Investigation Report

Babine Forest Products – Explosion and Fire – January 20, 2012

BC Safety Authority – Incident Investigation – Jurisdiction and Role

The BC Safety Authority administers the *Safety Standards Act* on behalf of the Province of British Columbia.[1] The *Safety Standards Act* and associated *Regulations* apply to the following products and persons doing regulated work on these products:

(i) amusement devices;
(ii) passenger ropeways;
(iii) boilers and boiler systems;
(iv) electrical equipment;
(v) elevating devices and passenger conveyors;
(vi) gas systems and equipment;
(vii) pressure vessels;
(viii) pressure piping;
(ix) refrigeration systems and equipment; and
(x) any other regulated product specified in the regulations.

Incidents involving products or work subject to the *Safety Standards Act* are required to be reported in accordance with Section 36 of the *Act*. The BC Safety Authority investigates these incidents in accordance with Section 37 of the *Act* and may appoint persons to assist with an investigation.

The role of the BC Safety Authority with respect to the investigation of incidents is to understand relationships between incidents, equipment and work that are subject to the *Safety Standards Act*. It is our aim for these investigations to prevent the recurrence of similar incidents and to initiate improvements toward the management of safety risks with regulated equipment and work. Often, these investigations are conducted in cooperation with other agencies including the Fire Officials, WorksafeBC, the Police and the Coroners Service.

This investigation report does not address issues of enforcement action taken under the *Safety Standards Act*. Any regulatory compliance activities arising from this incident will be documented separately.

[1] Some municipalities administer portions of the *Safety Standards Act*. See reference 1 at the end of this report for more details.

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Incident Synopsis

On January 20, 2012 at approximately 8:07pm, an explosion and fire occurred in the Babine Forest Products sawmill located at 19479 Highway 16 East, approximately 20 kilometers East of the town of Burns Lake, British Columbia.

The explosion and fire caused two fatalities and injured 20 people. The sawmill was destroyed by the explosion and fire.

Summary

Safety Officers and a certified fire and explosion investigator from SAMAC Engineering Ltd. were dispatched by the BC Safety Authority to the sawmill site to identify equipment and systems subject to the *Safety Standards Act*, evaluate the role that this equipment or its operation may have had regarding the incident and to identify non-compliances with the relevant *Regulations*. WorksafeBC assumed the role of lead investigating agency, responsible for overall control of the site and evidence removed for evaluation.

The investigation identified two possible areas of origin for the explosion in the basement of the sawmill structure. SAMAC Engineering Ltd., contracted by the BC Safety Authority to provide fire and explosion expertise, identified an area below the band saw near a motor control centre. WorkSafeBC identified a possible area of origin in the basement near a waste conveyor motor. The BC Safety Authority accepts that the explosion may have initiated from either basement location.

Gas, boiler and pressure vessel equipment that would have contained or used a combustible gas, vapour or liquid was evaluated. From these evaluations it is concluded that a leak or release of natural gas, propane, ethylene glycol or thermal fluid from this equipment did not contribute to the explosion.

Wood dust was the only other fuel source known to be within either basement area that was capable of producing the explosion. The damage produced and the witness descriptions of the explosions were consistent with combustible wood dust as the explosive fuel. It is therefore concluded that wood dust fueled the explosion.

A single most likely ignition source for the wood dust explosion was not found during the investigation. A motor control centre and light assembly were identified as possible ignition sources. It was also identified that a pre-existing fire could have ignited the explosion. Electrical equipment in operation within the identified basement areas was neither approved nor configured for safe operation within a combustible dust environment. Therefore the normal operation of this electrical equipment presented possible ignition sources for either a fire or the explosion and their possible contribution to the incident could not be ruled out. It is also possible that equipment not subject to the *Safety Standards Act* presented possible ignition sources, however, other equipment was not the focus of the BC Safety Authority investigation.

Electrical and Gas codes classify areas containing combustible dust as *hazardous locations,* requiring specific precautions to be taken in order to manage potential ignition sources. Facility owners and operators can manage combustible dust hazards by preventing the development of combustion hazards and/or by configuring equipment to safely operate in the presence of the hazard. Where facility operators elect to manage combustible dust instead of implementing *hazardous location* equipment configurations, these activities must be sustained such that a non-hazardous environment is always maintained.

At the time of the incident, the areas within the basement where the explosion originated were *hazardous locations* as defined by the electrical and gas codes due to the presence of combustible wood dust and operations that generated a suspension of wood dust in the atmosphere. At the time of the incident, equipment installed and in use within those areas was not certified for use or configured for *hazardous locations* containing combustible wood dust.

Configurations of electrical equipment were found that also did not comply with general installation code requirements. These configurations would have further increased the risk of electrical equipment acting as an ignition source for combustible wood dust.

The BC Safety Authority concludes the root cause of the incident to be the failure to effectively recognize and manage wood dust explosion hazards. This finding is based upon the:

- available wood dust explosion hazards, classifications and prevention standards material,
- history of fires at the site;
- evidence of wood dust found during the investigation;
- statements regarding the presence of wood dust at the facility by employees;
- conclusion that wood dust fueled the explosion, demonstrating the existence of *hazardous locations*; and
- configuration of electrical equipment for a 'non-hazardous' environment.

Owners and operators of wood processing facilities are responsible for the safe use of regulated electrical and gas equipment at their facilities, including the proper configuration of equipment used in *hazardous locations*. The safe use of equipment involves maintaining an environment that is suitable for regulated equipment. As a result of this incident and the investigation findings, the BC Safety Authority is considering ordering wood processing facility owners and operators to document an assessment of their facilities specifically for *hazardous locations* and effective hazard management. The assessment under consideration would be completed:

- by a professional that is qualified to identify combustible dust *hazardous locations*, and
- in accordance with a recognized industry standard for combustible dust *hazardous locations*.

The BC Safety Authority therefore makes the following recommendations to improve the identification and management of combustible dust *hazardous locations* by wood processing facility owners and operators.

Recommendations to Owners and Operators of Wood Processing Facilities:

Recommendation #1:
Document a facility assessment to identify *hazardous locations* that is completed:

- by a professional that is qualified to identify combustible dust *hazardous locations*, and
- in accordance with a recognized industry standard for combustible dust *hazardous locations*.

Recommendation #2:
Where *hazardous locations* are identified and contain regulated equipment, document a plan to either:

- develop and implement auditable wood dust management practices for these locations that are accepted by a qualified person as an effective means to manage the combustion hazard, or
- configure the equipment for safe operation given the presence of the combustible dust hazard. Safe operating configurations include:
    a) obtaining approval for operation in the *hazardous location,* or
    b) permanent removal of the equipment from the *hazardous location*.

Recommendation #3:
Incorporate any identified *hazardous locations* and the chosen means to manage the combustion hazards into the facility's *Fire Safety Plan*, or other suitable facility document(s).

Recommendations to the BC Office of the Fire Commissioner:

Recommendation #4:
Publish a list of professional qualifications suitable for individuals who identify wood dust combustion and explosion *hazardous locations* in an industrial environment.

Recommendation #5:
Identify suitable fire and explosion prevention guidance material to be used in BC for the identification and classification of *hazardous locations* due to combustible wood dusts.

Recommendation #6:
Add details of a qualified person and accepted guidance material related to *hazardous location* classification and management into the *Fire Safety Plan* requirements of the *BC Fire Code*.

Recommendations to the Canadian Standards Association:

Recommendation #7:
Specifically identify wood dust as a combustible dust belonging to group G dusts in section 18 of the *Canadian Electrical Code, Part 1*.

Recommendation #8:
Improve coordination between section 18 of the *Canadian Electrical Code* and referenced fire and explosion prevention standards for *hazardous location* identification and classification.

Recommendation #9:
Improve the natural gas and propane code requirements and accompanying guidance material relating to *hazardous location* identification and alignment with fire prevention standards.

Site Information

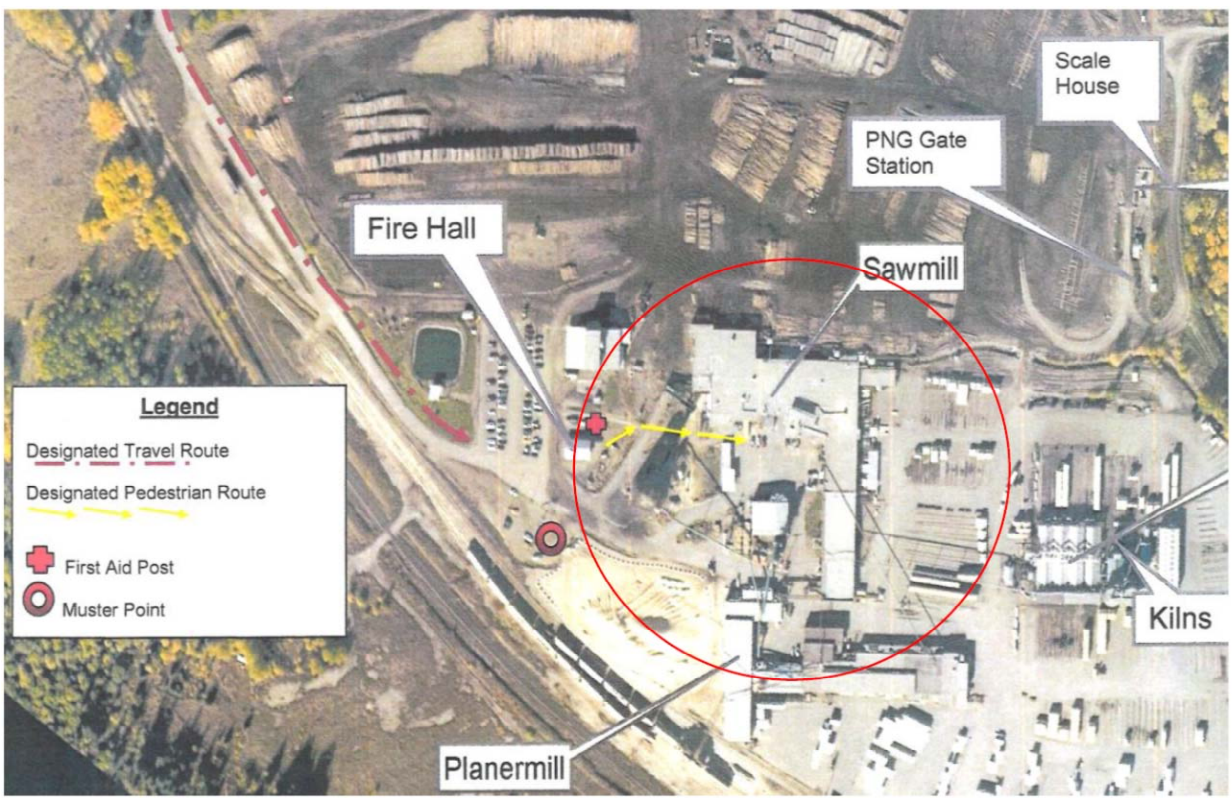
Overview of Site and Equipment Subject to the *Safety Standards Act*

Photograph 1 shows an aerial view of the Babine Forest Products site, which consisted of numerous buildings and structures including the sawmill. On January 20, 2012, the sawmill at Babine Forest Products site near Burns Lake utilized equipment that was subject to the *Safety Standards Act*.

Natural gas fuelled appliances, natural gas distribution components, propane storage, propane dispensing, portable propane cylinders and propane appliances were in use at the sawmill and are subject to the *Gas Safety Regulation*. These items are referred to as 'gas equipment' for the remainder of this report.

Boilers, pressure vessels and pressure piping systems were in use at the sawmill and are subject to the *Power Engineers, Boilers, Pressure Vessel and Refrigeration Safety Regulation*. These items are referred to as 'pressure equipment' for the remainder of this report.

Electrically powered appliances, electrical equipment, electrical signal and power distribution components were in use at the sawmill and are subject to the *Electrical Safety Regulation*. These items are referred to as 'electrical equipment' for the remainder of this report.



Photograph 1: Aerial view of the Babine Forest Products site prior to the explosion and fire of January 20th, 2012.

History of Fires at the Site

The BC Safety Authority investigated a fire that occurred at this site on February 23, 2011. It was concluded to have been fueled by wood dust within a motor control centre (MCC) cabinet and ignited by an electrical fuse failure.

Interview statements made by employees of Babine Forest Products indicate that a fire had occurred approximately two weeks prior to the explosion on January 20, 2012. It was stated that this fire was the result of hot work, such as welding, being conducted at the facility.

Employees stated that a fire, ignited by overheated roller bearings, had occurred within the sawmill on the day of the explosion (January 20, 2012). The fire was located in the Northwest section of the mill and was reported to be extinguished by approximately 5pm.

Employees stated that small fires at this mill were common. Reasons identified included:

- friction from moving parts combined with a dust buildup,
- electrical motor overheating due to dust build-up on cooling surfaces,
- small electrical sparks or arcs igniting wood dust,
- hot work, such as welding, within the building igniting wood dust.

Operating Environment at the Time of the Incident

In the days leading up to the incident, the outside temperatures at the facility were cold and dry. Average temperatures and humidity values for the Burns Lake region is summarized in Table 1 below.

Table 1: Average Temperature and Humidity

	Jan 16	Jan 17	Jan 18	Jan 19	Jan 20
Temperature* (°C)	-23	-31	-36	-34	-21
Relative Humidity* (%)	53	65	64	63	75

* Values stated are daily averages derived from hourly results obtained from the National Climate Data and Information Archive - www.climate.weatheroffice.gc.ca

The cold temperatures experienced in the days leading up to the incident resulted in the freezing of water and ethylene glycol within system pipes. Employees described activities that were being taken to thaw and repair burst pipes as well as to clean up leaked water while operations continued. Employees also stated that outside windows that were normally opened had been closed to improve internal heating.

Investigation

Safety Officers with expertise in gas, electrical and pressure equipment were dispatched to the sawmill site to identify equipment and systems subject to the *Safety Standards Act*, evaluate the role that this equipment or its operation may have had regarding the incident and to identify any non-compliances with the relevant regulations. An experienced and certified fire and explosion investigator (CFEI[2]) was contracted to assist the BC Safety Authority with the interpretation of explosion and fire damage and to assist with the investigation.

Explosion Areas of Origin

SAMAC Engineering Ltd. was contracted by the BC Safety Authority to provide fire and explosion investigation expertise. A possible area of explosion origin was identified in the basement below the band saw. This area's determination is discussed in the appended fire and explosion investigation report (Appendix A). WorkSafeBC identified a possible area of origin in the basement near a waste conveyor motor assembly labeled 8R-26[3]. On the evidence currently available, the BC Safety Authority accepts that the explosion could have originated from either of these areas. These areas are identified in Photograph 2.

BCSA investigation focused on equipment subject to the *Safety Standards Act* that:

1. could have supplied a fuel to the basement areas where the explosion originated, or
2. was located within the identified basement areas and could have ignited a fuel.

Photograph 2: Aerial view of the sawmill site after the explosion and fire of January 20, 2012. The circles indicate the possible areas within the basement where the explosion originated.

[2] CFEI is a professional designation granted to qualified persons by the (US) National Association of Fire Investigators (NAFI)

[3] This conveyor motor assembly was found labeled in the mill as 8R-26; however, mill drawings and documents identified it to be motor 8R-25. This report refers to this motor assembly as 8R-26 due to the mill labeling found. It is understood that this label could have been an error and the correct motor identification is 8R-25.

Fuel for the Explosion

Various combustible materials that could fuel an explosion were found within the basement area of the sawmill. Fuels that were found near the basement area under the band saw included natural gas, propane, thermal fluid, ethylene glycol and wood dust. Wood dust was found near the area of the conveyor motor assembly 8R-26.

Examination of appliances and associated piping using natural gas, propane, thermal fluid and ethylene glycol concluded that none of these fuels contributed to the initiating explosion. Detailed findings, discussion and conclusions relating to natural gas, propane and gas odor employee reports are contained in Appendix B. Findings, discussion and conclusions relating to thermal fluid and ethylene glycol system findings are detailed in Appendix C.

Wood dust samples from the sawmill were tested by WorkSafeBC to determine combustion and explosion characteristics. It was determined that wood dust accumulations at the facility presented a combustion and explosion hazard. Evidence of hazardous amounts of wood dust was found in both identified basement areas as well as throughout the sawmill. The cold and dry conditions listed in Table 1 may have increased the combustion and explosion risk of wood dust generated during the days preceding the incident. It is concluded that the explosion was fuelled by wood dust.

Wood Dust Explosions

"Dust explosions in industrial scenarios usually occur in a series. The initial ignition and explosion are most often less severe than subsequent secondary explosions. However, the first explosion puts additional dust into suspension, which results in additional explosions….In facilities such as grain elevators, these secondary explosions often progress from one area to another"[4]. Five conditions are generally required for a dust explosion to occur and these are represented as the dust explosion pentagon.

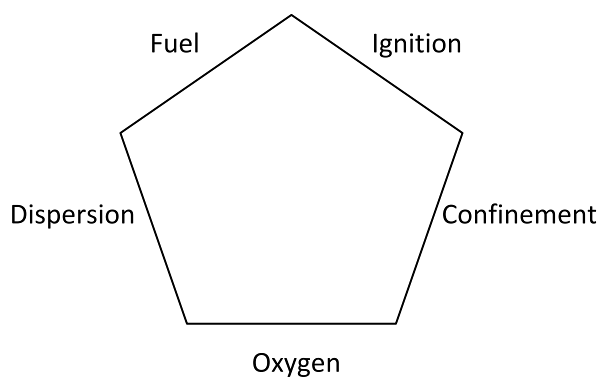


Figure 1: Dust explosion pentagon

<u>Fuel</u>
As discussed in the previous section, it was determined that wood dust fuelled the explosion at the sawmill.

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[4] (US) National Fire Prevention Association (NFPA) 921 – Guide for Fire & Explosion Investigations – section 21.9.7

Dispersion

A system of waste conveyors within the basement transported wood dust generated by the sawmill machinery and activity on the operating floor above to a location southwest of the sawmill structure. Waste conveyor systems are common in sawmills in British Columbia. The conveyor system was reported by employees during interviews to have contributed to wood dust dispersion at many locations within the basement, including both possible areas of origin. This system also provided a source of settled, or layered, wood dust available for dispersion and possible ignition. Employee interview statements indicate that this presence of wood dust was typical at the facility.

A dust blow-down operation was reported to have been completed at the band saw just prior to 8pm on the day of the incident. The blow-down operation removes wood dust by blowing compressed air over the machinery parts intended to be cleaned. The operation, as described by the employee, produced a dispersion of wood dust. This operation possibly added to a dispersion of wood dust in the area of the basement below the band saw.

Oxygen

The basement contained breathable air.

Confinement

The foundation structure combined with the placement of interior walls, conveyors and motor control cabinets within the basement provided locations where suspended wood dust would have been confined.

Employees stated during interviews that outside windows that were normally open were closed due to the cold weather, which may have increased the general containment of wood dust within the sawmill structure.

Ignition

There were many possible wood dust ignition sources within the sawmill basement. A single most likely ignition source for the wood dust explosion was not found during the investigation. A motor control centre and light assembly were identified as possible ignition sources. It was also identified that a pre-existing fire could have ignited the explosion. Electrical equipment in operation within the identified basement areas was neither approved nor configured for safe operation within a combustible dust environment. Therefore the normal operation of this electrical equipment presented possible ignition sources for either a fire or the explosion and their possible contribution to the incident could not be ruled out. These possible ignition sources are discussed further in this report.

It is also possible that equipment not subject to the *Safety Standards Act* presented possible ignition sources. Given the presence and mandate of WorksafeBC at this incident site, the BC Safety Authority only investigated possible ignition sources from equipment subject to the *Safety Standards Act.*

Electrical Ignition Hazards

The sawmill used numerous pieces of industrial equipment for its operation that were electrically powered. Control circuits and wiring between controls and equipment were located and routed throughout the facility. The sawmill facility also incorporated numerous electrical circuits to support basic utility infrastructure, such as lighting and general power distribution circuits with outlet receptacles. Normal operation or failures (e.g., fuse failure) of electrical equipment can produce a source of ignition unless specific mitigating precautions are taken for use in *hazardous locations*.

