner shutdown sequence by pressing a shutdown/cool-down button on the HMI screen. The computer system shut off the propane fuel to the burner and closed the damper to the combustion air duct. The computer system then started a timed water deluge to cool three significant areas of the system (shown above in Figure 1): the dryer inlet, which had to drop below 100°C; the dryer outlet, which had to drop below 55°C; and the recycle air duct, which had to drop below 55°C. These three temperatures have to be reached before the system goes into a 30-minute wait period with no water deluge cooling, intended to confirm that there are no hot spots or fires in the dryer system.

At 06:26, the HMI recorded another high temperature spike in the recycle air duct. The water deluge system activated, and the I.D. fan continued to circulate air.

At 07:00, the temperature of the burner outlet (between the burner and the dryer inlet) was recorded as being 406°C. Also at 07:00, there was a shift change. The Day Shift Operator remained in the control room. All other workers on the day shift — including the contractors (there were five on site) — attended a safety meeting and were assigned their work activities. Pinnacle's usual shift supervisor was on vacation, so the Production Superintendent was in charge of the burner cleanup activities.

At 07:08, the Day Shift Operator turned off the combustion air fan. The temperature of the burner outlet was recorded at 390°C. Pinnacle's procedures require the temperature of the burner outlet to cool down to below 80°C before shutting down the combustion air fan.

At 07:09, the Day Shift Operator turned the speed of the I.D. fan on dryer no. 1 down to 30% in preparation for workers to enter the burner and begin cleaning out the primary combustion chamber. This low speed allows the airflow to continuously circulate through the system and prevents airflow from exiting through the opened burner door. Normal operating speed is 75% to 85%.

At 07:30, the Production Superintendent told the Day Shift Operator to assist in the cleanout process at dryer no. 2, and then left the control room to conduct a new worker orientation. The Day Shift Operator went to dryer no. 2 as directed by the Production Superintendent. No Pinnacle personnel remained in the control room to monitor the shutdown of dryer no. 1 on the HMI system. The I.D. fan was still operating, and the drum in dryer no. 1 was still energized and rotating at this time.

At 07:31, two Pinnacle labourers unbolted the dryer no. 1 burner door, removed it from the burner, and slid the door out of the way to allow worker access in preparation for cleanout of the interior of the combustion chamber (see Figure 2). The burner outlet temperature was recorded as being 358°C. The Production Superintendent went down to inspect the condition of both burners and to verify the burner lockout prior to cleanup.

