

# Understanding the Fire and Explosion Hazards Associated with Additive Manufacturing Processes

Jason Reason, CIH, CSP, CHMM  
Director of Combustible Dust Services

# Jason Reason, CIH, CSP, CHMM

- ▶ 12.5 years as OSHA Compliance Officer
- ▶ Performed hundreds of DHAs and Design Reviews for AM operations
- ▶ Worked with several printer and AM equipment manufacturers to mitigate dust hazards
- ▶ Assisted in developing existing and new AM requirements for NFPA 660, NFPA 484, and 2021 IFC
- ▶ 2019 ASSP Fire Practice Specialty Safety Professional of the Year

# Jason Reason, CIH, CSP, CHMM

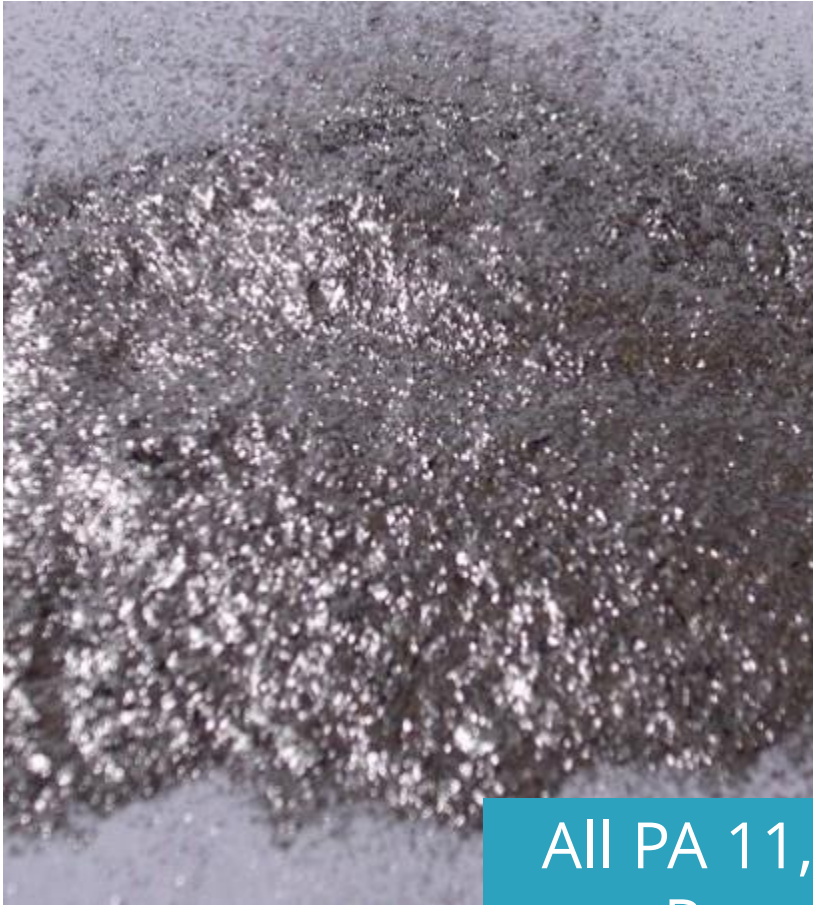
- ▶ NFPA Technical Committees
  - Chair of Committee for Wood & Cellulosic Materials (**NFPA 664**)
  - Committee for Fundamentals of Combustible Dusts (**NFPA 652**)
  - Committee for Combustible Metals and Metal Dusts (**NFPA 484**) – **AM Task Group Chair**
  - Committee for Handling & Conveying of Dusts, Vapors and Gases (**NFPA 91, 654 & 655**)
  - Correlating Committee for Combustible Dusts (**Over all NFPA combustible dust committees**)

# Beware of Safety Data Sheets!

- ▶ ~~Flammable Solid~~
- ▶ ~~Water Reactive Material~~
- ▶ Hydrogen Gas Generation
- ▶ SDSs should not be sole source to determine hazards



