TSIB HPT Lab

Scopes and Requirements

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1. Background

The Target Systems Integration Building (TSIB) will serve to provide long-term operational, project, and program support for ongoing and future high-power target system directives including High Power Targetry R&D.

The proposed HPT lab at TSIB addresses the needs and concerns highlighted in the Accelerator R&D sub-panel of the High Energy Physics Advisory Panel (HEPAP) for multi-MW proton beam facilities: "Realizing a multi-MW proton source to provide neutrino beam intensities at Fermilab beyond PIP-II project will require significant further R&D on targets and focusing systems, concentrated on tolerance of materials to radiation effects of intense beams."

- References
    - *Accelerating Discovery," [Online]. Available: https://science.energy.gov/hep/hepap/reports/*
    - *Particle Physics Project Prioritization Panel (P5), "Building for discovery: Strategic Plan for U.S. Particle Physics in the Global Context," 2014.*

In the recent past, major accelerator facilities have been limited in beam power not by their accelerators, but by the beam intercepting device survivability. The targets must endure high power pulsed beam, leading to high cycle thermal stresses/ pressures and thermal shocks. With future project such as LBNF, the increase in beam power will also create significant challenges such as radiation damage and radiation accelerated corrosion which physically alter the atomic structure of target materials. The radiation-induced defects will degrade the mechanical and thermal properties of the targets during irradiation, leading to premature failure of targets and beam intercepting devices. Therefore, understanding radiation damage and thermal shock effects of high energy, pulsed proton irradiation on candidate target materials is necessary to optimize physics production for both currently operating and future accelerator target facilities.

Fermilab currently operates a large hot-cell for repair and autopsy of NuMI targets and horns, it currently does not have a dedicated hot cell or PIE facilities for examination of activated materials.

2. Scope for HPT lab

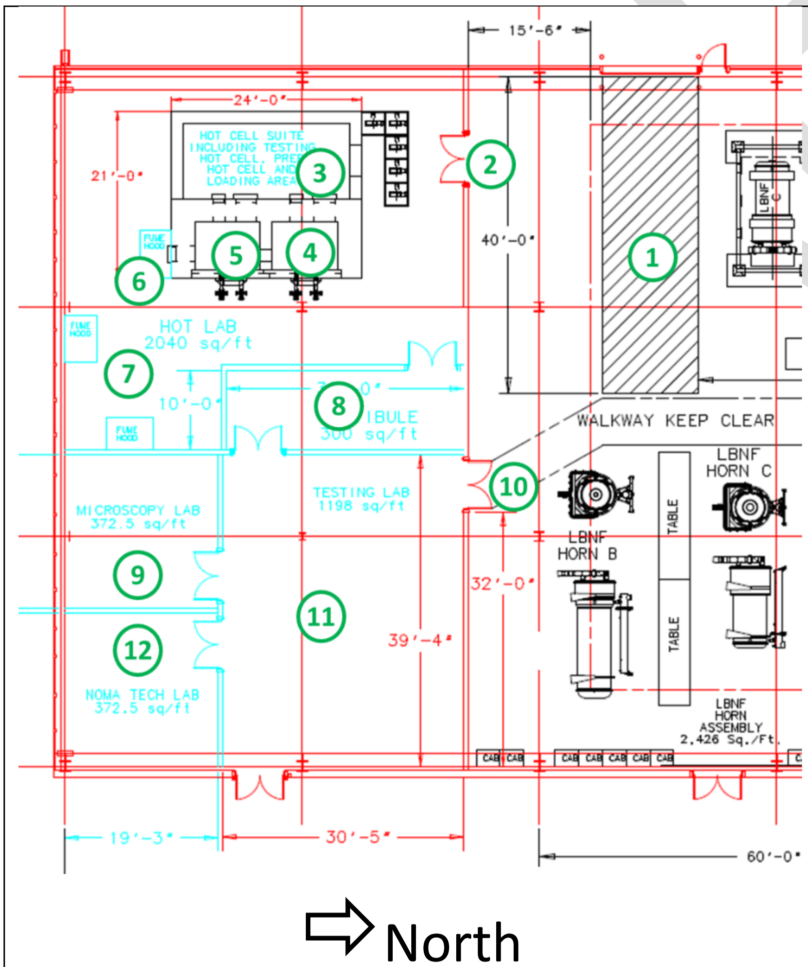
The scope of work to be conducted in the completed TSIB High Power Targetry Lab includes material science studies and post-service investigations in support of HPT R&D programs related to existing and future generation Fermilab Targetry development. The work can be summarized as follows:

- Radiation damage studies of irradiated materials – Materials that have been previously irradiated will be studied and tested to determine the effects of accelerator-based irradiation at different conditions upon physical and mechanical properties. See the TSIB HPT Lab Material Workflow Plan for details on sources of irradiated materials, associated levels of activity, and plans for safe handling of active materials in the HPT Lab.
- Materials science studies of non-active materials – Targetry materials and materials under consideration for use as targetry material will be studied and tested to establish baselines and evaluate their potential.

- Development of novel materials for use as targetry material and associated fabrication and production technologies.

In order to support the work, the TSIB HPT lab will include several areas (see preliminary layout in Figure 1):

- -Hot lab area (7) including a hot-cell suite (3, 4 and 5) and fume hood (6) for examination and mechanical and physical property testing of activated materials from operating beamlines and from dedicated irradiations;
- -A vestibule (8) to access the hot lab (7) from the testing lab (11), providing a radiation control point to allow controlled entry and exit to/from the hot lab.
- -Microscopy lab (9), adjacent to the hot lab area (7);
- -Cold specimen testing lab area (11) where thermal and mechanical testing can be performed on numerous materials to support HPT R&D program;
- -Novel material and technology development area (NOMATech lab), (12). The main objective of this lab is to develop and manufacture various novel material.



