SEMICONDUCTOR CLEANROOM DESIGN GUIDELINES

The following guidelines are to be incorporated into the planning, design, construction, and maintenance of Arizona State University's (ASU) facilities that include semiconductor and nano-fabrication R&D and pilot production operations.

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1. Facility

1.1 Introduction

1.1.1 Background

A. Phoenix has seen an explosion of growth in high-tech industries and related commercial enterprises, including research and development (R&D) opportunities. ASU anticipates the need for education and research to support advancements in the semiconductor market sectors and related products and processes. One of ASU's long-term initiatives is to provide new state of the art facilities for educational, research and development, and pilot production test bed platforms to form lasting partnerships and continue innovations with collaborations between the public and private sectors.

B. One of the key initiatives under consideration by ASU as a part of this larger plan is the construction of a new semiconductor manufacturing & R&D facility that continues the vision set forth by the current Macroworks Technology Works (MTW) facility in Tempe, AZ. The existing MTW facility currently serves this larger purpose, but it was originally constructed in 1996 by Motorola as a semiconductor manufacturing plant, was not specifically designed or built as an R&D and/or pilot production facility, and it is 25+ years old. This facility has been selectively updated and renovated, as needed, but does not currently incorporate all the latest industry best practices and standards for semiconductor research and limited manufacturing. In addition, the available area for clean fab production is limited by the existing available laboratory and cleanroom space and will not accommodate future projected growth.

C. The primary purpose of this document is to provide guidelines for the design of a new semiconductor R&D and limited production facility but shall also serve as a roadmap for evaluating targeted upgrades and/or remediating design renovations to ASU's existing MTW facility in Tempe, AZ. The existing MTW facility is not required to be renovated to completely align to the standards in this document but shall be used for a benchmark guideline accordingly.

1.2 Facility Goals and Requirements

1.2.1 Construction of a new semiconductor fabrication facility should achieve the following goals:

A. Serve as a state-of-the-art, world-class facility for the semiconductor and wafer production industry for R&D and test bed for current and future industry partners for ASU. Semiconductor manufacturing is the priority use but R&D should also be considered.

B. Incorporate the latest applicable building codes and standards for life safety.

C. Provide adequate flexible areas for R&D and industry partner production in a clean environment while meeting the most demanding semiconductor manufacturing facility needs.

D. Provide a facility with a projected lifespan of 50+ years that is capable of adaptation and flexibility.

E. The facility needs to include all aspects typical to the typical process workflows associated with semiconductor manufacturing including photolithography, wet and dry etch, thin films, metrology, etc. as well as probe/testing and advanced packaging as well.

F. The facility also needs to include supporting spaces that include supporting lab spaces such as bead blasting, shop spaces for maintenance, supporting house and process utilities, and administrative spaces (offices, conference rooms, centralized break rooms, and general storage areas.

G. Clean classifications in the fab areas may vary between Class 10 and Class 100,000 depending on process and tool requirements. See Section 1.5.2-C for applicable standards for clean classifications.

H. The facility needs to incorporate applicable established standards from ASU's existing design guidelines that should be included with any new design or design upgrades to existing facilities:

a. ASU website for Design and Construction Professionals: For design and construction professionals | Arizona State University (asu.edu)
b. ASU Project Guidelines organized by Construction Standards Institute (CSI) Divisions: Project-Guidelines.pdf (asu.edu)
c. ASU Guidelines for Site Improvements: www.asu.edu/fm/documents/project_guidelines/Site-Improvements-Design-Guidelines.pdf
d. ASU Sustainable Design Guidelines: www.asu.edu/fm/documents/project_guidelines/Sustainable-Design-Guidelines.pdf
e. ASU Accessibility Standards: ASU-Accessibility-Standards.pdf
f. ASU Engineering Design Guidelines: Engineering-Design-Guidelines.pdf (asu.edu)
g. ASU Laboratory Design Guidelines: laboratory Guidelines (asu.edu)
h. ASU Laboratory Standard & Design Guide – Lab Ventilation: https://www.asu.edu/ehs/design-guidelines/laboratory-ventilation.pdf
i. ASU Enterprise Technology Telecommunications and Design Standards
j. ASU Eyewash and Safety Shower Guidelines: www.asu.edu/ehs/design-guidelines/eyewash-shower-standard.pdf

k. ASU Flammable Liquid Storage Guidelines: www.asu.edu/ehs/design-guidelines/flammable-liquid-storage-cabinets.pdf
l. ASU Hazardous Material Storage Guidelines: www.asu.edu/ehs/design-guidelines/hazardous-material-storage.pdf
m. ASU Guidance for Pressure Vessels and Gas Cylinders: www.asu.edu/ehs/design-guidelines/pressure-vessels-and-compressed-gas-cylinders.pdf
n. ASU Code Required Building Signage Checklist: www.asu.edu/fm/documents/code-required-building-signage-checklist.pdf

1.3 Guidelines for Semiconductor Facility Design

1.3.1 Definition of a "Semiconductor Facility"

A. ASU defines a "semiconductor" facility as a location that houses dedicated areas for the research and development of materials and products for the field of nanotechnology and wafer production used in the manufacturing of microchips and related products. This facility is also used for limited "pilot production" and/or limited production for potential tenants occupying space with the facility utilizing the capabilities of the installed infrastructure.

B. The science behind the development, design, and construction of semiconductor facilities has advanced considerably in the past 15-20 years. An important point in the design and construction and operation of these facilities is that the fab and its supporting areas must be thought of as a "machine" with many more parts and complexities than a typical laboratory building and these intricacies must all be carefully considered on how they will be designed to function for the immediate forecasted needs for the facility safely, but how they will do so as efficiently as possible while keeping an eye on the future. The diagram below represents the many parts and pieces of a semiconductor fab facility and while any new ASU facility will not be needing to meet the requirements of a full wafer production operation with high yield targets, many of the typical processes and systems involved must still be considered. A facility that has capacity and flexibility to accommodate as wide a range of processes and associated tools and equipment for research and development as well as pilot production and limited production such as test lines or very scaled down low yield operations for researchers, smaller companies testing out new products, or tool manufacturers needing development space is a high-value asset to any university institution and can be a key attraction for bringing current and future talent to the Valley.

