

Case History 09: Ink dust explosion

The US Ink facility in New Jersey installed a new dust collection system in their pre-mix room (where some ingredients constituting the black ink are produced by mixing solid and liquid compounds in order to obtain a liquid suspension). The dust collection system was designed to start automatically when any of the mixing tank motors was energized and automatically shut off when all the 3 mixers of the pre-mix room were inactive. However, the dust collection system continued to run overnight a few days before the explosion, even when all the ink mixers were shut off. The malfunction was reported but the production continued normally.

On October 9, 2012, the day of the explosion, an operator saw a flash fire coming from the bag dump station where he usually worked. He immediately alerted his supervisor but did neither shut down the mixing operation running at the time nor the dust collection system. At about the same time, other workers heard a loud thump that shook the building. As the workers congregated at the entrance of the pre-mix room, they observed that the rubberized spiral-wound duct hose material that connected one of the ink mixers (T-306) to the dust collection riser appeared to be melting and dripping onto the tank. Suddenly, a large flash fire emerged from the room and engulfed the seven employees in flames.

The dust collection system was not designed to handle liquids, however, vapors were drawn out of the mixers and condensed in the dust collection system. This led to the formation of sludge material which self-heated and ignited the dust clouds of Gilsonite, carbon black, and clay in the ductwork above T-306.

Lessons learned:

- Necessity to develop better system controls (such as temperature and pressure indicators) as they were not installed for operators to monitor the mixing tanks and dust collection system during start up.
- Install automatic fire alarm systems
- Develop and implement a management of organizational change protocol to allow for the transfer of knowledge and information to new personnel, at a minimum including initial or refresher training in the following: safety and health procedure, lessons learned from previous incidents, technical information for equipment and routine plant operations.
- The design of the dust collection system did not match the needs for which it was implemented.



Burned ductwork over T-306

Reference

Report from Chemical safety and Hazard Investigation Board, Case study "Ink Dust Explosion and Flash Fires in East Rutherford, New Jersey"

CASE STUDY



Ink Dust Explosion and Flash Fires in East Rutherford, New Jersey

(Seven Employee Injuries)

2013-01-I-NJ



US Ink/Sun Chemical Corporation

East Rutherford, NJ
October 9, 2012

Key Issues

- Combustible Dust
- Engineering Design
- Management of Change
- Process Hazard Analysis
- Hazard Communication
- Management Oversight
- Regulatory Oversight

SUMMARY

This case study examines the explosion and flash fires that occurred at the US Ink manufacturing facility in East Rutherford, New Jersey, on Tuesday, October 9, 2012. Seven workers suffered burn injuries when they congregated at the entrance to the ink mixing room after hearing a loud thump from the newly installed dust collection system on the top of the facility and seeing signs of an initial flash fire from a bag dumping station. A second flash fire then occurred that led to the employee injuries.

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1 Introduction

On October 9, 2012, at approximately 1:15 pm Eastern Standard Time (EST), a flash fire caused burn injuries to seven workers, including three who sustained third-degree burns, at the US Ink/Sun Chemical Corporation ink manufacturing facility in East Rutherford, New Jersey. Workers were drawn to a black ink mixing room (commonly called the pre-mix room at US Ink) by the initial flash of the fire from a bag dumping station and by a loud thumping noise from the rooftop. As the workers congregated at the doorway, they observed a small fire in the ductwork of a newly installed dust collection system above a process mixing tank. Suddenly, a large flash fire emerged from the pre-mix room and engulfed the seven employees in flames. Coworkers responded to the seven injured employees and took them out of the building. Emergency responding units from the East Rutherford Volunteer Fire Department arrived on scene at 1:20 pm EST. Emergency responders transported the victims to the local hospital while firefighters began combating the fire. After the incident, production was suspended pending internal and external investigation by the company, U.S. Occupational Safety and Health Administration (OSHA), and U.S. Chemical Safety and Hazard Investigation Board (CSB). Some production of colored inks resumed about a week later, but black ink production was halted until the end of December.

1.1 Company Background

US Ink,¹ a division of Sun Chemical Corporation, is an ink manufacturer established in 1993 through the merger of two organizations, U.S. Printing Ink and the News Ink Division of Sun Chemical Corporation. US Ink maintains headquarters in Carlstadt, New Jersey, and had seven regional manufacturing locations across the country, including the East Rutherford facility, at the time of the incident. Sun Chemical Corporation is a global graphic arts corporation divided into a number of subsidiaries that encompass different segments of the market (such as ink, plates, pigments, and films). Sun Chemical owns and operates 143 active manufacturing facilities in and outside of the United States, with approximately 9,000 employees worldwide. At the time of the incident, the US Ink East Rutherford facility had 34 employees, and 28 employees were on shift.

1.2 Black Ink Process Description

The US Ink East Rutherford plant (built in the 1920s) manufactures both black and color oil-based ink for various commercial clients. A key step in the ink production process is mixing solid and liquid ingredients to produce a liquid suspension. The mixing operation for black ink ingredients is performed in the pre-mix room, where the October 9, 2012, incident occurred. Figure 1 depicts a simplified plan view of the pre-mix room containing three large mixing tanks in which the various ink formulations are made. The room is 30 feet wide by 17 feet deep and has cinder block walls up to the 30-foot ceiling height. The black ink manufacturing process at US Ink involved the pneumatic transfer² of bulk solid powder under vacuum to one of three mixing tanks, labeled as 106, 206, and 306 (T-106, T-206, and T-306, respectively).

¹ See <http://www.usink.com/about-us.html>.

² The pneumatic transfer process is a mechanical method of conveying materials via compressed or pressurized gases.

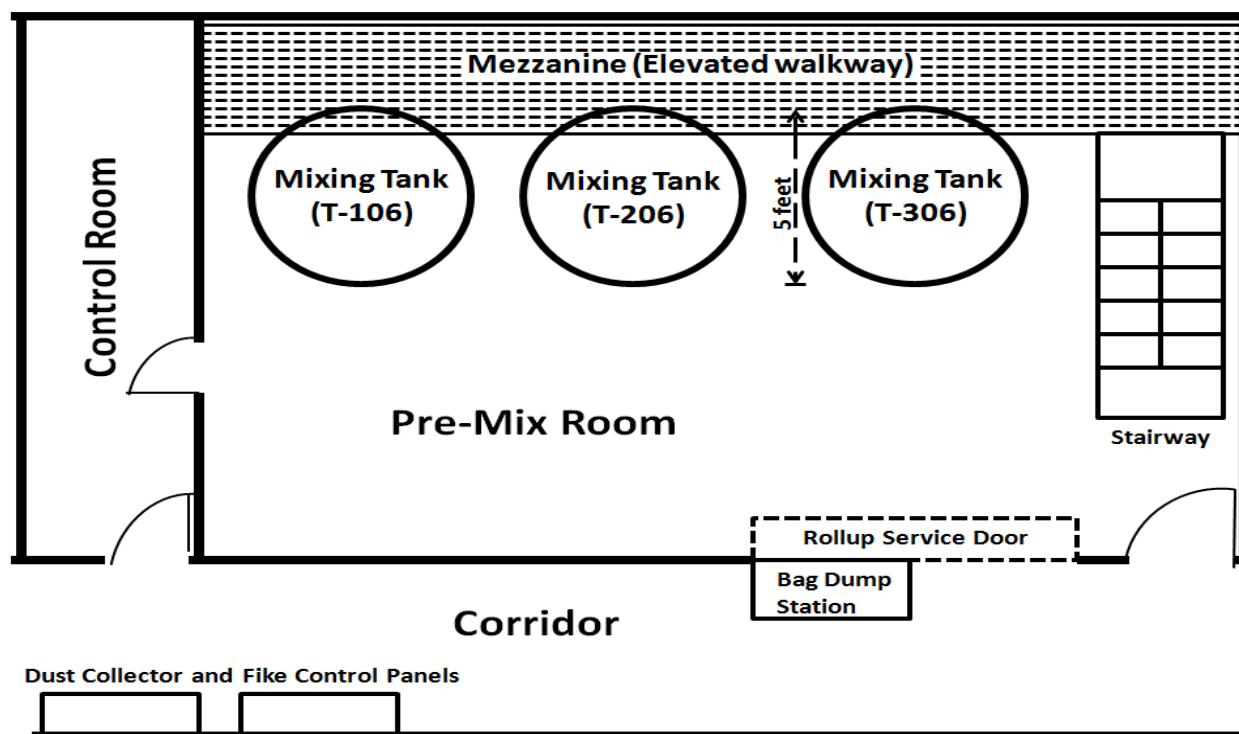


Figure 1. Pre-mix room layout³

Two solid ingredients, carbon black and kaolin clay, are received by rail (while Gilsonite is shipped by truck) to the facility and are transported to the mixing tanks by vacuum through piping from a manual raw material feeding station (known at US Ink as the bag dump station,⁴ shown in Figure 2) or by gravity from three overhead receiver hoppers containing carbon black and kaolin. The liquid ingredients are transported to the facility via rail and are pumped into the mixing tanks via pipes connected to the bottom of the tanks. All three mixing tanks are 5 feet in diameter and about 10 feet high. Operators coordinate the ingredient mixing process and monitor tank weights and temperatures from a control room adjacent to the pre-mix room. An automatic sprinkler system⁵ was installed as a fire protection feature in the pre-mix room.⁶

³ This diagram is not drawn to scale.

⁴ The bag dump station was positioned in the doorway of the pre-mix room. An overhead rollup service door was installed for access to the pre-mix room. At the time of the incident, the CSB found that the rollup service door was chained into a fixed rolled-up position to provide easier entry into the room. Witness accounts from plant employees and contractors indicated that Gilsonite dust generated from the bag dumping operation often accumulated around the facility but particularly on flat surfaces. US Ink did not provide an effective means of containing fugitive dust at the bag dumping station because emptied bags were often stacked alongside the bag dump, which in turn lofted dust into the air.

⁵ The sprinkler system was also connected to an automatic audible alarm. Once the sprinkler system was activated, an automatic signal was relayed via an external central monitoring station to the local fire department for immediate response.

⁶ During the incident, the sprinklers were activated after the second flash event.



Figure 2. Bag dump station

When complete, the mixed suspension contains both combustible and noncombustible particulate ink components. The heat generated as the solids are dissolved in the mixing tank increases the solution temperature to about 240°F. This increase in operating temperature is useful because it ensures complete dispersion of the solid materials into the liquid phase; it also contributes to greater evolution of condensable vapors. Once mixing is completed, a laboratory technician analyzes ink quality. If cleared, the batch is pumped into an empty tank for further processing (milling) and then to another tank in preparation for delivery to customers. Each batch weighs about 6,600 pounds when completed.

1.3 Dust Collection System

Before October 2012, the facility used a wet scrubber system⁷ to collect particulate materials during the dry material charging stages of the ink mixing process. However, the scrubbing system deteriorated over the years. In addition, the wet scrubber system did not prevent the release of fugitive dust into the pre-mix room when new ink formulations used higher powdery clay content, producing higher levels of particulate emissions. Therefore, a new particulate dust collection system was needed. The new dust collection system was installed to improve the management of particulate material and produce an overall improvement in the operating conditions of the black ink production process.

A US Ink lead engineer worked in collaboration with the manufacturer of the dust collection system⁸ to design the new dust collection system. The engineer retired before the dust collection system was installed and commissioned

⁷ Wet scrubber systems are devices that remove pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid by spraying it with the liquid, forcing it through a pool of liquid, or using some other contact method to remove the pollutants. Wet scrubbers remove dust particles by capturing them in liquid droplets.

⁸ Additional design specifications and support were provided by other US Ink engineers and by representatives of the manufacturers of the ductwork, dust collector, and fire explosion suppression and isolation system that was coupled to the dust collection system.

on Friday, October 5, 2012.⁹ The dust collection system illustrated in Figure 3 consisted of a branching system of various sizes of ducts, including flexible connectors attached to the top of each mixing tank and to the bag dump station. The flexible ducts joined an 8-inch duct, which transitioned to a 9-inch duct and ultimately a vertical 12-inch duct (riser) going up through the pre-mix room ceiling. Dust particles were suctioned through the ducts and riser into the exhaust fan–driven dust collector, located on the roof of the facility (Figure 3).

⁹ In Section 6, Safety Management Analysis, of this report, the CSB concludes that the engineer’s retirement led to a less comprehensive design review and commissioning process for the dust collection system.

