1. Introduction

Metal powders—including aluminum, titanium, magnesium, zinc, iron, cobalt, and specialized metal alloys—play a critical role in advanced research, additive manufacturing, energetic materials development, and materials science. However, their small particle size, high surface area, and reactive nature create a unique combination of fire, explosion, toxicity, and environmental hazards. These risks are amplified during physical processes such as weighing, transferring, mixing, milling, or acoustic agitation.

2. Purpose

This guideline establishes standardized safety practices for laboratory personnel handling metal powders, regardless of equipment type (e.g., acoustic mixers, blenders, shakers, metal 3D printers, or manual handling). It incorporates best practices from NFPA 484 (Combustible Metals), OSHA Hazard Communication, and general laboratory safety principles. All personnel working with metal powders must strictly follow these procedures to prevent injury, property damage, or uncontrolled reactive events.

3. Scope

This SOP applies to all laboratory personnel engaged in research involving metal powders on KSU-owned, leased, or operated facilities.

4. Responsibilities

- **Laboratory Personnel:** Follow all steps in this SOP, wear required PPE, and report incidents.
- **Principal Investigator (PI):** Ensure compliance, verify training, and approve experimental plans.
- **Environmental Health & Safety (EHS):** Provide training, review SOP annually, and audit compliance

5. Definitions

- **Combustible Metal Powder**: Finely divided metal particles capable of ignition or explosion when dispersed in air.

6. Procedure

A. Identification of Hazards

1.1 Combustible Dust & Explosion Risk

Fine particles of many metals (e.g., magnesium, aluminum, titanium, zinc) can ignite or explode when dispersed in air. Dust clouds can deflagrate inside vessels or in the open

environment. High-energy equipment, such as acoustic mixers, can increase dispersion and heating.

1.2 Fire Hazards

Reactive metals (Mg, Ti, Zr) ignite easily under friction, impact, or heat. Metal fires burn at extremely high temperatures and **cannot be extinguished with water**.

1.3 Static Electricity

Dry powders accumulate electrostatic charge that can spark ignition.
Mixing, pouring, or transferring powders significantly increases charge generation.
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1.4 Health Hazards

Inhalation of ultrafine metal particles can cause serious health effects including:

- Metal fume fever (e.g., zinc)
- Chronic lung damage (aluminum, cobalt, nickel)
- Sensitization or carcinogenic effects (chromium, nickel)
- Skin or eye contact may cause irritation or long-term effects

1.5 Chemical Reactivity

Some metal powders react violently with.

- Moisture
- Strong oxidizers
- Acids or halogens
- Organic binders
- Other incompatible metal powders

Hazard/Risk Assessment Table

Hazard	Likelihood	Severity	Risk Level
Dust Explosion (Mg, Ti)	Likely	Catastrophic	High
Fire from ignition source	Possible	Major	High
Static discharge ignition	Possible	Major	High
Inhalation of fine powders	Likely	Moderate	Medium
Chemical reactivity	Possible	Moderate	Medium
Vessel over pressurization	Unlikely	Major	Medium

B. Personnel Qualification

Only trained laboratory personnel may handle metal powders. Required competencies include:

- Understanding of combustible metal and dust hazards

- Knowledge of equipment used for mixing or processing (e.g., acoustic mixers, milling units)
- Emergency response procedures for metal fires, spills, and exposure incidents
- Documented proficiency with laboratory SOPs for powder handling, purging, and cleaning
- Personnel must complete hazard-specific training, including annual refresher sessions.

C. Control Measures

1.1. Engineering Controls

- Use sealed, mechanically sound mixing or processing vessels.
- Where possible, purge with inert gas (nitrogen or argon) before initiating operations.
- Install active temperature monitoring on mixing equipment.
- Use explosion-proof electrical systems and proper equipment grounding.
- Conduct powder weighing and transfer in a fume hood, glovebox, or enclosed HEPA-filtered containment system.

1.2. Administrative Controls

- Implement written SOPs for powder handling, inert gas purging, and decontamination.
- Complete hazard assessments per NFPA 484.
- Establish access control—restrict powder-handling operations to authorized personnel.
- Avoid ignition sources: open flames, hot surfaces, incompatible electrical devices.
- Post signage indicating combustible metal use.
- Establish strict housekeeping: no powder accumulation on surfaces.

1.3. Personal Protective Equipment (PPE)

The following PPE are required when working with metal powder, as a minimum:

- Respiratory protection: P100 or equivalent for powder handling. Higher level of respiratory protection may be required in certain operations such as metal 3D printing processes.
- Eye protection: Safety goggles or full-face shield.
- Body protection: Flame-resistant lab coat, long pants, closed-toe shoes.
- Gloves: Nitrile, neoprene, or other compatible materials.

Additional PPE may be required for reactive metals or high-energy operations.

D. Training Requirements

KSU employees or student working with or exposed to the hazards of metal powered should receive the appropriate level of training. This includes:

1.1. Initial Training

- Combustible metal and dust hazards
- Proper operation, shutdown, and emergency stop of mixers
- Understanding inert gas purging systems
- PPE usage and contamination control
- Fire extinguisher use—Class D extinguishers only

1.2. Annual Refresher Training

- SOP updates
- Emergency drills (fire, spill, exposure)
- Review of incident trends and corrective actions

E. Waste Management

Metal powder waste must be handled carefully to prevent metal fires or invalid chemical reactions.

- Collect residual powders using a HEPA-filtered explosion-proof vacuum or wet cleaning method with a non-reactive fluid.
- Never sweep or dry-wipe powders.
- Store waste in sealed, clearly labeled containers.
- Do not mix incompatible metal powders in waste containers.
- Contact EHS for dispose of metal powder waste through the university's hazardous waste protocols. Never dispose metal powder waste in general trash.

F. Incident Reporting

All safety incidents must be documented and reported immediately through the university's incident reporting process.

- Report fires, spills, equipment failures, and near-misses to the Lab Manager and EHS.
- Complete an incident report within 24 hours.
- EHS will lead investigation to identify the root cause and make recommendation for appropriate corrective actions.

G. Emergency Preparedness

- Maintain readily accessible Class D fire extinguishers.
- Never use water or CO_2 on metal fires (risk of violent reaction).
- Ensure emergency exits are unobstructed.
- Post emergency contact numbers prominently.

- For reactive metal fires, evacuate personnel and operate extinguishers from a safe distance.

H. Document Control

- This guideline will be reviewed annually by Environmental Health & Safety (EHS) and updated to reflect new hazards, equipment changes, or regulatory requirements.