IOWA STATE UNIVERSITY

Department of Agricultural and Biosystems Engineering (ABE)

TSM 416 Technology Capstone Project

Pyrophoric Waste Disposal

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1 PROBLEM STATEMENT

Problem Statement

Ames Laboratory is a National Laboratory operated by Iowa State University on behalf of the U.S. Department of Energy. They are dedicated to creating materials, inspiring minds to solve problems and addressing global challenges. Sarah Morris-Benavides, Matthew Besser and Roger Rink contacted Iowa State University's ABE Department to find dedicated students to help them with their problems surrounding their gloveboxes, furnaces, and arc melter. The problem that Ames Laboratory faces is safely cleaning and removing hazardous, often pyrophoric, waste materials from the machines. The purpose of this project is to purchase/fabricate equipment and/or create a procedure to clean the gloveboxes, furnaces and arc melter in a safe manner. One unknown surrounding this issue was whether or not our solution will involve fabrication and/or a procedure. Our job was to narrow down the scope and provide the best solution for Ames Laboratory. By doing so, not only will these machines be clean, but the laboratory will have standardized instructions for safe and effective glovebox waste removal.

Business Case Statement

Each researcher working with potentially hazardous materials in gloveboxes had general guidelines that they would follow, but there was no standardized procedure for any of them to work with. This posed potential safety risks due to uncertainty about the best way to dispose of pyrophoric materials. Cleaning primarily relied upon the judgment of each person to determine the best method of cleaning. Ames Lab ES&H was determined to improve this activity, giving us the perfect opportunity to help the overall safety within the laboratory.

2 Main Objective

Without a set procedure, there are concerns among some of the researchers and the ES&H department about safety. Our group then created a best practices document to effectively clean the machines in a safe manner. Improvement can be measured based on the satisfaction of the researchers and the ES&H department. If the machines are cleaned to their standards and the potential for incidents has been minimized, then our goal has been achieved.

- **Main Objective(s) and Specific Objectives**

Our main objective is to develop guidelines for cleaning procedures for gloveboxes, furnaces, and the arc melter. This will allow for the development of a standardized set of instructions to safely and effectively remove potentially hazardous waste from the interior of the lab equipment.

  - **Specific objectives include:**

- Purchase or fabricate cleaning equipment adjusted during the project.
- Determining procedural changes would be the best path forward.
- Design a Best Practices Guide that summarizes the results of our research.
- Design a Reference Guide that concisely displays our recommendations.

  - **Criteria:**

Completed project must deliver procedures or recommended equipment for laboratory personnel to use that will allow for cleaning chambers without incident, damage to the equipment, and at an implementation cost of less than $1000.

- **Rationale**

The goal of this project is to reduce the risk of incidents and the potential for injuries. This will be accomplished through the standardization of general procedures, identification or acceptable qualifications for tools and materials, and dialogue with other laboratories. This project should allow researchers to more easily train student personnel and provide a reference for the creation of SOPs.

- **Project Scope**

As students, it is difficult for us to fully understand the entirety of the research taking place at Ames Laboratory. We need to create a guideline that is generic enough that it would work in most circumstances yet specific enough to be used as a basis for specific SOPs. This best-practices guideline will specifically address personnel that has or will have the authorization to use gloveboxes, furnaces, and the arc melter. Other parts of the organization not included in the scope of our project include office personnel and other non-authorized staff.

3 Methods/Approach

A. Methods/Approach

  - **Reference Material(s)**:

The references we use in order to complete the project are members of Ames and Argonne National Laboratory. Their names and position titles can be found in the references section of this document.

- **Data collection**:

The data that we collected was qualitative data. This data includes:

- Material properties.
- Special atmosphere work environment.
- How to operate gloveboxes, furnaces, and arc melter.
- Procedures used by other laboratories.

- **Skills**:
  - Proper glovebox operation.
  - Understanding of the material's properties.
  - Understanding of potential hazards.
- **Solutions**:

Initially, there was much deliberation on how we would find or fabricate equipment that would be best suited for removing pyrophoric materials without introducing atmosphere to gloveboxes. After consultation with the researchers, many of our ideas were determined to be impractical. This ended up being another reason why we decided to shift our focus from equipment to procedural changes.

A significant piece of information was gathered from Duck Young at Argonne National Laboratory when we learned their way of cleaning was not drastically different. They also said that exposing the glovebox chamber to the atmosphere for cleaning was almost never done and speculated Ames Laboratory might have this problem due to improper housekeeping by students.