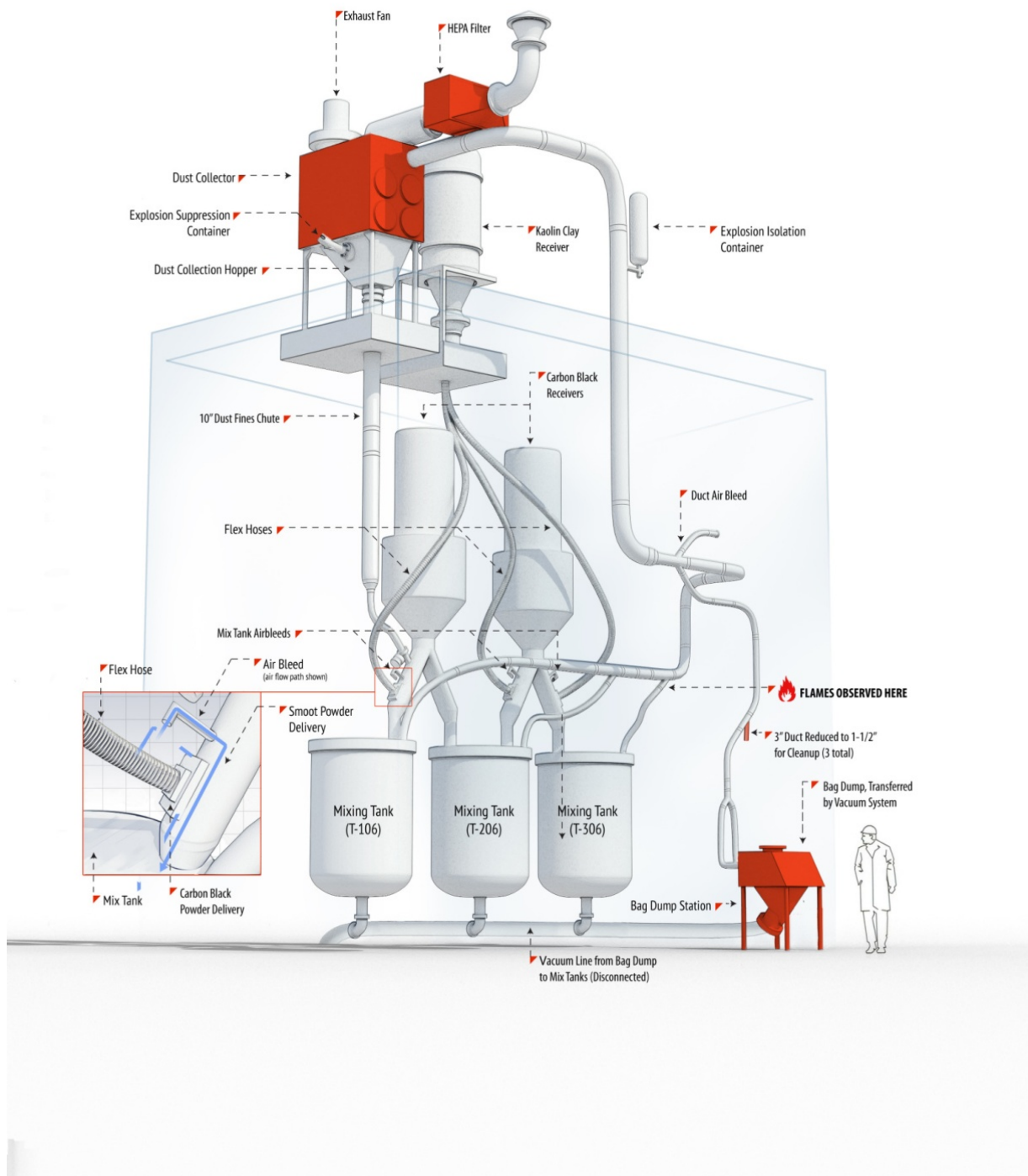


Figure 3. Overview of the newly installed dust collection system

The roof-mounted dust collector used an eight (four rows of two each) cylindrical filter cartridge system to remove the residual particulate dust. Dust-laden air and vapor from the mixing tanks entered the collector above the four cylindrical filter cartridges and was drawn down over the cartridges, where the dust was removed from the air stream. The dust collector was mounted with a 25-horsepower (hp) fan and an inlet total static pressure rating of a 17-inch water column. The 25-hp fan was designed to convey dust up to the collector at an airflow volume rate of 3,300 cubic feet per minute. The dust collector was mounted with a system fan with a 25-hp motor. The mounted fan for the dust collector discharged through a high-efficiency particulate air (HEPA) filter and then into the atmosphere. Compressed air periodically pulsed through the filter cartridges to dislodge the filtered dust into the hopper of the dust collection system. The collected dust was recycled into the ink-making process. A rotary airlock on the bottom of the hopper used gravity to control the discharge of recycled fugitive dust from the collector and back into the mixing tank (T-106) for reprocessing in the pre-mix room. Beyond the rotary air lock valve, the 10-inch-diameter pipe reduced to 4 inches in diameter at T-106.

The company added three housekeeping connections, not included in the initial design, to the vacuum system of the dust collection system for operator use in picking up dust and other debris in the pre-mix room.¹⁰ This auxiliary equipment attached to the ductwork associated with the bag dump station and to the main ducts above T-206 and T-306. The dust collector included an explosion suppression system (shown in Figure 4 and Figure 5), which would actuate and release the suppressant, sodium bicarbonate, if a rapid pressure increase occurred in the dust collector. The design intent focused on preventing damaging explosive overpressures in the collector and inlet duct in the event of a drastic pressure rise and on containing any explosion hazard within the dust collector.¹¹ Fike Corporation¹² manufactured the explosion suppression and chemical isolation system, and the designers recognized the explosion hazard associated with dust.

US Ink/Sun Chemical Corporation provided information—including specification of the raw materials utilized in the black ink pre-mix process, flash point of oils, and dust deflagration index (K_{ST}) values for solid ingredients—to the manufacturer of the explosion suppression and isolation system. Although US Ink/Sun Chemical originally considered a roof-mounted dust collector equipped with explosion vent panels for explosion protection and with a mechanical isolation valve, US Ink decided instead to use an explosion suppression and chemical isolation system. US Ink based this decision on reduced installation costs and external recommendations (from Fike and the third-party property loss prevention and risk management consultants hired by US Ink) to avoid any potential environmental releases of combustible dust particulates (or fire) into areas near residences.

¹⁰ The dust collection system design included four dust pickup points: three housekeeping connections and the opening at the bag dump station. The ductwork at the top of each mixing tank had a connection (6 inches in diameter) for dust collection, and two 6-inch connections at the bag dump hood allowed suctioning of dust particles from the dumping station. In addition, three 3-inch ducts were reduced to 1.5 inches in diameter for vacuum cleaning hoses that were added to the ductwork design for housekeeping purposes.

¹¹ The explosion suppression system would actuate and inject sodium bicarbonate via an independent suppression container and chemical isolation container located at two injection points in the system: the dust collector hopper (Figure 4) and the collector inlet riser (Figure 5). The suppressant was designed to be injected if a rapid pressure rise occurred in the dust collector and was intended to suppress a flame front from propagating from the dust collector back through the riser into the interconnected ductwork and pre-mix room.

¹² See www.fike.com.

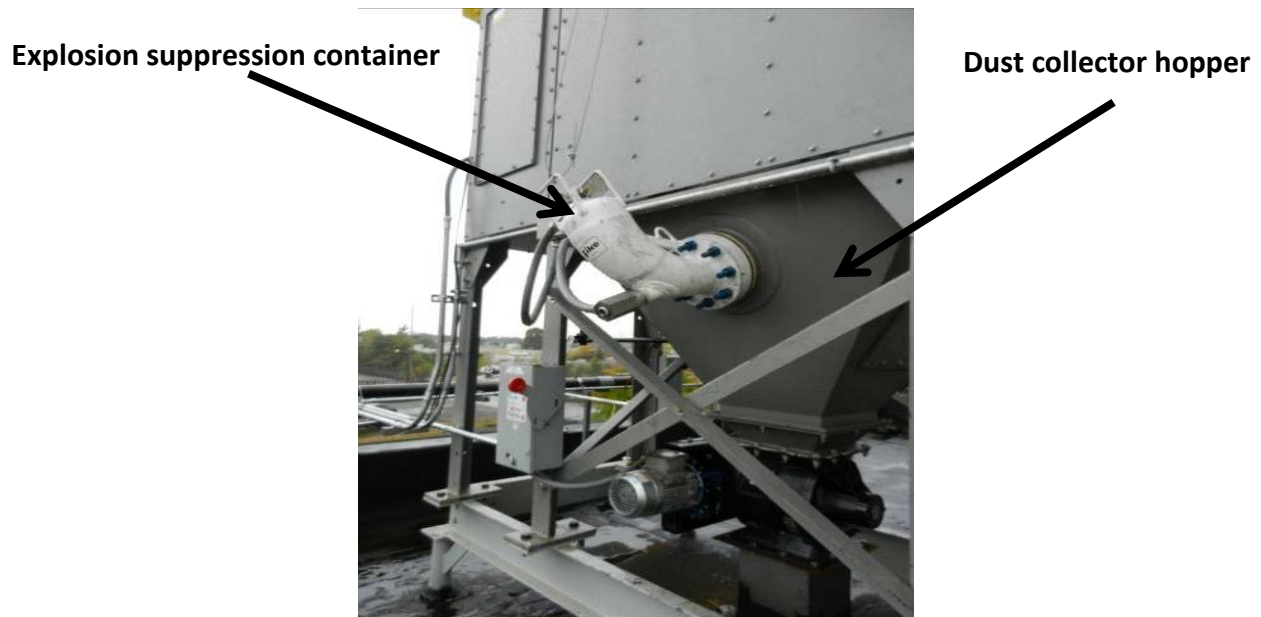


Figure 4. Dust collector with explosion suppressant



Figure 5. Dust collector inlet with explosion isolation

The new dust collection system was commissioned at the facility in the week preceding the incident. The flash fire occurred in the dust collection system during the first day of normal production after initial equipment start-up, on Tuesday, October 9, 2012.

1.4 Materials Involved in the Incident

The US Ink facility produces black and color oil-based inks for various clients but primarily for the print media industry. A typical black ink formulation at the East Rutherford plant includes the following ingredients:

- Petroleum naphthenic distillate¹³ (product name: Raffene® 750K oil)
- An alternative petroleum distillate (product name: mineral seal oil)
- Natural asphalt resin particulate (product name: Gilsonite¹⁴)
- Carbon black particulate pigment (product name: Printex 310¹⁵)
- Bentonite (aluminum silicate clay) particulate (product name: Bentone 34)
- An alternative aluminum silicate clay (product name: kaolin)
- Tall oil fatty acid, a minor ingredient (additive)

Gilsonite and carbon black are combustible while the petroleum distillate is flammable, so they can be considered as possible contributors to the formation of the explosive atmosphere on the day of the incident.¹⁶ The boiling points and flash points of the two oils are listed in Table 1.

Table 1. Oil properties (from Material Safety Data Sheets)

Property	Raffene Oil 750K	Mineral Seal Oil ¹⁷
Open cup flash point	360°F	275°F
Initial boiling point	550°F	492°F
Autoignition temperature	Not given	Not given

Mineral seal oil¹⁸ is more volatile than Raffene oil, but the flash points of both oils are sufficiently high (more than 200°F) to make them Class IIIB liquids according to the combustible liquids classification in the National Fire

¹³ Petroleum distillates (e.g., hydrocarbons such as mineral spirits, kerosene, white spirits, and naphtha) are often used as an organic solvent in painting and decorating (http://www.northerntails.com/images/What_are_Petroleum_Distillates.pdf). Heavier fractions such as naphthenic or paraffinic distillates are often used in ink manufacturing processes.

¹⁴ Gilsonite, a resinous hydrocarbon, is widely used as the primary carbon black wetting agent for black news inks and heat set and gravure inks. Gilsonite has a National Fire Protection Association (NFPA) flammability rating of 1, and special precautions warn that dust is subject to explosion upon contact with sparks, open flames, or temperatures in excess of 1,000°F (570°C).

¹⁵ Carbon black, with a particle size of PM-10 (particles with a diameter of 10 micrometers or less), is an odorless and insoluble powder with an autoignition temperature greater than 284°F. It can burn or smolder (decompose) at temperatures greater than 572°F and is virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. Although some grades of carbon black are sufficiently electrically nonconductive to allow a static charge buildup during handling, dust at sufficient concentrations can form explosive mixtures with air. Carbon black has an NFPA flammability rating of 1.

¹⁶ The American Gilsonite Company Material Safety Data Sheet (MSDS) for Gilsonite resin indicates that Gilsonite is not hazardous; however, in the storing and handling section, the MSDS states, "Avoid raising any powdered material into dust explosion hazard." The MSDS for carbon black states that OSHA classifies the product as hazardous and that dust at sufficient concentrations can form explosive mixtures with air. The MSDSs do not reference NFPA standards except in a carbon black MSDS where NFPA ratings are provided. Sun Chemical did have guidance on combustible dust (SunCare HSE Procedure 065, *Combustible Dust*), which included a section for references that listed NFPA 35, 68, 77, 484, and 654.

¹⁷ Citgo Petroleum Corporation, *Mineral Seal Oil Material Safety Data Sheet* (http://www.docs.citgo.com/msds_pi/19540.pdf).

¹⁸ The Citgo mineral seal oil MSDS suggests that it can burn but does not readily ignite. Mineral seal oil releases vapors when heated above the flash point temperature. In addition, it can ignite when exposed to a source of ignition. In enclosed spaces

Protection Association (NFPA) code *NFPA 30, Flammable and Combustible Liquids Code*.¹⁹ Occasionally, US Ink also used linseed oil, but not in the batches blended before the incident.

2 Incident Description

2.1 Events Before the Incident

The new dust collection system for the pre-mix room was commissioned for service on the morning of Friday, October 5, 2012, and then operated until the end of the production shift at 3:00 pm EST²⁰. At commissioning, US Ink employees who would operate the system (several black ink production supervisors and one of the day-shift operators) received 15 minutes of operational training and instruction as well as a walkthrough of the Fike explosion suppression and isolation system.²¹ Both the dust collection system and the Fike explosion suppression and isolation system were equipped with control panels (containing system status indicator lights), installed on the wall near the pre-mix room (Figure 1). As designed, the dust collection system started automatically when any of the mixing tank motors was energized and automatically shut off (after a specified delay) when all mixers were inactive. However, the dust collection system actually continued to run overnight, even when all the ink mixers were shut off.²²

On Saturday, October 6, 2012, the plant maintenance employees used housekeeping connections on the new dust collection system to vacuum dust and debris in the pre-mix room. A US Ink maintenance employee reported in an interview that upon arrival on his Saturday, although the mixing tanks were shut down the night before, the dust collection system had run all night, a departure from the initial design intent of automatic start-up and shutdown, in sync with the mixing tanks.²³ At the end of housekeeping activities, a maintenance employee manually shut down the dust collection system. Although the maintenance employee reported the dust collection system equipment malfunction to his superiors and to the electrical contractor that wired the dust collection system, US Ink/Sun Chemical Corporation management took no action to immediately investigate the failure or to shut down the ink mixing operation until the malfunction was corrected.²⁴ Employees restarted the mixing tanks and the dust

(such as the ductwork of the dust collection system), heated mineral seal oil vapor can ignite with explosive force. Mists or sprays can burn at temperatures below the flash point (http://www.docs.citgo.com/msds_pi/19540.pdf).

¹⁹ NFPA, a nonprofit standards organization, has been developing standards since 1896 that directly affect fire services at the department level. NFPA produces more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks (<http://www.nfpa.org/about-nfpa>). The codes are voluntary standards that industry can adopt and regulatory agencies can enforce. Standards are an attempt by an industry or profession to self-regulate by establishing minimal operating, performance, or safety criteria.

²⁰ Representatives from Fike had earlier provided a system orientation of the explosion suppression and isolation system to the US Ink maintenance staff on October 1, 2012.

²¹ Section 5, Engineering Design Analysis, includes a discussion of the failure to conduct system performance measurement at start-up and commissioning of the dust collection system.

²² The dust collection system was designed to be controlled by a controller whenever it was running, and the controller was set up to continuously control the fan and pulse jets whenever the dust collection system was in operation. However, the automatic shutoff did not engage as designed once the system was energized and thus had to be manually turned off and on by US Ink maintenance employees and pre-mix room operators.

²³ The CSB did not find any evidence that the automatic start system worked in sync with the mixing tanks at commissioning.

²⁴ US Ink/Sun Chemical Corporation management did not give stop-work authority to the maintenance employee or the night-shift pre-mix room operator to shut down dust collection system operation once a malfunction was reported. US Ink claimed it encouraged employees to report unsafe acts; however, the CSB did not find any record of a US Ink requirement for employees to shut down any equipment perceived as faulty that could lead to an unsafe condition or hazards. This lapse in

collection system on the Monday night shift, October 8, 2012, in preparation for the production runs scheduled for Tuesday, October 9, 2012.

