INVESTIGATION REPORT

COMBUSTIBLE DUST HAZARD STUDY

KEY ISSUES:

- FEDERAL REGULATIONS
- HAZARD AWARENESS
- FIRE CODE ENFORCEMENT

REPORT NO. 2006-H-1
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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 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.
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, 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

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
<th>Coverage or Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFPA 61</td>
<td>Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities – 2002.</td>
<td>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.</td>
</tr>
<tr>
<td>NFPA 68</td>
<td>Guidelines for Deflagration Venting – 2002</td>
<td>Provides technical guidance on designing, sizing, installing, and maintaining deflagration vents.</td>
</tr>
<tr>
<td>NFPA 69</td>
<td>Standard on Explosion Prevention Systems – 2002</td>
<td>Addresses the design of explosion prevention, protection, and mitigation systems.</td>
</tr>
<tr>
<td>NFPA 70</td>
<td>The National Electric Code® – 2005</td>
<td>Addresses electrical equipment and wiring requirements for special situations, including those in which an explosive atmosphere may exist. Defines combustible dust classified locations.</td>
</tr>
<tr>
<td>NFPA 499</td>
<td>Recommended Practice for the Classification of Combustible Dusts and Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas – 2004</td>
<td>Provides guidance for classifying dust processing locations for electrical equipment installation.</td>
</tr>
<tr>
<td>NFPA 664</td>
<td>Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities – 2002</td>
<td>Discusses facilities that process or manufacture wood and wood products, or that create wood dust and particles.</td>
</tr>
</tbody>
</table>

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 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. Ohio and Pennsylvania are the only two states of the nine surveyed that indicated that they require permits for industrial buildings involving combustible dust.

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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. 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. 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

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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.”

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.

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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) and the General Accounting Office (GAO). Although dust explosions initially fell following the alert, they increased again in 1980 and 1981.

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).
“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 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 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.

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; 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.

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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\(^8\) 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.

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\(^8\) 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). 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, 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](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, 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

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.