

Northwestern University Micro/Nano Fabrication Facility (NUFAB)

NUFAB SAFETY & PROTOCOL



NORTHWESTERN
UNIVERSITY

NUFAB
Northwestern University
Technological Institute
2145 Sheridan Road,
Evanston, IL 60208
<http://nufab.northwestern.edu/>
Email: nufab@northwestern.edu

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1.0 INTRODUCTION

Northwestern University Micro/Nano Fabrication Facility (commonly known as NUFAB) started its operation on March 1, 2010 in a temporary clean room in EG20 and NG32 Technological Institute with all new fabrication and characterization equipment. On August 1, 2013 it moved to a newly constructed state-of-the-art 6,500 square feet clean room with attached staff offices and conference room/viewing lobby in the F-Wing of the Technological Institute. 1000 ft² expansion was completed in December 2018 to accommodate more process tools as our usage grew. New fabrication tools are regularly added based on needs of our users and as new techniques and capabilities become available. The NUFAB resources are available for use to all Northwestern faculty and research students, as well as outside researchers. Please visit the NUFAB website <http://nufab.northwestern.edu/> to find out about currently available facilities and startup procedures.

NUFAB clean room contains class 100 (ISO 5) areas and hence requires specialized gowning and use protocols. Also, it is equipped with wet chemical benches and fully automatic hazardous gas cabinets. This orientation is designed to train new users on general protocols and hazards in the clean room.

The fabrication and characterization research equipment in NUFAB is fairly complicated to use and maintain, and may cause harm to the users if proper safety procedures are not followed. In addition, each piece of equipment is used by more than one research group for different research projects and hence requires special usage and maintenance procedures. For this reason, separate training documents have been developed for each piece of equipment including the wet benches. Users need to be trained and qualified by NUFAB staff to use any piece of equipment.

1.1 Goal

The goal of this document is to provide NUFAB clean room protocols in detail that includes startup information for new users, gowning, clean room operation and behavior, hazards and safety systems, and emergency evacuation.

1.2 Scope

All persons using NUFAB facilities are required to follow the procedures listed here or posted in the clean room. The scope of this document is limited to the NUFAB research users in the active research spaces (clean areas). Work activities in the NUFAB mechanical space and the NUFAB support chases are only performed by NUFAB staff, authorized Facilities staff or authorized contractors.

1.3 The NUFAB Staff

The NUFAB staff comprises of management and technical staff. Their contact information is available on NUFAB website. Please feel free to contact any of them for specific questions. The facility email address should be used for all general inquiries.

NUFAB Website: <http://nufab.northwestern.edu/>
NUFAB Email: nufab@northwestern.edu

2.0 USING NUFAB

2.1 Acknowledgment for Publications and Presentations

To expedite the access process, we do not require project submission and approval to use NUFAB facilities. However, if you are submitting work done at NUFAB for publication in scientific journals or conference presentations, we ask that you acknowledge NUFAB and inform us by sending an email to nufab@northwestern.edu. This information is critical to continue receiving our funding to support your research.

Please check out our website for the statement to be used for journal publications. You can use the logo on NUFAB website for your presentations.

2.2 Access Procedure

NUFAB has various fabrication and characterization equipment for self-use and staff provided service. Consult the NUFAB website for the currently available facilities, and if interested in using, follow the three steps below (Sec 2.2.1 to 2.2.3). Remember, NUFAB facilities are available for use to all NU researchers as well as all external academic and industrial users.

1. Meet with NUFAB staff (optional but encouraged).
2. Submit an application.
3. Complete training.

2.2.1 Meeting with NUFAB Staff

NUFAB staff can suggest the effective ways of accomplishing your project, and answer questions about the capabilities of each piece of equipment. You can either discuss on phone or request a face to face meeting with NUFAB staff free of charge. If you would like a meeting, email nufab@northwestern.edu with your availability and project description with the following information to make the meeting more productive for you.

1. Your name and department and the name of your faculty advisor (if applicable).
2. A brief description of your project.
3. In a PowerPoint presentation, provide details of the processes that you want to accomplish using NUFAB facilities. Use illustrations with the description, especially if you are planning to do fabrication.

2.2.2 NUFAB Application

There are different access procedures for internal (NU) and external (other academic or industrial) users which are available on NUFAB website. Utilizing past user feedback, we have made these procedures simple and hence efficient. As with all other aspects, we welcome user feedback on this process too.

2.2.3 Trainings

Trainings are offered through NUcore. Please follow the instructions provided here:

<https://nucore.northwestern.edu/facilities/nufab>.

Requirements for clean room user access are completion of:

- NUFAB Safety & Protocol Training for Clean Room Access,
- Office for Research Safety (ORS) Safety training modules

All required training modules must be completed successfully. ORS training certifications are transferable.

The NUFAB SAFETY & PROTOCOL ORIENTATION has two components: an online component and a hands-on component.

2.2.3.1 NUFAB Clean Room Training Part I - Online

The materials to read are available on the NUFAB website and also in the online training module. Make sure to read and understand the materials thoroughly before taking the online test as the test is fairly complex.

2.2.3.2 NUFAB Clean Room Training Part II – Hands-on

Requirements:

1. Successful completion of NUFAB Clean Room Training Part I - Online.
2. Valid ORS training certifications

Items to bring with you: WildCARD (the type that works on proximity card reader).

The purpose of this training is to familiarize the user with the clean room, equipment, procedures, and the associated safety protocols. Topics include: introduction to the clean room, gowning and cleanroom protocols, hazards of chemicals, how to read MSDS, chemical labeling, proper storage of solvents, hazards of solvents due to toxicity, flammability and reactivity, proper safety procedures, proper disposal of used halogenated and non-halogenated solvents, properties of acids and bases, proper mixing and dilution of acids and bases, proper storage of acids and bases, safety procedures for dealing with acids and bases, and procedures of properly disposing of waste chemicals. NUFAB staff may hand out additional training materials as part of this training.