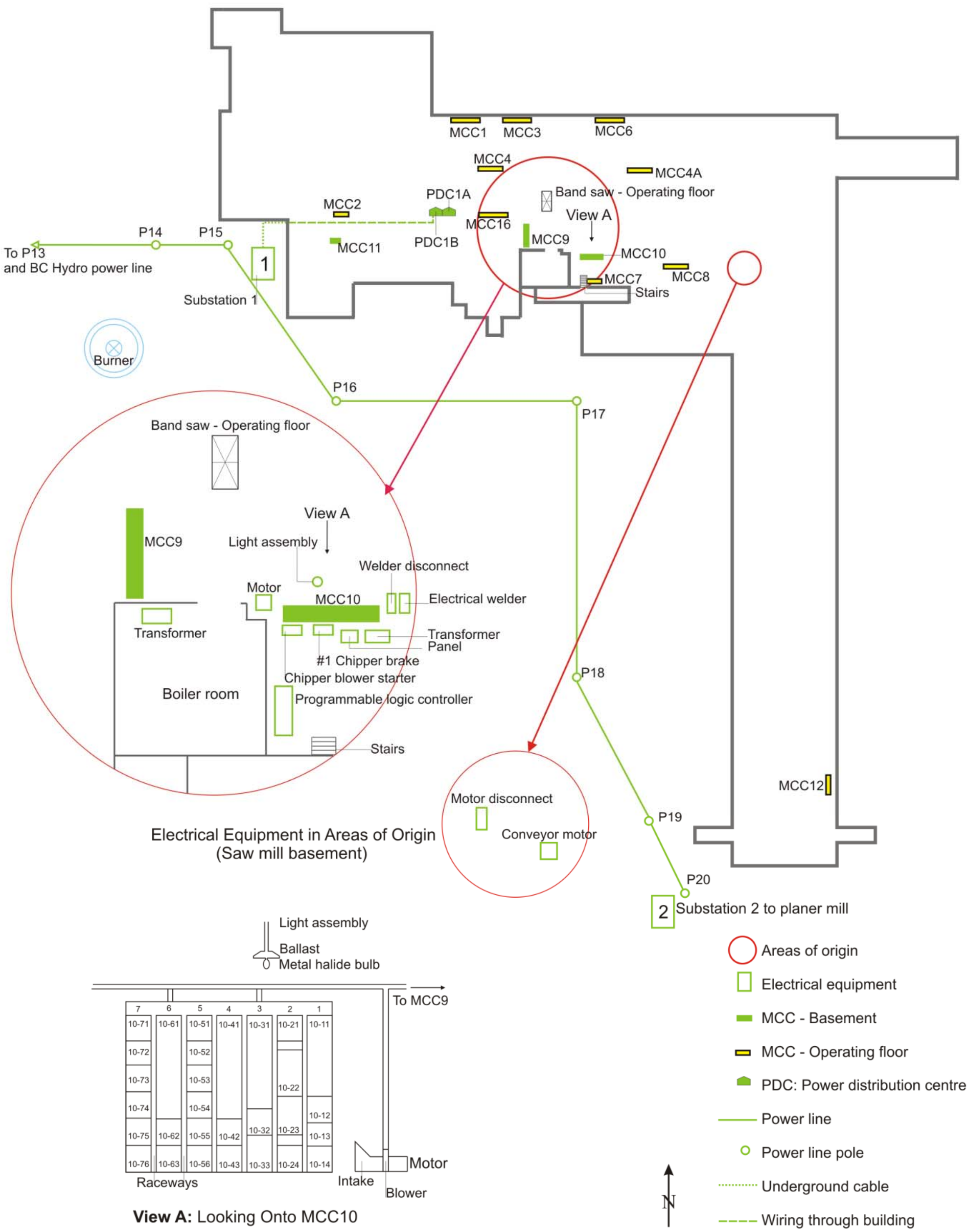


Figure 2: Plan view of mill - electrical equipment from supplied diagrams and investigation findings

Note: Figure 2 was produced from field observations and drawings provided by Babine Forest Products. Figures are intended for illustrative purposes only.

Electrical Equipment Found within the Possible Areas of Origin

The following electrical equipment was found within the possible areas of origin as illustrated in Figure 2:

- MCC #9
- MCC #10
- light assembly with metal halide bulb
- pressurization motor for MCC #9 and MCC #10
- electric welder and disconnect
- Programmable Logic Controller (PLC)
- lighting transformer
- panel
- chipper blower starter
- chipper #1 brake
- conveyor motor (8R-26)
- conveyor motor disconnect (8R-26)

Pressurization Motor for Motor Control Centre (MCC) #9 and MCC #10

Babine Forest Products employees stated that attempts were made to pressurize MCCs as a fire risk mitigation measure following a wood dust fire in February of 2011. The fire in February of 2011 started within an MCC in a different area of the sawmill. The intent was to keep dust out of the MCCs by maintaining a positive internal pressure, relative to the sawmill, from a supply of clean pressurized air from the blower motor. Employees stated that the pressurization system did not work as intended and was therefore not in use. The motor switch on the appliance was found in the ON position while the start/stop button on the motor disconnect switch was in the STOP position. The motor exhibited no evidence of arcing or electrical failure.

With the start/stop button in the STOP position, it is unlikely that the ventilation motor presented a source of ignition at the time of the incident.

Motor Control Centre (MCC) #9

MCC #9 was found to have all access doors in the closed and latched position. No evidence of arcing or electrical failure was observed internal to MCC #9 however cabinets closer to the ceiling exhibited evidence of internal fire. Wood dust was observed to be within the cabinets as shown in Photograph 3.

Clean pressurization air was not being supplied to MCC #9 and wood dust was found within the cabinets. Normal operation or failure of electrical equipment within MCC #9 are potential sources of ignition for a wood dust cloud or layer. MCC #9 was not identified as being a likely ignition source, however, wood dust found within MCC #9 presented a fire hazard.

Photograph 3: Example of wood dust accumulation in MCC #9

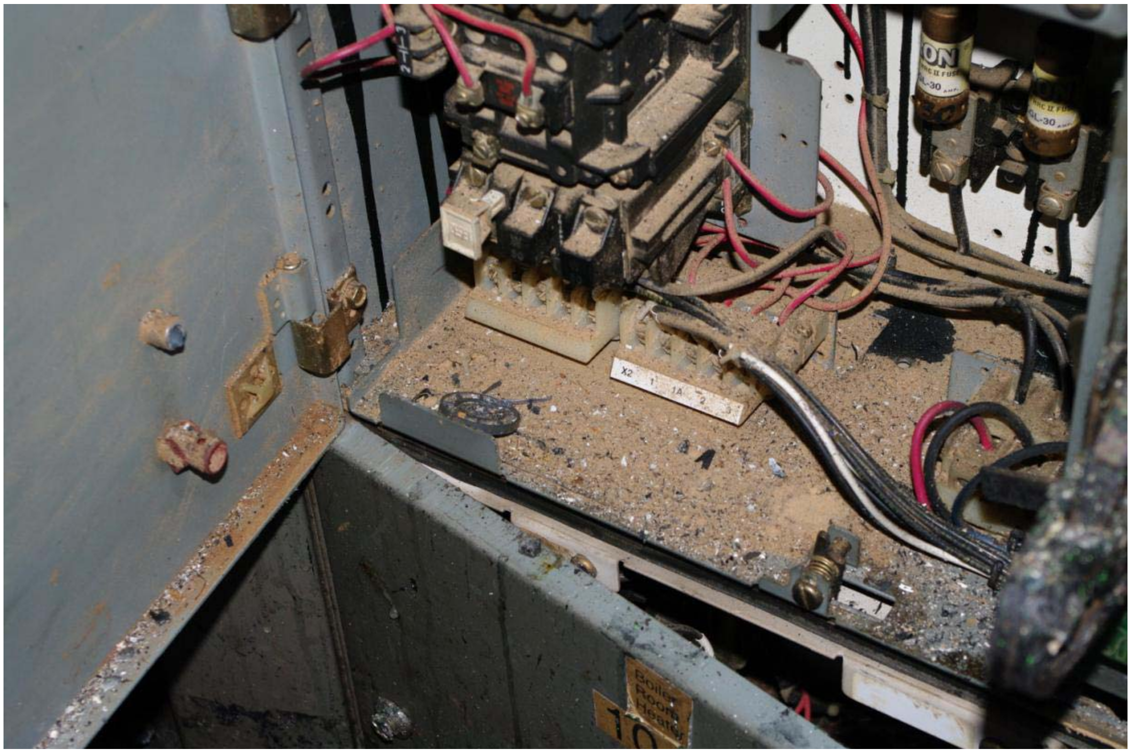
Motor Control Centre (MCC) #10

MCC #10 was found with cabinet access doors unlatched and doors to cabinets 10-11, 10-22, 10-61 and 10-71 in the open position. Wood dust was found within the cabinets as shown in Photograph 4. Electrical components within MCC #10 exhibited a greater amount and different pattern of fire damage than those within MCC #9. A possible fire or explosion from within MCC #10 was identified as a possible ignition source for the explosion (Appendix A).

Cabinet 10-31 contained six 400 MCM tap conductors feeding a breaker with one of the breaker lugs fractured and molten metal near the lug fracture as shown in Photograph 5. An evaluation was commissioned by WorksafeBC to review the fractured lug and molten material within cabinet 10-31 of MCC #10. It was communicated to BC Safety Authority investigators during this evaluation that the distribution of molten material was more consistent with a material that had dripped onto the lug rather than the result of an arc flash. The molten metal was analyzed and found to not be of the same composition as the lug material. As stated in appendix A, the position of MCC #10 had been shifted approximately 15cm south and 15cm east. This shift in position may have applied a mechanical load to the lug. It is more likely that the broken electrical feeder lug and molten material found deposited on the lug were a result of the explosion and fire rather than a cause.

Electrical motor control components can generate sparks during normal operation. MCC #10 contained numerous motor control components within its cabinets. Electrical equipment can also generate significant amounts of heat during normal operation. Hot spots on components can develop if cooling is impaired due to a layer or build-up of wood dust.

Clean pressurization air was not being supplied to MCC #10 and wood dust was found within the cabinets. Unsecured cabinet doors may have exposed electrical equipment to a combustible atmosphere outside of MCC #10. It is also possible that the cabinet doors were opened as a result of an explosion from within MCC #10. On the evidence currently available to the BC Safety Authority, the operation of or a failure of the electrical equipment within MCC #10 could have ignited a combustible cloud of wood dust that came into contact with it.



Photograph 4: Example of wood dust accumulation in MCC #10

Photograph 5: Fractured feeder lug in cabinet 10-31

400 Watt Metal Halide Light Bulb and Light Assembly

The light assembly shown in photographs 6 and 7 comprised of a ballast, 400 Watt metal halide bulb and a reflector. The reflector was found on the floor in front of MCC #10 and appeared to be an 'open' design, and no evidence of a shield was found in the area. The ballast and metal halide bulb were found in their installed locations above and in front of MCC #10, as shown in Figure 2 and Photographs 6 and 7. The bulb was intact and there was no evidence of electrical failure of the ballast or the bulb.

Photograph 6: Light assembly and metal halide bulb in front and above MCC #10

Photograph 7: Metal halide bulb product markings

Manufacturer's specifications associated with the bulb part number depicted in photograph 7 indicate a maximum bulb temperature of 400°C and a maximum base temperature of 250°C.

WorksafeBC commissioned testing for dust cloud and dust layer ignition temperature values of wood dust samples from the sawmill and identified a possible dust cloud ignition temperature of 430°C and a wood dust layer ignition temperature of 310°C.

The light bulb and base were in direct contact with the basement atmosphere. As discussed in appendix A, it is possible that wood dust accumulations on the light assembly surfaces developed reduced ignition temperatures due to pyrolysis in addition to interfering with proper cooling of the light assembly. The light assembly is therefore considered a possible ignition source.

Other electrical equipment found within the areas of origin

No evidence of arcing or electrical failure was observed on any other electrical equipment found within either area of origin. A detailed evaluation of conveyor motor labeled 8R-26 was commissioned by WorksafeBC and BC Safety Authority investigators witnessed that the motor functioned with no indications of an appliance failure prior to the incident. Hazardous accumulations of wood dust were found within the junction box and cooling fins of the motor as shown in Photographs 8 and 9.

In non-combustible environments, electrical equipment would typically only be considered a possible source of ignition under certain failure conditions. Electrical equipment can generate sparks and heat during normal operation with sufficient energy to present an ignition source for a combustible dust atmosphere or buildup of combustible dust on equipment surfaces. As such, electrical equipment that is certified for use within combustible environments will typically separate spark and heat generating components from the environment or limit the amount of electrical energy such that sparks and heat can not be generated during operation or failure. Electrical equipment operated within combustible atmospheres that is neither approved nor configured for safe operation within a combustible dust environment can present possible ignition sources during normal operation. The absence of failure of such equipment is therefore not sufficient to rule out the possibility of it being an ignition source.

Electrical equipment found within the areas of origin consisted of disconnects, push buttons, hydraulic oil tank heaters, switches, motors and lights. There were no indications that any of the electrical equipment found was certified for use in a hazardous environment containing combustible dusts. It is possible that electrical equipment located within either identified area of the basement provided an ignition source for wood dust.

Photograph 8: Wood dust deposits within conveyor motor junction box labeled 8R-26.

Photograph 9: Wood dust accumulation around conveyor motor labeled 8R-26.

Compliance with the *Electrical Safety Regulation*

This investigation found instances where electrical equipment was installed or used in a manner contrary to the *Canadian Electrical Code*[5]. Some non-compliant configurations found would have increased the risk of electrical equipment acting as an ignition source for a wood dust:

- cloud explosion or
- layer fire that could have become an explosion ignition source.

Details of these technical non-compliance findings are provided in Appendix D.

[5] The *Canadian Electrical Code*, Part 1 is adopted with amendments as the *BC Electrical Code* by the *Electrical Safety Regulation*. The BC amendments to the *Canadian Electrical Code* are not relevant to the discussions in this report. This report refers to *Canadian Electrical Code* in various locations which is intended to also include reference to the *BC Electrical Code*.

Hazardous Locations

Applicable safety codes require operators to identify and manage fire and explosion hazards. Special precautions are required at locations where fire and explosion hazards are likely to exist in order to control potential fuel or ignition sources.

Compliance with these codes require designers and operators to exercise a degree of foresight in respect of the actual operating conditions which may be encountered in the future: equipment which is code compliant at the time of installation or inspection may become non-compliant if hazardous environments are permitted to develop.

British Columbia Fire Code

The BC Safety Authority does not administer the *British Columbia Fire Code*; however, the code contains useful excerpts.

At the time of the incident, the 2006 edition of the *British Columbia Fire Code* was adopted by the Province of British Columbia. Division B, Part 5 – *Hazardous Processes and Operations* applies to "processes and operations that involve a risk from explosion, high flammability or related conditions that create a hazard to life safety". Section 5.3 – *Dust-Producing Processes* applies where *combustible dusts*[6] are produced in quantities or concentrations that create an explosion or fire hazard.

These sections of the *British Columbia Fire Code* require:

- Wiring or electrical equipment located in *hazardous locations*[7] to conform to the *British Columbia Safety Standards Act* and pursuant regulations for hazardous locations.
- The preparation of a *Fire Safety Plan* for hazardous processes or operations that includes (but not limited to) the control of fire hazards.
- Bonding and grounding of electrically conductive parts.
- Electrical interlocking of dust producing equipment to required dust removal equipment.
- Control or removal of equipment that may produce an ignition source and conformity to the hazardous locations requirements of the *British Columbia Safety Standards Act.*

Canadian Electrical Code

The *Electrical Safety Regulation* adopts the *Canadian Electrical Code* (with BC amendments) as the technical standard for most electrical equipment in the Province. For the purposes of compliance, electrical installations are compared to the edition of the *Canadian Electrical Code* that was in force at the time of the installation. It was reported that the sawmill completed a major electrical service and it was estimated that this work was completed around 2005. In 2005, the *Canadian Electrical Code, Part I, Nineteenth Edition, Safety Standard for Electrical Installations, Canadian Standards Association C22.1-02*

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[6] Combustible dusts means dusts and particles that are ignitable and liable to produce an explosion. (British Columbia Fire Code – 2006 Edition)

[7] The British Columbia Fire Code (2006 edition) refers to hazardous locations as being areas in which flammable gases or vapours, combustible dusts or combustible fibres are present in quantities sufficient to create a hazard.

was utilized as the BC Electrical Code. BC Amendments to the 2002 edition of the Code did not affect the requirements discussed below and the currently adopted standard is similar.

Section 18 of the Electrical Code applies to electrical equipment and wiring installed or used in *hazardous locations*. Rule 18-004 classifies *hazardous locations* according to the nature of the hazard, as follows:

(b) Class II locations are those which are hazardous because of the presence of combustible or electrically conductive combustible dusts;

(c) Class III locations are those which are hazardous because of the presence of easily ignitable fibres or flyings, but in which such fibres or flyings are not likely to be in suspension in air in quantities sufficient to produce ignitable mixtures.

Class II combustible dust atmospheres are divided into Groups E, F or G. Group G atmospheres are comprised of those "*containing flour, starch, or grain dust, and other dusts of similarly hazardous characteristics.*" Appendix B guidance material relating to Rule 18-008 of the *Canadian Electrical Code,* although not a binding requirement, includes wood flour in a list of combustible dusts. The group G definition and associated guidance material suggests a combustion hazard be considered when operating in the presence of wood flour or dust.

Section 18 prescribes installation techniques to separate the combustion hazards from potential electrical ignition sources in Class II and III *hazardous locations*, including:

- Use of metal conduits and sealed enclosures for wiring (18-202, 204, 252, 254, 302 & 352)
- Sealing and use of dust tight enclosures for switches, motor controllers etc (18-206, 256, 304 & 354)
- Use of outside clean air for electrical component ventilation (18-212, 262, 310 & 360)
- Use of luminaires and other equipment that is certified for the hazardous environment (18-216, 220, 264 and others)

Propane and Natural Gas Codes

At the time of the incident, the 2010 editions of the *Propane storage and handling code* (CSA B149.2-10) and the *Natural gas and propane installation code* (CSA B149.1-10) were adopted by the *Gas Safety Regulation*. Each code contains a section titled *hazardous locations* with the following requirement:

> *An appliance, unless certified for installation in a hazardous location, shall not be installed in any location where a flammable vapour, combustible dust or fibres, or an explosive mixture is present.*

The 2005 edition of the *Natural Gas and Propane Code Handbook (B149HB-05)* contains the following 'note on hazardous environments':

> *Hazardous environments, in relation to gas appliance installations may be practically defined as any space containing concentrations of flammable vapours, combustible dust or fibres, or explosive mixtures which may be ignited by appliance operation. Technical information on hazardous environments is available from the National Fire Protection Agency (NFPA). Refer to NFPA 499: Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas….*

Fire and Explosion Prevention Standards

Several (US) National Fire Protection Agency (NFPA) and industry standards are publically available that illustrate the fire and explosion hazards presented by wood dust. Table 2 below compiles published combustion and explosion characteristics of wood dust as well as other combustible dusts that are expressly identified by the *Canadian Electrical Code* as Group G atmospheres. Test data describing explosion and fire hazard characteristics can be sample specific - values presented in Table 2 are for general reference only.

Table 2: Sample Explosion and Fire Hazard Characteristics – derived from referenced documents

Material	Deflagration Index, K_{st} (bar-m/s)		Explosion Pressure P_{max} (bar)	Dust Layer Ignition Temperature (°C)
	Value	Group[4]		
Aluminum	415[2]	3 (very strong explosion)	12.4[2]	320[1]
Coal (bituminous)	129[2]	1 (weak explosion)	9.2[2]	180[1]
Sugar	138[2]		8.5[2]	370[1]
Wheat flour	87[3]		8.3[3]	360[1]
Wheat starch	115[2]		9.9[2]	380[1]
Wheat grain dust	112[3]		9.3[3]	Not Available
Wood flour	205[2]	2 (strong explosion)	10.5[2]	260[1]
Wood bark (ground)	Not Available	Not Available	Not Available	250[1]

Notes:

[1] *NFPA 499 – Classification of Combustible Dusts and of Hazards (Classified) Locations for Electrical Installations – 2008 Edition* – Table 4.5.2.

[2] *NFPA 68 – Standard on Explosion Protection by Deflagration Venting – 2007 Edition* – Table E1(a)

[3] *NFPA 61 – Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities – 2008 Edition* – Table A.6.2.1

[4] Hazard Communication Guidance for Combustible Dusts – Occupational Safety and Health Administration - OSHA 3371-08 2009. Four dust explosion classes are communicated for corresponding Kst ranges – 0 is assisgned a "no explosion" characteristic. Values between 0 and 200 is assigned a "weak explosion" characteristic. Values between 200 and 300 are assigned a "strong explosion" characteristic and values above 300 are assigned a "very strong explosion" characteristic.

Table 2 above illustrates that wood dust can have explosion and fire hazard characteristics similar to other known dusts that are identified as combustible dusts in the *Canadian Electrical Code*. NFPA 499 classifies wood flour as a group G combustible dust and NFPA 68 assigns wood flour a hazard class of "2", which is identified as having "strong explosion" characteristics by the US Occupational Safety and Health Administration. Given the above, wood dust and potential ignition sources exposed to wood dust are required to be managed. Locations where wood dust accumulates or is suspended in atmosphere are considered hazardous locations.

Testing of wood dust samples from the sawmill was conducted by WorksafeBC and confirmed that the wood dust at the facility presented explosion and combustion hazards as described in WorksafeBC Advisory dated August 16, 2012.

NFPA 664 - Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities identifies that "*portions of the facility where* [wood] *dust accumulations occur or where suspensions of wood dust in air could occur shall be equipped with electrical systems and equipment per*

Article 502 or 503 of NFPA 70, National Electrical Code[8]". With respect to *hazardous locations* due to dust accumulation, the standard generally describes the presence of a deflagration hazard when deflagrable wood dust[9] is present as a layer on upward facing surfaces at a depth greater than 3.2mm (1/8 in) over five percent of the area or $93m^2$ ($1000ft^2$), whichever is less.

Application of *Hazardous Location* Requirements

At the time of the incident, the identified areas of the basement should have been considered *hazardous locations* as described by the *Canadian Electrical Code*, propane and natural gas codes as well as other industry standards.

Accumulations of deflagrable wood dust were found on electrical equipment, wiring, within MCC cabinets and on upward facing surfaces throughout the facility. Given the

- history of wood dust fires at the facility,
- evidence of accumulated wood dust found during investigation, and
- descriptions of wood dust at the facility made by employees during interviews;

it is concluded that *hazardous locations* existed at the facility prior to the incident.

At the time of the incident, electrical equipment installed and in use within either area of origin was not compliant to section 18 of the *Canadian Electrical Code* for *hazardous locations* and therefore presented ignition hazards.

Compliance with the *Safety Standards Act*

The *Safety Standards Act* contains the following requirement:

> ***Operation and use of regulated products***
> ***69** (3) A person must not use a regulated product in a manner that is unsafe or that creates a risk of personal injury or damage to property.*

During installation, assumptions are made to support the selection of appropriate configurations and use of electrical equipment. Any condition deemed necessary for a particular configuration to be compliant at the time of installation must be maintained during operation. If operational activity results in a drift away from assumed conditions necessary for the type of installation to remain safe, so that a residual byproduct of production creates or contributes to a hazardous environment or location, compliance should be re-evaluated.

If wood dust management activities fail to maintain a non-hazardous environment, equipment and installations in use at those locations that are not certified or configured for such a *hazardous location* fail to remain in a safe condition and are non-compliant to the *Safety Standards Act*.

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[8] Article 502 or 503 of NFPA 70, National Electrical Code is similar to section 18 of the *Canadian Electrical Code* for *hazardous locations*. Article 500 is Hazardous (Classified) Locations while 502 is Class II [combustible dust] Locations and 503 is Class III [combustible dust] Locations.

