MOCVD
Laboratory Study

Engineering Centers Building
University of Wisconsin-Madison
(DFD Project No. 14J3G.3)

DRAFT
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A. Project Background and Project Scope

This project, as requested by UW-Madison, is a feasibility study for a new MOCVD (Metal-Organic Chemical Vapor Deposition) Laboratory in the Engineering Centers Building (ECB) on the UW-Madison campus. This study focuses on the occupancy requirements per the applicable codes, as well as equipment plans for the lab and any architectural, fire protection, plumbing, mechanical, and electrical changes required.

Project Background

UW-Madison College of Engineering hired a new faculty member whose research requires a specialized MOCVD laboratory. The lab will be designed and built to meet the needs of his research as outlined in this study. The timing of design and construction of the lab is such that some assumptions need to be made during this preliminary phase in order to determine the program, code, and design requirements.

The MOCVD lab will experiment with chemical deposits used to build semiconductors. Equipment includes self-contained units within the lab space that are connected to building services. A similar existing lab operated by Professor Luke Mawst is located in Room 2006 of ECB, and for the purposes of this study provides a precedent for the MOCVD lab.

Multiple locations within the building were identified as possibilities for the location of the new lab. The suite of Rooms 2064, 2064A, and 2064B was selected by College of Engineering to be the preferred location.

UW-Madison indicated that an MOCVD lab appears to be a high hazard (H-5) occupancy as defined by applicable codes because of the storage and use of high volumes of pyrophoric gases for semiconductor fabrication, and therefore has unique requirements.
B. Code Analysis

The Engineering Centers Building (ECB) at UW-Madison was completed in 2003. The original building was designed under the Wisconsin Administrative Code Department of Commerce (Comm) – September, 1998, Chapters 51-69, NFPA 101 Life Safety Code – 1997, and NFPA 45 Fire Protection for Laboratories Using Chemicals – 1996. Per these codes, ECB is a 4-Story, Class 2 Fire Resistive Type B, Instructional Use Building. The Building falls within Chapter Comm 56, Schools & Other Places of Instruction. The Laboratory Unit Fire Hazard Class is “B”.

The second floor is understood to be designed with two (2) control areas as shown on drawing A101. There is no available documentation of this, however these can be inferred from the hourly ratings designation on the original building documents.

Current applicable building codes include the International Building Code (IBC) – 2009, the International Existing Building Code (IEBC) – 2009, the International Mechanical Code (IMC) – 2009 and the International Fire Code (IFC) – 2009. This code analysis for the ECB modifications for the MOCVD Laboratory refers to these current codes.

The project as defined by the IEBC is Alteration Level 2, which means existing conditions within the building which met the code at the time it was approved do not need to be altered, except in the area of modification. This analysis indicates the code requirements and existing conditions, with required modifications indicated in the following section. Relevant definitions from the IBC are included at the end of this section.

It has been determined to proceed with design of the MOCVD Laboratory as an H-5 Occupancy based on the chemicals to be stored and used in the laboratory.

CODE ANALYSIS FOR H-5 HIGH HAZARD OCCUPANCY

I. HAZARDOUS MATERIALS

Upon initiation of the MOCVD project, the Primary Investigator (P.I.) provided a list that detailed expected chemical use and quantities of each material within the laboratory. For each chemical listed by the P.I., a Safety Data Sheet was provided which details the chemical hazards of each material (see Appendix A). The hazard of each chemical was then classified per IBC Section 307, and the quantities of each were tabulated per hazard classification (see Appendix A). The total quantities were compared to the Maximum Allowable Quantities (MAQs) for each hazard class as detailed in Tables 307.1(1) and 307.1(2). It was found that the quantities of pyrophoric materials proposed for use in the laboratory exceeds the MAQs listed in Tables 307.1(1) and 307.1(2), and the laboratory qualifies as H-5 per Section 307.7 of the IBC due to the expected semiconductor fabrication and research and presence of HPMs.