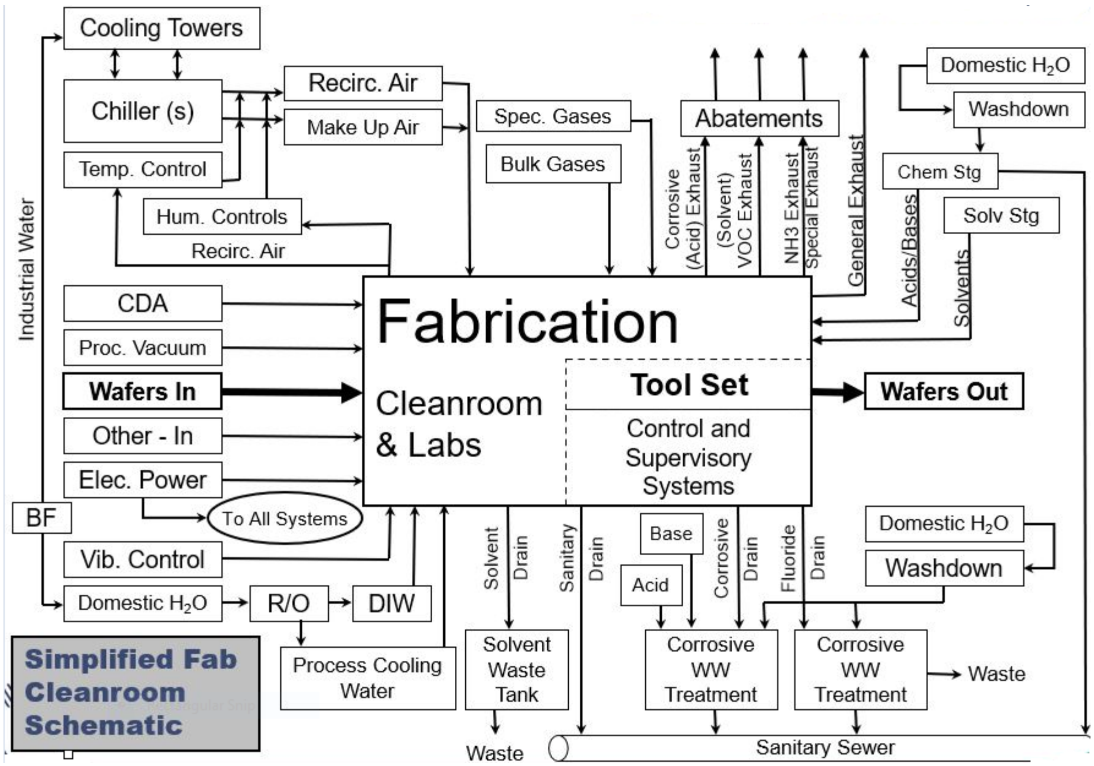


Figure 1- Semiconductor Facility Typical Utility Schematic

C. Semiconductor facilities have incorporated the following considerations into benchmark designs and solutions in the past 15-20 years:

1) Faster, Leak-tight Installation

2) More Efficient Planning and Design

3) Reduced Total Lifecycle Costs

4) Standardized Global Quality

5) Increased Productivity and Throughput Yield

6) Increased Modularity for Greater Flexibility and Ease of Expansion/Renovation

1.3.2 Facility Capacity Considerations

A. Any new semiconductor facility needs to be designed to be as flexible as possible for research and development (R&D) as well as limited production and pilot production for potential tenant users. There are two typical layout configurations for the design of clean spaces that can be considered:

1) Bay and Chase Configuration

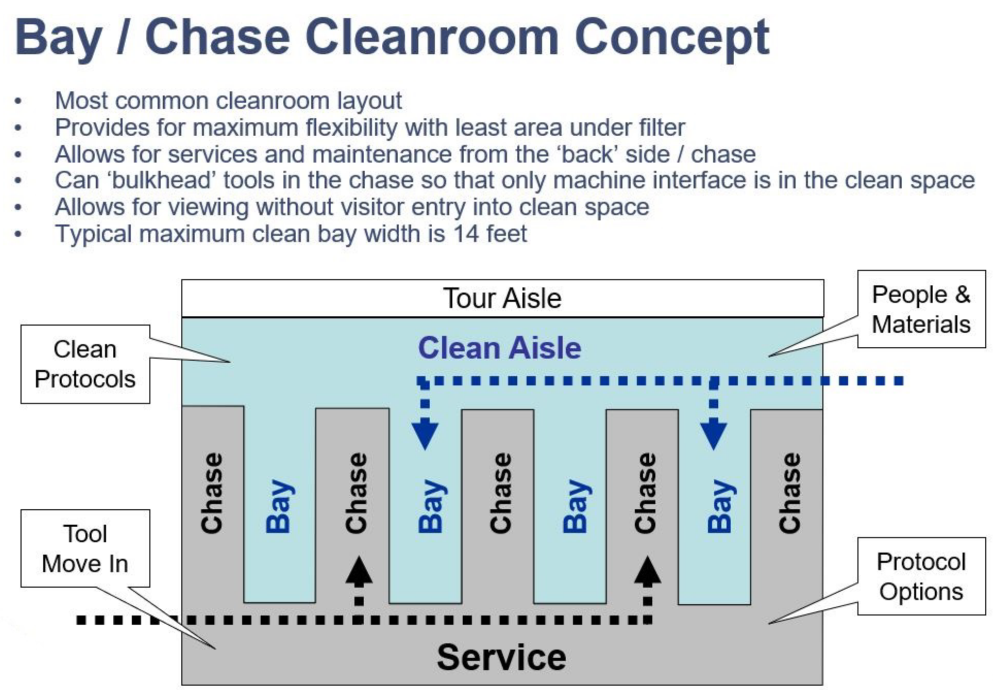


Figure 2 - Bay and Chase Cleanroom Configuration

2) Ballroom Configuration

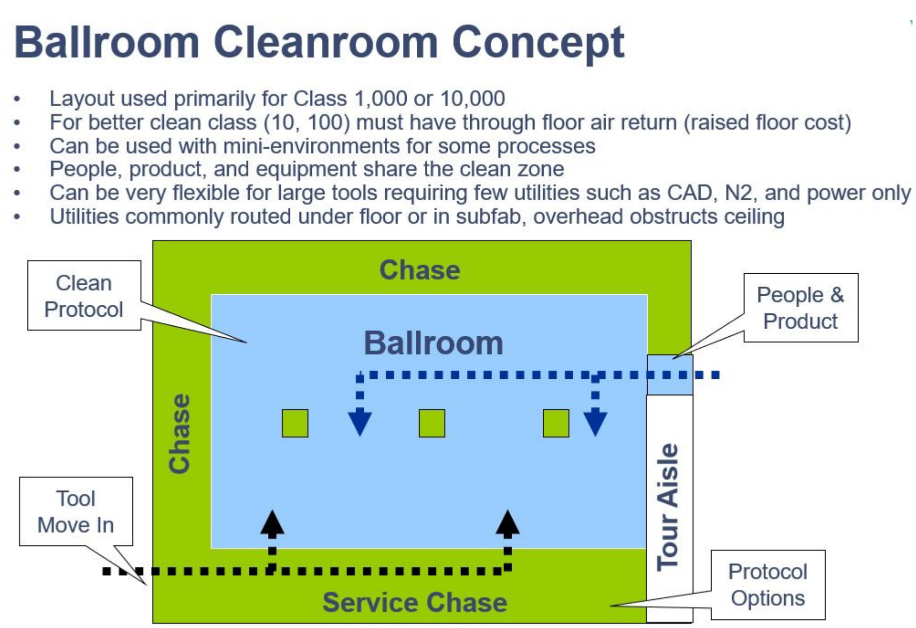


Figure 3- Typical Ballroom Cleanroom Configuration

B. For facilities that require flexibility that comes with R&D uses, a ballroom configuration is desirable over bay and chase. In addition, any ballroom configuration should be positioned over a subfab area on the level below which will also serve as a place for supporting equipment for the tools above and will be part of the cleanroom airstream. This type of configuration is known as a flow-through design which the clean air delivered from the interstitial space above the cleanroom flows down through the clean fab areas and then through the structure to the subfab below. An example of a configuration of a ballroom-type cleanroom over a flow-through subfab is shown below that also shows utility routings. The flow-through configuration will be through a raised access flooring system (RAF) over either a waffle slab or a recessed elevated slab deck with “pop-outs” or leave-outs for airflow from above to below.

