FURNITURE MANUFACTURING FACILITY DUST EXPLOSION

Lenoir, NC

November 20, 1994

NFPA INTERNATIONAL

FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101 USA
Telephone: 1-617-984-7263 E-mail: investigations@nfpa.org

FIRE INVESTIGATION REPORT

Furniture Manufacturing Facitity Dust Explosion

November 20, 1994

Prepared by
Edward Comeau
National Fire Protection Association

July 6, 1995

Acknowledgments

The investigation team for this incident was comprised of Martha Curtis, NFPA Senior Chemical Specialist, and Mark Chubb, Fire Code Coordinator for the Southern Building Code Congress International. I would like to acknowledge the invaluable contribution made by both of these individuals, both as part of the investigation team and in the preparation of this report.

I also would like to acknowledge the cooperation and assistance of the North Carolina Division of Occupational Safety and Health and the Lenoir Fire Department.

ABSTRACT

On Sunday, November 20, 1994, at approximately 3:41 pm, a series of explosions occurred at a furniture manufacturing facility in Lenoir, North Carolina. There were two fatalities and four injuries as a result of this incident.

The North Carolina Division of Occupational Safety and Health invited the NFPA Fire Investigations Department to participate in the investigation of this incident. On Tuesday, November 29, 1994, Ed Comeau, Chief Fire Investigator, and Martha Curtis, Senior Chemical Specialist, arrived at the facility. Mark Chubb, Fire Code Coordinator from the Southern Building Code Congress International (SBCCI), was on site participating in the investigation as part of the agreement between SBCCI and NFPA.

Prior to the arrival of the NFPA investigation team, the North Carolina State Bureau of Investigations (SBI) had been at the scene and had investigated the incident. SBI has responsibility for investigating all fire-related homicides in order to determine if there has been criminal intent. SBI determined that the nature of the incident was accidental and not criminal.

The incident occurred in the particle board manufacturing portion of the plant. Raw dust was taken in and refined into finished sheets of particle board that was used in the construction of furniture in other portions of the plant. This manufacturing line was the sole source of particle board for the plant's furniture-making operations.

Based on NFPA's site inspection and subsequent analysis, it was determined that there were three potential sources of ignition: a stray piece of metal in a grinding machine that sparked, a leak in an overhead oil line that atomized and subsequently ignited, or a natural gas leak in the vicinity of the thermal transfer unit that was ignited explosively.

Following the initiating event, four explosions occurred throughout the facility. These explosions were caused by dust in the facility that was placed into suspension in the air by each prior explosion. The dust in suspension then came into contact with an ignition source and ignited explosively. It was observed that there were large amounts of dust throughout the facility, and there were minimal efforts to control electrical ignition sources.

Two employees were killed and four were injured. Damage to the facility covered 139,000 square feet. Production will be interrupted for over nine months. An estimate of the property damage is not available. However, much of the building, as well as the production equipment, will have to be replaced.

