U.S. Chemical Safety and Hazard Investigation Board

CSB

Public Meeting – November 16, 2011

Hoeganaes Corporation

Iron Dust Flash Fires and Hydrogen Explosion

Gallatin, Tennessee

January 31, 2011
March 29, 2011
May 27, 2011

Investigation Team

- **Johnnie Banks**
  Investigations Team Lead
- **David Chicca**
- **Maria Mazzocchi**
- **Marc Sáenz**
- **Lucy Tyler**

Meeting Agenda

- Investigation Team Presentation
- Board Questions
- Panel Discussion
- Questions for Panelists
- Public Comment
- Other CSB Business
- Closing

Meeting Purpose

- Agency's interest in dust incidents
- Three incidents at the Gallatin facility
- Provide feedback and technical information to the community
- Present findings to the board
- Introduce recommendations

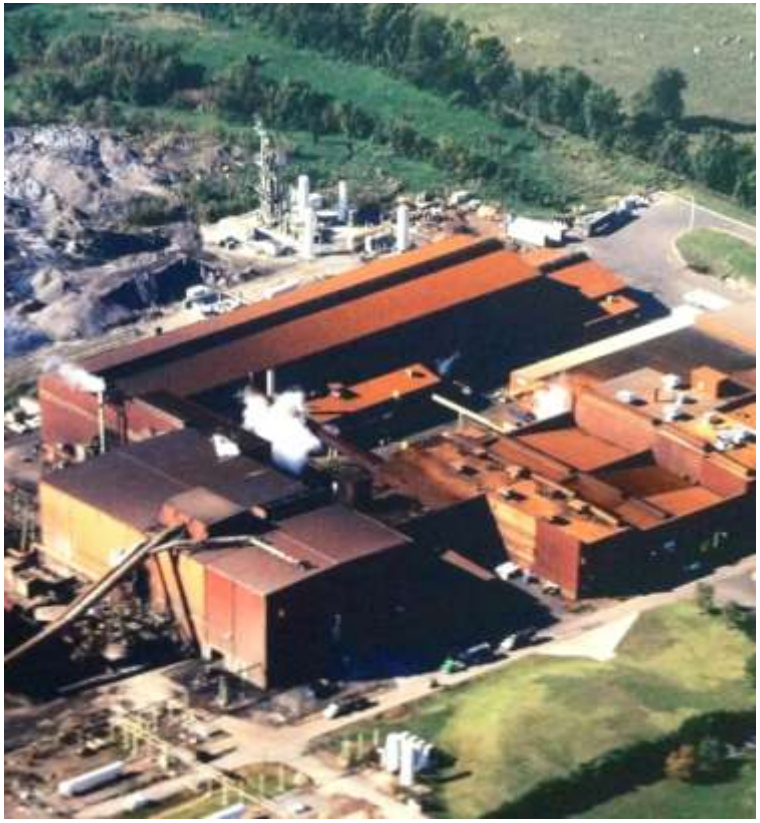
Investigation Team Presentation

- Company Overview
- Facility and Process overview
- Incident Animations
- Investigation Findings
- Staff Proposed Recommendations

Company Overview

- Worldwide producer of atomized steel and iron powders
  - Facilities in the US, Germany, China and Romania
- Headquartered in Cinnaminson, NJ
- Subsidiary of GKN
  - British multinational engineering company
  - GKN acquired Hoeganaes in 1999

Hoeganaes Gallatin, TN Facility



- 30 miles northeast of Nashville, TN
- ~180 workers
- Became operational in the 1980s
- Significant production increases

Powdered Metal Process

- Hoeganaes receives and melts scrap steel to meet customer specifications
- The molten iron is sprayed and cooled into a coarse powder
- Processed in annealing furnaces with hydrogen
- Crushed and milled into fine powdered metal product