2.2 Onset of Flash Fire and Explosion

On Tuesday morning, October 9, 2012, black ink production continued, with batches being run in all three mixers. When the batch in T-306 was completed, the pre-mix room operator emptied the tank. The operator left for lunch at about noon and returned to the pre-mix room at about 12:30 pm EST. At that time, a new ink batch was started in T-306. At about 1:00 pm, the pre-mix room operator was loading Gilsonite into the bag dump station (Figure 1) when he heard a strange (squealing)²⁵ noise from T-206. Because of the odd noise, the operator went to the control room to check the mixing tank temperature and speed to confirm that the equipment was working properly. As he left the control room, he saw a flash fire originating from the bag dump station where he had just been working. Without shutting down the mixing operation and the dust collection system from the control panels near the pre-mix room, the operator immediately proceeded to his supervisor's office to alert him of the fire, moving away from the pre-mix room. At about the same time, other workers heard a loud thump that shook the building.

In response to the flash from the bag dump station and the subsequent loud thump, workers congregated at the entrance to the pre-mix room. Employees stated that the rubberized spiral-wound duct hose material that connected T-306 to the dust collection riser appeared to be melting and dripping onto the tank (Figure 6).



Figure 6. Burned ductwork over T-306

2.3 Incident and Injuries

Two employees retrieved fire extinguishers to put out the flames. One employee ascended the stairs near T-306 in an attempt to extinguish the flames. The employee reported that before he was in position to discharge the extinguisher, he heard a "sizzling" sound from T-306 and saw an orange fireball erupt, advancing toward him. He squeezed the extinguisher handle and jumped from the stairs as fire erupted from the tank. The flames engulfed him and six other employees who were positioned outside the pre-mix room doorway.

management oversight allowed the dust collection system to continue running during the ink mixing operation until the system eventually failed on Tuesday, October 9, 2012.

²⁵ The squealing noise signaled a possible increase in the amperage, which would have necessitated the addition of more oil to the mixing tank. The pre-mix room operator testified to the CSB that upon checking the amperage chart for the mixing tanks, he discovered that everything was fine.

Another employee who approached the pre-mix room area noticed that the lights on the alarm panel for the dust collector explosion suppression system were red, indicating detection of a pressure rise and activation of the system. However, this system did not produce an audible alarm.²⁶ The employee alerted the other workers in the area that the explosion suppression system had activated and there was a fire. Just seconds before the large flash fire at T-306, the employee retreated from the pre-mix room area to call 911, but after running 25 to 30 feet, he was knocked to the ground by the pressure wave caused by the fireball. Witnesses observed not only the initial fireball from T-306 but also a thick black cloud venting into the corridor²⁷ just ahead of the fireball, and they reported an audible “whoosh.” These observations are consistent with the sights and sounds of a combustible dust deflagration.²⁸

All employee burn injuries resulted from the large flash fire and heated dust mixture that originated from above T-306 and propagated into the corridor from the entrance of the pre-mix room. The injured employees had clothing covered in black dust, and they experienced burns to exposed skin. Some burns occurred after their clothing ignited from the fireball. The injuries consisted mostly of burns to upper torsos, arms, necks, and heads. Other employees helped the injured employees out of the plant, and emergency responders transported the injured to hospitals. One of the injured employees was wearing a short-sleeve T-shirt that day and sustained third-degree burns on his left arm, neck, and upper torso. The employees were not wearing flame-resistant clothing (FRC).

To reduce the risk of thermal injury from flash fire incidents in production-related operations, workers are required to wear FRC. As part of its personal protective equipment (PPE) standard (29 CFR 1910.132), OSHA requires employers to provide workers with FRC in workplaces when flash fire or explosion hazards are present.²⁹ This standard also mandates that employers must conduct a hazard assessment of their workplaces to identify hazards that require the use of protective equipment. Because the US Ink facility did generate dusts, the potential existed for a dust explosion, flash fire, or both. If US Ink had followed OSHA guidance on hazard assessment and PPE selection, the US Ink/Sun Chemical safety managers would have identified “harmful dust” and provided additional PPE. The NFPA standard—*NFPA 2113* provides guidance for the selection, use, and maintenance of FRC.³⁰ NFPA 2113 states, “Factors in determining if flame-resistant garments are required shall include the presence of

²⁶ US Ink/Sun Chemical maintained that Fike did not fulfill its requirement to fully install and ensure the operation of an audible alarm, despite providing an initial specification that indicated the presence of an audible alarm. Best practices indicate that US Ink should not have accepted the new dust collector as complete if system start-up checks revealed that the audible alarms were not working as expected. Fike attested that the local visual and audible alarm for the explosion suppression and isolation control was operating when verified on October 1, 2012. However, the local audible output might not have been heard by US Ink employees on the day of the incident due to the ambient noise in the room. Also, US Ink did not incorporate any other area or building-wide audible or visual alarm or emergency responder notifications into their notification strategy.

²⁷ CSB investigator observations of the ceiling of the US Ink East Rutherford facility shortly after the incident indicated the outward L-shaped path of the fireball along the corridor near the pre-mix room.

²⁸ A deflagration is the propagation of a flame through a fuel-air mixture at less than the speed of sound. It can be either a flash fire or an explosion, depending on the level and consequences of the pressure generated during flame propagation.

²⁹ FRC can reduce the severity of burn injuries sustained during a flash fire when engineering and administrative controls fail. Usually worn as coveralls, FRC is made of treated natural or synthetic fibers that resist burning and withstand heat.

³⁰ National Fire Protection Association, *NFPA 2113: Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures*, 2012 Edition (Quincy, MA: NFPA, 2012).

flammable materials in the environment during process operations.” This standard would include dust. The CSB learned that no corporate policy required the use of FRC by US Ink plant employees.³¹

2.4 Fire Department and Emergency Response

The flash fire triggered the fire sprinkler system in the pre-mix room. Firefighters and other first responders arrived at the scene of the incident within 3 minutes of the first alarm.³² After they arrived and entered the plant, East Rutherford Fire Department personnel did not see any flames in the pre-mix room because the sprinklers had extinguished fires outside of the enclosed equipment.

Although they observed no visible signs of flames after the large flash event at T-306, responding firefighters reported that after checking with their heat sensors, they detected several ductwork fires and extinguished them with water after separating the affected ducts. The firefighters went up to the dust collector on the roof and opened the four covers on the cartridges but did not need to extinguish any residual burning materials in the collector because the explosion suppression and isolation system, which was designed to respond to any explosion within the dust collector, had already prevented the fire from entering the dust collector after the initial event. The design of the chemical suppression and isolation system protected the dust collector from explosion within the collector but did not extinguish any external fires.³³

3 Incident Analysis

Three distinct events occurred during this incident:

1. An employee observed a flash originating from the bag dump station, which attracted the attention of several workers in the area.
2. At about the same time, workers heard a large thumping sound that they described as coming from overhead, accompanied by a pulse that shook the entire building, drawing more workers from their respective workplaces to investigate.
3. After about 2 minutes, seven workers observed an approximately 1-foot flame directly over T-306. The flame then gained additional energy from the powdery mixture of accumulated carbon black, Gilsonite, and clay in the ductwork of the dust collection system. The mixture acted as fuel, and the fire flashed over the assembled workers in the doorway of the pre-mix room.

The CSB investigated three possible points of origin of the fire: within the dust collector, within the ductwork above T-306, or within T-306. Chemical test results,³⁴ engineering design analysis,³⁵ physical evidence of excessive

³¹ Sun Chemical Corporation, “Sun Chemical Material Safe Handling Form.” This form indicated the following for recommended personal protective equipment (PPE): respirator (organic vapor cartridge) or self-contained breathing PPE apparatus, disposable sleeves worn over long-sleeved uniform tops or disposable Tyvek suit, nitrile or Neoprene gloves, and safety glasses with side shields. In addition, the corporate Health, Safety and Environment (HSE) PPE policy lists examples of types of PPE that could be used, including protective clothing; however, FRC is not listed as a specific type of protective clothing. Although employees received some communications regarding appropriate PPE, the CSB investigation could not find any evidence to indicate that US Ink actually supplied FRC to employees.

³² East Rutherford Fire Department, *East Rutherford Fire Department Inspection and Incident Report*, October 22, 2012.

³³ National Fire Protection Association, *NFPA 654-2006: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, Section 7.13.1.2.1. This section states that where both an explosion hazard and a fire hazard exist in an air material separator, protection for each type of hazard shall be provided.

³⁴ Chemical test results are discussed in detail in Section 4, Sample Test Results and Incident Implications.

³⁵ Engineering design analysis is covered in detail in Section 5, Engineering Design Analysis.

deformation, heat charring of the ductwork directly above T-306, and corroborated witness testimony all indicated that the fire originated within the ductwork of the dust collection system.

3.1 Sequence of Fire and Explosion Events

The CSB concluded that the explosion and flash fires occurred because of continuous manually controlled heating of the mixing tanks and operation of the dust collection system for several hours after commissioning, with the system continuing to draw condensable vapors into the duct. Continuous operation of the dust collection system led to self-heating and spontaneous self-ignition of the accumulated sludge-like material and the powdery dust mixture of Gilsonite, carbon black, and clay in the ductwork above T-306. As a result of this activity, the dust collection system drew air past the site where the spontaneous ignition occurred, thereby enhancing combustion of the condensed vapors and combustible dust. With the dust collection system still in operation, the air in the system blew the dust mixture toward the collector while the fire burned. This situation caused ignition and a pressure rise in the dust collector, which was already filled with the blend of Gilsonite, carbon black, and clay.

Although the ignition led to a dust explosion within the dust collector, the pressure rise activated the Fike explosion suppression system, which prevented the structural failure of the dust collector.³⁶ The pressurized discharge of the explosion suppression canister caused the thumping sound that employees heard coming from outside the building. At the same time, the ignition at the dust collector and discharge of the 5-liter suppression and 9-liter isolation canisters created a pressure spike of 4.4 pounds per square inch gauge (psig) in the dust collector and caused the flame front to propagate counter-current toward the mixing tanks. This rapid pressure rise (and the associated rapid flame propagation back through the ducting) triggered an initial flash fire at the bag dump station and within the rubberized ducts above T-306 (where the second and more volatile flash fire occurred). After the incident, the CSB learned that the design total suppression pressure (maximum design pressure for suppressed explosion) predicted for the dust collector was 3.8 psig. The increase in the total suppression pressure occurred because of the higher rate of pressure rise of the dust mixture compared to the expected design K_{ST} of 165 bar-meters per second (bar-m/sec).³⁷

3.2 Fike Explosion Suppression System Data

Suppression Systems Incorporated (SSI)³⁸, a Fike distributor, provided pressure sensor data retrieved from the memory of the Fike system, using plots attached to a December 2012 Fike incident report. The report indicated that both the 5-liter extinguishing agent container on the dust collector and the 9-liter extinguishing agent container on the inlet duct discharged as designed on the day of the incident. The pressure sensor data pulled from the Fike system on the day of the incident shows the sequence of events in the dust collection system. The recorded data are shown in the graph in Figure 7.

³⁶ The Fike explosion suppression and isolation system prevented the structural failure of the dust collector by suppressing the deflagration and isolating the dust collector as designed.

³⁷ This is addressed in Table 3, ASTM E1226 dust explosibility test data.

³⁸ SSI is a Fike distributor and the installer of the Fike dust collection system at US Ink.

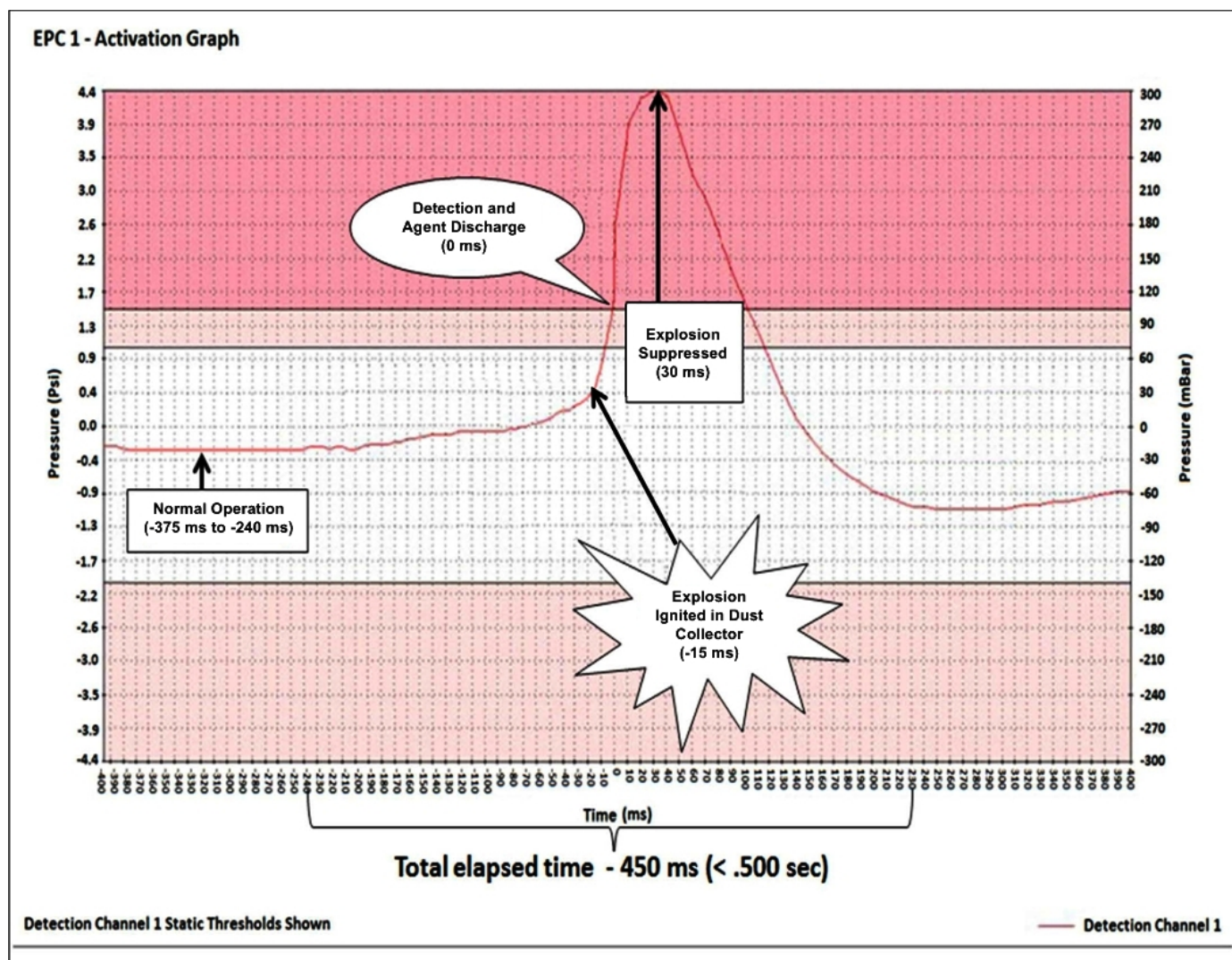


Figure 7. Annotated Fike system pressure plot³⁹

3.3 Impact of the Elimination of the Scrubber System

Before installation of the dust collection system, employees observed vapor escaping from the mixing tanks. When the wet scrubber system was removed, an unsealed makeshift vapor absorbent was installed at the opening of the tank heads. The operators used the vapor generation to gauge the speed and temperature of the mixing process. This qualitative information was the basis for their adjustment of the mixing process speed and served as their indicator of the escape of vapor from the process. Despite this, US Ink maintained that the operators relied on their training in the process to properly operate the mixers. In addition, the temperature of each of the tanks was measured and available at all times to the operators. Moreover, each batch ticket specified the target operating limits, which the operator used to prepare each batch of ink.