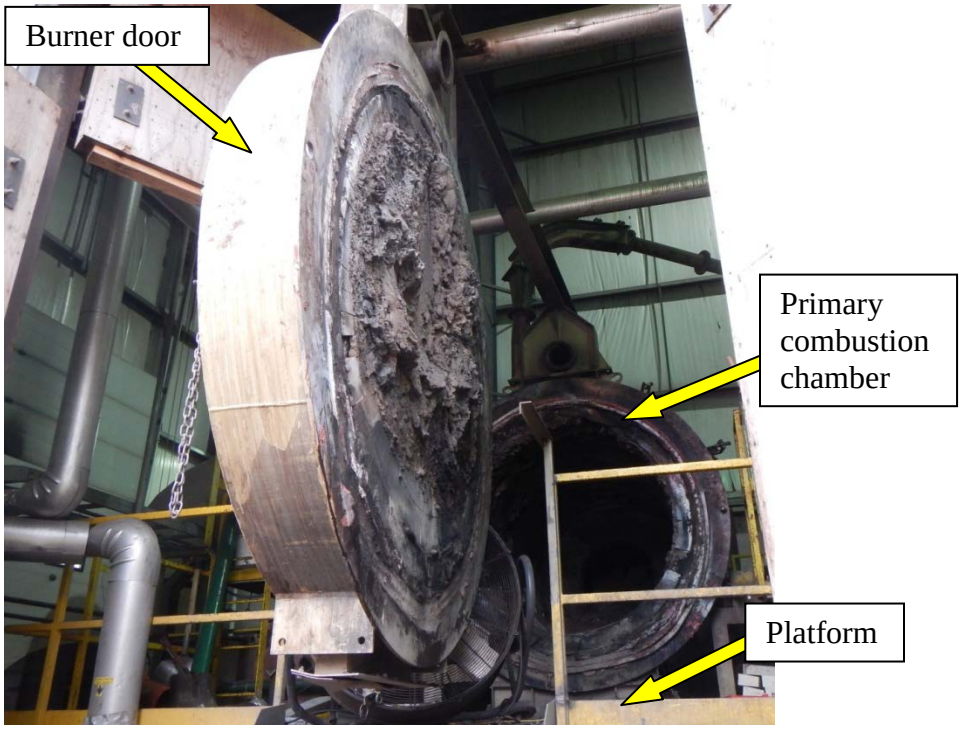

Figure 2: *The opened door of dryer no. 1's burner and its primary combustion chamber.*

At 07:39, the two Pinnacle labourers began cleaning out the primary combustion chamber of the burner. At 07:44, Labourer 1 came to assist in cleaning the burner. Evidence confirms the preparation and cleaning out of the front portion of the burner. The burner outlet temperature during the cleanup process had dropped to 324°C.

Between 08:00 and 08:16, the Welder was preparing to patch the ducting above dryer no. 1. He discussed the lockout procedures with the Lead Hand, who showed him where the motor control centre (MCC) switch for the I.D. fan is located. The I.D. fan was still operating at 30%. To

perform his work safely, the Welder needed the I.D. fan shut down and locked out. Neither the Welder nor the Lead Hand consulted with the Production Superintendent, who was in charge of the cleanup as well as locking out other components of the dryer systems. Pinnacle's lockout procedure is a group lockout that is to be done by two trained workers. This procedure allows several pieces of equipment to be locked out in a group. Once all the equipment is locked out, the keys are placed into a lockbox, which is also locked. This allows other workers or contractors to place only one lock on the lockbox so that they can safely work on equipment in that group.

At 08:19, the burner was clean, and all workers left the area.

At 08:24, the Welder shut down the I.D. fan at the MCC switch and locked the switch out. Airflow through the dryer no. 1 system slowed and stopped.

The Day Shift Operator was still working at the dryer no. 2 location. No one was monitoring the HMI screen. At 08:25, the computer system recorded a temperature spike to 162°C in the recycle air ducting. Also at 08:25, Labourer 1, Labourer 2, and Labourer 3 were at the dryer no. 1 burner opening and were about to place a portable fan at the burner door. Steam suddenly emerged from the burner, and the three workers backed away from the burner opening. The steam was likely caused by the automated spark detection and water deluge system detecting and spraying a hot spot in the dryer system.

At 08:27, the Production Superintendent was walking by the dryer drum when he observed smoke coming out of the dryer inlet expansion joints. He began yelling for the workers to get out of the burner building. At about the same time, Labourer 1, Labourer 2, and Labourer 3 placed the de-energized portable fan in the burner's combustion chamber. Then, smoke and steam were sucked back into the burner, and an explosion occurred. The three labourers were knocked off the burner access platform by the blast. All three suffered burns and bruising injuries.

2 Findings

2.1 Production process creates flammable gases

It was determined that flammable gases in the dryer system were ignited by high temperatures and caused the explosion.

Wood is used as fuel in the dryer's burner to produce heat to dry the wood waste in the dryer system. Forced air ventilation is supplied to provide oxygen for combustion and the drying air in the system. The heating of wood creates combustion products and gases, which include the flammable gases carbon monoxide and hydrogen. Typically ignition of the flammable gases can occur between 280° and 500°C. At high temperatures, as in the dryer burner, wood is completely burnt, and the flammable gases are consumed and do not accumulate. Under normal conditions in the rest of the dryer system, the gases from the heated wood waste are not at a sufficient

temperature and concentration to ignite. Ignition of the flammable gases can occur anywhere in the dryer system if they have accumulated to a sufficient concentration, if a supply of oxygen is available to support combustion, and if the gases are exposed to a high enough temperature source. If the gases ignite in a confined area, an explosion may occur.

