U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

COMBUSTIBLE DUST HAZARD STUDY

KEY ISSUES:

- FEDERAL REGULATIONS
- HAZARD AWARENESS
- FIRE CODE ENFORCEMENT

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Acronyms and Abbreviations

AA	Aluminum Association
ANSI	American National Standards Institute
ASSE	American Society of Safety Engineers
ASTM	American Society for Testing Materials
Borden	Borden Chemical
CalOSHA	California Division of Occupational Safety and Health
CCPS	Center for Chemical Process Safety
CSB	U.S. Chemical Safety and Hazard Investigation Board
CTA	CTA Acoustics, Inc.
ESC	Electrostatic Charging Tendency
GDC	General Duty Clause
GHS	*Globally Harmonized System of Classification and Labeling of Chemicals*
Hayes	Hayes Lemmerz International – Huntington, IN
HCS	Hazard Communication Standard
ICBO	International Conference of Building Officials
ICC	International Code Council

ICHEME	Institution of Chemical Engineers
IFC	International Fire Code
IMIS	Integrated Management Information System
IOSHA	Indiana Occupational Safety and Health Administration
K_{St}	Dust Deflagration Index
KYOSHA	Kentucky Department of Labor, Office of Occupational Safety and Health
LEL	Lower Explosion Limit
LEP	Local Emphasis Programs
MEC	Minimum Explosive Concentration
MIE	Minimum Ignition Energy
MIOSHA	Michigan Occupational Safety and Health Administration
MSDS	Material Safety Data Sheet
NASFM	National Association of State Fire Marshals
NCOSHA	North Carolina Department of Labor, Occupational Safety and Health Division
NEC	National Electric Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration

OTI	OSHA Training Institute
SEP	Special Emphasis Programs
SHIB	Safety and Health Information Bulletin
SIC	Standard Industry Code
UFC	Uniform Fire Code California Division of Occupational Safety and Health
UNECE	United Nations Economic Commission for Europe
West	West Pharmaceutical Services, Inc.

Executive Summary

Following three catastrophic dust explosions that killed 14 workers in 2003, the US Chemical Safety and Hazard Investigation Board (CSB) initiated a study of dust explosions in general industry and what can be done to reduce their risk. The CSB has concluded that combustible dust explosions are a serious hazard in American industry, and that existing efforts inadequately address this hazard.

The CSB investigations of the 2003 incidents--West Pharmaceutical Services, CTA Acoustics, and Hayes Lemmerz International--identified a number of common causal factors, and subsequent research into several other serious explosions in previous years revealed similar common factors. The CSB identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers and injured 718, and extensively damaged industrial facilities. The incidents occurred in 44 states, in many different industries, and involved a variety of different materials.

These findings illustrate the seriousness of the combustible dust hazard in U.S. workplaces, yet no comprehensive federal Occupational Safety and Health Administration (OSHA) standard exists to control the risk of dust explosions in general industry. Although OSHA has cited employers for failing to address combustible dust hazards, almost all those citations have followed an explosion, and so did not have a preventive focus. In addition, OSHA combustible dust citations have relied on the General Duty Clause (Section 5(a)(1)) or a variety of OSHA standards only tangentially related to dust explosion hazards (such as general housekeeping and electrical standards). In contrast, OSHA's Grain Handling Facilities Standard, issued almost 20 years ago, effectively reduced the number and severity of combustible grain dust explosions in the grain handling industry, and sets an example of OSHA addressing a similar problem through regulation

The CSB found that the National Fire Protection Association (NFPA) has issued comprehensive standards to prevent and mitigate combustible dust explosions; the standards are widely recognized by experts as effective and authoritative. They are also referenced in OSHA citations, within the International Fire Code, and by authoritative publications on combustible dust hazards. Indeed, the CSB concluded that if the three facilities that experienced catastrophic explosions in 2003 had complied with relevant NFPA standards, the explosions would have been prevented or their impact significantly reduced.

Although these NFPA combustible dust standards are generally incorporated directly or by reference into fire regulations of state and local jurisdictions, the CSB found that their adoption and enforcement is inconsistent and largely ineffective. Not all states have adopted fire codes that clearly reference NFPA standards, and jurisdictions within states often amend the state-adopted codes or adopt different codes. Most important, the CSB also found that local fire code enforcement officials rarely inspect industrial facilities, and when they do, officials focus primarily on life-safety issues such as sprinklers, extinguishers, and fire escapes, rather than on industrial hazards such as combustible dust. Furthermore, local fire code officials—as well as other health and safety professionals—are often unfamiliar with combustible dust hazards.

Unlike OSHA, which has the authority to set national workplace safety standards, no federal legislative authority, agency, or other government mechanism is empowered to require that minimum or uniform fire codes be adopted or enforced in all states. The highly decentralized, inconsistent, and non-uniform nature of the U.S. fire code system makes it infeasible to comprehensively change or improve the system such that combustible dust safety would be significantly impacted nationwide.

The CSB also found that Material Safety Data Sheets (MSDSs) generally fail to effectively communicate to employers and workers necessary information about combustible dust hazards or ways to prevent them. A CSB survey found that that nearly half of MSDSs for known combustible particulate materials contain no dust explosion warnings, only seven reference NFPA standards, and few contain practical information about preventing explosions. Furthermore, OSHA's Hazard Communication Standard (HCS) does not clearly state that it applies to combustible dusts, or that chemical manufacturers are responsible for identifying reasonably anticipated downstream uses of products that may, through processing or handling, generate combustible dusts.

The CSB recommends, therefore, that OSHA issue a comprehensive combustible dust standard for general industry that addresses hazard assessment, engineering controls, housekeeping, and worker training. The OSHA standard should be based on the well-recognized NFPA voluntary consensus standards. As interim measures during the lengthy rulemaking process, the CSB further recommends that OSHA conduct outreach and implement a special emphasis inspection program targeting industries particularly at risk for dust explosions, such as aluminum casting, plastics, pharmaceuticals, and wood products. Last, the CSB recommends that OSHA revise the HCS so that it explicitly applies to combustible dusts and that it requires MSDSs to include clear hazard warnings and information on safe handling practices, and that the American National Standards Institute amend Z400.1 to provide specific guidance on preparing MSDSs for combustible dusts.

1.0 Key Findings

1. At least 281 combustible dust fires and explosions occurred in general industry between 1980 and 2005, which

    - caused at least 119 fatalities and 718 injuries in the United States;
    - included seven catastrophic dust explosions in the past decade, involving multiple fatalities and significant community economic impact; and
    - occurred in a wide range of industries and involved many types of combustible dusts.

2. No Occupational Safety and Health Administration (OSHA) standard comprehensively addresses combustible dust explosion hazards in general industry.

3. OSHA's Grain Facilities Standard has successfully reduced the risk of dust explosions in the grain industry.

4. Secondary dust explosions, due to inadequate housekeeping and excessive dust accumulations, caused much of the damage and casualties in recent catastrophic incidents.

5. Consensus standards developed by the National Fire Protection Association (NFPA) that provide detailed guidance for preventing and mitigating dust fires and explosions are widely considered to be effective; however,

- these standards are voluntary unless adopted as part of a fire code by a state or local jurisdiction, and have not been adopted in many states and local jurisdictions, or have been modified.

- among jurisdictions that have adopted the fire codes, enforcement in industrial facilities is inconsistent, and, in the states the CSB surveyed, fire code officials rarely inspect industrial facilities.

6. The OSHA Hazard Communication Standard (HCS) inadequately addresses dust explosion hazards, or safe work practices and guidance documents, in Material Safety Data Sheets (MSDSs).

7. 41 % of the 140 combustible powder MSDSs the CSB surveyed did not warn users about explosion hazards, and only 7 referenced appropriate NFPA dust standards to prevent dust explosions.

8. The voluntary American National Standards Institute (ANSI) consensus standard for MSDS format and preparation, ANSI Z400.1, inadequately addresses combustible dust explosion hazards, and does not define combustible dust or discuss the need to include physical properties for combustible dusts.

9. Training programs for OSHA compliance officers and fire code inspectors generally do not address recognizing combustible dust hazards.

2.0 Introduction

Three catastrophic dust explosions killed 14 workers in 2003. After investigating these explosions, the U.S. Chemical Safety and Hazard Investigation Board (CSB) initiated a special study to improve understanding of the risks of dust explosions in general industry and what can be done to reduce them. This report presents the CSB findings from that study.

Chapter 3.0, “Dust Explosion Basics,” is a primer of basic concepts about dusts and dust explosions to assist non-technical readers, and is not intended to be an all-inclusive reference on the subject of dust explosions.

Chapter 4.0, “Study Description and Case Studies,” describes the objectives, scope, and methods of the study. All general industry sectors were examined except for those covered by federal regulations (grain industry and coal mining). The objectives of the study were to 1) determine whether combustible dust explosions pose a significant risk in general industry; 2) assess current efforts to manage those risks; and 3) recommend measures that may be necessary to reduce risks.

Chapter 4.0 also examines three CSB in-depth investigations that triggered the study, along with four additional case studies of dust explosion incidents available in some detail from the literature, concluding with a summary of the factors in these incidents:

- Workers and managers were often unaware of dust explosion hazards, or failed to recognize the serious nature of dust explosion hazards.

- Facility management failed to conform to NFPA standards that would have prevented or reduced the effects of the explosions.

- The facilities contained unsafe accumulations of combustible dust and housekeeping was inadequate.
- Procedures and training to eliminate or control combustible dust hazards were inadequate.
- Warning events were accepted as normal and their causes were not identified and resolved.
- Dust collectors were inadequately designed or maintained to minimize explosions.
- Process changes were made without adequately reviewing them for the introduction of new potential hazards.
- Government enforcement officials, insurance underwriters, and health and safety professionals inspecting the facilities failed to identify dust explosion hazards.

Chapter 5.0, "Dust Incidents – 1980 to 2005," summarizes the available information about dust explosions in general industry over the last 25 years. The CSB found that combustible dust explosions are a significant industrial safety problem. In the period analyzed, the study identified 281 combustible dust incidents that killed 119 and injured 718 workers, and caused significant material damage.

Chapter 6.0, "Hazard Communication and Preventing Dust Explosions," examines the effectiveness of MSDSs as a means to communicate information to prevent dust explosions. The CSB found that MSDSs generally do not provide sufficient information about the explosion hazards of combustible dusts. The CSB study also found that the guidelines for developing MSDSs provided by OSHA, ANSI, and the emerging *Globally Harmonized System of Classification and Labeling of Chemicals* (GHS) do not clearly instruct how to effectively convey the explosion potential of combustible dusts in MSDSs.

Chapter 7.0, "The Role of Voluntary Consensus Standards and Fire Codes in Preventing Dust Explosions," describes the NFPA voluntary consensus standards widely recognized by scientific and engineering experts, industry, and labor and regulatory bodies to provide effective technical guidance to prevent dust explosions in industry. These standards are not mandatory unless adopted as part of one of the two fire codes widely used in state fire systems across the United States. This chapter, therefore, evaluates the potential for the system of fire codes to serve as a mechanism to comprehensively reduce the risks of dust explosions in general industry nationwide.

The CSB found that adopting and enforcing these fire codes by individual states is quite fragmented, the result of a long-established history of independent operation at state and local levels. Furthermore, code adoption is not uniform across states, enforcement in industrial facilities is inconsistent, and fire inspectors are typically inadequately trained to recognize dust explosion hazards. In addition, no federal legislative authority, agency, or other government mechanism is empowered to require that minimum or uniform fire codes be adopted or enforced in all states. The CSB's analysis indicates that the fire code system's shortcomings prevent it from functioning as an effective mechanism to comprehensively reduce dust explosion risks in general industry.

Chapter 8.0, "OSHA Regulation of Dust Hazards," evaluates whether OSHA regulatory action is needed to address the combustible dust explosion problem in general industry. The CSB found that OSHA has no comprehensive standard to address the risk of dust explosions in general industry, although it has had a standard (The Grain Handling Facilities Standard) that has reduced dust explosion risks in the grain industry for almost two decades. This chapter also examines other tools currently at OSHA's disposal to prevent dust explosions, such as the General Duty Clause (GDC) and Special Emphasis Programs (SEP).

The CSB study concludes that an OSHA standard for dust explosion control in general industry is necessary to reduce risks, and that the technical principles embodied in two key NFPA consensus standards (NFPA 654 and NFPA 484) can serve as the basis for an effective OSHA standard.

Chapter 9.0 summarizes the conclusions of the research, and Chapter 10.0 presents recommendations to OSHA and ANSI to reduce the risks of dust explosions in general industry.

3.0 Dust Explosion Basics

Dust explosions can cause large-scale loss of life and catastrophic damage to facilities. This chapter describes a few basic concepts about dusts and dust explosions to inform non-technical readers about the causes and nature of dust explosions, but is not intended to be an all-inclusive reference on dust explosions. More precise descriptions of dust and dust explosion principles can be found in numerous scientific and technical references, some of which are listed in the "References" section of this report.

3.1.1 Combustible Dusts

Most solid organic materials, as well as many metals and some nonmetallic inorganic materials, will burn or explode if finely divided and dispersed in sufficient concentrations.[1] Combustible dusts can be intentionally manufactured powders, such as corn starch or aluminum powder coatings, or may be generated by handling and processing solid combustible materials such as wood and plastic pellets. For example, polishing, grinding, transporting, and shaping many of these materials can produce very small particles, which can easily become airborne and settle on surfaces, crevices, dust collectors, and other equipment. When disturbed, they can generate potentially explosive dust clouds.

Even seemingly small amounts of accumulated dust can cause catastrophic damage. The CSB estimated, for example, that the explosion that devastated a pharmaceutical plant in 2003 and killed six employees was caused by dust accumulations mainly under 0.25 inches deep. The NFPA warns[2] that more than 1/32 of an inch of dust over 5 percent of a room's surface area presents a significant explosion hazard.

[1] Ignitability and Explosibility of Dusts, Table A.1, Appendix A.2 (Eckhoff, 2003).
[2] NFPA 654 (2006).

3.1.2 Dust Fires and Explosions

Like all fires, a dust fire occurs when fuel (the combustible dust) is exposed to heat (an ignition source) in the presence of oxygen (air). Removing any one of these elements of the classic fire triangle (Figure 1) eliminates the possibility of a fire.

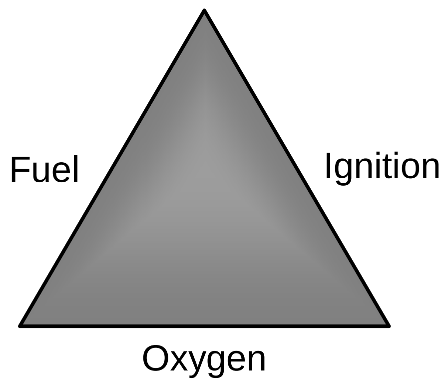

Figure 1. Classic fire triangle

A dust explosion requires the simultaneous presence of two additional elements—dust suspension and confinement (Figure 2). Suspended dust burns more rapidly, and confinement allows for pressure buildup. Removal of either the suspension or the confinement elements prevents an explosion, although a fire may still occur.

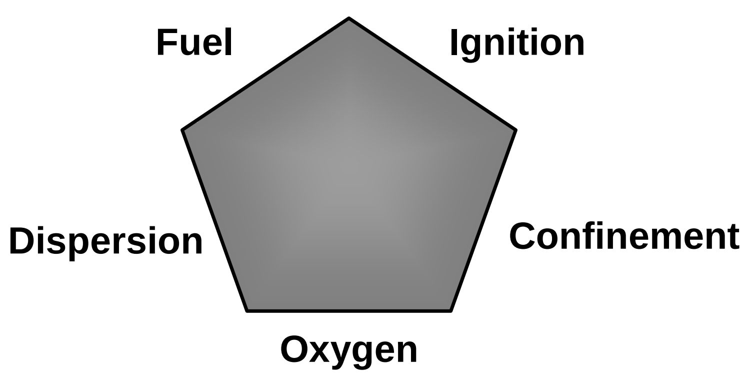

Figure 2. Dust explosion pentagon

Further, the concentration of suspended dust must be within an explosible range[3] for an explosion to occur. This is analogous to the flammability range commonly used for vapors (such as natural gas and propane). Dust explosions can be very energetic, creating powerful waves of pressure that can destroy buildings and hurl people across a room.[4] People caught in dust explosions are often either burned by the intense heat within the burning dust cloud or injured by flying objects or falling structures.

3.1.3 Primary and Secondary Dust Explosions

Dust explosions can either be *primary* or *secondary*. A primary dust explosion occurs when a dust suspension within a container, room, or piece of equipment is ignited and explodes. The dust collector explosion at Hayes Lemmerz (see section 4.2.3) is an example of a primary dust explosion.

A secondary explosion occurs when dust accumulated on floors or other surfaces is lofted and ignited by a primary explosion (Figure 3). The blast wave from the secondary explosion can cause accumulated dust in other areas to become suspended in air, which may generate additional dust explosions. Depending on the extent of the dust deposits, a weak primary explosion may cause very powerful secondary dust explosions.

Finally, the initiating event for a secondary dust explosion might not be a dust explosion at all. The incidents at CTA Acoustics, West Pharmaceutical Services, and Ford River Rouge (see sections 4.2 and 4.3) were secondary dust explosions initiated by events that were not, themselves, dust explosions.

[3] The lowest amount of dust in air that will explode is a commonly measured property, referred to as the Minimum Explosible Concentration, or MEC.

[4] Crowl (2003).