C. The ballroom configuration is ideal for rapid reconfiguration of the floor areas at the fab and subfab levels to allow for tenant changes, expansions, and/or contractions. Mini-environments for varying clean classifications can also be provided within the open ballroom area with or without modular walls. Similarly, supporting equipment can be changed out, added to, or removed easily in the subfab below that allows work to be done without interference to the fab operations above.

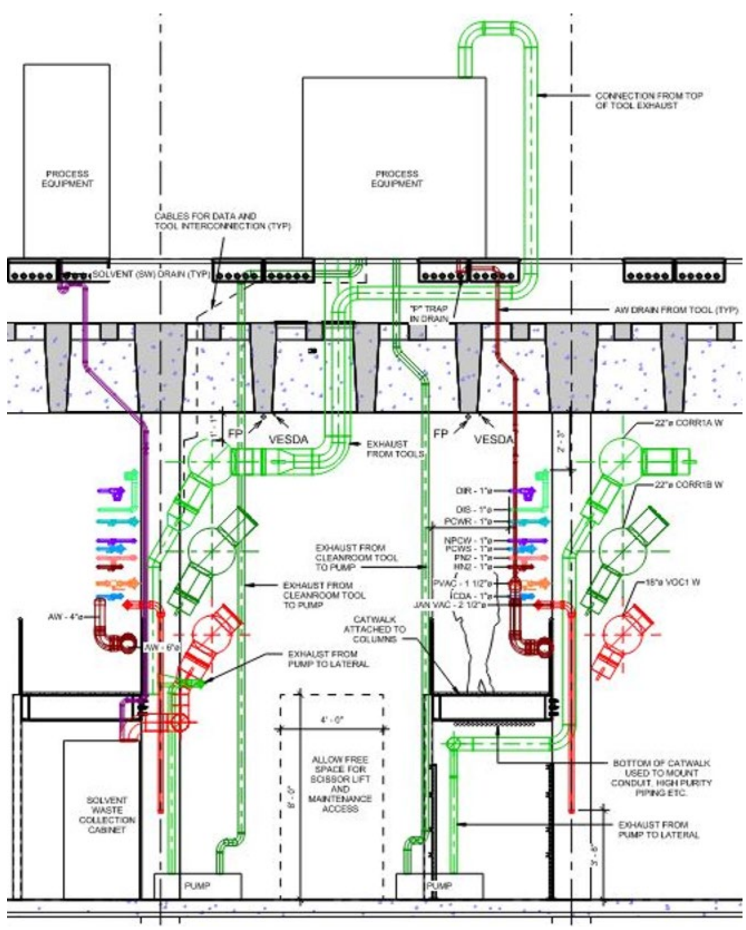


Figure 4- Fab/Subfab Section with Utility Routing Zones from Clean Fab above

D. While the ballroom configuration shown above is a practical option for most of the typical processes in semiconductor fabrication, tools and processes associated with photolithography are best located in a bay and chase configuration instead of a ballroom configuration with a flow-through subfab below. Many lithography tools have specific vibration, acoustic, or EMI requirements that may require a more robust slab or elevated deck design for mitigation. In addition, yellow or amber lighting meeting specific wavelength requirements needs to be considered that are different than the typical white lighting described further in this guideline.
Finally, many lithography tools have very tight environmental requirements that are easier to meet when these tools and their spaces are separated from other clean work areas for temperature, humidity, and other tool-related requirements.

There are a number of typical HVAC and air schemes for bay and chase cleanroom configurations available; two of the most typical are listed here for consideration. The first option shown utilizes recirculating air handlers (RCUs) with pressurized plenum boxes with in-grid HEPA filtration and lighting. This option is typically more costly but is more energy efficient over the lifetime of the cleanroom. The second option below utilizes a pressurized clean interstitial space and ductless fan filter units (FFUs) as needed to achieve the clean class required. Both schemes utilize return air chases as shown which also double as support equipment areas to support the tools in the clean bays which can be installed completely inside the bays or be "bulkheaded" to straddle the modular partition separation between the bay and chase.

Figure 5- Typical photolithography bay with yellow/amber lighting

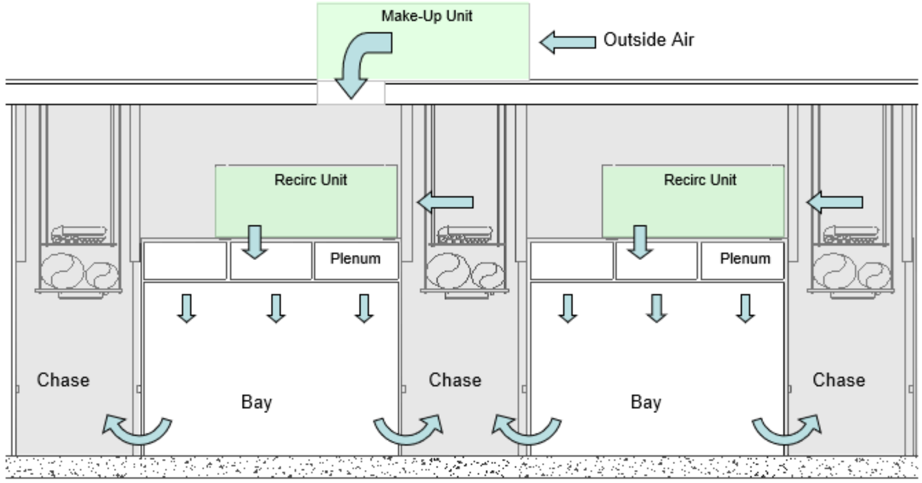


Figure 6- Bay and Chase Cleanroom Configuration with Pressurized Plenums and RAHUs

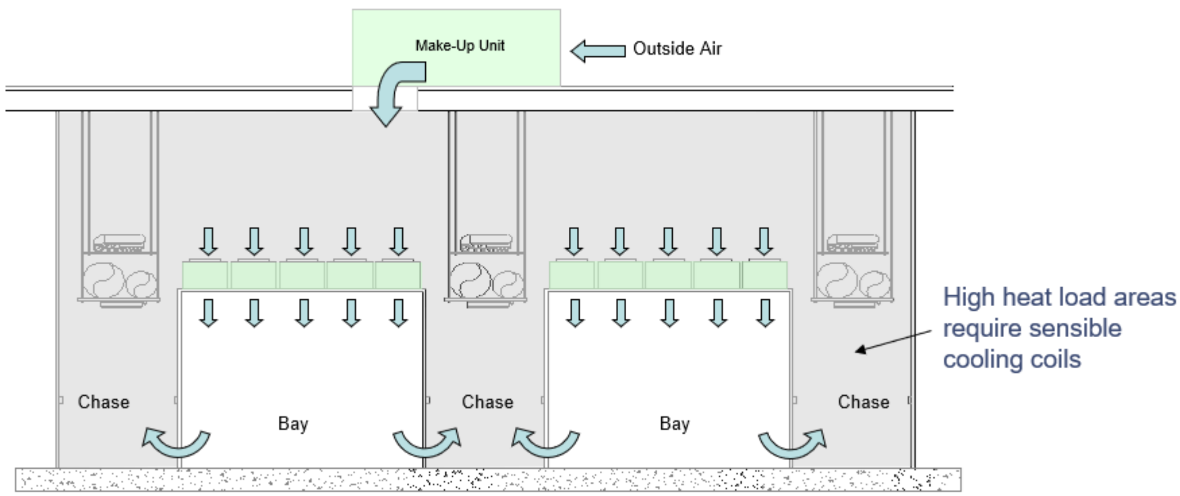


Figure 7- Bay and Chase Cleanroom Configuration with Pressurized Interstitial Space and FFUs

E. The amount and degree of redundancy to be provided for the overall facility needs to be considered for the primary uses and the nature of the work expected to be accommodated during its lifetime. Any applicable redundancies for MEP and life safety systems as outlined in ASU's other design guidelines should be followed and incorporated.

