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Requirements
for

Equipment Specifications

REVISION

Rev No.	DCN No.	Change Summary	Release Date	DCN Initiator	Document Owner
3	DCN0778	Added requirements for grounding and bonding chemical cabinets and delivery lines that house flammable, pyrophoric or reactive chemicals	3-19-12	J. Trodden	R. Segura

Prior revision history, if applicable, is available from the Document Control Office.

1. PURPOSE AND SCOPE

1.1 The purpose of this document is to establish the minimum requirements/specifications for equipment being installed at the College of Nanoscale Science and Engineering (CNSE) facility. Such equipment shall include Ozone Gas Generators, Gas Cabinets, Valve Manifold Boxes, T-Boxes, Gas Interface Box, Chemical Dispense Units, Waste Dispense Units, Chemical Storage Cabinets and Abatement Devices.

1.2 The requirements for local exhaust ventilation system components are not covered by this procedure but are covered in the CNSE Local Exhaust Requirements procedure, EHS-00053.

1.3 This document does not pertain to semi-conductor process systems.

2. DEFINITIONS

2.1 **Chemical Dispense Units**: A fully enclosed, noncombustible enclosure used to provide an isolated environment for liquid chemical in storage or in use.

2.2 **Chemical Storage Cabinets**: Polyethylene or metal coated polyethylene cabinets used to store and contain corrosive acid or corrosive-based materials.

2.3 **Excess Flow Valve**: A valve inserted into a compressed gas cylinder, portable tank or stationary tank that is designed to positively shut off the flow of gas in the event that its predetermined flow is exceeded.

2.4 **Gas Cabinets**: A fully enclosed, noncombustible enclosure used to provide an isolated environment for compressed gas cylinders in storage or use. Doors and access ports for exchanging cylinders and accessing pressure-regulating controls are allowed to be included.

2.5 **Exhausted Enclosure**: An appliance or piece of equipment that consists of a top, a back and two sides providing a means of local exhaust for capturing gases, fumes, vapors and mists. Such enclosures include laboratory hoods, exhaust fume hoods and similar appliances and equipment used to locally retain and exhaust the gases, fumes, vapors and mists that could be released. Rooms or areas provided with general ventilation, in themselves, are not exhausted enclosures.

2.6 **Hazardous Production Material (HPM)**: A solid, liquid or gas associated with semiconductor manufacturing that has a degree-of-hazard rating in health, flammability or reactivity of Class 3 or 4 as ranked by NFPA 704

and which is used directly in research, laboratory or production processes that have as their end product materials that are not hazardous.

2.7 **Ozone-Gas Generator**: Equipment which causes the production of ozone.

2.8 **Reduced Flow Valve**: A valve equipped with a restricted flow orifice and inserted into a compressed gas cylinder, portable tank or stationary tank that is designed to reduce the maximum flow from the valve under full-flow conditions. The maximum flow rate from the valve is determined with the valve allowed to flow to atmosphere with no other piping or fittings attached.

2.9 **Restricted Flow Orifices**: Orifice placed in a fitting or pipe to restrict the amount of flow that can go through the pipe or fitting.

2.10 **Splitter/T-Boxes**: Break in liquid double contained line where connections are housed.

2.11 **Valve Manifold Boxes**: Break in gas double contained line where connections are housed.

2.12 **Workstation**: A defined space or an independent principal piece of equipment using HPM within a fabrication area where a specific function, laboratory procedure or research activity occurs. Approved or listed hazardous materials storage cabinets, flammable liquid storage cabinets or gas cabinets serving a workstation are included as part of the workstation. A workstation is allowed to contain ventilation equipment, fire protection devices, detection devices, electrical devices and other processing and scientific equipment.

3. RESPONSIBILITIES

3.1 Environmental Health and Safety is responsible for program development and advice, and counsel to management and employees, professors, students, tenants, contractors, and vendor employees.

3.2 Employees are responsible for following this program.

3.3 Installation contractors, installation engineers, supervisors, managers and Professors are responsible for the implementation and oversight of this program.

4. SYSTEMS, EQUIPMENT AND PROCESSES IN CONTROL AREAS

4.1 The storage, use and handling of hazardous materials in amounts not exceeding the maximum allowable quantity per control area (*see NYS Fire Code Table 2703.1.1 for maximum allowable quantities*) shall comply with the following:

4.2 Containers, cylinders and tanks shall be designed and constructed in accordance with approved standards. Containers, cylinders, tanks and other means used for containment of hazardous materials shall be of an approved type.

4.3 Piping, tubing, valves and fittings conveying hazardous materials shall be designed and installed in accordance with approved standards. See Table 2 - Process Gas Installation Reference for a list of the gases used on site that require the use of single and double walled lines.

4.4 Piping, tubing, valves, fittings and related components used for hazardous materials shall be in accordance with the following:

4.4.1 Piping, tubing, valves, fittings and related components shall be designed and fabricated from materials compatible with the material to be contained and shall be of adequate strength and durability to withstand the pressure, structural and seismic stress, and exposure to which they are subject.

4.4.2 Piping and tubing shall be labeled.

4.4.3 Readily accessible manual valves; or automatic, remotely-activated, fail-safe emergency shutoff valves shall be installed on supply piping and tubing at the following locations:

- The point of use.
- The tank, cylinder or bulk source.

4.4.4 Emergency shutoff valves shall be identified; the location shall be clearly visible, accessible, and indicated by means of a sign.

4.4.5 Backflow prevention or check valves shall be provided when the backflow of hazardous materials could create a hazardous condition or cause the unauthorized discharge of hazardous materials.

4.4.6 Where gases or liquids having a hazard ranking of:

- Health Hazard Class 3 or 4

- Flammability Class 4
- Reactivity Class 3 or 4

4.4.7 In accordance with NFPA 704, for gases and liquids that are carried in pressurized piping above 15 pounds per square inch gauge (psig) (103 kPa), an approved means of leak detection and emergency shutoff or excess flow control shall be provided. Where the piping originates from within a hazardous material storage room or area, the excess flow control shall be located within the storage room or area. Where the piping originates from a bulk source, the excess flow control shall be located as close to the bulk source as practical.