U.S. Chemical Safety and Hazard Investigation Board

CSB

Incident Illustration

Bucket Elevator Flash Fire

January 31, 2011

2 Fatalities

Bucket Elevator Flash Fire

- Significant accumulations of iron powder on flat surfaces
- Bucket elevator dust collection system was out of service
- Elevator motor had exposed wiring and was not properly grounded

U.S. Chemical Safety and Hazard Investigation Board

CSB

Incident Illustration

Band Furnace Flash Fire

March 29, 2011

1 injury

Band Furnace Flash Fire

- Significant accumulations of iron powder on above surfaces lofted during maintenance activity
- Several ignition sources nearby
- Dust cloud formed next to a open-flamed furnace

Incident Illustration

Hydrogen Explosion and Secondary Iron Dust Flash Fires

May 27, 2011

3 fatalities, 2 injuries

Hydrogen Explosion & Secondary Dust Flash Fires

- The presence of hydrogen in the band furnace removes oxygen from the iron
- Delivered to the furnaces via pipes in an underground trench
- Hydrogen is supplied to Hoeganaes by an adjacent company

Hydrogen Explosion & Secondary Dust Flash Fires

- Hydrogen leak caused by corroded hydrogen piping
- No system in place to ensure hydrogen piping is inspected and maintained
- Flammable gas testing was not performed prior to opening the hydrogen pipe trench near several ignition sources

Hydrogen Explosion & Secondary Dust Flash Fires

- **No company procedures to respond to and mitigate suspected gas leaks**
- **Process area near band furnaces did not have appropriately rated electrical equipment for use near flammable gases**

Hydrogen Explosion & Secondary Dust Flash Fires

- **The hydrogen explosion overpressure lofted and ignited accumulations of iron powder**

U.S. Chemical Safety and Hazard Investigation Board

CSB

Combustible Dust Testing

Combustible Dust Testing

- Iron powder was the fuel source for the January and March 2011 incidents
- The May 2011 hydrogen explosion lofted and ignited accumulated iron powder on elevated surfaces
- The CSB collected samples of iron powder at the Hoeganaes facility for laboratory testing

U.S. Chemical Safety and Hazard Investigation Board

CSB

Iron Dust Combustibility Demonstration

Combustible Dust Testing

- CSB commissioned laboratory testing to determine Hoeganaes dust explosibility
  - 20 Liter (20L)Test Method, as specified by NFPA 484
  - 1 meter cubed ($1m^3$) Test Method
- Laboratory tests can predict how dusts can behave when dispersed near an ignition source

Combustible Dust Testing

Property	Definition	Application
K_{st}	Dust deflagration index (bar m/s)	Measures the relative explosion severity compared to other dusts
P_{max}	Maximum explosion overpressure generated in a test chamber (bar)	Used to design enclosures and predict severity of the consequence
Explosion Severity (ES)	Calculated value normalized to Pittsburgh coal dust; Class II test	Determines if Class II electrical equipment is needed
Pressure Ratio (PR)	Calculated value; explosibility screening test	Determines if a dust is explosible

Iron Powder Test Results

Bag house #4 sample (as received)	Result
Explosible ? (Pressure Ratio Calculation)	Yes
Ignitable?	Yes
K_{st} (bar m/s)	19
P_{max} (bar)	3.5

***The CSB also conducted 1m^3 testing from a different sample with a larger particle size; this did not ignite in the 1m^3 chamber**

Combustible Dust Testing

- **Dust testing results concluded that the iron powder at Hoeganaes is combustible and presents a serious flash fire hazard**

Hoeganaes Combustible Dust Testing

- Prior testing in 2009 and 2010 performed by Hoeganaes as a result of an insurance audit recommendation
- Testing results concluded that dust was explosible
- Hoeganaes testing results similar to CSB commissioned test results

Industry Dust Hazard Recognition

- **Metal dust hazards have been known and discussed throughout industry since the 1940s**
- **In addition to Hoeganaes, the CSB investigated 5 combustible dust incidents**