(1) -Truck bay
(2)-Material Access door to the hot lab
(3)-Unloading/loading area
(4)-Prep hot cell
(5)-Testing hot cell
(6)-Fume hood
(7)- Hot Lab
(8)- Vestibule
(9)- Microscopy lab
(10) - Personnel Access door to the testing lab
(11) – Testing Lab
(12) – NOMATech Lab (Novel Material and Technology)

Figure 1 – Preliminary Layout of the TSIB HPT Lab

2.1. Hot lab

The Hot Lab area (7) includes a hot-cell suite (3, 4 and 5) and fume hood (6) for mechanical and physical property testing of activated materials from operating beamlines and R&D material specimens for current and future high-power targets. Low activated samples can be tested in the fume hood (6) or the Hot lab (7) after being prepared in the hot cell suite and surveyed (and decontaminated, if necessary) in the fume hood (6). Each transfer of material and equipment through the different passthrough between the Hot Lab and the Hot Cells will follow the safety procedure in place (in compliance with the Fermilab Radiological Control Manual). The use of each passthrough is detailed in the workflow document.

The activated materials will come from several sources:

- The primary sources will be samples extracted from the current and future targetry components in the C0 hot cell. Material samples can be extracted from horn, production target, beam windows, collimators or any other Fermilab beam intercepting devices.
- The second source of activated samples will come from specimen fabricated for dedicated irradiation in support of the Fermilab HPT R&D program. These specimens will be small in size (order of an inch or smaller) for specific mechanical and thermal testing of activated materials (so-called R&D samples). These samples may be irradiated in facilities outside of Fermilab, or irradiated at Fermilab; however, Fermilab currently does not have dedicated and high-dose relevant irradiation stations on-site.

2.1.1. Hot cell suite

The TSIB HPT Lab hot cells will be dedicated to analyze and perform Post-Irradiation Examination on small samples only (1 mm to 100 mm scale).

The hot cell suite will include one unloading/loading area, one prep hot cell and one testing hot cell, as shown in Figure 2 and Figure 3. Each hot cell will be operated with 2 telemanipulators and a lead-glass window.