4.4.8 Supply piping and tubing for gases and liquids having a health-hazard ranking of 3 or 4 shall also be in accordance with the following:

- Piping and tubing utilized for the transmission of highly toxic, toxic or highly volatile corrosive liquids and gases shall have welded or flanged connections throughout except for connections located within a ventilated enclosure if the material is a gas, or an approved method of drainage or containment is provided for connections if the material is a liquid.
- Piping and tubing shall not be located within corridors, within any portion of a means of egress required to be enclosed in fire-resistance-rated construction or in concealed spaces in areas not classified as Group H Occupancies.

5. HAZARDOUS MATERIALS STORAGE CABINETS

5.1 **Construction:** The interior of cabinets shall be treated, coated or constructed of materials that are nonreactive with the hazardous material stored. Such treatment, coating or construction shall include the entire interior of the cabinet. Cabinets shall either be listed in accordance with UL 1275 as suitable for the intended storage or constructed in accordance with the following:

5.1.1 Cabinets shall be of steel having a thickness of not less than 0.0478 inch (1.2 mm) (No. 18 gauge).

5.1.2 The cabinet, including the door, shall be double walled with 1.5-inch (38 mm) airspace between the walls.

5.1.3 Joints shall be riveted or welded and shall be tight fitting.

5.1.4 Doors shall be well-fitted, self-closing and equipped with a self-latching device.

5.1.5 The bottoms of cabinets utilized for the storage of liquids shall be liquid tight to a minimum height of 2 inches (51 mm).

5.2 **Labeling:** Cabinets shall be provided with a conspicuous label in red letters on contrasting background which reads: HAZARDOUS - KEEP FIRE AWAY.

6. GAS CABINETS/ENCLOSURES

6.1 The following requirements shall apply to gas cabinets, VMBs, purifier cabinets GIBs and/or exhausted enclosures used for storing or otherwise containing gases with an NFPA rating of a 3 or a 4 for health and/or reactivity and 4 for flammability, unless otherwise noted.

6.2 Such cabinets must have leak detection/excess flow control that upon detection are interlocked to shut off flow of gas and send an alarm back to the Area Alarm Controller (AAC).

6.3 Such cabinets must have exhaust flow/pressure switches that are interlocked to shut off flow and send an alarm back to the Area Alarm Controller (AAC).

6.4 Such cabinets must be equipped with an EMO button. This EMO must be hard wired to the respective unit and have the ability to send a signal to AAC.

6.5 Optical flame detection shall be provided in such cabinets that use flammable gases. Heat detectors shall be mounted on the exhaust duct and set @ 120°F. Flame detection will be in the form of snap switches and must be wired back to the AAC for monitoring.

6.5.1 UVIR or dual IR detectors shall be installed in such cabinets that house pyrophoric materials. *Pyrophoric materials are those that have an auto ignition temperature of 130F or lower.*

6.6 The average velocity of such cabinets taken at the face of access ports shall be not less than 200 feet per minute (fpm) with a minimum of 150 fpm at any access port.

6.7 The following is a list of the gas cabinet and VMB types that are installed at CNSE with their associated flow requirements:

TYPE	FLOW REQUIREMENT (Non-Pyrophoric) cubic feet minute (cfm)	FLOW REQUIREMENT (Pyrophoric) cubic feet minute (cfm)
PFT Nanopurge A21/A212/P21/P212 Gas Cabinet	89 cfm	590 cfm
PFT Nanopurge A14/A18/P14/P18 VMB	130 cfm	440 cfm
Original style PFT two cylinder gas cabinet	220 cfm	275 cfm
Original style PFT three cylinder gas cabinet	275 cfm	--
Original style PFT VMB	100 cfm	100 cfm
Manual 8 Stick PFT VMB used for Hydrogen	50 cfm	--
Storage/Leaker cabinet	100 cfm	100 cfm

NOTE: The S2 report or F15 Tracer gas test report will be used to determine the air flow requirements for gas cabinets and VMBs that are provided by other manufacturers

6.8 Gas cabinets must be made of 12 gauge steel, door(s) must be self-closing and cabinet must be grounded.

6.8.1 Gas cabinets must be provided with self-closing limited access ports or non-combustible windows to give access to equipment controls.

6.8.2 The number of cylinders contained in a single gas cabinet shall not exceed three.

6.8.3 Gas cabinets shall be operated at a negative pressure in relation to the surrounding area.

6.9 Gas cylinder values connections must be unique and be different for each gas used.

6.10 Fire suppression and detection in the form of a sprinkler head must be installed in gas cabinets and VMBs.

6.11 Lines carrying gases that have a health or reactivity rating of a 3 or a 4 must be double contained and be constructed of a material that is compatible with the materials they are carrying. Lines carrying gases that have a flammability rating of 4 must be single contained and be

constructed of a material that is compatible with the materials they are carrying. See Table 2 - Process Gas Installation Reference for a list of the gases used on site and whether the lines consist of single or double wall construction.

6.12 When using gases that are considered pyrophoric such as Silane, the gas delivery line needs to have a distinct nitrogen purge that is monitored and will shut down the gas upon failure. The delivery line must also have a vent line that is designed to provide a 100:1 dilution, if activated.

7. RESTRICTED FLOW ORIFICES AND EXCESS FLOW VALVES

7.1 Restricted Flow Orifices (RFO) shall be installed on all gas cylinders that carry corrosive, silane/pyrophorics, highly toxics and flammables. RFO sizes shall be as follows: 0.030" for corrosives, 0.006" for silane/pyrophorics and highly toxics, and 0.010" for flammables. See Table 2 - Process Gas Installation Reference for a list of the gases used on site which require the use of restricted flow orifices and their sizes.