# AM Combustible Dusts/Powders



All PA 11, PA 12, and Other Plastic/Nylon Powders are Combustible Dusts

# Reactive Metal Alloy Powders

- ▶ Titanium (Ti64, Ti6242)
- ▶ Aluminum (AlSi10mg, F357)
- ▶ Iron (Carbon and Galvanized Steel)
- ▶ Zirconium
- ▶ Tantalum
- ▶ Niobium
- ▶ Magnesium

# Non-Reactive Metal Alloy Powders

- ▶ Copper
- ▶ Cobalt-Chrome
- ▶ Maraging Steel
- ▶ Stainless Steel 304/316
- ▶ Inconel 625/718

# AM Dust/Powder Equipment

- ▶ 3D Powder Printers
- ▶ Powder Conveying/Recovery Systems
- ▶ Vibratory Sieves
- ▶ Downdraft Benches/Tables
- ▶ Inert Gas Systems
- ▶ Gloveboxes
- ▶ Depowdering Units
- ▶ Immersion Separation Vacuums
- ▶ Furnaces
- ▶ Wire EDMs, CNC Machines, Bandsaws, etc.



# Ancillary Dust/Powder Equipment

- ▶ Grinders, Buffers, Polishers
- ▶ Abrasive Blast Cabinets
- ▶ Wood Shops
- ▶ Cold Spray
- ▶ Plastic Regrind
- ▶ Metal or Plastic Powder Production/Formulation

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- ▶ Thermite mixtures and exothermic reaction between a metal and metal oxide

**DO ANY STANDARDS  
ADDRESS AM COMBUSTIBLE  
DUST HAZARDS?**

# NFPA 484-2022

- ▶ Effective date September 15, 2021
- ▶ Scope
  - Production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion
  - Exceptions for labs using less than 2.0-pounds and industrial facilities using less than 5.0-pounds
- ▶ Legacy Metals (Chapter 17) vs. Other Metals (Chapter 18)

# Additive Manufacturing (Chapter 15)

- ▶ Extensive equipment and personnel electrostatic bonding and grounding
- ▶ Emergency AM equipment local and remote shutdown systems
- ▶ MAQ determination and storing powders
- ▶ Powder transfer and sieving
- ▶ 3D printers (powder bed and powder spray)
- ▶ Part extraction and post-processing
- ▶ Condensate filters

**All requirements are retroactive**

# 2021 IFC – Section 320 (AM)

- ▶ Industrial vs. Nonindustrial AM
- ▶ Operational permit
- ▶ Listing and labeling of all 3D printers
- ▶ Meet applicable Chapter 22 requirements
- ▶ Requires compliance with NFPA 484 (metals) and 654 (nonmetallic)
- ▶ Performance-based design alternatives



# Who Enforces NFPA 652 and 484?

1. Building Code Officials
2. Fire Marshals
3. Insurance Carriers
4. OSHA

# AM Combustible Dust Hazard Mitigation Process



# AM Building Design Considerations

1. Building Occupancy Classification
2. Powder Storage MAQs
3. Electrical Area Classification
4. Equipment and Personnel Electrostatic Bonding and Grounding
5. Water-based vs. clean agent fire suppression systems
6. Oxygen and LEL monitors
7. Waste inert gas ventilation systems

# Are DHAs Required for AM Facilities?

- ▶ Both NFPA 652-2019 (7.1.2) and 2018 IFC (2203.2) require DHA to be performed at any facility with combustible dusts/powders
- ▶ NFPA 484-2022 (7.2.1) also requires DHA and 15.2.1 requires DHA to include all AM equipment
- ▶ DHA requirement is retroactive in NFPA 652 and NFPA 484
- ▶ **DHA is required to be performed by a qualified person**

