Contents

Scope

This procedure covers safety and basic operating procedures required for access into the MAM Lab. These procedures will help ensure the following:

1. Minimize hazardous powder exposure due to inhalation or skin, eye, or mouth contact.
2. Metal powders never enter or leave the room in a way that can contaminate other building spaces.
3. Emphasizes safety awareness and controls to avoid injury or exposure to unhealthy substances or conditions.

All operations and maintenance procedures for the equipment in the Lab are covered in each specific tool's SOP (Standard Operating Procedure) and SMP (Standard Maintenance Procedures).

Lab cleaning, support equipment (vacuums, bins, supplies), and maintenance procedures are included in the MAM Lab SMP.

System Specifications:

The MAM Lab contains 3D metal printers, high temp furnaces, a downdraft table, support equipment, supplies, and hazardous printing materials. Specifications for each of the 3D printers are documented in their respective SOPs.

Safety

Introduction

The MAM Lab has a number of exposure risk areas; pyrophoric powders or fume particles, toxic powders or fume particles, laser energies, mechanical energies, inert gas asphyxiation and noise. Fume particles and very fine powders are of a size range that can deeply penetrate the lungs if inhaled. Additionally many of these fine particles are capable of translocating through skin or mucous membranes. These fine particles can stay suspended in the room's air for an extended time. Commonly printed alloys contain metals such as chromium and nickel which are identified as human cellular activity disruptors and also have the potential to cause cancer. Because of the nature of the materials processed in this lab, work activity safety protocols, engineering and administrative controls, and personal protective equipment are critical to prevent toxic metal powder exposure and contamination of spaces inside and outside of the lab.

The following situations are not allowed in the MAM Lab:

1. Food or beverages.
2. Disturbing or handling of powder without correct Personal Protective Equipment (PPE).
3. Violating safety interlocks (mechanical controls) on tools, unless following a documented service procedure, pre-approved by the manufacturer.

Use the provided stainless steel carts whenever moving heavy parts or powder containers in and out of a printer, furnace or the downdraft table. Lighter parts that have not been thoroughly vacuumed clean must be carried in at least a closed-lid tub to the downdraft table for further cleaning. Powder containers must always be securely closed unless actively in the process of transferring power.

Always wipe down the vacuum cleaner hose end and attachments, carts and any tubs after use and return them to their standard locations so that the next person can use them. Roll-up and immediately dispose of powder contaminated wipes in provided bins (plastic buckets with hole in lid).

General Lab Safety

If you hear the oxygen deficiency sensor alarming

Step	If	Then	Notes
1	You hear the oxygen deficiency alarm.	1. Exit the room, immediately. 2. Call emergency contacts – see list posted near the door. 3. Barricade the entrance so nobody can enter. 4. Keep the doors closed. 5. **Do not re-enter the room**, even if the alarm has stopped. Wait until emergency contact arrives to assess the situation. 6. Carefully remove any PPE's and store them in a black plastic bag by the door.	Barricades will be placed near the door in a labeled location.

