Experimental Safety Reviews and Education for the Research Laboratory – What If Analysis

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Experimental Safety Reviews in a Research Setting – Three Points

- If planning and preparation for a review is conducted in a particular manner, you could cancel the review at the last minute and still have derived benefits
- If the review is conducted in a particular manner, participants are better prepared to spot and prevent research incidents in the future.
- Students can apply these concepts to error / incident prevention activies in their own lives and in future employment applications aside from safety.

Process Safety Management Education
(P. Conlon)

LAB PROCESS SAFETY MANAGEMENT

- Student and Researcher Participation
- Process Safety Information
- Process Hazard Analysis
- Operating Procedures & Safe Work Permits
- Student and Researcher Training
- Pre-Startup Safety Review
- Mechanical Integrity
- Management of Change
- Emergency Planning and Response
- Incident Investigation
- Compliance Auditing

Based on 29 CFR 1910.119 – Process Safety Management of Highly Hazardous Chemicals

PHA Basics (P. Conlon)

LAB PROCESS HAZARD ANALYSIS

Address:

- Process Hazards
- Previous Incidents
- Engineering and Administrative Controls
- Consequences of Control Failures
- Human Factors
- Possible Health and Safety Effects on Employees (qualitative evaluation)

LAB EXPERIMENTAL HAZARD REVIEWS

- Team approach is ideal – include students where possible
- Members with experimental experience and knowledge
- System to address and document:
  - Findings and recommendations
  - Scheduling and completion of corrective actions
  - Communications with affected personnel
  - Document retention