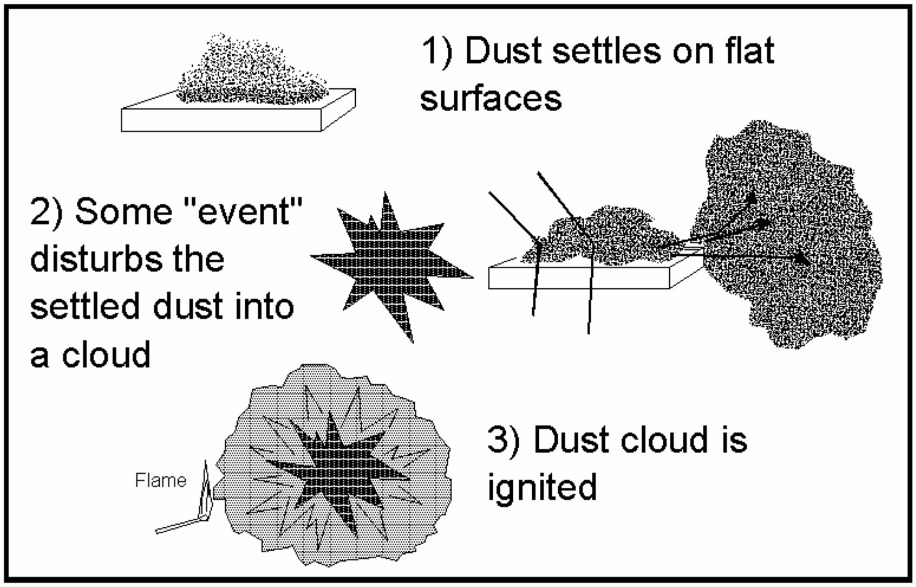

Figure 3. Secondary dust explosion

The best way to prevent secondary dust explosions is to minimize dust accumulations. Ensuring good housekeeping, designing and maintaining equipment to prevent dust leaks, using dust collectors, eliminating flat surfaces and other areas where dust can accumulate, and sealing hard-to-clean areas (such as the area above a suspended ceiling) can effectively prevent secondary dust explosions.

However, proper equipment and techniques to clean combustible dust accumulations must be used. Care must be taken to minimize dust clouds, and only vacuum cleaners approved for combustible dust locations used.[5]

3.1.4 Dust Explosion Propagation through Ducting

The Hayes Lemmerz (see section 4.2.3) and Jahn Foundry incidents (see section 4.3.3) involved dust explosions that spread through pipes or vent ducts, from one piece of equipment to other equipment or

[5] NFPA 654 (2006), 8.2.2.

other areas of the facility. In many cases, the pressure can increase as the explosion moves from one location to the next, increasing the damage. The NFPA standards for dust collectors consider the risk of propagation, with recommendations to provide isolation valves or distance to minimize chances of a dust explosion spreading to areas where workers may be present.

3.1.5 Explosible Dusts

Not all small particles burn. For example, salt and baking soda will not burn, no matter how finely they are ground, because they are not combustible materials. The NFPA defines a combustible dust as "[a]ny finely divided solid material that is 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) and [that] presents a fire or explosion hazard when dispersed and ignited in air."[6]

A few factors that determine how explosive a dust can be, as well as some key measurements for determining dust explosibility, are described below.

3.1.5.1 Particle Size

The ease of ignition and severity of combustible dust explosion are typically influenced by particle size. Finer particles are more explosive because they have large surface areas relative to their weight, allowing them to rapidly react with oxygen when dispersed in air and ignite.[7]

Combustible dusts with an average particle size smaller than 420 microns are considered by most reference sources to be explosive unless testing proves otherwise. To put the size of a micron in rough perspective, the particle size of table salt is around 100 microns. The phenolic resin powders that caused the catastrophic explosion at CTA Acoustics had a particle size of 10 to 50 microns in diameter, similar to talcum (baby) powder (Table 1).

[6] NFPA 654 (2000).

Table 1.

Particle size of common materials[8]

Common Materials	Size (microns)
Talcum powder, fine silt, red blood cells, cocoa	5 to 10
Pollen, milled flour, course silt	44 to 74
Table salt	105 to 149
Coarse sand	297 to 1000

3.1.5.2 Other Factors

Other factors that influence the explosiveness of dusts include moisture content; ambient humidity; oxygen available for combustion; the shape of the dust particle; and the concentration of dust in the air (minimum explosive concentration, or MEC).

3.1.6 Measured Dust Properties

Measuring key properties for a dust at the particular process conditions (temperature, particle size, moisture content, etc.) is the first step in evaluating and addressing the hazards of a combustible dust. The most commonly measured properties are listed in Table 2[9].

[7] The CSB studied the issue of nanoparticles (particles so small that their size is measured in nanometers) combustibility. No current research data suggests that materials in nanoparticle sizes are significantly more reactive; however, many experts the CSB consulted believe the issue warrants study.

[8] Source: http://www.wateruse.com/micron_equivalents.htm.

[9] The American Society for Testing Materials (ASTM) publishes the standard methods for measuring most of these properties.

Table 2. Measured properties of combustible dusts[10]

Property	Definition	ASTM Test Method	Application
K_{St}	Dust deflagration index	ASTM E 1226	Measures the relative explosion severity compared to other dusts.
P_{max}	Maximum explosion overpressure generated in the test chamber	ASTM E 1226	Used to design enclosures and predict the severity of the consequence.
$(dp/dt)_{max}$	Maximum rate of pressure rise	ASTM E 1226	Predicts the violence of an explosion. Used to calculate K_{St}.
MIE	Minimum Ignition energy	ASTM E 2019	Predicts the ease and likelihood of ignition of a dispersed dust cloud.
MEC	Minimum explosible concentration	ASTM E 1515	Measures the minimum amount of dust, dispersed in air, required to spread an explosion. Analogous to the lower flammability limit (LFL) for gas/air mixtures.
LOC	Limiting oxygen concentration	ASTM standard under development	Determines the least amount of oxygen required for explosion propagation through the dust cloud.
ECT	Electrostatic charging tendency	No ASTM standard	Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud.

[10] Dastidar et al. (2005).

4.0 Study Description and Case Studies

In 2003, the CSB investigated three significant dust explosions[11] that resulted in 14 fatalities, many serious injuries, and substantial property and other economic damage. Although the incidents occurred in three different industry segments and involved different processes, they shared many common causes, suggesting a possible widespread risk across broad sectors of general industry. The CSB therefore decided to conduct a special national study of the explosion hazards of combustible dusts and the effectiveness of existing efforts to reduce those hazards. This chapter describes the objectives, scope, and methods of the study. This is followed by summaries of the three CSB in-depth investigations that triggered the study, and of four additional significant dust explosion incidents. The chapter concludes with a summary of the common factors in many of these investigations.

4.1 Study Objectives, Scope and Methods

4.1.1 Objectives

The study answers the following questions:

- Are dust explosions in general industry a significant national problem?
- Do MSDSs effectively communicate dust explosion hazards?
- Do existing laws, regulations, fire codes, and/or voluntary consensus standards provide a means to effectively prevent and mitigate dust explosions?

[11] West Pharmaceutical Services, Kinston, North Carolina, January 29, 2003; CTA Acoustics, Corbin, Kentucky, February 20, 2003; and Hayes Lemmerz International, Huntington, Indiana, October 29, 2003.

- Do state governments effectively enforce fire codes that address combustible dust hazards?
- What additional state, federal, or private sector activities are necessary to prevent combustible dust fires and explosions?

4.1.2 Scope

The CSB study includes general industry, including food products, rubbers, metals, wood, pharmaceuticals, plastics, paint and coatings, synthetic organic chemicals, and other industries not covered by the OSHA Grain Handling Facilities Standard or the Mine Safety and Health Act regulations for coal mines.

4.1.3 Methods

The CSB used the following methods to obtain information for this study:

- direct investigation and analysis of three major dust explosion incidents;
- literature review and analysis of four detailed case studies;
- literature research;
- collection of incident information from several databases for a 25-year period;
- telephone surveys;
- compilation and analysis of MSDSs for combustible dusts; and
- consultation with experts from regulatory agencies, code and standards organizations, industry trade groups, and others.

In addition, the CSB solicited public comments in a *Federal Register* notice and held a one-day public hearing[12] on June 22, 2005, in Washington, DC (Appendix D). The agenda included CSB staff presentations; panel discussions with 16 invited experts from industry, state, and local governments and trade associations; and a public comment session.

4.2 The CSB Investigations of Dust Explosions

The following three sections summarize the findings of three in-depth CSB investigations of dust explosion incidents.

4.2.1 West Pharmaceutical Services, Inc.

On January 29, 2003, a massive dust explosion at the West Pharmaceutical Services facility in Kinston, North Carolina, killed six workers and destroyed the facility (Figure 4). The explosion involved a part of the building used to compound rubber.

West produced rubber syringe plungers and other pharmaceutical devices at the facility. In the rubber compounding process, freshly milled rubber strips were dipped into a slurry of polyethylene, water, and surfactant to cool the rubber and provide an anti-tack coating. As the rubber dried, fine polyethylene powder drifted on air currents to the space above a suspended ceiling.

Polyethylene powder accumulated on surfaces above the suspended ceiling, providing fuel for a devastating secondary explosion. While the visible production areas were kept extremely clean, few employees were aware of the dust accumulation hidden above the suspended ceiling, and the MSDS for the polyethylene slurry included no dust explosion warning. Even those employees who were aware of the dust accumulation had not been trained about the hazards of combustible dust. West did use a safety

[12] A video excerpt and complete transcript of the public hearing are available on CSB's website.

review process when the compounding system was designed and modified, but the dust explosion hazard was not addressed during the reviews.

Figure 4. West Pharmaceutical Services facility destroyed by polyethylene dust explosion[13]

OSHA, the local fire department, an insurance underwriter, and an industrial hygienist had inspected the facility, but none had identified the potential for a dust explosion. In addition, the electrical equipment above the suspended ceiling in the rubber compounding section was not rated for use around combustible dust, as the National Electric Code (NEC) requires (for areas where combustible dust can accumulate). The CSB determined that if West had adhered to NFPA standards for combustible dust,[14] the explosion could have been prevented or minimized.

[13] Photo by the CSB.

[14] NFPA 654 (2000) stipulates that areas that cannot be readily accessed for cleaning, such as the space above the ceiling at West, should be sealed to prevent dust accumulation.

4.2.2 CTA Acoustics, Inc.

On February 20, 2003, a series of dust explosions at the CTA Acoustics (CTA) facility in Corbin, Kentucky, claimed the lives of seven workers, injured 37, and destroyed the manufacturing facility(Figure 5). This facility primarily made acoustic insulation for automobiles.

The manufacturing process began by impregnating a fiberglass mat with phenolic resin, and then used air to draw the resin into the fiberglass webs. On the day of the explosion, a curing oven that had been left open because of a temperature control problem likely ignited the combustible resin dust stirred up by workers cleaning the area near the oven.

The CSB also found that plant design, work practices, and housekeeping problems contributed to causing the explosions. The CTA building was not designed to prevent or minimize secondary dust explosions (minimizing flat surfaces where dust can accumulate and using fire walls to separate production lines). Although management was aware of dust explosion hazards associated with the materials being used, dust had accumulated in dangerous amounts throughout the production areas, in vent ducting, and in dust collector housings, due to inadequate housekeeping and maintenance. In addition, employees routinely used compressed air and brooms to clean production lines, creating clouds of resin dust.

The MSDS for the resin used at CTA did not adequately communicate that the material posed a dust explosion hazard. In addition, the resin supplier, Borden Chemical (Borden), had not communicated to CTA the safety lessons from the 1999 Jahn Foundry resin dust explosion, even though documents obtained by the CSB indicated that Borden was aware of the explosion, which involved a resin similar to the one used at CTA.

The Kentucky Office of Occupational Safety and Health (KYOSHA) had inspected the facility, but had not issued citations regarding combustible dust hazards.

Figure 5. CTA Acoustics' production area after resin dust explosions[15]

In addition, the CTA facility had never been inspected by the Kentucky State Fire Marshal's Office, and frequent inspections by CTA's insurer had failed to identify phenolic resin as an explosion hazard. The CSB determined that if CTA had adhered to NFPA[16] standards for housekeeping and fire/explosion barriers, the explosions could have been prevented or minimized.

4.2.3 Hayes Lemmerz International

On October 29, 2003, aluminum dust exploded (Figure 6) at the Hayes Lemmerz International facility in Huntington, Indiana, killed one worker and injured several others. This explosion, which involved equipment used to remelt scrap aluminum, occurred in a part of the building where Hayes made cast aluminum and aluminum alloy automobile wheels.

[15] Photo by the CSB.

[16] NFPA 654 (2000).

Scrap aluminum from the wheel manufacturing lines was chopped into small chips, pneumatically conveyed to the scrap processing area, dried, and fed into a melt furnace. Transporting and drying the aluminum chips generated explosive aluminum dust, which was then pulled into a dust collector.

The CSB determined that the explosion likely originated in the dust collector, which had not been adequately vented or cleaned, and was located too close to the aluminum scrap processing area. The initial explosion spread through ducting, causing a large fireball to emerge from the furnace.

Figure 6. Intense fire following an aluminum dust explosion at Hayes Lemmerz International (Huntington, Indiana, October 29, 2003).

The dust collector system was not designed or maintained to prevent dust explosions, or to prevent a dust collector explosion from spreading through ducting. When the scrap and dust collector systems were added to the facility, Hayes did not follow management of change procedures that might have identified the dust explosion hazard.

Hayes had also not cleaned dust from overhead beams and other structures. Some of this accumulated dust exploded (a secondary explosion), damaging the building roof. Previous dust fires at the facility were not investigated, facility employees had not been trained on the explosive nature of aluminum dust, and the Indiana Occupational Safety and Health Administration (IOSHA) had not identified dust explosion hazards during previous facility inspections. The CSB, in its report, determined that if Hayes Lemmerz had adhered to the NFPA standard[17] for combustible metals, the explosion could have been prevented or minimized. The CSB report also included a recommendation for additional research to develop improved explosion protection for dust collectors in aluminum service.

4.3 Other Significant Dust Explosions

The CSB reviewed four additional significant dust explosions between 1995 and 2002 for which detailed reports were available. These explosions also caused fatalities and/or injuries, destroyed facilities, and caused significant community economic impact. These incidents involved causal factors similar to those identified in the three CSB dust explosion investigations (West, CTA, and Hayes).

4.3.1 Malden Mills

On December 11, 1995, an explosion and fire virtually destroyed the Malden Mills facility in Methuen, Massachusetts, injuring 37 (Figure 7). The Malden Mills facility produced Polartec fleece fabrics. According to reports by OSHA, the U.S. Fire Administration (USFA), and the Massachusetts State Fire Marshal's Office, the originating event was likely a dust explosion involving nylon flock fibers. While reports of previous events at the same facility indicated that nylon fibers were ignited by static electricity, managers and employees did not generally understand that the fibers were an explosion hazard before the Malden Mills explosion.

[17] NFPA 484 (2000).

Figure 7. Photo showing firefighting efforts following the nylon fiber explosion at Malden Mills (Methuen, Massachusetts, December 11, 1995).[18]

4.3.2 Ford River Rouge: Secondary Coal Dust Explosion

One of the seven boilers that supplied power to the Ford Motor Company's River Rouge manufacturing plant (near Dearborn, Michigan) exploded on February 1, 1999, killing six workers and injuring 36 (Figure 8). Although the initial event was a natural gas explosion, witness accounts of dust accumulations before the explosion provided strong evidence of a secondary coal dust explosion. Coal dust accumulated on horizontal surfaces in the powerhouse was lofted and ignited by the initial explosion.

Figure 8. Aerial of the Ford River Rouge facility powerhouse.[19]

One major finding of the Michigan Occupational Safety and Health Administration (MIOSHA) investigation of the explosion[20] was that housekeeping to minimize coal dust accumulations was inadequate.

4.3.3 Jahn Foundry: Resin Dust Explosion

A dust explosion in the Springfield, Massachusetts, casting facility for Jahn Foundry Corporation claimed the lives of three and injured nine on February 25, 1999; several foundry buildings were severely damaged (Figure 9).

Jahn Foundry produced iron castings from molten metal poured into shell molds. The molds were made onsite from sand and phenolic resin, and then cured in gas-fired ovens. A joint investigation team representing OSHA, the Massachusetts State Fire Marshal's Office, and the Springfield Arson and Bomb

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[18] Photo reprinted by permission, Associated Press.

[19] Photo courtesy of *NFPA Journal* July/August 2004.

[20] Zalosh, 1999; Mniszewski, 2004.

Squad, concluded that, due to heavy resin deposits found inside exhaust ducting and on building surfaces, the incident involved a resin dust explosion in the shell mold area. The dust likely ignited, spreading a flame front through the building, which disturbed settled dust, causing a catastrophic secondary explosion.

Figure 9. Shell mold building after Jahn Foundry Explosion (Springfield, Massachusetts, February 25, 1999).[21]

The investigation concluded that the underlying causes of the explosion included inadequate design and maintenance of the gas burner system, and inadequate housekeeping to minimize resin accumulation in the vent ducting. The resin used at Jahn Foundry was similar to the resin that fueled the explosions at CTA and made by the same manufacturer, Borden.

4.3.4 Rouse Polymerics: Rubber Dust Explosion

On May 16, 2002, a rubber dust explosion at the Rouse Polymerics rubber recycling plant in Vicksburg, Mississippi, resulted in the deaths of five workers and injuries to seven others (Figure 10). The rubber recycling process included a wet slurry operation, followed by gas-fired drying of fine rubber paste.

[21] Photo courtesy of Associated Press (as used in *SouthCoast Today* Feb. 27, 1999).

OSHA concluded that hot rubber entrained in the exhaust from product dryers fell onto the building roof, igniting a fire that was pulled into a product bagging bin. Evidence indicates that a primary fire occurred inside the bagging bin, which was not equipped with explosion venting, and spread to a screw conveyer. Dust layers that had accumulated on surfaces were lofted and ignited in a secondary explosion.

Figure 10. Emergency responders at Rouse Polymerics after explosion[22]

The OSHA investigation report indicated that design and procedures for operating the gas-fired dryers and dust collector were inadequate, as was housekeeping, and that plant personnel lacked awareness of the hazards of accumulated layers of combustible rubber dust. Investigators also linked ineffective management of change to the incident.

4.4 Discussion

The three CSB dust investigations (West, CTA, and Hayes) and the four other explosions described in this chapter identified factors common to all or most of the incidents:

[22] Photo courtesy of the *Clarion-Ledger*, May 17, 2002.

- Facility management failed to conform to NFPA standards that would have prevented or reduced the effects of the explosions.
- Company personnel, government enforcement officials, insurance underwriters, and health and safety professionals inspecting the facilities failed to identify dust explosion hazards or recommend protective measures.
- The facilities contained unsafe accumulations of combustible dust and housekeeping was inadequate.
- Workers and managers were often unaware of dust explosion hazards.
- Procedures and training to eliminate or control combustible dust hazards were inadequate.
- Previous fires and other warning events were accepted as normal, and their causes were not identified and resolved.
- Dust collectors were inadequately designed or maintained to minimize explosions.
- Process changes were made without adequately reviewing them for potential hazards.