Requirement(s):

Table 307.1 – Maximum Allowable Quantity per Control Area of Hazardous Materials Posing a Health Hazard
Table 415.8.2.1.1 – Quantity Limits for Hazardous Materials in a Single Fabrication Area in Group H-5
II. SEPARATION

Requirement(s): 2 Hour Fire-Rated Resistance Rating for fire barrier assemblies and horizontal assemblies between fire areas *(IBC Table 707.3.9)*
Self-closing fire door assembly with fire resistance rating of 1-1/2 hours *(IBC Table 715.4)*

Current Condition: Not Rated

III. LOCATION OF OCCUPIED LEVELS

Requirement(s): At or above grade

Current Condition: Level 2 (above grade)

IV. FLOORS

Requirement(s): Structural floor shall be of noncombustible construction
Floor forming part of an occupancy separation shall be liquid tight

Current Condition: Structural floor is concrete, therefore noncombustible
Finish floor is carpet with rubber cove base

V. SHAFTS AND OPENINGS THROUGH FLOORS

Requirement(s): Shaft enclosures shall have a fire-resistance rating of 2 hours.
Shaft enclosures shall be constructed as 2 hour rated Fire Barriers per IBC Section 707 or horizontal assemblies per IBC Section 712.
Openings shall be protected per IBC Section 715.
Penetrations shall be protected by an approved fire-resistant joint system designed to resist the passage of fire for a minimum of 2 hours per IBC Section 714.
Exhaust ducts shall not penetrate building separation walls. When exhaust ducts penetrate a fire separation, the duct shall enter fire-resistant-rated construction or shaft. Fire dampers shall not be installed.

Current Condition: (None)

VI. TRANSPORTING HAZARDOUS PRODUCTION MATERIALS TO FABRICATION AREA

(Not Applicable)

VII. CORRIDORS

(Not Applicable)

VIII. SERVICE CORRIDORS

(Not Applicable)
IX. STORAGE OF HAZARDOUS PRODUCTION MATERIALS

Requirement(s): Storage of HPM in fabrication areas shall be within approved or listed storage cabinets or gas cabinets or within a workstation. The storage of HPM in quantities greater than those listed in IFC 1804.2 shall be in liquid storage rooms, HPM rooms or gas rooms as appropriate for the materials stored. The storage of other hazardous materials shall be in accordance with other applicable provisions of the IBC and the IFC. Each cabinet shall be equipped with an automatic fire detection system. Pyrophoric Liquids and Class 3 Water Reactives: No more than 5.3 gallons of materials per cabinet.

Current Condition: (None)

X. PIPING AND TUBING

Requirement(s): Supply piping shall comply with ASME B31.3 Identification of Piping, Tubing, and HPM waste lines shall be identified per ANSI A13.1. Valves in the supply piping between the product containers and workstation shall fail closed.

Current Condition: (None)

XI. CONTINUOUS GAS DETECTION SYSTEMS

Requirement(s): Gas detection is required in HPM Production areas, HPM Room, within gas cabinets, and exhaust enclosures. System shall be able to detect levels Immediately Dangerous to Life and Health (IDLH) within the exhausted enclosure, ventilated enclosure, or gas cabinet. System shall be able to detect Flammable gases at less than 25% of the Lower Flammability Limit within the exhausted enclosure, ventilated enclosure, or gas cabinet. The detection system shall automatically shut off the gas system at the sources when a short term hazard is detected. System shall initiate both an audio and visual alarm. The system shall automatically close shut off valve at the source of the gas supply piping of the system being monitored.

Current Condition: (None)

XII. AUTOMATIC SPRINKLER SYSTEM PROTECTION IN EXHAUST DUCTS FOR HPM

Requirement(s): An automatic sprinkler system is required in exhaust ducts that convey gases, vapors, fumes, mists, or dusts generated from HPM in accordance with IFC and NFPA13. Sprinkler systems shall be installed at 12 foot intervals in horizontal ducts and at changes in direction. In vertical ducts, sprinklers will be at the top of the riser and at alternate floors.
Sprinklers in a corrosive environment shall be non-corrosive.

Current Condition: (None)

XIII. HAZARDOUS MATERIALS - GENERAL MECHANICAL REQUIREMENTS

Requirements per IMC 502.8

Requirement(s):
Mechanical ventilation shall be 1 cfm per square foot of floor area or greater per.
The system shall operate continuously.
A manual shutoff control for ventilation equipment shall be provided outside the room adjacent to the principal access door to the room. The switch shall be of the break-glass type and shall be labeled: VENTILATION SYSTEM EMERGENCY SHUTOFF.
The system shall be designed to prevent accumulation of vapors in areas of the space.
Gas rooms, exhausted enclosures, and gas cabinets shall be designed to operate at negative pressure.
For indoor dispensing and use – point sources, ventilation shall be provided at the point of potential fume generation.
Indoor dispensing and use: When areas for indoor dispensing and use exceed the MAQ’s, the space shall be ventilated.