[9] Deflagrable wood dust is generally referred to as wood dust that has explosive characteristics and is available to become suspended in atmosphere. NFPA 664 contains specific definitions for these terms.

As concluded previously, some areas of the sawmill that contained electrical equipment subject to the *Safety Standards Act*, were *hazardous locations* as described by the *Canadian Electrical Code*. Electrical equipment installed and in use within those areas was not approved for safe use within *hazardous locations (refer to appendix D)* and therefore presented ignition hazards within a combustible environment. The use of electrical equipment within certain areas of the sawmill was unsafe and not compliant with the *Safety Standards Act*.

Fuels Added to the Fire Following the Initial Explosion

The investigation examined appliances and associated piping that contained natural gas, propane, thermal fluid and ethylene glycol and concluded that none of these fuels contributed to the initiating explosion (refer to appendices B and C). It was determined that the initial explosion and fire damaged equipment carrying natural gas, propane and thermal fluid. These fuels were subsequently added to the fire.

Natural Gas

The natural gas supply line was found broken at the riser location, outside of the sawmill along the east wall. It was concluded that the explosion likely caused the break in the natural gas supply pipe at this location. Natural gas consumption by Babine Forest Products was recorded by the utility supplier on an hourly basis and the hourly consumption increased by a factor of five between 8pm and 9pm on the date of the incident, likely reflecting a leakage of fuel into the fire at the location of the break. The natural gas supply to the sawmill was turned off at 8:47pm on the date of the incident, approximately 40 minutes after the initial explosion.

Propane

Two propane cylinders were found within the sawmill structure. The cylinder found within the basement in the area under the band saw was examined in a laboratory and it was observed that the valve was in the closed position. The cylinder exhibited, what was described to BC Safety Authority investigators as, local heat and burn damage to the area near the overpressure relief valve. It is likely that this valve had opened to relieve the pressure of expanding propane as a result of the heat from the surrounding fire. The vented propane had likely ignited.

Thermal Fluid

Thermal fluid was supplied from a low pressure thermal fluid plant, or energy plant, outside of the sawmill structure to a heat exchanger located within the sawmill structure. The heat exchanger was found to have fallen off its support structure and a flange bolt was found to be fractured. Evidence of thermal fluid leaking from this location was found and it was concluded that this leak was likely caused by the explosion.

A witness described seeing intense burning at the area of the sawmill that contained the heat exchanger and presumed that thermal fluid was leaking into the fire. The valve that isolates the system supply of thermal fluid to the sawmill was closed by an employee that had returned to the mill and was not present during the explosion. It is estimated that between one and two hours may have passed between the explosion and when the thermal fluid supply to the sawmill was removed. It was later estimated that approximately 3400 US gallons of thermal fluid leaked from the system during the incident.

The investigation found that employees responsible for supervising the energy plant did not have the required qualifications to manage the equipment at this low pressure thermal fluid plant. A qualified person with suitable emergency procedures and training may have isolated the sawmill from the supply of thermal fluid earlier than what occurred. This non-compliance with the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation* may have influenced the amount of thermal fluid that was added to the existing fire; however, it did not contribute to the initial explosion.

Conclusions and Recommendations

Root and Contributing Causes of the Incident

The investigation determined that wood dust was the fuel for the explosion at Babine Forest Products on January 20, 2012. All necessary conditions for a wood dust explosion existed in the sawmill. A single 'most likely' ignition source could not be concluded. However, multiple possible ignition sources resulting from operating electrical equipment not being designed or installed for safe use in a hazardous wood dust environment were identified. Other possible ignition sources, not subject to the *Safety Standards Act,* may have been identified by other investigating organizations.

The BC Safety Authority identifies the root cause of the incident to be the failure to effectively recognize and manage wood dust explosion hazards. This finding is based upon the:

- available wood dust explosion hazards, classifications and prevention standards material;
- history of fires at the site;
- evidence of wood dust found during the investigation;
- statements regarding the presence of wood dust at the facility by employees;
- conclusion that wood dust fueled the explosion, demonstrating the existence of *hazardous locations;* and
- configuration of electrical equipment for a 'non-hazardous' environment.

The cold, dry environment in the days leading up to the incident and the non-compliant configurations of the electrical system likely increased the risk of explosion and fire at the site and are considered contributing causes.

Propane cylinders left within the sawmill structure and a failure to quickly isolate the supply of thermal fluid to the sawmill contributed to propane and thermal fluid fuels being added to the fire, following the explosion. A failure to ensure the energy plant was supervised by employees with required qualifications and emergency procedures may have contributed to the amount of thermal fluid added to the fire.

Recommendations

Owners and operators of wood processing facilities are responsible for the safe use of regulated electrical and gas equipment at their facilities, including the proper configuration of equipment used in *hazardous locations*. The safe use of equipment involves maintaining an environment that is suitable for regulated equipment. As a result of this incident and the investigation findings, the BC Safety Authority is considering ordering wood processing facility owners and operators to document an assessment of their facilities specifically for *hazardous locations*. The assessment under consideration would be completed:

- by a professional that is qualified to identify combustible dust *hazardous locations*, and
- in accordance with a recognized industry standard for combustible dust *hazardous locations*.

The BC Safety Authority may also consider ordering wood processing facility owners and operators that have identified *hazardous locations* containing regulated equipment to document a plan to either:

- develop and implement auditable wood dust management practices for these locations that are accepted by a qualified person as an effective means to manage the combustion hazard, or

- configure electrical and gas equipment for safe operation within the presence of the hazard. Safe configuration includes:
    a) obtaining approval for operation in the *hazardous location,* or
    b) permanent removal of the equipment from the *hazardous location*.

The BC Safety Authority therefore makes the following recommendations to improve the identification and management of combustible dust *hazardous locations* by wood processing facility owners and operators.

Recommendations to Wood Processing Facility Owners and Operators:
The following recommendations are made to wood processing facility owners and operators to ensure that *hazardous locations* are suitably identified and managed.

Recommendation #1:
Document a facility assessment to identify *hazardous locations* that is completed:

- by a professional that is qualified to identify combustible dust *hazardous locations*, and
- in accordance with a recognized industry standard for combustible dust *hazardous locations*.

Recommendation #2:
Where *hazardous locations* are identified and contain regulated equipment, document a plan to either:

- develop and implement auditable wood dust management practices for these locations that are accepted by a qualified person as an effective means to manage the combustion hazard, or
- configure the equipment for safe operation given the presence of the combustible dust hazard. Safe operating configurations include:
    a) obtaining approval for operation in the *hazardous location,* or
    b) permanent removal of the equipment from the *hazardous location*.

Recommendation #3:
Incorporate any identified *hazardous locations* and the chosen means to manage the combustion hazards into the facility's *Fire Safety Plan*, or other suitable facility document(s).

Recommendations to the BC Office of the Fire Commissioner:
Hazardous location identification, as described by the *Canadian Electrical Code*, natural gas and propane codes, requires specific explosion and fire prevention knowledge in order to apply fire prevention standards to an industrial environment. The following recommendations are made to the BC Office of the Fire Commissioner to assist owners and operators of wood processing facilities with their responsibilities to identify and manage *hazardous locations*.

Recommendation #4:
Publish a list of professional qualifications suitable for individuals who identify wood dust combustion and explosion *hazardous locations* in an industrial environment.

Recommendation #5:
Identify suitable fire and explosion prevention guidance material to be used in BC for the identification and classification of *hazardous locations* due to combustible wood dusts.

Recommendation #6:
Add details of a qualified person and accepted guidance material related to *hazardous location* classification and management into the *Fire Safety Plan* requirements of the *BC Fire Code*.

Recommendations to the Canadian Standards Association:
The *Canadian Electrical Code*, natural gas and propane codes are published by the Canadian Standards Association. Each of these codes contains sections titled *hazardous locations* that identify specific equipment requirements when operating in the presence of combustible dusts. The following recommendations are made to the Canadian Standards Association to improve the recognition of wood dust being a combustible dust and to improve alignment with fire prevention standards.

Recommendation #7:
Specifically identify wood dust as a combustible dust belonging to group G dusts in section 18 of the Canadian Electrical Code, Part 1.

Additional supporting discussion:
Section 18 of the 2012 Edition of the Canadian Electrical Code defines Group G dusts atmospheres as "comprising atmospheres containing flour, starch, or grain dust, and other dusts of similarly hazardous characteristics". This investigation identified that sufficient fire and explosion information is available in published standards to classify wood dust as having "similarly hazardous characteristics as flour, starch, or grain dusts". It is recommended that Section 18 of the Canadian Electrical Code be updated to specifically identify wood dust atmospheres as hazardous rather than its implied inclusion due to similarly hazardous characteristics.

Recommendation #8:
Improve coordination between section 18 of the *Canadian Electrical Code* and referenced fire and explosion prevention standards for *hazardous location* identification and classification.

Additional supporting discussion:
The *Canadian Electrical Code* adopts similar wording to the US National Electrical Code for *hazardous location* identification and classification. *NFPA 664 (Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities)* and *NFPA 499 (Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas)* contain hazard identification and classification language that mirrors the electrical codes however, these standards are not referenced by the *Canadian Electrical Code*. NFPA standards are also referenced by the National Fire Code of Canada and the BC Fire Code.

In the 2012 edition of the *Canadian Electrical Code*, the first edition of *IEC 60079-10-2 – Explosive atmospheres – Part 10-2: Classification of areas* was added as guidance for section 18 (appendix B of the *Code*). This international standard for area classification uses different classification terminology and structure than section 18 of the *Code*. The mismatch between code classification and guidance classification should be addressed as the code requirements are specific to area classification.

Recommendation #9:
Improve the natural gas and propane code requirements and accompanying guidance material relating to *hazardous location* identification and alignment with fire prevention standards.

Additional supporting discussion:
Gas codes CSA B149.1-10 and CSA B149.2-10 – *hazardous locations* are defined as being rooms that contain vapours corrosive to equipment or where a flammable vapour, combustible dust or fibres, or an explosive mixture is present. It is recommended that improved guidance be developed to interpret the term "present" and include the context of changing industrial operating environments. It is recommended that *hazardous location* identification be required in the Gas Codes and that recognized fire and explosion prevention standards be incorporated in the code rather than the handbook only.

References

1. The Province of British Columbia has entered into agreements with certain local governments to administer portions of the *Safety Standards Act*.

   Local governments that administer the *Electrical Safety Regulation*
   - City of Burnaby
   - City of North Vancouver
   - City of Surrey
   - City of Vancouver
   - City of Victoria
   - Corporation of the District of Maple Ridge
   - District of North Vancouver
   - Municipality of West Vancouver

   Local governments that administer a portion of the *Gas Safety Regulation*
   - City of Burnaby
   - City of Kelowna
   - City of North Vancouver
   - City of Richmond
   - City of Vancouver
   - Corporation of the District of Maple Ridge
   - District of North Vancouver

   The above local governments administer gas assessment programs for detached dwellings with gas services at a pressure of 14.0 kPa gauge or less as well as other buildings with gas services at a pressure of 14.0 kPa gauge or less with a total connected load for the meter of 120 kW or less.

2. Certified Fire and Explosion Investigator (CFEI) is a professional designation granted to qualified persons by the National Association of Fire Investigators (NAFI).

3. Natural gas odorization – see Canadian Standards Association (CSA) *Z662-07 Oil and gas pipeline systems*

   Propane odorization – see *CSA B149.1-10 Natural Gas and Propane Installation Code*, CSA *B149.2-10 Propane storage and handling code and* Standards Council of Canada (SCC) *CAN/CGSB 3.14-2006 Liquefied Petroleum Gas (Propane) for Fuel Purposes*

Appendix A

SAMAC Engineering Ltd. Fire Investigation Report

SAMAC
ENGINEERING LTD.

19 December 2012 [redacted]

Our File: [redacted]

[redacted]
British Columbia Safety Authority
200 – 505 Sixth Street,
New Westminster, BC. V3L 0E1

Dear [redacted]

Re: Babine Forest Products – Explosion & Fire
Incident Date: 20 January 2012
Your File [redacted]

1.0 INTRODUCTION

In accordance with your instructions, we have examined the available information in order to determine, if possible, the cause of the above noted explosion and fire.

2.0 INCIDENT AS UNDERSTOOD

The incident occurred at the Babine Forest Products sawmill located at 19479 Highway 16 East, approximately 20 kilometres east of Burns Lake BC. It is understood that on 20 January 2012 at approximately 20:07h an explosion and fire occurred in the sawmill.

Fire fighting operations were hampered by cold weather and water availability. The bulk of the fire was extinguished or had burned out within five days. However, spot fires continued to burn until 06 February 2012. There were 22 casualties including two fatalities and the mill was a total loss.

The scene remained under the control of the Police and BC Coroner's Service until about 01 February 2012 when it was released to WorkSafe BC. Worksafe BC assumed the role of lead investigating agency, responsible for overall control of the site and evidence removed for evaluation. WorkSafe BC and the BC Safety Authority (BCSA) each investigated the incident. The BCSA investigation team consisted of a gas, a boiler and an electrical safety officer as these disciplines are regulated by BCSA. In addition, SAMAC Engineering was contracted by BCSA to provide fire and explosion investigation expertise.

3.0 INFORMATION AVAILABLE

The following activities were performed during our investigation:

- examined and photographed the fire scene from 06 February 2012 to 23 February 2012 and again from 27 March 2012 to 05 April 2012,
- reviewed information provided including recorded and/or transcribed witnesses interviews,
- examined various pieces of sawmill equipment with the investigation team's safety officers,
- discussed the assessments of the investigation team's safety officers, and
- observed laboratory examinations of retained exhibits, 9 and 10 July 2012.

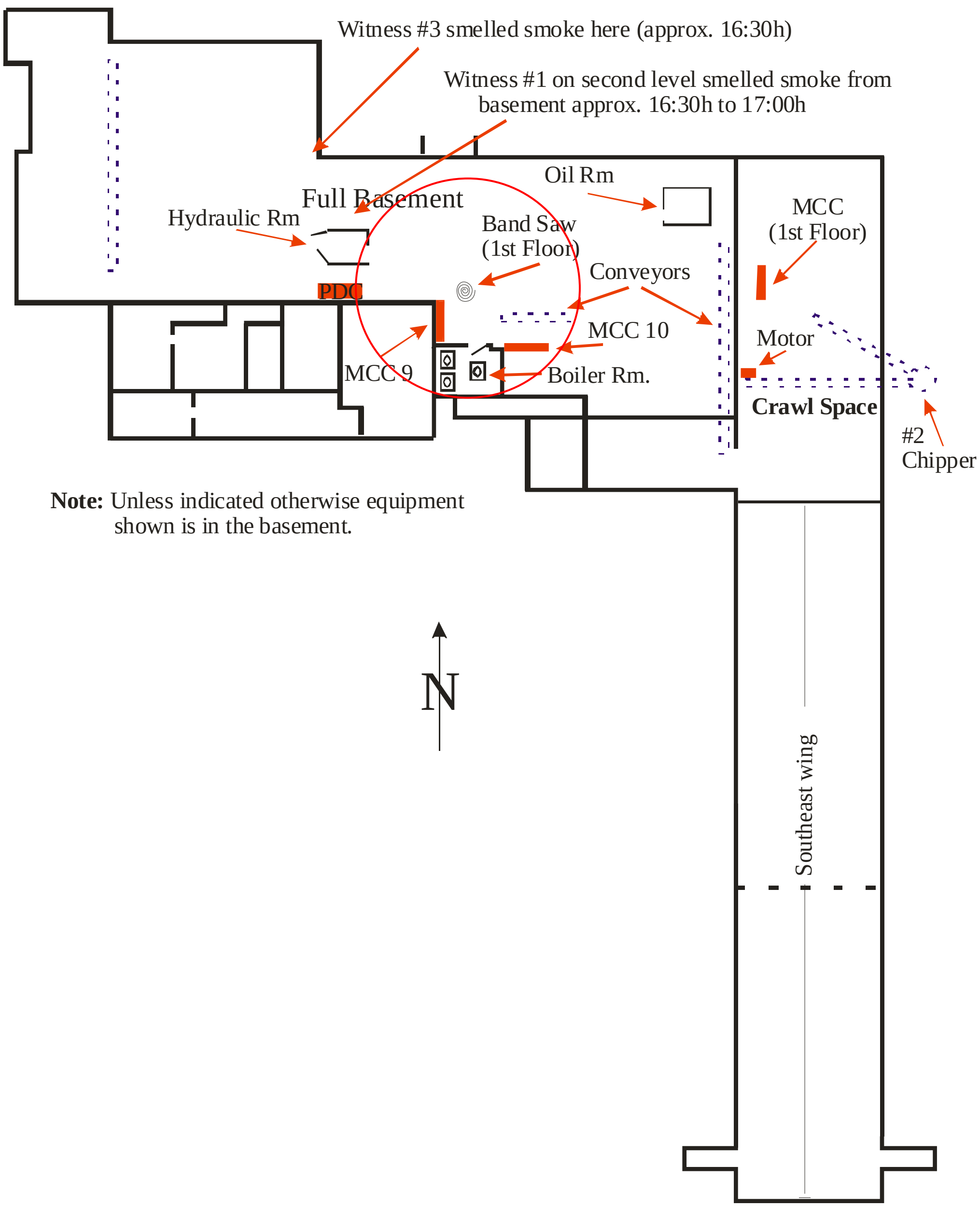


Figure 1: Basic footprint of the sawmill
(not to scale)

4.0 REVIEW OF INFORMATION

4.1 Description of the Mill

The mill was a two story steel frame structure with plywood walls and heavy timber floors and roof. The volume of wood used in the walls, floors and roof served as a large fuel load once the fire started.

There was a large amount of heavy electrical machinery in the mill including saws, conveyers, fans and pumps. The electrical machinery in the mill was controlled from large electrical panels known as Motor Control Centres (MCCs) (Figure 4 and Photograph 5). Each MCC had a number of cabinets containing electrical fittings of various kinds. MCCs were situated in various locations throughout the mill.

4.2 Explosion Potential

In order for an explosion to occur, five conditions are required. These are: an explosive fuel source, dispersion of the fuel, air mixed with the fuel in the right proportions, an ignition source and confinement. These are referred to as the Explosion Pentagon (Figure 2).

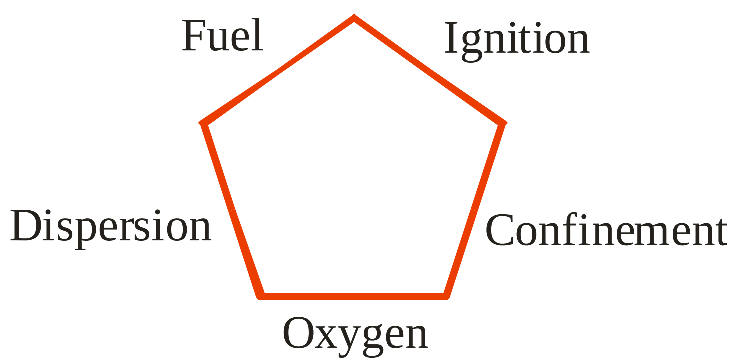


Figure 2: Explosion Pentagon

Potential explosive fuel sources in the mill included:

- natural gas for the boilers, hot oil heating system and other gas appliances,
- portable propane and acetylene cylinders,
- hydraulic systems,
- a substantial amount of fine wood dust on horizontal surfaces in the mill as well as inside some of the electrical panels and MCCs, and
- boilers and pressure vessels would not normally be considered fuel or ignition sources. However, the failure of a boiler or pressure vessel could cause the release of explosive fuels from the sources listed above.

There are three general types of explosions; Mechanical, Chemical, and Nuclear. An explosion fuelled by the types of fuels noted above, including dust, would be included in the Chemical Explosions classification. These could also be referred to as Combustion Explosions. Combustion explosions generate a high-pressure-gas blast-front as the result of an exothermic reaction from the ignition of the fuel. As the blast-front moves out from the origin of the explosion it increases in speed and resultant damage. As such, it is normal to see less blast damage in the area of origin where the velocity of the blast-front was lowest.

Potential ignition sources in the mill included:

- natural gas boilers, hot oil heating system and other gas appliances,
- electrical appliances, panels, wiring and fittings,
- portable propane and acetylene appliances,
- sparks from saws and machinery, and
- heat generated by machinery due to friction.

4.3 Fire Scene Observations

Fire scene observations key to determination of the origin were as follows (Photographs V1 to V20 and Figure 3):

Note: unless specified otherwise equipment referred to in the points below were located in the basement of the mill.

- the building was almost completely burned except for the south end of the southeast wing and the extreme west end of the main wing,
- before the explosion there had been a number of equipment rooms in the basement that housed electrical and mechanical equipment; most of these rooms were destroyed except in the west side and southeast end of the mill,
- debris from the explosion was found in a 360^{o} pattern around the mill,
- the blade cover for the band saw, centrally located on the first floor, was lifted vertically out of position,
- heavy roof timbers in the building were normally oriented with their ends north and south; the south ends of the heavy timbers above the band saw area were shifted to the west while the north ends of the timbers were still in place,
- the metal door of the boiler room, which would normally have swung out from the boiler room to the north, was pushed in to the south,
- in the boiler room, makeup air ducts and boiler exhaust ducts were displaced to the south,
- the west end of MCC-10 was pushed to the south approximately 15cm and the entire panel was pushed approximately 15cm to the east,
- with the exception of areas noted previously there was less blast damage to the immediate area of MCC-10 than to some other areas of the basement,
- the wire cable trays in most of the basement were coated with charred wood dust on the upper side (Photograph 8); however, there was minimal charred wood dust on the cable trays above MCC-10 (Photographs 9 and 10),
- the charred framing of the east wall of the Power Distribution Centre (PDC) room was found on the floor to the west of its normal location,
- the double doors of the hydraulic room next to the PDC were blown open to the west,
- large pieces of equipment in the west end of the basement were pushed to the west and north,

- in the east side of the building where the basement transitioned from a full basement to a crawl space, the transition wall and a safety railing were scorched on the west side and a heater in that area was displaced to the east,
- in the east side of the first floor MCC-8R was pushed over to the west, and
- there was a large hole in the floor in front of MCC-8R.