7.2 Excess flow control valves shall be installed on all lines that carrying such gases or liquids having a hazard ranking of 3 or 4 for health and reactivity and 4 for flammability. See Table 2 - Process Gas Installation Reference for a list of the gases used on site that require the use of excess flow control valves. Size and type shall be determined by the flow of gas, as required by the process.

8. CHEMICAL DISPENSE UNITS (CDU)/VALVE MANIFOLD BOXES (VMB), LIQUID DISPENSE SYSTEMS (LDS)

8.1 The following requirements shall apply to CDUs, VMBs, LDS and Splitter/T-boxes used for storing or otherwise containing liquids with an NFPA rating of a 3 or a 4 for health and/or reactivity and 4 for flammability, unless otherwise noted.

8.2 Such units must have liquid leak switches/detectors that are interlocked to shut off flow and send an alarm back to the Area Alarm Controller (AAC).

8.3 Such units must have exhaust flow/pressure switches that are interlocked to shut off flow and send an alarm back to the Area Alarm Controller (AAC).

8.4 Such units must be equipped with an EMO button. This EMO must be hard wired to the respective unit and have the ability to send signals to tool’s AAC, CDU’s AAC and/or VMB’s AAC.

8.5 Such units must be equipped with a secondary containment to be able to contain at a minimum 110% of the largest container and be provided with drainage to a bulk waste tank, a disposal area or to a treatment plant.

8.6 Materials of Construction:

8.6.1 If flammable or pyrophoric; unit must be made of at least 18 gauge steel, be double-walled (only required for bulk systems [systems with drums greater than 55 gallons]), be self-closing and be grounded.

8.6.2 If flammable or pyrophoric; containers, bubblers, or drums used inside such cabinets must be constructed of steel.

8.6.3 If flammable or pyrophoric; vessel and delivery lines should be grounded and electrically inter-connected. Delivery lines should also be conductive and should not have a non-conductive liner.

8.6.4 If corrosive; unit must be made of FM 4910 fire retardant plastic and be liquid tight.

8.6.5 If corrosive liquid; containers/drums used inside storage cabinets must be constructed of polyurethane.

8.7 Fire suppression and detection must be installed under the following conditions:

8.7.1 If the flammable unit is made of a combustible material, then fire suppression shall be used.

8.7.2 If more than 30 gallons (113L) of a flammable material is needed at a closed system workstation or is part of a workstation, then fire suppression must be installed to increase the allowable flammable material amount to 60 gallons (227L).If more than 50 gallons (189L) of a corrosive material is needed at a closed system workstation, then fire suppression must be installed to increase the allowable corrosive material amount to 100 gallons (378L).

8.7.3 If flammable unit does not meet the requirements listed in Section 8.1 and 8.4, then fire suppression shall be used.

8.8 Optical flame detection shall be provided in units that use flammable liquids. Heat detectors shall be mounted on the exhaust duct and set @ 120°F. Flame detection will be in the form of snap switches and must be wired back to the AAC for monitoring.

8.8.1 UVIR or dual IR detectors and/or very early smoke detectors shall be installed in units that house pyrophoric or water reactive materials.

Pyrophoric materials are those that have an auto ignition temperature of 130F or lower.

8.9 The average velocity of a CDU, VMB or LDS' taken at the face of access ports shall be not less than 200 feet per minute (fpm) with a minimum of 150 (fpm) at any access port.

8.10 Lines carrying liquids that have a health or reactivity rating of a 3 or a 4 must be double contained and be constructed of a material that is compatible with the materials they are carrying. Lines carrying liquids that have a flammability rating of 4 must be single contained and be constructed of a material that is compatible with the materials they are carrying. In general, stainless steel shall be used for flammable materials and plastic for corrosive materials. If the lines are not double walled then secondary containment must be provided. If secondary containment is not provided then fire suppression must be used. See Table 2 - Process Gas Installation Reference for a list of the materials used on site and whether the lines consist of single or double wall construction.

9. FLAMMABLE STORAGE CABINETS

9.1 Design and construction of Class I flammable and Class II combustible liquid storage cabinets shall be in accordance with this section.

9.2 Materials of Construction:

9.2.1 Cabinets shall be listed in accordance with UL 1275, or constructed of approved wood or metal in accordance with the following:

- Unlisted metal cabinets shall be constructed of steel having a thickness of not less than 0.044 inch (1.12 mm) (18 guage). The cabinet, including the door, shall be double walled with 1.5-inch (38 mm) airspace between the walls. Joints shall be riveted or welded and shall be tight fitting.

- Unlisted wooden cabinets, including doors, shall be constructed of not less than 1-inch (25 mm) exterior grade plywood. Joints shall be rabbeted and shall be fastened in two directions with wood screws. Door hinges shall be of steel or brass. Cabinets shall be painted with an intumescent-type paint.

9.3 **Labeling:** Cabinets shall be provided with a conspicuous label in red letters on contrasting background which reads: FLAMMABLE - KEEP FIRE AWAY.

9.4 **Doors:** Doors shall be well-fitted, self-closing, and equipped with a three-point latch.

9.5 **Bottom:** The bottom of the cabinet shall be liquid tight to a height of at least 2 inches (51 mm).

9.6 **Capacity:** The combined total quantity of liquids in a cabinet shall not exceed 120 gallons (454 L), with not more than 60 gallons (227 L) being Class I or II liquids.

9.7 **Number of storage cabinets**: Not more than three storage cabinets shall be located in a single fire area. Additional cabinets are allowed to be located in the same fire area if the additional cabinets (or groups of up to three cabinets) are separated from other cabinets or groups of cabinets by at least 100 feet (30 480 mm).

10. LIQUID WASTE SYSTEMS

10.1 The following is a list of the requirements for installing a liquid waste handling system at the CNSE Facility.

10.2 Level controls should be provided on collection drums/totes and so arranged to send an alarm to the AAC if a high liquid level is achieved.

10.3 Leak detection and exhaust flow pressure switches should be provided and be interlocked to alarm at the tool(s) and at the AAC.