Once this training has been completed, NUFAB staff activates the user's WildCARD to allow access to the clean room. Access may be denied after training certifications expire or as a result of disciplinary action.

Important:

- If you do not use NUFAB for a six-month period continuously, you may lose access to the NUFAB and authorization to use any equipment. In that case, the NUFAB training certifications will need to be repeated to gain access to the clean room.
- Using others WildCARD or helping others to enter or leave the clean room is strictly forbidden and may result in immediate revocation of your clean room access. If you do not

have your ID with you and you are an authorized user in good standing contact the NUFAB staff.

2.3 NUFAB Equipment Training

Authorization to use specific tools requires tool specific training and skills assessment. NUFAB users who have completed the hands-on training can request tool specific trainings in NUcore. This training may take one or more sessions depending on the complexity of the equipment. Ask your trainer for any other requirements for that particular equipment before you can become an independent user. After you complete the training, it is recommended that you use the equipment at least once during the daytime within the first week.

Important:

- No equipment can be used without training. You need to get training for each piece of equipment that you want to use.
- Only approved processes can be done. You are responsible for getting NUFAB staff approval for any new process.
- No equipment or facility modification or repair can be done by any user.
- You must be logged in to use each tool in NUcore. Using any tool while somebody else is logged in may result in suspension of your access to that tool.

2.3.1 Equipment Use

After authorization, equipment can be reserved in NUcore for use and activated in NUcore before using it. However, reservation is not required. If any equipment is available, it can be activated in NUcore and used right away. A link for NUcore is available on NUFAB website.

3.0 INTRODUCTION TO THE CLEANROOM

NUFAB clean room is located on the ground floor of the Tech Institute in the F-corridor. During normal business hours NUFAB offices are accessible to the public from Tech FG-70. The NUFAB layout is shown in Figure 1.

3.1 Entrance

Access to the clean room is restricted to authorized users. There is a WildCARD reader at the entrance and the exit of the clean room. These are proximity readers. You hold your card close to the reader to unlock and open the door.

3.1.1 Gowning Room

Gowning room is designed for gowning before entering the clean areas. It is divided into two by a stainless steel bench and the coverall racks. The first area you enter into is dirtier and requires only short shoe covers. The area past the bench and coverall racks is cleaner and requires full gowning.

The gowning room has all the gowning supplies, first-aid kit, spill control kit, and a cleaning rack for wiping off everything that needs to go in the clean areas.

3.2 Bays and Chases

The interior of the cleanroom utilizes a bay-chase design, with air supplied through the ceiling of the bays and returned through the chases. Sometimes, bays are also called 'white areas' and chases 'grey areas'.

3.2.1 Bays

Bays are the clean areas. Bay 1 is process bay, Bay 2 is photolithography bay, and Bay 3 is characterization bay (Figure 1). Bay 1 is further divided in to thermal, deposition/etch, and acid processing areas. Characterization bay has connected rooms for ebeam writer, FIB/SEM, packaging, and tool repair. The repair room is only accessible to NUFAB staff.

All research equipment is either bulkhead mounted through the wall or located in the bays.

NUFAB users work in the bays and are not allowed in the chases.

3.2.2 Chases

Chases surround all the bays. Support equipment like vacuum pumps, chillers, gas cylinders, and gas cabinets are located in the chases. Utilities like nitrogen, compressed air, and water lines run through the chases.

Chases are accessible only to NUFAB staff and authorized service personnel.

3.3 Clean Room Operation

The NUFAB cleanroom is an enclosed, isolated work area which incorporates a high standard of controls for humidity, temperature, and filtration to minimize all forms of particle matters and contamination.

A simplified clean room air flow pattern is shown in Figure 2. The outside air is filtered by pre-filters to remove big particles. If it is cold, then the air is heated to the desired temperature. Steam is added in the next stage followed by cooling. A fan unit circulates the air through the clean room. The air enters across the whole ceiling through HEPA filters at a constant velocity and travels rapidly downwards into the room in the form of parallel streams and exits through the raised perforated floor. The air is said to be travelling in laminar flow. The super clean air travelling downwards has the effect of picking up any particles in the air and flushing them away to the floor. In the chases the air flows from the floor towards the ceiling and then again through the HEPA filters. In a typical clean room air turns over 180 times per hour (three times per minute) but can be as high as ten times per minute.

HEPA filters are high efficiency particulate air filters. HEPA filters were originally developed during Manhattan Project to remove radioactive contaminants from the air in the development of the atomic bomb. These are 95 to 99.997% efficient for 0.3 micron size particles. In the clean room, their typical lifetime is 15 years. A more efficient filter is called ULPA (ultra low penetration air filter). It is 99.997% efficient for 0.12 micron size particles.