Current Condition: (None)

XIV. HAZARDOUS MATERIALS – REQUIREMENTS FOR SPECIFIC MATERIALS

Requirements per IMC 502.9

Requirement(s):
Corrosives – When the amount of corrosive exceed the MAQ’s set forth in IBC Table 307.1, ventilation shall be provided at the point of potential fume generation.
Flammable and combustible liquids – Space shall be ventilated at the greater of 1 cfm per square foot of floor space or 150 cfm. Ventilation shall be such to prevent accumulation of flammable vapors.
Failure of the ventilation system shall shutdown the dispensing system for the materials.
Silane Gas – Silane gases shall be housed in gas cabinets and exhausted enclosures. Inlet to all gas cabinets shall be at least 200 fpm average with not area below 150 fpm.

Current Condition: (None)

XV. VENTILATION

Requirement(s):
Per IMC 502.10, required in fabrication areas, workstations, HPM Rooms, gas cabinets, exhausted enclosures, and cabinets containing pyrophoric materials or class 3 water reactive materials.
Per IMC 502.10, cabinets containing pyrophoric liquids shall conform to IFC Section 1805.2.3.4.
Per IMC 415.8.10.2, exhaust ventilation system are not allowed to be designed to operate at less than 50% normal fan speed while on emergency power, when the system can be demonstrated that the ventilation system will maintain a safe environment.

Current Condition: (None)

**XVI. MOTORS AND FANS**

Requirement(s): Per IMC 503.2, spark proof fans shall be for exhaust that conveys explosive or flammable dust or vapors.

Current Condition: (None)

**XVII. HAZARDOUS EXHAUST SYSTEMS**

Requirements per IMC 510.

Requirement(s): Hazardous exhaust shall be independent from other systems.
Hazardous exhaust shall not share shafts unless the come from the same fire area.
System shall be designed using equal velocity or equal friction method.
Duct system shall be pre-balance by duct sizing with balance damper.
Balance dampers shall have a min-stop to prevent shutoff.
Contaminants must be captured in the space and diluted to below level listed in IMC 510.2.
Hazardous Ducts shall extend directly to the exterior and not through plenums or ducts.

Current Condition: (None)

**XVIII. DUCT CONSTRUCTION**

Requirement(s): Duct thickness shall be per IMC Table 510.8. Projected to be 20 gauge.
Duct joints shall have a minimum lap of 1 inch.
Explosion Relief: Systems exhausting potentially explosive mixtures shall be protected with an approved explosion relief system or by an approved explosion prevention system designed and installed in accordance with NFPA 69. An explosion relief system shall be designed to minimize the structural and mechanical damage resulting from an explosion or deflagration within the exhaust system. An explosion prevention system shall be designed to prevent an explosion or deflagration event from occurring.

Current Condition: (None)
XIX. TESTING

Requirement(s): Systems required for testing per IFC 2704.9 include:

- Gas detection systems, alarms and automatic emergency shutoff valves
- Limit control systems for liquid level
- Emergency alarms and supervisions required by IFC Sections 2704.9 and 2705.4.4.
- Monitoring and Supervisory Controls
- Manually active shutdown required by IFC Section 4103.1.1.1.

Testing Frequency shall be not less than annually, in accordance with manufacture recommendation, or in accordance with industry standards.

Current Condition: (None)
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<td>Hazardous Production Material (HPM)</td>
<td>A solid, liquid or gas associated with semiconductor manufacturing that has a degree-of-hazard rating in health, flammability or instability of Class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory or production processes which have as their end product materials that are not hazardous.</td>
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<td>Immediately Dangerous to Life and Health (IDLH)</td>
<td>The concentration of air-borne contaminants which poses a threat of death, immediate or delayed permanent adverse health effects, or effects that could prevent escape from such an environment. This contaminant concentration level is established by the National Institute of Occupational Safety and Health (NIOSH) based on both toxicity and flammability. It generally is expressed in parts per million by volume (ppm v/v) or milligrams per cubic meter (mg/m³). If adequate data does not exist for precise establishment of IDLH concentrations, an independent certified industrial hygienist, industrial toxicologist, appropriate regulatory agency or other source approved by the building official shall make such determination.</td>
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<td>Lower Flammable Limit (LFL)</td>
<td>The minimum concentration of vapor in air at which propagation of flame will occur in the presence of an ignition source. The LFL is sometimes referred to as “LFL” or “lower explosive limit”.</td>
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<td>Maximum Allowable Quantity (MAQ)</td>
<td>The limit of a hazardous material as written in tables 307.1(1) and 307.1(2) of Section 307 in the International Building Code (IBC). Section 307 of the IBC defines hazard classifications which are compared to tables 307.1(1) and 307.1(2). When the amount of a hazardous material exceeds the limits declared in tables 307.1(1) and 307.1(1), the tables indicates the hazard occupancy that applies to that space.</td>
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C. Analysis of Existing Conditions and Proposed Scope of Work