5.0 Dust Incidents – 1980 to 2005

To determine the extent of dust explosion hazards in the United States, the CSB investigators researched the history of dust fires and explosions from 1980 to 2005, and identified 281 major combustible dust incidents that killed 119 workers, injured 718 others, and destroyed many of the industrial facilities. Based on this data, the fatal or disabling/disfiguring injuries in the 2003 dust explosions, and the damages caused by those explosions, the CSB concludes that combustible dust incidents are a significant industrial safety problem.

5.1 Data Sources

The CSB searched a number of data sources (Appendix A) to identify incidents in the United States that met the following definition of a combustible dust incident:

> A fire and/or explosion—fueled by any finely divided solid material—that harms people or property.

The search covered various industrial sectors (lumber and wood products, food products, chemical manufacturing) that handle and/or generate combustible dusts.

The CSB excluded incidents involving:

- grain-handling or other facilities currently regulated by the OSHA Grain Handling Facilities Standard;
- coal mines;
- non-manufacturing facilities, such as hospitals, military installations, and research institutes; and
- transportation.

Appendix A lists the incidents with summary incident data. [23]

[23] The complete dataset is available at Dust Data File.

The OSHA Integrated Management Information System (IMIS) database is a significant source of data for incidents that involve injuries or fatalities. Other sources include a variety of public-domain databases, technical literature, and news accounts.

5.2 Combustible Dust Incident Data

The number of combustible dust incidents and resulting fatalities and injuries signifies a serious national safety hazard. Figure 11 displays the incidence and effects (injuries and fatalities) of combustible dust fires and explosions from 1980 to 2005.

5.2.1 Frequency

The CSB identified an average of 10 dust explosion incidents per year from 1980 to 2005. Although incidents increased in later years, this may be due to limitations in the data, including the possibility that earlier incidents were under-reported.

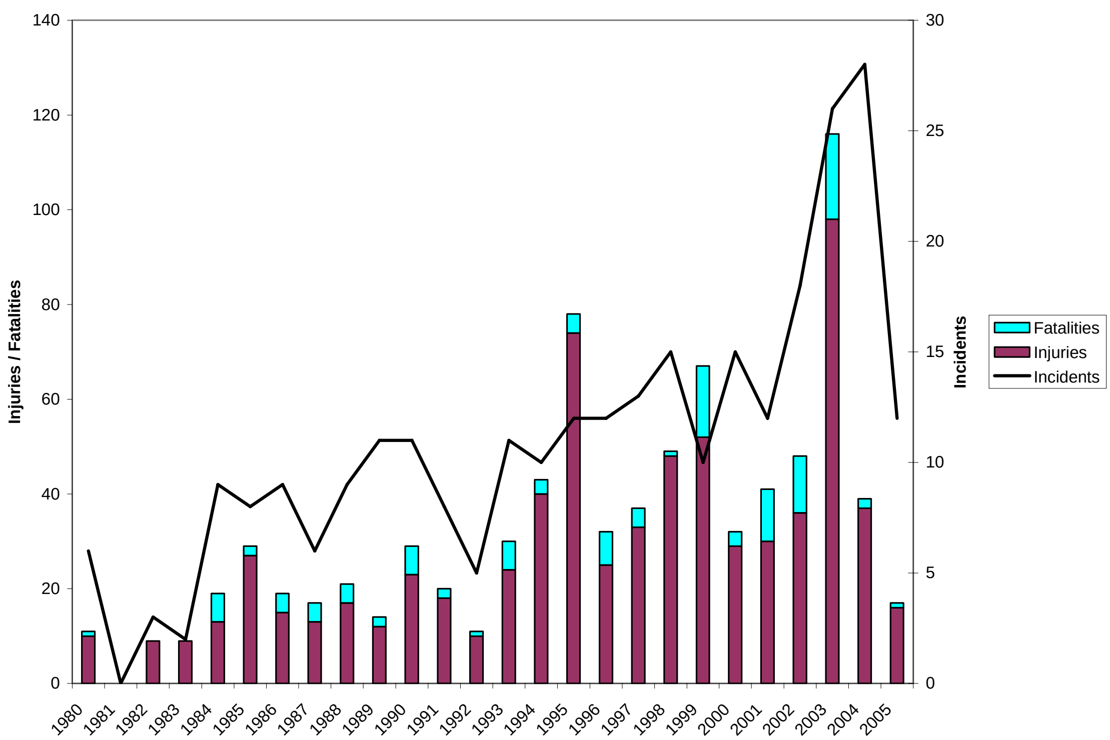

Figure 11. Dust incidents, injuries, and fatalities, 1980-2005

5.2.2 Fatalities and Injuries

The CSB identified 119 fatalities in 78 of the 281 incidents. Injuries totaled 718, and the data show an average of nearly five fatalities and 29 injuries per year. Injuries or fatalities occurred in 71 percent of the incidents..

5.2.3 Property Damage

Combustible dust fires and explosions also significantly damage property. Even though no government or private entity tracks total property loss due to industrial accidents, the CSB learned that the explosions at Malden Mills, CTA Acoustics, West Pharmaceutical, and Rouse Polymerics each caused damages costing many hundreds of millions. FM Global Insurance Company (FM Global, 2001) reports that from 1983 to 2003, 22 dust-related incidents (at FM Global insured properties) resulted in losses of over $1 million each; financial losses due to business interruption, lost wages, or community economic impacts are not included in that figure.

5.2.4 Geographic Distribution

Combustible dust incidents are a nationwide problem. The CSB data include combustible dust fires and explosions in 44 of the 50 states, with seven (typically with large concentrations of at-risk facilities) experiencing 10 or more incidents (Table 3).

Table 3. States with ten or more combustible dust incidents

Illinois	23
California	22
Ohio	15
Iowa	15
Indiana	13
Pennsylvania	12
Minnesota	10

5.2.5 Profile of Affected Industries and Equipment

Combustible dust explosions can occur in any industry handling combustible dusts, including metal fabrication, plastics, furniture and wood products, and chemical manufacturing (Figure 12); however, four industry sectors (food products, lumber and wood products, chemicals, and primary metals) account for over half.

The CSB found that in all industries, dust collectors are the equipment most often involved in incidents; similarly, Zalosh et al. (2005) report that dust collectors account for more than 40 percent of all dust explosions. Grinders, silos, hoppers, and mixers are also involved in numerous incidents.

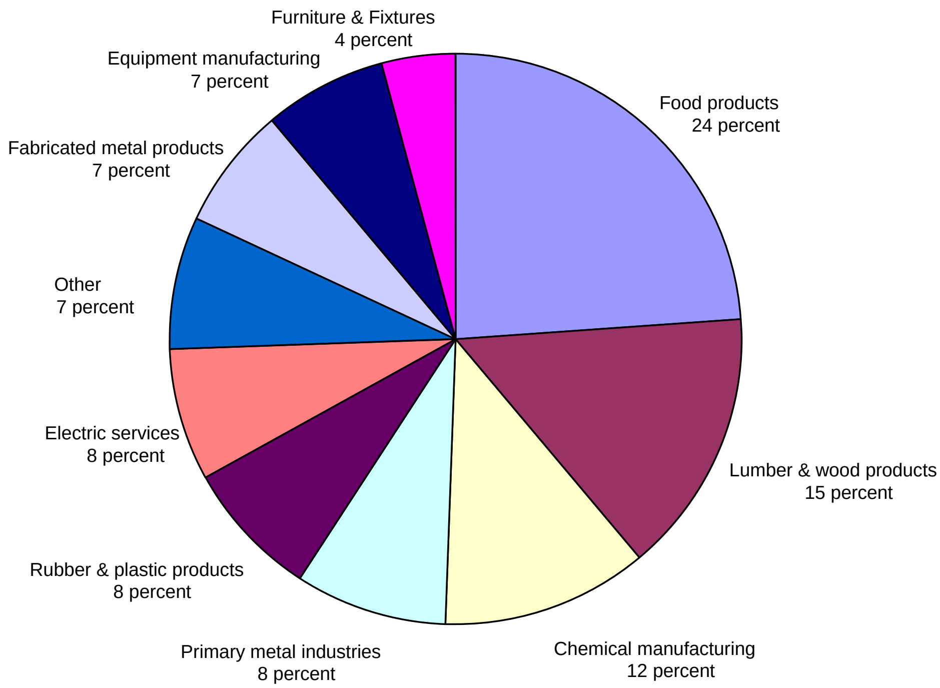

Figure 12. Distribution of combustible dust incidents by industry

5.2.6 Types of Dust Involved in Explosions

A wide range of materials cause combustible dust incidents (Figure 13). Wood, food-related products, and metals each account for over 20 percent of explosions, and plastics for 14 percent.

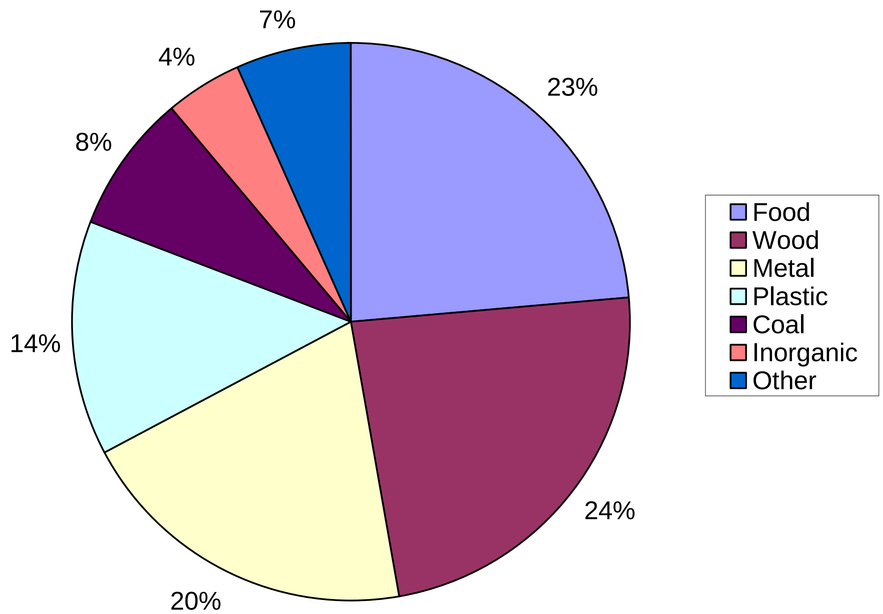

Figure 13. Distribution of combustible dust incidents by material

5.3 Data Limitations

The combustible dust incidents the CSB lists in Appendix A from 1980 to 2005 are likely only a small sampling, as no federal or state agency keeps specific statistics on combustible dust incidents, nor does any single data source provide a comprehensive collection of all these incidents.

Information about small combustible dust incidents and near-misses is also generally unavailable. For instance, because incidents that cause no fatalities, significant injuries, or major fires may not be recorded in the OSHA and fire incident databases, the true extent of the problem is likely understated. Due to these limitations, the CSB does not represent the incident data as complete or error-free, and other compilations of dust explosion data are available. The books included in the References of this report, Center for

Chemical Process Safety (CCPS, 2005) and Eckhoff (2003), contain useful data complilations of dust explosion incidents.

6.0 Hazard Communication and Preventing Dust Explosions

To properly manage workplace hazards, managers and employees need to be aware of the hazards and the necessary actions to eliminate or control them. OSHA's Hazard Communication Standard[24] (HCS) requires that chemical manufacturers determine the hazards of their chemical products, and that employers inform employees of the hazards and identities of workplace chemicals they are exposed to through training, labeling, and providing MSDSs. This chapter examines the coverage of combustible dust explosion hazards under OSHA's HCS and the effectiveness of MSDSs as a way to communicate information about preventing dust explosions. The chapter also evaluates the ANSI and the *Globally Harmonized System of Classification and Labeling of Chemicals* (GHS) guidance for using MSDSs to describe and explain the explosion potential of combustible dusts and prevention of dust explosions.

6.1.1 OSHA's HCS

The purpose of OSHA's HCS is to ensure that chemical hazard information is provided to users of hazardous chemicals so that they can better manage potential risks. MSDSs are the chief mechanism mandated by this standard to convey hazard information from chemical manufacturers and importers to users, and from employers to employees who may be exposed.

Employers must have an MSDS in the workplace for each hazardous chemical used. The MSDS must be readily available to employees who may be exposed, and the employer must communicate hazards described in the MSDSs through labeling and training.

[24] 29 CFR 1910.1200

6.2 MSDS Weaknesses in Addressing the Explosion Potential of Combustible Dusts

6.2.1 MSDS Problems Observed in the CSB Investigations

During two of the three CSB dust explosion investigations discussed (West and CTA), the CSB found that the MSDSs of the materials involved in the explosions did not clearly warn of the dust explosion hazards or adequately convey information to help prevent such explosions. Partly due to the absence of this information in the MSDSs, employees in these facilities—and to some extent management—were unaware that the materials could explode violently under certain conditions.

For example, the MSDS for the aqueous polyethylene slurry used at West listed no combustible dust hazards. In this case, the polyethylene powder in the slurry formed combustible dust when it dried, which then settled above a suspended ceiling where it became the fuel for a catastrophic explosion.

Likewise, the CSB found that the Borden MSDS for the phenolic resin that exploded at CTA did not provide adequate warning of the explosion hazard. In addition, specific hazard information in different sections of these MSDSs was incomplete and inconsistent. While the phenolic resin MSDS did state that the resins were combustible dusts and referenced NFPA 654 (*Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*), no specific safety warnings were listed and information was inconsistent with guidance in NFPA 654. For example, the Borden MSDS for the resin used at CTA recommended that employees “sweep (scoop) up and remove” accidental dust releases, while NFPA 654 advises against dry-sweeping to avoid generating airborne dust clouds.

Borden, which also manufactured the similar phenolic resin involved in the 1999 Jahn Foundry explosion, did not explicitly communicate to other users of phenolic resins the safety lessons learned from that explosion or adequately include such warnings in the phenolic resin MSDSs.

Borden was not the only company that issued an incomplete or inconsistent MSDSs: a survey of seven other phenolic resin MSDSs conducted as part of the CTA investigation showed that only two include clear dust explosion warnings.

6.2.2 The CSB Review of Combustible Dust MSDSs

As a result of the CSB's findings that MSDSs inadequately communicated the dust explosion hazard of the chemicals that exploded at West and CTA, the CSB conducted a review to explore whether the weaknesses in these MSDSs were also common in the MSDSs of other combustible dusts.

The CSB reviewed the MSDSs of 140 known combustible dusts or powders to evaluate how effectively they communicated the explosion potential. Although 59 percent included some language referring to the explosive nature of the dust, most of that information was not specific or placed in the best location for employee use.

Only seven of the 140 MSDSs referenced the applicable NFPA standard for managing dust hazards; however, the nature and placement of combustibility warnings did not clearly emphasize the explosion potential of these materials. Of the 83 MSDSs that did include some form of dust hazard warning, only 10 percent addressed the combustibility and explosion potential in the "Hazard Identification" section, where chemical users would be most likely to look to find critical hazard information.

None of the MSDSs listed the physical properties necessary to determine the explosion potential of the material, such as K_{St}, MIE, or MEC.[25] Finally, the MSDSs that recommended avoiding dust accumulations failed to explain that the reason is to minimize the potential for catastrophic secondary explosions. Appendix B contains a complete discussion of the MSDS analysis.

[25] These properties can vary depending on particle size, contamination, moisture content, and other specific conditions. However, data could be given for a representative sample of the as-shipped product, thus providing the MSDS reader with data relative to other substances.

6.2.3 Dust Explosion Hazards Arising Through Processing and Handling

The CSB also found that most of the MSDSs do not identify combustible dust explosion hazards that could be reasonably anticipated to develop through material processing or handling, evaporation of water or another solvent, or other factors that could result in generating a dusty product. Many solid or bulk materials may not be explosive, but may generate combustible dusts through handling or processing. For example, plastic pellets shipped from a polyethylene plant rarely pose an explosion hazard until they are handled and generate small particles as part of a different process, thus producing dust particles with explosion potential.

Similarly, aqueous solutions of a combustible material may dry to produce a combustible dust. Because the polyethylene slurry used at West was not considered hazardous as a liquid or paste, the manufacturer included no dust explosion hazard warnings on the MSDS, even though the manufacturer was aware that the slurry would dry to a powder during its intended use.

Omitting information about the potential creation of a dust explosion hazard is inconsistent with OSHA's HCS compliance directive,[26] which states that chemical manufacturers "must consider the potential exposures that may occur when purchasers use the product, and address the hazards that may result from that use on the label and MSDS prepared for the product."

The same compliance directive also states that employers must train employees "regarding the hazards of all chemicals in their work areas including by-products." Furthermore, an OSHA document that interprets the HCS states that chemical manufacturers must "assess the hazards associated with the chemicals, including hazards related to any anticipated or known use which may result in worker exposure."

[26] Hazard communication inspection procedures directive CPL 2-2.38 Paragraph (d)(1)(a).

6.2.4 Discussion

The CSB found that MSDSs for combustible dusts do not consistently or clearly communicate dust explosion hazards to product users as OSHA's HCS intends. MSDSs are valuable tools to inform employers and employees of potential hazards of the materials they are exposed to, including the potential for dust explosions, and the OSHA HCS has designated MSDSs as the primary method to convey hazard information. As such, MSDSs would be expected to clearly communicate dust explosion hazards to product users, list the physical properties so the explosion potential can be determined, and identify hazards that can reasonably be expected to develop through material handling or processing.

6.3 Coverage of Combustible Dust Under the OSHA HCS

The OSHA HCS states that all chemicals that present physical or health hazards must have an MSDS included in the company's hazard communication program. The HCS defines a "physical hazard" as:

> "a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive."

The HCS does not, however, explicitly mention combustible dusts, although the Preamble to the final HCS rule, OSHA interpretations, and guidance documents related to the HCS state that wood dust and grain dust are considered hazardous chemicals covered by the HCS, and that the HCS applies to downstream by-products. In addition, OSHA's recently released Safety and Health Information Bulletin (SHIB), *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions*, states that "[e]mployers with hazardous chemicals (including combustible dusts) in their workplaces are required to comply with 29 CFR 1910.1200, the Hazard Communication Standard." The HCS does not mention combustible dusts, and many manufacturers, employers, and employees may be unaware of the existence and significance of the clarifying interpretations and guidance documents or may not have access to them.

6.3.1 Discussion

OSHA's HCS does not state, in clear language, that combustible dust explosions are among the physical hazards that must be addressed in an MSDS and communicated to employees. Futhermore, many companies that produce or use combustible dusts may be unaware that information concerning the combustibility and explosion potential of a dust is required to be included in an MSDS, or that employees need to be trained about combustible dust hazards. The failure of the HCS to clearly address combustible dusts is a significant element in the failure of MSDSs to alert product users to the dust explosion hazard.