³⁹ The Fike system design plot is based on a dust explosion hazard corresponding to a maximum pressure (P_{Max}) of 10 bar gauge (barg) and a normalized rate of pressure rise (K_{ST}) of 165 bar-m/s.

US Ink/Sun Chemical claimed that each operator was trained to monitor the mixer temperature to ensure that it remained sufficiently low and to adjust the mixing operation accordingly to mitigate high mixing temperatures. However, one of the plant operators testified to CSB investigators that he relied on his individual instincts, observations of combustible vapor, and sounds generated during the mixing process to manually adjust (from the control room) the speed of the tank mixing agitators. After examining the US Ink control room, the CSB concluded that despite the presence of temperature gauges and recorders, no temperature control system governed the mixing tanks and that the ink mixing process design did not define any safe temperatures. With no automatic temperature control and no guidelines, plant operators relied on individual instincts, observations of vapor from combustible liquids, and sounds generated during the mixing process as the basis for manually adjusting (from the control room) the speed of the tank mixing agitators.

After installation of the dust collection system, operators in the pre-mix room could not observe the vapor and use it as an indicator because the dust collection system metal ducts were connected to the opening of the mixing tank heads. In addition, after removal of the scrubber system, the combustible vapor generated by the ink mixing operation could no longer be eliminated because the new dust collection system was not designed to release condensable vapor. The vapors subsequently were trapped within the ductwork of the dust collection system.⁴⁰

3.4 Physical Analysis of the Building and Mixing Tanks

Although minor cracks were visible on the exterior of the building wall, this incident caused no apparent structural damage to the building. Equipment in the pre-mix room (including ductwork, motors, electrical cables, and conduit) sustained extensive thermal damage. Portions of the dust collection ducting were separated, and at least one housekeeping connection end cap blew off. Moreover, extensive smoke and dust deposits accumulated on the structure and equipment surfaces in the hallway (ostensibly caused by the burning fireball) and around the pre-mix room.

After the incident, the CSB commissioned a visual and video borescope inspection⁴¹ of the mixing tank (T-306) to determine whether the second flash fire originated within T-306. The inspectors opened the top hatch and found the liquid level just below the set of toothed vertical agitation blades. Thick ink coatings were apparent on the visible portions of the interior walls and the top of the tank. The tank and mixing elements showed no indication of thermal degradation. In addition, the inspectors removed the motor of the overhead agitator on T-306 to check for damage to the agitation blades and found no major damage, only regular wear on the blade edges.

⁴⁰ Section 5, Engineering Design Analysis, discusses the lack of consideration of the presence of condensable vapor in the ductwork.

⁴¹ A borescope is an optical instrument used to inspect work areas or the inside of structures that are inaccessible by other means. The borescope is often inserted into the structure or work area through a small hole.

4 Sample Test Results and Incident Implications

The CSB observed removal of the dust collection system ductwork in December 2012. Investigators collected residue samples from six sections of the entire ductwork system (shown in Figure 8). They inspected the interior of various ductwork sections and took material samples from inside the ducts. These inspections revealed large accumulations of black, burned, and unburned materials. Most of the accumulations appeared to be black sludge-like material. The CSB investigators collected samples of the sludge-like material for further chemical composition analysis and testing to develop possible ignition scenarios.

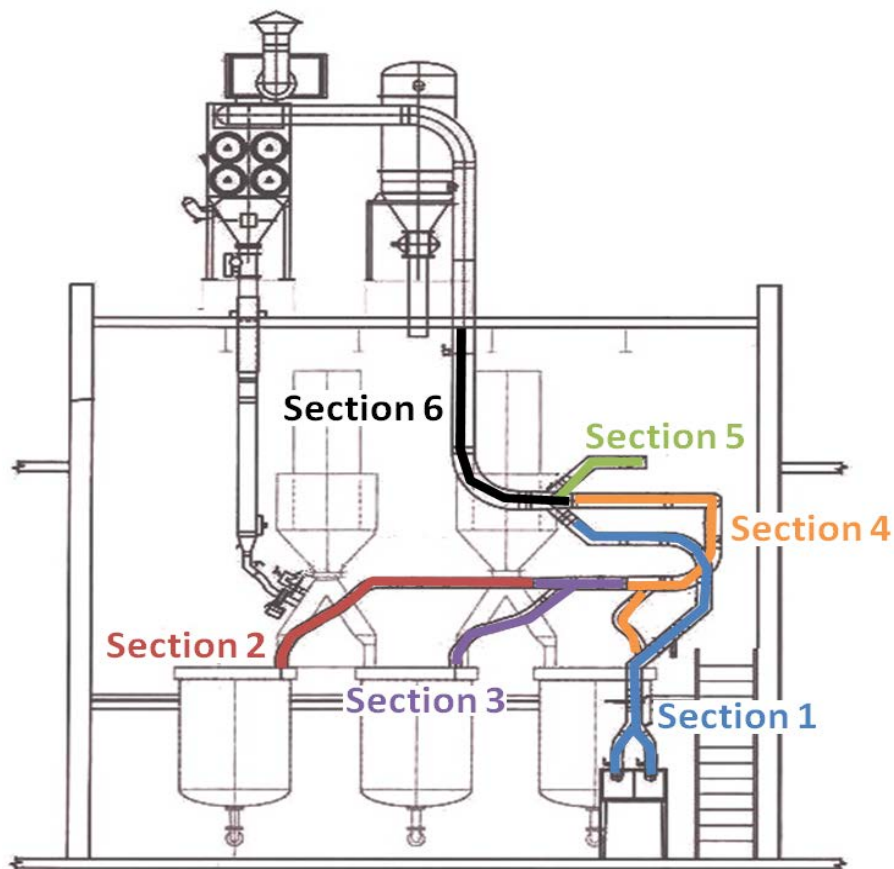


Figure 8. Ductwork sections for sampling

Several different types of tests were conducted on the samples. Chemical composition analyses were performed, using Fourier transform infrared spectrometry and gas chromatography/mass spectrometry. Ignitability and dust explosibility tests were conducted, using the ASTM International⁴² standard test method for ignition temperatures, minimum ignition energy, and dust explosibility. The composition analysis showed that the duct sludge was a

⁴² ASTM International (formerly the American Society for Testing and Materials) is a standards organization that develops, publishes, and delivers voluntary international consensus technical standards (<http://www.astm.org/ABOUT/overview.html>).

mixture of hydrocarbon oil, clay, and carbon black. Table 2 lists the different tests performed to develop possible ignition scenarios and the associated results.

Table 2. Test results

Sample Description	Test Conducted	Values
750 oil from supply tank	Closed cup flash point	378°F
Oil from T-306	Closed cup flash point	392°F
Oil from T-206	Closed cup flash point	338°F
Oil from T-106	Closed cup flash point	361°F
Carbon black	Hot air over layer ignition temperature	676°F
Gilsonite	Hot air over layer ignition temperature	453°F
Carbon black	Dust cloud minimum ignition energy	>10 J
Gilsonite ⁴³	Dust cloud minimum ignition energy	<3 mJ
Residue from duct section 2	Self-heating onset temperature	340°F
Residue from duct section 2 (lower region)	Spontaneous heating value ⁴⁴	1°F
Residue from duct section 2 (upper region)	Spontaneous heating value	0°F
Residue from duct section 3	Spontaneous heating value	0°F
Residue from duct section 4 (lower region)	Spontaneous heating value	0°F
Residue from duct section 4 (middle region)	Spontaneous heating value	3°F
Residue from duct section 4 (upper region)	Spontaneous heating value	4°F

4.1 Ignition Temperature and Spontaneous Heating Tests

The oil flash points and powder layer ignition temperatures are all higher than both the typical 240°F temperature for the mixing tanks and the maximum 300°F recorded for T-306 and T-106 on the day of the incident. The spontaneous heating data indicate a low tendency for spontaneous residue heating at temperatures around 180°F. Although the residue self-heating onset temperature was 340°F, the duct sludge before the incident would have had a lower self-heating onset temperature because it would have contained the more volatile components subsequently driven off during the incident fires.

⁴³ Previous incidents involving Gilsonite fires and explosions have occurred in underground mines. One such incident occurred in December 1910 in an asphalt mine in Oklahoma. In 1945, a fire resulted from a Gilsonite explosion at the Bonanza Mine in Utah. In 1953, a violent explosion and fire at the only Gilsonite mine in Utah killed eight miners (<http://www3.gendisasters.com/utah/8897/bonanza-ut-mine-blast-kills-eight-nov-1953>).

⁴⁴ ASTM International, *ASTM 3523-92: Standard Test Method for Spontaneous Heating Values of Liquids and Solids (Differential Mackey Test)*. According to this method, the spontaneous heating value of a substance is a measure of the ability of that substance to undergo self-heating reactions while supported by cellulosic or other fibrous materials in the air. It is an index of the autoignition tendency of the substance under such conditions. The spontaneous heating value can be lower than the test temperature. A negative result does not preclude spontaneous heating initiating at a temperature higher than the test temperature.

4.2. Minimum Ignition Energy Tests

Minimum ignition energy (MIE)⁴⁵ tests were conducted for Gilsonite and carbon black dust to determine their level of susceptibility to electrostatic discharge.⁴⁶ The low MIE measured for the Gilsonite sample, less than 3 millijoules (mJ) demonstrated that Gilsonite⁴⁷ dust clouds are susceptible to ignition from electrostatic discharges. However, the Gilsonite in the main trunk of the dust collector ductwork was mixed with carbon black and with oil vapor condensates. Because the carbon black was conductive, it greatly reduced the chances for electrostatic charging of high-resistivity materials such as the dust collector filter cartridges. Furthermore, the carbon black had a high MIE, more than 10 joules (J), making it not susceptible to electrostatic discharge ignitions unless mixed with enough Gilsonite to produce a mixture with an MIE less than 100 mJ. Therefore, electrostatic discharge ignition in the dust collector was less likely than the scenario described previously (i.e., duct accumulation, self-heating, and autoignition).

4.3. Dust Explosibility Tests

The CSB conducted ASTM E1226⁴⁸ explosibility tests to determine the explosion severity of the dust involved in this incident. Table 3 shows the resulting explosion pressure (P_{MAX}) and normalized maximum rate of pressure rise (K_{ST}) values for carbon black, Gilsonite, and dust samples collected within the dust collector.

Table 3. ASTM E1226 dust explosibility test data

Dust Sample Material	Particle Size Tested	P_{max} (barg)	K_{ST} (bar-m/sec)
Carbon black	98% <75 μ m	8.0	98
Gilsonite (first sample)	98% <75 μ m	8.1	199
Gilsonite (second sample)	97% <75 μ m	7.5	235
Dust collector sample 1	98% <75 μ m	8.3	123
Dust collector sample 2	98% <75 μ m	7.6	102

According to an SSI system design drawing, the design for the Fike dust collector explosion suppression and isolation system was based on a dust explosion hazard corresponding to a maximum pressure (P_{MAX}) of 10 bar gauge (barg) and a normalized rate of pressure rise (K_{ST}) of 165 bar-m/sec.⁴⁹ The P_{MAX} data for all five dust samples listed in Table 3 were less than 10 barg. The obtained K_{ST} values for three of the dust samples were less than 165 bar-m/sec,

⁴⁵ MIE is the minimum amount of energy required to ignite a combustible vapor, gas, or dust cloud.

⁴⁶ An electrostatic discharge occurs when two separated surfaces come into contact and then accumulated charges are transferred from one surface to the other via a discharge. For an electrostatic discharge to occur, one of the surfaces must be highly electrically insulating.

⁴⁷ The National Institute for Occupational Safety and Health conducted explosibility testing based on experimental mine explosions that indicated Gilsonite is 84 percent volatile, much higher than coal dust at 36 percent volatile (<http://www.msha.gov/S&HINFO/RockDusting/JLP-Exp-Mine-paper%20emald.pdf>).

⁴⁸ ASTM International, *ASTM E1226: Standard Test Method for Pressure and Rate of Pressure Rise of Combustible Dusts*. This method indicates that the values for maximum explosion pressure (P_{MAX}) and maximum rate of pressure rise are determined by using a 1-cubic-meter (m^3) or 20-liter sphere test apparatus. The dust sample is dispersed within the sphere and ignited by chemical igniters, and the pressure of the resulting explosion is measured. The cloud concentration is varied to determine the optimal dust concentration. The P_{MAX} and maximum rate of pressure rise are measured and used to calculate the dust deflagration index (K_{ST}) value of the dust cloud. These data can be used to design dust explosion protection measures (such as explosion relief venting, suppression, and containment) and to classify the explosion severity of a material.

⁴⁹ Engineers from US Ink provided Fike representatives with values for maximum rate of pressure rise (K_{ST}) for combustible materials used in the ink manufacturing process based on values that US Ink obtained from material suppliers.

but the K_{ST} values for the two Gilsonite dust samples were more than 165 bar-m/sec (Table 3). The low MIE and higher K_{ST} values indicate that Gilsonite is a faster-burning dust that represents both a greater susceptibility to deflagration and a more demanding explosion protection system challenge than the specified K_{ST} value of 165 bar-m/s.

4.4. Go/No-Go Dust Explosibility and Special Flammability Tests

The go/no-go dust explosibility screening test⁵⁰ (using a residue sample from the duct) and the special sludge oil flammability test were conducted to determine whether the burning sludge observed in the duct stub above T-306 after the dust collector explosion also could be partially responsible for the second fireball and explosion. The go/no-go explosibility test result demonstrated that the residue powder was indeed explosible at dust concentrations of 100 grams per cubic meter (g/m^3) and higher. The special sludge oil flammability test demonstrated that the burning sludge in the duct stub would not ignite the vapors in the tank itself if the tank liquid were at a temperature below its flash point, even if the burning sludge fell into the tank.