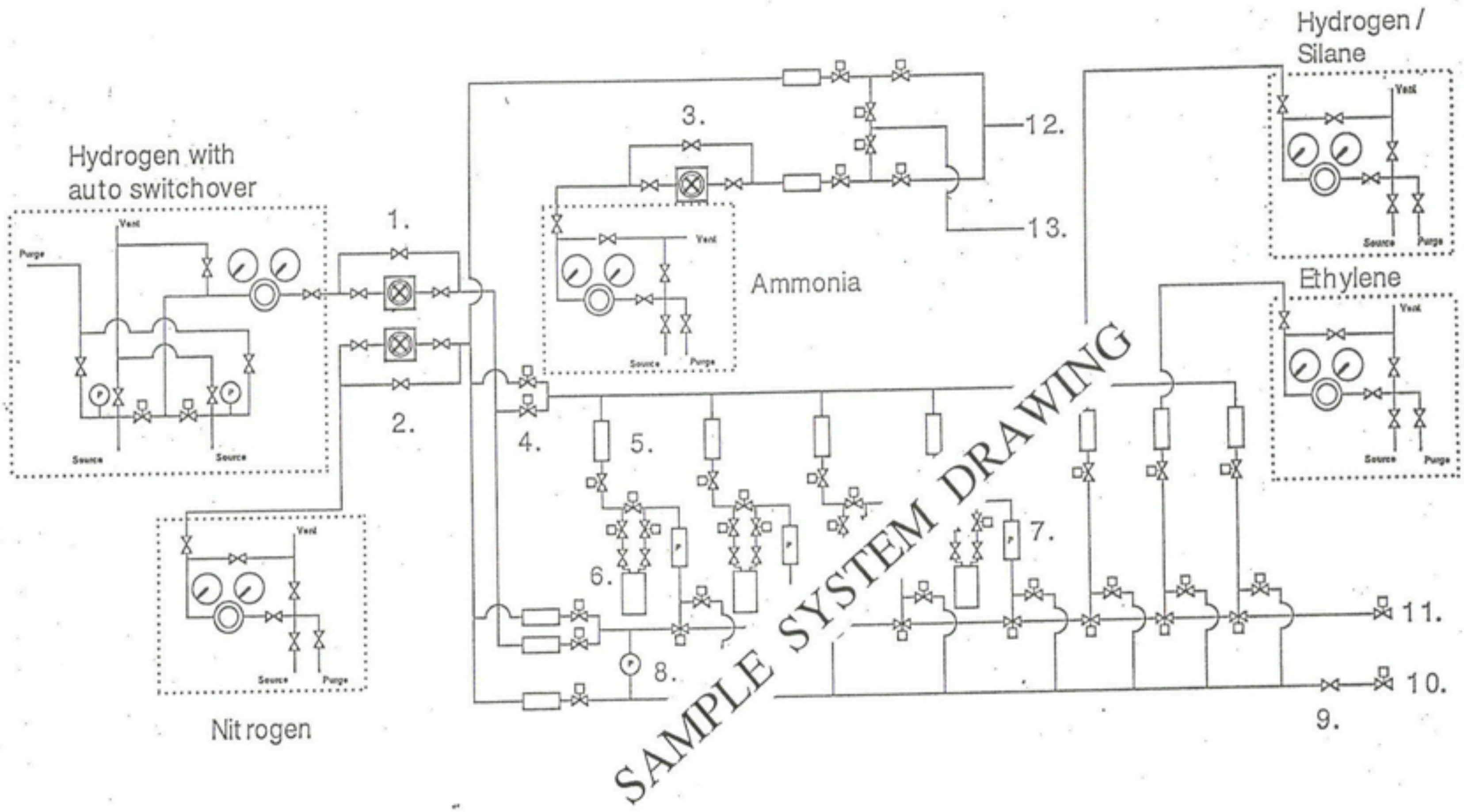
Step 1 – Preparing for the Review

- Either EH&S is contacted by the Principle Investigator (PI) or EH&S does the contact
- PI is directed to:
  - Arrange time for the review
  - Invite the **scientist** with primary responsibility for the **experiment**. This person will be responsible for having the review conducted and documented. EH&S will participate and facilitate if you would like.
  - Review team participants including maintenance
- Result – Accountability and Responsibility Verified – as well as realization that there may be other stakeholders with questions

Step 2 – Preparation for the Review

- PI is provided in advance with review forms, checklists, and brief description of how review is to be conducted.
- Instructions include requirement for:
  - **Detailed diagram** of the **experiment** (includes component parts)
  - Experiment description using the detailed diagram provided to the review team (Detailed Drawing as Necessary)
  - List of Materials and Potential Hazards
  - Bring any SOPs
  - Startup Checklist (Perhaps)

SAMPLE SYSTEM DIAGRAM



1. Hydrogen purifier
2. Nitrogen purifier
3. Ammonia purifier
4. Carrier gas selection valves
5. Metalorganic carrier gas MFC
6. Metalorganic bubbler
7. Metalorganic bubbler pressure regulator
8. Run/vent differential pressure gauge
9. Vent pressure regulation valve
10. Vent line, diluent and metalorganics
11. Run line, diluent and metalorganics
12. Vent line, ammonia
13. Run line, ammonia

Overview of Process and Equipment

Principal Investigator: ______________________________

Qualified Operator(s): ______________________________

Lab Location: ______________ Phone: ______________

Office Location: ______________ Phone: ______________

Brief Description of Process: ______________________________

Brief Description of Equipment: ______________________________

List the Chemicals Used:

Gases

Chemical Name	Max. Flow Rate	Typical Flow Rate	Typ. Flow Duration	# of Runs / Week

Liquids

Chemical Name	Max. Flow Rate	Typical Flow Rate	Typ. Flow Duration	# of Runs / Week

Solids

Chemical Name	Quantity in System	Quantity Consumed per month (year)

System Basics

What is the normal operating pressure of the system?____________________

List the types of alarms (audible, visible) on the system.____________________

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Does the system have the following: **EPO** (Em. Pwr. Off), **EGO** (Em. Gas Off), Gas Monitoring, Exhaust Flow Monitoring?____________________

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Can the following hazards exist?