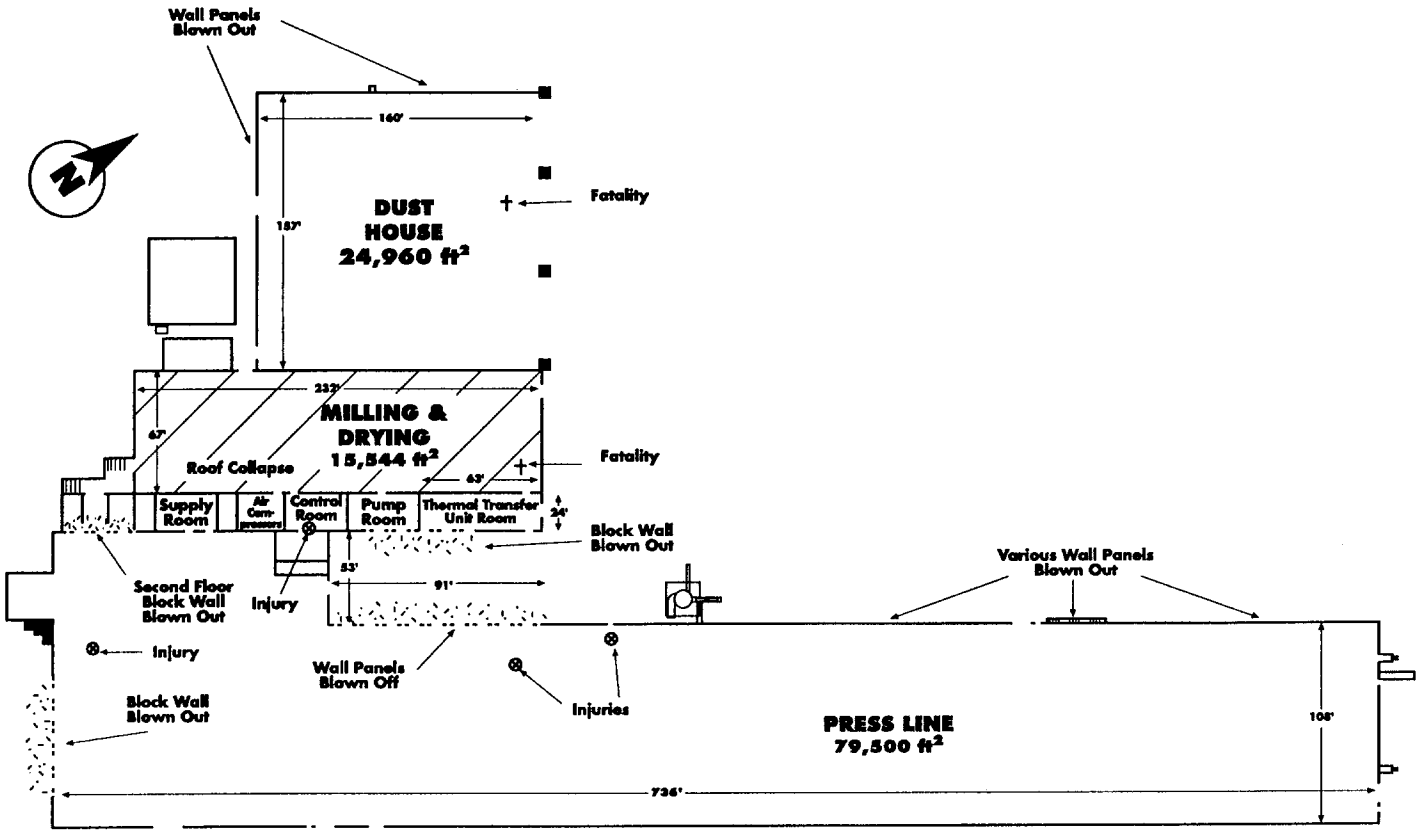
II. BACKGROUND

Occupancy Classification

The Miller Hill Complex is a large furniture manufacturing facility. The complex is comprised of the following separate operations: four manufacturing operations, a lumber yard, a warehouse, and a finish/quality control lab. Approximately 1,500 people are employed at this complex.

The area where the incident occurred took in dust from other facilities and then processed it into particle board sheets that were used in subsequent manufacturing processes in other parts of the facility. The scrap wood was ground into large particles by grinders located outside of the buildings. The resulting dust was then stored in the dust house, which was a 24,960-square foot structure approximately 33 feet high. From there, the dust was moved to the milling and drying area where it was further refined into the required size, dried, and then transported via ductwork into the press line area. At this point it was pressed into large sheets of particle board, which were used in the construction of furniture at other locations on the site.