On the basis of all the test results, the CSB concluded that the incident probably started with the self-heating and spontaneous ignition of the accumulated sludge (mostly Gilsonite and carbon black mixed with hydrocarbon oils) in the ductwork of the dust collection system. Transport of the burning sludge to the dust collector caused the dust collection explosion. The explosibility of the accumulated sludge and powder deposits in various sections of the duct combined with the flame propagation back from the dust collector explosion to cause more extensive residual burning in the various duct sections. Dust deposits in and around the ducting, including deposits produced from the dust collector explosion, dispersed as the US Ink employee climbed the stairs,⁵¹ intending to suppress the visible flame in the detached flexible duct above Tank 306. The residual flame ignited the dispersed dust, and the subsequent fireball dislodged and lifted more dust so that an expanding fireball vented through the doorway into the corridor. This expanding fireball (or flash fire) was responsible for the multiple burn injuries.

⁵⁰ The explosibility screening (go/no-go) test is used in the laboratory to determine whether a powder or dust will explode while in the form of a dust cloud when exposed to an ignition source. The test results for a material classify it as either a go type (explosible) or a no-go type (nonexplosible). Thus, the test is also known as the go/no-go test.

⁵¹ The dust dispersal may have been due to one of the following phenomena: (1) thermal failure of the flexible connection to T-306, (2) vibrations caused by the employee climbing the stairs, (3) initiation of the extinguisher discharge, or (4) sudden vaporization of a layer of condensed water vapor (produced by the burning sludge and dust) after the water dripped back into the tank and started sinking into the hot oil.

5 Engineering Design Analysis

CSB interviews with the US Ink design engineer, manufacturer, and distributor for the newly installed dust collection system revealed some design deficiencies. The CSB determined that improper design and operation of the new dust collection system were major contributing factors that led to the October 9, 2012, incident. The dust pickup points in the dust collection system pulled excessive quantities of dust and condensable vapors into the ductwork, which operated at low conveying velocities (as demonstrated by the quantities of accumulated dust found in the ductwork after operating the system for less than 2 days). This accumulation in the ductwork was the fuel for the primary deflagration that initiated the incident chain of events.

Other design issues contributing to material accumulation, observed post-incident in the ductwork of the dust collection system, include the following (each discussed in more detail in a subsequent section, as noted):

- Dust pickups at mix tanks that pulled air through the tank headspaces and extracted excessive quantities of condensable vapors and dust into the duct mains (Section 5.1)
- Dust loading from housekeeping dust pickups with insufficient makeup air (Section 5.2)
- Duct blockage because of failure to consider the effect of condensable vapors in the ductwork and the formation of cohesive dust (Section 5.3)
- Blockage of dust collector dust fines chute in 2 days of operation because of failure to consider cohesive dust fines in chute design (Section 5.4)
- Duct main blockage from low conveying velocity (Section 5.5)
- Lack of adequate system checkup at commissioning of the dust collection system (Section 5.6)
- Lack of system controlling parameters for operators to monitor performance and detect system degradation (Section 5.7)
- Dust collection system that was not designed to prevent and contain fires or extinguish fires (Section 5.8)

5.1. Mixing Tank Dust Pickups That Released Vapors and Dust into Duct Main

On the basis of analytical testing of the materials in the ductwork (summarized in Section 4), the CSB concluded that excessive quantities of condensable vapors were released into the ductwork of the dust collection system during its operation. An essential consideration in the design of a dust pickup of a dust collection system is how air enters the pickup and travels to the connected duct. In a closed system such as the mix tanks, air from the tanks is displaced when the tanks are filled with liquid or powders, and air must be drawn into the tanks as the liquid ink mixture is pumped out of the tank. At the US Ink East Rutherford facility, each of the three mixing tanks in the pre-mix room had a small air bleed duct (1.5 inches in diameter) on the rectangular powder fill chute from the carbon black delivery systems. Also attached was a flexible hose for delivering kaolin clay to the mixing tank. The tank was connected to the dust collection system through a flexible duct (6 inches in diameter) a few feet from the powder delivery chute (depicted in Figure 3).

During operation of the mixing tanks and the dust collection system, air entering the tank through the 1.5-inch air bleed duct fluidized some of the powder in the chute on the way to the mixing tank during powder addition. Once in the tank, the air and some of the powder dust mixture traveled across the tank headspace, also picking up condensable vapors before exiting the tank in the flexible duct. The air volume admitted through a 1.5-inch duct is

not sufficient for an adequate conveying velocity⁵² in the 6-inch duct for dust, so only the finest particle sizes will continue moving.

The CSB investigation revealed that the US Ink engineers initially had a design that would minimize high dust and condensable vapor loading of the dust collection system. However, the final design of the installed dust collection system did not avoid a continuous airflow through the tank headspace, which would discharge condensable vapors and dust mixture from each of the mixing tank headspaces into the moving air stream in the duct main.

5.2 Dust Loading from Housekeeping Dust Pickups with Insufficient Makeup Air

The addition of three housekeeping hoses to the system contributed additional dust to the main ductwork, but not the makeup air needed to convey the additional dust to the dust collector. The three (1.5-inch) hoses were connected to the bottom of the adjacent mix tank ducts via enlargement to a hose 3 inches in diameter. The American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual (IVM) states, "All branches should enter the main at the center of the transition at an angle not to exceed 45° with 30° preferred in most cases (Figure 5-23)."⁵³ In addition, ACGIH noted, "To minimize turbulence and possible particulate fall out, connections should be to the top or side of the main with no two branches entering at opposite sides."⁵⁴ The ductwork design for the US Ink dust collection system did not comply with this guideline.

The 3-inch ducts were disassembled during the investigation; they were plugged with free-flowing dust, a sign of insufficient conveying velocity (as illustrated in Figure 9). The connection of housekeeping hoses to a dust collection system is not a good practice because the pressure drop required to move air at 4,000 feet per minute (ft/min) in the 1.5-inch hose (1.5 to 2.0 inches of mercury or 20 to 27 inches of water column) is much greater than the available system static pressure of 17 inches of water column. In addition, doubling the duct diameter reduced the air velocity to less than 25 percent of that available in the hose, plugging the 3-inch duct in less than 2 days of operation.



Figure 9. Vacuum cleaning ducts, plugged after less than 2 days of operation

⁵² Conveying velocity is the minimum air velocity required to move or transport particles within a duct system. It is measured in feet per minute (ft/min).

⁵³ At the time of the incident, the 2007 edition of the IVM provided the applicable guidance; however, since then, ACGIH revised the guidance and published a 2013 edition of the IVM.

⁵⁴ American Conference of Governmental Industrial Hygienists, *Industrial Ventilation: A Manual of Recommended Practice for Design*, 26th Edition (Cincinnati, OH: ACGIH, 2007) 5-27.

5.3 Duct Blockage Because of Failure to Consider Effect of Vapors and Dust in Ductwork

The design of ductwork for the dust collection system did not reflect consideration of the presence of condensable vapor generated by the high temperature of the ink mixing process. US Ink did not make any provisions to prevent or clean out the uncontrolled condensation. The ACGIH IVM states, "If solid particulates or condensable vapors are being transported through the system, a minimum velocity is required."⁵⁵ The CSB concluded that the failure to consider the effect of condensable vapors in the design of the dust collection system led to formation of the sludge in the ductwork. In addition, the condensable vapors mixed with the dust, forming either a sludge in the duct or a cohesive dust in the dust collector.

The CSB learned that the system volume capacity for the US Ink dust collection system was 3,300 actual cubic feet⁵⁶ per minute (ACFM)⁵⁷ at 210°F, while the design for 6-inch duct velocity indicated at an estimated airflow rate of 1,150 ft/min. On the basis of a review of the heavy or moist dust description in Table 5-1 of the ACGIH IVM,⁵⁸ a minimum duct conveying or transport velocity⁵⁹ of 4,500 ft/min would have been more appropriate for the design of the dust collection system at US Ink.⁶⁰

The ACGIH IVM provides research data and information on the design, maintenance, and evaluation of industrial exhaust ventilation systems that are applicable to the US Ink dust collection system. A design minimum conveying velocity of 4,500 ft/min could have provided a more effective means of moving any moist dust within the dust collection system. US Ink did not provide any information or record that the engineers responsible for design and installation of the new dust collection system measured the dust conveying velocity of the system at commissioning. NFPA 654-2006,⁶¹ paragraph 7.6.1, states, "Ducts that handle combustible particulate solids shall conform to the requirements of NFPA 91." NFPA 654 (2006 edition)⁶² and NFPA 91 (2010 edition)⁶³ note the requirement, "All ductwork shall be sized to provide the air volume and air velocity necessary to keep the duct interior clean and free of residual material."

⁵⁵ American Conference of Governmental Industrial Hygienists, *Industrial Ventilation: A Manual of Recommended Practice for Design*, 26th Edition (Cincinnati, OH: ACGIH, 2007) 5-10.

⁵⁶ An initial US Ink dust collection system design intent drawing allotted 500 cubic feet per minute (cfm) exhaust to each mix tank and 1000 cfm to the bag dump. Another 300 cfm was allotted for the three cleanup hoses. A later order confirmation placed the system volume capacity at 3,300 acfm at 210°F.

⁵⁷ ACFM is a unit of volumetric capacity commonly used by manufacturers of blowers and compressors. This capacity is the actual gas delivery with reference to inlet conditions; it is the volume of gas (air) flowing anywhere in a system, independent of its density.

⁵⁸ American Conference of Governmental Industrial Hygienists, *Industrial Ventilation: A Manual of Recommended Practice for Design*, 26th Edition (Cincinnati, OH: ACGIH, 2007) 5-11.

⁵⁹ Conveying velocity is the minimum air velocity required to move or transport particles within a duct system. It is measured in ft/min.

⁶⁰ International Association of Plumbing and Mechanical Officials, *Uniform Mechanical Code* (Ontario, CA: IAPMO, 2009), Table 5-1, 46.

⁶¹ National Fire Protection Association, *NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2006 Edition (Quincy, MA: NFPA, 2006).

⁶² National Fire Protection Association, *NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2006 Edition (Quincy, MA: NFPA, 2006), 13.

⁶³ National Fire Protection Association, *NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 Edition (Quincy, MA: NFPA, 2010), 8.

5.4 Blockage of the Dust Collector Dust Fines Chute Because of Design Failure

The dust collector dust hopper and dust fines chute were filled with approximately 322 pounds of dust fines in just 2 days of system operation. The 10-inch-diameter chute reduced to 4 inches in diameter to return the fines to the mix tank. The cohesive dust in the 10-inch-diameter chute bridged the opening and did not flow through the 4-inch chute. The dust chute design did not allow for the stop-and-start nature of dust fines return.⁶⁴ If the incident had not halted operation of the process, the dust collector would have been plugged within a few more days of operation.

5.5 Duct Main Blockage from Low Conveying Velocity

The duct main⁶⁵ had insufficient conveying velocity until the three-way junction where the bag dump branch and the duct-mounted air bleed joined the duct from the three mix tanks and the housekeeping system pickups. The small 1.5-inch-diameter mix tank air bleeds would not admit enough air for conveying velocity in the 6-inch mix tank ducts or the 8-inch and 9-inch ducts with combined mix tank exhaust; this configuration created conditions in this section of the dust collection system that allowed the accumulation of condensable vapors and dust.⁶⁶ As stated previously, locating the duct air bleed ahead of the first mix tank would have provided a makeup air source for a reliable conveying velocity in the duct main.⁶⁷

5.6 Lack of Adequate System Checkup at Commissioning of the Dust Collection System

Outside contractors performed all construction and installation of the new dust collector. Sun Chemical selected two contractors to configure the dust collection system, based on direction from the US Ink senior engineer. US Ink/Sun Chemical Corporation did not perform onsite risk and hazard assessments before start-up of the new dust collection system to determine the effectiveness of performance of the newly installed dust collection system. In addition, after contractors completed the dust collection system installation, no onsite inspection or measurement of system performance parameters (such as airflow rate and conveying velocity) was conducted to ensure that the system was working appropriately.⁶⁸

No pitot tube⁶⁹ holes were visible in the ducts, indicating that no system pressure measurements were taken at commissioning of the dust collection system. NFPA 91 and NFPA 654 require initial system testing, including measurement of all system branches to verify that the system delivers target airflows and to set the blast gates as

⁶⁴ Very low conveying velocities in the ductwork, combined with air flow through the dust powder delivered in the chute, ended up putting dust and vapors into the duct but did not carry sufficient dust away through the recycle process and back into T-106.

⁶⁵ The duct main is the section of the ductwork where other incoming duct branches join the main duct.

⁶⁶ US Ink and its contractors responsible for the efficiency of the dust collection system performance did not perform any measurements to confirm the designed air flow rate and conveying velocity.

⁶⁷ Bag dump and duct air bleeds should have been located at the far end of the duct to provide continuous airflow.

⁶⁸ US Ink/Sun Chemical maintained that a US Ink contractor engineer performed a brief system start-up to ensure that everything was working properly. During that time, the suction of the dust collection system was checked. In addition, the conveying velocity was intended to be manually adjusted as production progressed, by use of the weighted damper, to ensure that the system was getting the right amount of suction. Although US Ink employees claimed there was too much suction (rather than too little), iterative testing of the process could not be performed to confirm actual flow rates as all the drops of dry materials had been completed for the day. Despite this argument by US Ink, the CSB asserts that visual observation of the suction rate by US Ink employees does not convey that a system start-up check or measurements were taken to quantify the performance and efficiency of the new dust collection system.

⁶⁹ A pitot tube is an instrument used to measure air or fluid flow velocity under pressure. The basic pitot tube consists of a tube pointing directly into the air or fluid flow. Pressure can be measured based on the level of fluid in the tube.

necessary. Section 10.3.1 of NFPA 91 specifies the requirement, “When installation of a new system is complete, the system shall be tested to demonstrate performance before acceptance by the user.”⁷⁰ Annex paragraph A.10.3 lists required system test activities, including:

- Measure the air volume, fan static pressure,⁷¹ motor speed and electric current, and temperature of air in the system
- Determine pressure drops across all components (such as air cleaning equipment)
- Record the test data and design specifications
- Compare the test data with design specifications and determine whether system alterations or adjustments are necessary to meet specifications⁷²

The CSB concluded that US Ink/Sun Chemical Corporation did not perform any of the previously listed tests after installation of the US Ink dust collection system. The commissioning data are critical because they provide a reference point for ongoing system monitoring and maintenance to ensure that the dust collection system runs within design parameters.