STRUCTURAL

Analysis of Existing Conditions

Suite 2064 has an occupancy loading of 50 psf. A significant additional load will be added with the installation of the new equipment. The new equipment (6700 lbs) will have a live load of approximately 130 psf which is considerably less than the designed allowable live load of 150 psf. Therefore no additional structural reinforcement will be required to support the new equipment. Please note that there are post-tensioned beams in the area and all suspended items will be hung from the built-in cleats in the joists. If additional hangers are required outside of the cleats, the reinforcement tendons must be located so that they are not damaged or cut when drilling into the existing structure.

In the Penthouse, a hole will be cut through the steel roof to allow ductwork to pass through. Steel channels will be installed around the opening to support the roof.

Proposed Scope of Work

- Structural Demolition:
  - Removal of Penthouse metal roofing to allow ductwork to pass through.

- Proposed Structural Work:
  - Installation of new beams to support the roof deck around the opening as well the weight of the new fan that will be added on the roof.

ARCHITECTURAL/GENERAL CONDITIONS

Analysis of Existing Conditions

Suite 2064 is currently used as a conference room with connecting support spaces. The existing enclosure is not rated, with the exception of the shared atrium wall which is 2-hour rated. Sets of doors connect the suite to Corridors 2000S and 2000T. Existing finishes include carpet, rubber base, painted gypsum wall board (GWB), exposed concrete, and ACT ceiling.

Proposed Scope of Work

The existing space will be divided into (3) three spaces (MOCVD Laboratory 2062, Generic Lab 2064A, and Corridor 2064) as defined below. New finishes will be specified to match existing finishes.

- Architectural/General Demolition:
  - Demolition of walls, including doors and all items within the walls, from floor to structure, dividing rooms 2064, 2064A, and 2064B.
  - Partial demolition of shared corridor wall to provide new opening.
  - Removal of existing ACT ceiling and all elements within ceiling throughout rooms 2064, 2064A, and 2064B.
  - Demolition of existing carpeting and base throughout new lab space. Existing carpeting and base to remain in new Corridor 2064.
  - Demolition of gypsum board wall finish throughout new lab space. Expose stud cavity to prepare for new wall surface.
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• MOCVD Lab 2062:
  o MOCVD Lab 2062 requires 2-hour wall construction. New walls will be constructed of metal studs with (2) two layers of GWB on each side. Existing metal stud partitions will be modified on the interior of the lab to minimize affects in adjacent spaces. A 2-hour rating can be achieved by adding a resilient channel over the existing metal studs and (2) two layers of GWB on the inside of the room. Penetrations will meet the requirements of IBC Section 714, as described in the sections to follow.
  o The exposed concrete wall in existing Room 2064A will be furred out to align with the finished face of existing Room 2064B. All associated elements within this wall will be modified.
  o Doors require a 1-1/2 hour rating and must be self-closing.
  o Door hardware must be labeled for a 1-1/2 hour rating.
  o Double Doors 2062-1 have additional requirements. The inactive leaf may have automatic flush bolts which function only when the active leaf is opened. Based on the door manufacturer, the door may require an astragal.
  o Liquid tight flooring is required. This will be accomplished with VCT flooring and a rubber cove base as well as sealing of all penetrations.
  o Equipment will be installed per drawing A202. See Appendix B – Equipment for additional information. Mechanical, Electrical, and Plumbing requirements are described in the sections to follow.
  o Walls and doors will be painted.

• Generic Lab 2064A:
  o Generic Lab 2064A does not have any fire rating requirements.
  o New partitions will be constructed of GWB on either side of metal stud framing.
  o Existing partitions receive a new layer of GWB on the inside of the room.
  o VCT Flooring with rubber base will be installed.
  o Walls and doors will be painted.

• Corridor 2064:
  o Rubber base will be installed along new walls.
  o New walls and doors will be painted.
  o New ACT ceiling will be installed.
  o Existing carpet will remain and modified for new construction.