10.4 Exhaust flow pressure switches should be provided and be interlocked to alarm at the tool(s) and at the AAC in case of exhaust failure.

10.5 Secondary containment must be provided.

10.6 Flammable waste cabinets must be made of 18 gauge steel, double-walled (bulk systems only), be self-closing, be grounded and have fire detection*.

10.6.1 Flammable drums used inside such cabinets must be constructed of steel.

10.7 Corrosive waste cabinets must be made of FM 4910 approved plastic.

10.7.1 Corrosive drums used inside such cabinets must be constructed of polyurethane.

10.8 Lines must be double contained and be constructed of a material that is compatible with the materials they are carrying. In general, stainless steel shall be used for flammable materials and plastic for corrosive materials.

10.8.1 If the lines carrying hazardous wastes are not double walled, then secondary containment must be provided. If secondary containment is not provided then fire suppression must be used.

11. OZONE GAS GENERATORS

11.1 Ozone gas generators having a maximum ozone-generating capacity of 0.5 pound (0.23 kg) or more over a 24-hour period shall be in accordance with this section.

11.2 **Design:** Ozone gas generators shall be designed, fabricated and tested in accordance with NEMA 250.

11.3 **Location:** Ozone generators shall be located in approved cabinets or ozone generator rooms. EXCEPTION: An ozone gas generator within an approved pressure vessel when located outside of buildings.

11.4 **Cabinets:** Ozone cabinets shall be constructed of approved materials and compatible with ozone. Cabinets shall display an approved sign stating: OZONE GAS GENERATOR - HIGHLY TOXIC - OXIDIZER.

11.4.1 Cabinets shall be braced for seismic activity.

11.4.2 Cabinets shall be mechanically ventilated with a minimum of six air changes per hour.

11.4.3 The average velocity of ventilation at makeup air openings with cabinet doors closed shall not be less than 200 feet per minute (1.02 m/s).

11.5 **Ozone gas generator rooms:** Ozone gas generator rooms shall be mechanically ventilated with a minimum of six air changes per hour. Ozone gas generator rooms shall be equipped with a continuous gas detection system which will shut off the generator and sound a local alarm when concentrations above the permissible exposure limit occur.

11.5.1 Ozone gas-generator rooms shall not be normally occupied, and such rooms shall be kept free of combustible and hazardous material storage. Room access doors shall display an approved sign stating: OZONE GAS GENERATOR - HIGHLY TOXIC - OXIDIZER.

11.6 **Piping, valves and fittings:** Piping, valves, fittings and related components used to convey ozone shall be in accordance with the following:

11.6.1 Piping shall be welded, stainless steel piping or tubing.

11.6.2 EXCEPTIONS: 1. Double-walled piping. 2. Piping, valves, fittings and related components located in exhausted enclosures.

11.6.3 Piping materials shall be compatible with ozone and shall be rated for the design operating pressures.

11.6.4 Piping shall be identified with the following: OZONE GAS - HIGHLY TOXIC - OXIDIZER.

11.7 **Automatic Shutdown:** Ozone gas generators shall be designed to shut down automatically under the following conditions:

11.7.1 When the dissolved ozone concentration in the water being treated is above saturation when measured at the point where the water is exposed to the atmosphere.

11.7.2 When the process using generated ozone is shut down.

11.7.3 When the gas detection system detects ozone.

11.7.4 Failure of the ventilation system for the cabinet or ozone-generator room.

11.7.5 Failure of the gas-detection system.

11.8 **Manual Shutdown:** Manual shutdown controls shall be provided at the generator and, where in a room, within 10 feet (3048 mm) of the main exit or exit access door.

12. PYROPHORIC OR WATER REACTIVE LIQUID DISPENSE CABINETS

12.1 Cabinets that dispense or use water reactive /pyrophoric liquids be installed with the following:

12.2 Liquid leak detection that will automatically shut off the dispensing system upon detection.

12.3 Delivery lines shall be constructed of high melting point materials such as 316L SST which has a melting point of ~1400°C..

12.4 Only DOT approved metal containers (stainless steel ampoules can withstand 1200 PSIA or similar) for liquid storage in the dispensing cabinet shall be used.

12.5 The gas inlet and liquid outlet on dispense containers/ampoules must meet the requirements set forth in the SEMI F96-0704 standard. In summary; this standard states that such containers shall be equipped with a gas inlet and liquid outlet port. The ports shall be located such that the dip tube is at the 3 o'clock position and the gas inlet at the 9 o'clock position. Both ports shall be fitted with ¼" OD face-seal connectors. The connectors shall be male on the gas inlet port and female on the dip tube port.

12.6 A fast-acting, high-sensitivity, smoke detection system (HSSD) or very early smoke detection (VESDA) to quickly detect the products of combustion expected as a result of a water reactive /pyrophoric liquid leak must be installed. This system should be capable of providing a hard-wired interface to the cabinet to automatically shut off the dispensing system upon detection.

12.7 Chemical cabinets shall only be installed in buildings that are automatically protected by an automatic sprinkler system.

12.8 The volume of pyrophoric/water reactive materials liquid at the workstation/tool shall be limited to 1.89 liters (0.5 gallons) or less.

12.9 Normally closed pneumatically operated valves in the chemical supply lines that fail safe in the closed position shall only be used.

12.10 If chemical delivery from the cabinet to the workstation/tool uses an inert carrier gas, then this carrier gas will be equipped with an overpressure switch which will automatically shut off the dispensing system if the switch sees a rise in pressure in the carrier piping.

12.11 Chemical cabinets shall be made from at least #18-gauge stainless steel and be provided with a door interlock that shall shut the valves in chemical supply piping in the event the cabinet doors are opened.

12.12 Chemical cabinets shall also be provided with continuous exhaust ventilation. Such exhaust shall be provided with a flow and heat monitoring device. Both monitoring devices shall be interlocked to shut valves in chemical supply piping in the event of an alarm condition.

12.13 Chemical cabinets shall be provided with secondary containment and with an emergency manual off (EMO) button, so when activated will automatically shut off the dispensing system and place the entire system in a safe shutdown condition.