During typical operations, these gases travel and are dispersed and diluted through the dryer system; this dilution is controlled by airflow. The airflow is provided by both the combustion air fan and the I.D. fan. Prior to the incident occurring, when the door to the burner's combustion chamber was initially opened, the combustion air fan was shut down but the I.D. fan was still running. This maintained airflow in the system. When the I.D. fan was shut down, the airflow stopped and allowed the flammable gases to accumulate in the dryer system. Also, with the airflow stopped prematurely, the dryer temperature to started increase significantly.

Labourer 1, Labourer 2, and Labourer 3 were in the doorway of the burner at the time of the explosion. They reported that there was a sudden intake of air into the combustion chamber and then the explosion occurred. This sudden intake of air is consistent with an oxygen-deprived fire, believed to be located in the recycle air ducting. With the rising temperatures in the system and the fresh supply of oxygen through the open burner door, the flammable gases ignited. This ignition in the contained dryer system led to an explosion, injuring the three workers.

2.2 Dryer no. 1 system cool-down process

The manufacturer's "Operating Safety Instructions" for the dryer systems were available at the Pinnacle mill but were not incorporated into the written safe work procedures. The "Maintenance" section of these instructions states: "Extreme care should be taken when opening the burner door for cleaning. Allow the burner to cool with combustion air fan running for 3 hours before opening the burner door." The "Operating Safety Instructions" section includes these instructions: "Care should be taken when opening the burner door for cleaning. It should be opened only after it has cooled for 3 hours, as described in the 'Operation' section of this manual." The instructions further state that the "timer will be activated to run combustion air fan motor and provide a cooling down period for the burner and refractory." This three-hour wait time allows for adequate cooling of the entire system once the system is shut down. None of the workers or managers interviewed was aware of this requirement. Pinnacle's "Dryer Shutdown Process" states that "the cooldown process is the most vulnerable operating mode of the dryer" and that "an abundance of air can cause any smoldering creosote in dryer ducts to flare up."

The cool-down process starts when the burner reaches a low fire rate and the wood fuel delivery stops. Burner no. 1's wood fuel auger was shut off at 05:12. The combustion air fan was shut down at 07:08, one full hour before the manufacturer's instruction of a three-hour cool-down, which should have continued until 08:12 at the earliest.

Pinnacle's "Standard Operating Procedure — Burner Clean Out" states that the burner temperature must be under 80°C before shutting off the combustion air fan, and then a lockout procedure must be followed prior to opening the burner door. The combustion air fan was shut

down before the 80°C criterion was met; the temperature of the burner outlet was recorded as 390°C at 07:08. This is almost five times higher than Pinnacle's own criterion. Shutting down the combustion air fan reduced the airflow. Leaving this fan on would have expedited the cooling process in the burner chamber.

Pinnacle had previously assessed the no. 1 burner combustion chamber and determined it not to be a confined space, but entry for cleanout required "critical safe work procedures" and an entry plan. Specifically, once the burner door had been opened, the temperature at the back of the burner needed to be below 35°C before entry by a worker. This was to be measured with an infrared temperature-sensing heat gun, but Cleanup Worker 1 reported that the heat gun could only measure the slag temperature and not the air temperature in the burner. Cleanup Worker 2 had used the thermal gun to test the slag temperature . He stated that the control room provides the burner temperature before the door to the burner is removed, but the burner outlet temperature at 07:31 was still 358°C when the no. 1 burner door was unbolted.