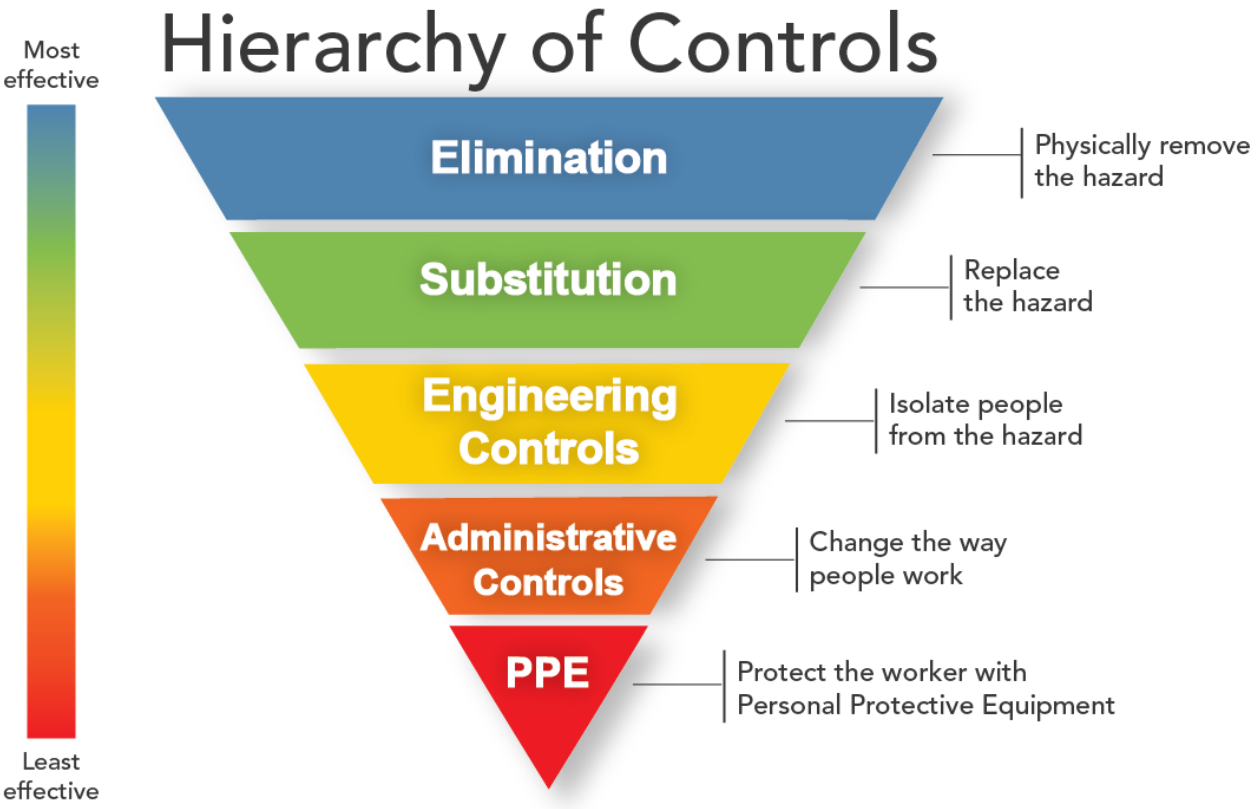
If you see any clouds of fume or particles, or piles of powder/particles of unknown origin

Step	If	Then	Notes
1	You see any clouds of particles or fume in the room.	1. Push the red Emergency Stop button on the involved tool. 2. Exit the room, immediately and close the doors behind you to contain the particles and any potential explosion. 3. Call emergency contacts – see list posted near the door. 4. Barricade the entrance so nobody can enter. 5. **Do not re-enter the room**. Wait until emergency contact arrives to assess the situation. 6. Carefully remove any PPE's and store them in a black plastic bag by the door	Barricades will be placed near the door in a labeled location.
2	If you see a pile of powder particles of unknown origin.	1. Assume it is hazardous and leave it in place. 2. Exit the room and carefully remove PPE per standard procedures. 3. Barricade the entrance so nobody can enter. 4. Call the MAM Lab emergency contact for a cleanup.	

Hierarchy of Controls (adapted from https://ehs.oregonstate.edu/respiratory-protection-program)

The Hierarchy of Controls approach is used to safeguard facility users while working around agents that may potentially cause unnecessary exposure. If possible, product Elimination or Substitution should be implemented first. If this is not possible, use of local Engineering Controls such as interlocks, mechanical exclusion, fume hoods or local capture systems are the next most effective and efficient means of protecting users from potential hazards found in the MAM Lab. Administrative Controls can help in protecting individuals by reassessing the task and procedures to see if exposure can be minimized or eliminated, if this can't be done then look at the possibility of job rotation to reduce the exposure time of any one person to keep below acceptable exposure levels for those activities. Lastly, when the first four methods are not feasible or cannot provide adequate protection, Personal Protective Equipment (PPE) such as respiratory protection equipment is often required.