Other CSB Dust Investigations

Investigation	Year	Material	# of fatalities
West Pharmaceutical Services	2003	Polyethylene powder	6
CTA Acoustics	2003	Phenolic resin	7
Hayes Lemmerz International	2003	Aluminum dust	1
Imperial Sugar	2008	Sugar dust	14
AL Solutions	2010	Titanium powder	3

CSB Dust Study Data

- The CSB issued a *Combustible Dust Hazard Study* in 2006
- Identified 281 dust fires and explosions between 1980 and 2005
  - 119 fatalities
  - 718 injuries
- 20% of dust fires and explosions were fueled by metal dusts

Hoeganaes Past Incidents

- Previous explosion and fire incident occurred at the Hoeganaes Riverton, NJ facility in 1992
  - One worker severely burned; died 2 years later
- In 1996, an iron dust fire in a dust collector at the Gallatin facility
  - One worker injured

Hoeganaes Past Incidents

- **Workers told CSB investigators there were multiple small dust flash fires at the Gallatin facility that did not result in any injuries**
  - **Hoeganaes did not mitigate the hazard**
  - **Operators were forced to tolerate conditions at the facility**
  - **No training to understand the potential for iron dust flash fires**

U.S. Chemical Safety and Hazard Investigation Board

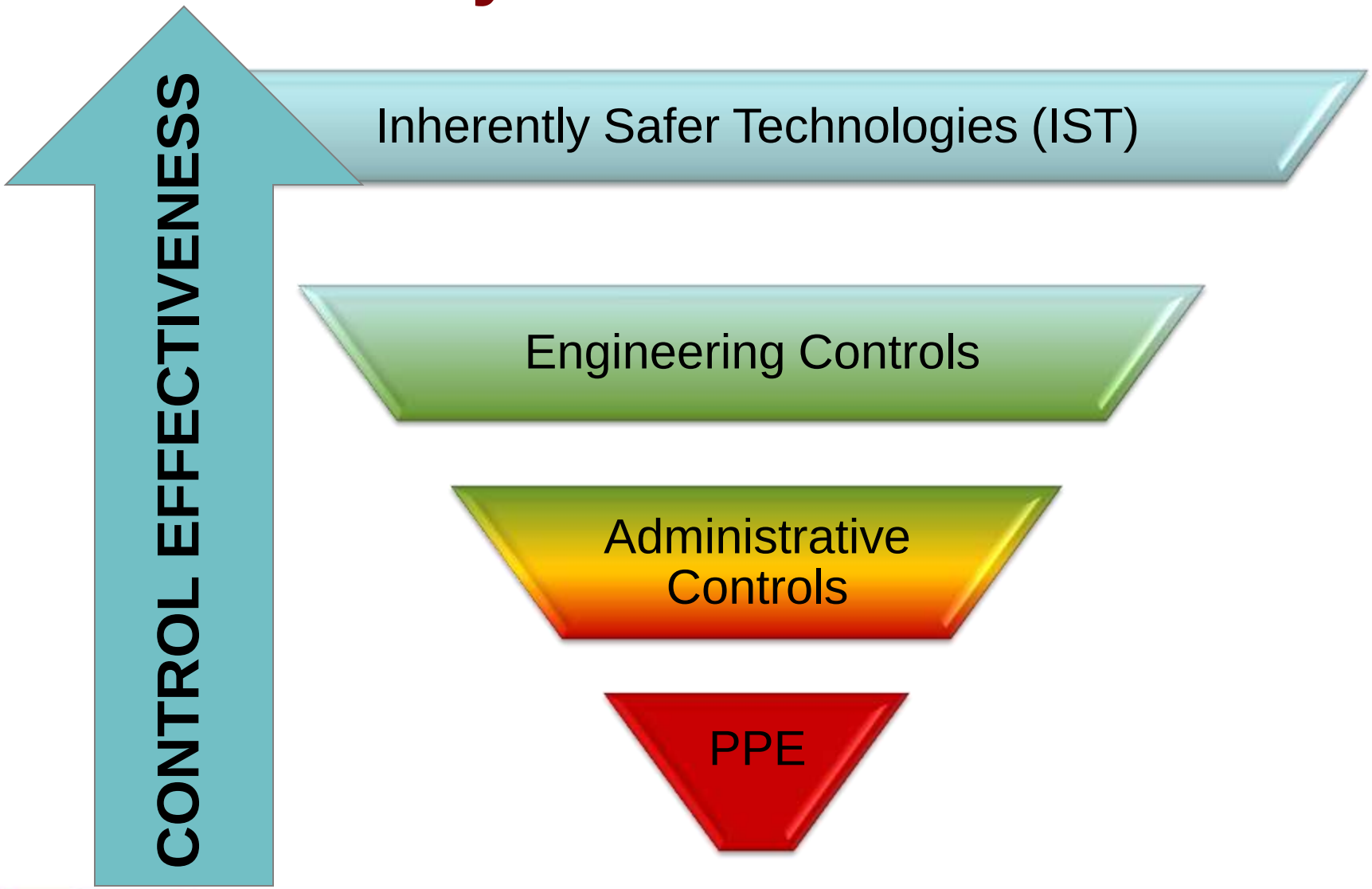
CSB

Hierarchy of Controls

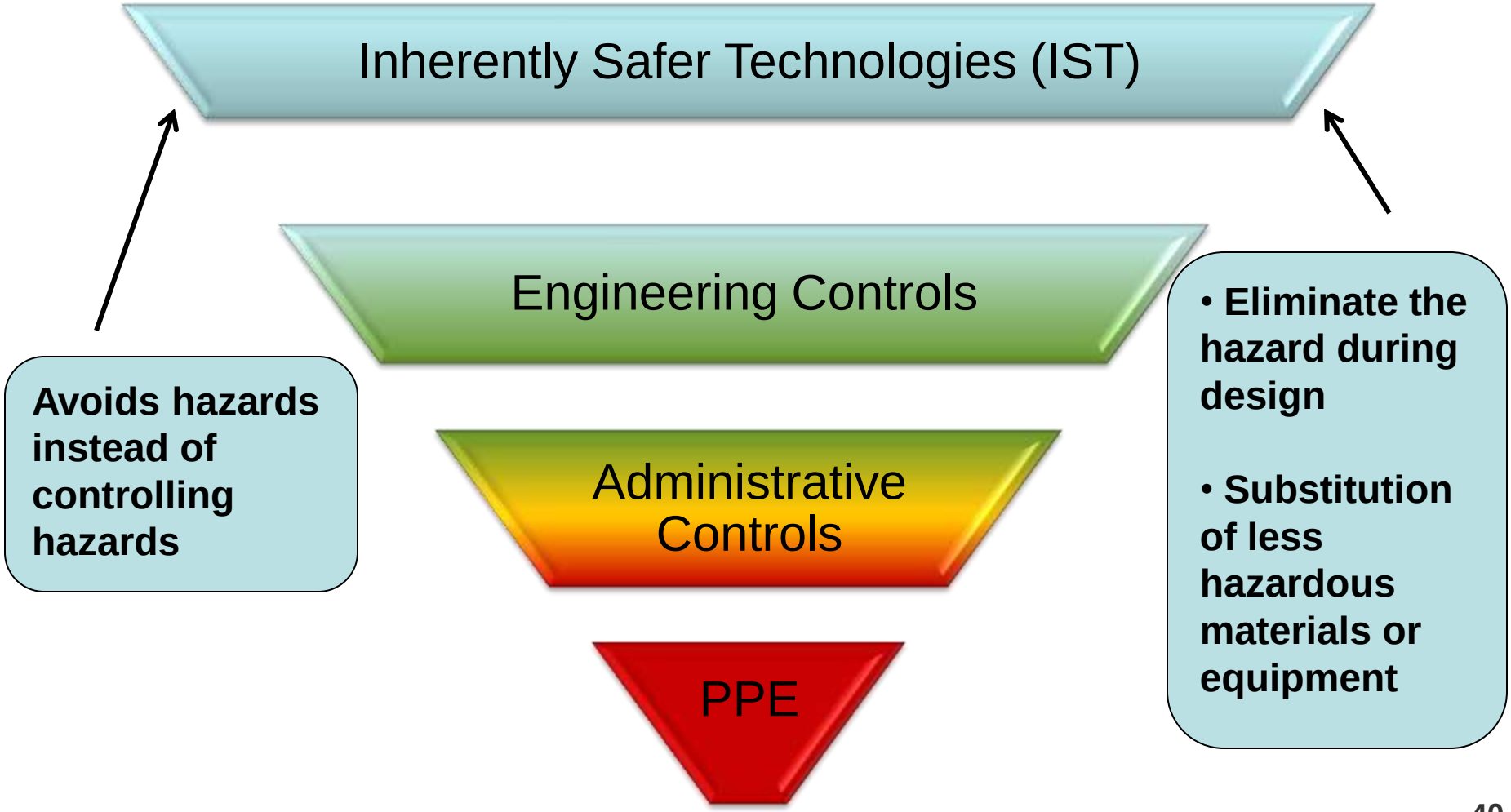
Hierarchy of Controls

- Concept recognized by health and safety professionals to control workplace hazards
  - Developed by the National Safety Council in the 1940s
  - Adopted into OSH Act of 1970
- Hierarchical order of control methods to prevent or mitigate worker injury or exposure

Hierarchy of Controls



Hierarchy of Controls



Hierarchy of Controls

Engineering Controls

Administrative Controls

PPE

Design options that automatically reduce risk

- **Well-sealed powder conveyance systems**
- **Appropriately sized dust collection**
- **Elimination of ignition sources**