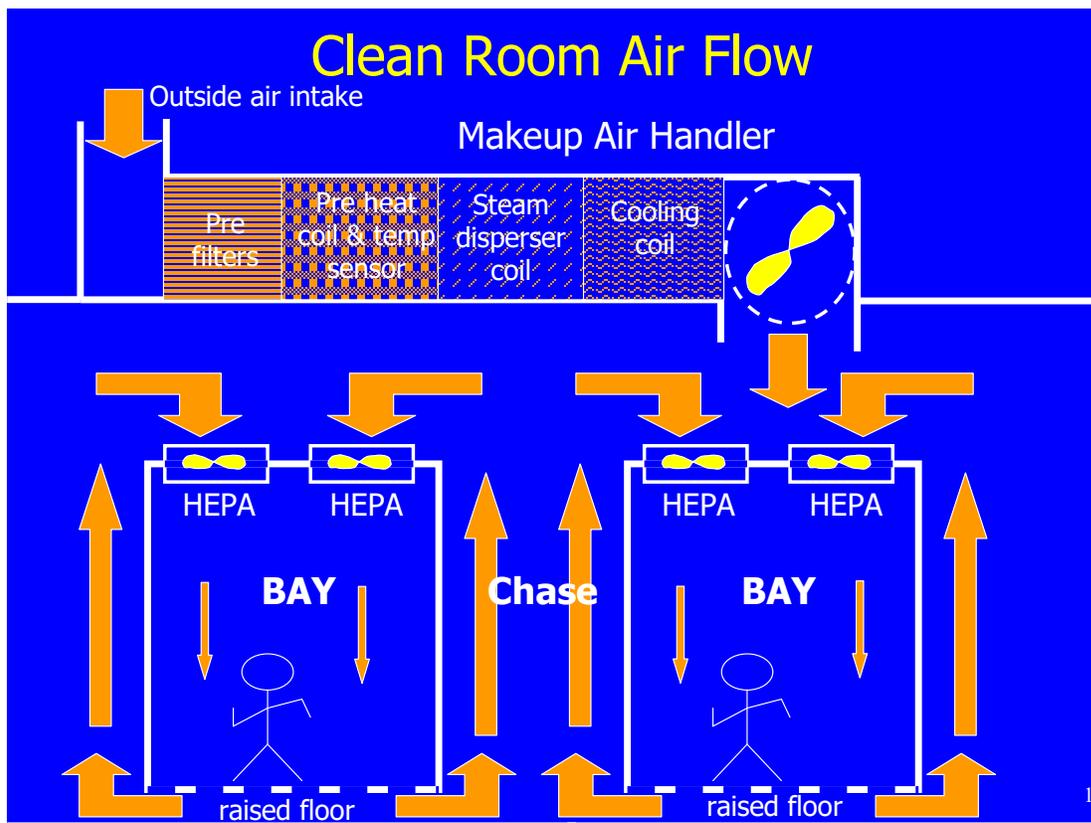


Figure 2: Simplified Clean Room Air Flow.

3.4 Clean Room Classifications

As the name tells clean rooms are cleaner than regular rooms. These are built using clean room building materials that don't shed particles for floors, walls, ceilings, doors, all fixtures, etc. Clean room classification is used to describe how clean a clean room is and is based on number of particles present in the room air. There are two standards that define the clean rooms: the Federal and ISO standards.

Federal Standard 209e defines a class 1 clean room as the one that contains less than 1 particle of size 0.5 micron or larger per cubic foot of space. Similarly, class 10 clean room has between 1 and 10 particles of 0.5 micron or larger per cubic foot, and so on. Generally, lithography bays are class 100 and process or characterization areas 1000 or higher in university clean rooms.

ISO 14644-1 standard specifies the decimal (base 10) logarithm of the number of particles 0.1 μm or larger permitted per cubic meter of air space. So, for example, an ISO class 5 clean room has at most $10^5 = 100,000$ particles per m^3 . Because 1 m^3 is approximately 35 ft^3 , the two standards are mostly equivalent when measuring 0.5 μm particles, although the testing standards differ.

Class	Maximum Particles/ ft^3					ISO Equivalent
	$\geq 0.1 \mu\text{m}$	$\geq 0.2 \mu\text{m}$	$\geq 0.3 \mu\text{m}$	$\geq 0.5 \mu\text{m}$	$\geq 5 \mu\text{m}$	
1	35	7	3	1		ISO 3
10	350	75	30	10		ISO 4
100		750	300	100		ISO 5
1,000				1,000	7	ISO 6
10,000				10,000	70	ISO 7
100,000				100,000	700	ISO 8

Table 1: US FED STD 209E Cleanroom Standards

Class	Maximum Particles/m ³						FED STD 209E equivalent
	≥0.1 μm	≥0.2 μm	≥0.3 μm	≥0.5 μm	≥1 μm	≥5 μm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room air

Table 2: ISO 14644-1 cleanroom standards.

The ordinary room air is approximately class 1,000,000 or ISO 9. The tables compare the two standards. US FED STD 209E was officially cancelled by the General Services Administration of the US Department of Commerce November 29, 2001 but is still widely used.

3.5 Clean Room Features and Specifications

The clean room environment is tightly controlled from a remote network computer. In addition to particles, the environmental specifications controlled are:

Temperature: 68 ± 2 °F

Humidity: 45 ± 5 %RH

A positive pressure is maintained in the clean room with respect to the general building areas to prevent air from dirty areas to enter clean room. Inside the clean room, the cleanest area has the most positive pressure.

In case of a detected fire or gas release inside the clean room, the ventilation system will switch the air pressure to the F-wing corridor to negative. The release of smoke or gas is thus contained within NUFAB.

The following facilities are generally available throughout the clean room.

Lab. vacuum: 25" to 28" of Hg

Compressed dry air: 44 °F DP (dew point), 110 psi, 24 scfm

House cleanup vacuum: For cleaning inside the clean room.

Plant nitrogen: 100 psi, 99.999% (5N purity) (boil-off from liquid nitrogen)

Liquid nitrogen: Fill up station at the tank

Emergency Power: Available for emergency lights and select equipment.

3.6 Airborne Particles

In clean rooms the biggest problem are the particles that we cannot see. The human eye can see objects bigger than about 10 to 20 μm across. Hair is about 100 μm and grain of salt is between 20 and 40 μm . Pollen is 10 μm and E. Coli bacteria is 0.6 to 15 μm . There are many types of particles that are too small for us to see.