In a correctly designed work situation PPE's would not be needed for normal operation, their main purpose would be as a fail-safe if other controls somehow failed (or that adequate controls would make the work impossibly difficult to accomplish). PPE's are never an acceptable operational substitute for the other four implementable control methods.



See the **NIOSH 2020 3D Printing with Metal Powder – Health and Safety Questions to Ask** document (it is also included at the end of this SOP) for more information on how these controls specifically apply to metal powder printing.

Personal Protective Equipment (PPE) Requirements

PPE is required anytime you are working in the room (using equipment, cleaning,..):

1. Safety glasses (as is standard in all ATAMI labs) if working on any tools.
2. Nitrile gloves when there is any possibility of contacting powder in the lab.
3. Laser-safe goggles or other approved bright light attenuating glasses, goggles or face shield, if observing laser melting through the tools laser-safe window for periods longer than a few minutes – these tool laser-safe windows protect our eyes from the laser energy wavelengths, but not necessarily for long, bright light energy exposures in our visible spectrum.

Lab coats are recommended, but not required. Contact OSU EH&S to request a lab coat.

Additional PPE requirements for any activity that involves disturbing or handling powder. Examples of activities that involve disturbing or handling powder include; loading or transferring powder, cleaning the print chamber of a 3D printer, removing and moving build parts that can shed power particles, and cleaning build parts in the downdraft table. Anyone within 6 feet (2 meters) of this type of activity is required to wear the same level of PPE's, specifically:

1. Full Tyvek bunny suit gowns.
2. Nitrile gloves. If handling parts with sharp or rough areas, use double gloves in case an outer glove gets torn.
3. PAPR respirator with P100 rated cartridge (such as the provided 3M Versaflo™). All PAPR users must be fully trained and certified by OSU EH&S - see Training Requirements section.

Hazardous Energies

Electrical and Laser

There is potential for electrical and laser hazard exposures during equipment maintenance. All tool specific maintenance safety protocols must be followed to avoid hazardous electrical and laser situations. Use the appropriate electrical lockout (lock-out tag-out hasps and padlocks) on any open tool electrical cabinet during maintenance.

Mechanical

The following pinch and sharp surface hazards are present in the lab and all lab users should use caution when handling or operating associated equipment:

1. Heavy build plates for ProX 300 printer.
2. Moving plates and parts in and out of the 3D printing equipment.

Stored/Potential

Compressed gases are present in laboratory piping, gas cylinders, and equipment. All OSU-standard gas hazard and cylinder procedures must be followed to prevent injury. Medium (40-80 psig) pressure gas lines are connected to the printers and furnaces, take care when connecting and disconnecting lines.

The tamping plate in the ProX 300 presents injury risk if the building compressed air is turned off and the "drop-lock" fails. Refer to ProX 300 specific procedures before exposing body parts to this hazard – it is best to first lower the tamping plate if working inside the ProX 300's open print chamber.

Thermal

The sintering/annealing ovens can reach high temperatures thus operation protocols must be strictly followed to avoid burns and fires. Formal training and process approvals are required before using the sintering/annealing furnaces to reduce these risks.

Risk of particle fires/explosions requires the following protocols:

1. Avoid all situations where powder is ever loose (not enclosed in storage container and) outside of printer build chamber or the downdraft table.
2. Follow all cleaning and operational protocols to avoid the build-up of any fume and metal particles inside powder printers.
3. Be meticulous about immediately cleaning up any powder spills outside of printing chambers. Uncontained powders can settle and accumulate on surfaces to a level where they present a dust explosion risk.

Materials/Consumables Hazards

Touching, inhaling or ingesting metal particles (powder & fume) is hazardous. Read the SDS for each powder and wear the appropriate PPE's before handling. Always keep the MAM Lab clean and free of any powder by using the Ruwac vacuum for cleaning inside and outside MAM Lab tools – **never blow, brush or sweep powder particles in the open lab space**.

If activities require getting powder on gloved hands use the Ruwac vacuum with the brush attachment to immediately vacuum off the powder-exposed glove areas. Do this often to minimize the transfer of powder. Never touch a clean surface with dirty gloves – if fine fume particles are involved, use an isopropyl alcohol dampened wipe to remove any remaining particles after vacuuming gloves. Immediately roll-up and dispose of particle contaminated wipes and place them in one of the three designated waste bin.