According to A-1-4.7.3.1 of NFPA 13, *Standard for the Installation of Sprinkler Systems,* (1994 Edition), this occupancy would be classified as an Extra Hazard Occupancy (Group 1). According to the 1994 edition of NFPA *101® Life Safety Code®,* this occupancy would be classified as a Special Industrial, Ordinary Hazard. These buildings would be classified as Type II-000 in accordance with NFPA 220, *Standard on Types of Building Construction* (1992 Edition)



TOTAL AREA = APPROX 125,000 ft²

Applicable Codes and Enforcement

The maintenance and operation of the plant is governed by the *North Carolina State Building Code,* which is based on the 1988 editions of the standard codes published by the Southern Building Code Congress International. Volume 5 of the North Carolina code is the state fire prevention code and specifies requirements for controlling hazards associated with dangerous operations and processes, storage, handling and use of hazardous materials, and maintenance of fire protection features and exits.

Chapter 37, "Lumber Yards and Woodworking Plants," of the 1994 *Standard Fire Prevention Code,* addresses the requirements for woodworking plants and applies to this incident. Referenced NFPA standards in this chapter include:

NFPA 10, *Standard for Portable Fire Extinguishers*

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*

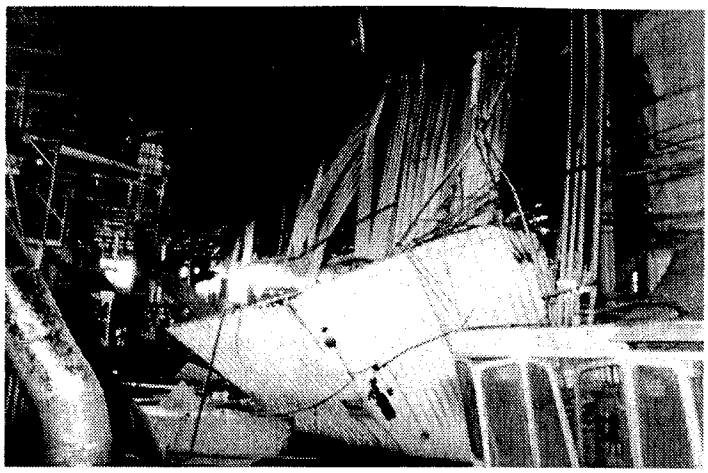
NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*

Chapter 21, "Prevention of Dust Explosions," of the *Standard Fire Code,* which references NFPA 68, *Guide for Venting of Deflagrations.*

NFPA 13, *Standard for the Installation of Sprinkler Systems,* and NFPA 70, *National Electrical Code®*, are also referenced by the *Standard Fire Prevention Code.*

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, is not referenced by the *Standard Fire Code,* but is recognized by the North Carolina *State Building Code* as being applicable by the authority having jurisdiction (AHJ) if appropriate.

The plant was usually inspected annually by representatives from the Lenoir Fire Department.



Blast damage. The right side of the lightweight metal panels housed the maintenance area which abutted the milling and drying area.

NFPA Codes

The following NFPA documents apply to this facility and its operations:

NFPA 10, *Standard for Portable Fire Extinguishers, 1994 edition*

NFPA 13, *Standard for the Installation of Sprinkler Systems, 1994 edition*

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances, 1995 edition*

NFPA 54, *National Fuel Gas Code, 1992 edition*

NFPA 68, *Guide for Venting of Deflagrations, 1994 edition*

NFPA 69, *Standard on Explosion Prevention Systems, 1992 edition*

NFPA 70, *National Electrical Code®, 1996 edition*

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials, 1992 edition*

NFPA 101®, *Life Safety Code®, 1994 edition*

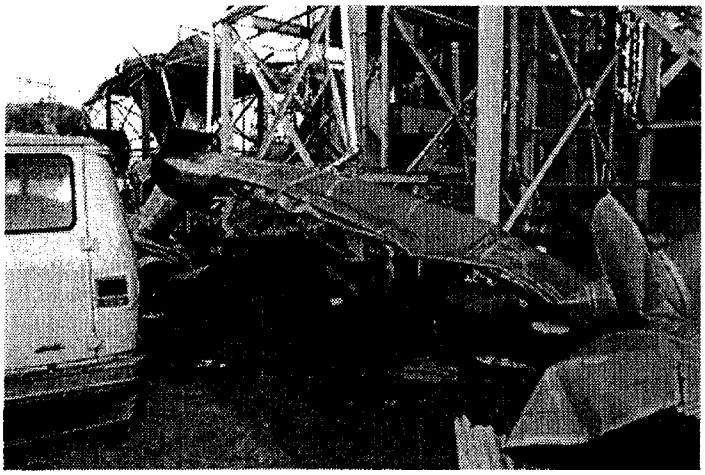
NFPA 600, *Standard on Industrial Fire Brigades, 1992 edition*

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials, 1990 edition*

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, 1993 edition*

The Building

The plant was constructed in 1971 and 1972. The structural frames of the buildings involved in the incident were unprotected, structural steel I-beams. The roof diaphragm was of lightweight steel trusses. The roof was constructed of built-up roofing material on metal decks. A variety of exterior wall panels were used, such as lightweight corrugated sheet metal or composite panels. In accordance with NFPA 220, *Standard on Types of Building Construction* (1992 Edition), these buildings would be classified as Type II-000.



Picture of the damage to some of the ductwork on the southeast side of the building.

Industrial Operations

There were a number of separate operations in this area that were related to the production of the particle board.

Dust was brought into the facility by truck from other locations. The dust was stored in the dust house, which was enclosed on three sides. The dust house was approximately 33 feet high and 24,960 square feet in area.

Dust was then moved from the dust house to a shaker that screened the material. It then was moved by pneumatic conveyors to an air classifier and on to another shaker. The dust was then transported through ducts to the pallmanns where it was further refined to the proper size to be used in the particle board production process. From the pallmanns, the dust was moved into two hoppers, depending upon the size of the dust. One hopper was for "fines," and the other was for the larger particles and was referred to as the "cores" hopper.

The dust then was transported by a pneumatic duct system to dryers that dried the dust to the proper consistency. From that point, the dust was conveyed to the press line area, where it was ten processed into the particle boards.

Heat for the particle board manufacturing process was provided by a thermal oil transfer unit, which was located adjacent to the milling and drying area. The heating unit for this process was located in a room that was enclosed on three sides by a reinforced masonry block wall. The fourth side was covered with corrugated metal siding and had a large opening to the exterior with a roll-up door.

The heating unit was fired by natural gas and was a "top-down" burner. The piping that carried the oil between the burner and the particle board press line was located at the ceiling level.

The facility was producing material seven days a week at the time of the incident.

Fire Protection Systems

There were a variety of sprinkler, fire alarm, and special suppression systems employed throughout the complex. A 24-inch municipal water main services the site. An underground, 10-inch private fire service main loops the site. In addition to the municipal water supply, there is a private water supply that is comprised of an elevated 500,000-gallon storage tank and a 2,000-gallon per minute, centrifugal, 200-horsepower electric fire pump.

The areas involved in the incident was protected by three sprinkler systems.

Area Protected	Number of Risers	Riser Size	Type
Dust House	One	6 inches	Dry
Milling and Drying	One	6 inches	Dry
Pressline	Four	8 inches	Wet

The sprinkler systems are electronically supervised for waterflow and valve positions by security personnel at a constantly attended location. Fire alarm systems were also monitored at this location. All of the sprinkler valves are inspected weekly by the plant fire chief.

The site is equipped with private fire hydrants and hose houses located in various locations throughout the site.

There were two Halon 1211 explosion suppression systems in place on the ductwork that fed the raw material into the pallmann grinders in the milling and drying area. One system had been disabled some years prior to this incident, and the other did not appear to have functioned properly.