___ Explosion
___ Implosion
___ Electrocution
___ Electric Shock
___ Electric Burn
___ Thermal Burn (hot)
___ Thermal Burn (cold)
___ RF Exposure
___ RF Burn
___ Radioactive Exposure
___ Allergic Reaction
___ Exothermic Reaction
___ Excessive Noise
___ Intense Light
___ Laser
___ Pinch Points
___ Falls
___ Struck By
___ Caught Between
___ Sharps / Cuts
___ Air Contamination
___ Water Contamination
___ Soil Contamination
___ Muscle Strain
___ Eye Strain

Laboratory Equipment Startup Checklist

- Clearances all appropriate
- Emergency systems (sprinkler, smoke alarms, gas alarms, etc) all functional from lab to Public Safety
- All items from applicable hazard reviews are resolved
- Lab Safety plan completed and approved
- Emergency procedures, including evacuation are in place
- All applicable employee / student training has been conducted
- All equipment interlocks have been tested and are operational
- Equipment using hazardous chemicals or gases have been tested with low hazard materials (baths filled with water, aspiration systems tested, inert gases used for hazardous gas equipment) with all systems found to be functional - no leakage,etc.
- Ventilation systems have been balanced and labeled, with ventilation alarm devices in place
- Appropriate electrical inspection has been performed
- Key work practices and procedures are understood (chemical/gas receiving, transport, disposal, gas cylinder changes, equipment troubleshooting and maintenance)

Comments

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Both Signatures Required for Approval for Startup

Lab Principal Investigator ________________________ Date:__________
Env. Health and Safety__________________________ Date:__________

A Little Training Prior to the Review Would be Ideal

- In Undergraduate and/or Graduate Academic Training
  - Common Incident Causes
  - Lessons Learned by Category

- At the Start of the Review
  - Scope and Limitations of the Review
  - Assumptions During the Review

Some Common Incident Causes

- Inadequate Understanding – Chemical, Physical Properties of Products / Byproducts
- Inadequate Engineering Controls
- Reliance on Work Practices in Lieu of Engineering Controls
- Inadequate Selection / Use of PPE
- Failure to Practice Lockout/ Tagout
- Human Factors Problems Not Recognized
- Inadequate Attention to Management of Change

Horror Stories (Lessons Learned)

- Disilane Fire (lockout / tagout)
- Clean Hood Hotplate (human factors)
- MOCVD Purge Sequence (engineering controls in lieu of work practices)
- Silane Scrubber (don’t make assumptions)
- Clean Room Immersion Heater (redundant controls and devastating business interruption)
- Hydrogen Fire in Glove Box (Mgt of Change)

Human Error
Trevor Kletz - "What Went Wrong"

"They know what they should do, want to do it, and are physically and mentally capable of doing it. But they forget to do it. Exhortation, punishment, or further training will have no effect. We must either accept an occasional mistake or change the work situation so as to remove the opportunities for error or make errors less likely."

STOP HERE – What has research group learned before review has even started ?

- Step 1 Result – Accountability and Responsibility Verified – as well as realization that there may be other stakeholders with questions
- Step 2 Result – Have schematic for use with review and for posterity – mgt of change. Understand what will need to be in place prior to startup. Have understanding of equipment operation and materials to describe process and hazards

Step 3 – Conduct Review

- Establish Ground Rules – Example - Won't Accept Procedural Controls only For High Severity Events – MOCVD example
- Facilitate by Allowing Sufficient Discussion for Process Owners (Grad Students, Post Docs) to Reach Appropriate Conclusions - "Muzzle the Experts" - "It's the Process Stupid"
- Document, Assign Follow Up Action – Reference Startup Checklist

"What-If" Analysis Form

Dept.:	Description of Operation:	By: Date:

What If?	Answer	Likeli-hood	Severity	Recommendations

Table 1. HAZOP Study Deviations Created from Guide Words and Design Parameters. From Leggett (ref 5