When adding powder, excavating builds or cleaning-up powder in a printer, use the Ruwac to capture any airborne powder that may occur due to disturbing loose powder in the print chamber or on the build plate. Always clean printer build chambers from the top-outside toward the bottom-inside to minimize the transfer of fine particles to gloves and gown sleeves – clean above the built part/s BEFORE cleaning and removing the printed parts. Take care in ensuring that gown sleeves don't get contaminated with powder and fume particles while reaching inside build chambers (forward walls should have already

been thoroughly cleaned before reaching deep inside printer). Any particles that do get on the sleeves should be immediately vacuumed off with the Ruwac brush attachment. If sleeves or other gown areas accidently become contaminated with fume or particles, roll-up and dispose of gowns to minimize transfer of these particles.

Vacuum and wipe-down (isopropyl alcohol dampened wipe) all tools and equipment that may have been exposed to powder before leaving the work area.

If you are considering a new powder or chemical (or method), and it has not been previously approved for use in the MAM Lab, fill out a Nanomaterial and Powder process SOP Form (an Administrative Control) and submit to ATAMI staff for approval (preferably before acquiring any new material/s).

Follow each MAM Lab tool's SOP for specific powder and fume protocols.

Please see the OSU online SDS system for any needed SDS's at https://oregonstate.bioraft.com/raft/research_tools/SDS

Interlocks

There are numerous interlocks (Engineering Controls) on the 3D printers to protect against gas, powder, mechanical or laser caused injury**. Only qualified service personnel are authorized to bypassed interlocks while servicing the tools.** If users defeat any interlocks their access to the tool/s will be revoked until a follow up investigation is completed.

Training Requirements (in order)

1. Passed all ATAMI required safety training.
2. Passed all University required safety training.
3. Thoroughly read and understood the contents of this document.
4. Completed all hands-on training for the room and signed off training form.
5. Completed ATAMI MAM Lab specific tooling training, read and understood the tooling's SOP, and signed off training form.
6. Filled out the OSHA Respirator Medical Evaluation Questionnaire at https://ehs.oregonstate.edu/sites/ehs.oregonstate.edu/files/pdf/occsafety/respirator_user_medical_evaluation_questionnairefillable.pdf and send it in confidential mail to OSU Occupational Health – address /location can be found here (https://occupationalhealth.oregonstate.edu/contact-ohs).
7. Receive PAPR certification by EH&S - contact Kent Lanning , Kent.Lanning@oregonstate.edu, to schedule EH&S certification. Annual re-certification is required as needed.

Guest Access

1. Guests may enter the lab if accompanied at all times by ATAMI Staff or a trained user. Guests must follow the same safety procedures as lab users.
2. There may be specific exceptions for construction activities, supplier equipment repairs, or specific tours.

Procedures

Entrance and Gowning procedure for lab users

All procedures below must be completed in the specified order to avoid metal powder contamination.

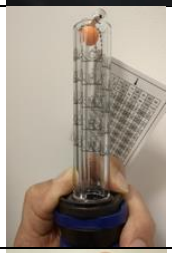
Step	Action	Notes
1	If you will be working on tools, don safety glasses (and lab coat as necessary).	

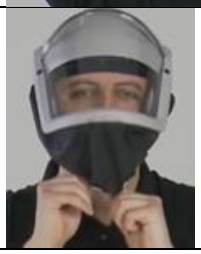
Donning gloves, Tyvek suit and PAPR respirator

Step	Action	Notes
1	Go to the Tyvek gown hanger rack.	**Steps for gowning must be followed in the order listed here to avoid transferring powder to clean surfaces.**
2	Hang your lab coat (if wearing one) on an open hanger to the left.	
3	Put on nitrile gloves.	If handling sharp powder laden parts, double glove.