There were several spark detection and suppression systems in several of the pneumatic conveyors and dust collectors. They utilized infrared detectors with water spray nozzles. The water supply for these systems were supplied by an 8-inch main.

Emergency Brigade

The Miller Hill complex has an emergency brigade of fifteen members who are full-time production employees in addition to their brigade duties. This brigade is trained to deal with incidents such as incipient level fires, confined space emergencies, and hazardous materials incidents. They are not equipped or trained for structural fire-fighting operations. They meet once a month for training and site inspections.

At any given time during the operations at the Mill Hill Complex, there was at least one member of the brigade on duty. At the time of the incident, the brigade fire chief was working in the milling and drying control room and was one of the employees who was injured.

Occupant Activities

There were six employees working in the dust house, milling and drying and pressboard areas of the plant at the time of the incident. Normally there would be seven employees in that area during that particular shift.

One employee was engaged in changing the blades on a piece of process equipment in the milling and drying area. Another employee was in the dust house and was "blowing down" some equipment using a compressed air hose. Both of these individuals were fatally injured.

The other four occupants who were injured were in various locations. One was in the control room, two were in the press line area, and the fourth was in the break room located on the second floor.

The Lenoir Fire Department

The Lenoir Fire Department is a paid department with fifty-six members. They staff two stations, with eleven members assigned to each shift at headquarters and six assigned to each shift at Station 2. The department has a total of four pumpers, two aerial apparatus, and one rescue unit. In 1994, the department answered a total of approximately 1,100 calls.

III. THE INCIDENT

Discovery and Occupant Activities

The incident occurred on Sunday afternoon, November 20, 1995. At the time of the incident, there were six employees working in the area of the plant where the most extensive amount of damage occurred.

Prior to the explosion, two groups of employees reported smelling odd odors. One group described it as "burning brownies," while the other compared it to burning cigarette butts. The odor was strong enough and unusual enough to cause them to determine the source.

One employee was standing in a door facing the thermal oil transfer unit room when she saw a fireball emerge from the opening. She was close enough that she received burns to her hands as she covered her head.

The view of the thermal oil transfer room from the doorway of the press line where one of the employees was standing at the time of the incident. She reported seeing a fireball emerge from the open door to the thermal oil transfer room. The masonry block wall in the right of the photo separated the room from the milling and drying area. The support column just left of the center of the photograph was where another wall was located prior to the explosion. The debris from this wall was blown to the left.

Another employee was in the control room at the time of the incident. He reported that he first became aware of an unusual event occurring in the direction of the pump room/boiler room. He then proceeded to evacuate the building, moving in the direction of the offices and was able to recall four additional explosions that occurred during his escape.

No attempts were made at manual suppression by any plant employees. The plant's security personnel received automatic alarms from sprinkler flow activation as well as telephone reports from within the plant.

Fire Department Notification and Response

The Lenoir Fire Department received several notifications of the incident. One report was transmitted by a helicopter pilot who observed an explosion at the Miller Hill Complex while flying in the vicinity. Another report was transmitted to the fire department by plant security, who had received waterflow activation alarms and telephone reports from employees within the facility.

The Lenoir Fire Department responded at 3:43 pm with twelve units. A request for mutual aid brought additional units from five neighboring communities to assist.

Upon arrival, a water supply using large-diameter hoselines from hydrants located off of the plant property was established. This was done because a large number of sprinkler water mains had been damaged in the incident, which compromised the water supply.

The primary focus of initial fire department operations was rescue. A significant fire had occurred in the thermal oil transfer unit room that had been caused by a reservoir of combustible oil that was ignited, and this required several hours of fire fighting using master streams The remainder of the fire fighting was limited to spot fires throughout the milling and drying area and the pressline areas. All four injured employees were able to self-evacuate. The remaining two employees were rescued by fire department personnel and transported to area hospitals, where they were subsequently pronounced dead. Fire department units were on the scene for twenty-seven hours.