1) Mechanical air systems (air handling units, exhaust fans) should be sized and specified meeting ASU engineering standards and requirements
2) Mechanical water systems (chilled water, heating hot water)
3) Mechanical exhaust systems for general and hazardous types (corrosive, VOC, solvents) as well as central or point of use (POU) scrubbing systems
4) House systems critical to process workflows that may be required to continue running in the event of a normal power loss that can provide either

continuous uninterrupted operation or a “safe shutdown”. These may include critical systems for tool operation such as process cooling water equipment, house and specialty gases equipment, clean dry air equipment, and vacuum equipment.

5) All life safety systems including fire protection (alarm and suppression), gas monitoring systems, emergency lighting, exit signage, and audible alarms are required to be on backup power per code requirements.

F. New facilities should be laid out with anticipation of a full range of potential tools and processes which typically include the following:

1) Wafer Starts and Laser Scribing
2) Diffusion
3) Metal Deposition
4) Photolithography & E-Beam Lithography
5) Dry Etch
6) Wet Etch
7) CMP
8) PECVD
9) Metrology
10) Package/Test/Assembly

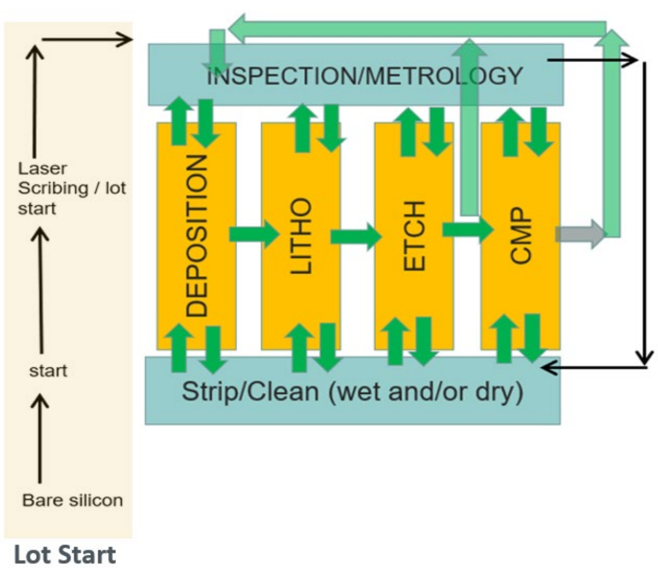


Figure 8-Typical Wafer Process Workflow for Semiconductor Facilities

1.4 Cost Drivers

1.4.1 There are many cost drivers and considerations that need to be considered in the planning, design, and construction of a semiconductor facility.

A. What clean classifications are required? This affects the number of air changes and treatment as well as quality of filters and construction materials.

B. Building and Fab Floor Heights: Height is driven by expected tools, equipment, and processes. Higher ceilings require more clean treated air. Typically, process tools are taller with larger substrates.

C. Use of Hazardous Production Materials (HPMs): Quantities of HPMs affect the occupancy classification (H vs. B occupancy) as well as limits on storage and usage of chemicals and gases required for typical semiconductor processes.

D. Air Management Strategy: Single Pass vs. Recirculated Air. Some spaces are required to incorporate single pass air per the building codes. Temperature and humidity requirements and deadband ranges can also affect cost due to tight environmental controls required.

E. Fab Configuration: Bay and Chase vs. Elevated Fab with Subfab. A bay and chase configuration requires only one level since all tools and equipment are on one level but flexibility for expansion and renovation is limited. An elevated fab cleanroom with a subfab below is more expensive but more flexible for future growth and renovations. Elevated fabs also typically required recessed decks with raised access flooring for utility routings.

1.5 Applicable Codes and Standards

1.5.1 A new semiconductor manufacturing facility should achieve the following goals:

A. The new facility shall be designed per all applicable local building and development codes for the jurisdiction where it shall be located. This design guideline is under the International Building Codes (IBC) and related codes. If a facility is built in a jurisdiction that does not require the international codes but another code, then the facility should be designed to comply with the more stringent of the two codes and standards.

1.5.2 The facility should be designed per the following accepted industry standards for semiconductor and wafer research, development, and manufacturing:

A. ASHRAE Design Guide for Cleanrooms: Fundamentals, Systems, and Performance- latest available edition

B. Compressed Gas Association (CGA) Standards

C. Federal Standard for Cleanrooms FS209E below (including cleanroom classifications)

US FED STD 209E						
Class	Maximum particles/ft^3					ISO
	≥ 0.1 µm	≥ 0.2 µm	≥ 0.3 µm	≥ 0.5 µm	≥ 5 µm	Equivalent
1	35	75	3	1	0.007	ISO 3
10	350	75	30	10	0.07	ISO 4
100	3500	750	300	100	0.7	ISO 5
1000	35000	7500	3000	1000	7	ISO 6
10000	350000	75000	30000	10000	70	ISO 7
100000	3.5 x10^8	750000	300000	100000	700	ISO 8

D. ISO Standard 14644-1 Cleanroom Classification Table

ISO 14644-1 Cleanroom Standards

Class	maximum particles/m³						FED STD 209E equivalent
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm	
ISO 1	10	2.37	1.02	0.35	0.083	0.0029	
ISO 2	100	23.7	10.2	3.5	0.83	0.029	
ISO 3	1,000	237	102	35	8.3	0.29	Class 1
ISO 4	10,000	2,370	1,020	352	83	2.9	Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1.0×10^6	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7	1.0×10^7	2.37×10^6	1,020,000	352,000	83,200	2,930	Class 10,000
ISO 8	1.0×10^8	2.37×10^7	1.02×10^7	3,520,000	832,000	29,300	Class 100,000
ISO 9	1.0×10^9	2.37×10^8	1.02×10^8	35,200,000	8,320,000	293,000	Room air

E. Factory Mutual (FM) Guidelines as well as any applicable insurance requirements per ASU

F. National Fire Protection Association (NFPA) Standards

G. SEMI Standards

H. Leadership in Energy Efficient Design (LEED) Version 4.1 as published by the US Green Building Council (USGBC)- Standards and Rating System for New Construction

I. Key tenants specific to semiconductor facility design include but are not limited to:

1) The IBC defines use and occupancy classifications under Chapters 3 and 4

2) Most R&D and limited production facilities are B or H occupancies

3) Maximum Allowable Quantities (MAQs) by hazard category and use type are outlined under Tables 307.1(1) & (2) and Tables 415.6.2 and 415.11.1.1.1- These tables are used to determine occupancy requirements

4) The occupancy types (H-5, H-2/H-4, B, S-1, etc.) then will drive construction type and separations within the facility

5) IBC Table 414.2.2 defines allowable gas and chemical limits by level as well as the number of separate occupancies by level

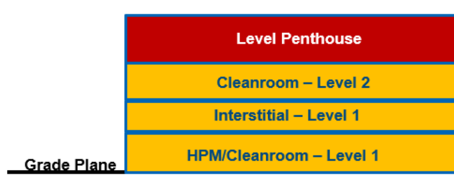
6) Hazardous Process Materials (HPMs) will drive the structural design by Structural Risk Category (IBC Chapter 16)