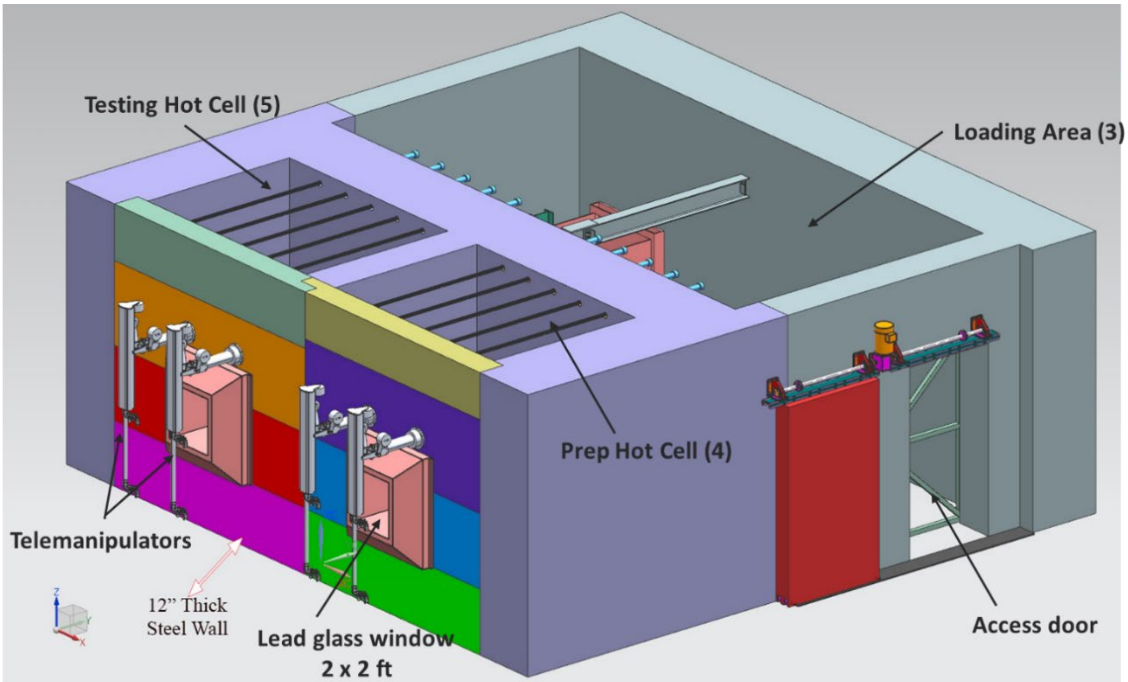


Figure 2 - TSIB HPT Hot Cell Suite 3D model

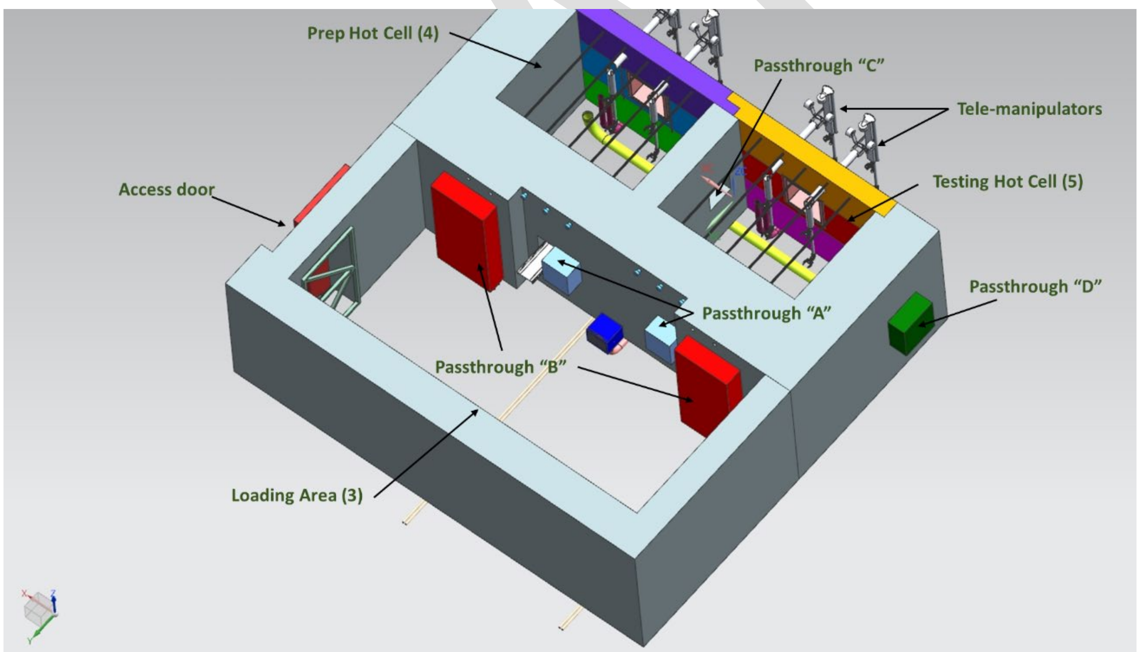


Figure 3 - TSIB Hot Cell Suite floor plan

When the Type-A container with the active material will arrive in the TSIB truck bay (1), it will be transferred through the material access door (2) and stored in the unloading/loading area (3) until the inner container is ready to be transferred in the Prep Hot Cell. A more detailed process to transfer activated material in the different hot lab area is described in the Workflow document. Maximum dose rates for each area of the Hot cell suite will be set by radiation safety and listed in the “TSIB HPT Lab Workflow Document”.

2.1.1.1. Loading area (3)

The loading area will be used:

- To receive the type-A container with the activated samples, open the lid of the shipping container and transfer the inner pot containing the activated material to Prep hot cell (4)
- to control, decontaminate as needed and transfer the testing equipment from the two hot cells (4) and (5) to the hot lab (7)
- to extract waste from the hot cells to the appropriate disposal/storage container/cask
- to temporarily store equipment if activated and decontaminate them if needed before storage in the hot lab.
- To install and transfer equipment in and out of hot cells
- To prepare the large equipment on a shield plug
- to house the HVAC Ventilation filtration unit of the 2 hot cells for controlled maintenance of the filters.

The door to access the loading area (3) is controlled by Radiation Physics Operations Department and will only be opened, and personnel access into the loading area (3) permitted, during the above activities in this area (3).

2.1.1.2. Prep Hot Cell (4)

The Prep Hot Cell (4) will be primarily used to open and remove sample containers from the inner pot, to open the capsule containing the activated samples, to extract and sort the individual sample and store them as needed prior to testing. All activities in prep hot cell (4) that need worker operation will be done remotely using remote manipulator arms.

Activities may include opening the specimen capsules, cutting samples in small size, polishing samples for SEM and decontamination (if necessary) of individual sample prior to Post-Irradiation Examination.

2.1.1.3. Testing Hot Cell (5)

The Testing Hot Cell (5) is where individual specimens (typically 1 mm to 100 mm scale) will be tested. Material tests will include mechanical tests (e.g. tensile, bend, fatigue) and physical property tests (e.g. dilatometry, thermal diffusivity, and ultrasonic). The Testing Hot Cell (5) will be prepared each time for a specific course of studies. Prior to the test of the specimen, any needed testing instruments not already installed in the Testing Hot Cell will be transferred into the cell via the passthrough “A” or “B”. Small equipment will be placed on a tray

After studies are complete, the specimens will be stored in local storage in the hot cell, transferred to the Prep Hot Cell (4) until disposal (see details in the workflow document). At all-time any unused activated material will be stored in local storage of the hot cell or disposed.

The details of the active material transfer and the use of each passthrough is detailed in the “TSIB HPT Lab Workflow Document”.

2.1.2. Fume Hood (6) and hot lab (7) activities

Fume hood (6) adjacent to the Testing Hot Cell (5) will be able to accept low-activated material via a passthrough “D” (Figure 3). Different thermal/mechanical tests will be handled in the fume hood. The fume hood will serve as a point of control for samples transferring out of the hot cell suite. A method to survey the samples or equipment will be developed.

Specific dose rate and activity limits for samples in the fume hood (6) and hot lab (7) will be determined by the Radiation Physics Operations department, taking into consideration the types of tests being performed and how personnel will be handling the material (I.e., by hands or use of tools), and how long samples may be handled by hand.

The potential testing equipment listed in appendix 1 can be set up in the fume hood (6) or in the Hot Lab (7) depending on the activation level of the sample to be tested.

If acceptable, testing will continue in the fume hood. If the sample dose meets dose rate and activity limits set by Radiation Physics Operations Department, the specimen may be transferred into the hot lab (7) for testing. The operator is expected to handle the specimens by hand for 2 minutes maximum when installation and removal from testing equipment are required. Testing are automated and the presence of worker close to the samples is not required.

After the test of the specimen is complete, it will be disposed or stored in a storage container or shielded cabinet dedicated for low activated material in the hot lab (7). A sample register will be maintained for the inventory of the samples in the containers and to track the dose rate and total activities.

The details of the active material transfer and the use of each passthrough is detailed in the “TSIB HPT Lab Workflow Document”.

2.2. Vestibule (8)

Only qualified personnel will be allowed to enter the ‘vestibule’ room (8) adjacent to door (10). Access through its entrance door will be limited with a control system. This room will contain friskers and PPEs required to allow safe entry and exit to/from the hot lab. Procedure will be developed to enter and exit the hot lab via the vestibule.

2.3. Testing Lab (11)

The Testing Lab (11) will be used to evaluate mechanical and physical properties of non-activated material. The list of potential testing equipment is described in Appendix 1. An area of the Testing Lab (North / East corner) will be equipped with a grinding/polishing station to prepare samples for microscopy study.

2.4. Microscopy Lab (9)

The microscopy lab (9) is where microstructural analysis of specimens through mostly Optical and Scanning Electron Microscopy will be performed. During initial operations, only non-activated samples will be tested in the microscopy lab (9), and a space will be reserved in the Hot Lab (South/East corner) to set up a digital microscope or other inspection instruments to allow examination and analysis of low activated samples.