Hierarchy of Controls

Engineering Controls

Administrative Controls

PPE

Procedures, training, or work practices to manage the hazard

- **Housekeeping**
- **Flammable gas monitoring**
- **Preventive maintenance**

Hierarchy of Controls

Engineering Controls

Administrative Controls

PPE

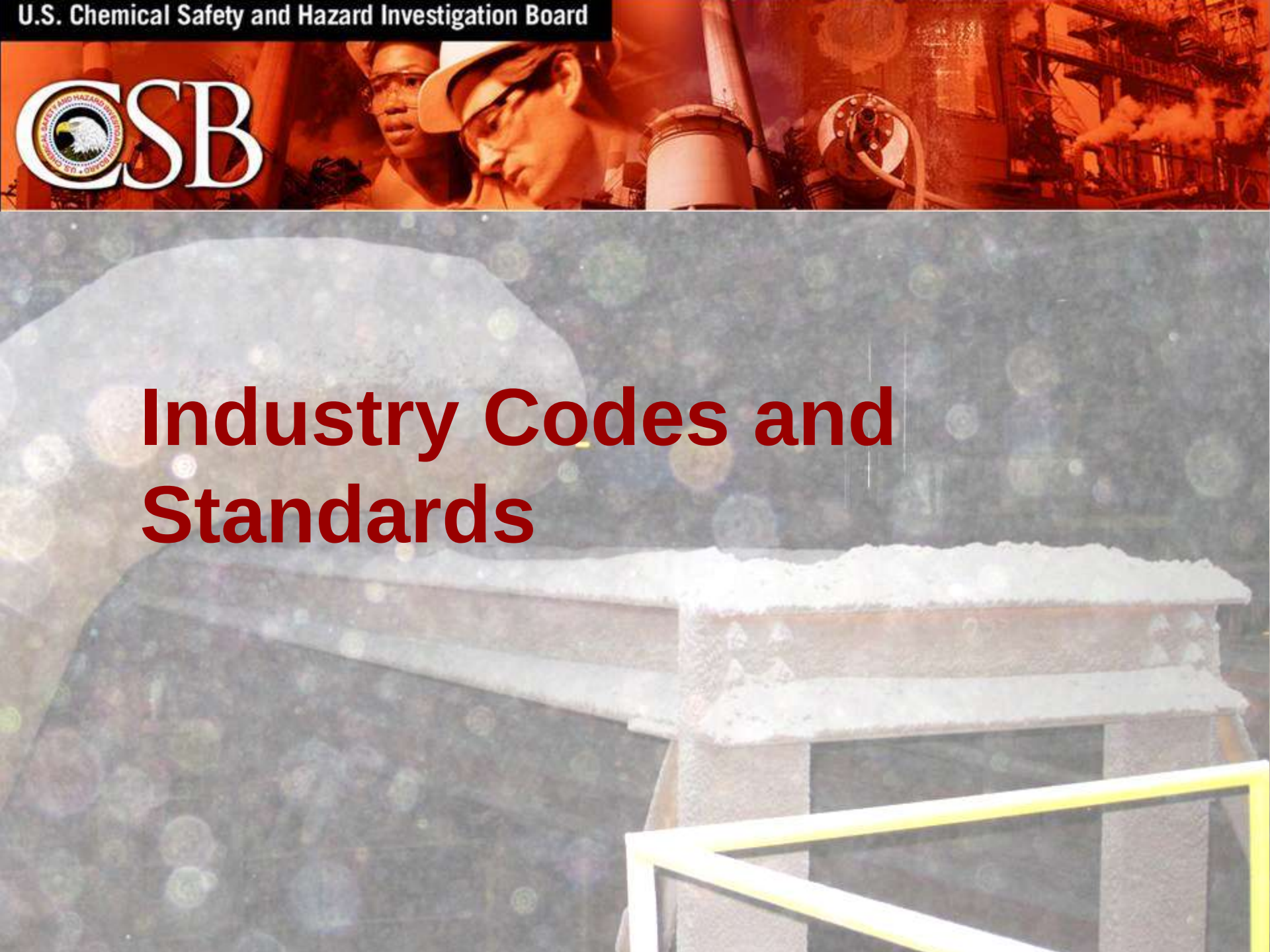
Equipment worn to shield worker from the hazard or exposure

- **Flame resistant clothing (FRC)**
- **Hard hat**
- **Safety shoes**

Hierarchy of Controls

- **Engineering controls are recognized throughout industry as the preferred method of dust explosion prevention above housekeeping and personal protective equipment (PPE)**
- **Hoeganaes lacked effective and appropriately maintained engineering controls to prevent iron dust accumulations**

Board Questions



Industry Codes and Standards

Occupational Safety and Health Administration (OSHA)

- Issues and enforces standards and programs for workplace safety and health
- OSHA Grain Dust Standard (1987)
  - Grain dust incident fatalities decreased by 60%
- No combustible dust regulation for general industry

CSB Combustible Dust Study

- The CSB recommended OSHA promulgate a General Industry Combustible Dust Regulation after its 2006 Combustible Dust Study
- OSHA issued advanced notice of rulemaking in 2009
  - Held various stakeholder meetings
  - Next meeting in December 2011
- No final rule has been published

CSB Combustible Dust Study

- **The CSB also recommended OSHA develop a national emphasis program (NEP) to address dust while the regulation was being developed**
- **OSHA issued a Combustible Dust NEP in October 2007.**

Combustible Dust NEP

- Not a regulation
- Inspection tool for compliance officers to apply existing standards to facilities that handle dust
- Can be applied to all dust processing operations but specifically targets certain industries by industrial classification codes (NAICS)

Combustible Dust NEP

- **The NAICS code for Hoeganaes was not listed in the NEP as a targeted industry with dust-producing operations**

Tennessee OSHA (TOSHA)

- Tennessee operates under a State worker safety plan
- States can develop individual worker safety and health programs
  - "At least as effective as" comparable Federal OSHA standards
  - Plans approved and monitored by Federal OSHA
  - States can also adopt federal standards and programs

TOSHA

- Tennessee OSHA adopted the Combustible Dust NEP in 2008
- State OSHA plans have the authority to add industry codes to the state-adopted NEP
- TOSHA did not add the industry code for Hoeganaes to the program
- Hoeganaes was not inspected for dust