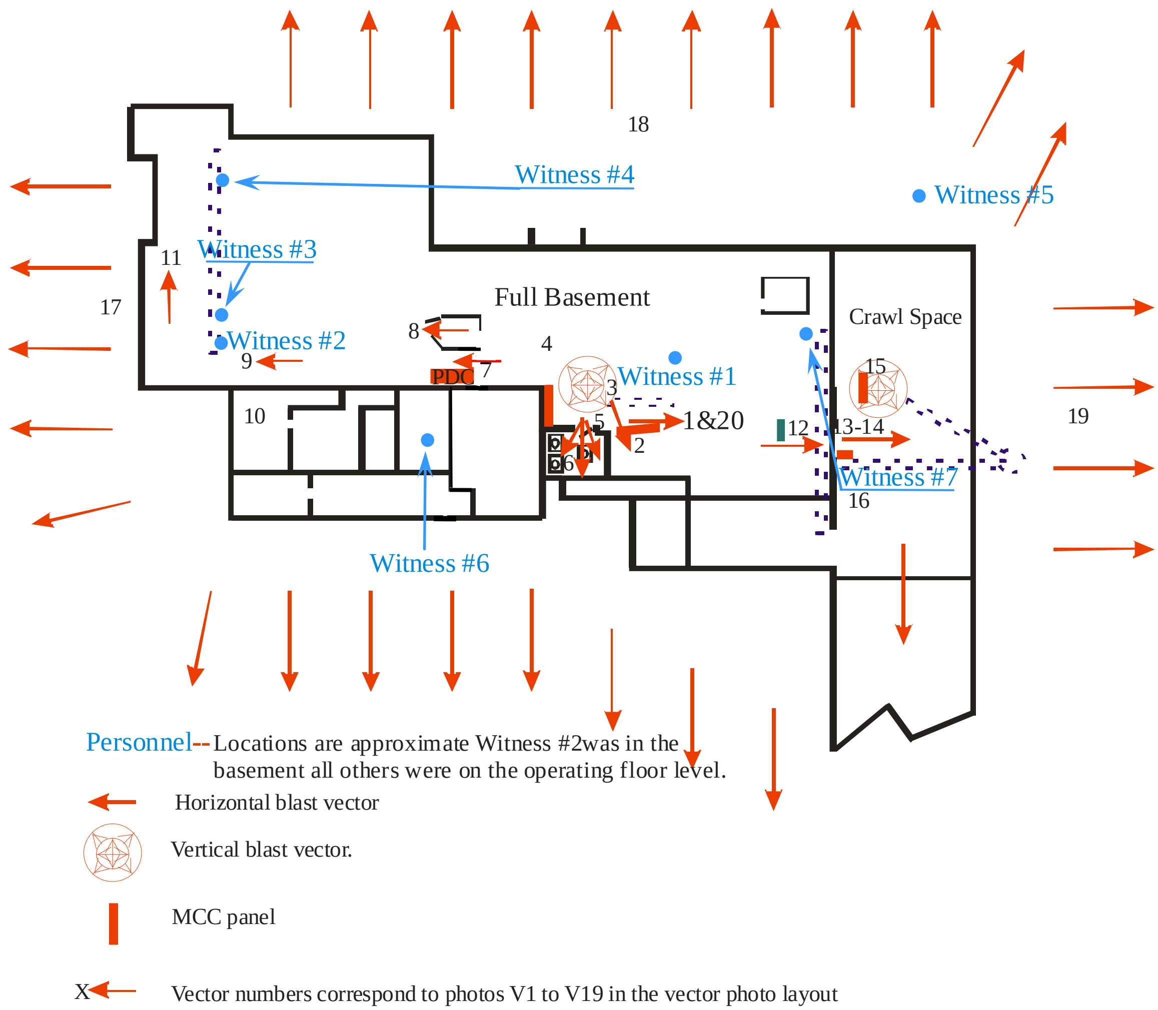


Figure 3 Partial building footprint showing blast vectors and witness locations
(Photographs V1 to V20)
(not to scale)

Fire scene observations (primarily of MCC 10) key to determination of the cause were as follows (Photographs 1 to 22, Figure 4 and Photographs M1 to M2:

- there was a burn pattern on the front of MCC-10 that was irregularly shaped and tended to follow the shapes of the individual cabinets,
- there was a relatively uniform horizontal burn pattern on the front of MCC-9,
- the doors of cabinets 10-11, 10-22, 10-61 and 10-71 were found in the open position and the door latches were in the open position,
- in MCC-10 the latches on the cabinets were V shaped,

- in MCC-10, the interiors of cabinets 10-31, 10-32, 10-41, 10-42, 10-51 to 10-55, 10-62, the lower part of 10-61 and 10-71 to 10-74 were extensively burned while the remaining cabinets were significantly less burned,
- in MCC-10, cabinet 10-41 was completely gutted,
- most of the equipment and horizontal surfaces in the basement were heavily coated with wood dust,
- there was a layer of wood dust inside MCC-9; MCC-9 was in the same area as MCC-10,
- the intake for the air pressurizing system for MCCs 9 and 10 was located on the floor next to MCC-10,
- there were carbon deposits inside the pressurizing system ducting for MCC-10,
- there was an open bulb 400 watt metal halide light fixture suspended above MCC-10; the bulb was intact but the shade was found on the floor in front of MCC-10, several of these metal halide lights were located in the basement of the mill, and
- of the potential explosive fuel sources known to have been present in the mill, no evidence was found to indicate that natural gas for the boilers, hot oil heating system or other gas appliances, portable propane and acetylene cylinders, hydraulic systems or boilers and pressure vessels caused or contributed to a primary or secondary explosion.

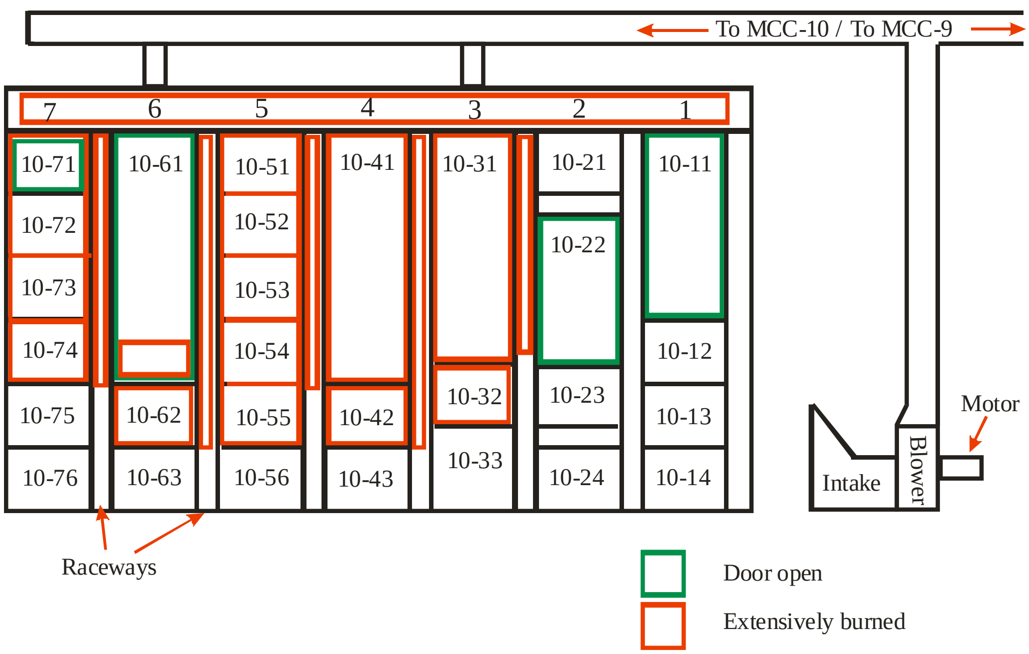


Figure 4: MCC-10
(not to scale)

4.4 Witness Information

Provided information from witnesses was as follows:

4.4.1 Witness #1

- he was the band saw filer,
- he came in to work at approximately 14:30h,

- there was no dust extraction and no cooling water for the saw blades,
- sometime around 16:30h to 17:00h while on the second level in the area of the band saws he smelled an odour like “a jack pine camp fire” from the level below,
- he mentioned the smoke smell to Employee #1 who told him Employee #2 had also smelled it and reported it to Employee #3; Witness #1 took no further action.
- he was in the area of the band saws when the explosion occurred,
- in the first event the floor came up beneath him and the roof went up, and
- in the second event, approximately 20 seconds after the first event, the walls were blown out.

4.4.2 Witness #2

- he was a security watchman,
- at approximately 20:00h the fire alarm went off so he went to investigate,
- he went into the mill, underneath #3 chipping saw operating booth, checked dry valves 21, 21a and 21b; the valves were ok,
- he thought he saw smoke coming from the Butt Reducer hydraulic pack but it turned out to be steam,
- he then went to #2 Step Feeder,
- he was in the southwest end of the basement when the explosion occurred,
- the lights flickered then the blast hit him,
- he made his way out through the compressor room, and
- he did not smell gas in the basement before the explosion.

4.4.3 Witness #3

- he operated a canter/barker (DBA),
- *early in his shift (approximately 16:30h) he smelled smoke “like something* smouldering”, and
- he heard another employee state “yeah, I’m over here by the cut-off saw belts. Where they come out of the mill. Putting out a fire or smouldering”.

4.4.4 Witness #4

- he was at a control panel between cut-off saws 1 and 2 facing west,
- the explosion came from behind him, and
- he did not smell anything prior to the explosion.

4.4.5 Witness #5

- he was operating number 4 cut-off saw,
- when the explosion happened the booth door blew open and the shack shook, and
- he smelled nothing unusual.

4.4.6 Witness #6

- he was in the millwright room by the electrical shop, and
- the floor came up and he was blown out into the yard.

4.4.7 Witness #7

- at the time of the incident he was (*on the operating floor*) at a saw sharpening station between Eliminator 1 and Edger 2 facing west,
- he turned toward the band mills and saw a fireball coming toward him,
- it came up, just about hit the roof, and then came toward him, and
- "It sure looked like it came from the band mills".

4.5 Sawmill Equipment

Sawmill equipment non-destructively examined at the scene with the investigation team's safety officers included gas, electrical and pressure vessel equipment regulated by the British Columbia Safety Authority (BCSA). The following equipment exhibited conditions warranting more detailed examination: remains of cabinet 10-31 from MCC-10, an electric conveyer motor, a light bulb and fixture from above MCC-10 and a gas valve and piping. All of the noted items were retained by WorkSafe BC for future examination.

4.6 Safety Officer's Assessments

Based on assessments of the team's safety officers:

1) No evidence was found that boilers or pressure vessels contributed to the cause of the fire.
2) A minor underground gas leak was found outside approximately 130 feet (40m) from the mill; no evidence was found to link the leak to the cause of the explosion. To date, no evidence has been found to link any of the regulated gas equipment to the cause of the explosion.
3) Electrical equipment remains a possible ignition source of the fire; items of interest include all electrical equipment in the identified area of origin.

5.0 ANALYSIS

5.1 Origin of the Explosion

Analysis of the origin of the explosion was based on the following information (Figure 3 and Photographs V1 to V20):

- the building was almost completely burned except for the south end of the southeast wing and the extreme west end of the main wing,
- before the explosion there were a number of equipment rooms in the basement that housed electrical and mechanical equipment; most of these rooms were destroyed except in the west side and southeast end of the mill,
- debris from the explosion was found in a 360^{o} pattern around the mill,

- the blade cover for the band saw, centrally located on the first floor, was lifted vertically out of position,
- heavy roof timbers in the building were normally oriented with their ends north and south, the south ends of the heavy timbers above the band saw area were shifted to the west while the north ends of the timbers were still in place,
- the metal door of the boiler room, which would normally have swung out from the boiler room to the north, was pushed in to the south,
- in the boiler room makeup air ducts and boiler exhaust ducts were displaced to the south,
- the west end of MCC-10 was pushed to the south approximately 15cm and the entire panel was pushed approximately 15cm to the east,
- in MCC-10, cabinet 10-31 contained six high voltage lines connected in pairs to three metal lugs; two of the lugs were found in normal condition while the third was extensively damaged,
- with the exception of areas noted previously there was less blast damage to the immediate area of MCC-10 than to some other areas of the basement,
- the charred framing of the east wall of the PDC room was found on the floor to the west of its normal location,
- the double doors of the hydraulic room next to the PDC were blown open to the west,
- large pieces of equipment in the west end of the basement were pushed to the west and north,
- in the east end of the building where the basement transitioned from full basement to a crawl space, the transition wall and a safety railing were scorched on the west side and a heater was displaced to the east,
- in the east end of the first floor MCC-8R panel was pushed over to the west,
- there was a large hole in the floor in front of MCC-8R,
- in the first event the floor came up beneath Witness #1, the band saw operator, and the roof went up,
- Witness #2 was in the southwest end of the basement when the explosion occurred, he made his way out through the compressor room,
- Witness #4 was at a control panel between cut-off saws 1 and 2 facing west, the explosion came from behind him,
- Witness #6 was in the millwright room by the electrical shop, the floor came up and he was blown out into the yard, and
- Witness #7 was on the operating floor at a saw sharpening station between Eliminator 1 and Edger 2 facing west; he stated "It (*the fireball*) sure looked like it came from the band mills".

Analysis of the explosion damage (Figure 3) showed the blast expanding out from the area of the basement below the band saw near where the boiler room, MCC-9 and MCC-10 were located (Figure 1, circled area). This area was below the band saw operated by Witness #1. Evidence from Witness #1 was that the floor came up from below him and the roof went up. The blade cover for the band saw being lifted vertically out of position, and the south ends of the heavy roof timbers being shifted to the west, also place the origin of the blast in the basement as noted above. Information from Witness #6 that the floor in the millwright room came up also places the origin of the blast in the basement. According to Witness #7 the fireball looked like it came from the band mills (*band saws*), which was where Witness #1 was. As such, Witness #7's information also places the origin at or below the band saws.

The band saw was in the same vertical plane as the south ends of the roof timbers. After the explosion, the south ends of the heavy roof timbers were shifted to the west while the north ends were still in place. This is very likely a result of the explosion lifting the roof above the band saw and at the same time blowing through the roof thus forcing the south ends of the timbers to the west.

The lower level of blast damage in the immediate area of MCC-10 in comparison to other areas of the mill is also an indicator that the explosion very likely originated in that area.

One of the cabinets in MCC-10 exhibited unusual conditions. Cabinet 10-31 contained six high voltage lines connected in pairs to three metal lugs. Two of the lugs were found in fair condition while the third was extensively damaged. A laboratory examination of the lugs on 09 July 2012 revealed that the damage to the extensively damaged lug was very likely mechanical damage. This damage very likely occurred as a result of lateral force on the lug when MCC 10 was pushed out of position by the explosion (Photographs V1 and V2). Based on this, failure of the lug in cabinet 10-31 can reasonably be ruled out as the cause of the explosion. However, the mechanical damage to the lug is a further indication that MCC-10 was moved to the east by an explosion in the basement in the area below the band-saw.

Based on the preceding information the explosion very likely originated in the area of the basement below the band saw.

MCC-8R, the MCC panel for the eliminator, was an anomaly because it was in the east end of the first floor but it was pushed over in a westerly direction. This very likely occurred when the blast-front from the explosion in the basement pushed through the floor, on the east side of MCC-8R, and the expanding gases blew the panel to the west.

5.2 Cause of the Explosion

Analysis of the cause of the explosion is based on the following information (Figures 3, 4, Photographs 1 to 22 and Photographs M1 to M21):

- the wire cable trays in most of the basement were coated with charred wood dust on the upper side; however, there was minimal charred wood dust on the cable trays above MCC-10,
- there was a burn pattern on the front of MCC-10 that was irregularly shaped and tended to follow the shapes of the individual cabinets,
- there was a relatively uniform horizontal burn pattern on the front of MCC-9,
- the doors of MCC-10 cabinets 10-11, 10-22, 10-61 and 10-71 were found in the open position and the door latches were in the open position,
- in MCC-10 the latches on the cabinets were V shaped,
- in MCC-10, the interiors of cabinets 10-31, 10-32, 10-41, 10-42, 10-51 to 10-55, the lower part of 10-61, 10-62 and 10-71 to 10-74 were extensively burned while the remaining cabinets were significantly less burned,

- in MCC-10, cabinet 10-41 was completely gutted,
- the west end of MCC-10 was pushed to the south approximately 15cm and the entire panel was pushed approximately 15cm to the east,
- most of the equipment and horizontal surfaces in the basement were heavily coated with wood dust,
- there was a layer of wood dust inside MCC-9 which was in the same area as MCC-10,
- the motor switch for the pressurizing system for MCC-10 was on at the time of the explosion but the start/stop switch was in the stop position,
- the intake for the air pressurizing system for MCC-10 was located on the floor next to MCC-10.
- there were carbon deposits inside the pressurizing system ducting for MCC-10,
- there was an open metal halide light fixture suspended above MCC-10; the bulb was intact but the shade was found on the floor in front of MCC-10,
- at about 16:30h Witness #1 and Witness #3 smelled smoke; sometime around 16:30h to 15:00h while on the second level in the area of the band saws Witness #1 smelled an odour like "a jack pine camp fire" from the level below,
- at approximately 20:00h the fire alarm went off so Witness #2 went to investigate,
- of the potential explosive fuel sources known to have been present in the mill, no evidence was found to indicate that natural gas for the boilers, hot oil heating system or other gas appliances, portable propane and acetylene cylinders, hydraulic systems or boilers and pressure vessels caused or contributed to a primary or secondary explosion, and
- there was a substantial amount of fine wood dust on horizontal surfaces in the mill as well as inside some of the electrical panels.

The event occurred as an explosion followed by a fire. As discussed in section 4.2, in order for an explosion to occur an explosive fuel source, dispersed and mixed with air in the right proportions, in a confined area in the presence of an ignition source would be required. The explosive fuel sources that would have been present in the mill at the time of the explosion were also listed in section 4.2. Of those fuels, no evidence was found that any of them except wood dust could have caused or contributed to either a primary or secondary explosion in the area identified as the origin. As such, all fuels except wood dust can reasonably be ruled as very unlikely. Of the explosive fuels noted, to date the only one proven to have been present in the identified area of origin is wood dust. Based on the evidence to date, wood dust very likely fuelled the explosion.

Reference C states: "Dust explosions frequently occur in two stages. A primary explosion of limited volume throws into suspension dust, which has accumulated in machines, on beams, ledges or other surfaces. Ignition of this dust cloud by the heat of the primary explosion or by a secondary ignition source results in a more violent secondary explosion."

Possible ignition sources of a primary explosion in the area of origin include:

- an electrical event in a panel such as an arc flash or other arcing or sparking of electrical contacts,
- flame from the natural gas boilers,

- spark or heat from electrical appliances, panels, wiring and fittings,
- heat or flame from portable propane or acetylene appliances,
- sparks from saws and machinery,
- heat generated by machinery due to friction, and
- a fire in the area of origin.

Flame from the natural gas boilers can be ruled out because the boilers were shut down at the time of the explosion. None of the propane or acetylene appliances examined exhibited conditions consistent with their being the cause of the explosion. As such they can be ruled as unlikely.

In the area of origin a large electrical panel identified as MCC-10 stood out as a possible source of the primary explosion. In a major fire such as this it would be normal to see a relatively uniform horizontal burn pattern on the front of MCC-10, had it been a result of the main fire. However, the burn pattern on the front of MCC-10 (Photograph 5) was irregularly shaped and tended to follow the shapes of individual cabinets. MCC-9 was in the same general area as MCC-10 (Figure 1) yet, in contrast to MCC-10 there was a relatively uniform horizontal burn pattern on the front of MCC-9. This suggests the burn pattern on MCC-10 was the result of an internal fire. All of the cabinets were interconnected via raceways for wiring (Figure 4). It is likely that an internal fire or explosion occurred inside MCC-10 and only became established in certain cabinets, possibly those that contained more wood dust, and the internal burning produced the burn pattern observed on the outside.

When MCC-10 was first examined, the doors of cabinets 10-11, 10-22, 10-61 and 10-71 which normally would have been closed and latched were found in the open position as were the latches. This could indicate that prior to the explosion the doors of these cabinets were not closed and latched properly. However, the latch bars for the cabinet doors were V shaped (Photograph M20). When latched panel doors with V shaped latch bars are forced open the V shape can cause the latch to rotate to the open position. As such, the position of the latches on the open cabinets is not a reliable indicator of whether or not they were left unlatched.

Most of the wood dust inside MCC-10 was burned away. However, wood dust accumulations were present in the less damaged cabinets of MCC-10 (Photograph 11) and wood dust deposits were observed in MCC-9 and MCC-12 which were less damaged. The intake for the air pressurizing system for MCCs 9 and 10 was on the floor next to MCC-10. Because the intake was in the dust contaminated environment, the pressurizing system could have introduced wood dust into the MCCs had it been used prior to the explosion without conducting a cleaning of the cabinets.

The carbon deposits inside the MCC pressurizing system ducting indicate that there was a combustible fuel (very likely wood dust) in the ducting prior to the explosion. The motor switch for the pressurizing system was on at the time of the explosion but the start/stop switch was in the stop position indicating the motor was off. Therefore, the combustion inside the ducting would have been due to fire burning back from the MCC-10 panel rather than fire being drawn in through the intake by the fan.

A possible explanation for the cabinet doors in MCC-10 being open, the combustion inside the pressurization system ducting and the irregular burn pattern on the front of MCC-10, is that a primary explosion occurred inside MCC-10 blowing the doors open. This could have caused wood dust outside MCC-10 to become suspended and ignited causing the second dust explosion which destroyed the mill. In order for this to occur dust would have had to be in suspension inside MCC-10 in the presence of an ignition source (the cabinet itself would have provided the confinement and the normal air in the cabinet would have provided the oxygen supply). There would have been on-going vibration in the mill due to the large machines and in some cases there can be a large jolt when a machine is started. Even with the air pressurizing for MCCs 9 and 10 off, dust inside MCC-10 could have been in suspension at a critical time due to on-going vibration and the starting of machinery. No evidence was found of arc flash inside MCC-10 so it can reasonably be ruled out. However, MCC-10 contained a large number of electrical switches, breakers and connections which could have provided an ignition spark for an interior explosion. No clear evidence was found that any of the cabinets ignited an explosion. However, as depicted in Photographs M1 to M24, some of the cabinets were so badly damaged that they could neither be confirmed nor ruled out as the ignition source of the explosion.