However, the microscopy lab is adjacent to the hot lab (7) to allow efficient/safe transfer of low-activated specimens back and forth via the vestibule, if/when approved by the ES&H Radiation Physics Operations Department. If tests of activated samples in the microscopy lab (9) is approved, dose rate and activity limits will also be imposed. Contamination and dose rate surveys will be performed prior to release to the microscopy lab (9), and samples will be tracked and stored, similar to what is done prior to release and use of activated samples in the hot lab (7).

The Microscopy Lab will initially have a nano-indenter, a high-resolution Digital microscope to image microstructure, evaluate surface roughness, conduct fractography, various other 3D measurements such as grain size, precipitates % age and to some extent contact less profilometry. The Microscopy Lab will accommodate future upgrades in microscopy equipment (e.g. SEM/EBSD).

2.5. NOMATech Lab (12)

The NOMATech Lab (12) will serve as NOvel MATerial and Technology development area. The main objective of this lab is to develop and manufacture various novel materials which have potential to be used as future high-power targets and beam intercepting devices. The goal is to manufacture various novel materials such as High Entropy Alloy (HEA), ceramic and metallic nanofiber samples. It is equipped with a lab-scale electrospinning set up and a semi industrial scale roll to roll electrospinning unit for higher volume production of various ceramics and polymer nanofiber matts. It will have a fume hood, an oven, one fire extinguisher, eye-wash, a wash-basin, Fire proof cabinet for flammable chemicals, storage cabinet of other chemicals. A list of chemicals is provided in the Appendix 2. Work in the NOMATech Lab will not include activated materials.

3. Requirements

3.1. TSIB HPT LAB

The following requirements are related to all the different areas in the HPT Lab (hot lab, vestibule, microscopy lab, testing lab and NOMATech lab):

- Wireless network
- Wire network in the different rooms with a minimum of 4 LAN plug per room, more in the largest room (hot lab and testing lab)
- Room Temperature/climate control in each area
- Dry walls to keep cleanness in the Labs.
- floor needs to have a surface treatment (epoxy) for easy maintenance and cleaning

3.2. Hot lab (7)

Maximum dose rates for each area of the Hot cell suite will be set by radiation safety and listed in the "TSIB HPT Lab Workflow Document".

The hot Lab (7) will have:

- negative pressure compared to the vestibule and the rest of the TSIB building (the sealing of the windows and walls to maintain the negative pressure needs to be determined by FESS/AE).

- sealed access doors (material door (2) and door between Hot Lab (7) and vestibule (8))
- Material access door to the hot lab is controlled by Radiation Physics Operations Department and will only be opened when a container is received into the hot lab (7).
- Access doors for personnel through the vestibule will be limited with a control system.
- 3 independent circuits with 4 to 6 duplex receptacles (125V/20A) each distributed around the room
- 2 to 4 receptacles (280V, 20 A, 1 phase)
- 1 receptacle (480V, 60A, 3 phases)
- One compressed air line (120 psi) near the hot cell suite to "feed" hydraulic testing equipment installed in the Testing Hot cell via feedthrough.
- One compressed air along the south wall of the Hot Lab
- A fire protection system to be determined by Fermilab ES&H/FESS life safety
- A chemical protection plan to be evaluated by Fermilab ES&H team.
- An independent floor drain system separated from the general TSIB building drain and sump system as determined necessary by Fermilab Radiation Safety group.
- one fireproof cabinet for flammable chemicals (~20-30 gallons)
- One storage cabinet for other chemicals/hazardous products
- One shielded storage to store the low activated material accepted for test in the hot lab and the fume hood
- 2 to 3 jumbo heavy-duty metal storage cabinets (48x 18 x 78")
- at least 1 test benches with outlet panels

The material access door (2) between the hot lab (7) and the truck bay (1) needs to be large enough to use a forklift, a pallet truck or similar. It could be a two doors access.

Each equipment running in the hot lab (appendix 1) will be set-up to minimize contamination spread in the area on a case by case basis.

A space will be reserved in the Hot Lab (South/East corner) to set up a digital microscope or other inspection instruments to allow examination and analysis of low activated samples.

3.2.1. Fume Hood (6) adjacent to Hot Cell Suite

The fume hood (6) adjacent to the Testing Hot Cell has a passthrough "D" between the two areas. This fume hood will be used to test low activated material. The maximum dose rate allowed in the fume hood is defined in the document "TSIB HPT workflow".

The fume hood needs:

- to be large enough to accept the few large testing equipment such as dilatometer or compact tensile test machine (potential equipment listed in the appendix 1).
- an independent ventilation to assure a negative pressure compare to the hot lab (but pressure higher than the Hot Cell Suite) and maintain the required face air velocity as per ANSI/AIHA/ASSE Z9.5 and ANSI/ASHRAE 110 – Laboratory Ventilation Package (or applicable standard).

- to be adjacent to the testing hot cell with a direct access via the passthrough “D”
- The exhaust (ductless or not) needs to be determined by FESS/AE.
    - a bag-in/bag-out system for fume hood will be determined/developed.
- 2 duplex receptacles (125V/20A)
- 2 receptacles (280V, 20 A, 1 phase)

3.2.2. Hot cell suite

3.2.2.1. Loading area (3)

The loading area (3) is used to safely transfer equipment and activated materials in and out of the hot cells while mitigating the exposure of workers in the hot lab. It is expected that access to the loading area will be under control of the Radiation Safety group (radiation safety padlock) and used as a control point for materials and equipment moving into and out of the hot cells.