Some industrial sources note that 80% of the contamination in cleanrooms result from people who work in them. The major source of contamination comes from the human body. This is brought about by skin flakes which leave the body, break up and disperse into the atmosphere. The flakes are 10 to 40 microns across and some 2 to 4 microns thick. The skin flakes become detached by the rubbing action of limbs or clothing, and by movement. The whole skin surface is shed and renewed every few days, which means that many hundreds of thousands of flakes are shed from the body each minute. Sitting quite still for example disperses 100,000 particles per minute into the environment. Moving your arms and hands and turning your head sheds about 500,000 particles per minute. Walking and climbing stairs or full body activity can generate ten million particles per minute. Other sources of particles can be shoe dust and outside air, wood, leather, and paper. Small particles hang on to each other and off of surfaces like equipment, ceiling, and walls by electrostatic or molecular adhesive forces, and come off by rubbing and touching.

Coughs and sneezes create considerable contamination, and it is nearly always directional. When coughing or sneezing step away from the samples and equipment. Do not talk towards the samples or equipment. Other ways that people can cause problems is by cross contamination, where matter is transferred by touch from one material surface to another.

Fast walking or arm movement creates turbulent vortices which disturb the laminar flow. Turbulent vortices can take particles up and outwards creating contamination. Keeping hands below the bottom of a carrier and the carrier held high allows the cleanest air to flow over the product.

Working in cleanrooms with special equipment and clothing requires a great deal of discipline and responsibility.

3.6.1 Terminal Velocity

The terminal velocity is given by

$$V_T = \frac{g \times d^2}{18 \times \mu} (\rho_s - \rho)$$

g = gravity = 9.8 m/sec²

d = diameter of the spherical object

μ = fluid viscosity = 1.78e-5 Kg/m/sec for air

ρ_s = density of the object = 1000 Kg/m³ for water or 10,000 Kg/m³ for metal (average)

ρ = density of the fluid = 1.2 Kg/m³ for air

From this equation, we can calculate that 1.5 μm size water particle (or 0.5 μm size particle of metal) will take 12 hours to fall 3 meters (i.e., from ceiling to floor). This tells us that small particles in the air take forever to fall to ground. However, the sky divers can reach 200 mph or even higher velocities by putting their heads down while diving by reducing air resistance. To give small particles higher velocities, clean rooms use laminar air flow through the HEPA filters in the ceiling with velocities high enough to push particles down in a fraction of a minute.

4.0 EMERGENCY PROCEDURES

The NUFAB cleanroom is fire rated in a higher hazard class as other laboratories. In case of accident or emergency the prime concern is the safety of the personnel. Follow the guidelines as outlined in this document.

If an alarm is activated, follow the instructions. If an alarm calls for evacuation, do it in orderly manner.

4.1 Emergency Evacuation

NUFAB exit plan is shown in Figure 3. It should be noted that regular cleanroom protocols do not apply in emergencies, instead follow the emergency protocols described here.



Figure 3: NUFAB Exit Plan

There are two scenarios that require immediate evacuation of the NUFAB facility

1. Activation of the fire alarm system, which is indicated by white strobes and an evacuation message.



Figure 4: White strobes for fire alarm system

2. Activation of a Gas Alarm Level 2 (Red Alarm) in the Toxic Gas Management & Control System is indicated by a red blinking light and a horn on a stacked light tower.



Figure 5: Light tower for gas alarm system

If you see strobes, flashing red lights or hear horns, stop whatever you are doing, and evacuate in quick but orderly manner. Use the nearest available emergency exit.

There are two main exits for NUFAB users. Exit through the Tech F-corridor and out of the Tech F/G wing, or exit through the vestibule onto the Tech Drive out of the building. To evacuate from the vestibule, you will need to use the yellow door unlock buttons. These are for emergency use only.

The NUFAB rally point is by the Tech Loading Dock.

NU police gets direct notification of all these events and is dispatched promptly. Wait at the loading dock and provide police any relevant information that you have.

4.1.1 Manual Activation of Emergency Alarms

The NUFAB users can manually activate the fire alarm or gas alarm. This should only be done if a user has a good reason to believe that there is a toxic gas or fire hazard in the clean room but the relevant alarm is not going off. The reasons could be a problem of a sensor that activates these alarms or a user brings in an unauthorized chemical that is not detected by the gas sensors in NUFAB, etc.

To activate the fire alarm, pull down on the red fire alarm pull station. These pull stations are located at every door exit (Figure 3). To activate the toxic gas alarm, lift the plastic flap and push the red button on any emergency gas off (EGO) station (Figure 6). There are nine blue EGO stations located in the cleanroom. A manual activation of the NUFAB EGO button, closes all cylinder gas valves, and sets off the red alarm lights and horn.



Figure 6: (From left to right) Emergency gas off station (blue), emergency door unlock (yellow), and fire pull station (red).

4.2 Emergency Contacts

For emergency call 911.

Give the following information:

1. Your name
2. Location
3. Nature of emergency (fire, chemical spill/leak, injury, etc.)

911 Emergency/After Hours Contact

Northshore University Health System - Evanston Hospital Emergency Room
2650 Ridge Avenue
Evanston, IL 60201
Tel: (847) 570-2111

Work related Medical Non-Emergencies for Undergraduate Students

Contact the Northwestern University Health Service (NUHS)
Location: 633 Emerson St. (Searle Hall)
Phone: 847-491-8100 (24/7 response)

Work related Medical Non-Emergencies for Graduate Students, Post Docs and Employees

Notify NUFAB staff. The supervisor will contact the Risk Management claims manager at (847) 491-5582. The claims manager will then contact OMEGA to arrange an appointment for an examination. Medical services are provided to Northwestern University employees at Occupational Medicine Evanston/Glenbrook Associates (OMEGA), 1000 Central Street, Suite 840, Evanston, (847) 570-2620, the primary care facility for work-related injuries and illnesses.