• Corridor 2000T:
  o The opening for door 2062-1 will be detailed to match openings throughout the corridor.
  o A GWB soffit will be installed over the ceiling and painted.
  o VCT flooring and rubber base will be installed.
  o New walls and doors will be painted.

FI RE PROTECTION SYSTEM

Analysis of Existing Conditions

The building is served by a combined domestic water and fire suppression water main from the campus water loop in the street. An existing fire pump located in the basement boosts the building fire suppression wet system and standpipe system. The standpipe system meets or exceeds 100 psig at the top of the riser per NFPA requirements.

For rooms 2064, 2064A, and 2064B there is currently an existing wet sprinkler system that serves the space. There are mains and cross mains in the ceiling space serving the area.
Proposed Scope of Work

- Fire Protection Demolition:
  - The existing sprinkler system serving rooms 2064, 2064A, and 2064B will be demolished for a new separately zoned sprinkler system for the proposed MOCVD Lab. Demolished piping will be capped at the existing main. Any existing mains and cross mains in the proposed space that serve existing adjacent spaces will need to remain.

- Proposed Fire Protection Work:
  - A new sprinkler zone will be required for the proposed MOCVD Lab space. The existing sprinkler riser and zone controls are located in Stair 2000G. The new sprinkler zone will be installed in the existing stair in a similar configuration as the existing sprinkler zone valves.
  - The new sprinkler system will serve the proposed MOCVD Laboratory 2062 space and also the sprinklers required for the exhaust ductwork through the roof.
  - The existing west sprinkler system serving the proposed renovated Generic Lab 2064A and Corridor 2064 will require reconfiguration for purposed new ceiling and walls.

Sprinkler heads are required in the exhaust ductwork entire run due to the H-5 classification of the space (refer to the HVAC section for further explanation). Where subject to freezing temperatures, dry sprinkler heads will be installed in the ductwork.

PLUMBING

Analysis of Existing Conditions

There currently is no plumbing serving rooms 2064, 2064A, and 2064B. There is lab air, lab hot water, and lab cold water capped in the ceiling space for future extension. Existing lab waste is also in the ceiling serving the lab spaces above, which will need to remain. The existing lab services are adequately sized for the proposed renovations.

Proposed Scope of Work

Plumbing demolition is limited to cutting into existing capped services in the ceiling space, and cutting and coring of the floor slab for new drainage. There are no existing plumbing fixtures in the space that require demolition.

Note that the existing floor slab is a post-tensioned concrete slab. The plumbing contractor will be required to x-ray the floor prior to core drilling.

- Proposed Plumbing Work:
  - Acid waste and vent will be required for the fume hood cup sink, the floor drain next to the hydrogen generator, and the floor drain under the emergency safety shower/eyewash unit. The new acid waste vent will tie into an existing 1-1/2” acid vent pipe located in the adjacent Biomedical 2043 room.
  - Lab cold water will be piped from the capped service in the ceiling to the fume hood cup sink.
  - The existing lab water capped in the ceiling is not large enough to serve the new safety shower/eyewash unit. Therefore, lab cold and hot water will need to be piped from the nearest adequately sized services.
  - Lab air will be piped from the capped service in the ceiling to the MOCVD Reactor.
  - House nitrogen will be piped from the corridor to the MOCVD Reactor.
Reverse osmosis water will be piped from the corridor to the hydrogen generator. The reverse osmosis will feed a DI polishing system prior to being piped to the hydrogen generator.

High purity hydrogen will be piped from the hydrogen generator to the MOCVD Reactor.

HEATING VENTILATION AND AIR CONDITIONING (HVAC)

Analysis of Existing Conditions

For rooms 2064, 2064A, and 2064B there are currently three (3) supply air terminals and three (3) exhaust air terminals. The existing supply and exhaust systems are for comfort cooling and heating as the space is not a pressure controlled laboratory in its current state.

In addition to the exhaust and supply duct that provide air for rooms 2064, 2064A, and 2064B, there is one supply air and one exhaust air main that transverse the existing room.

Existing hot water pipes serve the supply air terminal reheat coils. Additionally there is a set of process chilled water lines that enter the space from the north. The process chilled water lines are capped within the space in room 2064A and 2064B. Each pipe has a valve and blind flange which are ready to receive a connection.