**DO NOT rely on equipment manufacturer assessments!**

**DHA shall determine...**

**Determined by the DHA...**

# AM-DHA Process

Review of Building Design and  
Submit Documentation

Gather Information from  
Equipment Manufacturers

Issue Building Design Report for  
Building/Fire Code Officials

Onsite Visit to Evaluate Existing  
Equipment/Building Controls

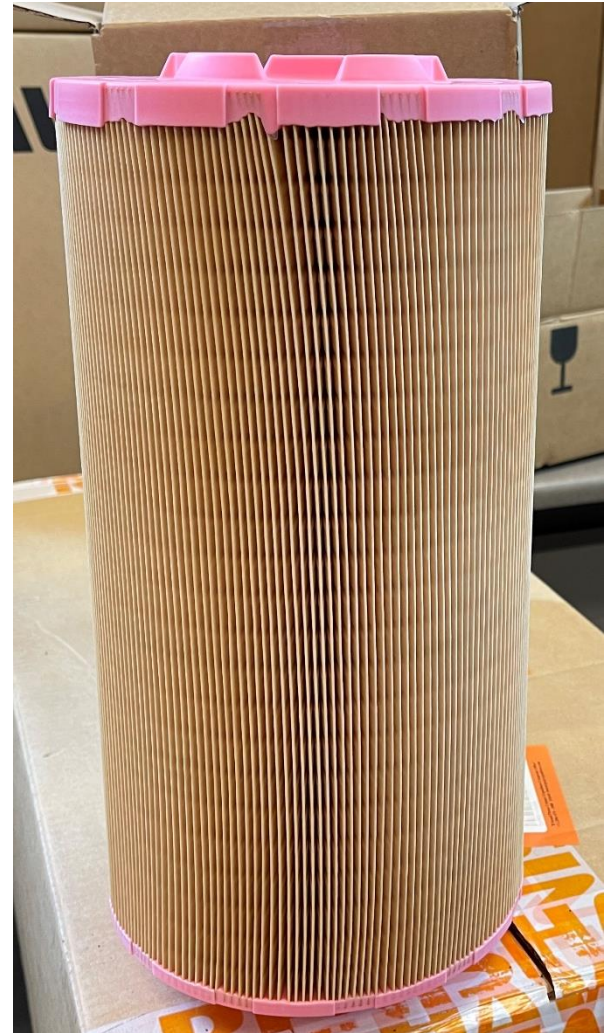
Issue DHA Report and Revise  
Based on Comments

# Anatomy of Effective AM-DHA

- ▶ All AM Equipment
- ▶ Metal Condensate
- ▶ Dust Collection Systems
- ▶ Inert Gas Systems
- ▶ Ignition Sources
- ▶ Sensors & Interlocks
- ▶ Powder Transfer
- ▶ Part Extraction
- ▶ Electrical Classification
- ▶ Preventative Maintenance
- ▶ Housekeeping
- ▶ Powder Storage
- ▶ Vacuum Cleaners
- ▶ EHS Programs/Training
- ▶ Waste Disposal
- ▶ Dust Testing

# Metal Condensate

- ▶ Over 40 spontaneous flash fires or smoldering incidents in 4 years
- ▶ Majority of flash fires occur from air or dry passivation
- ▶ Generally done in non-inert atmosphere
- ▶ NFPA 2112 FRGs required
- ▶ “Lifetime filters”





# Additional EHS Hazards

- ▶ Hybrid mixtures from binder jetting 3D printing
- ▶ Personnel exposure to dusts/powders
- ▶ Asphyxiation from inert gases
- ▶ Lockout/Tagout (LOTO)
- ▶ Laser radiation
- ▶ Electrical shocks and arc flashes
- ▶ Condensate filter/powder and other waste disposal

# NFPA 660 and Future of AM Dust Standards

- ▶ Maximum allowable storage quantities (MAQs) for metal powders
- ▶ Limitations on dry and air passivation of condensate filters
- ▶ Stricter requirements for AM-DHA qualified person
- ▶ Additional requirements for obtaining OEM information for AM-DHA
- ▶ NFPA Standard Dedicated to AM???

# AM Combustible Dust Actions

1. Do not use SDSs, testing data, or equipment manufacturer assessments as only sources for determining hazards or controls
2. Perform a DHA by an independent qualified person with documented AM expertise
3. Work with this person and equipment manufacturers to implement DHA recommendations
4. Use MOC and update DHA as conditions change

# Questions???

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