12.14 The Fire detection systems shall be monitored by the building Fire Alarm Control Panel (FACP) and shall provide an automatic text message at the FACP, and via the electronic paging system, to the Emergency Response Team (ERT) describing the location of the workstation/tool in the event of an alarm.

13. AIR POLLUTION CONTROL DEVICES

13.1 Please contact Robert Duff rduff@albany.edu directly for guidance on the type and installation of such devices.

14. HYDROGEN DILUTION AND ABATEMENT

14.1 **Issue:** Hydrogen (H_2) gas is highly flammable and potentially explosive under certain circumstances. Hydrogen gas has an explosive range of between 4% and 96% concentration in air. If hydrogen is released to either the ambient air inside the building or into exhaust ductwork above the lower explosive range (LEL) all that is required is a heat source, spark or open flame to ignite the gas. This could result in personal injury and or damage to equipment and facilities.

14.2 CNSE utilizes hydrogen gas detectors which are tied to our Toxic Gas Monitoring System (TGMS) to alert the Emergency Response Team (ERT) and Security if levels of hydrogen gas exceed 15% of the LEL (0.6%). In order to provide enough warning to react to increasing Hydrogen concentrations before the LEL is reached.

14.3 When un-reacted hydrogen gas is discharged from a tool chamber it is imperative to reduce the concentration to below the LEL of 4.4 % before it reaches a vacuum pump or other source of heat or spark.

14.4 Since hydrogen gas is typically purged from the process chambers with nitrogen gas (N_2), it is usually much less than 100% concentrations in the exhaust. It is preferable to have continuous exhaust/ discharge piping with welded, rather than mechanical, joints between the tool chamber(s) and exhaust duct(s) to avoid leakage to ambient air where it can react with oxygen. If routed through a vacuum pump, welded piping isn't considered as critical since these lines are typically under vacuum.

14.5 **Strategy:** The CNSE strategy has been to reduce the Hydrogen concentration to less than the LEL of 4.4 % at the vacuum pump by dilution with nitrogen.

14.5.1 Vacuum pumps expected to process Hydrogen or other flammable gases are typically purged with 30- 50 liters per minute (lpm) of N_2 gas to reduce the concentration below the LEL and to protect the pump. To reduce the concentration of Hydrogen to below 4% requires a 25:1 dilution. Since most semiconductor processes don't use more than 1 – 2 lpm of Hydrogen, 25-50 lpm of N_2 dilution at the pump should be adequate under those typical flows.

14.5.2 Example Calculation:

- 1 lpm H_2 (100%) + 25 lpm N2 (100%) = 26 lpm with 96% N_2 and 4% H2.
- 2 lpm H_2 (100%) = 50 lpm N2 (100%) = 52 lpm with 96% N_2 and 4% H2.

14.5.3 Most pump manufacturers specification indicate pump purges with N_2 shouldn't exceed 50 lpm as it will affect pump performance. If a process will be flowing more than 2 lpm of hydrogen through a process chamber, additional N_2 dilution will be needed to get below the 4.4% LEL at the pump.

14.6 **Abatement:** If the discharge from the vacuum pump goes directly to a thermal destruction abatement device, the exhaust gas doesn't need any dilution beyond the pump purge. Further dilution of the hydrogen concentration makes thermal destruction less efficient and more energy intensive.

14.7 **Dilution:** If the tool discharging Hydrogen doesn't have a thermal abatement device in which the hydrogen can be destroyed, dilution with an inert gas like N_2 to below the LEL is the only safe alternative. If the exhaust duct has a hydrogen sensor downstream from the vacuum pump discharge, the H_2 level needs to be below the TGMS monitoring warning set point of 0.6 % H_2 concentration. To reach that level, the exhaust gas can be diluted to less than the 4.4% LEL with N_2 and the rest of the way down to the 0.6 % TGMS alarm level with ambient air. It doesn't need to be diluted entirely with N_2.

15. PIPING SYSTEMS

15.1 Piping systems shall be marked in accordance with ANSI A13.1. Markings used for piping systems shall consist of the content's name and include a direction-of-flow arrow. Markings shall be provided at each valve; at wall, floor or ceiling penetrations; at each change of direction; and at a minimum of every 20 feet (6096 mm), or fraction thereof, throughout the piping run.

16. ANNUAL MAINTENANCE

At a minimum annual maintenance shall be performed on all equipment listed herein. Such maintenance shall consist of at least the following:

16.1 Visual integrity check of single and double walled lines.

16.2 Check of secondary containment.

16.3 If available, functionality checks of fire detection and suppression systems.

16.4 Check of interlocks: doors, pressure switches, exhaust flow, leak detectors, emergency off buttons, coaxial lines, calibration and/or change out of gas detectors.

17. RECORDS

17.1 All inspection records, records on installation and maintenance of equipment systems listed herein shall be kept on file in the EH&S office.