Injuries and Fatalities

Two employees died in the incident, and four were injured. One of the casualties was in the process of changing the blades on a grinding machine (commonly referred to as a pallmann) in the milling and drying area. The other casualty was blowing down a piece of equipment using an air hose in the dust house.

One of the injured employees was in the control room at the time of the incident. Another was in the break room on the second floor on the southwest end of the facility. Two other employees were working in the press line area. All four injured employees were able to return to work eventually.

Damage

The following physical damage occurred to the facility:

- The dust house had two of its exterior walls blown off by the force of an explosion in this area. The front of the dust house had no exterior wall and the fourth wall was a common wall with the milling and drying area.
- The milling and drying area had extensive damage throughout to the equipment, ductwork, and building. There were areas where total structural collapse occurred.
- The press line area had extensive damage to interior walls and equipment. Some exterior wall sections were blown away from the building. Spot fires occurred throughout the area, which directly impinged on the equipment, resulting in damage to the process equipment.
- The thermal oil transfer unit room had the most extensive fire damage. Due to the combustible fuel load in this area, fire burned for several hours before being brought under control.

All of the equipment contained within these areas experienced varying degrees of damage based on its exposure to the blast front, the flame front, direct flame impingement from subsequent fire, smoke damage, or indirect damage from structural collapse.Other areas affected included:

- The tower carrying all of the electrical service to the facility was damaged, cutting off the electrical service to the areas affected;
- Four external cyclones were damaged;
- One external bag collector was damaged;
- Ductwork throughout the facility was either directly damaged by the blast or damaged by subsequent structural collapse.

IV. ANALYSIS

Cause and Origin

As of the writing of this report, the specific cause and origin of the incident has not been definitively determined by the North Carolina Department of Labor. Two potential areas of origin have been identified: the thermal oil transfer unit room and the milling and drying area. Three possible causes have been identified:

(1) One potential cause is related to the pallmann grinding machines that were being worked on by one of the employees who subsequently died. Pieces of metal were found inside of the unit adjacent to the one that was being worked on which might have created sparks, which, in turn, ignited a cloud of dust within the machinery.

(2) Another potential cause is a leak in the oil lines in the vicinity of the thermal oil heating unit, which might have caused the oil to atomize and subsequently ignite explosively.

(3) A third potential cause is a natural gas leak in the thermal oil transfer unit room, which might have created a cloud of natural gas at the ceiling level. The wind was coming from the east, which would have forced the cloud further into the room and into the adjacent pump room through a 3-ft x 3-ft opening in the common wall between the pump room and the thermal transfer unit room at ceiling level.

Fire Growth and Spread

Based on the physical evidence and the testimony of employees present during the incident, it was determined that there were approximately five separate explosions in the thermal oil transfer unit room, milling and drying area and pressboard area of the plant.

The thermal oil transfer unit room had the largest amount of fire involvement. It took several hours for the Lenoir Fire Department to bring this area under control through the application of master streams. Spot fires were suppressed by the fire department in the press line area. Some parts of the process equipment exposed to these spot fires were damaged to the extent that they will have to be replaced.

Due to the damage to the sprinkler mains in the explosion, the fire department established an alternate water supply from a municipal hydrant off of the plant property. However, except for the fire in the thermal oil transfer unit room, fire control was not a significant factor in this incident. Their priority was on rescue and the hazard presented by the structural collapse.

Current Code Analysis

Sprinkler Protection. The facility was sprinklered. However, due to the damage, it was not possible during the on-site inspection to determine the specific configuration of the system, and the plans for the sprinkler system were destroyed in the incident. NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* (1993 Edition), Section 7-2, states that "Automatic Sprinklers, where provided, shall comply with NFPA 13, *Standard for the Installation of Sprinkler Systems.*" According to A-1-4.7.3.1 of the 1994 Edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*, this occupancy would be classified as an Extra Hazard Occupancy (Group 1).

