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Additive Manufacturing

ZACHARY PARKS
HS&E ENGINEER
FIRE PROTECTION

KANSAS CITY NSC National Security Campus
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WHAT IS ADDITIVE MANUFACTURING?

What is Additive Manufacturing?

- **Process utilized combustible and noncombustible powder dusts and high-power lasers.**
  - Picture to the right show residue dust powders in container to depict size of dust
- **Parts are created one layer at a time from metal or polymer powders.**
  - With extreme precision, the top layer is melted to the layer below using a laser or electron beams.
  - Lasers or electron beams are directed by CAD models of the parts.

What is Additive Manufacturing, Cont.

- **Many different types of Additive Manufacturing methods**
  - Liquid polymer machines
    - Use a pen containing a combustible polymer liquid
    - One layer is printed on top of others and dried
  - Wire feed machines
    - Minimal fire danger as no combustible dust is used
  - Dust Additive Manufacturing (focus of presentation)
    - Combustible and noncombustible powder is utilized
    - High internal temperatures
    - Processes cannot be completed in an oxygen atmosphere
    - Argon, nitrogen, helium, or a vacuum atmosphere is used

HAZARDS

Hazards

- **OSHA's Hazard Communication Guidance for Combustible Dusts indicates four explosion classifications in Kst values (ST 0 – ST 3)**

Dust explosion class*	Kst (bar.m/s)*	Characteristic*	Typical material**
St 0	0	No explosion	Silica
St 1	>0 and ≤200	Weak explosion	Powdered milk, charcoal, sulfur, sugar, and zinc
St 2	>200 and ≤300	Strong explosion	Cellulose, wood flour, and poly methyl acrylate
St 3	>300	Very strong explosion	Anthraquinone, aluminum, and magnesium

Source: Hazard Communication Guidance for Combustible Dusts, by Occupational Safety and Health Administration (OSHA) 3371-08. [Washington] U.S. Dept. of Labor, [2009]

Hazards - KCNSC

- **KCNSC known metals and metal alloys**
  - Aluminum-Silicone Alloy – ST2
  - Aluminum, Titanium, Stainless Steel Alloy, Tungsten, Molybdenum – ST1
- **KCNSC known polymers**
  - Polyplus (media blasting) – ST1
- **Within industry it's generally understood that ST3 class signifies high explosivity. However, even an ST1 class can cause a flash fire throughout your facility.**
  - Imperial sugar dust explosion and fire (hyperlink in photo)
    - Sugar dust falls into the ST1 category
    - Incident left 14 dead and 38 injured

Hazards – Metals (Bureau of Mines)

- **Titanium, thorium, aluminum, magnesium, and uranium have a <u>severe</u> relative explosion hazard**
  - Listed metals have an average minimum Ignition Energy (IE) of 29 milijoules.
    - The energy released by a small coin – about 2.3 g weight – dropped from a height of 25 mm is 0.25 milijoules.
    - A static discharge from a human being may reach 60 milijoules or more.
  - Average Maximum pressure associated with ignition/explosibility is 64 psig
    - 8.0 psi (destruction of buildings)
    - 3.5 psi (serious injury likely)
    - 1.0 psi (shatters glass)

- **Aluminum-silicon alloy and coal have a <u>strong</u> relative explosion hazard.**
  - Average IE: 70 milijoules; Average Max pressure: 69 psig

- **Aluminum alloys, tantalum, tin, and zirconium alloy have a <u>moderate</u> relative explosion hazard.**
  - Average IE: 111 milijoules; Average Max Pressure: 64 psig

- **Zinc, iron, tungsten, cobalt, and copper have a <u>weak</u> relative explosion hazard.**
  - Average IE: 1208 milijoules; Average Max Pressure: 38 psig

- **Nickel and Stainless steel have <u>no</u> relative explosion hazard.**

Source: Explosibility of Metal Powders, by Murray Jacobson, Austin R. Cooper, and John Nagy. [Washington] U. S. Dept. of the Interior, Bureau of Mines [1964]