4	Put your Tyvek gown on.	All people certified to use full PPE will have their own dedicated Tyvek gown and PAPR helmet. Pull the sleeves down over your gloves. Always carefully handle the bunny suit to avoid contaminating the inside surfaces.
5	Don the PAPR respirator as shown in the below instructions.	All PAPR respirator users are required to complete EH&S specific training and certification. If you are not certified and trained to use a PAPR respirator, you shall not use them.

Putting on the 3M Versaflo™ PAPR respirators

Step	Action	Notes
1	Get a battery from the battery table and verify charge. Test the battery charge by pressing the test button on the bottom of the battery.	
2	Connect the battery to one of the filter/blower assemblies	
3	Verify that a filter is installed in the air blower unit. 	**O**nly qualified lab users are allowed to change filters. If you suspect an issue with a filter or blower unit, contact ATAMI staff.
4	Put the powered blower belt around your waist, assuring a comfortable fit. Position the blower unit in the front for further testing.	Be careful not to let the blower unit slide off the belt and hit the floor.
5	Place the small end connection of the air hose into the outlet of the air blower unit and twist clockwise to lock in place. Then power-up the blower unit by pressing the blue button.	
6	Test the airflow by placing the floating ball meter into the free end of the air hose. Verify that the ball is at the top of the tube, per the reference card attached to the tube.	
7	Check that the in-use alarms are working by placing a hand over the outlet of the air hose The alarm should sound and the LED should flash after about 20-30 seconds. Turn unit off and on again by pressing the blue button	 If the unit doesn't test properly, do not use this unit and contact an ATAMI staff member.
8	Get your assigned helmet from the helmet cabinet. Ensure that it is clean and not contaminated by powder.	If the outside surfaces are contaminated by powder, they can be wiped down with the lab wipes and water. If the elastic cloth barrier or the inside surface is contaminated with powder, contact a qualified MAM Lab user for help.

9	Connect the free end of the air hose to the helmet as shown here – it should snap and lock into position.	
10	Rotate blower unit around to your back and place the helmet on your head with the visor raised. Adjust the head band knob to ensure a firm, comfortable fit.	
11	Lower the visor to the down position by pulling down gently on the cloth barrier shield until it is under the chin and is secure around the chin and tight to the face. This prevents particles from entering your breathing area, so be sure to adjust it properly.	 

Removing gloves, Tyvek suit and PAPR respirator

Step	Action	Notes
1	With cleaned or a fresh pair of nitrile gloves carefully remove your bunny suit and return it to its designated hanger location.	Always carefully handle the bunny suit to avoid contaminating the inside surfaces. If the bunny suit is heavily contaminated with powder, carefully roll it up to and place it in the trash bin.
2	Remove your nitrile gloves.	
3	Take off the PAPR by following the steps below	

Taking off the 3M Versaflo™ PAPR respirators

Step	Action	Notes
1	Make sure you removed your used gloves.	**Do this every time you remove the helmet.**
2	Raise the helmet visor, rotate the air blower to your front, remove the helmet and disconnect the air hose from the back of the helmet by squeezing the blue tabs inside the black ring.	Ensure that you DO NOT CONTAMINATE the inside of the helmet or the cloth shield.
3	Place the helmet in the assigned location in the helmet cabinet. Remove the air hose from the blower unit (twist counterclockwise and pull out) and then place it into the tub in the helmet cabinet.	
4	Turn off the blower unit (blue button) and carefully remove the blower unit and belt from your waist. Remove battery and place the blower unit in the storage cabinet.	Don't let the blower unit slide off of the belt and hit the floor.
5	Place the battery back on the charging station.	

How to Use the Downdraft Table

- Clean parts as much as possible in the printer with the RUWAC vacuum cleaner before moving to them to the downdraft table.
- After thoroughly vacuuming the built part and build plate, transport heavy pieces using the stainless steel carts – smaller pieces may be transported in small closed-lid tubs.
- Build plates can be heavy. Use caution to avoid pinching when handling heavy objects.