6.4 Coverage of Combustible Dust Hazards Under ANSI Z400.1–A Voluntary Consensus Standard

While the OSHA HCS lists the types of information that must be included in an MSDS, it does not specify a format. In response, OSHA and the Chemical Manufacturers Association[27] asked ANSI in 1993 to develop guidance for communicating chemical hazards,[28] which led to the development of ANSI Z400.1, *American National Standard for Hazardous Industrial Chemicals - Material Safety Data Sheets,*[29] a voluntary consensus standard that provides a format for reporting and organizing MSDSs.

However, like the OSHA HCS, the ANSI standard does not explicitly address combustible dusts, define combustible dust, or describe the need to address the potential explosion hazards associated with combustible dusts.

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[27] This organization is now the American Chemistry Council.

[28] Gullickson (1996) *American National Standard for Hazardous Industrial Chemicals- Material Safety Data Sheets.*

[29] ANSI (1993).

And while the ANSI standard lists specific properties that should be included for flammables (e.g., flash point), it provides no specific guidance on the need to include equivalent information on physical properties (such as $K_{St,}$, MIE, and MEC) in MSDSs for combustible dusts. One panelist, representing a large manufacturing firm, stressed at the CSB's public hearing (June 22, 2005) the need for producers of potentially combustible dusts to develop dust explosion hazard data and ensure that it is included in the MSDS:

> "Including these and other fire, explosion, and reactivity data on MSDS would promote a better understanding of the hazards posed by a substance, facilitate process hazards analysis for PSM [Process Safety Management] and RMP [Risk Managment Plan][30] compliance, enable companies to design more effective and comprehensive programs for protecting workers from those hazards, enable workers to better understand the hazards posed by the substances and articles they handle, and provide workers with the information they need to protect themselves and meaningfully participate in workplace safety programs."[31]

In 2003, the ANSI committee that most recently revised ANSI Z400.1 asked the CSB to review the draft document. The CSB commented then that the standard inadequately addressed combustible dust hazards; however, the committee declined to address this issue in that revision of the standard.

[30] Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119 and Environmental Protection Agency Risk Management Plan Rule 40 CFR 68.

[31] James Mulligan, representing Lockheed Martin.

6.5 *Globally Harmonized System of Classification and Labeling Chemicals (GHS)*

Chemical manufacturers sell chemicals in many countries that may have different requirements for conveying safety information through MSDSs, labels, and other means. The United Nations Economic Commission for Europe (UNECE), whose representatives came from many member countries, led an effort to develop a Globally Harmonized System (GHS) to address uniform chemical hazard communication.

In 2003, UNECE published the GHS, and many countries are now adopting this consensus approach. The U.S. participated actively in developing the GHS, and OSHA served as the official U.S. representative to the UNECE subcommittee that led its development. Although OSHA has not officially adopted the GHS, OSHA recently announced[32] that it is considering modifying its HCS to make it consistent with the GHS.

Because of the GHS' potential impact, the CSB examined how the GHS addresses the explosion hazards of combustible dusts. Unfortunately, the CSB found that the GHS, like the OSHA HCS and ANSI Z400.1, inadequately addresses the explosion potential of combustible dusts. For instance, combustible dusts are addressed in an annex, which states that if combustible dust hazards exist, they should be addressed; however, dust explosion hazards are not defined and no guidance on what information to include in an MSDS or on a label is provided.

6.6 Discussion: Improving Hazard Communication to Prevent Dust Explosions

In summary, the CSB found that MSDSs for combustible dusts generally fail to communicate the dust's explosion potential, information about managing the hazard, or references to widely accepted control

[32] Speech by Edwin J. Foulke, Jr., Assistant Secretary of Labor, to the American Industrial Hygiene Conference and Expo, May 17, 2006.

methods such as the NFPA standards. The CSB also found that guidance for developing MSDSs, currently available in the United States and internationally, fails to specify the need to include this important information. These weaknesses result in the hazards being insufficiently communicated to employers and employees.

The CSB therefore concluded that communicating combustible dust hazards to downstream businesses and employees would be significantly improved by revising OSHA's HCS (29 CFR 1910.1200), ANSI Z-400.1, and the GHS. These documents should be revised so that the explosion hazard of combustible dusts is clearly communicated and included in companies' hazard communication programs, and that the type and location of information about this hazard and how to prevent it are clearly specified and appear on MSDSs. OSHA is currently reviewing the HCS for possible amendments.[33]

[33]OSHA Advance Notice of Proposed Rulemaking, *Federal Register, 71 Fed. Reg. 71-53617-53627*, September 12, 2006.

7.0 The Role of Voluntary Consensus Standards and Fire Codes in Preventing Dust Explosions

Scientific and engineering experts, industry, labor, and regulatory bodies recognize that the NFPA voluntary consensus standards provide effective technical guidance to prevent industrial dust explosions. The NFPA standards[34] that address combustible dust explosion hazards provide the basis for the technical requirements of the two fire codes widely used in state fire systems across the United States: the NFPA's Uniform Fire Code (UFC) and the ICC's International Fire Code (IFC).

The first part of this chapter describes the NFPA standards pertaining to combustible dusts. Because state and local fire or building code systems are the only existing mechanisms with the potential to legally enforce the NFPA's recommended good practices, this chapter also describes the two fire code systems[35] and evaluates their potential to reduce risks of dust explosions in general industry. This chapter describes: how these standards have been legally adopted and enforced through state fire codes; the results of a CSB survey to evaluate the effectiveness of adopting and enforcing fire codes in different states; and the codes' impact on preventing combustible dust fires and explosions.

This chapter concludes with a discussion of fire code systems' ability to effectively address and reduce the risks of dust explosions in general industry nationwide.

7.1 NFPA Standards to Prevent and Control Dust Explosions

The NFPA's two principal voluntary consensus standards to prevent and control dust explosion risks are NFPA 654 (*Standard for the Prevention of Fire and Dust Explosions from the Manufacturing,*

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[34] Throughout this report the CSB uses the term *Standard* to refer to NFPA voluntary consensus standards, and *Code* to refer to legislation or other official adoption of consensus standards into enforceable law.

[35] A full discussion of the two fire codes is beyond the scope of this report because of the documents' complexity: they address many fire control topics beyond those related to dust explosion hazards.

Processing, and Handling of Combustible Particulate Solids–2006) and NFPA 484 (*Standard for Combustible Metals–2006)*. These standards, typically updated every five years, have long been recognized as the benchmarks for good engineering practice for handling most combustible dusts in general industry. NFPA 654, *Standard for the Prevention of Dust Explosions*, was issued in 1942, and the NFPA combustible dust standards have been regularly expanded and revised since. In addition to being incorporated into the NFPA Fire Code, the standards are used directly by many industry professionals (designers, engineers, health and safety experts, etc.) as guidance to prevent dust explosions.

7.1.1 NFPA 654

NFPA 654 applies to the manufacturing, processing, blending, conveying, repackaging, and handling of combustible particulate solids and their dusts. It covers all combustible dusts, except those specifically addressed in other NFPA standards, and is one of the most cited documents for control measures for combustible dust hazards (OSHA, 2005; CCPS, 2005).

NFPA 654 details the hazards of combustible dusts, specifies building construction requirements and the type of equipment to use in dust-handling operations. It addresses selection and design of protective systems by referencing other NFPA standards (Section 7.1.3). The standard also recommends that facilities implement management systems to prevent dust explosions, addressing:

- hazard evaluation,
- change management,
- maintenance and inspection,
- housekeeping, and
- procedures and training.

The CSB found that if the requirements of NFPA 654 had been applied at West and CTA, the incidents would have been prevented or significantly mitigated. Specifically, CTA and West had not implemented NFPA recommended practices, including analyzing their processes for hazards, controlling fugitive dust emissions and ignition sources, constructing buildings to address dust hazards, and training employees. NFPA 654 requires, for example, that “spaces inaccessible to housekeeping shall be sealed to prevent dust accumulation” and that “interior surfaces where dust accumulations can occur shall be sealed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations.” However, at West dust that accumulated above a suspended ceiling was difficult to detect and remove.

Similarly, the CSB investigation revealed that the CTA facility did not conform to NFPA 654, which requires that facilities minimize horizontal surfaces where dust can accumulate, equip buildings with explosion venting, and clean surfaces “in a manner that minimizes the generation of dust clouds.”

7.1.2 NFPA 484

NFPA 484 applies to fine particles of metals, including aluminum, magnesium, and others, and is distinct from NFPA 654 because the nature of metallic dusts makes them exceptionally vulnerable to ignition. Once ignited, metal dusts release large amounts of energy; therefore, some of the protective systems required by NFPA 654 would be inappropriate for metal dust hazards.

NFPA 484 provides detailed information about equipment design and explosion protection systems, and required management systems to address combustible dust hazards, and discusses appropriate testing to determine if a dust explosion hazard exists.

The CSB found that the consequences of the Hayes Lemmerz incident could have had less severe if NFPA 484 been applied, especially in terms of location, design, maintenance, and explosion protection for dust collectors, all factors in the Hayes incident (Figure 14).

Figure 14. Hayes Lemmerz did not follow NFPA 484 guidance on locating and maintaining the dust collector, which exploded on October 29, 2003.

7.1.3 Other NFPA Combustible Dust Standards

Several other NFPA standards address facilities that produce or handle specific combustible dusts or other factors related to dust explosions (Table 4). These standards are typically cross-referenced when relevant issues overlap, and are incorporated into the NFPA's UFC.

Table 4. Other NFPA Standards related to combustible dust explosion hazards

Standard	Title	Coverage or Purpose
NFPA 61	*Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities* – 2002.	Applies to facilities that receive, dry, handle, process, blend, use, mill, package, store, or ship bulk dry agricultural material; their products or dusts; or facilities that handle or manufacture starch, or facilities that handle and process oil seed.
NFPA 68	*Guidelines for Deflagration Venting* – 2002	Provides technical guidance on designing, sizing, installing, and maintaining deflagration vents.
NFPA 69	*Standard on Explosion Prevention Systems* – 2002	Addresses the design of explosion prevention, protection, and mitigation systems.
NFPA 70	*The National Electric Code®* – 2005	Addresses electrical equipment and wiring requirements for special situations, including those in which an explosive atmosphere may exist. Defines combustible dust classified locations.
NFPA 499	*Recommended Practice for the Classification of Combustible Dusts and Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas* – 2004	Provides guidance for classifying dust processing locations for electrical equipment installation.
NFPA 655	*Standard for the Prevention of Sulfur Fires and Explosions – 2001*	Discusses facilities that handle, grind, process, pulverize, or crush elemental sulfur.
NFPA 664	*Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* – 2002	Discusses facilities that process or manufacture wood and wood products, or that create wood dust and particles.

7.2 State Fire Codes

Fire codes are comprehensive regulations for fire prevention and control, and include a broad range of requirements to prevent and control fires and explosions in occupied buildings, industrial facilities, and other structures. States and many smaller jurisdictions typically adopt one of the two main national fire codes: the UFC, published by the NFPA; or the IFC, published by the ICC. State fire code coverage is roughly evenly divided between the two codes, although some states have not adopted any statewide fire code.

The states have mainly focused fire code enforcement has been fire hazards in occupied structures such as schools, hospitals, and office buildings, but not in industrial facilities, and not on dust explosion control requirements, which are only a small portion of the broader code requirements.

7.2.1 The NFPA UFC

The NFPA's UFC explicitly incorporates the requirements of many of its relevant combustible dust standards, including NFPA 654, NFPA 484, and other standards pertaining to dust explosion prevention.

7.2.2 ICC Fire Code

Chapter 13 of the IFC covers combustible dust hazards. This one-page chapter provides brief performance requirements addressing the prohibition of ignition sources where combustible dust is generated, stored, manufactured, processed, or handled, and advises that combustible dust accumulations be minimized and not collected by any means that will put combustible dust into the air.

IFC Chapter 13 also incorporates by reference NFPA dust standards. Instead of mandating compliance with the referenced NFPA standards, the IFC "authorizes" the "code official" (the government authority having jurisdiction) to enforce "applicable provisions" of the NFPA standards.

While IFC Chapter 13's reference to the NFPA standards indicates that fire code officials should enforce NFPA 654 and 484, the enforcement process is often indirect. Some states, like Indiana, enforce standards referenced by the IFC only if they are separately adopted through a formal process. Indiana formally adopted the 1998 editions of NFPA 654 and NFPA 651 (the old aluminum dust standard, which has since been merged with other metal dust standards into NFPA 484), making them legally enforceable by local fire code inspectors as part of IFC Chapter 13. However, updates of the NFPA standards are not enforceable in Indiana until the state formally adopts them.

In addition, the CSB found that references to other codes may be unclear to fire code officials. In North Carolina, for example, many local code officials familiar with IFC Chapter 13 were unaware of the IFC's reference to the NFPA codes. Furthermore, the NFPA codes referenced in Chapter 13 were not covered in the state's training curriculum.

7.3 Effectiveness of State Fire Code Systems in Controlling Combustible Dust Explosion Hazards

Theoretically, state and local fire codes provide a potential mechanism to control industrial dust explosion hazards by mandating the good industry practices of the NFPA combustible dust standards. The codes' usefulness depends, however, on factors such as the effectiveness of enforcement mechanisms and resources available for enforcement, including the availability and skills of enforcement personnel.

Likewise, conforming with the NFPA dust standards is widely recognized as effective in preventing combustible dust explosions, and would likely have prevented or reduced the consequences of the three explosions the CSB investigated (West, CTA, and Hayes). Local fire inspectors had inspected Hayes and West prior to the dust explosions; however, neither they nor state officials detected the hazards. None of the inspections identified the combustible dust hazards, even though the dust accumulations were obvious at Hayes, and West had a suspended ceiling in a potentially dusty area, which the NFPA 654 standard recommends against.

The CSB also found very limited inspection resources for industrial facilities and inadequate training for inspectors about dust explosion hazards. These findings raised serious questions about the effectiveness of the fire code systems in North Carolina, Indiana, and Kentucky, where the explosions occurred.

To develop a more comprehensive national picture of these issues, the CSB surveyed the fire code programs in nine states in addition to North Carolina, Kentucky, and Indiana. The states (California, Iowa, Illinois, Maryland, Michigan, Minnesota, Ohio, Pennsylvania and Texas) were selected from among the 15 with the largest number of reported dust explosion incidents in the last two decades. The survey's goal was to better understand the effectiveness of the adoption and enforcement of fire codes in different states, and the fire codes' impact on preventing combustible dust fires and explosions. The following sections summarize the survey's findings.

7.3.1 Code Adoption

In its survey, the CSB found that code adoption varies across states and smaller jurisdictions. Texas and Michigan have no statewide fire prevention codes, although some local jurisdictions have adopted their own. In some states, local jurisdictions may make enforcement and adoption decisions independently from the code the state adopts. For example, a local jurisdiction in Maryland can adopt more stringent requirements than the state-adopted NFPA 1; Baltimore City adopted the IFC in lieu of the state-adopted fire code. In addition,

7.3.2 Code Enforcement

The CSB found little enforcement of fire codes in industrial facilities. In fact, of the surveyed states, only two, Ohio and Pennsylvania, have programs to inspect industrial facilities, either for initial permitting or for ongoing fire code compliance; most states inspect industrial facilities only after a complaint or a fire.

In addition, most jurisdictions focus on life-safety issues; as such, most enforcement resources of local code authorities are dedicated to means of egress, fire extinguishers, etc. in schools, hotels, nursing homes, hospitals, night clubs, and other such facilities, as opposed to industrial fire and explosion hazards including combustible dust hazards or hazardous materials' use and storage. Another problem is that inspections are often conducted by local fire departments, whose members likely have limited knowledge of industrial processes and hazards.

Therefore, even where state and local fire codes make the NFPA combustible dust standards enforceable as law, the states the CSB surveyed were not actively enforcing them. Industrial facilities are generally not being inspected by fire code officials, and when inspected, the fire code officials generally lack the focus on industrial facilities and the knowledge to detect and address dust explosion hazards.

7.3.3 Permits

The IFC requires that a government authority issue an operating permit to facilities that use or generate combustible dust. An ICC representative[36] stated in CSB's Combustible Dust Public Hearing (June 22, 2005) that permits are important to inform building and fire officials of potentially hazardous operations in a facility, yet most states do not require permits for operations that involve combustible dusts.

The CSB investigations found that although North Carolina and Indiana had adopted the IFC, both had excluded the IFC's requirement that facilities using combustible dust obtain permits from local fire authorities. As a result of the 2003 West Pharmaceutical explosion, North Carolina changed its law to mandate permits for combustible dust operations to ensure that local fire code officials are aware of dust explosion hazards in facilities within their jurisdictions.[37] Ohio and Pennsylvania are the only two states of the nine surveyed that indicated that they require permits for industrial buildings involving combustible dust.

[36] David Conover, representing the ICC.

[37] Chris Noles, representing the North Carolina Office of State Fire Marshal, CSB's Combustible Dust Public Hearing.

7.3.4 Training

The CSB found that training programs for fire inspectors do not generally cover combustible dust hazards. Eight states in the survey do not specifically address combustible dust hazards in inspector training programs. Texas is the lone exception: their inspectors are required to demonstrate knowledge of combustible dust hazard prevention. In response to the CSB recommendations, Kentucky and North Carolina are now training fire inspectors about dust explosions.

The U.S. Fire Academy (the Academy), a branch of the United States Fire Administration, provides extensive training for fire service personnel in state, county, municipal, and volunteer positions. The Academy curriculum includes training on fire prevention methods and permit inspections, but does not specifically address combustible dust hazards.

Although some jurisdictions have begun to address dust explosion hazards in fire inspector training, the CSB survey showed that many fire officials have no ready access to the training needed to recognize and address dust explosion hazards.

7.4 Miscellaneous Efforts to Address Dust Control Hazards

The CSB also examined efforts by professional organizations, trade groups, and others to address the explosion hazards of combustible dust. Given the wide diversity of industries and processes that may be a risk, however, no industry associations could adequately address more than a small number of those at risk. A few of the more significant programs are described below.

The Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AIChE) published a comprehensive technical book, *Guidelines for Safe Handling of Powders and Bulk*

Solid[38] [39]. CCPS and other professional organizations, including the American Society of Safety Engineers (ASSE): the Society of Fire Protection Engineers (SFPE); and the Safety and Chemical Engineering Education Program (SACHE), offer education and seminars about dust hazards.

