# Standard Operating Procedures - Matrix for new process involving carbon monoxide

Table G-1

**(Columns 1–4)**

| **Evaluate Each Step or Task** | **Hazard Identification - Known and Potential Hazards - Safety constraints & restrictions** | **Specific issues identified** | **Risk Assessment - What is most likely to go wrong - what are the most severe consequences even if unlikely?** | **Literature search and consultation with experienced supervisors for lessons learned** |
| --- | --- | --- | --- | --- |
| Regulatory Concerns | Understanding applicability, cost constraints, lack of options, delays, require assistance, permits | Fire codes for flammable compressed gases limits storage amounts and conditions, regulators, tubing, connections and may require special storage, alarms, etc. Fire code requires conditions for safe egress. Compressed gases are regulated by NFPA and OSHA. NFPA and IFC also regulate toxic gases (see below). | Improper storage can lead to a leak or high vol. gas release. Improper connections can lead to a leak or static buildup. Emergency response may be impeded by lack of shut off valves or kill switches. Lack of fire alarms/suppression could result in catastrophic fire damage. For flammable gas CO, regulatory concerns relate to flammability, toxicity, and gas under pressure (see below). | NFPA codes have been written to address deficiencies in construction, operations, storage, etc. that had led to loss of life. Literature reviews should uncover laboratory accidents involving most flammable gases, compressed gases, many pieces of equipment and many processes. Additionally, the release of toxic gases is well documented |
| Human Factors | Inexperienced worker, new experiment, work hours, follows directions, medical conditions, effect of errors, effect of cold or fatigue, language barrier | Relatively new graduate student from overseas with limited command of English. New experiment for this student. | Student may misunderstand parts of scientific procedure/safety procedures. Student may not have been adequately prepared or trained. Student may not be able to acquire emergency help. | Student should be required to review literature extensively to understand the hazards, potential for accidents, measures for mitigation or prevention of an accident. |
| Facility | Lighting, hand wash sink, egress, electrical circuits, ventilation, emergency equip., code adherence, confined space, storage arrangements, sturdy shelves |   | Is gas segregated from oxidizers? Is cylinder secured? Does the cylinder impede egress? Are there sprinklers in the laboratory and/or the hood? |   |
| Materials | Biological, Radiological, Chemicals; for chemicals--flammability, toxicity, PEL, Physical data, reactivity, corrosivity, thermal & chemical stability, inadvertent mixing, routes of exposure | The flammable gas is carbon monoxide, a toxic gas with a GHS acute toxicity rating of 3 and no physiological warning properties. Must be used at 100%, passed through a synthesis unit, and released. May run continuously for 24 hours. | Potential for fire, but if leak develops, exposure risk is high. Realize that a gas leak can only be detected w/monitoring system; note potential for slow buildup of toxic gas, and potential for chronic sub-acute poisoning; effects of illness may be delayed | At the time of publication OSHA guidance is found at: http://www.osha.gov/SLTC/healthguidelines/carbonmonoxide/recognition.html Lessons Learned: http://thepost.ohiou.edu/content/plans-initiated-prevent-carbon-monoxide-leaks ; recommend internet search for other information |
| Equipment and Labware | Materials integrity, maintenance, piping, electrical, relief systems, ventilation systems, safety mechanism |   | Ensure use of appropriate piping with adequate safety mechanisms |   |
| Process | Unsafe quantity or concentration, unsafe temp, pressure, flow or composition, deviations, potential for runaway reaction |   | Identify potential ignition sources. Is there a possibility of an explosive quantity? |   |
| Effect of change in design or conditions | More energetic or toxic, increase potential for release, hazards of scale up |   |   |   |
| Possibility for additive or synergistic effect or unknown effects | Lack of expertise or knowledge, newly synthesized materials, untested or unfamiliar equipment, materials or processes |   |   |   |
| Effluents and waste management | Challenges to proper disposal, potential for exposure or contamination, hazardous releases to air or water |   | Is gas used up in experiment or will some be released? |   |
| Availability of PPE | Inadequate PPE or shielding for hazard, cost factors, worker compliance, lack of alternatives |   | Eye protection, shielding, flame resistant lab coat, gloves. Wear nonsynthetic clothing. |   |
| Emergency Response resources | Inadequate or unavailable, lack of knowledge about emergency procedures |   | Identify location of fire extinguishers. Review how to request emergency assistance. |   |
| Potential failure points or routine activities with high risk of harm | Weighing toxic materials on lab bench, opening an autoclave, hard to close caps, lack of "kill" switch |   | Automatic shut off in the event of a fire? |   |