- Always use full PPE – Gloves, Tyvek gown and PAPR when handling or disturbing powder particles.
- Use caution when blowing-out printed parts inside the downdraft table. High pressure jets can cause particles to swirl outside of the confinement air curtain of the downdraft table's air envelope. Direct the blowing-out air streams down and to the back of the table while standing back at least 6" or 150 mm from downdraft table entrance – this allows proper air flow (isolation) between your body and the table.
- Always use the operating downdraft table for any powder transfer activities, such as transfers between containers or loose powder part excavation.
- All powder sieving must be completed inside the operational downdraft table.
- **Do not run the downdraft table when not needed**. Running the table for long, extended times will make the MAM Lab very humid.

Step	Action	Notes
1	Clean all parts as much as possible using the Ruwac vacuum cleaner before cleaning (blowing-out) in the downdraft table. The Ruwac vacuum can also be used to capture most of the blown-out particles while doing this work inside the downdraft table.	The downdraft table's purpose is to prevent exposure to airborne powder. Do not use it as a powder collector.
2	Use the stainless steel carts or small closed-lid tubs to transport parts to the downdraft table. DO NOT CARRY POWER CONTAINING PARTS ONLY BY HAND TO DOWNDRAFT OR ACROSS THE ROOM.	Un-cleaned parts should only contact the printer, the stainless steel carts (or small tubs) and the downdraft table. This procedure is intended to minimize spreading powder around the MAM Lab.
3	Check that the water valve to the table is open – handle in-line with pipe – photo shows valve in closed position.	
4	Turn on the downdraft table (and light). Make sure the Manual Fill switch is in the off position.	
5	Carefully clean the part toward the middle of the table's work area.	Ensure that particles do not escape the downdraft table's confinement envelope.
6	After cleaning, wipe down all surfaces with towels and water or alcohol. Roll-up and directly dispose of towels into bin (plastic barrels with round hole in lid).	Surfaces include: Build plates Cart surfaces (and/or small transport tubs) All table surfaces All tools (including the Ruwac hose and attachments).
7	Dispose of all extra metal parts into an appropriately labeled Ziploc®-type bag or solid waste container. Carefully zip or cap them so that any expelled air will be directed into the downdraft table area.	The downdraft table is not a long term storage location. If leaving parts (or powder containers) on the surface for follow up work, label them with your name and date – be considerate of other MAM Lab users and leave ample space for them to use the downdraft table.
8	After cleaning the table, cart, tub and parts, turn off the table, light and close the water valve.	