5.7 Lack of System Controlling Parameters for Operators to Monitor Performance

Dust collection system designs seek to overcome the anticipated flow resistance of the hoods, ducts, dust collector, auxiliary equipment, and exhaust stack. Many possible causes for anticipated resistance in these areas could affect system performance. For example, dust buildup in a duct reduces flow but increases local duct pressure between the dust collector and the plug; an increase in filter differential pressure restricts flow to the entire system, reducing hood exhaust airflow and hood static pressures. By knowing the pressure profile of different points in the system, as established with a newly commissioned system, operators can monitor changes in this information to enable timely interventions to keep the system working. Although the US Ink dust collection system had some remote indicators of differential pressures for the dust collector and the HEPA filter, none of the pressure gauges displayed action limit information, and no local static pressure devices near the mixing tanks or the bag dump hood warned the operator of performance problems, as recommended in the ACGIH manual, “Industrial Ventilation, A Recommended Practice for Operation and Maintenance.”⁷³

5.8 Dust Collection System Not Designed to Prevent, Contain, or Extinguish Fires

US Ink employee testimonies revealed that the rubberized flexible hoses were the first part of the system to fail when the duct fire started. The US Ink mixing tanks had flexible hose lengths of 6 to 8 feet, which increased airflow

⁷⁰ National Fire Protection Association, *NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 Edition (Quincy, MA: NFPA, 2010), 15.

⁷¹ Static pressure (SP) is defined as the pressure in the duct that tends to burst or collapse the duct and is expressed in inches of water gauge. It is usually measured with a water manometer, hence the units. SP can be positive or negative with respect to the local atmospheric pressure but must be measured perpendicular to the air flow. American Conference of Governmental Industrial Hygienists, *Industrial Ventilation Manual*, 28th Edition (Cincinnati, OH: ACGIH, 2013).

⁷² National Fire Protection Association, *NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 Edition (Quincy, MA: NFPA, 2010), 18.

⁷³ The ACGIH IVM recommends performing system testing at the time of initial installation (commissioning) to verify the volumetric flow rates and to obtain other information that can be compared with the original design data. Initial system testing is also necessary to provide a baseline for periodic maintenance checks. The ACGIH IVM recommends static pressure measurements and close visual inspections during maintenance checks if no alterations have been made to the system. American Conference of Governmental Industrial Hygienists, *Industrial Ventilation: A Manual of Recommended Practice for Operation and Maintenance*, 26th Edition (Cincinnati, OH: ACGIH, 2007), Chapter 2, “Commissioning and Proof of Performance.”

restriction at the mixing tanks.⁷⁴ The hose lengths of 8 to 10 feet at the bag dump station also added resistance to that branch. US Ink maintained that flexible ducts were used because the ink mixers were on weight scales. In addition, US Ink believed that the flexible ducts—constructed of Conduct-O-Flex, a material which had a conductive spiral core and was specifically intended (and used by US Ink) to prevent static buildup—were properly bounded and grounded to the rigid duct and mixer connections. The recommended best practice suggests using flexible duct only to aid mobility of moving parts or equipment and making lengths as short as possible (usually not more than 3 feet).⁷⁵

In addition, rubberized flexible hoses are not electrically conductive because airborne powder moving through a plastic or rubberized hose can generate some static electrical charge. Combustible dust particles with a low MIE can ignite because of an electrostatic discharge from a nonconductive hose. The combustible flexible hoses used in the dust collection system design burned through rapidly and ultimately released the flash fire from the top of T-306 into the pre-mix room. The fire did not seriously damage any of the metal ducts, but all of the flexible hoses along the fire path suffered severe burns.

A detailed examination of the US Ink dust collection system revealed the absence of duct cleanout doors. Duct cleanouts are commonly needed for dust collection systems as part of routine system monitoring and maintenance. The ACGIH IVM states, “Where the air contaminant includes particulate that may settle in the duct, clean-out doors should be provided in horizontal runs, near elbows, junctions, and vertical runs (see Figure 5-17).”⁷⁶ Cleanout doors provide access to clean out accumulated dust and also serve as locations where firefighters can introduce water to fight fires. Because the US Ink facility had no cleanout doors,⁷⁷ the East Rutherford firefighters had to break a section of ductwork to apply water to smoldering ductwork sections.

The CSB inspection of the US Ink dust collection system indicated that ducts with cross-sections larger than 75 square inches (about 9.5 inches in diameter) did not have an automatic fire extinguishing system.⁷⁸ Chapter 9 of NFPA 91 (2010 edition)⁷⁹ specifies, “Any portion of an exhaust system utilizing combustible components or having the potential for combustible residue buildup on the inside, where the duct cross-sectional area is greater than or equal to 75 in² (480 cm²), shall be provided with an automatic extinguishing system within the duct and at the duct

⁷⁴ The flexible hoses used in the dust collection system design were longer than needed and led to failure points during the incident.

⁷⁵ National Fire Protection Association, *NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 Edition (Quincy, MA: NFPA, 2010). This standard emphasizes the need to minimize the use of flexible hose, using it only for equipment that needs to move and then only in lengths as short as possible.

⁷⁶ American Conference of Governmental Industrial Hygienists, *Industrial Ventilation: A Manual of Recommended Practice for Design*, 26th Edition (Cincinnati, OH: ACGIH, 2007), 5-27.

⁷⁷ US Ink/Sun Chemical maintained that the dust collection system featured “easy-open” connections between pieces of the ductwork, which enabled easy inspection (and cleaning) of the ductwork interiors. US Ink believed that the easy-open connection was used in place of duct cleanout doors and as such served a similar purpose. Although the easy-open connection provided a reasonable alternative to the cleanout doors, firefighters could not use it to apply water to burning duct sections.

⁷⁸ The ductwork assembly from section 6 (ductwork that was vertically installed from the pre-mix room up to the rooftop and continuing to the dust collector, as shown in Figure 8) was measured at 12 inches in diameter.

⁷⁹ National Fire Protection Association, *NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 Edition (Quincy, MA: NFPA, 2010), 15.

intake, hood, enclosure, or canopy, or shall be constructed of material listed for use without sprinkler protection.”⁸⁰ Although the Fike chemical suppression and isolation system attached to the dust collector stopped an explosion, it was not designed to extinguish fires, other than preventing backward flame propagation from the dust collector past the location of the chemical isolation device.⁸¹ In addition, incorporating sprinklers or some other extinguishing system in the 12-inch duct might have helped minimize duct damage on the day of the incident. Moreover, sprinklers are prudent for a dust collector protected by a chemical suppression system because an explosion suppression and isolation system is not designed to extinguish a fire in the ductwork or in the dust collector. CSB investigations revealed that US Ink engineers and the third-party loss prevention and risk management consultants (hired by US Ink/Sun Chemical Corporation) considered including internal sprinkler protection and explosion venting within the dust collector but ultimately decided against including sprinklers because of installation of the Fike explosion suppression and isolation system and because of cost-effectiveness factors.

6 Safety Management Analysis

The lack of adequate oversight by Sun Chemical Corporation management personnel in the planning, design, installation, and commissioning of the dust collection system likely contributed to the October 9, 2012, incident. The CSB identified significant management issues, including inadequate project oversight, ineffective employee training on the dust collection mechanism, and failure to adequately communicate lessons learned from a previous incident.

6.1 Inadequate Project Oversight and Misrepresentation of MOC Exemption

Before design of the new dust collection system, the engineering team filed a Capital Appropriations/Asset Request (CAR),⁸² which contained various levels of approvals from the local plant, engineering department, local operations manager, division controller and accounting department, corporate environmental health and safety department, and CAR approval committee. Sun Chemical project management policy requires the CAR, which must be prepared if the total cost of a project exceeds \$350,000. The estimate for the US Ink dust collection system exceeded \$350,000 in capital costs; therefore, a CAR was required.

In the CAR environmental health and safety section, a checkbox indicating the need for a process hazard analysis (PHA) or management of change (MOC) was not checked, indicating that neither a PHA nor a MOC was necessary for the dust collection system.⁸³ During interviews with company engineers and senior management, CSB

⁸⁰ NFPA 91 is applicable to the incorporation of a sprinkler system in the ductwork design because it is a standard for exhaust systems for air conveying of vapors, gases, and mists (all generated from heating of ink ingredients and oils) and for noncombustible particulate solids (such as bentonite, used by US Ink).

⁸¹ Fike explains this failure of the isolation device to prevent backward flame propagation by citing a more rapid flame propagation speed than was expected based on the specified K_{ST} value of 165 bar-m/s. The more rapid flame propagation speed may have been associated with the formation of a flammable hybrid (combustible dust plus vapor) in the ducting and collector.

⁸² The CAR system was designed so that Sun Chemical managers, engineers, and company decision-makers could approve projects electronically and so that information relating to the approval and rejection of a project could be saved for later reference.

⁸³ The requirements for PHA and MOC procedures are described in: National Fire Protection Association, *NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2006 Edition (Quincy, MA: NFPA, 2006), Section 4.2 and Section 4.3.

investigators learned that the engineering team considered installation of the dust collection system as a replacement in kind for the old wet scrubber system.

The CSB investigation revealed that corporate engineering managers who were responsible for executing the US Ink dust collection system project at Sun Chemical relied on the judgments and decisions of their reports and did not adequately oversee the dust collection system project. The new dust collection system is completely different from the old wet scrubber system, with different functions and design specifications. US Ink/Sun Chemical management did not seek a building permit for a completely new process because they failed to acknowledge that a PHA was required for the new process.⁸⁴ If a PHA had been conducted, it would have triggered consideration of additional safety factors, including the need to obtain a building permit. The CSB determined that, as a result, US Ink/Sun Chemical management provided inadequate oversight of the capital project.

6.2 Inadequate Management of Organization Change and Contractor Oversight

A senior engineer who retired from US Ink before completion of the project coordinated the design of the dust collection system.⁸⁵ Upon retirement of the senior engineer, another US Ink engineer and an engineering contractor assumed oversight of the dust collection project. Although not fully involved in initial design of the dust collection system, the new engineers completed contractor hiring and equipment ordering and oversaw installation of the dust collection system. There was no record of adequate communication of transitional knowledge concerning the handover of the dust collection system from the retired senior engineer to the new engineers. External contractors (who were not fully involved in the design concept of the dust collection system) performed all construction and installation activities for the new dust collection system. The engineers communicated primarily by telephone and emails to the subcontractors, without observing the actual installation process for the dust collection system.

CSB interviews with the US Ink engineers revealed that US Ink/Sun Chemical Corporation lacked an adequate and effective process for management of organizational change. No procedures allowed for transferring and retaining design knowledge and forwarding information to the new engineer. In this case, the company relied on the retired senior engineer solely for technical guidance throughout the design, construction, and installation phases of the dust collection system. When the original design engineer left, accountability for the dust collection system fell to the new engineer, who was not directly involved in the initial design of the dust collection system, and to the in-house contractor engineer, who made frequent trips to the East Rutherford facility to observe progress on the installation process for the dust collection system. However, US Ink/Sun Chemical claimed to rely on the expertise of the manufacturers of the dust collection system and on their contractors for smooth operation of the system. As a result, US Ink/Sun Chemical did not provide additional contractor oversight for the dust collection project. In addition, the new engineer did not consult other company engineers who could support the design, installation, and commissioning of the dust collection system.

6.3 Ineffective Hazard Communication and Emergency Response Planning

Employee injuries likely would have been prevented if US Ink had developed and implemented an effective hazard communication and emergency response plan. US Ink fire and explosion emergency procedures called for a designated chief coordinator to use the public address system to announce the fire and its location as soon as it

⁸⁴ The US Ink East Rutherford facility was not covered by OSHA process hazard management (PHM). However, NFPA 654 (2006 edition) requires that a combustible dust hazard assessment must be conducted and used as the basis for choices in fire and explosion protection systems. In addition, conducting an assessment of the major deficiency areas of the dust collection system would have at least triggered the need for PHA.

⁸⁵ Contractors and manufacturers that specialized in dust collection systems fabricated and installed the dust collection system.

was observed. The designee also had the task of pulling the alarm box outside the main office and calling the fire department. The plant evacuation plan required all employees to evacuate the building immediately after the fire alarm was pulled. On the day of the incident, the designated fire coordinator did not perform any of the duties (announcing the fire or pulling the alarm box) because he was among those injured while assembled at the entrance to the pre-mix room. Although the pre-mix room operator informed the designee about the first flash fire from the bag dump station, the employee decided to go to the pre-mix room to observe the situation instead of performing his duties as the plant-designated fire coordinator.

In addition, the US Ink hazard communication and emergency response plan did not require that an employee attempt to control a fire with an extinguisher after a manually triggered fire alarm was actuated; rather, the plan required employees to evacuate the building immediately. Because no fire alarm sounded, employees attempted to extinguish the fire. Although all employees eventually evacuated the building, the evacuation did not occur until after the injuries were sustained. Witness interviews revealed that although the company occasionally conducted training and fire drills, employees did not follow the existing emergency response plan on the day of the incident.⁸⁶ This circumstance indicated that the fire hazard and emergency training received by plant employees was inadequate.

The sprinkler system in the pre-mix room was connected to an automatic audible alarm that was relayed to the East Rutherford Fire Department, but no record indicated that the automatic fire alarm provided adequate (if any) notification to employees. The CSB observed that no other automatic fire alarm system was located anywhere in the US Ink East Rutherford facility. An effective automatic fire alarm would have immediately notified employees of the flash fires and triggered an immediate evacuation; instead, employees congregated at the entrance of the pre-mix room. The manual alarm notification system that US Ink adopted was ineffective on the day of the incident. NFPA 72 (National Fire Alarm Code, 2007 edition⁸⁷) specifies requirements for the installation and operation of automatic fire alarms and other fire detection systems, including audible and visible fire emergency notification systems.

6.4 Ineffective Employee Training on Dust Collection Mechanism

After initial start-up of the dust collector, a 15-minute meeting was held on October 5, 2012, for supervisors and one of the day-shift operators⁸⁸ and was less than adequate. At the meeting, the system manufacturer provided a walkthrough of the dust collection system and a brief interpretation of visual indicators. The meeting did not include information on how the dust collection system was designed to work and how operators could troubleshoot problems. This limited training did not adequately prepare the staff to address a malfunction of the dust collection system. In addition, US Ink did not develop a fire or explosion incident prevention program to reinforce employee understanding of the potential hazard severity associated with the newly installed dust collection system. Moreover, no mechanism was in place for pre-mix room operators to determine changes in dust collection system performance.

⁸⁶ The CSB review of records for fire safety training and drills indicated that the hazards of combustible dust explosions were communicated to the employees; US Ink employees followed the “pre-planned” annual drills; and seven employees were injured on the day of the incident as a result of the failure to follow the hazard communication procedures outlined in the training and fire drills.

⁸⁷ National Fire Protection Association, *NFPA 72: National Fire Alarm and Signaling Code*, 2007 Edition (Quincy, MA: NFPA, 2007).

⁸⁸ The night-shift pre-mix room operator did not receive the 15-minute walkthrough and instructions.