After further deliberation between ourselves and our sponsor, we decided that equipment purchases or fabrication would likely be impractical or too expensive. We eventually settled on creating guidelines that would standardize some aspects of dealing with the disposal of pyrophoric materials from gloveboxes. This would provide another effective means of reducing the potential for incidents

- **Organization:**

Regular meetings with our project sponsor took place every Friday unless they had a conflict. During weeks it was not possible to meet, an email summary of progress was drafted and sent.

Less regular meetings took place between our group and two researchers at the lab. These meetings were scheduled on an as needed basis so that we could familiarize ourselves with the equipment we would be working with.

B. Timeline

The project started September 20th, 2019 with a deadline of March 13th, 2020. There were many individual deadlines along the way with lab meetings, research and other deliverables. Details on our project schedule can be found in the Appendixes.

4 RESULTS

Results/Deliverables

The main deliverables for this project includes a Best Practices Guide. The guide has a great impact on the cleaning and removal of materials for the machines. The purpose of the Safe Practices Guide is to be a comprehensive document. This provides a detailed list of hazards, instructions and recommended equipment in order to perform the task proficiently. This will allow researchers to quickly refresh their memory on what needs to be done in order to perform the task correctly. Initially, we were asked to fabricate our solution, but after research and discussion with the researchers, we found that a procedural-based solution would be a better solution. Although this was an obstacle that we faced, it helped us learn valuable skills that will further prepare us for the future. We were able to learn more about teamwork, communication, and networking throughout the process. These skills have helped each of us grow as individuals.

Recommendations

Our recommendation for Ames Laboratory is to use our guide as intended. Once again, these guides are recommendations, not an official SOP. The following steps should be taken in order to ensure the safety of all machines and researchers.

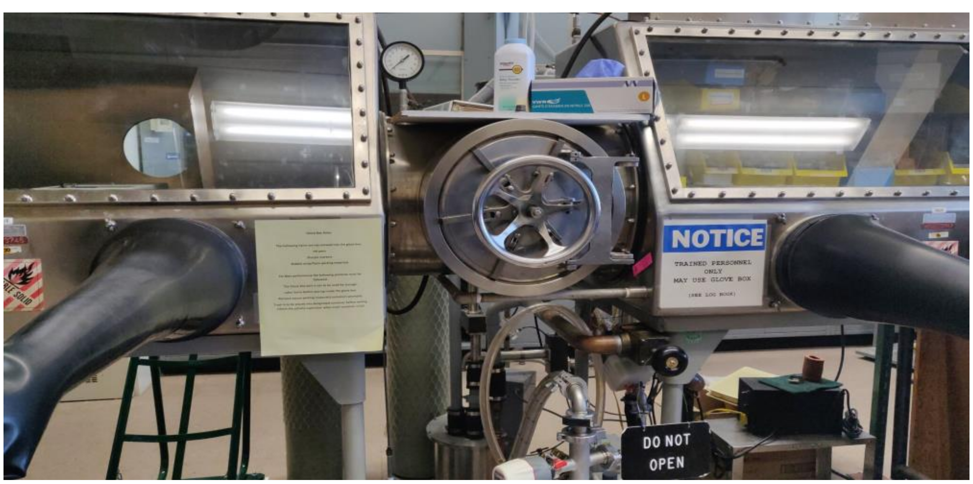
1. Review our documents and take note of our recommendations.
2. Use their expertise in the material properties to ensure all recommendations can be safely used in the laboratories.
3. Schedule a meeting to discuss potential changes.
4. Create an SOP based on the best practices guideline to fit a specific laboratory.

5 Broader Opportunity Statement

Our project applies to a pretty small audience. It may be found useful by other national laboratories or research laboratories, but seems unlikely to be useful elsewhere. This project is directed towards laboratories that have an emerging focus on laboratory safety. These other laboratories currently aren't doing anything drastically different from Ames Laboratory. We learned this through discussions with Duck Young Chung. He informed us that there wasn't a set procedure at Argonne National Laboratory. According to Duck Young, this issue wasn't a current issue for them. This leads us to ask questions about what his personal procedure was and how we can solve the issue at Ames Laboratory. His input had a great influence on the guides we proposed to Ames Laboratory.

The amount of time, effort, and cost other laboratories would be willing to spend to alleviate the problem is unknown. Once again, Duck Young stated that using an SOP within Argonne National Laboratory isn't currently practiced by his group. It goes to show that there are going to be some variations in the problems different labs need to deal with.