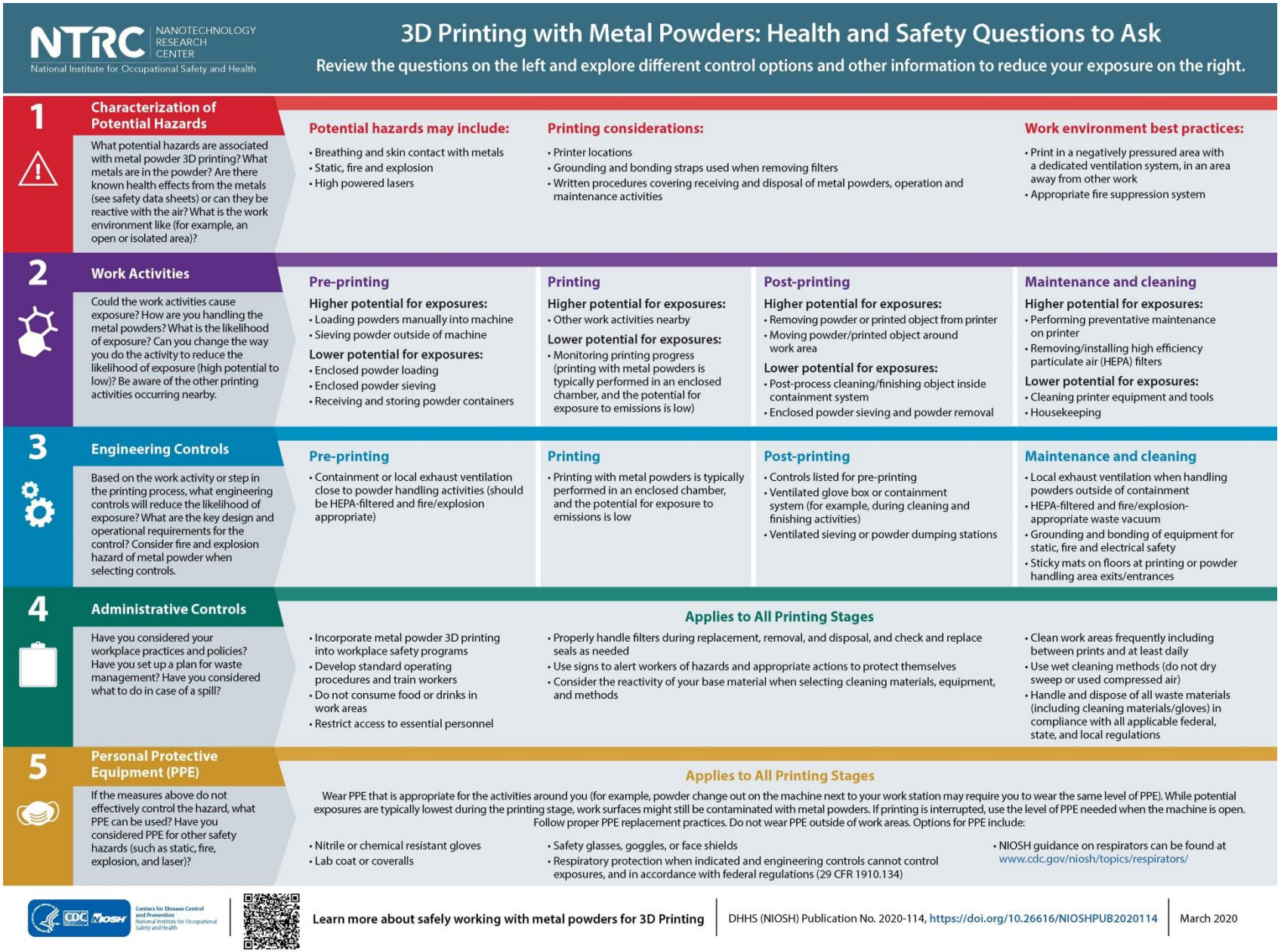
Other resources

3M Videos for how to use Versaflo™ PAPRs

Using the battery and filter unit.

Using the helmet.

Revision	Date	Description/Change	Curator
0	3/25/2019	New document	Randy Greb
1	5/6/2019	Added downdraft table procedures. Added safety cautions regarding using carts.	Randy Greb
2	6/26/2019	Typo updates, room access and training updates	Randy Greb
3	2/18/2020	Updated EHS contact name	Randy Greb
4	1/1/2021	Updated Training links to make this easier to read.	Randy Greb
5	11/30/2021	Updated gowning procedures, updated room entry procedures, COVID specific notes.	Randy Greb
6	9/20/2022	Updated text and links to reflect current procedures	Nick Wannenmacher
7	1/3/2023	Edits and updates	Nick Wannenmacher
8	11/30/2023	Edits and updates	Nick Wannenmacher



NTRC NANOTECHNOLOGY RESEARCH CENTER
National Institute for Occupational Safety and Health

3D Printing with Metal Powders: Health and Safety Questions to Ask

Review the questions on the left and explore different control options and other information to reduce your exposure on the right.

1 Characterization of Potential Hazards

What potential hazards are associated with metal powder 3D printing? What metals are in the powder? Are there known health effects from the metals (see safety data sheets) or can they be reactive with the air? What is the work environment like (for example, an open or isolated area)?

Potential hazards may include:

- Breathing and skin contact with metals
- Static, fire and explosion
- High powered lasers

Printing considerations:

- Printer locations
- Grounding and bonding straps used when removing filters
- Written procedures covering receiving and disposal of metal powders, operation and maintenance activities

Work environment best practices:

- Print in a negatively pressured area with a dedicated ventilation system, in an area away from other work
- Appropriate fire suppression system

2 Work Activities

Could the work activities cause exposure? How are you handling the metal powders? What is the likelihood of exposure? Can you change the way you do the activity to reduce the likelihood of exposure (high potential to low)? Be aware of the other printing activities occurring nearby.