According to reports from the Lenoir Fire Department, portions of the sprinkler system were severely damaged by the explosion and were flowing large volumes of water from broken mains.

Electrical Wiring. The North Carolina Department of Insurance, Engineering Division, was requested by the North Carolina Department of Labor to evaluate the facility with respect to requirements for electrical service. Based on this evaluation, they made the following finding:

"In general, plant areas not directly exposed to dust, all electrical wiring should be classified as Class III, Division 1. In areas directly exposed to dust, such as silos, conveyors, etc., the classification would be Class II, Division 1 or 2."

The electrical wiring observed in this facility employed general wiring methods. This allowed for the accumulation of dust within electrical enclosures and created the potential for ignition sources related to arcing from within these enclosures.

In Chapter 5, Electrical Equipment, of NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* (1993 Edition), 5-1.2 states that "In local areas of the plant where a hazardous quantity of dust accumulates or is present in suspension in the air, all electrical equipment and installations in those local areas shall comply with Article 502 or Article 503 of NFPA 70, *National Electrical Code®*, as applicable."

Dust Accumulation. NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* (1993 Edition), 4-1.1 states that "Provisions shall be made for systematic, thorough cleaning of the entire plant at sufficient intervals to prevent the accumulations of finely divided wood dust that might be dislodged and lead to an explosion."

There were large amounts of dust on the equipment and on the structural support members. Depths of approximately 4 inches were observed in undamaged and damaged locations. Some electrical switch gear boxes had wood dust of approximately 2 inches in depth within them. No one was able to provide a housekeeping schedule for dust control and, according to interviews, there were no regularly scheduled housekeeping operations.

According to analysis of dust samples carried out by the North Carolina Department of Labor, between 32 percent and 42 percent of the samples tested had dust sizes less than 200 microns. The testing agency classified the wood dust tested as having a dust potential four times greater than coal dust.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* (1993 Edition), states in 2-5.1 that "Interior surfaces and ledges shall be designed to minimize dust accumulation." Paragraph 2-5.2 states that "Surfaces not readily accessible for cleaning shall be inclined at an angle of not less than 45 degrees from the horizontal to minimize dust accumulation."

The use of sloped surfaces to minimize dust accumulation was observed in only one area, above a series of large electrical cabinets. There were a number of horizontal surfaces, such as structural members, where the accumulation of dust up to approximately 4 inches was observed.

Explosion Venting and Explosion Suppression Systems. NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities (1993 edition),* states in 3-1.2 that "If a dust explosion hazard exists in equipment, rooms, buildings, or other enclosures, such areas shall be provided with explosion venting. An acceptable alternative to explosion venting is an approved explosion suppression system installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems.*"

The investigation team did not observe any explosion venting design incorporated into the design of any of the structures involved. The explosion suppression systems on the ductwork to the pallmann grinders utilized Halon 1011. One system had been rendered inoperable sometime prior to the incident. The other system did not operate during the incident for unknown reasons.

V. DISCUSSION

Based on the site visit and interviews with personnel from the facility, the following conditions were observed that might have contributed to the initiating sequence or exacerbated the damage:

Dust Accumulations. There were significant amounts of dust on equipment and structural members in the press line area. It could not be determined if there was a regular schedule of housekeeping dedicated to minimizing the accumulation of dust. From the investigation and testimony provided by those on site, NFPA ascertained that there were probably four separate dust explosions that occurred following the initiating event. Proper housekeeping would have helped to minimize the chances of these dust explosions occurring. In addition, use of sloped surfaces would have also helped to minimize the accumulation of dust in certain areas.

Electrical Wiring. The method of wiring employed throughout the area of the plant that was inspected could be classified as a general wiring method. Rigid conduit was used, but the enclosures were not dust-tight. Accumulations of up to 2 inches were observed in the bottom of some enclosures. If dust was placed into suspension as the result of an explosion, the potential for further ignition and explosion would exist.