National Fire Protection Association (NFPA)

- Industry consensus organization that develops and maintains standards and codes related to fire prevention and response
- Adopted by federal, state, and local entities into regulations and ordinances
- Voluntarily adopted by private companies

NFPA 484

- **NFPA 484, *Standard for Combustible Metals* contains provisions for protecting people and facilities from metal fires and explosions**
- **Addresses facilities that produce, handle or store combustible metals and alloys**

NFPA 484

- The authority having jurisdiction was not required to enforce NFPA 484
  - City of Gallatin or Fire Department
- Hoeganaes did not voluntarily adopt NFPA 484
- Had Hoeganaes applied provisions of NFPA 484, the conditions that led to these incidents could have been mitigated.

NFPA 484

- Specifies test methods for combustible dusts
- Addresses various elements of hierarchy of controls
  - Design and engineering controls to prevent dust accumulation
  - Guidelines for housekeeping programs

International Code Council (ICC)

- **Member-focused association that develops codes for public and industrial safety**
  - **Building safety and fire prevention codes**
  - **No regional limitations**
  - **ICC Codes are adopted state-wide or in local jurisdictions in all 50 states**
  - **Offers code assistance, certification and training to members**

International Fire Code (IFC)

- The ICC develops and maintains the IFC
- The IFC establishes minimum requirements for residential and industrial fire prevention
- Can be adopted and enforced by local or state jurisdictions
- The IFC is adopted by the State of Tennessee and the City of Gallatin

IFC Chapter 22 – Combustible Dust-Producing Operations

- Briefly lists general requirements for preventing dust explosions
- Housekeeping
  - Minimizing combustible dust accumulations
- Sources of ignition
  - Prohibits activities involving an open flame where dust is generated, stored, or handled

IFC Chapter 22 – Combustible Dust-Producing Operations

- IFC cites NFPA 484 and other NFPA dust standards
- IFC wording can be interpreted as voluntary
- 2204.1 Standards:
  - "The fire code official is authorized to enforce applicable provisions" of NFPA 484 and other NFPA dust codes and standards

IFC Chapter 22 – Combustible Dust-Producing Operations

- **State of TN specifically excludes optional or voluntary provisions of adopted fire codes.**
  - **IFC 2006 is adopted by reference**
  - **Which "shall not be construed as adopting any provision of the cited publications which establishes an optional or recommended, rather than mandatory, standard or practice…"**

IFC Chapter 22 – Combustible Dust-Producing Operations

- The City of Gallatin and the Gallatin Fire Department (GFD) are responsible for enforcing the requirements of the IFC that address combustible dust
- The GFD did not enforce the general requirements of the fire code for combustible dust

IFC Chapter 22 – Combustible Dust-Producing Operations

- GFD inspected the facility 2 weeks prior to the 3rd incident in May 2011
  - Did not recognize iron dust accumulations as a fire hazard
  - Did not inspect the facility against the general requirements of IFC for combustible dust

Key Findings

Key Findings

1. Significant accumulations of iron powder fueled flash fire incidents
2. Hoeganaes management personnel were aware of metal powder combustibility hazards but did not mitigate the hazard through engineering controls and housekeeping

Key Findings

3. Hoeganaes lacked employee training and procedures for flammable gas leaks

4. OSHA did not include the Iron and Steel Mills Industry Classification Code for Hoeganaes as a targeted industry for the Combustible Dust National Emphasis Program (NEP)

Key Findings

5. The 2006 International Fire Code (IFC), which was adopted by the City of Gallatin, does not require jurisdictions to enforce NFPA standards for the prevention of dust fires and explosions

6. The State of Tennessee and the City of Gallatin do not enforce "optional or recommended" standards or practices of the IFC

Key Findings

7. The Gallatin Fire Department inspected the Hoeganaes facility after the first two iron powder flash fires and did not address combustible dust hazards present at the facility just weeks before the third fatal hydrogen explosion and dust flash fire.