7) Higher Education Facilities may look to use IBC Section 428 for allowing more control areas and higher MAQs than B occupancies

8) The codes also have limits on the locations of H occupancies per the figure below:

Location of H Occupancy Spaces

- **H occupancies are not permitted below <u>grade,</u>**
    - …without a variance from AHJ
- **H occupancies are restricted above <u>grade</u>**
    - Dependent on construction type
        - Limits the occupancy & room size
        - Limits the location
- **H occupancies are not counted as control areas**



Level	Control Areas	B Occ. Max Allowed per control area	H2/H3/H4 Allowed [1]	H5 Allowed [1]
2	3	75%	Yes	Yes
1	4	100%	Yes	Yes
-1	3	75%	No	No

Figure 9- H Occupancy Location Requirements per the International Codes

9) Other Guidelines that can help fill gaps that the typical codes leave:

a. ASHRAE for general recommendations on HVAC Design

b. ASHRAE for pipe sizing based on pressure drop or velocity

c. FM Guidelines and ASTM Standards to cover approved materials

d. Toxic Gas Ordinance (TGO) and SEMI for double-contained piping for hazardous gases

e. ASU University Design Guidelines and EHS Procedures and Policies

10) Finally, other considerations include best practices which at times can be more stringent than code requirements- Examples of this for semiconductor facilities are shown in the figure below.

MEP Design Implications due to Life Safety

- Mechanical
  - Code: HVAC Sizing to meet required fresh air requirements
  - Best practice: HVAC sizing to account for process, Specific Materials of Construction – Teflon Coated vs. Stainless Steel Ductwork
- Electrical
  - Code: NEC requirements for electrical equipment Classifications based on Flammable or combustible concentrations and quantities, NEC Articles 700, 701, 702 for Emergency/UPS power requirements
  - Best Practice: UPS backup TGMS to ride transition to code required emergency power
- Plumbing
  - Code: Health Hazard 3 & 4 = All welded, No mechanical fittings
  - Best Practice: Welded fittings for all hazardous piping, double contain all toxic, highly toxic, and corrosives

2. Civil and Site Requirements and Considerations

2.1 Topographical and Geotechnical Requirements

2.1.1 The new semiconductor facility should be located on a project site that includes or incorporates the following features:

A. The site is flat but capable of modification to allow adequate storm water management to meet local jurisdictional requirements.

B. The site should have ready access to major arterial roadways for vehicular traffic but should have ample area to allow for typical setbacks for vibration, acoustic, and electromagnetic tool requirements.

C. The site should be free from aerial restrictions from local airports or local zoning that limits building and projection heights to 150 feet above the mean grade plane or less.

D. The site should be adequately sized to allow reasonable and expected expansion.

E. Adequate geotechnical surveys, including borings, test pits, etc., required to provide a comprehensive report on any site under consideration for a new semiconductor facility shall be undertaken by a qualified geotechnical or civil engineer licensed in the State of Arizona.

F. Any site selected for new facilities must take local requirements into account including storm water detention/retention as well as flood management and mitigation. This includes developing a storm water pollution prevention plan (SWPPP). Stormwater management should also include all best and current practices as well as local requirements enforced by the permitting authorities.

G. The site should be generally arranged to place components of the facility that can be considered sensitive for operations and/or potentially hazardous toward the “rear” of the site from what is considered the main frontage road or roads. The actual fab areas should be typically located in the “middle” of the site with any administrative or office areas located near the “front” of the facility with MEP support and storage for hazardous and non-hazardous materials should be located generally near the “rear” or back of the site. This arrangement will serve to help isolate the high-value fab and cleanroom areas from potential outside interferences but also serve as secure barriers to these areas.

2.2 Site Setback Considerations (Vibration, Acoustic, and EMI)

2.2.1 The project site master plan should consider reasonable setbacks expected for the tools involved with the typical semiconductor manufacturing processes, including potential interference from outside sources involving electromagnetic interference (EMI), vibration, and acoustics.

2.2.2 When performing initial layout exercises and options for site plans, it is important to consider the potential impact of outside interference sources as these can hugely affect the operations of the fab facility, particularly any sensitive tools or processes. Potential sources of interference can include but are not limited to vehicle traffic, high voltage power line runs, heavy centralized machinery located at or near grade (cooling towers, VOC scrubbers, exterior waste treatment facility machinery, mechanized lifts, overhead aircraft if near an airport, etc.). Ultimately, the project design team for any new facility would need to plot and analyze all potential sources of interference to locate “dead” areas where sensitive tools for processes such as photolithography could be located in the overall scheme of the facility.

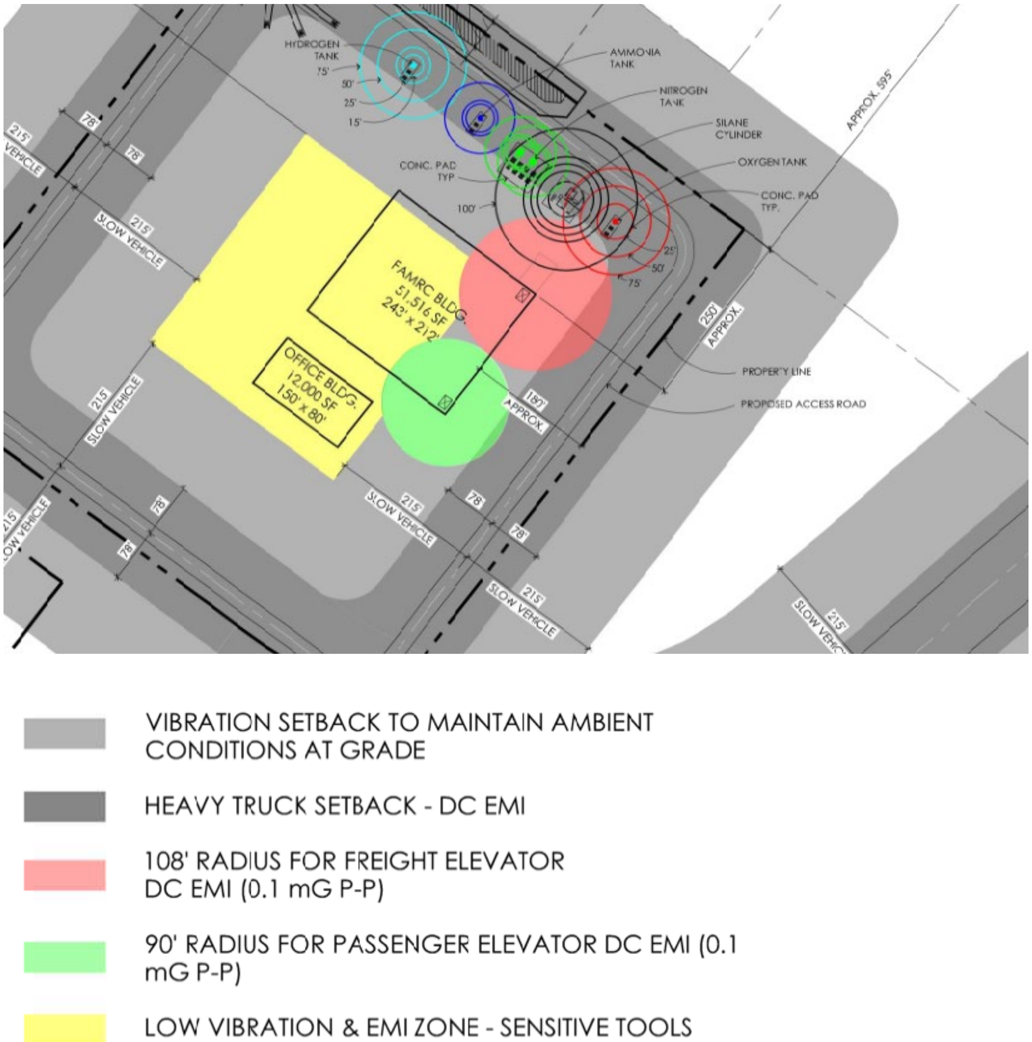


Figure 10- Sample Site Setback Plan with Legend for Vibration, Acoustic, and EMI Parameters Considered