Proposed Scope of Work

- Demolition
  - The three (3) existing supply air terminals (AT-2064, AT-2064A, and AT-2064B) and associated supply duct will be removed to make way for the installation of the new ductwork required for the new MOCVD system. Two (2) Exhaust air terminals (EV-2064A and EV-2064B) will be removed. The existing supply main ducts, exhaust main ducts, as well as the duct for EV-2043A will remain.
  - All air devices (Grilles, Registers, and Diffusers), save for the exhaust grill served by EV-2064, will be removed from rooms 2064, 2064A, and 2064B.
  - Duct Branches for air terminals (AT-2064, AT-2064A, AT-2064B, EV-2064A, and EV-2064B), will be removed back to the duct mains.
  - The hot water piping associated with the supply air terminals (AT-2064, AT-2064A, and AT-2064B) will be removed back to the main.

- New Supply Ducts
  - For Generic Lab 2064A, one (1) new supply terminal and new supply distribution ductwork will be installed to serve the room and provide make-up air for the exhaust ventilation. Air terminal will be located in room 2064A.
  - For the MOCVD Lab 2062, one (1) new supply terminal and supply air distribution ductwork will be installed to serve the room and provide make-up air for the exhaust ventilation. Air terminal will be located in room 2064A.
  - A Fire Damper will be installed in the new supply air duct for room 2062 at the wall between rooms 2062 and 2064A.
  - The supply ventilation volume for room 2062 will be sufficient to make up the exhaust ventilation and maintain the room at a negative pressure to the surrounding spaces.

- Room 2064A Exhaust Duct
  - For new room 2064A, one (1) new exhaust terminal will be installed with new exhaust distribution ductwork.
  - The new exhaust will work in conjunction with the new supply air terminal for room 2064A to maintain a neutral pressure within the space.

- Room 2062 Exhaust Ducts and Fans
One (1) new 22” exhaust main will be installed penetrating the south wall of room 2062. The duct will then turn east, penetrate the east wall of room 2043, penetrate the atrium wall and rise to the fourth floor. The duct will then penetrate the atrium wall into room 4001 where it will be ducted to the roof and connected to two new N+1 redundant exhaust fans located on top of the penthouse in the fan pit (see Appendix D).

- Exhaust duct will be 20 gauge material.
- The exhaust duct will have sprinkler heads every 12 foot of horizontal run, at every change of direction, at the top of the riser, and at every other floor below the riser.
- The exhaust duct will be wrapped in fire rated insulation between where the duct exits room 2062 to where the duct leaves the building. The insulation will be rated for 2 hours (ASTM E814 “F” and “T” fire ratings, UL or equivalent third party listed, labeled and specifically evaluated for such purpose in accordance with ASTM E2336). The insulation will have a foil-scrim-polyethylene fiberglass reinforced factory applied jacket.

- Exhaust Fans for Room 2062
  - The new exhaust fans will be located on the penthouse roof in the existing fan pit.
  - Each new exhaust fan will be 460v/3ph, and exhaust approximately 3,225 cfm from Room 2062.
  - The new exhaust fans will be fully redundant, connected to emergency power, and of a spark-proof construction.
  - The fans will be mounted on a new roof curb on the roof.

- MOCVD Laboratory Equipment Exhaust Requirements
  - Each lab equipment device will be connected and ventilated per manufacturer’s recommendations.
  - All airflows and connection sizes will be confirmed during design process.
  - One (1) MOCVD unit, three exhaust connections, two (2) 400 cfm connections to the control cabinet, one (1) 750 cfm connection to the reactor cabinet.
  - One (1) Gas Scrubber Unit exhaust connection of approximately 400 cfm.
  - One (1) Ammonia Purifier exhaust connection of approximately 150 cfm.
  - Three (3) gas cabinets, one exhaust connection each at approximately 175 cfm.
  - One (1) Fume hood, one exhaust connection of approximately 600 cfm. The fume hoods was assumed to be 6’ Fischer Hamilton Pioneer or equivalent.

- Existing Exhaust and Supply Duct Mains in Room 2062
  - A new fire damper will be installed in the 34” diameter supply duct at the north wall where the duct leaves the new space 2062.
  - Existing exhaust ducts within the new room 2062 that pass through the space but do not serve the space will be wrapped in fire-resistant insulation sufficient to achieve a 2 hour fire resistance rating.

- Process chilled water
  - New process chilled water pipes (PCHS/PCHR) will be connected to the MOCVD Reactor. Connection will be made to one of two existing process chilled water blind flanges within the space.
  - New process chilled water pipes (PCHS/PCHR) will be connected to the Hydrogen Generator. Connection will be made to one of two existing process chilled water blind flanges within the space.