Key Findings

8. Instead of utilizing engineering and administrative controls such as dust collection systems and housekeeping programs, Hoeganaes relied on FRC to protect workers from iron dust flash fires.

Key Findings

9. GKN and Hoeganaes did not provide corporate oversight to ensure the Hoeganaes Gallatin facility was adequately managing combustible dusts prior to and throughout the succession of serious incidents at the Gallatin facility.

Staff Proposed Recommendations

Recommendations Overview

- **Primary tool to improve industrial safety programs and practices**
  - **Federal and state regulatory improvements**
  - **Industry and company practices**
  - **Trade association standards and outreach**

Recommendations Overview

- Directly address incident findings and causes
- Focus on management system improvements to prevent recurrence
- Recommendations Dept. monitors progress and updates status at www.csb.gov/recommendations

Staff Proposed Recommendations

Occupational Safety and Health Administration (OSHA)

1. Develop and publish a proposed rule for a combustible dust standard within one year of the approval of this case study.
2. Ensure that the forthcoming OSHA Combustible Dust Standard includes coverage for combustible metal dust including iron and steel powders.

Occupational Safety and Health Administration (OSHA)

3. Revise the Combustible Dust emphasis program to include facilities that produce, handle, process, or generate iron and steel powders or dusts.

Tennessee OSHA (TOSHA)

4. Revise the combustible dust emphasis program to include facilities that produce, handle, process, or generate iron and steel powders or dusts.

Hoeganaes Corporation

5. Conduct periodic independent audits of the Hoeganaes Gallatin facility for compliance with the applicable NFPA codes and standards for combustible dusts, electrical classifications, hydrogen, and flame resistant clothing.

Hoeganaes Corporation

6. Develop training materials that address combustible dust and plant-specific metal dust hazards and train all employees and contractors. Require periodic (e.g., annual) refresher training for all employees and contractors.

Hoeganaes Corporation

7. Implement a preventive maintenance program, as well as leak detection and mitigation procedures for all flammable gas piping and processing equipment.

International Code Council (ICC)

8. Revise IFC Chapter 22, *Combustible Dust Producing Operations* to require mandatory compliance and enforcement with the detailed requirements of the NFPA standards cited in the chapter.

Metal Powder Producers Association (MPPA)

9. Communicate the findings of this report to all your members, such as through a safety article in an upcoming monthly newsletter.

City of Gallatin, TN

10. Require all facilities covered by IFC Chapter 22 to conform to NFPA standards for combustible dusts including NFPA 484.

Gallatin Fire Department

11. Ensure that all industrial facilities in the City of Gallatin are inspected at least annually for compliance with the International Fire Code.

12. Implement a program to ensure that fire inspectors and response personnel are trained to recognize and address combustible dust hazards.

Staff Proposed Recommendations

Board Questions

Panel Discussion

Panelists

- Dr. Paul Amyotte, P. Eng.,
  - Dalhousie University, Nova Scotia
- Dr. Robert Zalosh
  - President, Firexplo
  - NFPA 484 Committee Member
- John M. Cholin, P.E., FSFPE, M.E.E,
  - President, J.M Cholin Consultants, Inc.

Panelists

- **Guy Colonna**
  - **Division Manager, NFPA**
- **Bruce E. Johnson**
  - **Director of Fire Service Activities, ICC**
- **Tammy Miser**
  - **Founder, United Support and Memorial for Workplace Fatalities**

U.S. Chemical Safety and Hazard Investigation Board

CSB

Public Comment

U.S. Chemical Safety Board

2175 K St. NW Suite 400

Washington, DC 20037

202-261-7600

www.csb.gov

U.S. Chemical Safety and Hazard Investigation Board

CSB

Public Meeting – November 16, 2011

Hoeganaes Corporation

Iron Dust Flash Fires and Hydrogen Explosion

Gallatin, Tennessee

January 31, 2011
March 29, 2011
May 27, 2011