2.2.3 Excessive vibration can be caused by activities inside or outside the building. Vibration affecting the processes and characterization of substrates must be minimized or eliminated. Slab design, column spacing, HVAC components and mounting designs, will all have significant effects on vibration and will be reviewed relative to the stated tool criteria.

2.2.4 Advanced metrology tools, such as scanning electron microscopes (SEM) and transmission electron microscopes (TEM), will require more stringent vibration requirements that can go down to VC-G. A site survey will determine if the more stringent vibration requirements can be met. All areas housing sensitive instruments must have design consideration for potential interference from vibration, noise, and EMI sources. The structural design, including the waffle slab, raised access flooring system, and slab on grade in these areas must be designed to accommodate the most stringent tool requirements for vibration. Other considerations may include highly sensitive tools such as Deep UV scanners, ACEMs, SEMs, etc. which have very stringent requirements for vibration (VC-E to VC-G) and may require additional site and structural considerations to meet these tool requirements. Refer to the Structural portion of this document for additional guidance and information.

Table 1- Noise and Vibration Criteria

Criterion Curve	Max Level$^{(1)}$micro-in./sec (dB)	Detail Size$^{(2)}$microns	Description of Use
Workshop (ISO)	32,000 (90)	N/A	Distinctly felt vibration. Appropriate for workshops and non-sensitive areas.
Office (ISO)	16,000 (84)	N/A	Felt vibration. Appropriate to offices and non-sensitive areas
Residential Day (ISO)	8000 (74)	75	Barely felt vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and lower-power (to 20X) microscopes.
Op. Theatre (ISO)	4000 (72)	25	Vibration not felt. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A	2000 (66)	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity, and projection aligners, etc.
VC-B	1000 (60)	3	An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron linewidths.
VC-C	500 (54)	1	A good standard for most lithography and inspection equipment to 1 micron detail size.
VC-D	250 (48)	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operation to the limits of their capacity.
VC-E	125 (42)	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems, and other systems.
VC-F	62.5	N/A	Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation.

Criterion Curve	Max Level(1)micro-in./sec (dB)	Detail Size(2)microns	Description of Use
VC-G	31.3	N/A	Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation
(1) As measured in one-third octave bands of frequency over the frequency range 8 to 80 Hz (VC-A and VC-B) or 1 to 80 Hz (VC-C through VC-G). (2) The detail size refers to line width in the case of microelectronics fabrication, the particle (cell) size in the case of medical and pharmaceutical research, etc. It is not relevant to imaging associated with probe technologies, AFMs, and nanotechnology.			

2.3 Site Access Considerations

2.3.1 There should be restricted and controlled access points from the adjacent roadways for vehicular traffic of multiple sizes and types (cars, mid-size straight drive trucks, 65 ft. semi-tractor trailers). However, access points should be limited and control points for each ingress/egress point should be carefully considered by the design team.

2.3.2 There should be dedicated restricted and controlled entry and exit access points for larger trucks for deliveries and shipping, including products, tools, equipment, and chemicals and gases. Provisions for potential “oversized load” deliverables should be considered and incorporated for the pathways that have direct access to the facility’s loading docks.

2.3.3 Security checkpoints are required for all access points.

2.3.4 Site access points must take local traffic conditions and requirements into account and may warrant a traffic study for permitting.

2.3.5 Vehicular drive aisles should be provided with adequate clear signage, including pavement markings.

2.3.6 Parking areas should be sized to meet local building codes and anticipated full-time equivalent (FTE) occupancy counts, visitors, offsite maintenance workers and vendors, etc.

2.3.7 Accessible parking meeting IBC Chapter 10 requirements for vehicle stall counts and appropriate signage and markings with a clearly delineated accessible route must be provided near the main entrance for the facility.

2.3.8 The site plan must allow take into account fire department/authority truck access in compliance with the AHJ’s requirements taking fire hydrant locations, fire department connections, and drive aisles into account. All designated fire lanes shall be denoted with appropriate signage and painted striping as required and no parking or loading/unloading zones shall be denoted.

2.4 Hazardous Materials Storage Considerations

2.4.1 Adequate space should be allocated for the secure and safe storage of hazardous materials including a defined Materials Accumulation Area (MAA) that will be a separate enclosure for chemical waste and related materials.

2.4.2 The MAA should be sufficiently robust in construction meeting applicable building codes for the expected enclosure classification driven by the anticipated quantities of chemicals and gases (maximum allowable quantities). The MAA structure should be designed as a bunker (masonry and/or concrete construction and envelope).

2.4.3 If planned stored and used chemicals justify this, then a separate chemical storage depot/building independent of the main facility structure can be considered for high use bulk items that would not be stored in the dispensing rooms until used. Separate storage structures for these types of uses would need to comply with IBC Table 415.6.2 for hazardous storage buildings maximum allowable quantities. Certain bulk gases typically used in the semiconductor manufacturing process (nitrogen for purging, oxygen, etc.) should be stored onsite in bulk tanks with appropriate supporting equipment for purification and/or vaporizing. Dedicated piping to the facility shall be routed to the bulk gas yard where located.

2.4.4 The total site and building areas allocated for HPMs and for occupancies more stringent than H-5 (H1 to H4) must be carefully considered so sufficient space is provided for a potential diverse range gases and chemical types to ensure maximum flexibility.

2.5 Site Security (Passive and Active Means)

2.5.1 Perimeter fencing is required for safety and security around the entire site perimeter. Additional fencing inside the secure perimeter at high hazard areas such as bulk gas yards, exterior storage areas, mechanical and electrical exterior equipment, and loading areas needs to be incorporated.

2.5.2 Fencing may be painted metal or chain link and should be at least 8 ft. above the finished grade typically. All fencing must meet any applicable local zoning ordinances. Department of Homeland Security (DHS) requirements for facilities with a certain amount of HPMs onsite may need to be considered and incorporated which may include more hardened measures. Refer to the ASU guidelines for additional standards:

Project-Guidelines.pdf (asu.edu)

www.asu.edu/fm/documents/project_guidelines/Site-Improvements-Design-Guidelines.pdf

2.5.3 Gates are to be automated sliding types remotely operated via card access.

2.5.4 The site lighting provided must meet minimum footcandle requirements for safe use and access and comply with all local ordinances for lighting levels. All site lighting must be LED and meet applicable sustainability requirements. In addition, site lighting must meet any local zoning ordinances for light pollution control.