	Guidewords for HAZOP Deviations						
Parameter	More	Less	No	Reverse	As well as	Part of	Other than
Flow	Higher flow	Lower flow	No flow	Reverse flow	Extra material in stream	Mis-directed flow	Loss of flow control
Pressure	Higher pressure	Lower pressure	Vacuum		Explosion		
Temperature	Higher temperature	Lower temperature					
Level	Higher level	Lower level	Empty	Loss of containment			Different level
Time	Too long/too late	Too short/too soon	Missed hold time				Wrong time
Utilities	Too much flow, pressure, etc.	Partial loss of utility	Complete loss	Utility feeds reversed	Utility contaminated		Wrong utility hook-up
Reaction	Fast reaction/ runaway	Slower reaction	No reaction	Back reaction	Unexpected reaction(s)	Incomplete reaction	Wrong recipe
Quantity	Too much added	Too little added	None added	Material removed	Additional chemical		

Table 1. HAZOP Study Deviations Created from Guide Words and Design Parameters

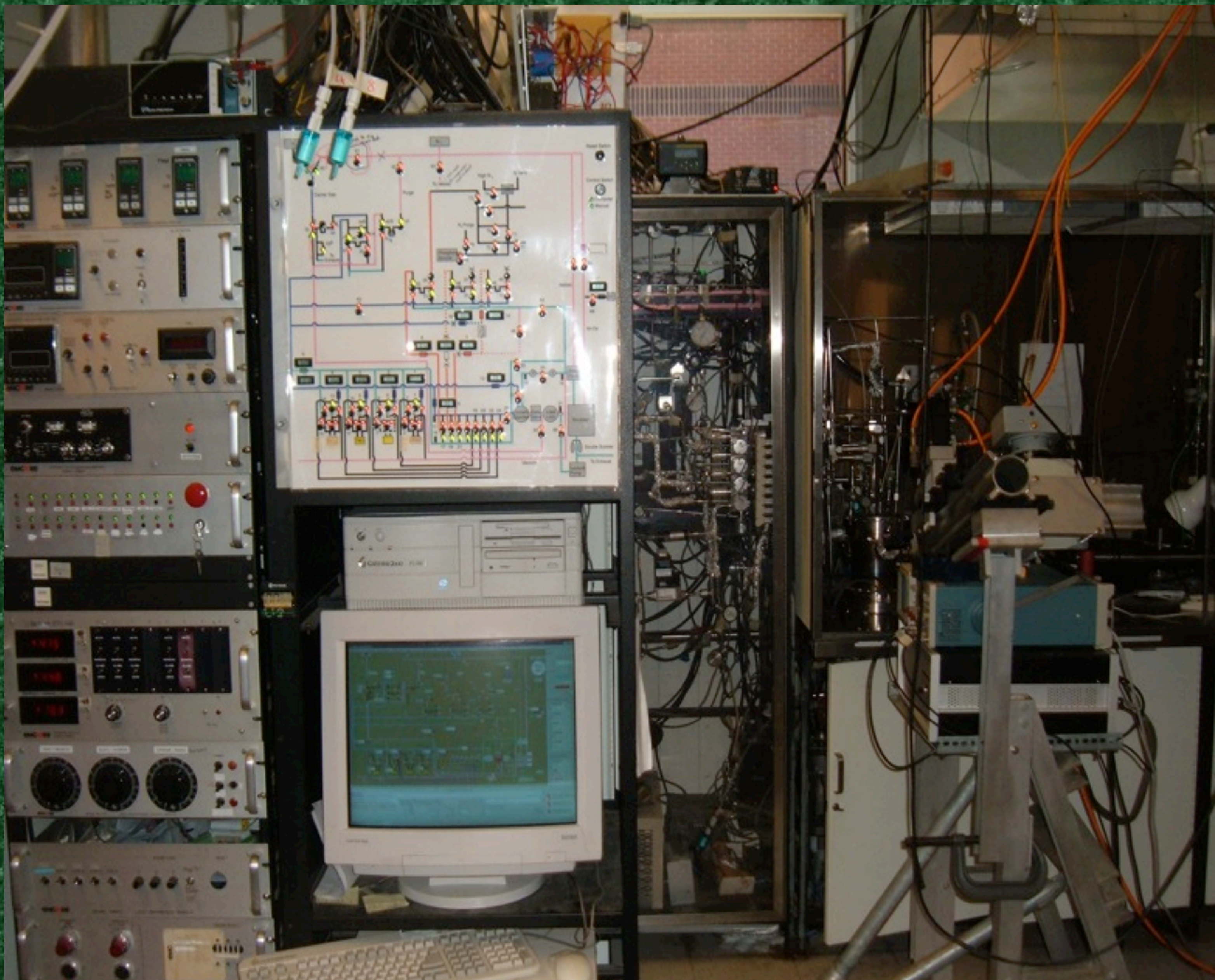
Department: Chemistry	Desc. of Operation: Use of Toxic / Flammable Gas in Small Cylinder in Fume Hood Page 1 of 4	By: Review Team Date 7/12