4.3 External Emergency Response

Upon activation, the F/G wing fire alarm system summons University Police (UP) and Evanston Fire Department (EFD). UP and EFD will assess the situation with NUFAB users, available NUFAB staff, Risk Management, and Office for Research Safety (ORS) staff through interviews, and video surveillance.

In case of an activation of a Gas Alarm Level 2 (Red Alarm), the UP Communication Officer calls NUFAB staff, the ORS page group, Facilities Manager on-duty, and dispatches NU officers to the NUFAB rally point at the Tech Loading Dock or F-wing ground floor. If UP can establish no communication with NUFAB users or staff, ORS may ask the responding UP supervisor to preemptively evacuate the Tech F/G wing by manually activating the fire alarm. If video surveillance shows a person down in NUFAB, UP notifies EFD via 911. EFD responders may enter NUFAB if it is safe to do so, and a person needs to be rescued.

Only trained personnel equipped with necessary personal protective equipment and knowledge of information from the HMI touch screen shall enter the NUFAB facilities after an alarm.

A Human Machine Interface (HMI) touch screen is in the F-corridor ground floor outside the NUFAB entrance and in the Tech Fire Command Center. NUFAB staff and other authorized persons can silence an audible alarm of the Honeywell System on the HMI touch screen or via a physical push-button at the Honeywell Central Control Panel in the NUFAB mechanical room 1st floor.

5.0 NUFAB EMERGENCY AND SAFETY EQUIPMENT

5.1 Emergency Equipment

The locations of safety showers and eye wash stations, fire extinguishers, emergency phones, and first-aid kit are shown on Figure 7.

Emergency Phones: There are two emergency phones, one at the main entry/exit and another one at the emergency exit in vestibule. Press the button on these to reach NUPD.

Safety showers/eye wash stations: There are seven safety showers/eye wash stations. Their locations are indicated on the floor plan in Figure 7.

Fire Extinguishers: Locations of CO₂ fire extinguishers are indicated on the floor plan in Figure 7. Do not attempt to extinguish burning gases until the gas supply is shut off. Activate the fire alarm pull station before using a fire extinguisher. Follow PASS: Pull, Aim, Squeeze, and Sweep.



Figure 8: Fire extinguisher in its cabinet

Automatic Fire Sprinkler System: The Tech F/G Wing is connected to an automatic fire sprinkler system. NUFAB has a preaction-automatic fire sprinkler system, which means that two components of the NUFAB fire suppression system have to be activated to have sprinkler water flow. Individual sprinkler heads are heat-activated.

Fire Alarms: The Technological Institute F/G wing fire alarm is activated in case of fire, smoke detection, sprinkler water flow or manual pull station activation. A respective audible message and white strobes indicate fire alarm activation. Evacuate all floors of the Tech F/G Wing immediately. In case of uncontrolled fire in NUFAB, use the ‘pull handles’ located at all emergency exits to activate the fire alarm and evacuate the Tech F/G wing.



Pull handle for manual actuation of fire alarm

Figure 9: Manual Actuation of Fire Alarm

If a fire alarm or gas alarm is activated inside the NUFAB cleanroom the air balance of the NUFAB clean room turns from positive to negative. If a fire alarm is activated anywhere else in the Tech F/G wing the air balance of the NUFAB clean room remains positive.

Honeywell Toxic Gas Monitoring and Control System (Honeywell System)

The Honeywell System is comprised of two separate detection systems; one for toxic gases (VERTEX) and another one for flammable gases (MIDAS). Gas sampling points are installed in various locations. The Honeywell System or the manually activated emergency gas-off (EGO) buttons can act on pneumatic gas supply valves and other system components. The Human Machine Interface (HMI) logs data and displays the current status.

There are two HMI touch screens installed close to the NUFAB exits. NUFAB users can view the HMI touch screen at the NUFAB entrance and see the Honeywell System status at any time. A third HMI touch screen is in the Technological Institute Fire Control Room.