18. APPENDIX

Appendix A - HPM Leak Integrity Requirements

Table 1
Equipment Installation Typicals

Equipment Type	Tie into AAC/FACP[4]	Delivery Lines	COAX	Fire Suppression/Detection	Secondary Containment	Grounded	EMO	Materials of Construction	Exhaust Duct Material	Pneumatic Valves	BN2 Switch	Door Switches	Excess Flow Valve	Method of Drainage
Gas Cabinets														
flammable	X	Stainless Steel		X		X	X	#12 Gauge Steel	Stainless Steel	X	X	X	X	
pyrophoric	X	Stainless Steel	X	X		X	X	#12 Gauge Steel	Stainless Steel	X	X	X	X	
corrosive/oxidizer/toxic	X	Stainless Steel	X				X	#12 Gauge Steel	Stainless Steel	X	X	X	X	
highly toxic	X	Stainless Steel	X				X	#12 Gauge Steel	Stainless Steel	X	X	X	X	
Gas VMB														
flammable	X	Stainless Steel		X		X	X	Steel	Galvanized	X	X	X	X	
pyrophoric	X	Stainless Steel	X	X		X	X	Steel	Galvanized	X	X	X	X	
corrosive/oxidizer/toxic	X	Stainless Steel	X				X	Steel	Galvanized	X	X	X	X	
highly toxic	X	Stainless Steel	X				X	Steel	Galvanized	X	X	X	X	
GIB Boxes		Stainless Steel				X	X	Steel	Galvanized	X	X	X		
Liquid Dispense Cabinet/Pre-Cursor/Vaporizers (Fire suppression only if >30 gallons in total[3])														
flammable	X	Stainless Steel		X[2]	X	X	X	#18 Gauge Steel	Galvanized	X	X	X		
pyrophoric	X[4]	Stainless Steel	X	X[2]	X	X	X	#18 Gauge Steel	Stainless Steel	X	X	X		
corrosive/oxidizer/toxic	X	Stainless Steel	X		X		X	#18 Gauge Steel	Galvanized	X	X	X		
highly toxic	X	Stainless Steel	X		X		X	#18 Gauge Steel	Galvanized	X	X	X		
Chemical Dispense Unit (CDU)														
corrosive/oxidizer	X	PFA/PVC	X		X		X	Polyurethane	Lined Stainless			X	X	X
flammable/combustible	X[4]	Stainless Steel		X	X	X	X	#18 Gauge Steel	Stainless Steel			X	X	X
Chemical Valve Manifold Box (VMB)														
corrosive/oxidizer	X	PFA/PVC	X		X		X	Polyurethane	PVC			X	X	X
flammable/combustible	X	Stainless Steel		X	X	X	X	Steel	Stainless Steel			X	X	X
Chemical T/Splitter - Box														
corrosive/oxidizer	X	PFA/PVC	X		X		X	Steel	PVC			X		X
flammable/combustible	X	Stainless Steel		X	X	X	X	Polyurethane	Stainless Steel			X		X
Waste Collection Unit														
flammable	X[4]	Stainless Steel	X?	X[2]	X	X	X	#18 Gauge Steel	Stainless Steel			X		X
corrosive/oxidizer/toxic	X	PFA/PVC	X?		X		X	Polyurethane	PVC			X		X
Ozone Generator (Gas Only)	X	Stainless Steel	X				X	Steel	Galvanized	X		X	X	
Ozone Generator (Ozonated Water)	X	PFA/PVC	X				X	Polyurethane	PVC			X	X	X
Scrubber	X	Stainless Steel					X	#18 Gauge Steel	Galvanized/ Stainless Steel			X		X

NOTES:
1 - Blank
2 - Use a fast acting high sensitivity smoke detection system (HSSD) or very early smoke detection (VESDA)
3 - Fire suppression shall only be installed in cabinets that house >30 gallons of a flammable material
4 - Fire detection alarms shall be tied to the AAC and the FACP

Stainless Steel: 316L Stainless Steel shall be used for all delivery lines
PFA/PVC: Perfluoroalkoxy/Polyvinylchloride
Lined Stainless Steel: Stainless Steel ductwork with Teflon lining

NOTE: Please refer to TGMS Typical Installation Worksheet, EHS-000031 TGMS Operation and Maintenance Specification, Appendix C for further information on Gas Detection, Heat Detection, Exhaust Flow Monitoring and UV/IR requirements.

Table 2
Process Gas Installation Reference

DISCLAIMER: *Toxic, Pyrophoric and reactive materials are typically contained within double walled piping*

Gas Name	Symbol	NFPA RATING			Classification	Gas Distribution	RFO[7] (Y/N)	EFV (Y/N)
		H	F	R	Toxic(T), Corrosive(CO), Pyrophoric(P), Flammable(F), Cryogenic(CR), Irritant(IR), Inert(IN), Oxidizer (OX), Reactive (R)	Single Containment(S) or Double Containment(D)		
Acetylene	C2H2	0	4	2	F,R	S	N	Y
Ammonia	NH3	3	4	0	F, CO	D	Y	Y
Argon	Ar	1	0	0	IN	S	N	Y
Arsine	AsH3	4	4	0	T, F	D	Y	Y
Arsenic Pentafluoride	AsF5	4	0	1	T, CO	D	Y	Y
Boron Tribromide	BBr3	3	0	2	CO	D	Y	Y
Boron Trichloride	BCl3	3	0	1	CO	D	Y	Y
Boron Trifluoride	BF3	4	0	1	CO, T	D	Y	Y
Butane	C4H4	0	4	0	F	S	N	Y
Butene	C4H8	0	4	0	F	S	N	Y
Carbon Dioxide	CO2	0	0	0	IN	S	N	Y
Carbon Monoxide	CO	2	4	0	F, T	D	N	Y
Cabonyl Sulfide	COS	3	4	1	F, T	D	Y	Y
Carbon Tetrafluoride (F-14)	CF4	2	0	0	IN	S	N	Y
Chlorine	Cl2	4	0	0	OX, T	D	Y	Y
Diborane	B2H6	4	4	4	P, T, F, CO, WR	D	Y	Y
Dichlorosilane	H2SiCl2	4	4	1	F, T, CO, F, WR	D	Y	Y
Disilane	Si2H6	0	4	1	P, F	D	N	Y
Ethylene	C2H4	2	4	2	F	S	N	Y
Fluorine	F2	4	0	2	T,CO,OX, WR	D	Y	Y
Fluorine/Argon/Neon mixture	F2/Ar/Ne	4	0	2	T,CO,OX, WR	D	Y	Y
Forming Gas (Hydrogen/ Nitrogen mixture)	H2N2	0	0	0	IN	S	N	Y
Freon 11 (Trichlorofluoromethane)	CCl3F	2	0	1	IN	S	N	Y
Freon 12 (Dichlorodifluoromethane)	CCl2F2	1	0	1	IN	S	N	Y
Freon 14 (Tetrafluoromethane)	CF4	0	0	0	IN	S	N	Y
Freon 22 (Chlorodifluoromethane)	CHClF2	2	0	0	IN	S	N	Y
Freon 23 (Trifluoromethane)	CHF3	1	0	1	IN	S	N	Y
Freon 32 (Difluoromethane)	CH2F2	0	4	0	F	S	N	Y
Freon 41 (Methyl Fluoride)	CH3F	1	4	0	F	S	N	Y
Freon 113 (Trichlorotrifluoromethane)	CHF3	1	0	0	IN	S	N	Y
Freon 115 (Chloropentafluoroethane)	CCl3FCClF2	1	0	1	IN	S	N	Y
Freon 116 (Hexafuoroethane)	C2F6	1	0	0	IN	S	N	Y
Germane	GeH4	4	4	4	T, F, WR	D	Y	Y
Hafnium	Hf	2	3	2	F	S	N	Y
Helium	He	1	0	0	IN	S	N	Y
Hexafluorobutadiene	C4F6	3	4	0	F, T	D	Y	Y
Hydrogen	H2	0	4	0	F	S	N	Y
Hydrogen Bromide	HBr	3	0	0	CO	D	Y	Y
Hydrogen Chloride	HCl	3	0	0	CO	D	Y	Y
Hydrogen Fluoride	HF	3	0	2	CO, T	D	Y	Y
Lanthanum	La	3	1	1	CO,W	D	Y	Y
Liquid Nitrogen	LN2	3	0	0	CR, IN	NA	N	Y
Liquid Oxygen	LO2	3	0	0	OX, CR	NA	N	Y