A primary explosion violent enough to blow open the doors of the cabinets would also have blown the wood dust off the cable trays above MCC-10. This would explain why there was no charred wood dust in the cable trays above MCC-10 in contrast to large amounts on the cable trays in all other areas of the basement. The airborne wood dust from the cable trays above MCC-10 could then have been ignited, by either the primary explosion or by an ignition source outside of MCC-10, causing the secondary explosion. The mill structure would have provided confinement for the second explosion and the normal air supply in the mill would have furnished the necessary oxygen.

The metal halide light above MCC-10 is another possible ignition source of dust in suspension. The maximum bulb temperature of the metal halide light bulb above MCC-10 was rated at 400^0C and 250^0C at the base. Tests by WorkSafe BC of dust samples from the mill indicated a possible dust cloud ignition temperature of 430^0C and a possible dust layer ignition temperature of 310^0C. Based on this, under conditions where the surface of the bulb could be maintained wood dust free, a halide light like the one above MCC-10 would be an unlikely ignition source. However, if part of the unprotected halide bulb became coated in wood dust, over time the heat from the bulb would have caused the ignition temperature of the wood dust to become reduced through pyrolysis. Over time the ignition temperature of dust on the halide bulb could have become reduced enough to be ignited by the bulb either in layer or in suspension. Due to the post-fire condition of the bulb the possibility that it was the ignition source could neither be confirmed nor ruled out.

Another possible ignition source of the explosion that must be considered is that there may have been a fire in the basement. At about 16:30h Witnesses #1 and #3 smelled smoke. Witness #1, who was on the second level in the area of the band saws, stated he smelled an odour like “a jack pine camp fire” from the level below. One level below the band saws was very near to MCC-10. Both individuals understood that the cause of the smoke that they each smelled had been dealt with. However, it is possible that there was still something smouldering in the mill which could have ignited wood dust in suspension.

Witness #2 reported that the fire alarm activated at approximately 20:00h, approximately seven minutes before the explosion. The fire alarm is activated by a drop in pressure in the sprinkler system. A drop in pressure in a sprinkler system can be due to a leak in the system or by the opening of a sprinkler head due to a fire. Witness #2 investigated and found nothing. However, by the time of the explosion Witness #2 was still in the process of checking the mill and had not yet found the cause of the alarm activation or reached the area of origin. As such the possibility that the explosion was caused by a pre existing fire in the area of origin cannot be ruled out.

Based on the forgoing information, the five elements required for an explosion to occur were all present in the mill in the area of origin.

6.0 CONCLUSIONS

6.1) The explosion very likely originated in the area of the basement below the band saw where the MCC-9 and MCC-10 were located.

6.2) The five elements required for an explosion to occur were all present in the mill in the area of origin.

6.3) Several possible ignition sources were identified including: the cabinets in MCC-10, an unprotected metal halide light, electrical appliances, panels, wiring and fittings, sparks from saws and machinery and heat generated by machinery due to friction.

We trust that the contents of this report are consistent with your current needs. Inspection notes and file material have been retained for future use as required.

Yours truly,
SAMAC Engineering Ltd.

Chris deRosenroll C.D., CCFI, CFII, CFEI

Reviewed by:
Steve MacInnis, P.Eng.

Attachment(s): 63 Photographs
Annex A: References

Annex A: References

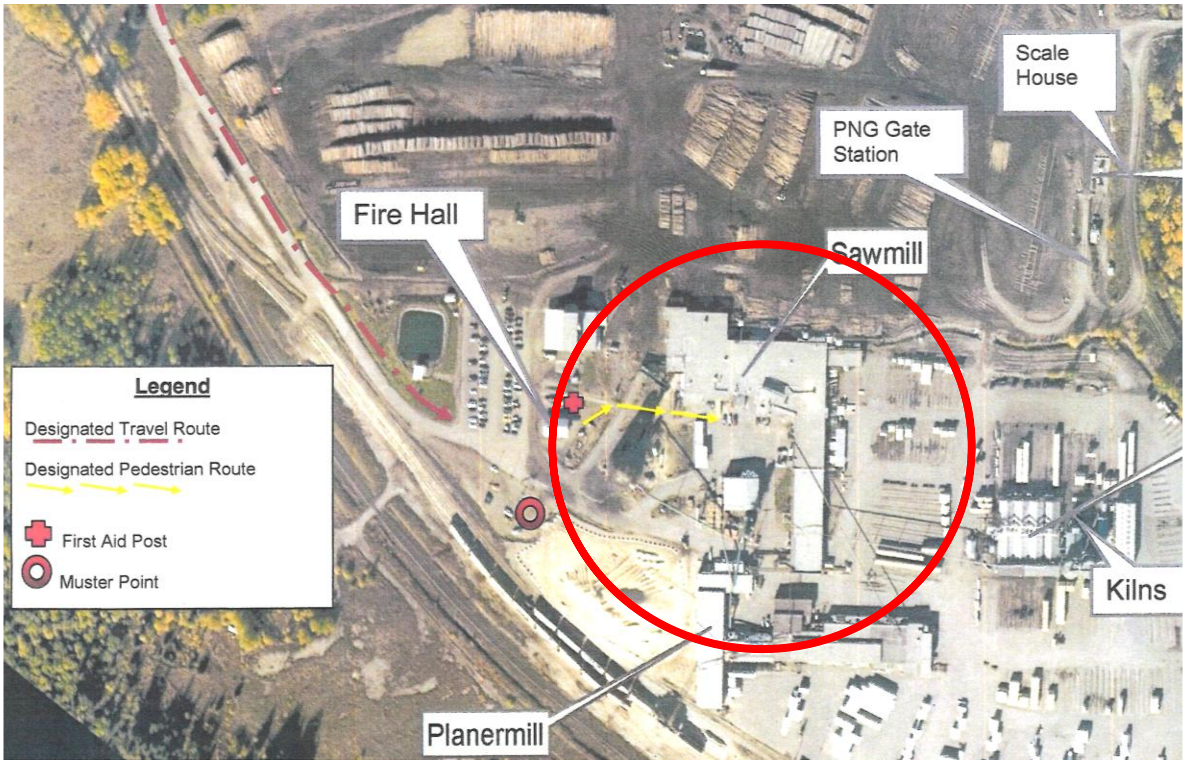
1) National Fire Protection Association (NFPA) Fire Protection Handbook

2) NFPA 921, Guide For Fire and Explosion Investigations

3) NFPA Inspection Manual

4) CSA Guide for the Design, Testing, Construction, and Installation of Equipment in Explosive Atmospheres

5) Metal Halide Lamps, Harvard University Health and Safety Group



Photograph 1

Looking at a pre-fire aerial view of the sawmill sight.

Photograph 2

Looking at a post-fire view of the sawmill.

Note: the circled area corresponds to the circled area in Figure 1 of the attached report.

Photograph 3

Facing north looking at the area indicated by the red circle in Photograph 2.

Note: the location of the band saw (red arrow).

Note also: the boiler and MCC-10 are located in the basement (green arrow).

Photograph 4

Facing northeast looking at a closer view of the areas referred to in Photograph 3.

Note: the band saw (red arrow) and the boiler room and MCC-10 located in the basement (green arrow).

Photograph 5

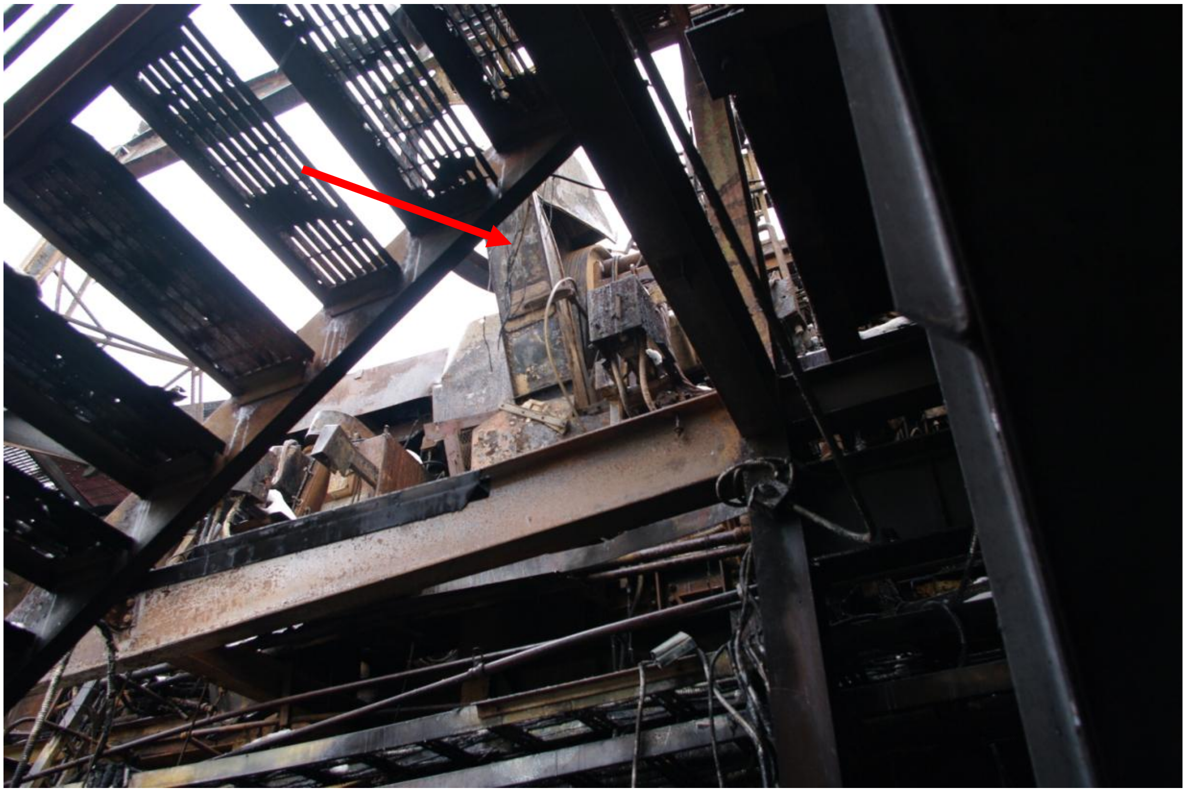
Looking at the front of MCC-10.

Note: rather than being a uniform V pattern the burn pattern on the front of the panel follows the shapes of individual cabinets.

Note also: the locations of sub panels 10-31 (red arrow) and 10-13 (green arrow). Cabinet 10-13 is further referred to in Photograph 11.

Photograph 6

Looking from above at the location of the band saw (red arrow) in relation to MCC-10 (green arrow) and the boiler room (yellow arrow).



Photograph 7

Looking at the band saw (arrow) from MCC-10.

Photograph 8

Looking at an example of charred sawdust on wire cable trays. This is typical of the condition of cable trays in the basement of the mill.

Photograph 9

Looking at the cable trays above MCC-10.

Note: the absence of charred sawdust.

Photograph 10

Looking at the cable trays by the conveyer next to MCC-10.

Note: the absence of charred sawdust.

Photograph 11

Looking at the accumulation of sawdust inside MCC-10, sub panel 10-13.

Photograph 12

Looking at the accumulation of sawdust inside MCC-9 (arrows).

Photograph 13

Looking at the accumulation of sawdust inside MCC-12.

Photograph 14

Looking at the interior of MCC-10, subpanel 10-31.

Note: the location of the three lugs (red outline).

Photograph 15

Looking at a closer view of the three lugs in subpanel 10-31.

Note: two lugs are intact but the third (arrow) is broken up.

Photograph 16

Looking at the metal halide light above MCC-10.

Note: residue on the upper bulb surface (circle).

Photograph 17

Looking at the information on a metal halide light bulb identical to the one shown in photograph 16.

Photograph 18

Looking at the interior of the ventilation ducting for MCC-10.

Note: the charred deposits on the inner surface.

Photograph 19

Looking at the interior of the transition on the blower for the ventilation system for MCC-10.

Note: the charred deposits on the inner surface (arrow).

Photograph 20

Looking at the PDC.

Note: before the explosion the PDC was in a fully enclosed room.

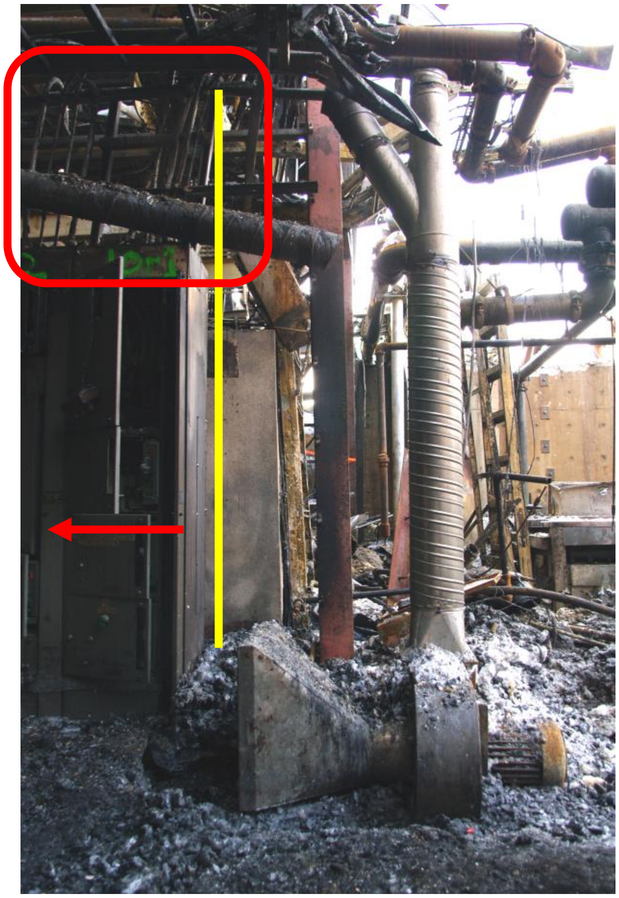
Photograph 21

Looking at the motor taken into evidence by Worksafe BC from the east side of the mill basement.

Note: the sawdust on and around the motor.

Photograph 22

Looking at an example of the dust levels in the basement of the mill. This photograph was taken in the east side of the basement.



Photograph V1

Looking at the west end of MCC-10 from the front.

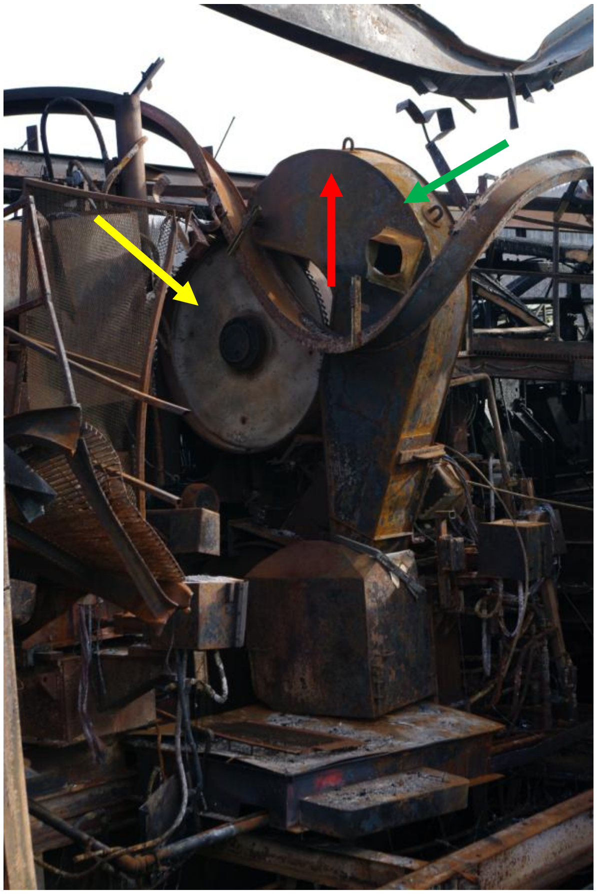
Note: the angle of the wires at the top of the panel (red outline) indicates an eastward movement of the panel.

Note also: the red arrows in photographs V1 to V20 indicate the blast direction and correspond to the numbered arrows in Figure 4 of the report.

Photograph V2

Looking at the west end of MCC-10 from the end.

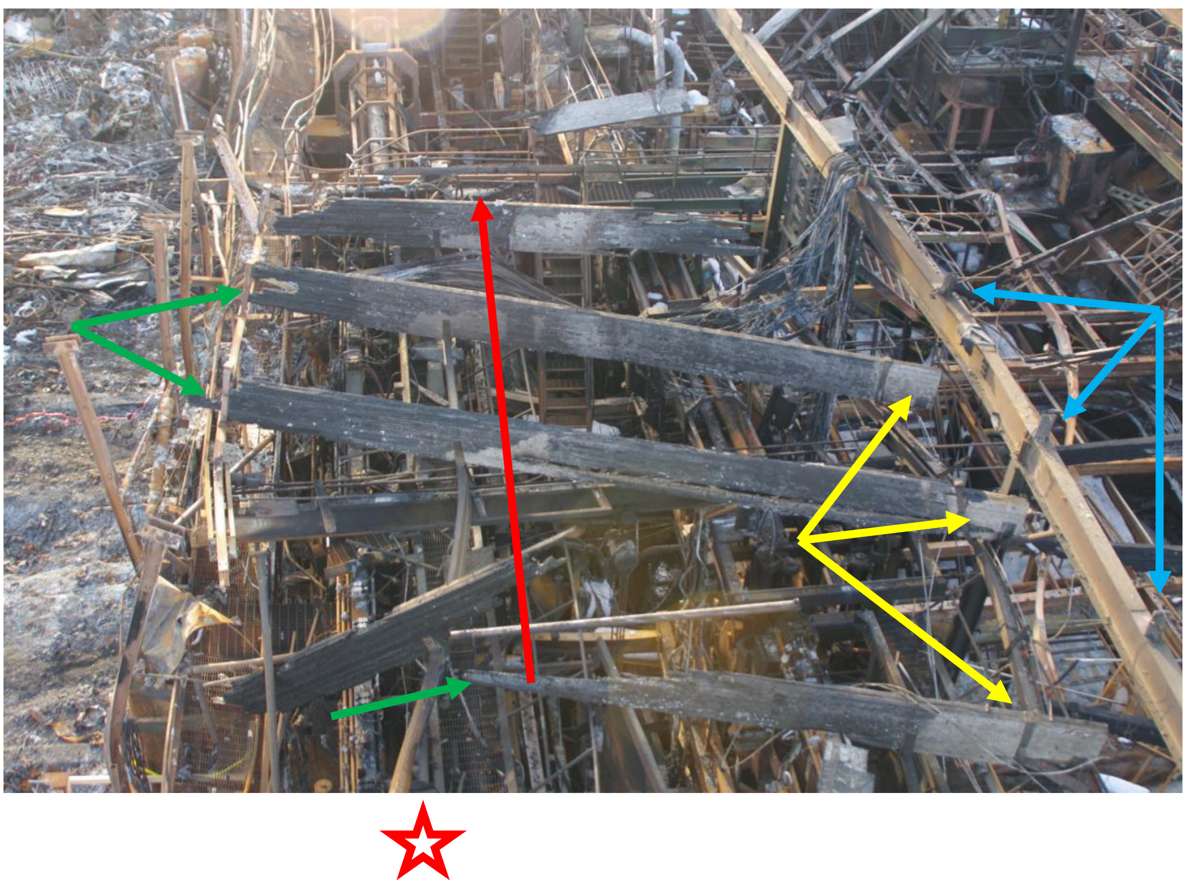
Note: the angle of the wires at the top of the panel (red outline) indicates a southward movement of the panel.



Photograph V3

Looking at the band saw.

Note: the blade shield (green arrow) would normally cover the wheel (yellow arrow).



Photograph V4

Looking at the roof beams above and to the west of the band saw (star).

Note: the south ends of the beams (green arrows) have shifted to the west while the north ends (yellow arrows) are close to their normal locations but have dropped out of the brackets (blue arrows) that secured them to the steel I beam.

Photograph V5

Looking at the door to the boiler room.

Note: the door which would normally have opened out, was found open into the boiler room as indicated by the red vector arrow.

Note also: before the explosion the boiler room was completely enclosed.

Photograph V6

Looking at the boiler room from the south side.

Note: the makeup air duct (green arrow) and the boiler exhaust ducts (yellow arrows) were pushed to the south of their normal positions.

Photograph V7

Looking at the framing of the east wall of the PDC room (green arrow).

Note: the base of the framing (yellow arrow) is in its normal location however, the top has been pushed over to the west.

Photograph V8

Looking at the doors to the hydraulic room by the PDC room blown open to the west.

Photograph V9

Looking at the hard hat of Witness #2 photographed in the southwest end of the basement.