HAZARD CONTROLS

Hazards - KCNSC

- **Examples of controls at the KCNSC:**
  - Physical Separations,
  - Grounding and Bonding,
  - Electrical Static Dissipative (ESD) Flooring,
  - MAQs (if not in Hazardous Occupancy)
  - Housekeeping Requirements,
  - HVAC,
  - Low O_2 monitoring
  - Vacuum(s),
  - Location on Exterior Walls,
  - Minimum of Two Exits, and
  - Internal hazards controlled by inert atmospheres (argon and nitrogen) or by vacuum atmosphere

Examples of Safety Features at KCNSC

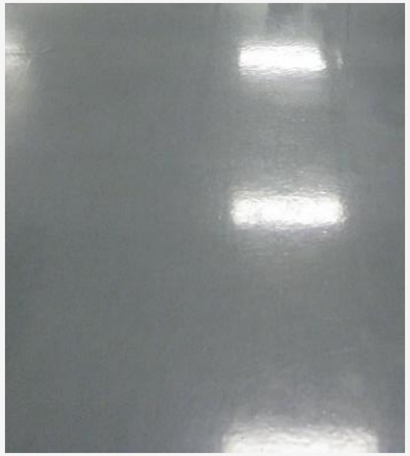
Evolution of storage capability

Original Containers from Manufacturer:

Stainless Steel Bin Funnel:

Examples of Safety Features at KCNSC, Cont.

Electrostatic Dissipative Flooring:



Footwear Conductivity Tester:

Examples of Safety Features at KCNSC, Cont.

HVAC (HEPA Filatration):

Physical Separation of Hazards:

Examples of Safety Features at KCNSC, Cont.

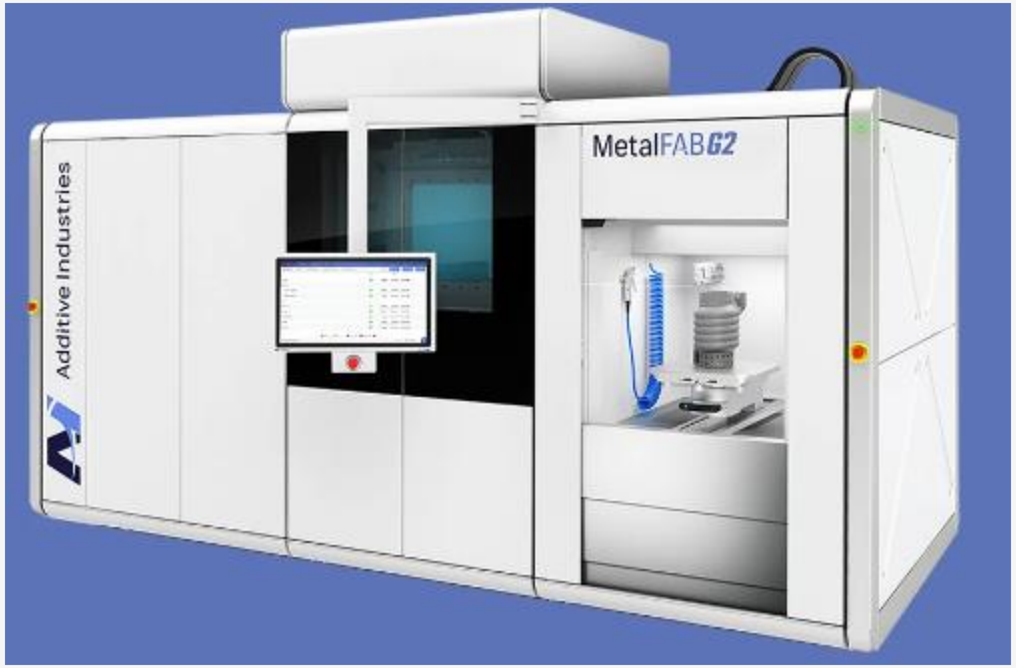
Dedicated Vacuums:

Closed Systems:

Examples of Safety Features at KCNSC, Cont.