The loading area needs:

- the access door controlled by Radiation Physics Operations Department. It will only be opened, and personnel access into the loading area (3) permitted, during the activities described in section 2.1.1.1.
- to have an entrance door large enough to have pallet jack and jib crane to access the loading area
- a frisker station and designated step-off are at the exit of the door of the loading area in the hot lab.
- to have a negative pressure compared to the Hot Lab area
- to house the HVAC Ventilation filtration unit of the 2 hot cells for controlled maintenance of the filters.
- Penetration for electrical utilities
- At least two duplex receptacle (125V/20A) and two receptacles (280V, 20 A, 1 phase)
- A fire protection system to be determined by Fermilab ES&H team/FESS life safety
- to have shield wall thickness large enough to mitigate the exposure of workers in the hot lab. The requirements of the wall thickness are defined in section 3.2.3.1
- To be large enough:
    - To set up the Hot Cell HVAC unit with access to the bag-in bag-out filter exchange system
    - to allow access and work space around the Type-A container during preparations for transfer activities
    - to accept a lifting devices with mobile shielding panel enabling transfer of activated materials from/to the Type-A container
    - To accept and maneuver a pallet truck (or similar) when transferring the Type-A container from the truck bay via the Hot Lab
    - To install a permanent jib crane (1 ton load)
    - To be able to store a shield plug (large passthrough “B”) and have space around to install a large equipment and prepare cabling
    - to be able to temporarily store equipment removed from the Testing Hot Cell for later use in the Hot Cells, or until ready for decontamination

3.2.2.2. Prep Hot Cell (4)

The maximum dose rate allowed in the hot cells is defined in the document "TSIB HPT workflow". The potential testing equipment to be used in the Prep Hot cell is listed in appendix 1.

The prep hot cell will have the following features:

- 2 telemanipulators
- one lead glass window (Lead glass window thickness = thickness defined by the vendor depending on layer density used, dimension: 30" x 30")
- One small passthrough "A"
- One large passthrough "B"
- A small passthrough "C" between the two hot cells
- Proper ventilation to ensure a negative pressure inside the hot cells. Since potential generation of contamination is greatest in the Prep Hot Cell, a negative air pressure, relative to the other Hot Cell Suite areas and the surrounding Hot Lab, will be maintained with the Hot Cell Suite Ventilation system.
- the ventilation system needs to keep negative pressure in the testing hot cell (4) and (5) when any passthrough is open
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation (front wall) for rapid access to the worker.
- A fire protection system to be determined by Fermilab ES&H team/FESS life safety
- In-cell lifting capability of 1000 lbs
- A storage to accept several paint cans/inner pots with lower activated samples (number of cans/pots to be defined depending on the space available below the worktable)
- A vault/storage to accept one paint can / inner pot for high dose samples
- Walls/floor of the hot cell should be finished/sealed with surface treatment (epoxy?) to improve lighting and for easier decontamination
- 5 replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cables, utilities (fluid, compressed air)
- Penetration for HVAC system, cables and controls

3.2.2.3. Testing Hot cell (5)

The maximum dose rate allowed in the hot cells is defined in the document "TSIB HPT workflow". The potential testing equipment to be used in the Prep Hot cell is listed in appendix 1.

The Testing Hot Cell will have the following features:

- 2 telemanipulators
- one lead glass window (Lead window thickness = thickness defined by the vendor depending on layer density used, dimension: 50"W x 30"H)
- One small passthrough "A"
- One large passthrough "B"
- A small passthrough "C" between the two hot cells
- The testing hot cell will have another passthrough "D" to transfer low activated material and equipment in the adjacent fume hood

- Proper ventilation to ensure a negative pressure inside the hot cells. Since potential generation of contamination is greatest in the Prep Hot Cell, a negative air pressure, relative to the other Hot Cell Suite areas and the surrounding Hot Lab, will be maintained with the Hot Cell Suite Ventilation system.
- the ventilation system needs to keep negative pressure in the testing hot cell (4) and (5) when any passthrough is open
- A storage to accept several paint cans/inner pots with lower activated samples (number of cans/pots to be defined depending on the space available below the worktable
- A vault/storage to accept one paint can / inner pot for high dose samples
- Enough working surface in the testing hot cell to accept the 2 testing equipment that will stay in the hot cell: Dilatometer (2 x 1x 1 ft) and Tensile Test machine (3.5x1.5x4.5), plus one large equipment. The hot cell should accommodate the flexibility to change testing equipment depending on the specific course of studies.
- 5 replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cable, utilities (fluid, compressed air)
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation for rapid access to the worker.
- Fire protection to be evaluated by Fermilab ES&H team
- In-cell lifting capability of 1000 lbs
- Walls/floor of the hot cell should be coated with surface treatment (epoxy?) to improve lighting and for easier decontamination
- Penetration for HVAC system

3.2.3. General requirement for the hot cells

3.2.3.1. Walls

The wall thickness of the hot cell suite is defined to minimize the dose received by the worker outside of the hot cell suite. The front wall of the hot cell suite is made of steel and supports the telemanipulators and the lead-glass windows. The other walls of the suite are made of concrete to reduce the cost

Based on preliminary simulations (refer to the shielding calculation document), the wall thickness of the 2 hot cell is defined as 1 ft of equivalent steel (or 3 ft of concrete). The wall between the loading area (3) and the hot cells is 2 ft of concrete. The walls between the unloading/loading area, the hot lab is 1.5 ft of concrete). The back wall of the building will serve as the back wall of the loading area. The thickness is defined as 2 ft of concrete.

The wall thickness between the 2 hot cells can be reduced as long as it supports the passthrough between the 2 areas and provides some minimal shielding between the two cells.

3.2.3.2. Passthrough

Each hot cell will be equipped with different passthroughs to have access to the loading area and the fume hood (Figure 3). All the passthroughs will include seal doors to meet the ventilation of the hot cell suite requirement

The smaller passthrough “A” (at least 1.5 x 1.5 ft) will serve to transfer the samples and other small tools in the inner container.

The larger passthrough “B” will serve only when larger equipment needs to be transfer in or out of the hot cell. The size is defined by the larger equipment listed in the appendix 1. The larger passthrough “B” is designed as a shield plug (see concept in Figure 4) and will serve only when larger equipment needs to be transferred in or out of the hot cell. At least two plugs will be available: one to close the hot cell and the other one in the loading area with a large equipment under preparation.