Through safety professionals and other sources, investigators learned that most of the major pharmaceutical companies have aggressive dust control programs. Representatives of the industry shared some typical programs with the CSB, but agreed that the high attention paid to dust hazards is also motivated by the high cost and toxicity of primary drug ingredients. Furthermore, the industry has not developed a concerted outreach program to promote dust explosion prevention among smaller companies and generic drug manufacturers.

The Aluminum Association (AA) provides training and literature to promote the awareness of aluminum dust explosion hazards and suggests methods to eliminate or reduce risk of explosions.

One industrial insurance company, FM Global, has developed guidance and training on preventing and mitigating dust explosions.[40] FM Global publishes the *Property Loss Prevention Data Sheet 7-76, Prevention and Mitigation of Combustible Dust Explosions and Fires–2005*, which presents design information, directed at loss-prevention engineers, for controlling combustible dust hazards.

7.5 Discussion

The NFPA voluntary consensus standards are widely recognized to provide effective technical guidance to prevent dust explosions in industry; however, adopting and enforcing them by individual states in their

[38] CCPS (2005).

[39] Berger statement before CSB hearing (June 22, 2005).

[40] The CSB found that West, CTA, and Hayes were all regularly inspected prior to the explosions by their respective risk insurance providers. However, none resulted in the facility being made aware of the risk of dust explosions, and the inspection reports contained no recommendations or guidance for preventing dust explosions.

fire codes is quite fragmented. As a fire code expert at the CSB's Combustible Dust Public Hearing (June 22, 2005) said, "[t]here's a patchwork of enforcement, because each state makes its own decision about how it's [the standard] to be enforced."[41]

The evidence from the CSB investigations in North Carolina, Kentucky, and Indiana, combined with a survey of nine additional states, found that state fire code systems fail to comprehensively address the problem of industrial dust explosions in general industry at the national level.

The CSB learned that the fire code system is decentralized, and that code adoption varies across states and even across smaller jurisdictions, such as counties and cities. Some states have adopted no fire codes, and some adopt only portions of the existing voluntary fire standards or allow smaller jurisdictions to modify the fire codes, often weakening them.

Finally, enforcement in industrial facilities is inconsistent, and fire inspectors are typically inadequately trained to recognize dust explosion hazards. Although the IFC references the NFPA codes, not all states are able to enforce standards referenced in the adopted code without additional legislative or regulatory action. Unlike OSHA regulations, which set national standards and require those states that run their own programs to establish standards and enforcement that are "at least as effective" as federal standards, no federal legislative authority or agency is empowered to mandate a harmonization of all state fire codes or their enforcement.

[41] George Miller, representing the National Association of State Fire Marshals.

8.0 OSHA Regulation of Dust Hazards

The Occupational Safety and Health Act (the OSH Act) authorizes OSHA to issue mandatory standards as a means to "assure safe and healthful working conditions for working men and women." The OSHA standards apply to covered workers in every state, although the 21 states with state plans may issue different standards that are "at least as effective as" federal standards.

While combustible dusts present a serious explosion hazard in American industry, no comprehensive general industry OSHA standards exist to address these hazards. OSHA's Grain Handling Facilities Standard, issued in 1987, addresses only the hazards of combustible grain dust in specific types of facilities, and several other OSHA standards partially address different limited aspects of the combustible dust problem.

8.1 OSHA Adoption of NFPA Dust Standards

When it passed the OSH Act in 1970, Congress stipulated that OSHA should adopt appropriate consensus and technical standards and codes into OSHA's safety and health regulations. OSHA did adopt many NFPA standards, including NFPA 30 (for flammable and combustible liquids); NFPA 62 (for dust explosions in sugar and cocoa facilities); NFPA 70 (the National Electric Code); and NFPA 656 (an older standard that addressed ignition sources in spice-grinding operations), but did not adopt NFPA 654 and NFPA 651 (for dust explosions…plastics and aluminum), even though both existed at the time of the OSH Act.

Federal policy still encourages agencies to adopt appropriate consensus standards. In 1995, Congress enacted Public Law 104-111, the "National Technology Transfer and Advancement Act" in its Section 12(b)(1), which explicitly encourages that:

> "All Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments."

8.2 Grain Handling Facilities Standard

In 1987, OSHA issued the Grain Handling Facilities Standard due to the "significant risk of job-related injury or death caused by the inadequate rate of private hazard-abatement expenditure in grain handling facilities." The standard applies to grain elevators, feed mills, flour mills, rice mills, dust pelletizing plants, dry corn mills, soybean flaking operations, and the dry grinding operations of soycake.

The Grain Handling Facilities Standard was issued as a result of a series of grain dust explosions in the late 1970s and early 1980s. During one period in December 1977, five grain elevator explosions killed 59 and injured 49 workers.

OSHA initially tackled the grain dust explosion problem by disseminating information on dust explosion hazards in facilities handling agricultural products, including a 1977 OSHA Alert, which followed two rounds of Congressional hearings and federally sponsored studies by the National Academy of Sciences (NAS)[42] and the General Accounting Office (GAO).[43] Although dust explosions initially fell following the alert, they increased again in 1980 and 1981.[44]

In justifying its conclusion that the Grain Handling Facilities Standard was needed, OSHA stated in the Preamble:

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[42] NAS (1982).

[43] GAO (1979).

[44] Kauffman, C. William, "Recent Dust Explosion Experiences in the U.S. Grain Industry," *Industrial Dust Explosions*, ASTM STP 958, Kenneth L. Cashdollar and Martin Hertzbert, Eds., American Society for Testing and Materials, Philadelphia, 1987, pp. 243-264.

> "Private markets fail to provide enough safety and health resource due to the lack of risk information, the immobility of labor and the externalization of some of the social costs of worker injuries and deaths. Workers comp systems do not offer an adequate remedy because the premiums do not reflect specific workplace risk, and tort liability claims are restricted by state statutes preventing employees from suing their employers. While certain voluntary and environmental standards exist, their scope and approach fail to provide adequate worker protection for all workers. Thus OSHA has determined that a federal standard is necessary, and that its provisions will enhance competitive market forces by internalizing the societal costs of workplace accidents."

When OSHA reviewed the Grain Handling Facilities Standard[45] in 2003, it found that since the standard had been instituted, grain explosions were down 42 percent, injuries 60 percent, and fatalities from grain explosions 60 percent. On average, OSHA estimates that the Grain Handling Facilities Standard has prevented five deaths per year. The National Grain and Feed Association (NGFA) stated[46] that its industry had experienced "an unprecedented decline in explosions, injuries and fatalities at grain handling facilities" since 1980. Further, the NGFA credited the standard with stimulating technological advances in the design, layout, and construction of grain handling facilities.

8.3 OSHA Enforcement of Combustible Dust Hazards

8.3.1 The GDC

When no OSHA standard addresses a specific hazard, OSHA may use paragraph 5(a)(1) of the OSH Act (also known as the General Duty Clause, or GDC) to cite an employer. The GDC states,

> "Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees."

[45] OSHA 2003.

[46] Statement of the NGFA at the OSHA Public Meeting to Review the Grain Handling Facilities Standard (29 CFR 1910.272) Chicago, Illinois; July 28, 1998; p. 2 (OSHA Docket No. H-117C, Ex. 4).

The GDC is the only regulatory tool OSHA can use to require adherence to the NFPA standards applicable to combustible dust; however, several requirements must be met to justify a GDC citation:

- A condition or activity in the employer's workplace presents a hazard to employees.
- The employer or the employer's industry recognizes the hazard.
- The hazard is likely to cause death or serious physical harm.
- The hazard can feasibly be eliminated or materially reduced.

In addition to direct evidence that an employer knew about a specific hazard, recognizing a hazard is also defined by OSHA as industry recognition, which may be demonstrated by a consensus standard, such as an NFPA standard. Such standards may also be used to identify feasible ways to reduce the hazard.

OSHA has used the GDC to cite violations of recognized combustible dust hazards in 207 inspections since 1980;[47] most of the violations cited relevant NFPA combustible dust standards. Enforcement under the GDC, however, is largely reactive: GDC citations are often issued in response to an accident, complaint, or referral from some other enforcement agency.

8.3.2 Other OSHA Standards That Address Dust Explosion Hazards

Other OSHA standards, described below, partially address some of the preventive actions relevant to dust explosions; however, these apply only to specific industries or are limited in scope. The references to dust hazards contained in the miscellaneous standards do not address design, maintenance, hazard review, explosion protection, and numerous other considerations for preventing and mitigating dust fires and explosions addressed in the NFPA consensus standards.

[47] OSHA IMIS Inspection Data.

8.3.3 Special Industry Standards

In addition to the Grain Handling Facilities Standard, OSHA has regulations that address safety and health issues, including limited aspects of combustible dust hazards, in bakeries and sawmills.

The Bakery Equipment Standard (29 CFR 1910.263) specifically and prescriptively addresses personnel safety protections required on bakery equipment, and focuses only on explosions with respect to bakery ovens.

The Sawmills Standard (29 CFR 1910.265) prescribes explosion protection and design considerations for saw dust ducts and collection equipment. However, it does not apply to furniture factories or other industries where wood dust explosion hazards may also exist.

8.3.4 Housekeeping Standard

The OSHA Housekeeping Standard (CFR 1910.22) requires that “all places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition.” Although OSHA has used this standard to cite employers in dust explosion cases, the standard does not specifically address dust explosions, nor does it define or specifically tackle secondary dust explosions.

8.3.5 Electrical Standards

The OSHA Electrical Standards are based on NFPA 70 (NEC), and discuss possible ignition sources for a dust explosion. The NEC defines requirements for wiring, boxes, and other electrical components for each hazard class; however, it does not speak to the multitude of other possible dust explosion ignition sources or other prevention methods.

8.3.6 Materials' Handling and Storage Standards

The OSHA Powered Industrial Trucks Standard (29 CFR 1910.178) specifies the types of these vehicles permitted where combustible dusts are present. The General Materials Handling Standard (29 CFR 1910.176) briefly mentions that storage areas "shall be kept free from accumulation of materials that constitute hazards from tripping, fire, explosion, or pest harborage," but does not clearly indicate that combustible dusts are included, and neither of these apply to manufacturing processes.

8.4 Special Emphasis Programs (SEP)

OSHA uses Special Emphasis Programs (SEP) to select and target inspections and outreach for industries where specific hazards may exist, and where these hazards are not adequately addressed by other enforcement programs. OSHA has used SEPs to promote safety while formal regulations were being developed, such as the Process Safety Management (29 CFR 1910.119) and Bloodborne Pathogens standards. SEPs also include outreach intended to raise employer awareness of the hazards the SEPs are designed to reduce or eliminate.

OSHA can institute SEPs nationally or regionally; however, it has not instituted national SEPs for combustible dust hazards in general industry.

8.4.1 OSHA Harrisburg Area Office Local Emphasis Program

Local Emphasis Programs (LEPs) are SEPs that address hazards that pose a particular risk to workers in a local jurisdiction. In 2003, OSHA's Harrisburg Area[48] office launched a LEP focused on combustible dust hazards in response to three dust explosions in the area over a two year period. The LEP targeted industries in food processing, metal plating and plastics, and later, aluminum finishing.

[48] OSHA is organized into 10 geographic regions and 73 area offices. Harrisburg is one of 10 area offices in Region III, which includes Pennsylvania, Delaware, Virginia, Maryland, West Virginia, and the District of Columbia.

After receiving the communication about the LEP inspections, many of the targeted employers asked for OSHA's help in mitigating the dust explosion hazard. However, shortly after the LEP was launched, OSHA staff concluded that they lacked the required expertise and the program was temporarily suspended. Because the OSHA Training Institute (OTI) did not offer the necessary training, the OSHA staff received additional training from private sector experts. The outreach effort and subsequent inspections identified workplaces with serious combustible dust problems, and the Harrisburg area inspectors issued over 150 citations related to the LEP.

8.4.2 Discussion

SEPs are generally temporary efforts designed to address better compliance with existing standards or with existing voluntary guidance while a permanent standard is being developed. Once an emphasis programs ends, attention to the issue is likely to drop, particularly when no standard exists to rely on when the SEP expires.

Unlike an OSHA standard, which burdens employers with determining if they are covered by a standard, OSHA emphasis programs task OSHA with identifying affected industries and reaching out with educational materials and enforcement. Effective outreach in the area of combustible dust hazards is particularly difficult given the wide diversity of industries that may be a risk. The Harrisburg combustible dust LEP showed that while OSHA can do that outreach, it is very resource-intensive.

8.5 State OSHA Activities

The CSB evaluated states' OSHA plans ("state-plan states") to determine if any such state had regulations or programs to prevent combustible dust explosions.

California is the only state with its own combustible dust standard covering general industry. The California Division of Occupational Safety and Health (CalOSHA) standard requires proper housekeeping, electrical grounding, and that dust collectors be placed outdoors.

However, CalOSHA personnel told the CSB that enforcing this regulation is difficult because the standard defines dust explosion hazards in terms of a Lower Explosion Limit (LEL).[49] According to CalOSHA, the courts have also made enforcement following an explosion difficult because the particle size in the samples collected from settled dust after an explosion are generally larger and heavier than the airborne dust that may have caused the explosion.

North Carolina's OSHA (NCOSHA) and KYOSHA have initiated outreach and enforcement programs in response to the CSB recommendations from the West and CTA investigations, respectively. The NCOSHA published a two-page safety alert on combustible dust hazards,[50] which it sent to over 2,300 targeted facilities. The KYOSHA is targeting inspections in certain industries that involve dust explosion hazards, and is training inspectors to recognize dust explosion hazards during all KYOSHA inspections.

8.6 OSHA Inspector Training

The CSB evaluated training for OSHA compliance officers in recognizing and addressing combustible dust hazards, and found that OSHA's training programs do not address combustible dust hazards. OSHA compliance officers are trained through area and regional programs and by the OSHA Training Institute (OTI). The OTI curriculum includes a four-day seminar on safety and health for grain handling operations, but no other course focuses on combustible dust hazards.

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[49] This is the term the California regulation uses, although the more appropriate measurement for combustible dusts is minimum explosive concentration (MEC.)

[50] http://www.dol.state.nc.us/osha/etta/CombDust.pdf.

In evaluating the Harrisburg, Pennsylvania, combustible dust LEP, the Area Office Director recommended that the OTI "develop a training course which addresses the specific hazards and control methods of explosive dusts in general industry applications (not just grain elevators)."

The lack of training in recognizing and addressing combustible dust hazards for OSHA inspectors leaves them not well positioned to address such hazards in the course of their general industry inspections.

8.7 OSHA Safety and Health Information Bulletin

OSHA's only outreach activity in the area of combustible dusts has been a July 2005 federal OSHA-produced Safety and Health Information Bulletin (SHIB), *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions*. The SHIB contains information and resources to help at-risk facility managers and workers identify the hazard in their workplace, and directs them to applicable NFPA standards and other guidance documents.

Although the SHIB is available on OSHA's website,[51] OSHA has not developed an outreach program to inform at-risk companies of potential risks and the information in the combustible dust SHIB. For instance, OSHA's web page, "Safety and Health Topics," includes an alphabetical index of over 150 topics, but "combustible dust explosions" is not among them.

8.8 Discussion

Despite the seriousness of the combustible dust problem in general industry, OSHA has no comprehensive standard to require employers in general industry to implement dust explosion prevention and mitigation. In fact, OSHA enforcement efforts are confined to using the GDC in addition to a patchwork of individual standards that address limited, specific aspects of the problem, and most

[51] http://www.osha.gov/dts/shib/shib073105.html.

enforcement comes after an incident has occurred. In contrast, OSHA's Grain Handling Facilities Standard provides a model for OSHA action that has proven effective in reducing catastrophic dust explosions in the grain industry.

OSHA has the authority to set national workplace safety standards and require those states that run their own programs to establish standards and enforcement that are "at least as effective" as federal standards. Also, OSHA has a solid technical basis from which to develop such standards: the NFPA dust control standards, which reflect the widely accepted consensus of scientific and engineering experts from industry, the fire community, and regulators on ways to prevent or minimize the risks and consequences of dust explosions. Fire codes are less effective, as no federal legislative authority or agency is empowered to mandate a harmonization of all state fire codes and their enforcement.

9.0 Conclusions

Dust explosions are a serious problem in American industry. During the past 25 years, at least 281 major combustible dust incidents were reported, that killed 119 and injured 718 workers, and destroyed many industrial facilities.

The CSB found that industry and safety professionals often lacked awareness of combustible dust hazards, as MSDSs ineffectively communicate to employers and workers the hazards of combustible dust explosions and ways to prevent them. For instance, neither the OSHA HCS nor the ANSI guidance for reporting and organizing information in an MSDS provide clear requirements or instructions for including and warning about combustible dust explosion hazards.

The CSB and other agencies investigating serious dust explosions found a number of common causal factors for dust incidents. First, the facilities failed to follow the widely recognized standards of good engineering practice in the NFPA's voluntary consensus standards. As a result, facilities did not implement appropriate engineering controls, adequate maintenance and housekeeping, and other measures that could have prevented the explosions. These standards have been available for over a half century, and are updated for new technical and scientific knowledge regularly.

In addition, most states adopt one of two national fire codes (the IFC or UFC), which incorporate, through NFPA consensus standards, principles and practices that can help prevent and mitigate combustible dust explosions. The technical guidance in the NFPA standards is widely considered to be effective, but because the U.S. fire code system allows states to adopt only parts of it and local jurisdictions to adopt codes different from the state's, implementing comprehensive changes or improvements to effectively to tackle the problem of dust explosions on a national scale is difficult. The CSB also found that even where the codes have been adopted, state and local fire authorities seldom inspect industrial facilities to ensure compliance, and fire inspectors are often inadequately trained to recognize dust explosion hazards. The CSB study concluded, therefore, that these fire code systems alone cannot serve as a viable mechanism to reduce dust explosion risks in general industry nationwide.

Finally, despite the seriousness of the combustible dust problem in industry, OSHA lacks a comprehensive standard to require employers in general industry to implement the dust explosion prevention and mitigation measures embodied in the widely accepted NFPA consensus fire standards. Although OSHA has cited employers for dust explosion hazards, most OSHA enforcement activities related to combustible dust hazards have been in response to incidents, rather than focusing on prevention. The only comprehensive OSHA standard that addresses combustible dust hazards—the 1987 Grain Handling Facilities Standard—has effectively reduced the risk and consequences of grain dust explosions, and incorporates many of the same principles that can be found in the NFPA standards.