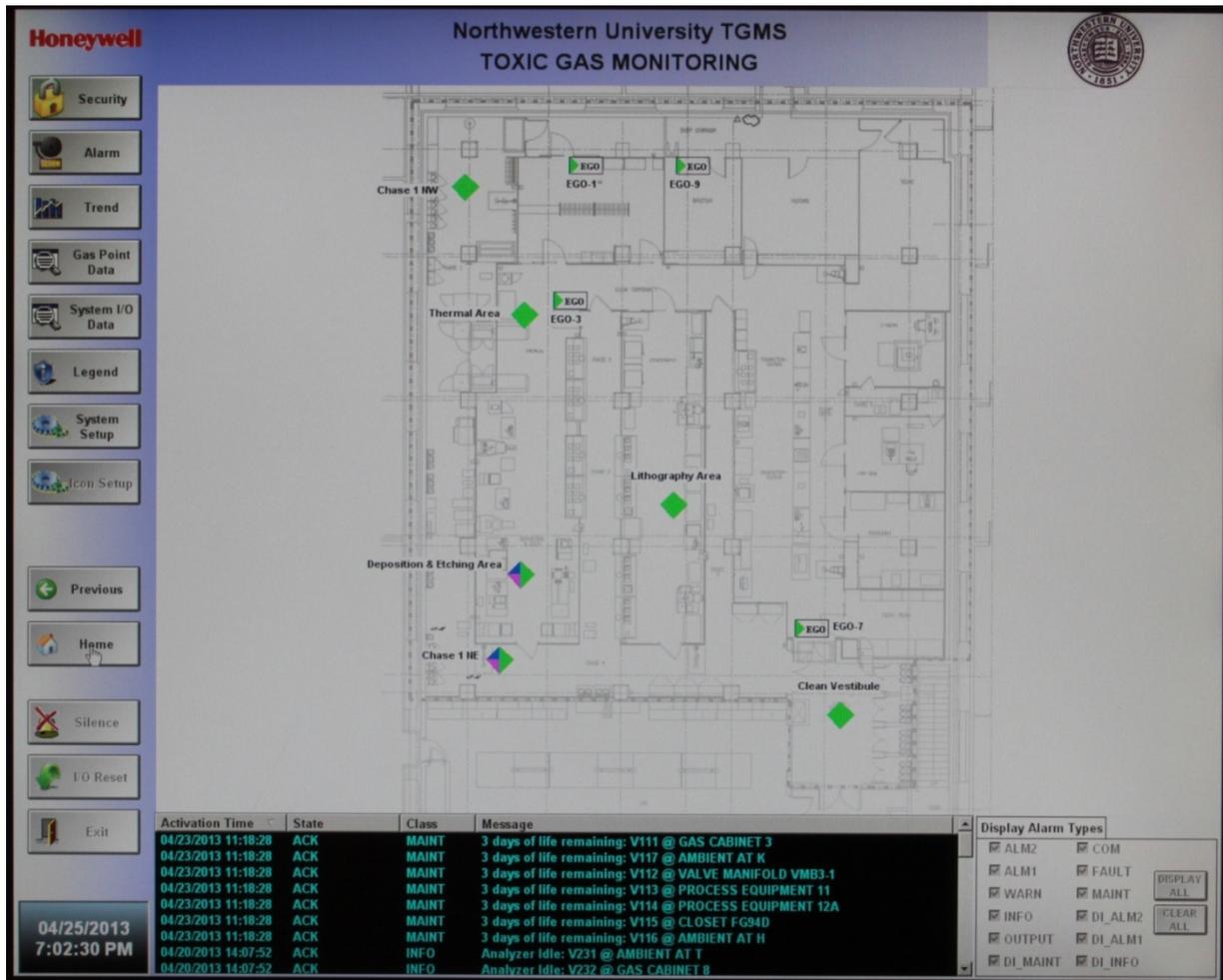


Figure 10: Home Screen of the HMI

When the Honeywell System detects high levels of hazardous gas in the ambient air, it will shut off the flow of the hazardous gas at the gas cylinder valve, switch the air balance of the NUFAB clean room from positive to negative, and activate visual and audible alarms.



Figure 11: Toxic gas alarm

A Gas Alarm Level 2 is indicated by an audible signal and a red flashing light. All NUFAB users and staff must evacuate the facility and NUFAB mechanical space upon activation of a red alarm.

A Gas Alarm Level 1 is indicated with a yellow light. This indicates a low level leak for which evacuation is not required.

Blue light indicates that the system needs attention but is functioning properly. No evacuation is required for blue light.

A Honeywell System trouble or the activation of an EPO on a gas cabinet or valve manifold box is indicated by a blue light.

Bench and Tool Emergency Power Off (EPO) or Emergency Machine Off (EMO) Buttons

Some benches or tools have an EPO or EMO. Manually push the button only in a local tool emergency.



Figure 12: Solvent bench

Tool or bench exhausts

Only operate tools with a working tool or bench exhaust.



Figure 13: Do not operate if an exhaust failure is indicated on the tool display!

Emergency door release

The NUFAB suite exit door to the Tech Drive vestibule is normally locked and secured. Use the door release handle on the wall in an emergency.



Figure 14: Pull handle to unlock emergency exit doors

NUFAB users are only permitted to exit through this door in a declared emergency.

Sliding glass doors have a break away feature that must only be used in an emergency only.

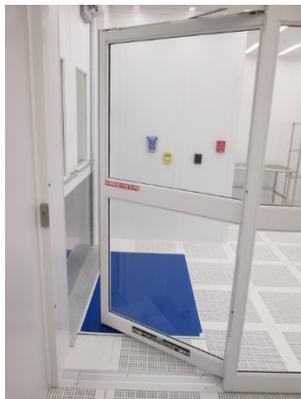


Figure 15: Break away sliding glass doors

5.2 Safety Equipment

- Safety Goggles:** Safety glasses are available in the gowning room (FG74) but users can bring their own safety goggles or safety glasses if preferred. These are available from Office of Research Safety (ORS).
- Face Shields:** Face shields are available inside clean room at the entrance of the acid processing area.
- Chemical Resistant Gloves:** These gloves are available at the entrance of the acid processing area.
- Heat Resistant Gloves:** These gloves are available at furnaces inside the cleanroom.
- Chemical Resistant Aprons and Sleeves:** These are available at the entrance of the acid processing area.
- Chemical Respirators:** It is the responsibility of the users to contact ORS to complete a review of the engineering controls. The use of chemical respirators must be first approved by ORS.
- Face Masks:** Dust masks are available in the gowning room (FG74).
- Chemical Spill Kits:** Chemical spill kits are available in the gowning room (FG74) for acids, bases, and solvents
- Material Safety Data Sheets (MSDS):** Are available online.

5.3 Access Control

During normal business hours NUFAB offices are accessible to the public from the Tech FG-70 entrance. NUFAB staff controls access to the clean rooms. Security access levels are limited to user groups, time of day, user needs, and training completion. Some access doors have additional alarm settings. Blocking doors open can set off alarms.

NUFAB uses NUcore and the NU WildCARD as a scan-in/scan-out system to track cleanroom users and use times.

Video surveillance equipment is installed throughout the NUFAB suite.

All vendors and visitors have to register with NUFAB staff prior to entry. User access is denied after training certifications expire or in disciplinary situations.

6.0 CLEANROOM PROTOCOL

6.1 Proper Street Attire

- Clean clothes
- Closed shoes with appreciable sole thickness and heels no more than two inches. No sandals.
- No makeup or cosmetics.
- No dangling jewelry. No sharp rings or bracelets that might cause a glove tear or puncture.