Gas Name	Symbol	NFPA RATING			Classification	Gas Distribution		
		H	F	R	Toxic(T), Corrosive(CO), Pyrophoric(P), Flammable(F), Cryogenic(CR), Irritant(IR), Inert(IN), Oxidizer (OX), Reactive (R)	Single Containment(S) or Double Containment(D)	RFO[7] (Y/N)	EFV (Y/N)
Methane	CH4	0	4	0	F	S	N	Y
Methyl Chloride	CH3Cl	3	4	1	F, T	D	Y	Y
Methylsilane	CH3SiH3	0	4	0	F	D	N	Y
Nitric Oxide	NO	4	0	0	OX, T	D	Y	Y
Nitrogen	N2	1	0	0	IN	S	N	Y
Nitrogen Trifluoride	NF3	3	0	0	OX, T	D	Y	Y
Nitrous Oxide	N2O	2	0	0	OX	S	N	Y
Octane	CH3(CH2)6CH3	1	3	0	F	S	N	Y
Octafluorocyclobutane	C4F8	1	0	0	IN	S	N	Y
Octafluorocyclopentene	C5F8	3	0	1	T	D	Y	Y
Ozone	O3	4	0	0	OX, T	D	Y	Y
Ozonated water	O3*	4	0	0	OX, T	D	N	Y
Oxygen	O2	0	0	0	OX	S	N	Y
PDE-100	CF4 & O2				IN	S	N	Y
Phosphine (Pyrophoric @15%)	PH3	4	4	0	P, F, T	D	Y	Y
Phosphorus Trifluoride	PF3	3	0	1	CO	D	Y	Y
Propane	C3H6	1	4	0	F	S	N	Y
Silane	SiH4	0	4	1	P, F	D	N	Y
Silicon Tetrafluoride	SiF4	3	0	2	CO, T	D	Y	Y
Silicon Tetrachloride	SiCl4	3	0	1	CO	D	Y	Y
Sulfur Dioxide	SO2	3	0	0	CO, T	D	Y	Y
Sulfur Hexafluoride	SF6	1	0	0	IN	S	N	Y
TEOS	TEOS	2	2	1	COMB	S	N	Y
Titanium tetrachloride	TiCl4	3	0	2	CO, T	D	Y	Y
Tetrafluorogermane	GeF4	3	0	2	CO, T	D	Y	Y
Trimethylaluminum	TMA	3	4	4	P, T, W	D	Y	Y
Trimethylsilane	(CH3)3SiH	2	4	1	F	D	N	Y
Pentene	C5H10	0	4	0	F	S	N	Y
Tungsten Hexafuoride	WF6	4	0	1	T, CO	D	Y	Y

Notes:

1. All gas lines shall be constructed of stainless steel.
2. All liquid chemical lines that are pressurized to 15 psi or greater that carry materials with Health and Reactivity NFPA rating of 3 or greater, must be double contained plastic.
3. All liquid chemical lines that are pressurized to 15 psi or greater that carry materials with Flammables with NFPA rating of 4 must be single walled stainless.
4. Pyrophorics highlighted in yellow
5. Armaflex 1/2" will be used for insulation of lines. This may have to be modified for C5H10 and SiCl4 to 1".
6. Only lines identified that require heat tracing are BCl3 and SiCl4.
7. An RFO shall be installed in the gas cylinder valve. 0.030" for corrosives, 0.006" for silane/pyrophorics and highly toxics, and 0.010" for flammables.

* Determined that the hazard ratings for ozonated water are the same as ozone gas. Ozonated water (plastic lines), ozone g

When such materials are used outdoors in above-ground piping systems or within buildings, they shall be in accordance with ANSI B31.9 and one of the following:
1. Suitably protected against fire exposure. 2. Located where leakage from failure would not unduly expose people or structures. 3. Located where leakage can be readily controlled by operation of accessible remotely located valves.
In all cases, nonmetallic piping shall be used in accordance with NFPA 30:3-3.6.

Appendix A – HPM Leak Integrity Requirements

1. PURPOSE

The purpose of this appendix is to set out the leak integrity requirements for all equipment containing HPMs at the College of Nanoscale Science and Engineering (CNSE). This appendix shall be adhered to whenever a new HPM line is installed or an existing HPM line is altered at the CNSE.