Photograph V10

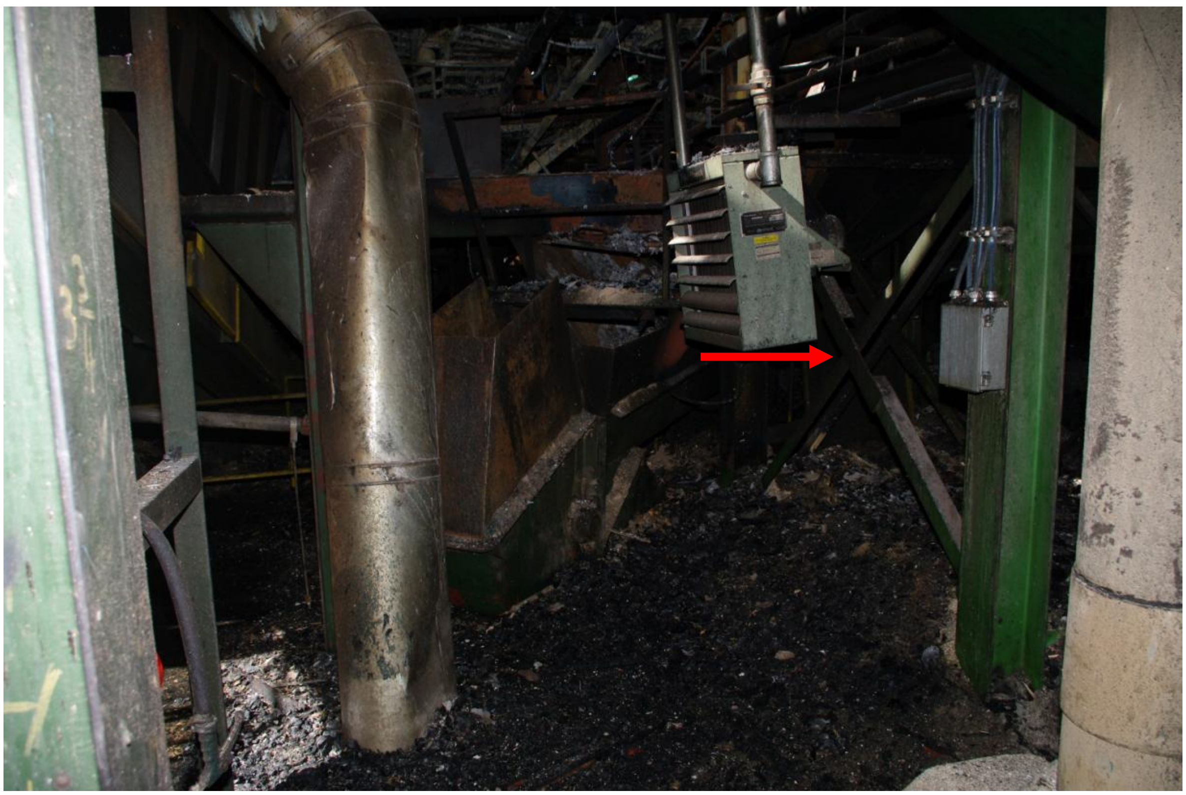
Looking at the compressor room through which Witness #2 escaped.

Note: before the explosion this room was completely enclosed with no exit to the outside.

Photograph V11

Looking at a heating unit in the west end of the basement.

Note: the unit was blown in a northerly direction and turned over on its side exposing the bottom (green arrow).



Photograph V12

Looking at a heater in the east end of the basement.

Note: the bottom of the heater was pushed to the east.

Photograph V13

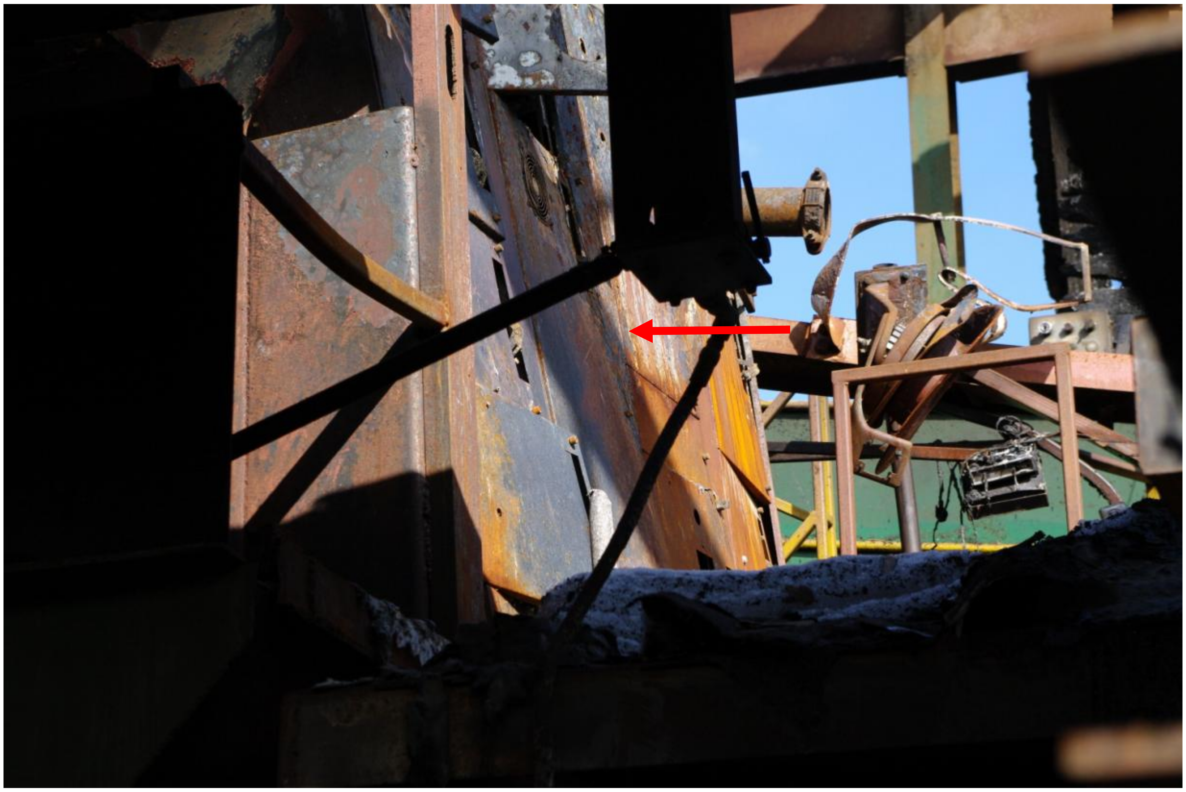
Looking at the east side of the guardrail used to prevent personnel from falling from the crawl space, in the east side of the mill into the basement.

Note: this side of the rail is relatively clean compared to the opposite side (Photograph V14).

Photograph V14

Looking at the west side of the railing shown in photograph V13.

Note: the condition of this side of the rail in comparison to the other side.



Photograph V15

Looking at the MCC panel for the eliminator.

Note: this panel was in the east side of the building and the top of the panel was pushed toward the west (arrow).

Note also: this photograph was taken through the opening through which a blast from the basement would have travelled striking the MCC panel .

Photograph V16

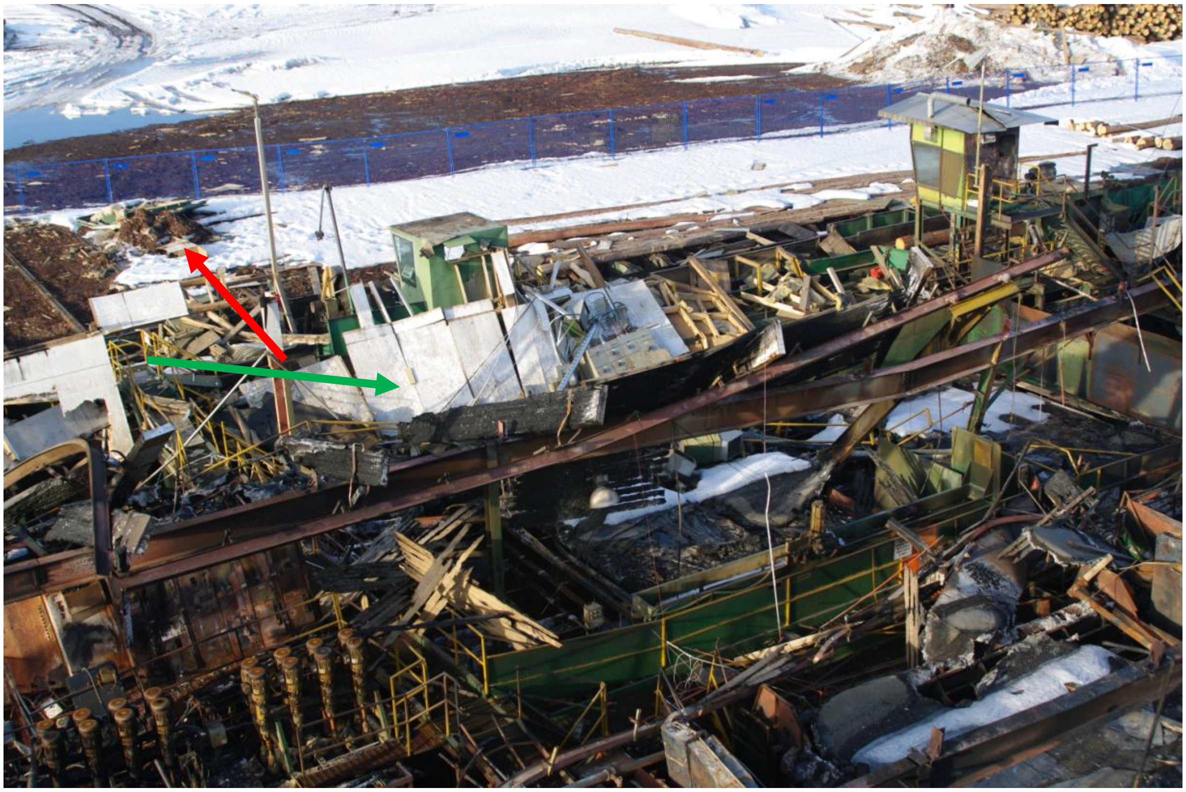
Looking at a machine guard on a conveyor in the southeast wing of the mill.

Note: the direction of the blast was from north to south (arrow).

Photograph V17

Looking at the west end of the mill.

Note: the debris on the ground is the west exterior wall which was blown out to the west.



Photograph V18

Looking north from above the mill.

Note: the north walls (green arrow) were blown out to the north.

Photograph V19

Looking east from the east end of the mill.

Note: the east walls (green arrows) were blown out to the east.

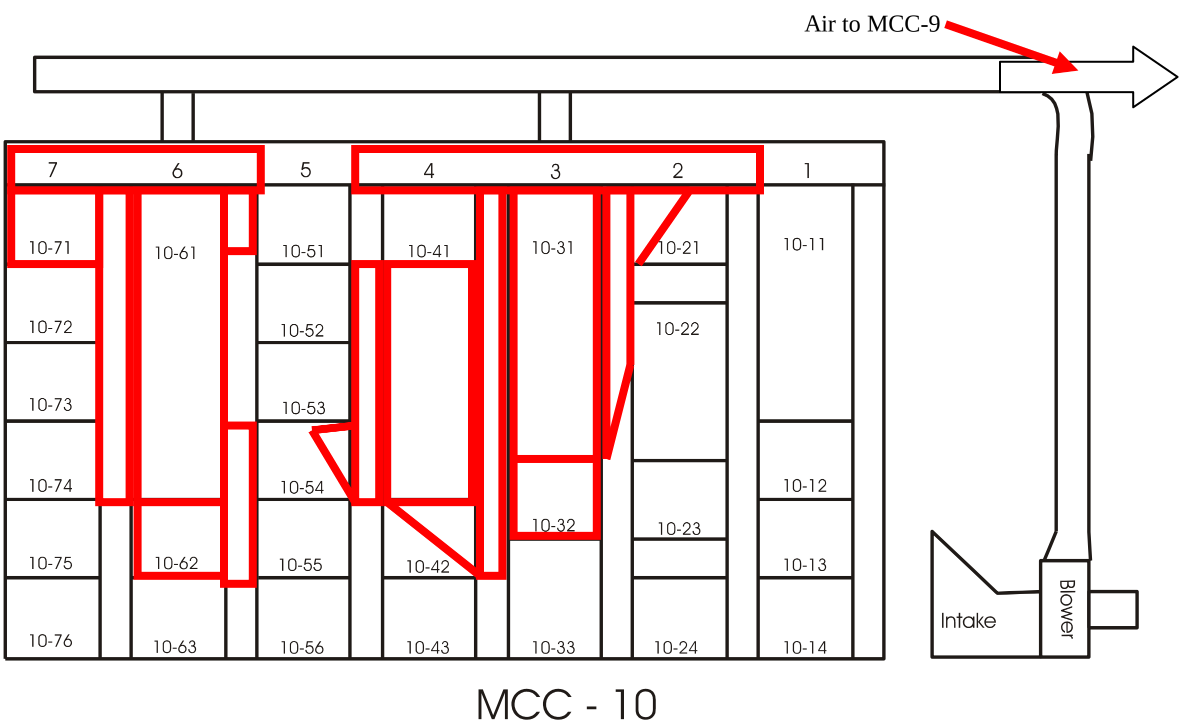
Photograph V20

Looking at the damaged lug in cabinet 10-31.

Photograph M1

Looking at the front of MCC-10.

Note: the burn pattern on the front of the MCC.



Photograph M2

Looking at a line drawing of MCC-10.

Note: the red outlines are intended to duplicate the burn pattern on the MCC as shown in Photograph M1.

Photograph M3

Looking at cabinet 10-11.

Note: the interior of this cabinet was extensively burned.

Photograph M4

Looking at cabinets 10-11 (top) to 10-14 (Bottom).

Note: the condition of cabinets 10-12 to 10-14 as compared to 10-11.

Note also: wood dust can be seen in the bottom two cabinets (arrows).

Photograph M5

Looking at the interior of cabinet 10-32.

Note: the extensive burn damage.

Photograph M6

Looking at cabinet 10-41

Note: when the door of this cabinet was opened the contents fell out.

Photograph M7

Looking at cabinet 10-42.

Note: the interior of the cabinet was completely burned and the tops of the fuse holders were pushed out toward the front of the panel (circle).

Photograph M8

Looking at cabinet 10-51.

Note: the interior of the cabinet was completely burned however all components were present; also the fuse holders (circle) were separated from the base.

Photograph M9

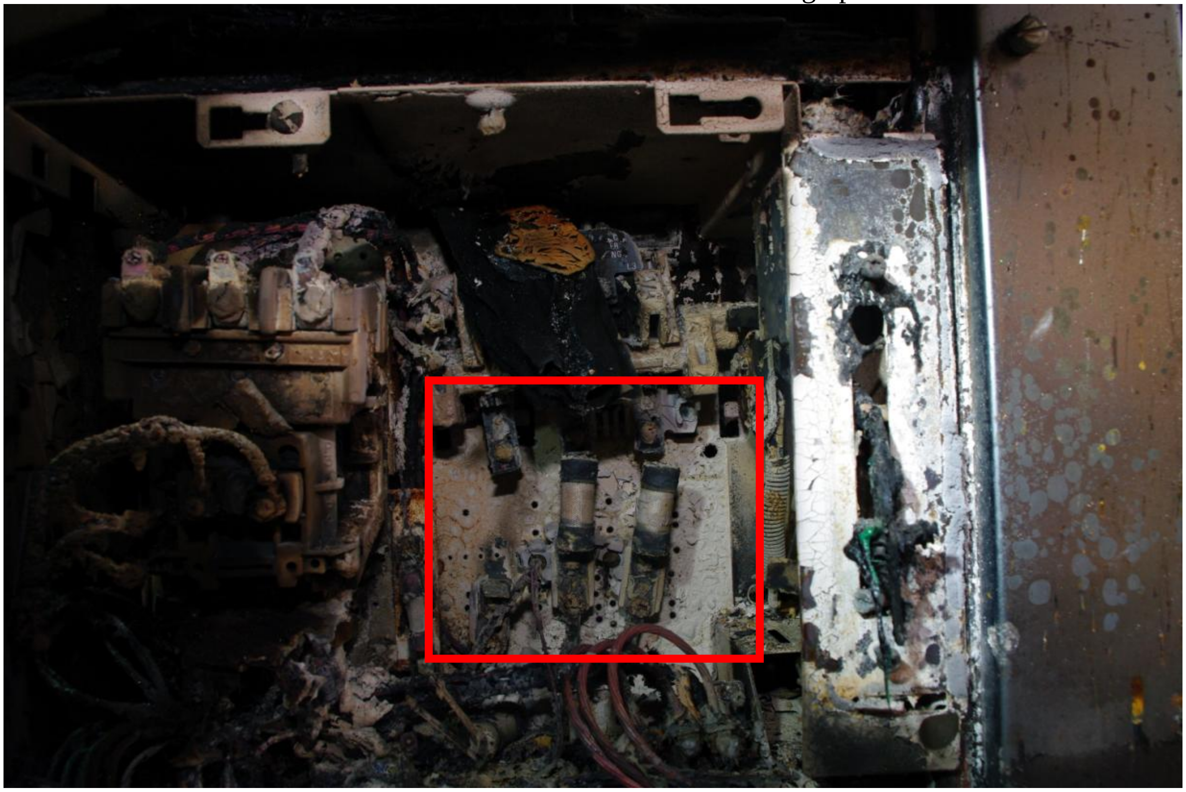
Looking at cabinet 10-52.

Note: the condition of this panel was slightly less damaged than cabinet 10-51.

Photograph M10

Looking at cabinet 10-53.

Note: in this cabinet the fuse mountings were destroyed (rectangle), two fuses were present (circle) and one fuse was missing.



Photograph M11

Looking at cabinet 10-54.

Note: the interior of the cabinet is heavily damage and the fuse holders are disrupted (rectangle).

Photograph M12

Looking at cabinet 10-55.

Note: as with the previously shown cabinets the interior of this one was heavily damaged.

Photograph M13

Looking at cabinet 10-61.

Note: damage to this cabinet was primarily at the bottom (circle).

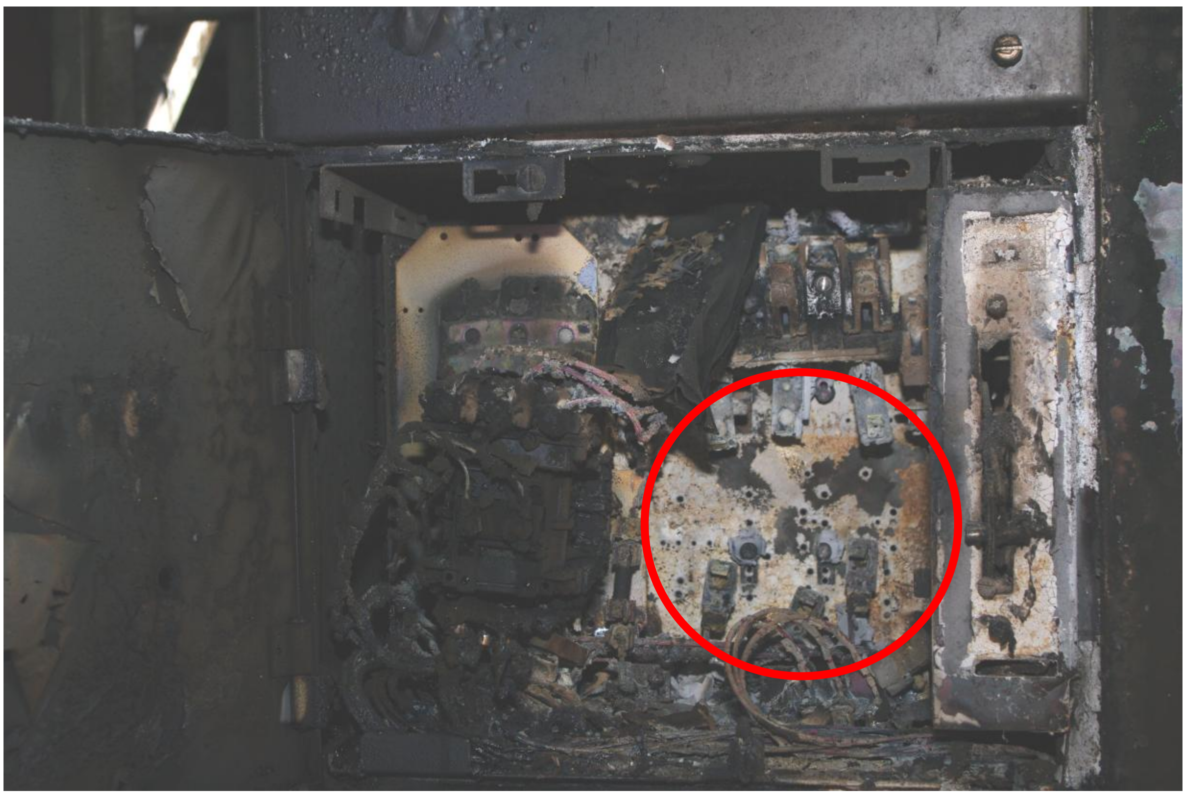
Photograph M14

Looking at cabinet 10-62.

Note: damage to this cabinet coincides with the damage to the bottom of cabinet 10-61.

Photograph M15

Looking at cabinet 10-71.



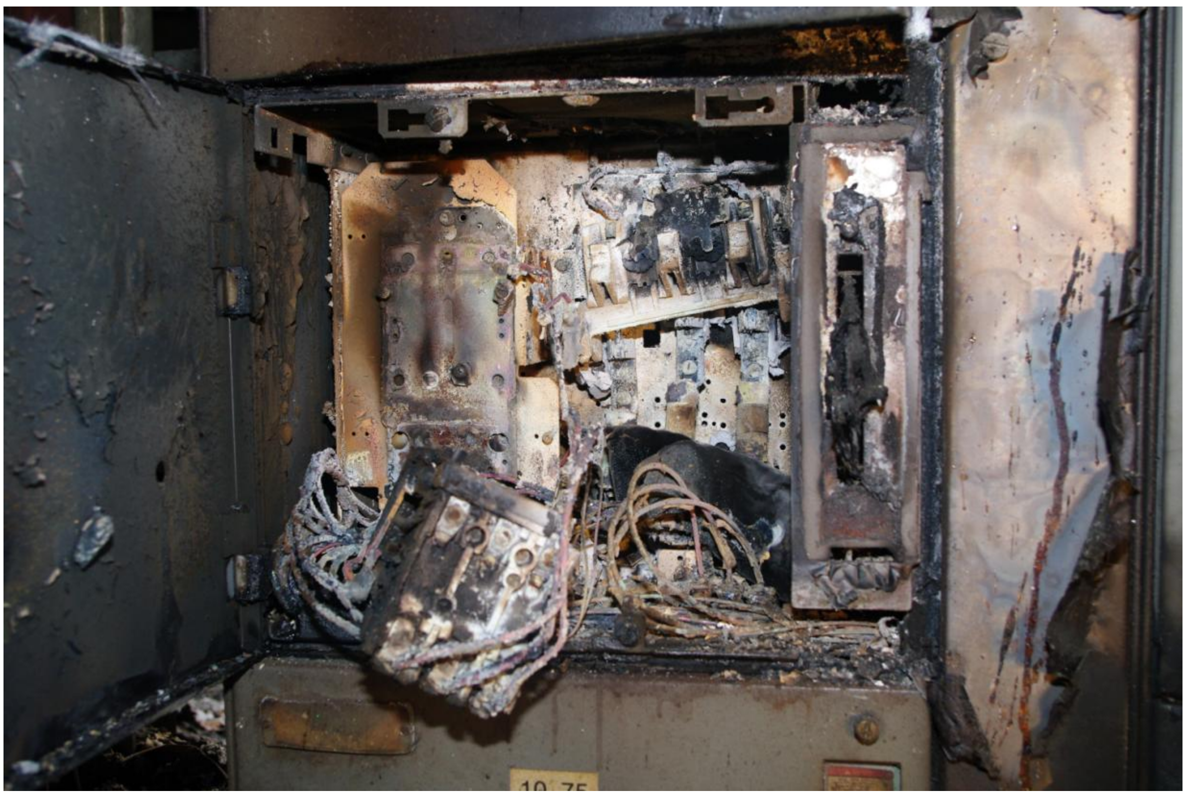
Photograph M16

Looking at cabinet 10-72.