6 Graphical Abstract



7 REFERENCES

- Sarah Morris- Benavides-Sponsor (Ames Laboratory)
- Daniel Kayser- Environmental Specialist (Ames Laboratory)
- Matthew Besser- Manager, Materials Preparation Center (Ames Laboratory)
- Roger Rink- Researcher (Ames Laboratory)
- Duck Young Chung- Principal Materials Scientist (Argonne National Laboratory), November 2019
- Stuart Feinberg- Chemical Safety Specialist (Argonne National Laboratory)

8 APPENDIXES

THE Ames Laboratory
Creating Materials & Energy Solutions
U.S. DEPARTMENT OF ENERGY

I. Best Practices Guideline

Use this form to document the Environmental Safety & Health information associated with the procedure.

Procedure Title: <u>**Glovebox cleaning**</u>

Dept:	Bldg/Rm:	Supervisor:

Procedure Overview:

This guide will provide general equipment and procedural guidelines to aid in decision making in the lab. This guide is not a standard operating procedure; it is intended to be used as a broad overview of laboratory best practices while disposing of pyrophoric materials. This guide assumes that the glovebox user has been trained on the operation of the specific glovebox they are working with.

Hazard Control Measures:

Lab coat, eye and hand protection, and closed-toe/heel shoes must be selected as required by Section D of the ISU Laboratory Safety Manual. The table below provides a list of protective measures that may be required.

Latex gloves	**Insulated gloves**	**Face Shield**	**Respirator**
Nitrile gloves	**Safety glasses**	**Lab Coat**	**Fume hood**
Neoprene gloves	**Vented goggles**	**Apron**	**Biosafety cabinet**

Vinyl gloves	**Splash goggles**	**Dust mask**	**Glove box**
Leather/Work Gloves	**ANSI Z41 Safety Footwear**	**Flame Resistant Lab coat**	
Other:			

Useful Information:

1. Detailed information may be available in the ServiceNow database but may also be available solely as internal documents.
2. Information regarding specific chemicals should be available in the Quartzy database. It is possible the Quartzy database will not have been updated for a few months. Internal documents may be available with the most up to date information.
3. Anything removed from a glovebox should be treated as pyrophoric until proven otherwise.
4. Ensure all materials can fit and that solvents and additional barriers are appropriate for use within the glovebox.
5. Ask for clarification anytime it is unclear what is appropriate for a given situation.

Recommended Materials:

1. Cleaning:
   I. Hand-held brush and dustpan, Kimwipes, paper towels, terry wipes, or dusting cloths are possible options.
   II. Vacuum cleaner.
2. Solvents:
   I. Methanol.
   II. Isopropyl Alcohol.
3. Sealable container (Options may include glass jars, paint cans, or zip lock bags)
4. Additional barriers:
   I. Mineral Oil.
   II. Lime Powder.

Procedure:

***This procedure assumes that the researcher knows how to operate a glovebox.**

1. Determine a safe area for the waste container to be placed prior to beginning the cleaning process, such as a hot bench or fume hood. The area should be clear of any materials that could start a secondary fire if a reaction occurs.

2. Load necessary cleaning materials into the glovebox transfer chamber in advance. Some materials need to be kept under a vacuum for an extended period of time to ensure minimal oxygen contamination within the glovebox.

3. Containers being moved into the glovebox should be opened before putting them under a vacuum. Failure to do so may result in the destruction of the container or contamination of the glovebox atmosphere.
   NOTE: If you are unsure of the appropriate technique, ask the glovebox manager.

4. Start by sweeping up large particles into a pile using a brush and dustpan.

5. If applicable, refer to the steps below for vacuum cleaner usage:
    I. A vacuum cleaner may be provided in some gloveboxes.
    II. Vacuum particles that remain after the sweeping process.
    III. Empty the vacuum cleaner by dumping particles into the container.
    IV. The vacuum cleaner can easily overheat in an argon atmosphere. Avoid running it continuously for more than a minute. Aim for a 20% duty cycle (1 minute on followed by 4 minutes off) and adjust down as needed to allow the motor time to cool.
    V. It may be prudent to keep a record of what materials were vacuumed. An example of a record-keeping tool can be found in Appendix A.
    VI. If a vacuum cleaner is going to be placed into a glovebox that does not already have one, potential qualifications can be found in Appendix B.

6. It may be necessary to wipe down the glovebox with Kimwipes, paper towels, dusting cloths, or solvents.
    NOTE: Not all gloveboxes allow for solvents to be used due to the risk of contaminating the atmosphere. Use caution and refer to the appropriate SOP prior to use.