Grounding/Bonding:

Enclosed-System Processing:



DESIGN COMPLIANCE METHODS

Design Compliance Methods

- **Code Compliance is achieved using one of the following methods:**
  - Prescriptive Based Approach
  - Performance Based-Design Approach

- **Performance-Based Design Approach allows for risk mitigation based on a set performance criteria.**
  - This approach could allow AM locations to be in occupancies other than Group H based on risk mitigation capabilities.
  - Could allow increased operations in leased facilities based on risk mitigation strategies.
  - Leased facilities present unique challenges due to the Stakeholders involved in Key Decisions.
    - The KCNSC has both owned and leased facilities
      - Utilized Jensen Hughes for a performance-based design for our leased facility.

Design Compliance Methods, Cont.

- **Combustible Dust-Producing Operations**
  - *International Building Code (ICC)*
    - Applies to construction, alterations, relocation, enlargement, repair, equipment, use and occupancy, etc.
    - Determines Maximum Allowable Quantity per Control Area (IBC, Table 307.1)

TABLE 307.1(1)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD[a, j, m, n, p]

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[b]			USE-CLOSED SYSTEMS[b]			USE-OPEN SYSTEMS[b]	
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas cubic feet at NTP	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas cubic feet at NTP	Solid pounds (cubic feet)	Liquid gallons (pounds)
Combustible dust	NA	H-2	See Note q	NA	NA	See Note q	NA	NA	See Note q	NA
Combustible fiber[q]	Loose Baled[o]	H-3	(100) (1,000)	NA	NA	(100) (1,000)	NA	NA	(20) (200)	NA

Design Compliance Methods, Cont.

- **Note q from IBC, Table 307.1:**
  - *"Where manufactured, generated or used in such a manner that the concentration and conditions create a fire or explosion hazard based on information prepared in accordance with [IBC] Section 414.1.3."*

- **IBC Section 414.1.3:**

[F] 414.1.3 Information required.
A report shall be submitted to the *building official* identifying the maximum expected quantities of hazardous materials to be stored, used in a *closed system* and used in an *open system*, and subdivided to separately address hazardous material classification categories based on Tables 307.1(1) and 307.1(2). The methods of protection from such hazards, including but not limited to *control areas*, fire protection systems and Group H occupancies shall be indicated in the report and on the *construction documents*. The opinion and report shall be prepared by a qualified person, firm or corporation *approved* by the *building official* and provided without charge to the enforcing agency.

For buildings and structures with an occupancy in Group H, separate floor plans shall be submitted identifying the locations of anticipated contents and processes so as to reflect the nature of each occupied portion of every building and structure.

Design Compliance Methods, Cont.

- **IFC, Chapter 22 Scope:**
  - The equipment, processes, and operations involving dust explosion hazards shall comply with the provisions of [IFC] and NFPA 652. In addition, the following shall be considered:
    - *Permitting*
    - *Owner Responsibility*
    - *Dust Hazard Analysis (DHA)*
    - *Sources of Ignition*
    - *Housekeeping*
    - *Implementation of Specific Hazard Standards*

Performance Based Design Requirements

- **The following must be considered in addition to the IFC requirements per NFPA 652:**
  - General Requirements
    - Approved Qualifications
    - Documentation Requirements
    - Sources of Data
    - Maintenance of Design Features
  - Risk Component and Acceptability
  - Performance Criteria
    - Life Safety
    - Structural Integrity
    - Mission Continuity
    - Mitigation of Fire Spread and Explosions
    - Effects of Explosions
  - Design Scenarios
    - Fire Scenarios
    - Explosion Scenarios
  - Evaluation of Proposed Design
  - Retained Prescriptive Requirements

What Code Changes Can We Expect?