Note: the extensive damage and destruction of the fuse mounts (circle).

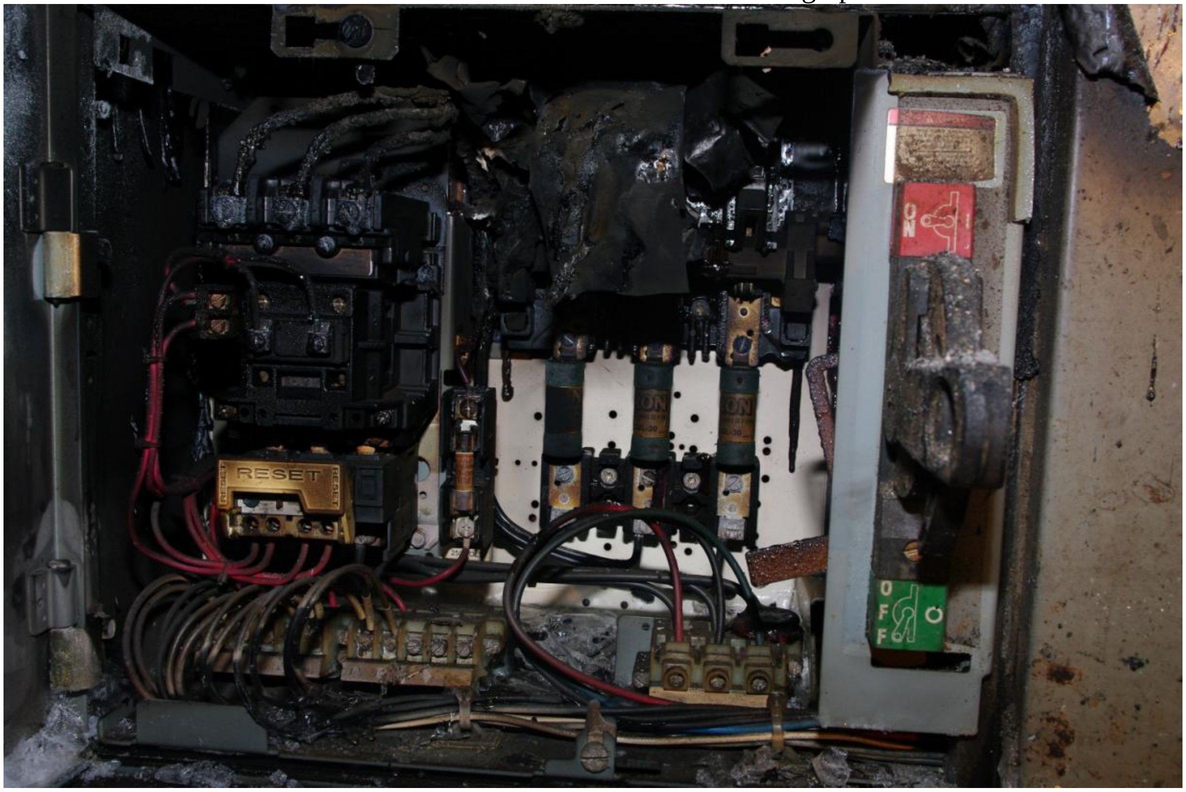
Photograph M17

Looking at cabinet 10-73.



Photograph M18

Looking at cabinet 10-74.



Photograph M19

Looking at cabinet 10-75.

Note: the damage to this cabinet was primarily at the top.

Photograph M20

Looking at the door latch bars on cabinets 10-12 and10-13.

Note: the V shape of the latch bars (arrows).

Photograph M21

Looking at the bottom interior of cabinet 10-13.

Note: the layer of wood dust.

Appendix B

Natural Gas and Propane Equipment Findings

Gas Equipment Subject to the *Gas Safety Regulation* B2

Gas Equipment Field Investigation Findings
- Natural Gas Supply B4
- Gas Odor Reports B7
- Gas Equipment Found within the Area of Origin B8

Gas Equipment Subject to the *Gas Safety Regulation*

Gas equipment discovered within the sawmill structure is listed in Table B1. Installed locations are identified in Figure B1. Gas equipment installation and use was evaluated as either a source of fuel or an ignition source within the areas of origin.

Equipment	Fuel	Model
Boiler #1	Natural Gas	Rudd CB200CC 2000 Mbtuh
Boiler #2	Natural Gas	Superhot AAE-2040-N-E-M 2000 Mbtuh
Boiler #3	Natural Gas	Superhot AAE-2040-N-E-M 2000 MBH
Direct Fired Make Up Air Heating Unit	Natural Gas	Roberts Gordon RDF50BIEN 500 MBH
Direct Fired Make Up Air Heating Unit	Natural Gas	Roberts Gordon RDF100CIEN 1000 MBH
Babbit Pot	Natural Gas	Unknown Approx 30-50,000 btuh
Roof-Top Office Heating Unit	Natural Gas	Undetermined
Regulator A	Natural Gas	Fisher 620 Inlet pressure 60 psi Outlet pressure 20-35 psi Body size 1”
Regulator B	Natural Gas	Unable to identify “CRANE 300 RAILROAD” was marked on the body mounting ring. Regulator destroyed. Inlet press 20-35 psi Outlet press 7”-5 psi
Regulator C	Natural Gas	Large diaphragm style, Unable to identify. Regulator, inlet pressure 60 psi, outlet pressure 7”wc Load 6000 Mbtuh
Various Gas Piping	Natural Gas	Underground – schedule 40 yellow jacket black iron - welded Aboveground – schedule 40 black iron - threaded
Catalytic Heater and portable 20lb fuel cylinder	Propane	Make and model not determined
Torch and portable 20lb fuel cylinder	Propane	Make and model not determined

Table B1: Gas equipment found within the sawmill structure

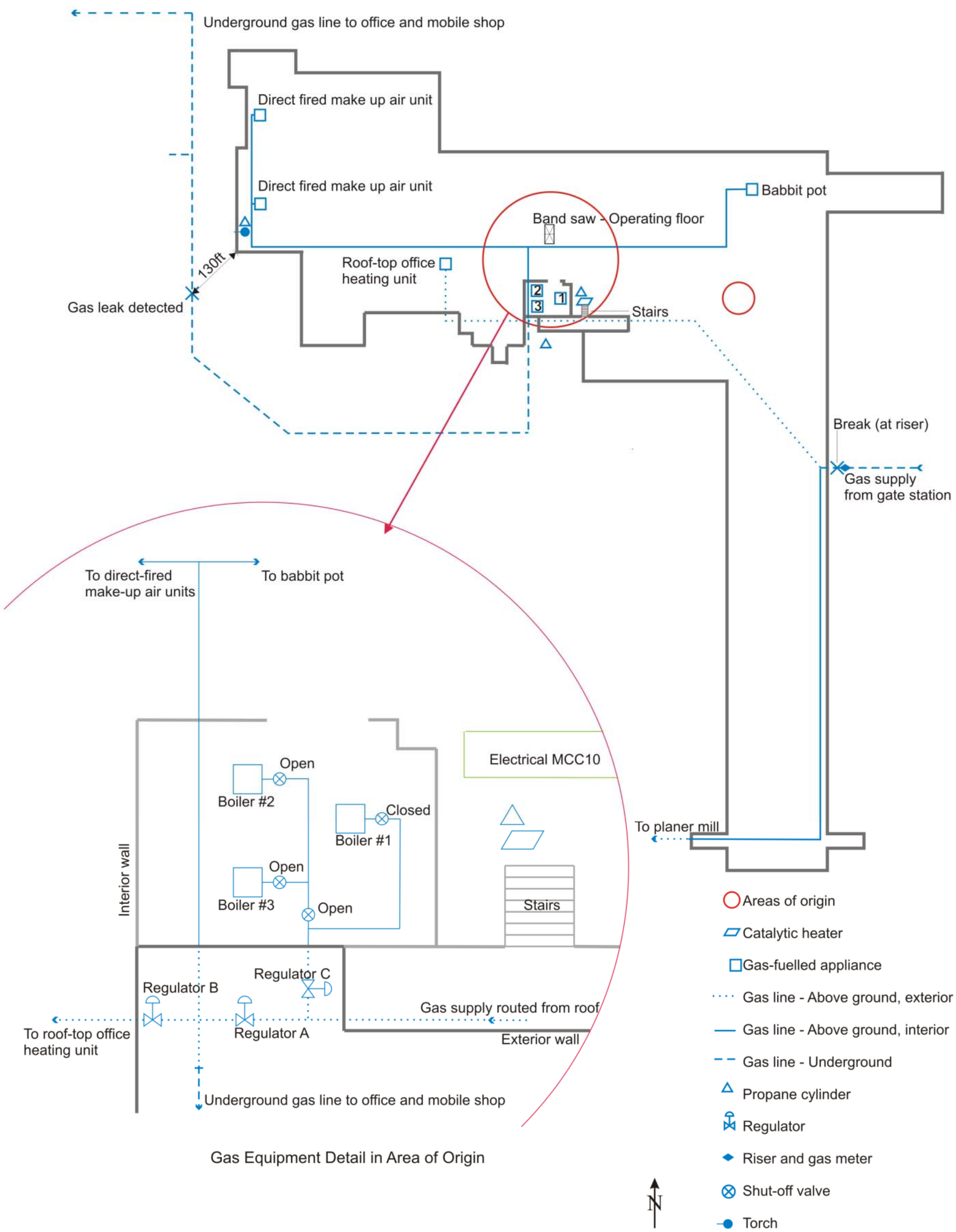


Figure B1: Plan view of mill - gas system and equipment

Note: Figure B1 was produced from field observations and drawings provided by Babine Forest Products. Figures are intended for illustrative purposes only.

Gas Equipment Field Investigation Findings

Natural Gas Supply

Natural gas piping and distribution components were examined to determine if a natural gas leak could have existed prior to the explosion and fire.

Natural gas leak outside of sawmill structure

Underground gas piping outside of the sawmill was pressurized and tested for leaks. One leak was detected west of the sawmill, approximately 40m (130ft) from the structure (and 150m (500ft) from the nearest potential area of origin) as indicated in Figure B1. The underground leak was found to be venting to the surface, next to a hydrant shed. The leakage rate was estimated in the field to have been approximately three cubic feet per hour. The investigation revealed no migration paths into the sawmill structure other than through atmosphere.

The distances of 40m between the leakage location and the nearest sawmill structure and approximately 150m to the nearest area of origin are significant when considering the migration of a low flow of natural gas through an unrestricted atmospheric environment.

Conclusion

This natural gas leak did not supply a combustible fuel mixture to the area of origin in the sawmill basement.

Potential leakage at boiler #1 shut-off valve

The shut-off valve supplying boiler #1 was found in the closed position. Leak tests conducted in the field suggested that gas may have leaked past the shut-off valve or at the valve seams prior to the incident. All other above ground gas piping and piping within the sawmill was pressure tested and no other leaks were found.

An analysis was commissioned by WorksafeBC to evaluate the natural gas supply shut-off valve to boiler #1. The evaluation was observed by BC Safety Authority investigators to not produce any readily identifiable leaks at the valve flange seals or the valve body seams. The evaluation did not produce a readily identifiable bypass condition within the valve.

Conclusion

The evaluation suggests that the shut-off valve for natural gas supply to boiler #1 was performing its function in the OFF position, preventing the flow of natural gas to boiler #1, which was undergoing maintenance.

Connection of boiler #1 to the natural gas supply union

The gas pipe supplying boiler #1 was found disconnected from the boiler manifold. The threads securing the union to the pipe were found damaged. It was reported that maintenance was being conducted on boiler #1. During an interview with the individual conducting this maintenance work, the person stated that the union connecting boiler #1 to the natural gas supply was left in a secured position.

An evaluation was commissioned by WorksafeBC to evaluate the thread damage to the union connecting boiler #1 to the natural gas supply. Thread damage was only found on the union and not on the mating thread of the nut. It was communicated to BC Safety Authority investigators that there was no relative hardness difference that would have explained damage to the union threads and not the nut threads. The damage to the threads was not consistent with what would be expected had the union been properly secured for usage and subsequently torn apart.

Conclusions
It is unlikely that the union connecting boiler #1 to the natural gas supply was properly secured at the time of the incident. However, given that:

- the pressure of the natural gas supply at the shut-off valve was low (approximately 7 inches of water column),
- the shut-off valve was in the off position and likely functioning as expected at the time of the incident, and
- an employee reported no detection of gas odor within the area of origin and the boiler room on the afternoon of the incident;

it is unlikely that natural gas was supplied to the area of origin from the connection of boiler #1 to the gas supply piping.

<u>Regulator assemblies</u>
Gas regulator assemblies installed on the outside wall of the sawmill, near the area of origin as shown in Figure B1, were found destroyed or severely damaged.

Although near the area of origin in the basement under the band saw, the regulators were installed outside of the sawmill structure. There was no evidence suggesting a possible leak from a regulator assembly prior to the incident. Any leakage from a regulator assembly prior to the incident would likely have been vented to outside atmosphere as there were no likely migration paths into the sawmill from this location. The location of the regulators against the outside wall of the area under the band saw exposed them to the effects of the explosion. The explosion probably caused the regulator assembly damage.

Conclusion
It is unlikely that natural gas was supplied to either identified basement area from the regulator assemblies.

<u>Break in natural gas line at riser</u>
The natural gas supply line was found broken at the riser location, outside of the sawmill along the east wall approximately four feet above ground as shown in Figure B1.

The sawmill gas supply riser travelled directly from the riser to the roof outside of the east wall of the sawmill. A leak at this location would be vented directly to atmosphere. During interviews, witnesses stated that the sawmill roof was lifted several feet in the air by the explosion which could have applied a vertical force to the natural gas supply pipe at the riser location.

Conclusions
It is unlikely that a natural gas leak at this location could have supplied a combustible fuel mixture to the areas of origin in the sawmill basement.

It is likely that the explosion caused the break in the natural gas supply pipe at this location.

Increased gas consumption at the time of the incident

Natural gas consumption by Babine Forest Products was recorded by the utility provider on an hourly basis. Reports indicate that hourly consumption increased by a factor of five between 8pm and 9pm on the date of the incident. The utility provider reported that the natural gas supply to the sawmill was turned off at 8:47pm on the date of the incident.

Approximately 40 minutes elapsed between the initial explosion and when the natural gas supply was removed from the sawmill. No evidence was found that suggests a significant breach of the natural gas supply system prior to the incident.

Conclusion

Damage to the natural gas supply system caused by the explosion and fire probably breached the system sufficiently to account for the five-fold increase in natural gas consumption between 8pm and 9pm on the date of the incident.

Gas Odor Reports

During interviews, twelve employees reported smelling a gas like odor at the sawmill before or on the date of the incident. A total of 46 employees stated they did not notice any gas odors prior to or on the day of the incident. Figure B2 represents the general areas associated with these odor reports.

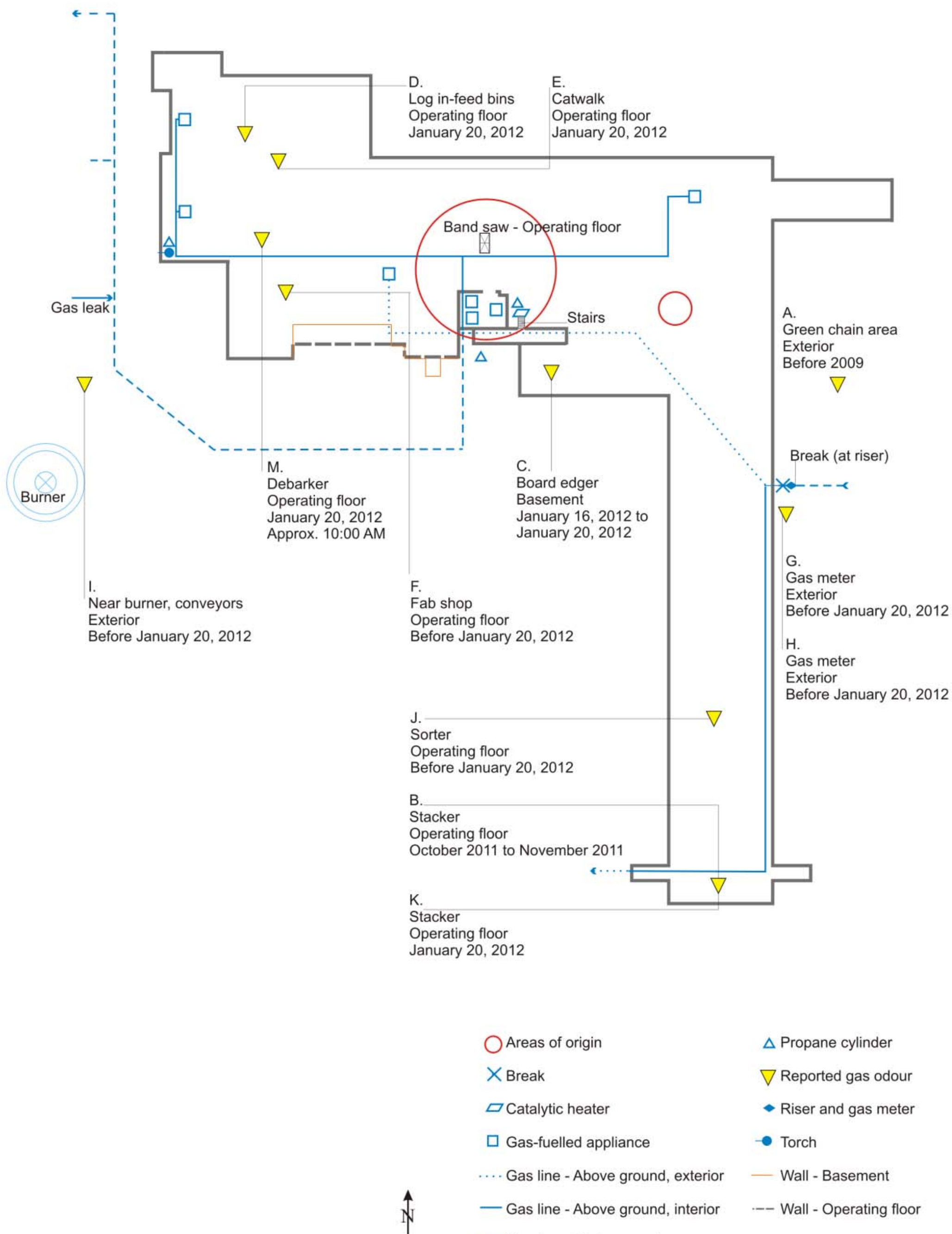


Figure B2: Plan view of mill - gas odor reports from interview statements

Note: Figure B2 was produced from employee interview statements and drawings provided by Babine Forest Products. Figures are intended for illustrative purposes only.

Odorants are added to natural gas and propane to provide a means to warn of the presence of gas. Odorant concentrations are intended to be readily detectable when the concentration of gas is at or above 20% of the explosive concentration limit[10]. Reports of odorant concentrations leading up to the date of the incident show that the odorant was consistently detectable.

Descriptions of gas odors from interviews were generally not indicative of a strong or steady gas presence in one location or near the area of origin. Gas odor near the board edger in the basement was reported to have been investigated by the employee of Babine Forest Products responsible for the natural gas supply system. This employee stated that the natural gas supply lines in the boiler room were checked during the afternoon of January 20, 2012 and no gas odors were detected at that time.

Conclusion

Gas odor reports at the sawmill are not consistent with an explosive level of natural gas (or propane) in the area of origin.

Gas Equipment Found within the Areas of Origin

The following gas equipment was found within the basement area under the band saw as illustrated in Figure B1:

- Boilers #1, #2 and #3
- Catalytic heater and associated 20lb portable propane cylinder

No gas equipment was found in the area near conveyor motor labeled 8R-26.

<u>Boilers #1, #2 and #3</u>

Boilers #1, #2 and #3 were not burning natural gas at the time of the incident. The natural gas supply to Boiler #1 was found to be shut-off and the unit was reported to be undergoing maintenance. Control switches for Boilers #1, #2 and #3 were reported to have been locked out at the electrical control panel and the natural gas supply valve positions found are represented in Figure B1. Some aluminum pilot lines within boilers #2 and #3 were found to be damaged or missing.

Natural gas supply piping and valves to boilers #1, #2 and #3 are discussed above as part of the natural gas supply. Controls for boilers #1, #2 and #3 were reported to be locked out at the electrical control panel.

Internal valve and control diagrams were reviewed for boilers #2 and #3 and there is no reported reason to suspect that these boilers would leak natural gas when in a locked out condition, provided that pilot lines upstream of internal controls were installed when gas was supplied to the boiler.