Pre-printing

Higher potential for exposures:

- Loading powders manually into machine
- Sieving powder outside of machine

Lower potential for exposures:

- Enclosed powder loading
- Enclosed powder sieving
- Receiving and storing powder containers

Printing

Higher potential for exposures:

- Other work activities nearby

Lower potential for exposures:

- Monitoring printing progress (printing with metal powders is typically performed in an enclosed chamber, and the potential for exposure to emissions is low)

Post-printing

Higher potential for exposures:

- Removing powder or printed object from printer
- Moving powder/printed object around work area

Lower potential for exposures:

- Post-process cleaning/finishing object inside containment system
- Enclosed powder sieving and powder removal

Maintenance and cleaning

Higher potential for exposures:

- Performing preventative maintenance on printer
- Removing/installing high efficiency particulate air (HEPA) filters

Lower potential for exposures:

- Cleaning printer equipment and tools
- Housekeeping

3 Engineering Controls

Based on the work activity or step in the printing process, what engineering controls will reduce the likelihood of exposure? What are the key design and operational requirements for the control? Consider fire and explosion hazard of metal powder when selecting controls.

Pre-printing

- Containment or local exhaust ventilation close to powder handling activities (should be HEPA-filtered and fire/explosion appropriate)

Printing

- Printing with metal powders is typically performed in an enclosed chamber, and the potential for exposure to emissions is low

Post-printing

- Controls listed for pre-printing
- Ventilated glove box or containment system (for example, during cleaning and finishing activities)
- Ventilated sieving or powder dumping stations

Maintenance and cleaning

- Local exhaust ventilation when handling powders outside of containment
- HEPA-filtered and fire/explosion-appropriate waste vacuum
- Grounding and bonding of equipment for static, fire and electrical safety
- Sticky mats on floors at printing or powder handling area exits/entrances

4 Administrative Controls

Have you considered your workplace practices and policies? Have you set up a plan for waste management? Have you considered what to do in case of a spill?

Applies to All Printing Stages

- Incorporate metal powder 3D printing into workplace safety programs
- Develop standard operating procedures and train workers
- Do not consume food or drinks in work areas
- Restrict access to essential personnel
- Properly handle filters during replacement, removal, and disposal, and check and replace seals as needed
- Use signs to alert workers of hazards and appropriate actions to protect themselves
- Consider the reactivity of your base material when selecting cleaning materials, equipment, and methods
- Clean work areas frequently including between prints and at least daily
- Use wet cleaning methods (do not dry sweep or used compressed air)
- Handle and dispose of all waste materials (including cleaning materials/gloves) in compliance with all applicable federal, state, and local regulations

5 Personal Protective Equipment (PPE)

If the measures above do not effectively control the hazard, what PPE can be used? Have you considered PPE for other safety hazards (such as static, fire, explosion, and laser)?

Applies to All Printing Stages

Wear PPE that is appropriate for the activities around you (for example, powder change out on the machine next to your work station may require you to wear the same level of PPE). While potential exposures are typically lowest during the printing stage, work surfaces might still be contaminated with metal powders. If printing is interrupted, use the level of PPE needed when the machine is open. Follow proper PPE replacement practices. Do not wear PPE outside of work areas. Options for PPE include:

- Nitrile or chemical resistant gloves
- Lab coat or coveralls
- Safety glasses, goggles, or face shields
- Respiratory protection when indicated and engineering controls cannot control exposures, and in accordance with federal regulations (29 CFR 1910.134)
- NIOSH guidance on respirators can be found at www.cdc.gov/niosh/topics/respirators/

CDC NIOSH Centers for Disease Control and Prevention National Institute for Occupational Safety and Health

Learn more about safely working with metal powders for 3D Printing

DHHS (NIOSH) Publication No. 2020-114, https://doi.org/10.26616/NIOSHPUB2020114 | March 2020