6.2 Bringing Items in the Clean Room

You need training to clean and bring items in the clean room. Ensure the items are clean room compatible and authorized. All material surfaces must be wiped down before entering the clean room. The cleaning supplies are provided in the gowning room. Follow the procedure below:

1. Bring the item with you to the gowning room.
2. Place the item on the wire rack.
3. Wear gloves, hairnet, and face mask.
4. If the item was double plastic-bagged in clean room, remove the outer bag and discard in trash. No cleaning is required. The second bag should be removed inside the cleanroom. However, if the item is not clean room packaged, wipe down all surfaces thoroughly.
5. Place the item on the wire bench along the east wall.
6. After gowning up, pick up the item and take it with you to the clean room.

6.2.1 Items not Allowed in the Clean Room

Anything that sheds particles or emit odor/evaporates is not allowed in the clean room.

Some examples of prohibited materials are:

- Cardboard or its products
- Paper (only clean room notebooks allowed)
- Napkins (only clean room wipes allowed)
- Lead pencil and eraser (ball-point pens allowed)
- Leather
- Wood or its products
- Fine powders

If you are not sure about an item, please ask staff.

6.3 Taking Items out of the Clean Room

You need to be trained and authorized to do this. Also, items should be authorized. Make sure the items belong to you. You must get permission from staff for anything that belongs to NUFAB. Double-bag the items if you will be taking those to another cleanroom. Follow the procedure below:

1. Bring the item to the gowning room and place it on the wire bench along the east wall.
2. Remove gowning, pick up the item and take it with you.

6.4 Entry and Exit

Do not bring coats or personal items to the NUFAB clean room! There is no space available to store personal items in the Gowning Room. Make sure your shoes and clothes are clean. Personal cleanliness is very important since people are the biggest source of contamination in the clean room.

6.4.1 Entry

1. Get rid of any candy or gum.
2. Clean your shoes in the shoe cleaner in the entry corridor.
3. Clean your shoe soles on the rug.
4. Wear the short shoe-covers.
5. Walk over the Dycem mat.
6. Hold your WildCARD close to the proximity reader at the gowning room entrance. The sliding door will open and your name will be displayed on the monitor. The gowning room is divided in to two areas divided by a bench and coverall racks. The first area you enter is dirty and requires short shoe covers only. With short shoe covers, you cannot go to the clean area and with long shoe covers on you cannot come to the dirty side.
7. Put on the gloves. Handle gloves only from their sleeves. Get the right size gloves from the glove bins. Do not touch your skin on the outside of the gloves other than the sleeves.
8. Put on a hair net. Make sure your hair and ears are completely inside the hairnet.
9. Put on a face cover. Face covers are required for all.
10. Put on the coverall and pull the hood over your forehead hiding all hair. Then close the zipper all the way. It is important to wear the right size coverall so that its legs cover your ankles.
11. Sit on the bench separating the dirty and clean areas with your legs on the dirty side.
12. Put on long shoe cover on one foot and swing it on the clean side. Put it on the second foot and swing it on the clean side also.
13. Wear the safety glasses, preferably outside the hood.
14. Check for any exposed hair or any torn gowning in the mirror and fix.
15. Press the sliding door button and enter the clean room. The sliding door on the west side is for entry only. The sliding door on the east side is for exit.



Figure 16: Proper gowning; Look in the mirror for any exposed hair and fix.

6.4.2 Exit

1. Go to the Gowning Room through the sliding door on the east side.
2. Take the safety glasses off and leave those in its bin.
3. Sit on the bench with your feet on the clean side.
4. Take off long shoe cover from one foot and swing it over to dirty side of bench. Repeat with the second foot.
5. Take off coverall and place it on the hanger.
6. Discard your hair net, face cover, and gloves in the trash can.
7. Hold your WildCARD near the reader and leave the Gowning Room as the door opens. Your name will move from 'current users' to 'last users' on the screen.
8. Take off the short shoe covers and leave in their bin.

Important Points to Remember:

- **Order of gowning** is: small shoe covers, gloves, hairnet, face cover, coverall, long shoe covers, safety glasses. Remove in reverse order.
- As soon as you see holes or tears in shoe covers, coveralls, or hairnets, return to the Gowning Room, discard and replace items.

6.5 Proper Behavior in Clean Room

- Absolutely no food is allowed anywhere in the clean room. Food means any kind of food including candies, chewing gum, cough drops, drinking water, etc.

- No smoking is allowed in the building including clean room and all the labs.
- Keep the table tops, equipment tops, and chemical hoods organized.
- Leave the chairs organized in their proper place. Do not move chairs from one room to another. If you move a chair within a room, move it back to its original place after use. No chair should be left in a place where it is obstructing peoples' movement in and out of the room or around the equipment.
- Do not sit on the floors. This brings dirt from the floor in to the air.
- Do not nap or sleep on chairs. This is a serious safety hazard to you and others.
- Do not run or walk fast in the clean room.
- Do not lean on equipment, hoods, tables, etc. It is a safety hazard.
- If you need to open zipper of your coverall, go to the Gowning Room.
- Use clean room wipes sparingly since these are lint-free and hence quite expensive.
- Do not touch your face or skin with clean room gloves on.
- Do not throw trash on the floor
- Always leave your belongings in your storage box. Anything left outside your box will be removed

6.6 NUFAB Equipment Use

- Use only the equipment that you are trained on and authorized to use.
- If the equipment is 'Down' in NUcore, do not attempt to use.
- Do not try to fix any equipment. Never open equipment panels, lethal voltages may be present.
- If you see a "Danger: lockout-tagout" sign; do not attempt to start equipment and do not remove the sign.
- Use proper safety equipment, like insulating gloves while using furnaces or pouring cryogenic liquids.
- Use phones in cleanroom to notify NUFAB staff of any equipment problems. Messages can also be sent through NUcore if staff is not available on phone.
- Use the equipment for the process you are trained for. Any changes in the process or any new process, no matter how minor, must be approved by the NUFAB staff before use.
- You must provide all the required information for each use in NUcore.
- Follow all the equipment specific instructions that you received during training on particular equipment.
- If you don't have access to the equipment in NUcore, you are not authorized to use that equipment.
- Equipment operating procedures are for guidance only and are not substitute for training.
- If in doubt, do not use your best judgment but ask the management.