6.5 Failure to Communicate Lessons Learned from Previous Incident

Before October 9, 2012, a similar fire incident involving a mixing tank occurred at the US Ink East Rutherford facility on February 29, 2008, when the East Rutherford Bureau of Fire Safety and the East Rutherford Fire Department responded to a fire incident at the US Ink facility. The fire occurred in an ink mixing tank (about 80 percent oil and 20 percent carbon black). According to the East Rutherford Bureau of Fire Safety, the fire occurred because of overheating of ingredients in the mixing tank. The official report documenting the emergency response indicated that the ductwork at the top of the tank was consumed by the flames generated during the fire. An employee initially attempted to suppress the fire with a fire extinguisher but, after failing to do so, exited the building.⁸⁹ The US Ink security service company notified the East Rutherford Fire Department, and responding units extinguished the fire.

No injuries were reported as a result of this previous incident. US Ink did not address any lessons learned from this incident. It did not discourage employees from attempting to extinguish fires in an environment with flammable vapor and combustible dust. In addition, the company did not install temperature indicators and temperature interlocks that would activate when the temperature from the ink mixing operation became too high.

7 Regulatory Analysis

7.1 U.S. Occupational Safety and Health Administration

7.1.1 Combustible Dust Standard

The CSB has investigated multiple combustible dust incidents since 2003. The agency initiated a study of dust explosions in general industry after three catastrophic incidents in one year, and it issued the *Combustible Dust Hazard Study* in 2006. This CSB study identified 281 combustible dust incidents between 1980 and 2005, which led to the deaths of 119 workers, injured 718, and extensively damaged numerous industrial facilities.⁹⁰ The need to control the risk of dust explosions in general industry became apparent, and as a result, the Board issued six recommendations; one advocated a new federal OSHA standard based on existing NFPA standards for combustible dust.

The CSB study found that a comprehensive federal regulation specific to combustible dust was necessary because the reliance on industry to voluntarily comply with consensus standards, fire codes, or both was insufficient to control combustible dust hazards. US Ink did not consistently follow NFPA-prescribed design requirements or ACGIH standards when designing its new dust collection system (discussed in Section 5). Moreover, OSHA enforcement of existing regulations failed to address dust hazards. OSHA initially cited US Ink and fined it \$25,000 for the October 9, 2012, incident, characterizing the accident as a dust explosion. The citations included violations of OSHA standards for exit routes, storage and handling of liquefied petroleum gases, portable fire extinguishers, and hazard communication. However, many of the listed violations were not causally linked to the flash fire that

⁸⁹ The US Ink hazard communication and emergency response plan did not require an employee to try to control a fire with an extinguisher but instead required employees to evacuate the building immediately when a fire alarm sounded. Industry best practices discourage employees from attempting to extinguish fires in a combustible dust environment because this approach could be deadly.

⁹⁰ U.S. Chemical Safety and Hazard Investigation Board, *Final Report: Combustible Dust Hazard Study*, Investigation Report No. 2006-H-1 (Washington, DC: CSB, 2006) (<http://www.csb.gov/combustible-dust-hazard-investigation/> and http://www.csb.gov/assets/1/19/Dust_Final_Report_Website_11-17-06.pdf).

burned the seven workers. Consequently, US Ink corrective actions to address those violations would not prevent or mitigate the risk of a future combustible dust incident. OSHA inspectors need a comprehensive standard to regulate the design and operation issues of processes involving combustible dust to effectively prevent combustible dust incidents.

Since 2006, the CSB has continued to investigate catastrophic combustible dust incidents in all types of industries. For example, just 2 years after the CSB issued its study, an explosion of sugar dust at the Imperial Sugar Company manufacturing and packaging facility in Port Wentworth, Georgia, killed 14 workers and injured 38 others. In 2010, an explosion involving titanium dust ripped through the AL Solutions, Inc., processing facility for titanium and zirconium scrap metal in New Cumberland, West Virginia, killing three workers and injuring one. Just over a year before the US Ink incident, the CSB investigated three iron dust incidents at the Hoeganaes Corporation steel and iron powder manufacturing facility in Gallatin, Tennessee, that killed five workers and injured three others in 2011. The findings from these investigations reinforced the CSB 2006 study findings and led to reiteration of the CSB recommendation to OSHA to issue a combustible dust standard and to do so promptly. The CSB also has been tracking combustible dust incidents, documenting 50 accidents involving combustible dust that caused 29 fatalities and 161 injuries from 2008 to 2012.⁹¹

To date, OSHA has not promulgated a combustible dust standard, although it has started the rulemaking process. In 2009, OSHA published an Advance Notice of Proposed Rulemaking (ANPR) for combustible dust that defines the hazard as “all combustible particulate solids of any size, shape, or chemical composition that could present a fire or deflagration hazard when suspended in air or other oxidizing medium.” US Ink carbon black and Gilsonite powders are characterized as “combustible” according to Material Safety Data Sheets (MSDSs) and therefore would be covered by this proposed rule.

Although the agency has continued to place the combustible dust rule on its regulatory agendas over the years, OSHA has not moved forward in rulemaking. As a result, the CSB held a public meeting in Washington, DC, on July 25, 2013, declaring OSHA actions “unacceptable” because of the delay in issuing a combustible dust standard, and the CSB also placed the issue of combustible dust on its Most Wanted Chemical Safety Improvement Program list.⁹²

OSHA does recognize that regulating combustible dust will prevent these accidents. Previous OSHA experience in regulating dust explosions in the grain industry proved that the number and severity of grain dust explosions decreased after promulgation of the Grain Handling Facilities Standard in 1987. During a 2003 regulatory review of

⁹¹ U.S. Chemical Safety and Hazard Investigation Board, *Final Report: AL Solutions*, Investigation Report No. 20011-3-I-WV (Washington, DC: CSB, 2011), Appendix C (http://www.csb.gov/assets/1/19/Final_Case_Study_7.161.pdf, accessed August 13, 2014).

⁹² U.S. Chemical Safety and Hazard Investigation Board, *U.S. Chemical Safety Board Determines OSHA Response to Seven Open CSB Recommendations on Dust, Fuel Gas, and Process Safety Management to Be “Unacceptable”; Board Votes to Designate a Combustible Dust Standard as “Most Wanted”* (Washington, DC: CSB, 2013) (<http://www.csb.gov/us-chemical-safety-board-determines-oshare-sponse-to-seven-open-csb-recommendations-on-dust-fuel-gas-and-process-safety-management-to-be-unacceptable/>).

Also: U.S. Chemical Safety and Hazard Investigation Board, *U.S. Chemical Safety and Hazard Investigation Board Recommendations Status Change Summary* (Washington, DC: CSB, 2013) (http://www.csb.gov/assets/recommendation/Status_Change_Summary_Dust.pdf, accessed August 12, 2014).

the standard, OSHA found that grain explosions had declined by 42 percent, injuries by 60 percent, and fatalities by 70 percent.⁹³

Furthermore, recent OSHA inspection data indicated that inspectors were using the general duty clause (GDC) almost seven times more often for citations related to combustible dust than for all other citations. Inspectors use the GDC when no specific standard applies to a recognized hazard. OSHA found that the most common GDC violations for dust hazards cited equipment that was not adequately equipped to prevent excessive dust accumulations, failure to effectively protect systems to prevent a dust explosion or deflagration, and failure to reduce ignition sources in the presence of dust. These hazards are addressed in consensus standards, which inspectors referenced when using the GDC. OSHA concluded that the “unusually high proportion” of GDC citations supported the need for a comprehensive OSHA combustible dust standard.⁹⁴

7.1.2 OSHA Combustible Dust Education and Enforcement Efforts

Since the release of the CSB 2006 study, OSHA has made efforts to educate employers who might have combustible dust hazards. On its website, OSHA created a resource page (“Combustible Dust: An Explosion Hazard”) that includes guidance for workers and emergency responders on precautions to take when handling or responding to incidents involving combustible dust.⁹⁵

OSHA also has increased its enforcement actions, moving toward identifying and correcting combustible dust hazards as a result of some of the CSB recommendations from the 2006 study. In October 2009, OSHA reported training more than 350 compliance officers on combustible dust and developed other training courses that both federal OSHA and state personnel have attended since December 2007.⁹⁶

OSHA also initiated the Combustible Dust National Emphasis Program (NEP) in 2007, an inspection program to target specific industry hazards during a specified time period. OSHA reissued the Combustible Dust NEP in 2008 after the Imperial Sugar accident to intensify enforcement activities for facilities that have combustible dust hazards. States that fall under federal jurisdiction, such as New Jersey, are required to inspect in accordance with the Combustible Dust NEP. Each OSHA Area Office receives a list of establishments in that geographical region with North American Industry Classification System (NAICS) codes that correspond to industry sectors identified by OSHA as “industries with more frequent and/or high consequence combustible dust explosions/fires” (as listed in Appendix D-1 of the Combustible Dust NEP directive) or to industries “that may have potential for combustible dust explosions/fires” (as listed in Appendix D-2 of the Combustible Dust NEP directive). On the basis of its familiarity with local industries, the OSHA Area Office can make appropriate additions or deletions. Random number selection is then used to identify facilities where the area office will conduct programmed Combustible Dust NEP inspections in a given fiscal year. Each OSHA Area Office must conduct at least three inspections per year at establishments with NAICS codes that appear in Appendix D-1 of the Combustible Dust NEP directive and at least one inspection per year at establishments with NAICS codes that appear in Appendix D-2.

⁹³ “Regulatory Review of OSHA’s Grain Handling Facilities Standard,” 29 *Code of Federal Regulations* (CFR) 1910.272, February 2003 (<https://www.osha.gov/dea/lookback/grainhandlingfinalreport.html>, accessed August 13, 2014).

⁹⁴ U.S. Occupational Safety and Health Administration, Advance Notice of Proposed Rulemaking, 29 CFR Part 1910, “Combustible Dust: Proposed Rule,” 74 *Federal Register* (FR) 22, October 21, 2009.

⁹⁵ U.S. Occupational Safety and Health Administration, *Combustible Dust: An Explosion Hazard* (<https://www.osha.gov/dsg/combustibledust/enforcement.html>, accessed August 13, 2014).

⁹⁶ U.S. Occupational Safety and Health Administration, *Status Report on Combustible Dust National Emphasis Program*, October 2009 (https://www.osha.gov/dep/combustible_dust/combustible_dust_nep_rpt_102009.html, accessed August 14, 2014).

The NAICS code assigned to the US Ink Facility (325910, Printing Ink Manufacturing) does not appear on either the Appendix D-1 list or the Appendix D-2 list of the OSHA Combustible Dust NEP directive. This NEP even identifies Class II locations as hazardous sites with the presence of certain substances, such as “carbonaceous dust” (i.e., carbon black).⁹⁷ The OSHA Region II Area Office did not use its discretionary authority to add the U.S. Ink facility to either list. Therefore, the facility was never subjected to a programmed inspection under the Combustible Dust NEP.

Moreover, as previously mentioned, no dust-related citations resulted from the US Ink inspection after the October 9, 2012, incident, although the incident was characterized as a dust explosion.⁹⁸ The Combustible Dust NEP requires an inspection in accordance with its guidelines after an accident involving combustible dust and provides guidance on citations, noting, “A citation under section 5(a)(1) of the OSH Act (the general duty clause) may be issued for deflagration, explosion or other fire hazards that may be caused by combustible dust within a dust collection system or other containers, such as mixers.”⁹⁹ No such citation was issued to US Ink, calling into question how effectively the Combustible Dust NEP and training on combustible dust are communicated to OSHA local area offices.

7.1.3 National Impact of the NAICS Code

The latest U.S. Census data show that the total number of establishments¹⁰⁰ in the United States with NAICS Code 325910 (Printing Ink Manufacturing) is 429, with 11,488 paid employees. Of these sites, 5 percent are in New Jersey¹⁰¹ and employ 364 workers.¹⁰² Because no comprehensive OSHA standard regulates the hazards of combustible dust in general industry, many of these employees remain at risk of a combustible dust explosion and fire at their workplaces.

7.2 State of New Jersey

7.2.1 New Jersey State Uniform Construction Code Act

In 1975, the New Jersey state legislature enacted the State Uniform Construction Code (UCC) Act, which is administered by the Department of Community Affairs (DCA), the primary agency in the state for building codes and standards. This act provided for a single mandatory construction code and for a fundamental restructuring of the enforcement process. Hence, the UCC—that is, New Jersey Administrative Code (N.J.A.C.) 5:23, et seq.—was adopted and became effective on January 1, 1977.¹⁰³ Under the current New Jersey UCC, a number of subcodes

⁹⁷ U.S. Occupational Safety and Health Administration, *Combustible Dust National Emphasis Program (Reissued)*, CPL 03-00-0008 (Washington, DC: OSHA, 2008).

⁹⁸ OSHA Inspection Detail, October 9, 2012, “Sun Chemical Inc. Inspection No. 704178.015” (https://www.osha.gov/pls/imis/establishment.inspection_detail?id=704178.015, accessed November 21, 2014).

⁹⁹ OSHA Instruction, “Combustible Dust National Emphasis Program (Reissued),” March 11, 2008 (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=directives&p_id=3830#purpose, accessed November 21, 2014).

¹⁰⁰ Establishment is defined as “a single physical location where business is conducted or where services or industrial operations are performed” (<https://www.census.gov/econ/susb/definitions.html>, accessed August 15, 2014).

¹⁰¹ New Jersey has a total of 25 establishments under NAICS Code 325910.

¹⁰² U.S. Census Bureau, *Statistics of U.S. Businesses, 2011 Annual Data* (http://www.census.gov/econ/susb/data/download_susb2011.html, accessed August 15, 2014).

¹⁰³ Bureau of Construction Project Review website (<http://www.state.nj.us/dca/divisions/codes/offices/constructionprojectreview.html>, accessed September 5, 2014).

have been adopted, such as the International Building Code (IBC) (2009 edition) and the National Electric Code (2011 edition).

The New Jersey UCC mandates that any installation of new equipment requires the owner to file an application for a construction permit, which involves various building permits for electrical, fire, and plumbing.¹⁰⁴ A permit application leads to an inspection by the local building authority and ensures that appropriate codes (e.g., building, electrical, plumbing, and fire codes) are followed. The CSB found that US Ink did not submit an inquiry to the local building department, the East Rutherford Building Department, to determine whether a construction permit for the new dust collection system was necessary. Therefore, US Ink never applied for a building permit, and as a result, the building department did not inspect the new dust collection system before the incident.

The CSB found that US Ink did not apply for the permit because it thought an exemption applied under the New Jersey UCC, which excludes “manufacturing, production and process equipment.” Equipment covered under the exemption is defined as “all equipment employed in a system of operations for the explicit purpose of the production of a product” and lists “air pollution equipment, such as scrubbers” as the type of equipment that is exempted.¹⁰⁵ US Ink applied this exemption to its dust collection system because it considered the system as “air pollution equipment” connected to the manufacturing process, capturing raw materials and recycling them back into the pre-mix room to produce the final ink product.