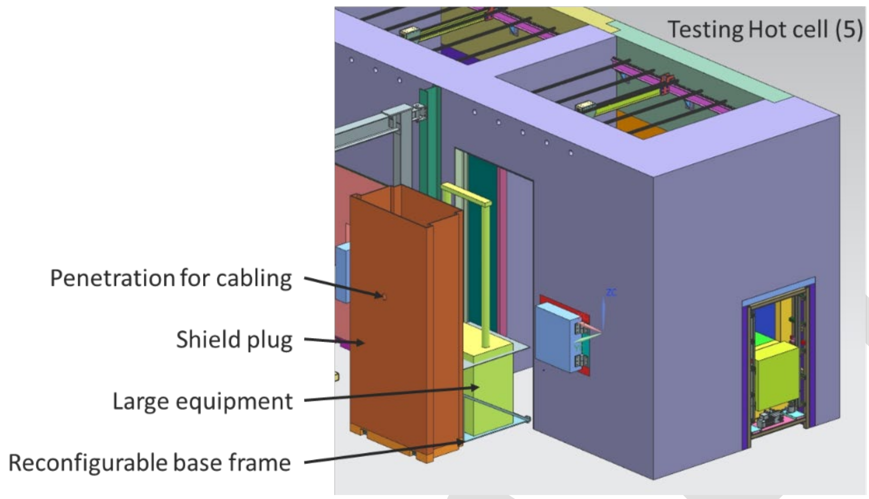


Figure 4 – concept of large passthrough “B” with one large equipment placed on the shield plug

A small passthrough “C” (at least 1.5 x 1.5 ft) between the two hot cells will be used to transfer the samples from the perp hot cell to be tested in the testing hot cell and from the testing hot cell to the prep hot cell for storage when testing is complete.

A passthrough “D” (at least 1.5 x 1.5 ft) in the testing hot cell will serve to transfer low activated samples in the fume hood adjacent to testing hot cell.

3.2.3.3. Ventilation system

The HVAC need to meet the following requirement:

- ensure a negative pressure inside the different hot lab area as described above.
- The system will include pressure monitoring.
- The pressure differential between the two hot cells, between the hot cells and the loading area, and between the testing hot cell and the fume hood, needs to be low enough to be able to open easily the passthrough.
- When a passthrough is opened system needs to keep the pressure in the hot cells equal or lower compare to the loading area or the fume hood.
- When passthrough “C” is opened, it needs to keep the Prep hot cell at a pressure equal of lower compare to the Testing hot cell
- Pre-Filter will be installed in the hot cell to keep contamination inside.
- High efficiency filters with a 0.3 microns pore size will be installed in the loading area as close as possible to the hot cell exhaust for controlled maintenance.
- Charcoal adsorber will be installed to retain any volatile gases

Need to define the following spec to meet the above requirement

- Min and max air flow?
- Size of the duct pipes?
- Position where to have the duct pipe in the hot cell (bottom or top of the hot cell)?
- Exhaust to outside?

Vestibule

The access door between the hot lab and the vestibule needs to be sealed to maintain a negative pressure in the hot lab area.
The access through its entrance door will be limited with a control system.

3.3. The vestibule needs:

- To be large enough to accept:
  - at least one cabinet/table to store Friskers (for point of control before to enter in the testing lab from the hot Lab) and PPE
  - at least one bench to wear booties/PPE if needed
- a frisker station and designated step-off area near the door to exit the hot lab
- At least two duplex/ quadruplex receptacle (125V/20A) and two receptacles (280V, 20 A, 1 phase)

Testing Lab (11)

3.4. The access door between the testing lab and the TSIB High Bay will be limited with a control system.

The access doors need to be large enough to use a forklift or a pallet truck or similar. It could be a two doors access.

The testing Lab needs:

- 4 independent circuits with 4 to 6 duplex receptacles (125V/20A) each distributed around the room and including 2 quadruplex receptacles in the center of the room from the floor
- 4 receptacles (280V, 20 A, 1 phase) + 1 outlet in the center of the room
- 2 receptacles (480V, 60A, 3 phases) on North and East side of the testing lab
- 2 compressed air (120 psi) along the south and North wall of the Hot Lab
- Storage cabinets for tolls, small equipment, samples, …
- A polishing station with a sink (with domestic water),
- A fire protection system to be determined by Fermilab ES&H/FESS life safety
- 3.5. A chemical protection plan to be evaluated by Fermilab ES&H team
- space for equipment as listed in appendix 1
- Space for two workstations/desks with computer

Microscopy Lab (9)

The access door between the testing lab and the microscopy lab will be limited with a control system.

The microscopy lab needs:

- 2 circuits with 2 to 4 duplex/quadruplex receptacle (125V/20A) + one with at least 30A for SEM each distributed around the room

- 4 receptacles (280V, 20 A, 1 phase) distributed around the room
- 1 faucet (flow up to 1 l/min and Pressure up to 0.25 MPa) and 1 drain for SEM installation in the future
- Storage cabinet for tools, and samples
- Space for equipment as listed in appendix 1
- Space for one workstation/desk with computer

NOMATech Lab (12)

The access door between the testing lab and the NOMATech lab will be limited with a control system.

The NoMATech Lab needs:

3.6.