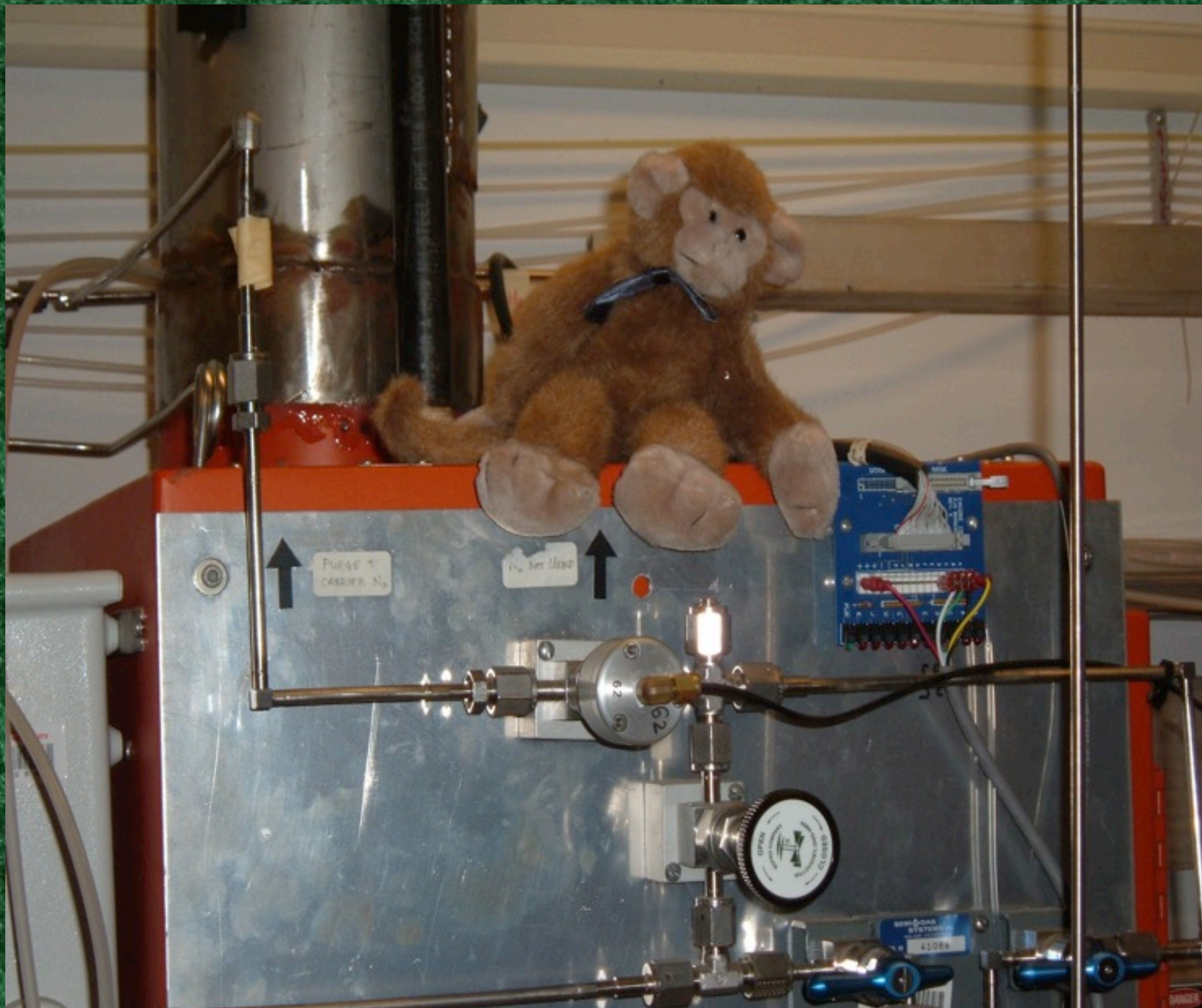
What If?	Answer	Likeli-hood	Conse-quences	Recommendations
1. Power to exhaust fan is lost ?	1. Possible exposure to toxic gas if gas flow continues	1. Likely	Serious	1. Provide Emergency Power and normally closed gas valve
2. Mechanical Failure of Exhaust Fan ?	2. Same as above	2. Quite Possible	Serious Minor	2. Same as above and consider connection to multiple fans
3. Regulator fails or creeps and allows full cylinder pressure to apparatus ?	3. Apparatus or tubing failure and gas release if not able to handle full cylinder pressure	3. Quite Possible	Serious	3. Use flow restricting orifice in cylinder valve to limit flow or install excess flow shutoff valve. Consider gas monitor that is interlocked to shut down gas flow
4. Cylinder regulator guage blows ?	4. High pressure gas release and possible exposure	4. Low Prob	Serious	4. Same as above
5. Gas leak downstream of regulator – hood face at 18 inches ?	5. Lower pressure gas release but potential exposure which increases with gas flow rate	5. Quite Possible	Serious	5. Same as above
6. Gas leak downstream of regulator – hood face at 30 inches with operator at hood ?	6. Same as above but high potential for exposure	6. Quite Possible	Serious	6. Same as above and restrict hood opening while gas flowing via interlock or stop and consider use of SCBA if access during flow is necessary
7. Cylinder contains wrong contents ?	7. Potential exothermic reaction or if not, ruined experiment (and apparatus ?)	7.Low Prob	Serious	7. Check cylinder tag, not just cylinder stencil.