The CSB concludes that OSHA should issue a comprehensive dust standard that applies to general industry. This comprehensive dust standard should rely on the consensus of technical approaches in such areas as hazard assessment, engineering controls, housekeeping, worker training, and others embodied in the NFPA standards. The CSB also recommends that OSHA amend the HCS, and that ANSI amend its guidance, ANSI Z400.1, to improve the quality of combustible dust information in MSDS.

10.0 Recommendations

Occupational Safety and Health Administration (OSHA)

1. 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
   - hazard assessment,
   - engineering controls,
   - housekeeping,
   - building design,
   - explosion protection,
   - operating procedures, and
   - worker training.

2. Revise the Hazard Communication Standard (HCS) (1910.1200) to:
   - Clarify that the HCS covers combustible dusts, including those materials that may reasonably be anticipated to generate combustible dusts through downstream processing or handling.
   - Require Material Safety Data Sheets (MSDSs) to include the hazards and physical properties of combustible dusts, as well as clear information on safe handling practices and references to relevant consensus standards.

3. Communicate to the United Nations Economic Commission for Europe (UNECE) the need to amend the Globally Harmonized System (GHS) to address combustible dust hazards by
   - defining combustible dusts,
   - specifying the hazards that must be addressed in chemical information sheets, and
   - addressing the physical properties that must be included on a chemical information sheet pertinent to combustible dusts.
4. Provide training through the OSHA Training Institute (OTI) on recognizing and preventing combustible dust explosions.
5. While a standard is being developed, identify manufacturing industries at risk and develop and implement a national Special Emphasis Program (SEP) on combustible dust hazards in general industry. Include in the SEP an outreach program focused on the information in the Safety and Health Information Bulletin (SHIB), *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions.*

American National Standards Institute Z400.1 Committee

Modify ANSI Z400.1 *American National Standard for Hazardous Industrial Chemicals--Material Safety Data Sheets* to recommend that MSDSs include information on:

- combustible dust hazards, safe handling practices, and references to relevant fire codes in MSDS;
- hazard information about the by-products of materials that may generate combustible dusts due to processing or handling;
- identification of combustible dust hazards and selection of physical properties to include in MSDS.

11.0 REFERENCES

American National Standards Institute (ANSI), 1993. *ANSI Z400.1, American National Standard for Hazardous Industrial Chemicals--Material Safety Data Sheets.*

Babrauskas, Vytenis, 2003. *Ignition Handbook*, Fire Science Publishers, Issaqua, WA.

Barton, J. A., and H. D. Seaton, 1986. "Preventing Dust Explosions—A Case History," *Chemistry in Britain*, July 1986.

Center for Chemical Process Safety (CCPS), 2005. *Guidelines for Safe handling of Powders and Bulk Solids,* AIChE/CCPS, New York, NY, 2005.

Crowl, Daniel A. *Understanding Explosions,* AIChE/CCPS, New York, NY, 2003.

The US Chemical Safety Board (CSB), 2004, *Investigation Report, Dust Explosion, West Pharmaceutical Services, Inc.*, U.S. Chemical Safety and Hazard Investigation Board (CSB), September 2004.

CSB, 2005. *Investigation Report*. Combustible Dust Fire and Explosions, CTA Acoustics, Inc., February 2005.

CSB, 2005. *Investigation Report*. Aluminum Dust Explosion, Hayes Lemmerz International-Huntington, Inc., September 2005.

Dastidar, Ashok Ghose, et. al., 2005. "Evaluation of Dust and Hybrid Mixture Explosion Potential in Process Plants," *Process Safety Progress.* Vol. 24, No. 4, December 2005.

Earley, J.M. et. al.,1999. *National Electric Code Handbook 1999*, 8th Ed., National Fire Protection Association.

Ebadat, Vahid, 2003. “Is Your Dust Collection System an Explosion Hazard?”*Chemical Engineering Progress*, October 2003.

Eckhoff, Rolff, 2003. *Dust Explosions in the Process Industries,* 3rd Ed. Gulf Professional Publishing, Houston, TX.

Eckhoff, Rolff, 2005. *Explosion Hazards in the Process Industries.* Gulf Professional Publishing, Burlington, MA.

Febo, Henry, 2004. “Combustible Dust Hazards and Loss Prevention,” presentation to the U.S. Chemical Safety and Hazard Investigation Board, January 20, 2004.

FM Global, 2001. “Property Loss Prevention Data Sheet 7-76: Prevention and Mitigation of Combustible Dust Explosions and Fire.” Factory Mutual Insurance Company, 2001.

GAO, 1979. U.S. General Accounting Office. “Grain Dust Explosions -- An Unsolved Problem,” HRD-79-1, March 21, 1979.

Goings, John E. and Jef Snoeys, 2002. “Explosion Protection with Metal Dust Fuels,” *Process Safety Progress*, Vol. 21, No. 4, December 2002.

Gullickson, Richard,1996. *Reference Data Sheet on Material Safety Data Sheets*, http://www.MSDSsearch.com/msdshistory.htm.

Kletz T., 1994. *Learning from Accidents*, 2nd Ed. Butterworth Heinemann.

Mniszewski, Kim et. al., 2004. "Power Loss. The 1999 Ford Power Plant Explosion: A Study of Problems Encountered During Large-Loss Fire Investigations," *NFPA Journal* July/August 2004.

National Academy of Sciences (NAS), 1982. "Report of the Panel on Causes and Prevention of Grain Elevator Explosions of the Committee on Evaluation of Industrial Hazards," National Materials Advisory Board, National Academy of Sciences, National Academy Press, Publication 367-2, Washington, DC, 1982.

Occupational Safety and Hazard Association (OSHA), 1998. Hazard Information Bulletin *Dust Explosion Hazard in Certain Textile Processes,* October 1998.

OSHA, 2000. Technical Information Bulletin, *Potential for Natural Gas and Coal Dust Explosions in Electrical Power Generating Facilities.* November 2000.

OSHA, 2002. *Region 4 Report on Explosion at Rouse Polymerics,* U.S. Department of Labor (USDOL).

OSHA, 2003. "Regulatory Review of OSHA's Grain Handling Standard [29 CFR 1910.272]," http://www.osha.gov/dcsp/compliance_assistance/lookback/grainhandlingfinalreport.html, February 2003.

OSHA, 2005. Safety and Health Information Bulletin, *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosion,* July 2005.

National Fire Protection Association (NFPA) 61, 2002. *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, 2002 Edition.* NFPA, Quincy, MA.

NFPA 68, 2002. *Guide for Venting of Deflagrations, 2002 Edition.* NFPA, Quincy, MA.

NFPA 69, 2002. *Standard on Explosion Prevention Systems, 2002 Edition.* NFPA, Quincy, MA.

NFPA 70, 2005. *The National Electric Code – 2005.* NFPA, Quincy, MA.

NFPA 484, 2002. *Standard for Combustible Metals, Metal Powders, and Metal Dusts, 2002 Edition.* NFPA, Quincy, MA.

NFPA 484, 2006. *Standard for Combustible Metals, 2006 Edition.* NFPA, Quincy, MA.

NFPA 499, 2004. *Recommended Practice for the Classification of Combustible Dusts and Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 2004 Edition.* NFPA, Quincy, MA.

NFPA 654, 2006. *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, 2006 Edition.* NFPA, Quincy, MA.

NFPA 654, 2000. *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, 2000 Edition.* NFPA, Quincy, MA

NFPA 655, 2001. *Standard for the Prevention of Sulfur Fires and Explosions, 2001 Edition.* NFPA, Quincy, MA.

NFPA 664, 2002. *Standard for the Prevention of Fires and Explosions in wood Processing and Woodworking Facilities, 2002 Edition.* NFPA, Quincy, MA.

National Advisory Committee on Occupational Safety and Health (NACOSH, 1996. "Report of the Hazard Communication Workgroup to the National Advisory Committee on Occupational Safety and Health." September 12, 1996.

Snoeys, Jef et al., 2004. "Modeling of Dust Explosions in Industrial Processes: Use of Explosion Simulations for Explosion Isolation Design," 2004 Loss Prevention Conference, paper 49d, American Institute of Chemical Engineers (AIChE).

U.S. Fire Administration (USFA). *Manufacturing Mill Fire (Methuen, MA – December 1995)*, Technical Report Series.

Ural, Erdem, 2005. "Dust Explosion Venting Through Ducts," 2005 Loss Prevention Conference, paper 91e, AIChE.

US Department of Labor (USDOL), 1999. "Joint Foundry Explosion Investigation Team Report, Jahn Foundry Corporation, Springfield, MA, February 25, 1999."

Wright, Michael, 2005. Representing the United Auto Workers et. al., transcript of statements at CSB public hearing on June 22, 2005.

Zalosh, Robert, 1999. "A Tale of Two Explosions." 1999 Loss Prevention Conference, AIChE.

Zalosh, Robert, Stanley Grossel, Russell Kahn, and Daniel Sliva, 2005. "Dust Explosion Scenarios and Case Histories in the CCPS Guidelines for Safe Handling of Powders and Bulk Solids," 39th AIChE.

Loss Prevention Symposium Session on Dust Explosions, Atlanta, April 2005.

APPENDIX A

COMBUSTIBLE DUST FIRE AND EXPLOSION INCIDENT DATA

Dust Incident Data Research

1.0 Data Sources

- OSHA Integrated Management Information System database
- The accident database from ICHEME
- Lexis/Nexus periodical search
- NFPA One Stop Data Shop fire incident data
- National Fire Incident Reporting System
- CCPS Loss prevention symposia case studies
- CCPS Guidelines
- Data provided by Dr. Robert Schoeff
- CSB Incident screening article collection
- *Industrial Fire World* incident listings

1.1 Incident Data Summary

The following summarizes key information on the combustible dust incidents identified by the CSB. The complete dataset is available at Dust Data File.

Table 5. Dust fire and explosion incidents, 1985 to 2005

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
1	1980	1/24/1980	IN	0	0	Food	Food products
2	1980	2/1/1980	MN	1	8	Food	Food products
3	1980	2/8/1980	IL	0	0	Food	Food products
4	1980	5/9/1980	OK	0	2	Food	Food products
5	1980	5/10/1980	NC	0	0	Food	Food products
6	1980	7/22/1980	FL	0	0	Food	Food products
7	1982	1/1/1982	NE	0	0	Inorganic	Chemical Manfact - Miscellaneous
8	1982	5/6/1982	MN	0	9	Plastic	Chem manufact - Industrial organic chemicals
9	1982	10/18/1982	IA	0	0	Food	Food products
10	1983	4/19/1983	WI	0	9	Wood	Furniture & fixtures
11	1983	5/1/1983	NC	0	0	Wood	Furniture & fixtures
12	1984	2/20/1984	KY	0	1	Food	Food products
13	1984	2/23/1984	OH	0	1	Inorganic	Chem manufact - Miscellaneous chemical products
14	1984	6/8/1984	IL	1	3	Food	Food products
15	1984	6/15/1984	OH	1	4	Coal	Electric Services
16	1984	6/19/1984	IA	1	1	Metal	Primary metal industries
17	1984	7/18/1984	CA	0	0	Coal	Stone, clay, glass, & concrete products
18	1984	7/23/1984	CO	1	2	Coal	Electric Services
19	1984	8/10/1984	WV	2	0	Coal	Primary metal industries
20	1984	8/31/1984	NH	0	1	Metal	Equipment manufacturer - industrial
21	1985	2/14/1985	OR	0	1	Wood	Lumber & wood products
22	1985	4/3/1985	IL	1	13	Inorganic	Packaging & storage
23	1985	6/4/1985	WY	0	3	Coal	Electric Services
24	1985	6/12/1985	IA	0	1	Food	Food products
25	1985	6/18/1985	NM	0	0	coal	Stone, clay, glass, & concrete products
26	1985	6/24/1985	VA	0	7	Wood	Furniture & fixtures
27	1985	8/2/1985	UT	0	0	Inorganic	Equipment manufacturer - industrial
28	1985	10/24/1985	GA	1	2	Plastic	Chem manufact - Industrial organic chemicals
29	1986	2/28/1986	WI	0	4	Wood	Food products
30	1986	6/18/1986	CA	0	4	Food	Food products
31	1986	7/1/1986	OH	1	1	Metal	Chem manufact - Miscellaneous chemical products
32	1986	7/22/1986	IL	0	1	Plastic	Chem manufact - Miscellaneous chemical products
33	1986	7/29/1986	MN	0	2	Coal	Electric Services
34	1986	9/8/1986	TN	1	1	Wood	Lumber & wood products
35	1986	9/13/1986	OH	2	0	Food	Packaging & storage
36	1986	12/15/1986	IL	0	0	Food	Food products
37	1986	12/31/1986	VA	0	2	Wood	Lumber & wood products
38	1987	2/4/1987	NY	1	5	Metal	Fabricated metal products
39	1987	3/18/1987	AL	1	0	Wood	Furniture & fixtures

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
40	1987	3/27/1987	IN	1	2	Metal	Primary metal industries
41	1987	4/8/1987	IN	1	0	Plastic	Rubber & plastic products
42	1987	6/10/1987	UT	0	6	Metal	Fabricated metal products
43	1987	9/13/1987	AL	0	0	Food	Food products
44	1988	1/14/1988	MN	0	0	Food	Food products
45	1988	3/19/1988	CA	0	3	Food	Food products
46	1988	3/30/1988	NJ	0	2	Pharmaceutical	Chem Manufact - Pharmaceutical Preparations
47	1988	4/15/1988	NC	0	2	Wood	Lumber & wood products
48	1988	5/12/1988	OH	1	8	Metal	Equipment manufacturer - industrial
49	1988	7/13/1988	OH	1	2	Metal	Primary metal industries
50	1988	11/19/1988	OH	1	0	Plastic	Chem manufact - Plastics materials & synthetic resins
51	1988	12/2/1988	MN	0	0	Food	Food products
52	1988	12/2/1988	AL	1	0	Wood	Lumber & wood products
53	1989	1/11/1989	PA	1	0	Metal	Primary metal industries
54	1989	1/25/1989	MI	0	1	Food	Food products
55	1989	2/3/1989	KS	0	0	Food	Food products
56	1989	2/14/1989	IA	0	0	Food	Food products
57	1989	3/2/1989	PA	1	2	Metal	Fabricated metal products
58	1989	5/12/1989	IL	0	0	Food	Food products
59	1989	7/13/1989	AR	0	7	Plastic	Fabricated metal products
60	1989	8/7/1989	IN	0	2	Wood	Rubber & plastic products
61	1989	10/24/1989	MN	0	0	Coal	Electric Services
62	1989	11/13/1989	IA	0	0	Food	Food products
63	1989	11/22/1989	IA	0	0	Food	Food products
64	1990	1/17/1990	OH	2	1	Metal	Chem manufact - Miscellaneous chemical products
65	1990	2/19/1990	OR	0	9	Wood	Paper products
66	1990	3/31/1990	IN	0	7	Metal	Electric Services
67	1990	4/20/1990	MD	0	2	Metal	Primary metal industries
68	1990	6/21/1990	AR	2	0	Metal	Primary metal industries
69	1990	6/29/1990	PA	0	2	Metal	Primary metal industries
70	1990	9/27/1990	IL	0	0	Food	Food products
71	1990	10/22/1990	CA	0	1	Textile	Textile products
72	1990	11/5/1990	MI	0	0	Food	Food products
73	1990	11/9/1990	MD	0	1	Metal	Primary metal industries
74	1990	11/27/1990	VA	2	0	Wood	Lumber & wood products
75	1991	4/1/1991	IA	0	0	Food	Food products
76	1991	4/11/1991	OR	0	1	Wood	Lumber & wood products
77	1991	6/6/1991	CA	1	1	Inorganic	Chem Manufact - Pharmaceutical Preparations
78	1991	6/12/1991	NH	0	1	Plastic	Equipment manufacturer - industrial
79	1991	9/1/1991	NM	1	2	Wood	Lumber & wood products
80	1991	9/21/1991	CA	0	2	Metal	Rubber & plastic products
81	1991	9/24/1991	IA	0	0	Food	Food products

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
82	1991	12/17/1991	MI	0	11	Inorganic	Chemical Manfact
83	1992	6/3/1992	RI	0	2	Food	Food products
84	1992	7/31/1992	MD	0	1	Metal	Primary metal industries
85	1992	10/3/1992	IN	1	0	Metal	Equipment manufacturer - industrial
86	1992	11/18/1992	SD	0	2	Wood	Lumber & wood products
87	1992	12/4/1992	NC	0	5	Wood	Lumber & wood products
88	1993	1/6/1993	NY	2	2	Pharmaceutical	Chem Manufact - Pharmaceutical Preparations
89	1993	2/8/1993	NH	0	8	Wood	Lumber & wood products
90	1993	3/21/1993	IA	0	0	Food	Food products
91	1993	3/24/1993	SC	2	2	Plastic	Chem manufact - Plastics materials & synthetic resins
92	1993	4/26/1993	NY	0	0	Pharmaceutical	Chem Manufact - Pharmaceutical Preparations
93	1993	5/12/1993	IN	0	1	Plastic	Stone, clay, glass, & concrete products
94	1993	5/17/1993	MN	1	0	Food	Food products
95	1993	9/3/1993	PA	1	0	Metal	Stone, clay, glass, & concrete products
96	1993	9/27/1993	OR	0	1	Wood	Lumber & wood products
97	1993	10/25/1993	NJ	0	9	Food	Food products
98	1993	12/2/1993	MD	0	1	Metal	Fabricated metal products
99	1994	4/21/1994	IA	0	0	Food	Food products
100	1994	4/21/1994	IN	0	22	Coal	Electric Services
101	1994	5/28/1994	IA	0	0	Food	Food products
102	1994	6/1/1994	MD	0	3	Wood	Furniture & fixtures
103	1994	6/16/1994	MN	0	2	Food	Food products
104	1994	7/16/1994	CA	0	1	Textile	Textile products
105	1994	9/14/1994	FL	0	0	metal	Equipment Manfacturer
106	1994	9/16/1994	AZ	1	6	Inorganic	Chemical manfact
107	1994	11/20/1994	NC	2	4	Wood	Lumber & wood products
108	1994	12/16/1994	CA	0	2	Wood	Unknown
109	1995	1/4/1995	KY	1	0	Metal	Primary metal industries
110	1995	2/28/1995	IL	2	25	Metal	Equipment manufacturer - transportation
111	1995	3/24/1995	IL	0	4	Food	Food products
112	1995	3/25/1995	VA	0	1	Metal	Fabricated metal products
113	1995	5/22/1995	PA	0	1	Inorganic	Chem manufact - Industrial inorganic chemicals
114	1995	7/30/1995	IL	1	0	Food	Food products
115	1995	9/26/1995	IA	0	0	Food	Food products
116	1995	9/29/1995	CA	0	6	Wood	Lumber & wood products
117	1995	11/16/1995	WA	0	0	Metal	Fabricated metal products
118	1995	12/11/1995	IA	0	0	Food	Food products
119	1995	12/11/1995	MA	0	37	Plastic	Textile products
120	1995	12/13/1995	NH	0	0	Plastic	Rubber & plastic products
121	1996	1/9/1996	FL	1	0	Inorganic	Equipment manufact - transporation
122	1996	1/24/1996	AZ	0	3	Coal	Primary metal industries
123	1996	2/27/1996	IL	1	2	Coal	Electric Services