2.5.5 Bulk gas yards and critical onsite utility items (overhead trestles, electrical and mechanical gear, and equipment) should be adequately fenced with controlled gate access.

2.5.6 Site security should include provisions for monitored/recorded security cameras per ASU standards. Project-Guidelines.pdf (asu.edu)

2.6 Utility Routings (Above and Below Grade)

2.6.1 Utility routings are to be above and below grade as recommended by best practices and industry standards.

2.6.2 Specialty gas piping routing from tanks and equipment in all bulk gas yards should be routed in overhead steel trestles adequately protected from potential damage from vehicles and similar threats. While gases can be run underground it is recommended these services be routed above grade for ease of service and maintenance. Double containment should be included for hazardous gases.

2.6.3 Electrical routings from feeds from offsite sources should be below grade in concrete encapsulated duct banks to primary and secondary gear. Refer to ASU Project Guidelines in the link above.

2.6.4 Dedicated routings for wet utilities (domestic and fire water, sanitary sewer, storm water) should be below grade and work with the site master plan and the storm water management plan as designed by a civil engineer licensed in the state of Arizona.

3. Structural Requirements and Considerations

3.1 Building Foundation Considerations and Requirements

3.1.1 The structural design will need to incorporate requirements as determined by a dedicated geotechnical report for any new site. the applicable building codes, and anticipated tool requirements, especially vibration mitigation.

3.1.2 Structural foundations must be sufficiently robust and accommodate expected dead and live loads typical to semiconductor R&D and pilot production facilities. Note: selected areas for tools that are sensitive to vibration or EMI should be provided with sufficient thickness and/or epoxy-coated reinforcing as recommended by qualified experts on the design team.

3.1.3 Foundation designs may include slab-on-grade, over-spread and isolated footings, drilled piers, mat slabs, or a mixed type.

3.1.4 The foundation should include elevation changes that are expected for elevators, trenches for utility routings, thicker slabs for vibration-sensitive tools, and recessed areas for containment of potential spills.

3.1.5 All concrete designs for foundations and slabs should be normal weight concrete type with rebar reinforcing as determined by the structural engineer. Concrete mix designs, including max. compressive strength, admixtures, slump limits, etc. shall be determined by the structural engineer for any new facility. All concrete shall be specified and placed per applicable American Concrete Institute (ACI) standards.

3.1.6 A minimum 8mm thick moisture barrier shall be provided under all slab on grade areas and shall be taped to ensure no gaps in edges. All openings in the moisture barrier required for utility routings should be adequately sealed at all edges. A moisture barrier is recommended to protect the slab on grade and the flooring systems from potential damage from infiltration from the soil and fill. However, concrete sealers that are compatible with the selected flooring systems are recommended for all slabs on grade.

3.2 Floor Loading and Other Slab Characteristics

3.2.1 The thickness and strength of the concrete floor of the manufacturing area and all mechanical equipment is designed to achieve VC-E vibration criteria. The design of the floors and structure shall incorporate all recommendations from the vibration consultant to achieve the required criteria for the vibration sensitive instruments.

3.2.2 Stiff and massive floors are preferable to achieve required vibration criteria. The floors must be extremely flat to insure stability of photolithography and measurement tools. Flatness of concrete shall meet the Very Flat criteria as listed in American Concrete Institute (ACI) 117-90 (see Table below):

Table 2- ACI Flatness of concrete

Floor profile quality classification	Minimum $F_F F_L$ number required			
	Test area		Minimum local F number	
	Flatness F_F	Level F_L	Flatness F_F	Level F_L
Conventional				
Bullfloated	15	13	13	10
Straightedged	20	15	15	10
Flat	30	20	15	10
Very flat	50	30	25	15

3.2.3 Moisture barriers under slab on grade are to be provided meeting the requirements of Section 3.1.6 above. Tools in any elevated clean fab area over a subfab area shall be located on a raised floor system over the waffle slab. Some may require specialized pedestals. The same degree of levelness as noted above applies to the raised floor system supporting tools.

3.2.4 The design for the concrete waffle slab structure and the raised flooring system must accommodate the heaviest planned tools for the elevated cleanroom areas. Tool live loads per SF will be evaluated and will be incorporated into the specifications for the concrete structure and raised flooring system. The design basis for the raised access floor is a heavy-duty aluminum or steel access floor system. Refer to Section 4.6.1-E for dead and live load capacities for this system.

3.3 Building Structural Framing Considerations and Requirements

3.3.1 Structural framing above grade may be a combination of reinforced concrete and steel members. Typically, poured in place concrete framing is utilized for the lower or subfab levels at grade and either concrete framing or steel framing is utilized for the upper levels at the fab level and any interstitial areas above.

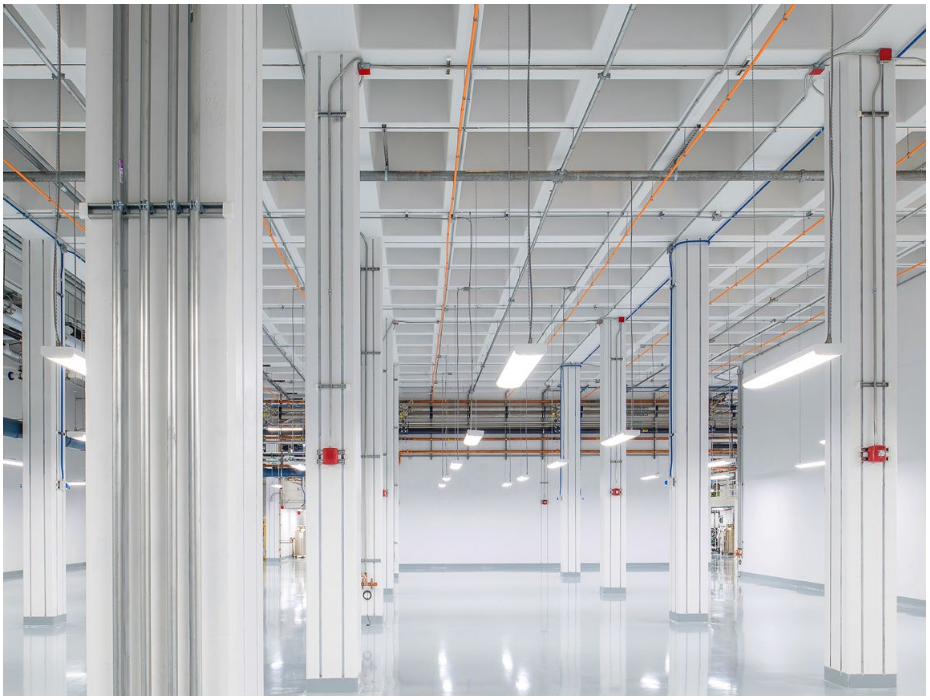


Figure 11- Subfab with regularly space concrete columns and waffle slab framing above below fab level

3.3.2 Reinforced concrete framing may require selected areas with epoxy-coated rebar for electromagnetic mitigation, if required or recommended by the project design team.

3.3.3 Steel framing may be bolted or welded per AISC standards and per the guidance of the structural engineer.

3.3.4 It is recommended that all steel framing within the clean envelope be finished with cleanroom-rated epoxy paints/coatings that will not be encapsulated with other building materials.

3.3.5 All steel framing requiring any fire-rating due to the design requirements in the cleanroom envelope, including roof framing, is to be coated with intumescent paint- no cementitious fireproofing shall be allowed in the cleanroom envelope.