The I.D. fan had been off for approximately four minutes at the time of the explosion. The I.D. fan was locked out by the Welder contrary to Pinnacle's procedure as it is written (Lock Out Procedure #CS-113-A-1 Group Lock Out) and as explained to WorkSafeBC investigators by the Production Superintendent, who was responsible for conducting the group lockout on the day of the incident. Although the Lead Hand showed the Welder where the I.D. fan's MCC switch was located, he did not ensure that the Welder understood that his lock should be applied only to the group lockout box after the group lockout was completed by the Production Superintendent, and not on the ID fan's MCC switch.

The I.D. fan is monitored by the control room operator. Once the Production Superintendent tells the operator to shut off the I.D. fan, the operator ensures that a certain temperature criterion is met and then shuts this fan down. In this case, the Day Shift Operator was not in the control room monitoring the system, and the Welder turned this fan off at the MCC switch. This defeated the control room safety systems.

With the I.D. fan off, the water deluge safety system's effectiveness was reduced as it relies on the airflow to draw the water spray through the system to cool it. When the fan is off, the water sprays at the nozzle locations only and does not get dispersed throughout the system. When the I.D. fan was shut down early, the air circulation was reduced and the flammable gases accumulated rather than being diluted throughout the dryer system. The lack of air circulation also prevented the water deluge system from functioning effectively to cool the hot temperature spikes, which allowed temperatures to rise in the dryer system to the degree that the flammable gases ignited.

2.3 Failure to monitor the dryer system

The Day Shift Operator had been doing maintenance work at the dryer no. 2 system as directed by the Production Superintendent. He was returning to the control room when the explosion occurred. Pinnacle's "Burns Lake HMI Start Up/Shut Down Instructions" clearly state: "*WARNING: Keep a close eye on the dryer temperatures during this [cool-down] process.*"

The control room operator's responsibilities typically include monitoring temperature changes and implementing safety control functions using the HMI system. When the Day Shift Operator was reassigned to work in another area of the mill, he could not monitor and react to the temperature changes and alarms or other hazardous situations that were occurring within the system, such as when the I.D. fan was shut down. This resulted in high temperatures and fires being able to develop in the system, which, combined with the lack of air circulation, prevented the removal of flammable gases.

The HMI safety systems of the dryer were not monitored, and this allowed the explosion to occur.

3 Conclusions

3.1 Cause

3.1.1 Flammable gases accumulated and exploded

An accumulation of flammable gases in a contained dryer system was exposed to high temperatures and oxygen, leading to an explosion. A fire or hot spot was present in the system, and with the burner door open, an in-rush of oxygen occurred, resulting in an explosion that injured Labourer 1, Labourer 2, and Labourer 3.

3.2 Underlying factors

3.2.1 Not following procedures to permit adequate cooling time

Pinnacle's written procedure for burner cleanout was not followed. The combustion air fan was turned off before the burner outlet cooled to 80°C. Also, the burner manufacturer's instructions were not followed; the instructions require the combustion air fan to remain on for three hours before the burner door is opened. By not incorporating the manufacturer's instructions, Pinnacle's procedures were not adequate to safely cool the dryer system. These two failures resulted in cleanup work being started in the combustion chamber while high temperatures were still present.

3.2.2 No operator in the control room

The Production Superintendent told the Day Shift Operator to assist with the cleanup, and the control room was left unattended. High temperatures developed within the system, and the Day Shift Operator was not in a position to monitor or control them.

3.2.3 Lack of effective coordination

The I.D. fan was shut down and locked out at the MCC switch by a contractor (the Welder) without the knowledge of the Production Superintendent or the Day Shift Operator. This resulted in temperatures rising in the system while workers were cleaning the burner. This fan shutdown should have been done in the control room by the control room operator, who could monitor when it was safe to do so, and then the group lockout should have been completed. Lack of coordination between the Production Superintendent, the Lead Hand, and the Welder were factors in this incident as well as the failure to effectively coordinate the control room operator's duties.