However, although the New Jersey UCC did not regulate the dust collection equipment at US Ink, the new structural and electrical changes involved in installing the new dust collection system still required US Ink to file for a construction permit. The New Jersey UCC states that it is unlawful to “repair, renovate, alter, reconstruct or demolish a structure...without first filing an application with the construction officials.”¹⁰⁶ A 1992 *New Jersey Register* notice explains:

Highly specialized, often preassembled equipment designed for commercial or industrial use, manufacturing, production and process equipment, or “process equipment,” is often unique to its function and designed beyond the referenced standards in the UCC. This makes it impractical or impossible for code officials to review it in an appropriate way. They do, however, review electrical, water, and sanitary connections to such process equipment, as these can affect public safety.¹⁰⁷

This notice explains the intent of the exemption, to relieve code officials from inspecting the function and design of such equipment when the New Jersey UCC at the time referenced no standards on which to base their enforcement. However, the connections or structural building changes associated with that equipment still require a permit. Consequently, the East Rutherford Building Department cited the company after the October 2012 incident for not obtaining a construction permit.¹⁰⁸

Nevertheless, if the construction permit had been obtained, it would only have required the East Rutherford facility to comply with structural and electrical code requirements. The New Jersey UCC would not have covered the design of the dust collection equipment because of the existing exemption for “manufacturing, production and process

¹⁰⁴ N.J.A.C. 5:23-2.14.

¹⁰⁵ N.J.A.C. 5:23-2.2(a)1.

¹⁰⁶ N.J.A.C. 5:23-2.14(a).

¹⁰⁷ *New Jersey Register* 24:19 (October 5, 1992), 4.

¹⁰⁸ “Notice and Order of Penalty, US Ink Corp/Sun Chemical Corporation,” February 20, 2014.

equipment.” New Jersey exempted that equipment because of the lack of referenced standards in the UCC to assist code officials. However, once New Jersey adopted the IBC,¹⁰⁹ which includes engineering and fire protection standards set by consensus organizations such as the NFPA, the explanation from the 1992 *New Jersey Register* notice was no longer valid. In New Jersey, no current building or fire standards have jurisdiction over the design of the dust collection system at US Ink. The company received environmental permits for its dust collection system before installation.¹¹⁰ The New Jersey environmental standards, however, only set minimum emission standards to control pollution rather than safety requirements to prevent a fire and explosion.

If the dust collection equipment had been covered by the current New Jersey UCC, US Ink would have been required to follow the IBC (2009), which requires occupancies handling combustible dust (such as carbon black) to comply with fire protection standards such as NFPA 654,¹¹¹ which US Ink did not apply appropriately in the design of the dust collection system (discussed in Section 5). The IBC defines H-2 occupancies as “buildings and structures containing materials that pose a deflagration hazard or a hazard from accelerated burning” and lists combustible dusts as a type of such material. Combustible dust in the code is defined as “finely divided solid material that is 420 microns or less in diameter and which, when dispersed in air in the proper proportions, could be ignited by a flame, spark or other source of ignition.” According to its MSDS, the carbon black at US Ink met this definition. Under these provisions, US Ink would be required to have a licensed professional develop and present the engineering drawings to be submitted as part of the permit application.¹¹² The licensed engineer who coordinated the design of the dust collection system for US Ink likely would have evaluated the drawings to ensure compliance with IBC (2009) requirements.

In the absence of a federal combustible dust standard, states must rely on their own regulations. New Jersey code officials would need authority under the New Jersey UCC to enforce provisions that oversee the design of dust collection equipment, which would require a revision of the UCC. Such revisions are needed to require companies in New Jersey that use such equipment (such as US Ink) to follow minimum design standards intended to protect workers and the public.

The New Jersey DCA promulgates New Jersey UCC regulations¹¹³ and also provides administrative guidance and technical assistance to local departments in the state. Specifically, the DCA provides training¹¹⁴ and licensing to building code officials throughout the state, administered by the Bureau of Code Services, Division of Codes and Standards.¹¹⁵ Additional training on engineering design standards for processes involving combustible dust will be needed for local building code officials if their authority is expanded to inspect this type of process equipment.

Furthermore, training is needed to ensure that facilities handling combustible dusts receive the appropriate occupancy classification. US Ink was not accurately classified as an H-2 occupancy that handled combustible dust. The initial building permit identified the US Ink facility as an F-1 and S-1, which are for factory and storage

¹⁰⁹ New Jersey first adopted the IBC in 2003 and adopted more recent revisions over the years; the last edition was adopted in 2010. New Jersey model code adoptions are summarized on the website (http://www.state.nj.us/dca/divisions/codes/codereg/pdf_regs_former/nj_model_code_adopt_5_7_12.pdf).

¹¹⁰ US Ink Preconstruction Air Permit, Operating Certificate PCP100002.

¹¹¹ International Code Council, *International Building Code*, 2009 Edition (Country Club Hills, IL: ICC, 2009), Chapter 4, “Special Detailed Requirements Based on Use and Occupancy,” Section 415.6.1.

¹¹² N.J.A.C. 5:23-2.15.

¹¹³ N.J.A.C. 5:23-1.2.

¹¹⁴ DCA provides training on NFPA codes.

¹¹⁵ N.J.A.C. 5:23-5.2.

occupancies. However, according to the IBC, F and S occupancies are not required to follow NFPA standards for combustible dust hazards. The DCA should provide training to local building officials on hazardous materials, such as combustible dusts, to ensure that the correct classification is assigned and appropriate building requirements are followed.

8.0 Key Findings

As a result of the US Ink investigation, the CSB makes the following findings:

1. **A flammable mixture consisting of hydrocarbons and combustible dusts accumulated in the ductwork during the start up of US Ink's dust collection system. The mixture spontaneously ignited leading to a series of events that caused a flash fire, burning 7 workers.** US Ink/Sun Chemical Corporation did not obtain building, fire, or electrical permits for the construction and installation of the new dust collector. In addition, the East Rutherford Building Department does not have a strict permit, code notification, and enforcement process to ensure compliance with the New Jersey UCC.
2. **A The original design of the dust collection system was intended strictly for dust collection but was modified before commissioning to include a housekeeping function. This also caused insufficient flow rate and contributed to an accumulation of a flammable mixture in the duct system.** Although the design, construction, and installation of the new dust collector required capital project approval at the corporate level, US Ink/Sun Chemical Corporation did not provide adequate oversight of, and communications (including discussions on the possible implications of the presence of vapors from heated combustible liquids) with, contractors for the dust collection system project.
3. **System controls, such as temperature and pressure indicators, were not installed for operators to monitor the mixing tanks and dust collection system during start up. This led to the overheating of the flammable dust mixture which accumulated in the ductwork, and ignited above T-306.** The mix tank dust pickup design, which continuously drew air through powder and vapor in the tank headspace, led to the accumulation of dust and condensable vapor in sections where other duct branches joined the main ductwork (duct main), providing fuel for the duct fire that initiated the sequence of events.
4. **US Ink/Sun Chemical Corporation did not provide adequate oversight into the planning, design, installation and commission of the dust collection system. As a result, safety management elements such as a Process Hazard Analysis and Management of Change procedures were not conducted.** The original design of the dust collection system was intended strictly for dust collection but was modified before commissioning to include a vacuum cleaning function, with insufficient flow rate that restricted air movement and contributed to an accumulation of hazardous materials in the duct system.
5. **No processes were in place to confirm adequate start up or commissioning of the dust collection system. As a result, the blockage of the ductwork went undetected and design flaws were not revealed until after the flash fire occurred.** The dust collection system design did not ensure adequate minimum conveying velocity in all dust branches, resulting in plugged ducts and a deposited mixture of carbon black, Gilsonite, clay, and oil within a few days of start-up and accumulating dust fuel in the ducts for the resulting fire. In addition, the use of combustible rubber hoses for ducts and powder chutes contributed to the duct fire and explosion.
6. **US Ink's hazard communication, emergency response plan, and other incident prevention programs did not reinforce an understanding of the potential hazard associated with flammable vapors entering the dust collection system and mixing with the combustible dust.** No local temperature and pressure indicator

monitored the mixing tanks and dust collection system. This situation likely led to the mixing temperature exceeding safe limits by a margin sufficient to cause the already self-heated vapors of oil and ink dust powder to ignite the accumulated materials in the ductwork above T-306.

7. **US Ink/Sun Chemical Corporation did not obtain a construction permits for the installation of the new dust collection system.** Because of the lack of adequate commissioning or confirmation of adequate performance at start-up, the design flaws were not revealed until the dust explosion. In addition, the dust collection system was not systematically monitored and maintained; no processes were in place to detect the duct plugging that occurred.
8. **No federal agency, or state agency in New Jersey regulates combustible dust hazards.** The hazard communication and emergency response plan and other incident prevention programs did not reinforce an understanding of the potential hazard severity associated with dust produced by the new dust collection system. For example, no automatic fire alarm system was in place in the other areas of the pre-mix room, as required by NFPA 72.
9. **A comprehensive OSHA federal regulation specific to combustible dust is needed because the reliance on industry to voluntarily comply with fire protection and engineering standards is insufficient to control combustible dust hazards.** The New Jersey DCA conducts training for internal personnel and local building code officials on some of the NFPA standards in the New Jersey UCC but does not provide training on combustible dust hazards or relevant NFPA standards that address combustible dust.
10. **OSHA did not include the NAICS code for printing ink manufacturing (325910), the industry classification code for US Ink, to its list of industries in the Combustible Dust NEP. OSHA inspectors refer to this list as guidance on inspections for combustible dust hazards in their region.** A comprehensive federal regulation specific to combustible dust is necessary because the reliance on industry to voluntarily comply with consensus standards and fire codes is insufficient to control combustible dust hazards. OSHA did not include printing ink manufacturing (NAICS Code 325910), the industry classification code for US Ink, in its Combustible Dust NEP when it was issued in 2007 or reissued in 2008.
11. **The New Jersey Uniform Construction Code (UCC) adopts the International Building Code, which does reference fire protection and engineering standards for facilities that handle combustible dusts, such as NFPA 654. However, the UCC exempts certain process equipment that could apply these provisions.**
12. **The New Jersey Department of Community Affairs conducts training for local building code officials on some of the NFPA standards in the New Jersey UCC but does not provide training on relevant NFPA standards that address combustible dust hazards,**

9.0 Reiterated Recommendation

U.S. Occupational Safety and Health Administration

The absence of a general industry safety standard for combustible dust remains an important safety issue because catastrophic dust incidents continue to occur throughout industry. Therefore, the CSB reiterates the recommendation originally issued to OSHA in the 2006 *Combustible Dust Hazard Study*.

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|----------------|---|
| 2006-01-I-H R1 | Issue a standard designed to prevent combustible dust fires and explosions in general industry. Base the standard on current National Fire Protection Association (NFPA) dust explosion standards (including NFPA 654 and NFPA 484) and include at least the following: |
|----------------|---|

- Hazard assessment
- Engineering controls
- Housekeeping
- Building design
- Explosion protection
- Operating procedures
- Worker training

10.0 Recommendations

As a result of its investigation of this accident at the US Ink facility, the CSB makes a number of safety recommendations.

U.S. Occupational Safety and Health Administration

- 2013-01-I-NJ R1 Add North American Industry Classification System (NAICS) Code 325910, Printing Ink Manufacturing, to the list of industries in Appendix D-1 or Appendix D-2 of Combustible Dust National Emphasis Program (NEP), Directive CPL 03-00-008.
- 2013-01-I-NJ R2 Communicate with all OSHA Area Offices to encourage appropriate application of the following existing provisions of the Combustible Dust NEP, Directive CPL 03-00-008:
- Paragraph IX, Section A2, indicates that area offices may add to their Combustible Dust NEP establishment lists those facilities in their jurisdictions with a Standard Industrial Classification System code, NAICS code, or both (other than those listed in Appendices D-1 and D-2 of the Combustible Dust NEP directive) if those facilities have a known pattern of combustible dust hazards.
 - Paragraph IX, Section B4, indicates that if a fatality or catastrophe investigation is performed at a facility because of a combustible dust deflagration or explosion, the inspector shall use the guidelines in *Fatality/Catastrophe Investigation Procedures*, Directive CPL 02-00-137, and in the Combustible Dust NEP, Directive CPL 03-00-008.

New Jersey Department of Community Affairs

- 2013-01-I-NJ R3 Revise the exemption for “manufacturing, production, and process equipment” under the New Jersey Uniform Construction Code (N.J.A.C 5:23-2.2) to require that equipment involved in processing, handling, or conveying combustible dust comply with the design and operating requirements of the current edition of the International Building Code.
- 2013-01-I-NJ R4 Develop and implement training for local code officials on the National Fire Protection Association (NFPA) standards referenced in the New Jersey adoption of the International Building Code (IBC) for occupancies with a high hazard classification (Group H); specifically, include training on equipment that handles combustible dust and the hazards involved.
- 2013-01-I-NJ R5 Promulgate a regulation that requires all occupancies handling hazardous materials to inform the local enforcement agency of any type of construction or installation of equipment at an industrial or manufacturing facility. Also require local enforcement agencies to evaluate the information to determine whether a construction permit is required.

US Ink/Sun Chemical Corporation

- 2013-01-I-NJ R6 At the US Ink East Rutherford facility, install automatic fire alarm systems consistent with NFPA 72 (the National Fire Alarm Code) in manufacturing areas (such as mixing) where heat generation could occur.
- 2013-01-I-NJ R7 Revise the Capital Appropriations/Asset Request (CAR) form procedure for new installations and modifications to existing equipment to require at a minimum the following:
- Process hazard analysis (PHA)
 - Management of change (MOC)
 - Review of engineering drawings for permits
 - Safety management of contractors
 - Training of plant operators based on applicable dust collection system guidelines and standards, including NFPA 91 and NFPA 654
- 2013-01-I-NJ R8 Develop and implement a management of organizational change protocol to allow for the transfer of knowledge and information to new personnel, at a minimum including initial or refresher training in the following:
- Safety and health procedures
 - Lessons learned from previous incidents
 - Technical information for equipment
 - Routine plant operations

CSB investigation reports are formal detailed reports on significant chemical accidents and include key findings, root causes, and safety recommendations. CSB hazard investigations are broader studies of significant chemical hazards. CSB safety bulletins are short general-interest publications that provide new or noteworthy information on preventing chemical accidents. CSB case studies are short reports on specific accidents and include a discussion of relevant prevention practices. All reports may contain safety recommendations when appropriate. CSB investigation digests are plain-language summaries of investigation reports.



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U.S. Chemical Safety and Hazard Investigation Board
Office of Congressional, Public, and Board Affairs
2175 K Street NW, Suite 400
Washington, DC 20037-1848
(202) 261-7600