8. Cylinder pressure is incorrect ?	8. Regulator guage could fail – rapid release of high pressure gas	8. Low Prob	Serious	8. Same as above (see http://www.aiha.org/insideaiha/volunteergroups/labHandScommittee/Pages/ArsineGasRelease.aspx
9. Apparatus contains oxygen when gas is introduced ?	9. Explosion potential if gas hits flammable range and ignition source is present	9. Quite Possible	Serious	9. Assure purge with inert gas before introducing flammable gas if ignition source may be present (consider automation)
10. Residual process gas in equipment when opened ?	10. Potential exposure to toxic gas	10. Quite Possible	Serious	10. Same as above – test atmosphere or use SCBA

Additional Benefits from Review

- Participants Learn and Remember Expectations – Useful for Future Projects
- Procedural Controls are Rolled Into SOPs (also could test SOPs during review)
- Participants Learn the Process
- PHR itself is documented for future reference
- Can apply to non research applications – Lab Exhaust / HVAC, etc

Making an Impression -Retaining Key Concepts




PURGE +
CARRIER N2
N2 Not Used

What If for Students (and Parents)

- You Drive Too Fast
- You Lose Your Wallet
- You Place Something on the Roof of Your Car
- You Leave Something Valuable Behind In Your Unlocked Locker at the Gym

What If Assessment – Team Members

- Todd Houts – University of Missouri
- Gail Hall – Boston College University
- Susan Newton – John Brown University
- Mary Beth Koza – University of North Carolina – Chapel Hill