- 2 circuits with 2 to 4 duplex/quadruplex receptacle (125V/20A) each distributed around the room
- 4 receptacles (280V, 20 A, 1 phase) distributed around the room
- A fume hood
- A sink with domestic water
- A fire protection system to be determined by Fermilab ES&H/FESS life safety
- A chemical protection plan to be evaluated by Fermilab ES&H team
- Fireproof cabinet for flammable chemicals (45 gallons capacity),
- 1 Storage cabinet for other chemicals
- 1 jumbo heavy-duty metal storage cabinets (48x 18 x 78")
- Space for equipment as listed in appendix 1

4. Risk and mitigation

Risk	Area	Mitigation
Contamination	areas adjacent to the hot cells and the hot lab (7)	- each transfer of activated material from the hot cells will follow FRCM and ALARA procedures in place and will be controlled by ES&H team - Control for free contamination will be performed in the hot cells and in the fume hood before each transfer - RWP will be developed for each operation scheduled in the hot lab involving activated material - negative pressure will be maintained at all time in the hot cell suite with lower pressure in the Prep and Testing Hot Cells - negative pressure will be maintained at all time in the hot lab - negative pressure will be maintained in the fume hood when samples with contamination risk are presents - continuous pressure monitoring in hot cell and the hot lab - Testing samples (only low activated material) with contamination risk will operate with fume hood closed - the ventilation will have a prefilter in the hot cells and high efficiency filters with 0.3-micron and a charcoal adsorber to retain any volatile gases. The HVAC unit will be in the loading

		area (3) with bag-in/bag-out filter for quick and easy maintenance - vestibule will provide a radiation control point to allow controlled entry and exit to/from the Hot Lab (frisker station with a designated a step-off area) - each unused samples will be stored in a paint can / inner poet placed in a retractable storage in the prep hot cell or in the testing hot cell - when samples are not anymore needed for further tests, they will be disposed to the proper waste management system - equipment will be placed on a tray to collect any debris that may fall during operation and to ease the decontamination process if needed
Ventilation system failed	Hot Lab (7)	- Sealed doors will contain any contamination in the area. - Continuous monitoring of pressure inside the hot cell suite and the fume hood
Contaminated Water spills	Hot Lab (7)	- no drain system in the hot cell suite - Limit water volume used in the hot cells. - Separate draining system than the TSIB building system with a dedicated reservoir - Capability to test the water for activation or contamination before proper disposal - When equipment run by hydraulic force, have the container outside the hot cell in the loading area - When a water spill risk is identified for a specific test, the testing setup will be setup in a tray as secondary containment, and large enough to contain the larger volume of water. - Water leak sensors installed in and around the fume hood -
Fire risk	Hot lab (7)	- Fire protection plan to be evaluated by Fermilab ES&H team, including smoke detectors - maintain low levels of combustible materials and flammable chemicals in the hot Lab - reduce the fire charge in each hot cell when samples are under preparation (in Prep Hot Cell) or under test (Testing Hot Cell). - inventory of chemical product (if any) will be maintained and will be visible in the workstation area
Fire risk	Testing lab (11), Microscopy lab (9) and NOMATech Lab (12)	- Fire protection plan to be evaluated by Fermilab ES&H team, including smoke detectors - maintain low levels of combustible materials and flammable chemicals - inventory of chemical product (if any) will be maintained and will be visible in the workstation area

Chemical risk	Hot Lab (7), Hot cell suite	- the ventilation will have a prefilter in the hot cells and high efficiency filters with 0.3-micron filter and charcoal adsorber at the exhaust of the hot cells in the loading area. - All chemicals/processes in the hot cells will be reviewed for gas release issues before permitting in the hot cells - inventory of chemical product (if any) will be maintained and will be visible in the workstation area - fume hood will be used for any chemical process - A chemical protection plan in place (to be evaluated by Fermilab ES&H team) - Fireproof cabinet for flammable chemicals in the hot lab (7)
Chemical risk	Testing Lab (11) and NOMATech Lab (12)	- fume hood will be used for any chemical process - inventory of chemical product (if any) will be maintained and will be visible in the lab - Fireproof cabinet for flammable chemicals - Cabinet for other chemical products - A chemical protection plan in place (to be evaluated by Fermilab ES&H team)
Nanoparticle risk	NOAMTech Lab (12) and polishing station in the Testing Lab (11)	- procedure in place to limit airborne nanoparticle when using colloidal suspension
High Voltage (spark) risk	NOMATech lab (12)	- develop procedure and protection against high voltage sparks
Tele manipulator failure	Hot Lab (7)	- If the grip system failed on one arm, it could be replaced with the other arm - Have procedure in place to replace the tele-manipulator
Ergonomic risk (long stand working with tele-manipulators in front of the hot cells)	Hot Lab	- To be developed

Appendix 1 – list of potential equipment in the different lab/area

1. Hot Lab / Fume Hood

The testing equipment listed below can be set up in the fume hood or in the hot lab depending on the activation level of the sample to be tested.

List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements			Utilities (water/air cooling, compressed air?)	Comments
		phase	Voltage (V)	Nominal Current Draw / unit (A)		
Fume hood	8 x 3 x 5	1	110-115	10	NA	
Fatigue test machine (Instron 8801, with controls under the test frame)	3.5x2x5	1	110	10	NA	Can do both fatigue and tensile. Can be equipped with furnace
Custom-fatigue test	2.3x1.1x1.1	1	208	2		
Dilatometer	3.5x1x1 (just the testing head which can be separated) 8x3x4 (Complete system with accessories)	1	208~240	16	Autonomy cooling system	Existing at MI-8.
Tensile Test machine (Shimadzu)	2.5x2x5	1	110	10	NA	Existing. At MI-8
Ultrasonic tester	NA	NA	NA	NA	NA	Portable
Infrared thermal imaging camera	3.25" x 3.25" x 6"	1	110-220 AC	1	NA	portable
High resolution digital microscope (Keyence VHX-7000)	6x3x6	1	120	1.5		
DIC system						

2. Prep hot cell

Several equipment will be installed permanently in this hot cell:

List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements			Utilities (water/air cooling, compressed air?)
		phase	Voltage (V)	Nominal Current Draw / unit (A)	
Retractable storage	3.5x2x3	TBD			NA
Capsule opener (PNNL designed)	1x1				NA
Commercial cutting wheel (diamond wheel saw)	1.1x1.3x1.1	1	100-240	1	Water internal circulation. To be developed for Hot Cell.
Commercial polisher + Recirculating Filtration System	2x 2.5x3 2.2 x 2.2 x 3.2	1 1	100-240 115	5	Dimension based on standard polisher. We need one dedicated for activated material, new dimension will be smaller. Will have a recirculating filtration system. Standard system has a 7-gallon capacity
EDM ?					
A tool box for remote handling and manipulation of the material and equipment	NA	NA	NA	NA	NA
light					NA
Visual camera					NA

All the commercial equipment will be designed for activated material work to mitigate contamination of the hot cell and for easy maintenance and cleaning.