6.7 Proper Chemical Use

- Do not order any chemical without prior approval of the NUFAB management. Submit chemical name, its MSDS (material safety data sheet), quantity, and container size that you

want to order by email to the management prior to placing order. The approval email reply from management is your receipt.

- Before approval, the safety staff may ask you to write SOP (standard operating procedure) for extremely hazardous chemicals and get it approved.
- Chemicals can be very dangerous and even lethal. It is your responsibility to follow all the safety precautions described in MSDS of each chemical that you use.
- Always look for NFPA (national fire protection association) ratings in MSDS. All chemicals are rated from 0 to 4, 4 being the most hazardous.
- Deaths have been reported from concentrated acid burns to as little as 2.5% of body surface. That is the equivalent of a single hand.
- If exposure to hydrofluoric acid (HF) or buffered oxide etch (BHF) occurs, rinse with plenty of water for 5 minutes, apply calcium gluconate, and go to the nearest hospital.
- All the chemicals must be used in the proper chemical hoods. Only exceptions are the solvents in squeeze bottles (like acetone, methanol, and isopropanol) that can be removed from the solvent hoods if necessary for cleaning but must be returned to the solvent hoods after use.
- You must use full PPE i.e., chemical resistant aprons, gloves, sleeves, and face shields when working with dangerous chemicals. Any additional safety equipment must be used if required in the MSDS of the particular chemical.
- Always rinse the glassware, the work surface of the hood, and your gloves thoroughly with water after a wet chemical process. Do not touch anything with contaminated gloves.
- Focus on your work when using dangerous chemicals. Do not talk or attend phones.
- Clean room wipes are expensive, so use sparingly.
- **If you have to leave a chemical process running** while you are gone, you must:
 1. Label each chemical clearly with its name and any precautions if necessary
 2. Write your departure time and approximate time to come back
 3. Your name and faculty advisor's name and your phone number
- Absolutely no hazardous chemicals are discarded in sinks that drain to the sewer. Use all wet bench drains for chemicals according to their label.



- **Chemical Storage:** Chemicals must be stored in correct storage; acids must be stored in acid cabinets and solvents must be stored in solvent cabinets.

- **Mixed Chemicals:** These must be properly labeled with each component and its ratio, your and your faculty advisor's name and phone number, and date mixed. These must be stored in proper storage.
- **Waste Chemicals:** There are five mixed waste streams in NUFAB caustic, acid, hydrofluoric acid, non-halogenated solvents and halogenated solvents. Strictly separate these waste streams by using the labeled cup sinks. The waste streams are collected at the back of the hood and managed through NUFAB staff.
- **Chemical Transport:** To transport chemicals between rooms, always use chemical transport cart or carrier. Never remove chemicals in beakers from the hood.

6.7.1 Specific Chemical Precautions

- When mixing etches, always add acid (AAA). Never add water (NAW) to acid.
- Never mix acids and solvents, they can catch fire.
- Never mix acetone waste with piranha solution or hydrogen peroxide waste.

6.7.2 Compressed Gas Cylinders and Cryogenic Liquids

- Only NUFAB staff is authorized to enter the chases to change, replace, or otherwise handle the compressed gas cylinders.
- Use insulating gloves and eye protection and follow all other guidelines when handling cryogenic liquids.

6.8 Proper Sample Handling

- Do not grab samples with hands, always use proper tweezers. This keeps the samples clean and also saves you from sharps if the samples break in your hands.
- Stainless steel tweezers are good for handling samples and for use with solvents. Use Teflon tweezers or holders with any other chemical.
- Get proper storage holders for your samples and always use those for storage and transport.
- Do not put wet samples on equipment chucks.
- Do not leave broken samples on the equipment chucks or tables

6.9 Buddy System

For safety reasons, no user is allowed to work in the NUFAB clean rooms alone except between 9AM and 5PM when NUFAB staff is close by. If you work past 5pm or before 9am you must plan to work with another user so that there are at least two people in the clean room at any time.

6.10 Visitors to the Clean Room

Prior permission from the NUFAB Management is required for clean room tours or for bringing visitors. If permission is granted, you will be responsible for proper gowning and behavior of your visitors in the clean room. The visitors must be accompanied at all times by an authorized person. Visitors are only allowed observation, and are strictly prohibited to operate any equipment.

7.0 VIOLATIONS OF NUFAB SAFETY POLICY AND OPERATING PROCEDURES

You must practice the safety policy and operating procedures described in this document. Any violations will be considered on case by case basis by the management and penalties will be imposed. Persistent violations will result in permanent revocation of your access to all NUFAB facilities.

Glossary

Gas Alarm Level 1 (Yellow)

Ambient Toxic (25% TLV of the respective toxic gas as monitored by the VERTEX component)

Gas Alarm Level 2 (Red)

Ambient Toxic (50% TLV of the respective toxic gas)
Ambient Flammable (20% LEL of hydrogen in air)

Lower Explosive Limit (LEL)

The MIDAS component of the Honeywell System is calibrated to hydrogen in air.
The LEL for hydrogen in air is 4%.

25% LEL = 1% hydrogen in air

50% LEL = 2% hydrogen in air

Threshold Limit Value (TLV)

The American Conference of Governmental Industrial Hygienists publishes the TLVs.