- Ventilation and Pressure monitoring system
  - New room pressure sensors will be installed to monitor the room pressure between both the corridor and room 2062, and room 2064A and room 2062.
  - The airflow for supply air terminal AT-2062 will modulate to maintain room 2062 at a negative pressure relative to the surround spaces.
The exhaust ventilation system will be provided with an exhaust system monitoring system. The system will indicate the status of the fan systems, including if the system is running normally, if the system is running with a back-up fan, or if the system has suffered a failure. The monitoring system will monitor the room pressure relative to the surrounding spaces as well as the pressure within the gas-cabinets to ensure negative pressure for the room and cabinets. An alarm will be indicated by the monitoring system if the pressures fall outside of the safe parameters. The monitoring system will notify the building fire alarm system and all required parties in the event of an alarm. The parties to be notified will be confirmed upon installation of the system.

FI RE ALARM SYSTEM

Analysis of Existing Conditions

The fire alarm system throughout this building is an addressable system. The system is code compliant and is adequate for this space.

Proposed Scope of Work

- Existing fire alarm system devices and associated wiring will be relocated as required for the building modifications. Additional fire alarm annunciation devices required to assure code compliant coverage of all the remodeled spaces will need to be provided. Additional fire alarm devices required to monitor new equipment and associated alarms will need to be provided.

ELECTRICAL/LIGHTING

Analysis of Existing Conditions

There are more than adequate electrical services throughout the building, fed from the generator, to handle the new equipment proposed as part of this project. Currently, there are 480V services available in the Basement & Penthouse, and there are 208V services available in Electrical Room #2077 which is adjacent to the project area.

In the Basement, Switchboard ESWBD-BB, a 2000-amp, 480V, 3-Phase, 3-Wire switchboard is available and Motor Control Center EMCC-BA, a 600-amp, 480V, 3-Phase, 3-Wire motor control center is available to feed new 480V loads. These existing service locations are identified on attached sheet E201.

In the Penthouse, Motor Control Center EMCC-PA, a 1600-amp, 480V, 3-Phase, 3-Wire motor control center is available to feed new 480V loads. This existing service location is identified on attached sheet E203.

In Electrical Room #2077, Panel ERP2A, a 100-amp, 208V, 3-Phase, 4-Wire panel is available to feed new 208V & 120V loads. This existing service location is identified on attached sheet E202.

The existing lighting & controls throughout the project area consist of 2x4 fluorescent troffers and switches that will need to be disconnected and removed within the MOCVD and Generic Laboratory spaces. Existing lighting/controls within the Corridor spaces may remain provided they meet the building standard for the new occupancy types. The balance of electrical devices throughout the project area will also need to be removed within the MOCVD Laboratory space, as the new space will require Class 1,
Division 2 grade equipment. Existing devices within the Generic Laboratory and Corridor spaces may remain provided they meet the building standard for the new occupancy types.

Proposed Scope of Work

- **MOCVD Laboratory 2062:**
  - The new space will be considered a Class 1, Division 2 space, and thus will require electrical equipment rated for this classification. Exact classification for this space will be confirmed prior to final design/construction.
  - Equipment connections will be fed from the existing 480V or 208V services itemized above, and as described on attached sheets E201, E202, & E203. As noted on sheet E202, provide monitoring of all equipment and associated alarms, through the existing fire alarm system, as required. In addition, confirm which MOCVD space equipment will require Ethernet, and provide these connections, as required.
  - New lighting and controls will be provided throughout the space and will be fed from the local electrical panel(s). The new lighting throughout the space will be a GE #H4T83L series fixture, or equivalent. Light fixtures will be provided in an adequate quantity to provide a minimum of 30 footcandles on the work surface. All lighting controls will be manual and will be rated for the classification of the space. All conduits that enter the MOCVD space (Class 1, Division 2) will be continuous and will be provided with seal-offs, etc. to maintain the classification requirements of the space.
  - New devices, controls, disconnects, starters, etc. will be provided throughout the space as required by the equipment manufacturer and as required by code. Any/all devices, controls, disconnects, starters, etc. within the MOCVD space will be Nema 7 rated for the classification of the space. All conduits that enter the MOCVD space will be continuous and will be provided with seal-offs, etc. to maintain the classification requirements of the space.

- **Generic Laboratory 2064A:**
  - The new space will be building standard lab space.
  - New lighting and controls will be provided throughout the space and will be fed from the local electrical panel(s). The new lighting throughout the space will match the building standard for lab space. Light fixtures will be provided in an adequate quantity to provide a minimum of 30 footcandles on the work surface. All lighting controls will match the building standard.
  - New devices will be provided throughout the space to match the building standard for lab space.