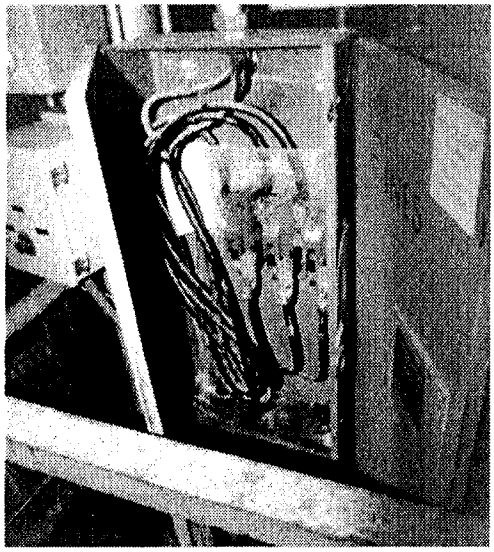
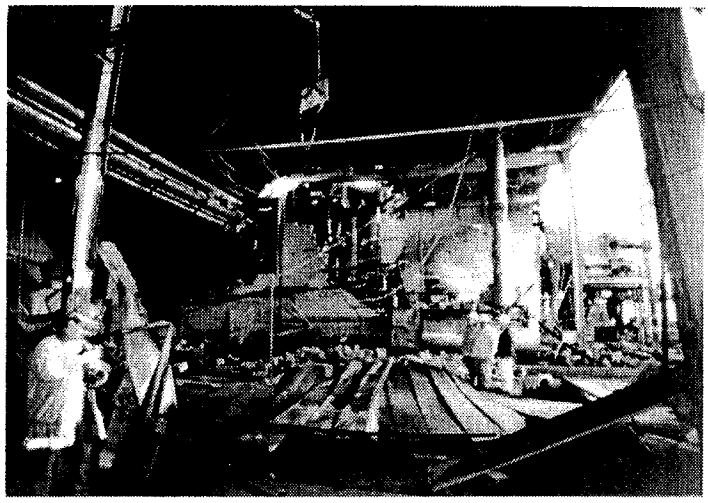


Photo of dust accumulation in the bottom of an electrical control panel.

Explosion Venting. NFPA could not ascertain if explosion venting was incorporated into any of the building design. However, with the exception of the dust house, all of the building components that did release as a result of the explosions landed in congested or occupied areas. Furthermore, major structural components were damaged in the explosion, resulting in significant roof collapse in some areas of the plant.



In the foreground are the lightweight metal panels that were blown off of the structural members in the press line area. In the background is the thermal oil transfer unit room. The masonry block wall was blown in the viewing direction.

SUMMARY

This incident resulted in fatal injuries to two employees, injured four additional employees, and damaged over 139,000 square feet of the facility. The particle board production line will not be back in service until at least August of 1995.

A significant contributing factor to the widespread damage was the accumulation of dust that was placed into suspension by the initiating event and then exploded when the dust clouds came into contact with ignition sources. Proper housekeeping procedures could have helped to reduce the extent of damage that occurred.

There were a number of potential electrical ignition sources throughout the facility. General wiring methods were employed, which did not provide the required level of protection in this type of facility. In addition, several electrical control panels were observed to have an accumulation of dust within them, which created a potential for ignition within these enclosures if the dust were to be placed into suspension. Use of the proper classification of electrical wiring would have helped to reduce the potential ignition sources.

Two explosion suppression systems were installed on ductwork leading into the grinding equipment. However, one of the systems had been disabled a number of years prior to this incident, and it is not known if the other system had been operated. No other explosion suppression systems were observed throughout the facility.

There are a number of recognized dangers in this type of operation that can be addressed with current technology and operating methods. The application of this technology and these operating methods could have helped to either eliminate or reduce the life loss, the injury, and the extent of damage that occurred.