2. SCOPE

The scope of this appendix includes verifying the leak integrity of all gas lines, secondary containment gas lines, gas cabinets, valve manifold boxes (VMBs), gas interface boxes (GIBs), tool gas boxes, tool interconnecting vacuum lines, tool exhaust/vent lines, liquid chemical lines, secondary containment liquid chemical lines, liquid chemical VMBs, liquid chemical delivery units (CDU), tool liquid chemical deliver units, tool liquid chemical VMBs, liquid drains subjected to any HPMs, as well as any other equipment used for handling/moving/containing any HPMs used within the CNSE facility.

3. DEFINITIONS

3.1 **HPM** – is a Hazardous Production Material.

3.2 **Leak** – is a path(s) in a sealed system that will allow material to pass through it when a partial pressure differential exists. There are two typical mechanisms for such a leak, a mechanical passage or a porous material through which material can diffuse or permeate.

3.3 **Inboard Leak** – is a leak from outside to inside the tested system, when the external partial pressure surrounding the system is greater than the internal partial pressure.

3.4 **Internal Leak** – is a leak occurring across a flow barrier of a component of the tested system, such as the seat of a closed valve.

3.5 **Outboard Leak** – is a leak from inside to outside the tested system, when the internal partial pressure is greater than the external partial pressure surrounding the system.

3.6 **Standard Leak Rate** – is the quantity of helium at 295 K (22 ^{o}C) and 101.3 kPa (1 atm) flowing through a leak when the partial pressure of

helium on the high-pressure side is 101.3 kPa and the partial pressure on the low-pressure side is much lower.

3.7 **Measured Leak Rate** – is the quantity of helium at the recorded testing conditions of temperature and pressure flowing through a leak.

Measured Leak Rates should be converted to *Standard Leak Rates* via the following equation prior to comparison with the CNSE requirements set out in this document.

- Stand Leak Rate = Measured Leak Rate * *Pressure Correction* * *Temperature Correction*
  - *Pressure Correction* = (101.3 kPa)/(Actual He Absolute Pressure)
  - *Temperature Correction* = (Actual Absolute Temperature)/(295K)

4. HPM LEAK INTEGRITY REQUIREMENTS

4.1 All systems for handling/moving/containing *gaseous/vaporous* HPMs shall be free from any standard leaks greater than $1 * 10^{-7}$ Pa l / s ($1 * 10^{-9}$ mBar l / s) via both Helium Leak Detection, as well as Pressure-Decay Leak Detection.

4.2 All systems for handling/moving/containing *liquid* HPMs shall be free from any standard leaks greater than $1 * 10^{-4}$ Pa l / s ($1 * 10^{-6}$ mBar l / s) via both Helium Leak Detection, as well as Pressure-Decay Leak Detection.

5. HPM LEAK INTEGRITY TESTING

5.1 All systems for handling/moving/containing *gaseous/vaporous* HPMs above atmospheric pressure shall pass Outboard Leak testing with the HPM system charged with inert gas at least 125% of the intended delivery/process pressure of the HPM gas/vapor.

5.2 All systems for handling/moving/containing *gaseous/vaporous* HPMs at or below atmospheric pressure shall pass Inboard Leak testing with the HPM system evacuated of inert gas to at least 75% of the intended delivery/process pressure of the HPM gas/vapor.

5.3 All systems for handling/moving/containing *liquid* HPMs shall pass Outboard Leak testing with the HPM system charged with inert gas at least 125% of the intended delivery/process pressure of the liquid HPM.

5.4 The project manager for all installations/alterations must provide a suitable leak checking procedure in writing to CNSE EHS for approval prior to performing any HPM Leak Integrity Testing.

- The project manager should verify that any Pressure-Decay Leak Detection procedure (submitted to CNSE EHS for approval) takes into account:

    1) the accuracy of all pressure gauges,

    2) the attainable temperature stability of any system tested, and

    3) the total combined volume of any system tested.

- The project manager should also verify that any such procedure, clearly describes how any isolation valves (to be tested within the system), will be controlled throughout the testing. In addition, a pre-test controlled leak introduction-step suitable to verify that any isolation valves (to be tested within the system) will be appropriately controlled throughout the testing.

- The project manager should verify that any Helium Leak Detection procedure (submitted to CNSE EHS for approval) clearly outlines the reasons for substituting Inboard for Outboard or Outboard for Inboard Helium Leak Detection for any system to be tested. They should also verify that:

    1) there is a reasonable method of marking each fitting/connection after it has been tested,

    2) the qualifications of the individual(s) to conduct the testing, and

    3) the make/model/calibration of the Helium Leak Detector to be used to conduct the testing is included in the procedure

6. DUPLICATE RECORDS

Leak Check Data Sheets (EHS-00064-F1) must be completed for each HPM handling/moving/containing system or subsystem of every tool before any HPMs are introduced to the tool. All end points of each HPM system/subsystem must be labeled with tags clearly showing:

1) the Hex ID of the tool involved,

2) the index of the particular system/subsystem,

3) the letter designation of the particular end point, as well as

4) the date plus initials of the individuals conducting the testing.

7. LEAK CHECK DATA SHEET (SAMPLE)

Sample EHS-00064-F1
LEAK CHECK DATA SHEET

Tool Hex ID: _____
HPM System/subsystem Index: _____
HPM System/subsystem End Points: _____ **through** _____

PRESSURE-DECAY LEAK DETECTION

	START	STOP	Delta	Pass
Date and Time:			-	-
Pressure Reading:				Yes ☐
Temperature Reading:				Yes ☐

Pre Test Controlled Leak Completed: Yes ☐ No ☐

HELIUM LEAK DETECTION

Type of Test: Inboard ☐ Outboard ☐

Start Date and Time:	Stop Date and Time:
Starting Background Leak Rate:	Final Background Leak Rate:
Number of Fitting/Connections Tested:	Number of Leaks Repaired:

Pre Test Controlled Leak Completed: Yes ☐ No ☐

All Tested Fittings and Connections Marked: Yes ☐ No ☐

APPROVAL

Test Performed by: _____ Date: _____

Test Approved by: _____ Date: _____

EHS Approval by: _____ Date: _____