Boilers #2 and #3 were reported to have been test fired during December 2011 and operating properly. Proper operation would have required the aluminum pilot lines to have been installed at that time. It is likely that the missing pilot lines were a result of the explosion and fire.

Conclusion

It is unlikely that natural gas was supplied to either identified basement area from boiler #1, #2 or #3. It is unlikely that boiler #1, #2 or #3 could have provided an ignition source for a combustible atmosphere within the basement area under the band saw.

[10] See reference 3 at the end of this report for standards defining natural gas and propane odorant limits.

Propane fueled catalytic heater

The propane fueled catalytic heater was reported in an interview to have been in use on the morning of January 20. The appliance was located in the basement and was reported to be used to heat a glycol transfer pump and piping. The heater was reported to have been turned off prior to the incident.

An analysis was commissioned by WorksafeBC to evaluate the propane cylinder supplying fuel to the catalytic heater. The cylinder valve was observed to be in the closed position and it was communicated to BC Safety Authority investigators that approximately 1lb of propane was remaining in the cylinder.

Heat damage was observed on the cylinder in the area near the pressure relief valve.

There was no identifiable make or model number on the catalytic heater. The manufacturer and specifications for this heater were not determined.

Discussion

The findings related to the cylinder are consistent with the employee report that the heater was turned off and not in use at the time of the incident. It is possible that propane within the cylinder expanded as a result of the heat from a surrounding fire sufficiently to open the relief valve and vent propane to the surrounding area.

Paragraph 4.7.2 of *B149.2-10 Propane Storage and Handling Code* relates to the use of appliances in hazardous locations and states:

> *An appliance, unless certified for installation in a hazardous location, shall not be installed in any location where a flammable vapour, combustible dust or fibres, or an explosive mixture is present.*

During an interview, an employee stated that the catalytic heater replaced previously used heaters due to safety concerns related to the combustibility of the wood dust.

Catalytic heaters are often marketed as safe relative to other heaters because the use of a catalyst reduces the temperature of surfaces exposed to the atmosphere. Some are certified as explosion proof and certified for use in *hazardous locations*.

> Explosion proof typically means that the heater enclosure will withstand the effects of an internal explosion and prevent the release of gases at temperatures greater than that for which the unit is certified. Explosion proof does not mean that the heater will not cause an explosion if used in an environment for which it has not been specifically certified for safe use.
>
> Certified for use in hazardous areas means that the appliance has been certified to a specific category and type of environment. A temperature code is identified and relates to the maximum temperature of exposed surfaces. Certified for use in hazardous areas does not mean that the appliance is certified for use in all hazardous areas.

Proper installation and use of a catalytic heater in an area containing flammable vapours, combustible dust or combustible fibres requires the user/installer to identify the hazards and use an appliance rated specifically for that hazard.

Catalytic heaters certified for use in *hazardous locations* displaying temperature code “T1” can have surface temperatures up to 450°C.

WorksafeBC commissioned dust cloud and dust layer ignition temperature testing of wood dust samples from the sawmill and identified a possible dust cloud ignition temperature of 430°C and a wood dust layer ignition temperature of 310°C.

Conclusions

Although it was not determined if the catalytic heater in use was properly certified for the dust hazard present in the area of origin, it is possible that the surface temperatures were higher than what would be needed to ignite either a wood dust cloud or layer.

As indicated in the SAMAC Engineering Ltd. report (Appendix A), blast vectors and explosion damage suggest an explosive force originated in front of MCC #10. The catalytic heater was found behind MCC #10.

It is unlikely that the catalytic heater and associated propane cylinder supplied a fuel source to the area of origin prior to the existence of a fire.

It is unlikely that the catalytic heater provided an ignition source to the area of origin at the time of the incident.

The propane cylinder likely supplied fuel to the area during the fire.

Appendix C

Boiler and Pressure Vessel Equipment Findings

Pressure Equipment Subject to the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation* **C2**

Pressure Equipment Field Investigation Findings

- **Ethylene Glycol System and Piping** **C4**
- **Thermal Fluid Piping and Heat Exchanger** **C4**
- **Boiler and Pressure Vessel Equipment Found within the Areas of Origin** **C5**

Compliance with the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation **C6**

Pressure Equipment Subject to the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation*

Boiler and pressure vessel equipment discovered at the sawmill site is listed in Table C1. Installed locations are identified in Figure C1.

Pressure Equipment	Pressurized Contents	Unit Information
Boiler #1	Ethylene glycol	Rudd CB200CC Heating surface area: $16m^2$
Boiler #2	Ethylene glycol	Superhot AAE-2040-N-E-M Heating Surface Area: $15m^2$
Boiler #3	Ethylene glycol	Superhot AAE-2040-N-E-M Heating surface area: $15m^2$
Sawmill Heating Pipes and Valves	Ethylene glycol	NPS 6 Piping
Thermal Fluid Heat Exchanger	Heat transfer fluid (shell side) Ethylene Glycol (tube side)	American Standard SN 84H43070-02 MAWP 150psig CRN# F3854.1
Thermal Fluid Distribution Piping and Valves	Thermal fluid	NPS 4 Piping
Sawmill Air Receiver	Air	Unit was not observed during field investigation
System Air Receiver	Air	Steel Fabricating & Welding Co Limited CRN # E529.1234567890T MAWP 137psi at 550°F SN 5657652
#2 Air Compressor	Air	Silvan Industries Inc CRN # L8095.567890134 MAWP 160psi at 250°F , MDMT 20°F at 160psi SN 679773, CUST PN 02250120-612 Pressure Relief Setting – 160psig
Sullair Air Compressor	Air	Silvan Industries Inc CRN # M5333.5678901234 MAWP 175psi at 250°F , MDMT 20°F at 175psi SN 674918, CUST PN 02250100-802 Pressure Relief Setting – 175psig
#1 Air Compressor	Air	Silvan Industries Inc CRN # C7021.610327 MAWP 150psi at 250°F , MDMT 20°F at 150psi SN 674918, CUST PN 02250100-802 Pressure Relief Setting – 150psig
Air Dryer and Filter	Air	Not Known
Air Dryer and Filter	Air	Not Known
Air System Piping	Air	N/A

Table C1: Boiler and Pressure Vessel Equipment Identified at Babine Forest Products

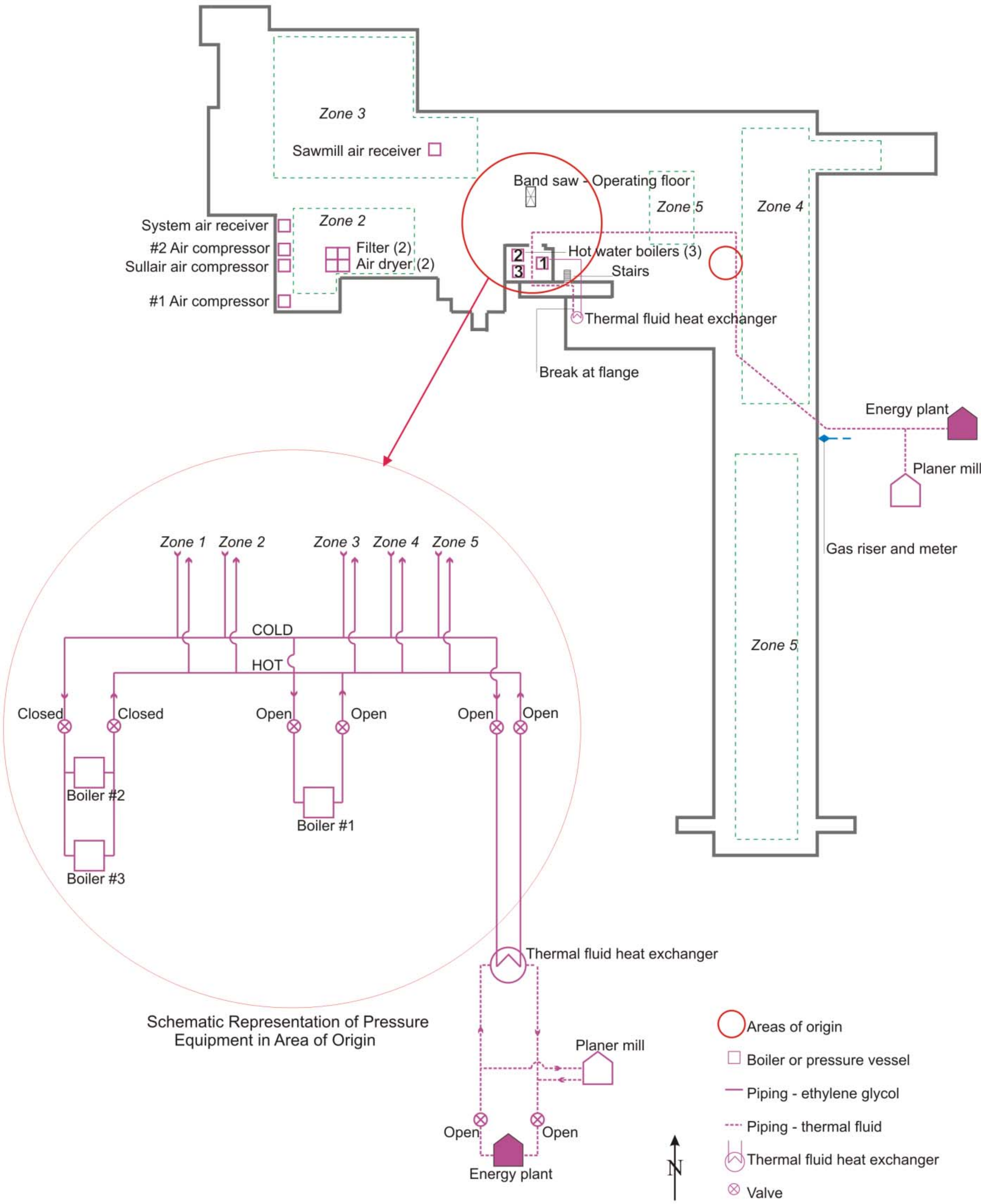


Figure C1: Plan view of mill - boiler and pressure vessel equipment

Note: Figure C1 was produced from field observations and drawings provided by Babine Forest Products. Figures are intended for illustrative purposes only.

Pressure Equipment Field Investigation Findings

Ethylene Glycol System and Piping

Ethylene glycol was circulated within the sawmill and heated from three hot water boilers and/or a heat exchanger as shown in Figure C1. Valve positions found are indicated in Figure C1. Ethylene glycol fluid can present explosion and fire hazards under certain conditions. No evidence of ethylene glycol piping or piping component failures was found. It is unlikely that this equipment contributed to the incident.

Thermal Fluid Piping and Heat Exchanger

Thermal fluid was supplied from an energy plant outside of the sawmill structure to a heat exchanger located within the sawmill structure. The heat exchanger was found to have fallen off its support structure. A flange bolt that was part of the thermal fluid valve train assembly was found to be fractured as shown in Photograph C1. Thermal fluid residue was found in the area of the heat exchanger. There were no other findings that would indicate a failure of thermal fluid piping or thermal fluid leakage.

Photograph C1: Broken bolt at valve flange to heat exchanger

The location of the heat exchanger against the wall near the area of origin likely exposed it to the effects of the explosion. The explosion probably caused the heat exchanger to have fallen off its support structure and fractured the valve flange bolt, resulting in a leakage of thermal fluid estimated by Wellons Canada to be approximately 3400 US gallons. The mill thermal fluid isolation valves are shown in Figure 1 in the open position. These valves were open at the time of the incident and subsequently closed during fire fighting activities.

Conclusions
It is unlikely that thermal fluid was leaked at the heat exchanger prior to the explosion.

It is likely that following the explosion, the damage to the valve flange bolted connection produced a supply of thermal fluid to the then existing fire.

Boiler and Pressure Vessel Equipment Found within the Areas of Origin

Boilers #1, #2 and #3 and their associated piping and valves were found within the area of origin under the band saw as illustrated in Figure C1. Valve positions shown are as found during the investigation with the exception of the mill thermal fluid isolation valves from the energy plant: these valves were open at the time of the incident and subsequently closed during fire fighting activities. No boiler or pressure vessel equipment was found in the area near the conveyor motor labeled 8R-26.

Compliance with the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation

This investigation found that pressure vessel supervision was conducted by unqualified individuals which may have contributed to the addition of thermal fluid to the fire, following the initial explosion.

Administrative Requirement

Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation
Definitions and Interpretations for this regulation
2 "fourth class plant" *means*

(c) a low pressure thermal fluid plant that exceeds 500 m^2 of boiler capacity but does not exceed 1 500 m^2 of boiler capacity,

"chief engineer" *means a power engineer who is designated by the owner to be responsible for the operation and maintenance of a plant and who is responsible for ensuring that all regulated work in the plant is performed by appropriately qualified persons;*
"shift engineer" *means a power engineer who is a person in charge of a plant under the supervision of a chief engineer or one who is in charge of a plant when the chief engineer is absent;*

Plant classifications
44 *(1) A plant classification referred to in this regulation requires a power engineer with a corresponding or higher class of certificate of qualification to be appointed as chief engineer of that plant.*

Continuous supervision status plant operation
45 *…the person in charge of the plant must be present at all times in the plant boiler room, refrigeration machinery room, engine turbine room or in the immediate vicinity within the plant premises while the plant is in operation.*

What a fifth class power engineer may do
24 *A fifth class power engineer's certificate of qualification entitles the holder to be*

(a) a shift engineer of a fourth class plant.

Condition Found

The total heating surface of the energy plant that supplied heated thermal fluid to the sawmill was 800 square meters. The energy plant was a fourth class plant requiring a chief engineer who holds a minimum Certificate of Qualification as a fourth class power engineer and shift engineers who hold a minimum Certificate of Qualification as a fifth class power engineer.

During interviews with employees of Babine Forest Products, it was determined that two dayshift kiln operators were in charge of the plant during their working shifts and that a nightshift attendant monitored the plant operation in their absence. Neither of the day shift kiln operators or the nightshift attendant held a Certificate of Qualification as a power engineer of any class.

Conclusion

The supervision of the energy plant was not in compliance with the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation.* As discussed earlier in the report, an estimated 3400USG of thermal fluid was lost during the incident and qualified energy plant supervision with suitable emergency procedures and training may have isolated the sawmill from the system supply of thermal fluid prior to this loss. This non-compliance may have influenced the amount of thermal fluid that was lost by the system and was likely added to the fire.

Appendix D

Electrical Non-Compliances – Increased Risk of Electrical Ignition Sources

Compliance with the Electrical Safety Regulation

Safe Use of Electrical Equipment in *Hazardous Locations*	**D2**
De-rating of Current Capacities of Conductors in Cable Trays	**D3**
Electrical Bonding	**D4**
Electrical Motor Ventilation	**D4**

Compliance with the *Electrical Safety Regulation*

The *Electrical Safety Regulation* adopts the Canadian Electrical Code (with BC amendments) as the technical standard for most electrical equipment in the Province. For the purposes of compliance, electrical installations are compared to the edition of the *Canadian Electrical Code* that was in force at the time of the installation. It was reported that the sawmill completed a major electrical service upgrade and it was estimated that this work was completed around 2005. In 2005, the *Canadian Electrical Code, Part I, Nineteenth Edition, Safety Standard for Electrical Installations, Canadian Standards Association C22.1-02* was utilized as the BC Electrical Code. BC Amendments to the 2002 edition of the Code did not affect the non-compliances discussed below.

This investigation identified the following non-compliances to the *Electrical Safety Regulation* that increased the risk of electrical equipment in the areas of origin providing a source of ignition for a hazardous wood dust environment.

Safe Use of Electrical Equipment in Hazardous Locations

Technical Code Requirements

2-300 General requirements for maintenance and operation

(1) All operating electrical equipment shall be kept in safe and proper working condition.

Section 18 – Hazardous Locations

18-04 Classification

Hazardous locations shall be classified according to the nature of the hazard, as follows:

- *(d) Class II locations are those which are hazardous because of the presence of combustible or electrically conductive combustible dusts;*
- *(e) Class III locations are those which are hazardous because of the presence of easily ignitable fibres or flyings, but in which such fibres or flyings are not likely to be in suspension in air in quantities sufficient to produce ignitable mixtures.*

Section 18 prescribes installation techniques to separate the combustion hazards from potential electrical ignition sources in Class II and III hazardous locations, including:

- Use of metal conduits and sealed enclosures for wiring (18-202, 204, 252, 254, 302 & 352)
- Sealing and use of dust tight enclosures for switches, motor controllers etc (18-206, 256, 304 & 354)
- Use of outside clean air for electrical component ventilation (18-212, 262, 310 & 360)
- Use of luminaires and other equipment that is certified for the hazardous environment (18-216, 220, 264 and others)

Discussion

Electrical installations are generally configured for non-hazardous locations. These configurations assume that wood dust is managed in such a manner as to maintain the non-hazardous environment. When wood dust management fails to maintain a non-hazardous environment and electrical equipment is permitted to continue operation, techniques prescribed by Section 18 are required to keep equipment operating in a safe working condition.

Condition Found
Explosion and Fire Hazard Findings:
- Wood dust was found within cabinets of MCC #9 and MCC #10.
- Wood dust was found within the ventilation ducting for MCC #9 and MCC #10.
- Wood dust was found layered on top of cables and electrical components within the basement area of origin under the band saw and other locations that were observed.

Electrical Equipment Findings:
- Wiring was not routed within metal conduits and sealed enclosures.
- Motor Control Centres were not sealed to prevent the ingress of combustible dust.
- Ventilation system for MCC #9 and MCC #10 was not in use. When in use this system would have drawn air from beside MCC #10 and not clean air from outside of the building.
- Luminaires were of the open design and did not contain hazardous location certification indications.
- No electrical equipment within the areas of origin was observed to have been certified for use in a hazardous location.

Conclusion
At the time of the incident, the areas of origin were *hazardous locations* as classified by section 18 of the *Canadian Electrical Code*. At the time of the incident, electrical equipment installed and in use within the areas of origin was not compliant to section 18 of the *Canadian Electrical Code* for *hazardous locations* and therefore not compliant to rule 2-300. This non-compliance leads to a condition where potential ignition sources exist within a combustible *hazardous location*. At the time of the incident, electrical equipment within the areas of origin was not compliant with the *Electrical Safety Regulation*.

De-rating of Current Capacities of Conductors in Cable Trays

Technical Code Requirement
12-2210 Ampacities of conductors in cable trays

(3) in ventilated and ladder-type cable trays, where the air space between adjacent conductors, cables, or both is less than 25% of the diameter of the larger conductor or cable, and for any spacing in a non-ventilated cable tray, the ampacity of the conductors or cables shall be the value as specified in Table 2 or 4 multiplied by the correction factor specified in Table 5C for the total number of conductors in the cable trays.

Condition Found
MCC#9: Feeder cables to MCC #9 were protected by an 800 Amp circuit breaker. Two 400MCM conductors per phase were found installed for the motor load of 443 hp.

MCC#10: Feeder cables to MCC #10 were protected by a 1200 Amp circuit breaker. Two 350MCM conductors per phase were found installed for the motor load of 418 hp.

Discussion
MCC#9: The maximum allowable current for 400MCM conductors in Table 2 of the Code is 345 Amps yielding a maximum allowable current carrying capacity of 483 Amps, de-rated per Table 5C of the Code for compact routing in the cable tray.

MCC#10: The maximum allowable current for 350MCM conductors in Table 2 of the Code is 325 Amps yielding a maximum allowable current carrying capacity of 455 Amps, de-rated per Table 5C of the Code for compact routing in the cable tray.

Conclusion

The conductor size of the feeders supplying MCC #9 and MCC #10 have allowable currents of 483 and 455 Amps, respectively. The load for MCC #9 is shown to be 443 hp at 480 volts or 633 amps. The load for MCC #10 is shown to be 418 hp at 480 volts or 598 Amps. The feeder conductor size for MCC #9 and MCC #10 were not compliant to the *Electrical Safety Regulation*. This non-compliance may have contributed to overheating of feeder cables to MCCs #9 and #10, which were located in the basement area below the band saw.

Electrical Bonding

Technical Code Requirement

12-2208 Provisions for bonding

(1) Where metal supports for metal cable trays are bolted to the tray and are in good electrical contact with the grounded structural metal frame of a building, the tray shall be deemed to be bonded to ground.

(2) Where the conditions of Subrule (1) do not apply, the metal cable tray shall be adequately bonded at intervals not exceeding 15 m and the size of bonding conductors shall be based on the ampacity of the largest ungrounded conductor…

Condition Found

MCC bonding conductors were not connected to the cable tray between MCC#10 and the PDC. There was no evidence of a bonding conductor for MCC #9.

Discussion

A short circuit between a cable and the cable tray between MCC #10 and the PDC could have produced sparking or heating at mechanical connections of the tray.

Large fault currents in MCC #9 could have damaged small bond conductors in the motor and control cables as the fault utilized these small conductors with the building steel to return to the main system ground.

Conclusion

Provisions for electrical bonding of cable trays associated with MCC #9 and MCC #10 were not compliant to the *Electrical Safety Regulation*. This non-compliance could have increased the risk of ignition sources within the area.

Electrical Motor Ventilation

Technical Code Requirement

28-016 Ventilation

(1) Adequate ventilation shall be provided to prevent the development around motors of ambient air temperatures exceeding 40°C for integral horsepower motors and 30°C for fractional horsepower motors.

(3) *In locations where dust or flying material will collect in or on motors in quantities that interfere with the ventilation or cooling of motors, thereby causing dangerous temperatures, suitable types of enclosed motors that will not overheat under prevailing conditions shall be used.*

<u>Condition Found</u>
Some electric motors found in the facility had cooling fins and surface areas significantly contaminated with wood dust. Other motors were found to be completely covered with wood dust, impairing proper cooling of the equipment and providing heat insulation rather than dissipation.

<u>Conclusion</u>
Installation and use of electric motors were not compliant to the *Electrical Safety Regulation*. The sawdust and debris from the waste and chip conveyors was allowed to accumulate on the motors such that the motors were insulated, impairing motor cooling. Overheated motors could produce an ignition source for a wood dust cloud or layer.