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
124	1996	3/4/1996	VA	0	1	Tobacco	Tobacco products
125	1996	4/27/1996	CA	1	0	Metal	Equipment manufacturer - industrial
126	1996	6/25/1996	TN	0	1	Metal	Primary metal industries
127	1996	7/10/1996	PA	0	0	Food	Food products
128	1996	7/20/1996	NE	1	15	Food	Food products
129	1996	7/30/1996	VA	0	1	Plastic	Equipment manufacturer
130	1996	8/14/1996	NM	2	0	wood	lumber & wood products
131	1996	11/5/1996	UT	0	2	Metal	Chem manufact - Miscellaneous chemical products
132	1996	12/24/1996	PA	1	0	Metal	Primary metal industries
133	1997	1/7/1997	IL	0	5	Paints	Equipment manufacturer - transportation
134	1997	1/10/1997	IL	0	5	Food	Food products
135	1997	2/13/1997	OH	0	2	Metal	Fabricated metal products
136	1997	4/16/1997	PA	2	0	Inorganic	Chemical manfact
137	1997	5/16/1997	CA	0	1	Food	Food products
138	1997	5/18/1997	CA	0	6	Food	Food products
139	1997	6/17/1997	OH	0	0	Food	Food products
140	1997	7/30/1997	UT	1	4	Inorganic	Chemical manufact
141	1997	9/12/1997	NJ	0	1	Organic	Chem manufact
142	1997	9/30/1997	CT	0	3	Plastic	Textile products
143	1997	10/20/1997	MN	0	0	Food	Food products
144	1997	11/24/1997	OH	0	2	Metal	Fabricated metal products
145	1997	12/18/1997	TX	1	4	Metal	Fabricated metal products
146	1998	1/5/1998	PA	0	0	Metal	Primary metal industries
147	1998	3/24/1998	NC	0	2	Wood	Furniture & fixtures
148	1998	3/27/1998	NH	0	0	Wood	Fabricated metal products
149	1998	4/11/1998	CA	0	1	Wood	Lumber & wood products
150	1998	4/13/1998	IL	0	0	Plastic	Rubber & plastic products
151	1998	5/4/1998	TX	1	1	metal	wholesale trade-durable goods
152	1998	5/17/1998	TN	0	2	Food	Food products
153	1998	7/1/1998	CA	0	1	Wood	Lumber & wood products
154	1998	7/1/1998	MS	0	4	Plastic	Equipment manufacturer - medical
155	1998	7/7/1998	KS	0	1	Food	Food products
156	1998	7/28/1998	IN	0	17	Coal	Electric Services
157	1998	8/10/1998	CA	0	1	Wood	Furniture & fixtures
158	1998	8/28/1998	TX	0	1	Food	Food products
159	1998	8/28/1998	TX	0	16	Plastic	Equipment manufacturer - industrial
160	1998	10/12/1998	OR	0	1	Wood	Lumber & wood products
161	1999	2/1/1999	MI	6	30	coal	Electric Services
162	1999	2/17/1999	IL	1	0	Metal	Fabricated metal products
163	1999	2/25/1999	MA	3	9	Plastic	Primary metal industries
164	1999	4/5/1999	AL	1	1	Metal	Primary metal industries
165	1999	4/24/1999	VA	0	4	Wood	Lumber & wood products

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
166	1999	8/12/1999	MD	0	1	Inorganic	Chem manufact - Miscellaneous chemical products
167	1999	8/16/1999	GA	3	4	Coal	Electric Services
168	1999	9/22/1999	NJ	0	2	plastic	Rubber & plastic products
169	1999	10/3/1999	CO	1	0	Wood	Lumber & wood products
170	1999	10/4/1999	MS	0	1	Plastic	Rubber & plastic products
171	2000	1/22/2000	NM	0	3	Food	Food products
172	2000	2/3/2000	MO	1	0	Wood	Chem manufact - Industrial organic chemicals
173	2000	2/3/2000	IN	1	0	Metal	Primary metal industries
174	2000	3/7/2000	CA	0	1	Metal	Electric Services
175	2000	3/16/2000	CA	0	2	Metal	Fabricated metal products
176	2000	3/22/2000	NY	0	1	Food	Food products
177	2000	3/23/2000	TN	0	1	Food	Food products
178	2000	3/24/2000	CA	0	1	Metal	Primary metal industries
179	2000	4/4/2000	CA	0	1	Wood	Fabricated metal products
180	2000	5/4/2000	TX	0	3	Food	Food products
181	2000	6/12/2000	PA	0	6	Plastic	Rubber & plastic products
182	2000	7/5/2000	MD	0	1	Wood	Lumber & wood products
183	2000	8/17/2000	OH	0	1	Plastic	Chem manufact - Miscellaneous chemical products
184	2000	10/25/2000	OR	0	4	Wood	Lumber & wood products
185	2000	10/26/2000	CA	1	4	Plastic	Rubber & plastic products
186	2001	1/10/2001	NH	0	1	Wood	Lumber & wood products
187	2001	1/31/2001	KS	0	0	Food	Food products
188	2001	2/14/2001	PA	3	10	Wood	Lumber & wood products
189	2001	3/14/2001	MD	1	0	Inorganic	Chem manufact - Miscellaneous chemical products
190	2001	5/19/2001	IL	1	1	Food	Food products
191	2001	5/25/2001	MI	0	9	Wood	Lumber & Wood products
192	2001	8/29/2001	MT	0	2	Coal	Electric Services
193	2001	9/8/2001	IL	0	0	Food	Food products
194	2001	9/21/2001	MI	0	2	Food	Food products
195	2001	10/3/2001	IN	5	0	Metal	Chem manufact - Miscellaneous chemical products
196	2001	10/15/2001	NV	1	3	Inorganic	Propellants & explosive manufacturing
197	2001	12/11/2001	PA	0	2	Metal	Fabricated metal products
198	2002	1/16/2002	MI	1	0	Coal	Electric Services
199	2002	1/23/2002	NE	0	13	Plastic	Rubber & plastic products
200	2002	2/11/2002	OH	0	0	Plastic	Unknown
201	2002	2/13/2002	IL	1	2	Coal	Electric Services
202	2002	5/16/2002	MS	5	7	Plastic	Rubber & plastic products
203	2002	5/26/2002	NJ	0	0	Food	Food products
204	2002	6/6/2002	PA	0	3	Metal	Primary metal industries
205	2002	6/10/2002	NC	0	0	Wood	Furniture & fixtures
206	2002	7/19/2002	SC	0	0	Plastic	Chemical manfact
207	2002	8/8/2002	OR	1	3	Food	Food products

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
208	2002	8/8/2002	MS	1	0	Textile	Packaging & storage
209	2002	8/25/2002	TN	1	0	Metal	Chem manufact - Industrial inorganic chemicals
210	2002	9/5/2002	MN	1	4	Food	Food products
211	2002	9/20/2002	KS	0	0	Food	Food products
212	2002	11/18/2002	NC	0	3	Plastic	Rubber & plastic products
213	2002	12/26/2002	AL	1	0	Wood	Lumber & wood products
214	2002	12/27/2002	ID	0	0	Wood	Lumber & wood products
215	2002	12/27/2002	WI	0	1	Metal	Primary metal industries
216	2003	1/21/2003	IL	0	1	Plastic	Automotive services
217	2003	1/23/2003	MO	0	0	Wood	Lumber & wood products
218	2003	1/29/2003	NC	6	38	Plastic	Rubber & plastic products
219	2003	2/10/2003	WI	0	0	Coal	Electric Services
220	2003	2/14/2003	NC	0	2	Wood	Furniture & fixtures
221	2003	2/20/2003	KY	7	37	Plastic	Rubber & plastic products
222	2003	2/25/2003	TN	0	0	Wood	Lumber & wood products
223	2003	2/25/2003	TN	0	0	Wood	Lumber & wood products
224	2003	3/7/2003	NY	0	0	Wood	Lumber & wood products
225	2003	3/12/2003	PA	0	0	Wood	Lumber & wood products
226	2003	3/14/2003	MI	0	0	Metal	Fabricated metal products
227	2003	3/17/2003	PA	0	0	Metal	Fabricated metal products
228	2003	4/9/2003	IN	0	0	Wood	Unknown
229	2003	5/20/2003	KY	1	3	Food	Food products
230	2003	5/23/2003	CA	0	2	Wood	Furniture & fixtures
231	2003	5/30/2003	IA	0	1	Coal	Electric Services
232	2003	7/9/2003	IL	1	1	Metal	Fabricated metal products
233	2003	7/22/2003	SC	0	0	Plastic	Chem Manufact - Pharmaceutical Preparations
234	2003	7/30/2003	SD	0	0	Metal	Fabricated metal products
235	2003	8/11/2003	OR	0	1	Wood	Rubber & plastic products
236	2003	8/26/2003	NC	0	0	Food	Food products
237	2003	9/2/2003	MA	0	1	Wood	Lumber & wood products
238	2003	9/5/2003	OH	0	0	Plastic	Equipment manufacturer
239	2003	10/1/2003	OH	2	9	Wood	Lumber & wood products
240	2003	10/22/2003	KY	0	0	Plastic	Rubber & plastic products
241	2003	10/29/2003	IN	1	2	Metal	Primary metal industries
242	2004	1/12/2004	IA	0	0	Food	Food products
243	2004	1/15/2004	OR	0	2	Wood	Equipment Manfacturer
244	2004	2/11/2004	NE	0	0	Wood	Furniture & fixtures
245	2004	2/12/2004	IL	0	0	Coal	Electric Services
246	2004	2/16/2004	OK	0	0	Coal	Electric Services
247	2004	2/19/2004	OH	0	3	Wood	Lumber & wood products
248	2004	2/23/2004	MI	0	0	metal	Primary metal industries
249	2004	3/16/2004	AR	0	0	Wood	Lumber & wood products

#	Year	Date	State	Fataliti	Injurie	Fuel	Facility Type
250	2004	3/16/2004	OK	0	0	Plastic	Rubber & plastic products
251	2004	3/17/2004	WA	0	2	Wood	Lumber & wood products
252	2004	4/6/2004	KS	0	0	Food	Food products
253	2004	4/7/2004	IL	0	0	Coal	Electric Services
254	2004	4/8/2004	NC	0	1	Food	Food products
255	2004	5/6/2004	WI	0	0	Wood	Lumber & wood products
256	2004	5/16/2004	NJ	0	0	Pharmaceutical	Chem Manufact - Pharmaceutical Preparations
257	2004	6/10/2004	NC	0	3	Plastic	Chem manufact - Miscellaneous chemical products
258	2004	6/25/2004	WI	0	4	Metal	Fabricated metal products
259	2004	7/6/2004	TX	1	2	Metal	Equipment Manfacturer
260	2004	7/20/2004	CT	0	2	Plastic	Rubber & plastic products
261	2004	9/14/2004	OH	0	1	Metal	Primary metal industries
262	2004	9/16/2004	CA	0	0	Wood	Paper products
263	2004	9/18/2004	MA	1	16	Food	Food products
264	2004	9/23/2004	IL	0	0	Wood	Furniture & fixtures
265	2004	9/28/2004	IL	0	0	Coal	Electric Services
266	2004	10/12/2004	IN	0	0	Plastic	Rubber & plastic products
267	2004	11/23/2004	Il	0	0	Plastic	Rubber & plastic products
268	2004	12/3/2004	OH	0	1	Wood	Food products
269	2004	12/8/2004	MD	0	0	Wood	Equipment Manfacturer
270	2005	2/25/2005	KY	0	2	Plastic	Rubber & plastic products
271	2005	5/3/2005	CA	0	2	Pharmaceutical	Chemical manfact
272	2005	6/1/2005	IA	0	1	Inorganic	Rubber & plastic products
273	2005	6/10/2005	TN	0	5	Paints	Chemical Manfact
274	2005	7/4/2005	WA	0	0	Organic	Stone, clay, glass, & concrete products
275	2005	7/8/2005	ME	0	0	Wood	Lumber & wood products
276	2005	7/22/2005	WI	0	2	Metal	Equipment Manfacturer
277	2005	7/26/2005	OR	0	0	Wood	Lumber & wood products
278	2005	10/14/2005	WI	1	1	Wood	Lumber & wood products
279	2005	11/9/2005	IL	0	0	Plastic	Equipment Manfacturer
280	2005	11/14/2005	IA	0	2	Wood	Lumber & wood products
281	2005	11/17/2005	MT	0	1	Inorganic	Chemical manfact
		Totals		119	718		

APPENDIX B

MATERIAL SAFETY DATA SHEET ANALYSIS

1.0 Introduction

MSDSs are the primary document for communicating the hazards of a chemical compound, and convey these hazards from the manufacturer to the purchaser (employer), and from the employer to employees. As such, the OSHA HCS requires employers to maintain MSDSs in the workplace; however, HCS also requires chemical hazard communication through package labeling and employee training.

Typical MSDSs give information about the chemical compound, including its name(s) or components, emergency contact information, physical and health hazards, means of protecting workers from exposure, physical data, emergency and fire-fighting measures, and environmental information for the proper use and disposal of the material.

In its investigations of the explosions at West Pharmaceutical and CTA Acoustics, the CSB found that the MSDSs for the materials that exploded inadequately communicated combustible dust hazards. For the purposes of this Dust Hazard Study, the CSB reviewed the MSDSs of 140 known combustible dusts to statistically determine if the problem of inadequate dust hazard communication is widespread; the following section discusses the results.

2.0 Results Summary

Approximately 59 percent of the MSDSs sampled include some language referring to the explosive nature of the dust. However, only a handful (seven of 140) reference the appropriate NFPA standard for managing dust hazards, and none list physical properties of combustible dusts or explain why dusty conditions should be avoided (to minimize secondary explosion potential).

3.0 Sources and Methodology

3.1 Base Population

The CSB investigators consulted published references to determine what types of materials are considered combustible dusts, and used this information to determine the number of MSDSs to sample and the sample strategy. The references included:

- *Dust Explosions in the Process Industries* by Rolf Eckhoff – Appendix A Table A-1;
- *Guidelines for Deflagration Venting* (NFPA 68) – Annex E; and
- *The NEC Handbook* by Earley, Sheehan, and Caloggero – Table 2-5.

The CSB developed a list of 231 combustible compounds, which formed the base population for sampling.

3.2 MSDS Sources

The CSB used the many MSDSs available on the Internet for this study, but the majority of MSDSs sampled came from the Vermont Safety Information Resources, Inc. (SIRI) website.[1]

The CSB searched the SIRI MSDSs site for all 231 of the materials in the combustible dust list, and found MSDSs for 140.

3.3 Sampling and Analysis Strategy

Given the relatively small size of the base population, the CSB included all of the 140 available MSDSs in the survey, rather than perform a statistical sampling of the data.

The 140 MSDSs were divided into nine compound families:

Product Family	Agricultural and food	Chemical	Carbonaceous	Metal	Pharmaceutical and nutritional	Pigment and dye	Plastic, rubber, and resin	Pesticide	Other
Number of MSDS	18	50	6	13	6	0	28	6	13

In addition, the CSB wanted to determine if the age of the MSDS was a factor in the presentation of dust hazard language (i.e., do newer MSDSs address dust hazard more completely?). A wide range, from 1980 to 2005, of MSDSs was obtained, and categorized by decade (1980s, 1990s, and 2000 or newer).

The CSB examined the MSDSs for dust combustion and explosion hazard warnings, using the following criteria to judge the quality of the information:

- Is the hazard stated explicitly and unambiguously? For example, "This material in its finely divided form presents an explosion hazard" as opposed to "Avoid dusty conditions."
- Is the hazard presented in the Hazard Information Section of the MSDS (i.e., Section 2 of the ANSI Z400.1 MSDS Format)?
- Is the hazard warning repeated in appropriate sections of the MSDS?
- Is any physical data appropriate to dust explosibility included (e.g., K_{St}, MIE, MEC, MIT)?

[1] http://siri.org/.

- Does the MSDS refer the reader to the appropriate NFPA Standard for additional information (e.g., NFPA 654 for chemical dusts, NFPA 484 for metal dusts)?

- Does the MSDS include warning against accumulation of dusts and guidance on the appropriate methods for removing the accumulations?

4.0 Findings

4.1 General Findings

MSDSs are a primary tool used to educate employees about the hazards of the material they handle and should therefore use clear language to explain hazards, reference an appropriate NFPA standard for managing dust hazards, contain some form of dust hazard warning, and ensure that the dust hazard warning is located in a section of the MSDS where users are likely to find it.

Of the 140 MSDSs sampled, 83 (59 percent) contain language that discusses the dust combustibility or explosibility hazard. The percentages of MSDSs with some form of dust hazard warning language range from 44 percent for chemicals to 83 percent for carbonaceous materials.

The CSB also found that only seven MSDSs reference an appropriate NFPA standard for managing dust hazards; however, none addresses the relevance of the NFPA standard for using and handling the material. Only 14 address the dust combustibility and explosibility hazard in the “Hazard Identification” section of the MSDS. None of the MSDSs reviewed contain any physical data relevant to the dust explosibility.

Finally, although many of the MSDSs that contain a dust hazard warning state that dusty conditions should be avoided, none explicitly state that dust accumulations should be avoided to prevent secondary dust explosions.

4.2 Location of Dust Hazard Information

Where a dust hazard warning is included, the CSB found that most (68 percent) address the dust hazard primarily in the MSDS section titled "Fire Fighting Measures." Since much of that section is intended to guide fire-fighters on fighting a fire and protecting themselves, an MSDS user is not directed to this section if no mention of a combustibility hazard is made earlier in the MSDS.