- **International Fire Code (IFC), 2018 Edition**
  - *Combustible Dust-Producing Operations (CH. 22)*
    - Group H occupancy no longer required for controlled combustible dust hazards.
      - Information found in commentary.
      - Indicated to clarify ICC position.

apparatus to determine the hazard class of a dust. The results of such tests were reported for common dusts by P. Field in his book *Dust Explosions*, which describes, in tabular form, the explosion data for selected combustible dusts. In each column, values of the table are derived experimentally using a special explosion apparatus. For each property, values are presented to fully describe the explosion characteristics of the given material. Dust hazard classes are expressed as ST-1 through ST-3, with ST-1 being the highest hazard, as portrayed in *The SFPE Handbook of Fire Protection Engineering*.

During the drafting of the code, combustible dust was not included in Table 5003.1.1(1) because of the inherent difficulty in establishing a maximum allowable quantity (MAQ), and for determining if and when the MAQ had been exceeded. An occupancy with an uncontrolled combustible dust hazard is classified in Group H-2 in accordance with Section 307.4 of the *International Building Code*® (IBC®), with the exception of certain woodworking uses classified as Group F-1. Many spaces with uncontrolled combustible dust hazards should be classified in Group H-2. However, others may fall into Group F or S, depending on the specifics of the process and the safety controls provided for the process. Accordingly, beginning in the 2012 edition of the code, a new row in Table 5003.1.1(1) added combustible dust to the MAQ table, so the code user would not miss this important hazard category. Note q directs the code user to pertinent sections in this code and the IBC to determine if a dust hazard exists by an engineering evaluation. The content of Note q is also included in IBC Section 307.4. This approach places the responsibility on the building owner to determine whether a dust hazard exists. Modifications to Chapter 22 of this code and Section 426 of the IBC now require any recognized combustible dust hazard to be controlled, whether new or existing. As a result, the requirement to classify as a Group H-2 occupancy will no longer be applicable to new construction and will eventually be eliminated in existing occupancies as they are brought into compliance with these requirements.

Purpose

Awareness and knowledge of the hazards of dusts and powders are less common than of flammable liquids and gases; however, explosions and fires involving dusts and powders are just as hazardous in many industrial settings. The requirements of this chapter seek to reduce the likelihood of dust explosions by managing the hazards of suspensions of ignitable dusts. Ignition source control and good housekeeping practices in occupancies containing dust-producing operations are emphasized.

2021 IFC Code Changes

IFC, Chapter 22 Scope:

- **Scope**
- **Permitting**
- **Dust Explosion Prevention**
  - Critical Depth Layer
  - Dust producing and handling equipment
  - Dust collection and conveying systems
  - Standard operational procedures
  - Emergency Response Plan
  - Training
- **Dust Explosion Screening Tests**
  - Combustibility and explosivity tests per NFPA 652
  - Sample criteria
- ~~**Owner Responsibility**~~
- ~~**Sources of Ignition**~~
  - Moved to dust explosion prevention
- ~~**Housekeeping**~~
  - Moved to dust explosion prevention
- **Implementation of Specific Hazard Standards**
  - Dust Hazard Analysis (DHA)

KEY CONSIDERATIONS

Key Considerations

Obstacles with leased facilities

- **Potential Stakeholders:**
  - Department of Energy (DOE)
  - NNSA
  - Field Office
  - Government Services Agency (GSA)
  - Land Owners
  - Insurance Company
  - Property Management Company
  - Building Code Authority/Officials
  - First Responders
  - Design Contractors
  - ITM Contractors
  - Management/Operating Organization

- **Design Considerations:**
  - Locally Adopted Codes and Standards
  - DOE Codes and Standards
  - Owner Insurance Standards
  - Etc.

Why Such a Demand for Industry Growth?

- **Quality**
  - Inert atmosphere reduces probability of oxidation.
  - Allows for product to meet specified particulate sizes.
- **Research and Development Production Increases**
  - Current AM production is slow and occurs on a per-part basis.
  - The future of AM may include modular units to increase production speed.
    - This could involve multiple lasers of different settings and could increase the size of units.
- **Reduced Waste**
  - Parts with complex geometries can be created with little waste.
  - Unused material is sieved and returned to process if quality standards are met.
- **Product Quantity**
  - Raw material quantities are reduced as waste is reduced.

QUESTIONS?

EMAIL: ZPARKS@KCNSC.DOE.GOV