**(Columns 5–9)**

| **Evaluate Each Step or Task** | **Strategies to Eliminate, Control or Mitigate Hazard**  | **Suggested strategies to address identified hazards** **(Plan A)** | **Ask Again - What Could Go Wrong? Consider atypical or less likely events - Identify possible Failure points or known failures of prior strategies** | **Plan B to Eliminate, Control or Mitigate** | **Will Standard Precautions be Adequate? (Develop written criteria)** |
| --- | --- | --- | --- | --- | --- |
| Regulatory Concerns | CHP, OSHA carcinogen regulations, controlled substances DEA regulations, permits for select agents and/or radioactive materials, etc. Review compliance plan with EHS or other local and national experts. Consult technical experts from gas vendor for guidance. Make a checklist using applicable regulations and insert into lab safety manual or CHP  | Verify within code limits using checklist and other identified compliance strategies. For CO, a gas cabinet or other exhaust cabinet is required for storage. Determine if small volume cylinders can be used and store them in the fume hood. | Think about why these codes exist. What purpose are the regulations requiring certain connections, tubing materials, shut off valves and switches, safe egress, fire monitoring and suppression, toxic gas alarms?  | Identify compliance weakness (e.g., old building without sprinklers). Identify secondary measures that could address these deficiencies: install sprinklers, install extra alarm systems; have emergency backup support ready; isolate experiment to safest part of lab, move experiment to sprinklered lab | Standard precautions are probably not adequate without considering the regulations addressed in the review and checklist. Once the checklist is completed and plans are determined to be adequate, this part of the SOP could be standard. |
| Human Factors | Reiterative training, enforce lab rules, supervision, ascertaining worker knowledge, ensure worker is well-informed, practice small, SOPs, buddy system. Ensure student has taken all relevant training including emergency response. Student should be directly supervised until he/she has shown proficiency in all aspects of hazard control and emergency response. Student should write SOP and review with senior lab staff. | Student should be adequately trained and supervised. A dry run or scaled down experiment should be performed first. | Most likely human failure would involve communication difficulties. These must be addressed in advance as well as monitored during a hazardous experiment. | Supervisor and student should discuss scenarios for potential gas leak, fire, explosion, and supervisor should be satisfied that student can address these. Alternatively, student may assist more experienced lab worker. | SOP may be developed if experiment becomes routine, as long as clear indications are present regarding when to consult supervisors or review safety plan. |
| Facility | Ensure proper environment and conditions - **can use checklist** | Checklist to verify proper configuration prior to start work each day. |   |   |   |
| Materials | Eliminate, substitute or reduce amt.? Detection & warning methods? Use of administrative, engineering or PPE controls (expand). Completely enclose process in fume hood, if possible; use gas monitoring/alarm systems, normally -closed valves which shut off with power failure, create lab SOP requiring checking of all systems before an experiment. May only be used during work hours or if monitored. If leak is detected, turn off gas sources and evacuate lab. | Use mixture with inert gas if possible. Keep quantity to a practical minimum. |   |   |   |
| Equipment and Labware | Integrity check, right tool for job, maintenance, correct use, troubleshoot, normal and emergency operations delineated | Conduct integrity check each day prior to work. |   |   |   |
| Process | Change process, small tests, test runs without hazard present, acquire expert assistance, secondary controls, emergency response actions | May wish to conduct dry run with nitrogen or compressed air. Identify potential ignition sources and check for these each day. |   |   |   |
| Effect of change in design or conditions | Assume and prepare for increased risks, identify these in order of potential, require review by experts, require continuous monitoring, install safeguards, warning systems, shutdown mechanisms and remote monitoring | Conduct thorough review when changing out cylinders. |   |   |   |
| Possibility for additive or synergistic effect or unknown effects |   |   |   |   |
| Effluents and waste management | Must be resolved before experiment, proper disposal containment and methods for experiment waste |   |   |   |   |
| Availability of PPE | Design experiment to reduce reliance on PPE, combine control methods, prohibit use of inadequate PPE |   |   |   |   |
| Emergency Response resources | Buddy system, alarms, ensure availability of equipment & personnel, emergency drills & training, spill kits, AED. All lab staff must have fire extinguisher training. | Conduct a drill involving one or more emergency scenarios prior to conducting experiment. |   |   |   |
| Potential failure points or routine activities with high risk of harm | Review and change work practices, extensive training, instructions to address unexpected - failures, breakage |   |   |   |   |

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