- **Corridor 2064:**
  - The new space will be building standard corridor space.
  - New lighting and controls will be provided throughout the space and will be fed from the local electrical panel(s). The new lighting throughout the space will match the building standard for corridor space. Light fixtures will be provided in an adequate quantity to match the building standard for corridor space. All lighting controls will match the building standard.
  - New devices will be provided throughout the space to match the building standard for corridor space.

- **Penthouse**
  - Two (2) new HVAC exhaust fans will be provided on the roof of the building. These new fans will be fed from the existing Penthouse service as indicated on sheet E203. Provide starters/disconnects as required by the manufacturer and as required by code. Provide Nema 3R starters/disconnects for equipment located on roof.
## D. Budget

### PRELIMINARY PROJECT BUDGET

The Project Budget Estimate is summarized as follows:

<table>
<thead>
<tr>
<th>Construction Cost</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Construction &amp; General Conditions</td>
<td>$115,800</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>$19,730</td>
</tr>
<tr>
<td>Plumbing</td>
<td>$24,400</td>
</tr>
<tr>
<td>HVAC</td>
<td>$227,550</td>
</tr>
<tr>
<td>Electrical</td>
<td>$119,620</td>
</tr>
</tbody>
</table>

Subtotal Construction Cost: $506,700

Estimating Contingency: $101,340 (20%)

**Total Construction Cost**: $608,040

<table>
<thead>
<tr>
<th>Other Project Costs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Fees</td>
<td>$60,804</td>
</tr>
<tr>
<td>Project Contingency</td>
<td>$60,804</td>
</tr>
<tr>
<td>DFD Fees</td>
<td>$26,754</td>
</tr>
<tr>
<td>Work By Owner</td>
<td>-</td>
</tr>
<tr>
<td>Moveable Equipment</td>
<td>-</td>
</tr>
<tr>
<td>Special Equipment</td>
<td>-</td>
</tr>
<tr>
<td>Other Allowances</td>
<td>-</td>
</tr>
</tbody>
</table>

Subtotal Project Cost: $148,362

**TOTAL PROJECT COST**: $756,402

Refer to Appendix C for Detailed Budget Estimate.
OVERALL PROJECT SCHEDULE

The Project Schedule is summarized as follows:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract for A/E Services</td>
<td>1 month</td>
</tr>
<tr>
<td>Develop/Review Budget</td>
<td>1 month</td>
</tr>
<tr>
<td>Develop Preliminary Plans</td>
<td>1 month</td>
</tr>
<tr>
<td>Complete Review &amp; Design Report</td>
<td>1 month</td>
</tr>
<tr>
<td>Complete Bid Documents</td>
<td>2 month</td>
</tr>
<tr>
<td>Review Bid Documents (DFD)</td>
<td>1 month</td>
</tr>
<tr>
<td>Bidding and Contracting</td>
<td>2 month</td>
</tr>
<tr>
<td>Construction (See Below)</td>
<td>2 month</td>
</tr>
<tr>
<td>Estimated Total Time:</td>
<td>12 months</td>
</tr>
</tbody>
</table>

*Project Schedule is based on DFD Capital Budget Cost Estimating Guidelines for a Design-Bid-Build project. Other delivery methods could affect the overall project schedule.*
F. Appendices

APPENDIX A – CHEMICALS
- Chemical List
- Chemical Assessment
- Safety Data Sheets

APPENDIX B – EQUIPMENT
- Equipment Schedule
- Cut sheets, Shop Drawings, and Product Data

APPENDIX C – DETAILED COST ESTIMATE

APPENDIX D – EXISTING AND PROPOSED DRAWINGS
- T101  Title Drawing
- A101  Key Plan
- A201  Second Floor Demolition Plan
- A202  Second Floor Proposed Plan
- F201  Second Floor Proposed Plan – Fire Protection
- P200  Mezzanine Proposed Plan – Plumbing
- P201  Second Floor Proposed Plan – Plumbing
- M101  Second Floor Demolition Plan – HVAC
- M201  Second Floor Proposed Plan – HVAC
- M202  Penthouse Proposed Plan – HVAC
- E201  Basement Overall Plan – Electrical
- E202  Second Floor Proposed Plan – Electrical
- E203  Penthouse Overall Plan – Electrical