7. Once glovebox cleaning has been completed, all waste and cleaning materials should be placed into the container(s).
    I. If your glovebox does not permit the use of mineral oil or lime powder within the glovebox, it may be used in a secondary container once the primary container has been removed.
        1. Remove the primary container from the glovebox.
        2. Place mineral oil or lime powder into the secondary container.
        3. Place the primary container in the secondary container and seal.
    II. Do not draw a vacuum when removing the primary container from the glovebox to ensure the seal is not broken.
    III. Overpack, such as lime or mineral oil, may be added to a secondary container outside of the glovebox. The primary container holding the pyrophoric materials would then be placed inside.
    IV. Steps should be taken to ensure the container is properly labeled. Individuals unfamiliar with the cleaning that just took place should understand that opening the container could breach containment and risk a pyrophoric reaction. See ServiceNow for proper instructions on container labeling.

8. Schedule an immediate pickup prior to removing materials from the glovebox if they cannot be adequately contained or submerged. See ServiceNow or contact ES&H at (515)-294-2153.

II. HAZARD ASSESSMENT

Use the hierarchy of controls to document the hazards and the corresponding control measure(s) involved in each step of the procedure.

Consider *elimination or substitution* of hazards, if possible.

Engineering Control(s): items used to isolate the hazard from the user (i.e. fume hood, biosafety cabinet).

Administrative Control(s): policies/programs to limit the exposure to the hazard (i.e., authorizations, designated areas, time restrictions, training).

Required Personal Protective Equipment (PPE): indicate PPE including specific material requirements if applicable (i.e., flame-resistant lab coat, glove material, type of respirator or cartridge, etc.).

Hazard	**Engineering Control(s)**	**Administrative Control(s)**	**Required PPE**

III. Training Record

Use the following table to record the training associated with this Standard Operating Procedure.

Print Name	**Signature**	**Date**

Note: Attach to or file with written materials and method

Appendix A

Vacuumed Materials List:

Vacuumed Material	Hazard	Date

Appendix B

- List of potential vacuum cleaner characteristics:
  - Price: Viewed as disposable or hazard-specific.
  - Secondary filters and attachments pose a pyrophoric hazard when removed from the glovebox.
  - Corded. (Batteries don't go through the antechamber.)
  - Hose attachment. (Easy to maneuver within the glovebox.)
  - Bagless. (Easy to empty material.)
  - Small dimensions. (Needs to fit in the antechamber.)
  - Filter that can capture small particulate.

Appendix C

Waste Determination flow chart:

1. Does the waste meet any of the four characteristics listed below:

	Ignitable:			Corrosive:	Reactive:	Toxic:
Physical State	1) Liquids:	2) Solids that can cause fire through:	3) Gas:	Liquids:	Any state	Any state
Conditions	Not an aqueous solution of <24% alcohol by volume **AND** Flash point <60C/140F	Friction - Absorption of moisture - Spontaneous chemical changes - **AND** when ignited burns so vigorously & persistently it creates a hazard	<13% in air is flammable flammable range in air >12%	1) pH ≤2 or ≥12.5 2) corrodes steel ≥0.25in/year	1) Normally unstable & undergoes violent change w/o detonation 2) Reacts violently w/ water 3) Forms potentially explosive mixtures w/ water 4) When mixed w/ water, generates enough toxic gases/vapors/fumes to cause danger to human health or environment 5) Cyanide/Sulfide bearing waste when exposed to pH ≤2 or ≥12.5 generates enough toxic gases/vapors/fumes to cause danger to human health or environment 6) Capable of detonation/explosive reaction if subjected to strong initiating source or heated under confinement 7) Capable of detonation/explosive reaction at standard temperature and pressure	Contains any of the following: Metals: Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver Solvents: Benzene, Cresol (o, m, or p), 2,4-Dinitrotoluene, Methyl Ethyl Ketone Halogenated solvents: Chlorobenzene, Chloroform, 1,4-Dichlorobenzene, 1-2-Dichloroethane, 1,1-Dichloroehtylene, Hexachlorobenzne, Hexachlorobutadiene, Hexachloroethane, Trychloroethylene
EXAMPLES	acetone, hexane, toluene	iron powder, magnesium ribbon, benzoyl peroxide	hydrogen, butane, propane	hydrochloric acid, sodium hydroxide soln.	lithium, lithium nitride, potassium cyanide	Alloys containing any of the metals are considered toxic.
GHS Symbols					 	

2. Does the material contain engineered nanoparticles?
3. Is the waste listed? If the waste is listed in 40 CFR 261 is must be managed as a hazardous waste.
4. Are materials (i.e. paper ,plastic, PPE, equipment, spill clean-up debris, etc) contaminated by a characteristic and/or listed waste?

If the answer is yes to any of the above the material is a hazardous waste and must be disposed of through ESH.

Note: Additional information can be found in ServiceNow knowledge based articles by searching on the word "Waste".