3. Testing hot cell

No permanent equipment is expected in the testing hot cell except specific remote handling tool box.

List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements			Utilities (water/air cooling, compressed air?)	
		phase	Voltage (V)	Nominal Current Draw / unit (A)		
Tensile Test machine (PNNL)	3.5x2x5 (Just the test frame)	1	110	10	Servo-hydraulic system. Hydraulic lines required	Instron 8801. Can do both tensile and fatigue
Custom-fatigue test	2.3x1.1x1.1	1	208	2		
Furnace for tensile test machine	To be fitted inside tensile tester	1	208	16	No cooling	
Hardness tester						
DIC system						

4. Vestibule

List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements			Utilities (water/air cooling, compressed air?)
		phase	Voltage (V)	Nominal Current Draw / unit (A)	
Friskers					

5. Testing lab

List of existing equipment	Dimension [WxDxH, ft]	Electrical requirements			Utilities (water/air cooling, compressed air?)
		phase	Voltage (V)	Nominal Current Draw / unit (A)	
Commercial grinder/polisher	1.3x 2.3x2.1	1	100-240	5	METPREP3 From allied high tech
dilatometer	8x3x4	1	208	16	LINSEIS L75
Fermilab Fatigue Machine	5x3x4	1	208-240	2	
Mechanical load frame (Mecmesin 5kN existing)	5x3x7	1	208-240	10	
Mechanical load frame (Shimadzu)	8x6x7	1	120	10	
List of future potential equipment					
diamond wheel saw	1.1x1.3x1.1	1	100-240	1	TechCut4 from allied high tech
Fatigue/tensile testing Machine Instron 8801	3.5x2x8.5	1	110	10	
Furnace for load frame	To be fitted inside the load frame	1	220	16	
thermal bench test					
Vibration test stand					
laser flash diffusivity					
profilometer					
Split Hopkinson pressure bar					
hardness tester					
DIC system					

6. Microscopy lab

List of existing equipment	Dimension [WxDxH, ft]	Electrical requirements			
		phase	Voltage (V)	Nominal Current Draw / unit (A)	
High resolution digital microscope (Keyence VHX-7000)	6x3x6	1	120	1.5	
Nano-indenter	6x3x6	1	120	4	
List of future potential equipment					
AFM					
SEM	4x6				
EBSD add-on to SEM					
Micro-mechanics stage (add to SEM)					

7. NOMATech lab

List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements			
		phase	Voltage (V)	Nominal Current Draw / unit (A)	
fume hood for chemical mixing	8 x 3x5	1	120	6	Existing at MI-8
High temperature furnace	3x3x4	1	208-240	15	
Nanofiber electro-spinning machine	8x6x8	1	120	10	

Appendix 2 – list of potential chemicals in the different lab/area

1. Chemical list in NOMATech Lab

material	quantity	MSDS link
Aluminum 2,4-pentanedionate	1000 gm	SDS
acetic acid (CH_3COOH)		
Acetone	5 litre	SDS
Polyvinyl pyrrolidone (PVP)	5 kg	SDS
Ethyl Alcohol	5 litre	SDS
Polyacrylonitrile(PAN)	200 gm	SDS
Zirconium carbonate , basic powder (CH2O7Zr2)	500 gm	SDS
Ammonium Metatungstate Hydrate	500 gm	SDS
Zirconium oxide nanoparticle dispersion	500 ml	SDS
Aluminum Oxide nanodispersion Purity: 99% (metals basis)	500ml	
Poly(ethyleneimine) solution,	500 gm	SDS
Dimethyl sulphoxide (DMSO)	500ml	SDS
Poly(acrylic acid)	500 gm	SDS
4-styrenesulphonic acid, sodium salt hydrate (SASH)	100gm	SDS
Zirconium n-propoxide	500gm	SDS
Yttrium acetate hexahydrate	200 gm	
Yttrium nitrate hexahydrate ($Y(NO_3)_3.6H_2O$)	200 gm	SDS
Dispersible SWCNT Nanotubes	10 gm	SDS
N-propanol	2 litre	SDS
Polycaprolactone	500 gm	SDS

2. Chemical list in Testing Lab

material	quantity	MSDS link
Acetone	1 gallon	SDS
Ethyl Alcohol or Methyl Alcohol	1 gallon	SDS
Diamond Suspension, Glycol Based Polycrystalline, 9 Micron,	16 oz.	SDS
Diamond Suspension, Glycol Based Polycrystalline, 6 Micron	16 oz.	SDS
Diamond Suspension, Glycol Based Polycrystalline, 3 Micron	16 oz.	SDS
Diamond Suspension, Glycol Based Polycrystalline, 1 Micron	16 oz.	SDS
GreenLube Polishing Lubricant	32 oz.	SDS
Colloidal Silica Suspension, 0.04 Micron	32 oz.	SDS
EpoxySet Kit, Incl. 128 oz. (3.6 kg) Resin, 16 oz. (450 g) Hardener,	128 + 16 oz.	SDS
Mold Release, PTFE Based	12 oz. Spray	SDS
FinalPrep Alumina Polishing Solution, De-Agglomerated, 0.05 Micron	16 oz.	SDS

Appendix 3 – list of potential material in the hot cells

material	**Hazard/SMDS**
Titanium and Titanium alloys	Metallic, solid
Tungsten and Tungsten alloy	Metallic, solid
High Entropy Alloys	Metallic, solid
Nanofiber (ZrO_2, ceramic, metallic components)	
Carbon-graphite	solid
Beryllium	Metallic, solid
Electrical cables	
Fluid lines	
LED	
Testing equipment (mainly metallic components)	
Polishing product?	