An important section for discussing dust hazards is the "Hazard Identification" section, which is usually on the first or second page of the MSDS. Other sections of the MSDS, such as "Accidental Release Measures" and "Handling and Storage," are useful for including information on dust hazards, handling, and clean-up methods.

4.3 Physical Data

The CSB found that none of the 140 MSDSs contained any physical data appropriate to dust explosion hazards. Physical data parameters, such as K_{St}, MIE, MEC, and MIT, should be included in the section titled "Physical and Chemical Properties."[2]

4.4 Hazard Warning Language

Some MSDSs contained very general dust explosion warnings. Examples of common language used in selected MSDSs:

- "Powder material may form explosive dust-air mixtures";
- "Avoid conditions that generate dust. This product may form flammable dust-air mixtures";
- "Powder suspended in air will produce an explosive flash."

A few MSDS address the dust hazard more completely, as in the following from one MSDS for zinc stearate[3]:

- Minimum dust cloud ignition temperature is 690C (1274F). Fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source, is a potential dust explosion hazard. Minimum explosible concentration: 0.02 g/l (air) (Bureau of Mines, 1968). Maximum explosion pressure: 68 lb/sq in @ 0.3 ounces per cubic foot. Sensitive to static discharge. Explosion hazards apply only to dusts, not to granular forms of this product. Avoid dust formation and control ignition sources. Employ grounding, venting and explosion relief provisions in accordance with accepted engineering practices in any process capable of generating dust and/or static electricity. Empty only into inert or non-flammable atmosphere. Emptying into a non-inert atmosphere where flammable vapors may be present could cause a flash fire or explosion due to electrostatic discharge.

The CSB concluded that additional guidance is needed on the format and content of combustible dust warnings and information in MSDSs.

4.5 Newer MSDSs

The CSB found that MSDSs from the 2000s are much more likely to contain dust hazard warning language than those prepared in the 1980s. Only 42 percent from the 1980s contained dust hazard

[2] Including these parameters gives the user quantitative evidence of the severity of the dust explosion hazard and guidance for designing protective measures.

[3] MSDS Number Z4275 for Zinc Stearate, Mallinckrodt Baker, Inc., Dec. 10, 2004.

language; however, 60 percent of those generated in the 1990s and 77 percent of those from the current decade (2000 and newer) include such language.

APPENDIX C

STATE FIRE CODE SURVEY

1.0 State Fire Code Survey

The CSB learned about fire code adoption, enforcement, and inspections within the three states (North Carolina, Kentucky, and Indiana) affected by the explosions the CSB investigated in 2003. To expand understanding of how states address fire codes, the CSB surveyed fire code adoption and enforcement practices in nine additional states.

1.1 Survey Sample

The CSB surveyed nine states: California, Illinois, Iowa, Maryland, Michigan, Minnesota, Ohio, Pennsylvania, and Texas. Together with Kentucky, Indiana, and North Carolina (studied in previous CSB investigations), the sample totaled 12 of the 50 states, or 24 percent.

The CSB selected the states to survey based on the number of combustible dust incidents within each. California was not among the top nine, but was selected because it is the only state with its own regulation addressing combustible dust hazards.

1.2 Survey Methodology and Questionnaire

The nine states were surveyed regarding fire code adoption, code enforcement, and inspector training pertaining to combustible dust. The number of combustible dust incidents reported in the CSB Incident Database from each state, as well as their geographical region, determined the states selected for the survey sample. Where available, the CSB examined the content of the state fire codes.

The CSB investigators conducted the survey mainly by telephone or email with officials in each state's Fire Marshal's office. The survey asked:

1. What fire/building codes does the state use? (IFC, NFPA, other?)
    a. How long has this code been in effect?
    b. Has the state modified the model code it adopted in any way that is related to combustible dust?
    c. Has the state modified the model code it adopted in any other significant way?
    d. Is it a state-wide code or are local jurisdictions free to choose their own?
    e. Are the dust codes included (IFC Chapter 13, NFPA 484, 654)?
2. What state department(s) are responsible for
    a. Fire code adoption or amendment?
    b. Fire code enforcement?
    c. State and local fire official training?
3. Does the state building code require compliance with applicable combustible dust provisions of the IFC or NFPA?
    a. Are permits required for combustible dust occupancy?
    b. (For states that use the IFC codes) Do permits also require compliance with NFPA combustible dust codes?
    c. IFC States: If a building is constructed for a certain occupancy and later engages in work involving combustible dusts, what action must the employer take? Is the employer required to get a combustible dust permit as required under IFC Chapter 13, Paragraph 1301.2?
4. Are industrial facilities routinely inspected for fire code violations?
    a. Or are only “High Risk Occupancies” (schools, churches, nightclubs, daycare facilities, apartments, etc.) inspected?
    b. By whom (state officials, local officials)?
    c. How often?
    d. What triggers an inspection?
    e. What types of things are inspected? (e.g. primarily life safety – fire extinguishers, exits, etc.)
    f. (For states that use the IFC codes) Does the scope of inspections also address NFPA combustible dust codes?
    g. Are there different inspection criteria (frequency, scope) between incorporated or unincorporated areas?
    h. Do you coordinate with the state OSHA or other agencies regarding fire code inspections?
    i. Are there written regulations or procedures that outline inspection procedures? Can you provide a copy of the regulations or procedures?
    j. Are there provisions for retroactivity?
5. Do inspectors receive training in combustible dust hazards?
    a. How much? How often?
    b. Who conducts the training?
    c. Who decides the subjects of the training, what curriculum is used, what subjects are covered? (Is there a state government Board or Department)?
    d. (For states that use the IFC codes) Does your training also cover NFPA combustible dust codes?
    e. Can you provide a copy of the curriculum that includes combustible dust training information?
6. Are you aware of any dust explosions in the state over the past ten years? Are they common?

1.3 Summary of Responses

Table 20. Summary of state fire code survey responses

State	Code	State or Local Enforcement	Industrial Facility Inspections
Minnesota	IFC**	State code establishes minimum; local jurisdictions may adopt more stringent requirements	As required by jurisdiction, not mandated by state
Ohio	IFC	Statewide	Mission to inspect all facilities that may be dangerous from a fire safety standpoint
Pennsylvania	IFC	Statewide, optional enforcement by local municipalities. Otherwise, state enforces	Yes, for initial permit. Once issued, no requirement for periodic inspections
Iowa	UFC*	Local municipalities not required to use NFPA codes; 34 municipal departments conduct local inspections with codes that must be at least as stringent as the State Fire Marshal Rule[4]	No
Illinois	UFC	No response	If complaints are received about the facility
Maryland	UFC	State code, but local jurisdictions can adopt more stringent requirements. Baltimore City did not adopt state fire code, adopted IFC	In accordance with federal law, or in response to complaints
California	UFC	State code establishes minimum, local jurisdictions may adopt more stringent requirements	There are no statutory inspection frequencies for industrial occupancies
Michigan	UFC	Local governments may adopt own fire codes. No state-mandated fire code	Enforced locally; state fire inspectors inspect only state-regulated facilities
Texas	--	No statewide code; only certain municipalities and counties have fire code	No

* Uniform Fire Code (NFPA 1) **International Fire Code

[4] The State Fire Marshal Rule does not address combustible dust.

APPENDIX D

June 22, 2005 PUBLIC HEARING

1.0 The CSB's Combustible Dust Public Hearing

The CSB convened a public hearing on dust explosion issues on June 22, 2005, at the Ronald Reagan Building and International Trade Center in Washington, D.C. Nearly 100 attended the day-long hearing, and 16 panelists, representing industry, academia, fire services, insurance, and regulators, spoke. Panel topics (see attached agenda) ranged from technical barriers to improving dust explosion prevention, to the difficulties in enforcing NFPA standards through state fire code inspections.

At the hearing's conclusion, several speakers addressed the need for further action on preventing dust explosions. The full transcript of the public hearing is available on the CSB's website.

The following are the meeting agenda, including panelists' names and excerpts from the *Federal Register* notice that preceded the hearing.

Agenda

8:30 to 8:45	Opening Remarks
	CSB Board Chairman Carolyn Merritt
8:45 to 9:30	Panel A: Combustible Dust Fires and Explosions
	CSB Staff: Angela Blair, Giby Joseph
9:30 to 10:15	Panel B: Societal Impacts of Dust Fires and Explosions
	James Edwards, victim, West Pharmaceutical Services via video courtesy of WRAL
	Video of CTA Acoustics Burn Victims, Courtesy of the Discovery Channel
	Mike Wright, United Steelworkers of America
10:15 to 10:30	Break
10:30 to 11:30	Panel C: Status and Effectiveness of Fire Codes for Dust Fire and Explosion Prevention
	Al Mitchell, Fire Marshal, State of Kentucky
	Chris Noles, Office of State Fire Marshal, North Carolina
	George Miller, National Association of State Fire Marshals (NASFM)
	Guy Colonna, National Fire Protection Association
	Dave Conover, International Code Council

11:30 to 12:30	Lunch
12:30 to 2:00	Panel D: Voluntary Combustible Dust Fire and Explosion Prevention Programs
	Tom Hoppe, CIBA Specialty Chemicals
	Chuck Johnson, Aluminum Association
	David Oberholtzer, Valimet
	Randy Davis, Kidde-Fenwal
	Henry Febo, FM Global
2:00 to 2:15	Break
2:15 to 3:45	Panel E: Technical Barriers to Dust Explosion Prevention and Protection
	Rolf Eckhoff, Professor, University of Bergen, Norway
	Erdem Ural, Loss Prevention Science and Technology, Inc.
	John Going, FIKE Corporation
	Walt Frank, ABS Consulting
	James Mulligan, Lockheed Martin
3:45 to 4:30	Public Comment
4:30	Closing Remarks
	CSB Board Members Merritt, Bresland and Visscher

Excerpts from the Federal Register Notice Concerning the Public Hearing

[Federal Register: May 6, 2005 (Volume 70, Number 87)]
[Notices]
[Page 23980-23982]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr06my05-34]

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CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

Public Hearing: Combustible Dust Hazards

AGENCY: U.S. Chemical Safety and Hazard Investigation Board (CSB).

ACTION: Notice announcing Sunshine Act public hearing and requesting public comment and participation.

SUPPLEMENTARY INFORMATION:

A. Introduction
B. Background
C. CSB Hazard Investigation
D. Investigation Objectives
E. Request for Comments
F. Form and Availability of Comments
G. Registration Information
H. Sunshine Act Notice

A. Introduction

In 2003, CSB investigated three accidents involving combustible dust explosions. CSB found that issues related to hazard awareness, regulatory oversight, and effectiveness of fire code enforcement were common to these three accidents. CSB's preliminary data indicate that a significant number of combustible dust fires and explosions have occurred in industry in the last twenty-five years. The data will be presented at the hearing. Additionally, individuals knowledgeable about dust explosion hazards will present information to the Board and respond to Board questions. Following these presentations there will be an opportunity for public comment.

B. Background

In 2003 CSB investigated 3 combustible dust explosions. A total of 14 individuals were killed and 81 injured in these events. In January 2003, an explosion and fire at the West Pharmaceutical Services facility in Kinston, North Carolina resulted in the deaths of six workers and injuries to 38 others. CSB investigated this accident and concluded that the explosion was the result of the deflagration of polyethylene powder that had accumulated above a suspended ceiling in the processing area of the facility.

In February 2003, a combustible dust explosion occurred at the CTA Acoustics facility in Corbin, Kentucky, killing 7 workers and injuring 37. CSB found that the fuel for the explosion was phenolic resin used to produce insulation materials for the automotive industry. The explosion began near a curing oven, where routine cleaning lofted accumulated resin dust that was ignited by fire in an oven on which the doors were left open. Numerous secondary deflagrations caused damage and injuries throughout the facility.

In October 2003, one worker was killed and six others injured when an aluminum dust explosion occurred at Hayes Lemmerz International in Huntington, Indiana. The report of CSB's investigation into this accident is expected to be approved by the Board soon.

The occurrence of three fatal combustible dust explosions within one calendar year prompted the Board to commence a broader study of the extent, nature and prevention of combustible dust fire and explosion hazards.

C. CSB Hazard Investigation

The objectives of CSB's investigation include:

1. Determining the number and effects of combustible dust fires and explosions in the United States during the twenty-five-year period beginning in 1980. CSB is excluding the following types of incidents for the purposes of this study:

(a) Those occurring in grain-handling or other facilities that are currently regulated by OSHA's grain handling standard.

(b) Those occurring in coal mines or other facilities covered by MSHA regulations. Incidents involving coal dust at power generation plants and other facilities not covered by MSHA regulations are not excluded.

(c) Incidents occurring in non-manufacturing facilities such as hospitals, military installations and research institutes.

(d) Incidents involving transportation or transportation vehicles.

(e) Incidents occurring outside the United States or U.S. territories.

2. Evaluating the extent and effectiveness of efforts by state and local officials to prevent combustible dust fires and explosions.

3. Evaluating the effectiveness of existing hazard communication programs and regulations in making facility managers and workers aware of the fire and explosion hazards of combustible dusts.

4. Determining what additional state, federal or private sector activities may be necessary to prevent future combustible dust fires and explosions.

D. Request for Comments

CSB solicits written or verbal comments on the following issues. The public hearing will address a selection of these issues, pending level of public interest and available time.

1. CSB is currently researching and cataloging combustible dust incidents that have occurred in the United States since 1980. This survey has identified nearly 200 combustible dust incidents involving

approximately 100 fatalities and 600 injuries. The sources of data include: the Occupational Safety and Health Administration (OSHA) incident database; the Institute of Chemical Engineers (ICHEME) accident base; Lexis/Nexus; and the National Fire Protection Association (NFPA). CSB will consult other data resources as the research continues.

a. Are there other sources of data on combustible dust incidents that may not have been captured in these databases?

b. Regarding any specific combustible dust incident(s) that you are aware of, were the causes of the incident(s) determined? If yes, what were they?

c. Are you aware of any materials or conditions that have contributed to the causation of major combustible dust incidents that may not have been identified in the technical literature or addressed in existing codes or guidelines?

2. A preliminary survey by CSB has found that approximately 25% of identified incidents occur in the plastics, pharmaceuticals, paints and other industries addressed within the scope of NFPA 654 (Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids), approximately 23% each in metal and wood industries, and 20% in the food (excluding grain handling) industry, with 10% involving coal dust (not including mines).

a. Should CSB investigation examine only those industries within the scope of NFPA 654, or also address combustible dust hazards in metal, food, coal (other than mining) and wood industries?

b. To what extent do the problems described below (lack of awareness, poor enforcement of existing codes, etc.) exist in each of these industries?

c. Are there significant differences in the causes or the means of preventing explosions in industries handling combustible plastic, metal, wood, food, coal or other dusts?

3. Both the NFPA and the International Code Council (ICC) have developed codes that address combustible dust hazards.

a. What are the strengths and weaknesses of the NFPA and ICC standards for combustible dust?

b. Are changes necessary in any of these standards to better prevent combustible dust fires and explosions?

4. In two investigations, CSB found that Material Safety Data Sheets for materials that may form combustible dusts did not adequately communicate explosion hazards. In addition, many MSDSs do not communicate the potential hazards of materials that may generate combustible dust as a result or byproduct of processing.

a. Does OSHA's Hazard Communication Standard clearly address combustible dust hazards?

b. Should OSHA provide better guidance on how combustible dust hazards should be addressed under the Hazard Communication Standard?

c. How effective are current MSDSs in communicating combustible dust hazard warnings?

d. Are there examples of MSDS that communicate these hazards better than others?

e. What can be done to improve the ability of MSDSs to communicate more effectively the hazards of combustible dusts and information on how to control those hazards?

f. Are there other written materials that more effectively communicate the hazards of combustible dusts to downstream users?

g. How effective is hazard labeling in communicating the hazards of combustible dusts?

5. Is additional research needed to resolve any technical issues or barriers, or issues around which no industry consensus has been reached in order to better control or prevent combustible dust explosions?

6. How do states address combustible dust hazards?

a. Do most states cover combustible dust hazard in some manner under their fire codes?

b. Do some states have occupational safety standards that address combustible dust hazards?

c. Are there examples of state occupational safety programs that have used the General Duty Clause to address combustible dust hazards?

d. Are there other examples that show how state governments have effectively addressed combustible dust hazards?

7. CSB has found that the primary regulatory mechanism for controlling or eliminating combustible dust hazards is enforcement of fire codes by local fire code officials. CSB found that awareness of combustible dust hazards among local fire code officials in several states is generally low.

a. What are the barriers to enforcement of fire codes?

b. Is the establishment and enforcement of state building and fire codes effective in preventing combustible dust incidents?

c. Are there examples of states where there is effective enforcement of fire codes addressing combustible dust hazards?

8. CSB has found that some facilities that have experienced serious dust explosions had been inspected by their insurers, but that these inspections had not identified combustible dust hazards.

a. Do/should insurers play a role in preventing dust explosions?

b. Are there barriers inherent in the structure of the insurance industry that prevent the industry from effectively addressing dust hazards?

c. What can be done to encourage the insurance industry to address these hazards more effectively?

d. What training, inspection protocols and educational curricula are available to risk insurance inspectors?

9. CSB has found that awareness about combustible dust hazards throughout industry, including occupational health and safety professionals, is generally low.

a. What forms and methods of outreach, training, education guidelines or regulations have been successful in raising awareness of combustible dust hazards and explosion prevention among safety professionals, facility owners, managers and workers?

b. How can local and national safety or fire officials identify, target and reach at-risk industrial establishments with preventive information?

10. Are there model programs for managing combustible dust hazards in industry?

a. Are there examples of effective combustible dust safety training programs?

b. Are there examples of effective products (brochures, guidelines, alerts, training material, etc.) or campaigns that have successfully communicated preventive information about dust explosions to different affected sectors?

c. Is there a means to make these programs available across the affected industries?

11. Is there a role for the federal government in preventing combustible dust explosions?

a. Is the OSHA Grain Handling Facilities standard (CFR 1910.272) a model for a general industry combustible dust standard?

b. Do data exist to evaluate how the number and severity of combustible dust incidents in the grain industry have been affected by the OSHA Grain Handling Facilities standard?

c. Would an OSHA standard addressing combustible dust hazards be effective in preventing explosions?

d. Are there other federal government agencies that could play a role in issuing regulations or raising awareness?