3.4 Structural Slab Design and Trenches

3.4.1 Trench locations, extents, and dimensions for liquid waste are to be determined for the subfab area. All trenches will be covered with removable metal covers. Trench covers will be in easily managed sizes no longer than 3 feet.

A. The trench dimensions will accommodate all the planned waste lines with space included for maintenance access. All trench interiors will be coated with antistatic, highly chemical resistant epoxy poured onto flooring for leak protection. There will be spill sensors in the trench connected to TGM and BAS.

B. For all drain piping slopes, assumption is 1/8 inch per foot. 2 inches clear above piping.

1.) Drains serving high viscosity fluids must be sized to account for the increased viscosity. Collect waste as close to where it is generated as possible. Larger pipe diameters or additional pipe sloping may be required. Provisions for flushing or unclogging should also be considered.

C. Pressurized corrosive waste (diluted) from scrubbers can run overhead to a lift station located in trench or in a MEP support area or can be gravity drained to a central collection or treatment area. The preferred method is to employ gravity drainage for waste removal as much as possible. NOTE: All AWN piping must be contained in trenches with easy access; no industrial or lab waste piping is allowed below the slab on grade.

D. A lift station will require a sump pump and lift station fully lined pit that will be lower than the trench and must have capacity for anticipated peak and average flows. The lift station should be in the mechanical and plumbing support room and will be well ventilated to minimize any fumes.

3.4.2 The slab for all sensitive areas is to be a continuous slab construction. Isolation from adjacent slabs in non-sensitive areas may be required depending on the analysis of the vibration/acoustic specialist working with the structural engineer for each site condition. The slab thickness shall be determined by the Structural Engineer and Vibration Consultant once ambient conditions are understood and compared against the requirements for the equipment. Specialty vibration isolation structures for all the support equipment chase rooms housing the pumps and other vibration generating equipment will be a "Jack-Up-Slab." This area will require a depression in the main slab to allow for the cast-in-place jacks to be installed for supporting the isolated slab.

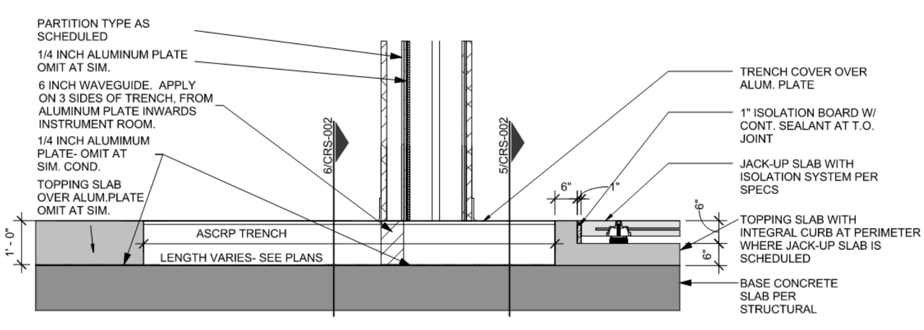


Figure 12- Sample Detail of Trench in Sensitive Tool Area with Specialty Partition Types and Isolated Jack-Up Slabs for Supporting Equipment

3.4.3 For any cast in place trenches for slabs in defined areas with sensitive tools at grade (vibration, acoustic, or EMI sensitivity) the trench shall be designed to allow any cabling, water lines and communication lines to pass between the instrument room, control room and equipment chases. Backfilling the trench with sand is a preferred method for mitigating sound transfer through the trench from the equipment chase and control rooms to any primary instrument rooms.

3.4.4 All penetrations for utilities from an upper floor cleanroom where the raised access floor system and waffle slab are provided, shall be through pop-outs in the waffle slab cavities between the regularly spaced ribs. The pop-out openings can be circular or rectangular but the minimum dimension in either direction should be not less than 14” wide to allow a 12” diameter duct to pass from the fab to the subfab below.

A. The pop-outs consist of appropriate plastic or metal frames cast in the waffle slab concrete with a gasket around the opening.

B. The sleeve for the pop-out will extend the full width of the waffle slab cavity and can be steel or an approved plastic form with support for the raised access floor pedestals. No cover plates will be provided; all penetrations will be feed-through only.

C. No firestopping is required at the joints as the cleanroom and the sub areas below will be the same occupancy classification. Where penetrations occur for utility routing, gratings shall be used to prevent hazards from falling through from the raised access floor system to the sub area below.

Figure 13- Raised Access Flooring System in Elevated Clean Fab with Waffle Slab and Grated Pop-outs-Utility Routing Zone from Fab Above and Subfab Below

D. All raised access flooring panel types and pop-out fill patterns shall allow for safe personnel and tool support and the prevention of dropping hazards.

3.5 Dead and Live Load Considerations and Requirements

3.5.1 The project team will need to calculate dead and live loads for cleanroom envelope and support areas to incorporate into the design phases. Dead loads can include suspended items such as MEP, walkable cleanroom ceiling, and catwalks. Live loads will include people moving through walkable ceiling and catwalks. Loads can vary dependent on the location of the cleanroom and support areas.

3.5.2 For below grade or multilevel, design considerations such as moving traffic and pedestrian loads should be calculated.

3.5.3 As a rule of thumb, the following live load criteria for the various areas in the facility should be considered by the design team:

A. Fab and Subfab Areas- 300 PSF LL

B. MEP Supporting Areas- 100 PSF LL

C. Circulation Areas on MIMO Pathways- 300 PSF LL

D. Administrative Areas- 40 PSF LL

3.5.4 Future potential loads shall also be considered to allow flexibility in design.

4. Architectural Requirements and Considerations

4.1 Code and Life Safety Considerations

4.1.1 The new facility design will be designed to all current and applicable codes and standards as mandated by the AHJ where the project is located, including all architectural, mechanical, electrical, plumbing, fire protection, and energy efficiency standards.

4.1.2 The new facility design will conform to the applicable city Planning and Zoning regulations and mandates from the ASU Fire Marshall (FMO) requirements.

4.1.3 In addition to all guidance within this document, the new facility shall also utilize the ASU EHS Laboratory Standards & Design Guidelines located online at: For design and construction professionals | Arizona State University (asu.edu) Note: These design guidelines shall be used only for relevant items in the clean semiconductor facility not specifically covered within these guidelines but still subject to ASU requirements.

4.2 Facility Layout Considerations

4.2.1 Any new facility should include the following layout considerations that are typical design features in semiconductor facilities that include cleanrooms:

A. Clean fabrication areas should be located generally in the “center” of the overall building to provide a non-clean and supporting “buffer” zone around the cleanroom and related fabrication perimeter partitions. This will also serve to provide daylighting opportunities for desirable areas such as administrative, common, and support spaces but also serve to reduce potentially harmful daylight intrusion into the cleanroom/fab areas.

B. Clean fabrication areas should be located on an elevated level above grade level to allow for a flow-through subfab and supporting areas for house and process equipment.

C. Dedicated “utility routing zones” should be pre-planned and considered when developing any new facility for both horizontal and vertical axes. These routing zones may include multiple utility types and should be laid out and spaced to allow safe and viable maintenance (valves provided in easy reach) and should include pathways for personnel to access these utility pathways. These pathways may be in dedicated chases that may require appropriate fire ratings and material classifications appropriate for the occupancy classification and construction type. Example: plenum-rated cabling may be required in high volume or interstitial spaces.

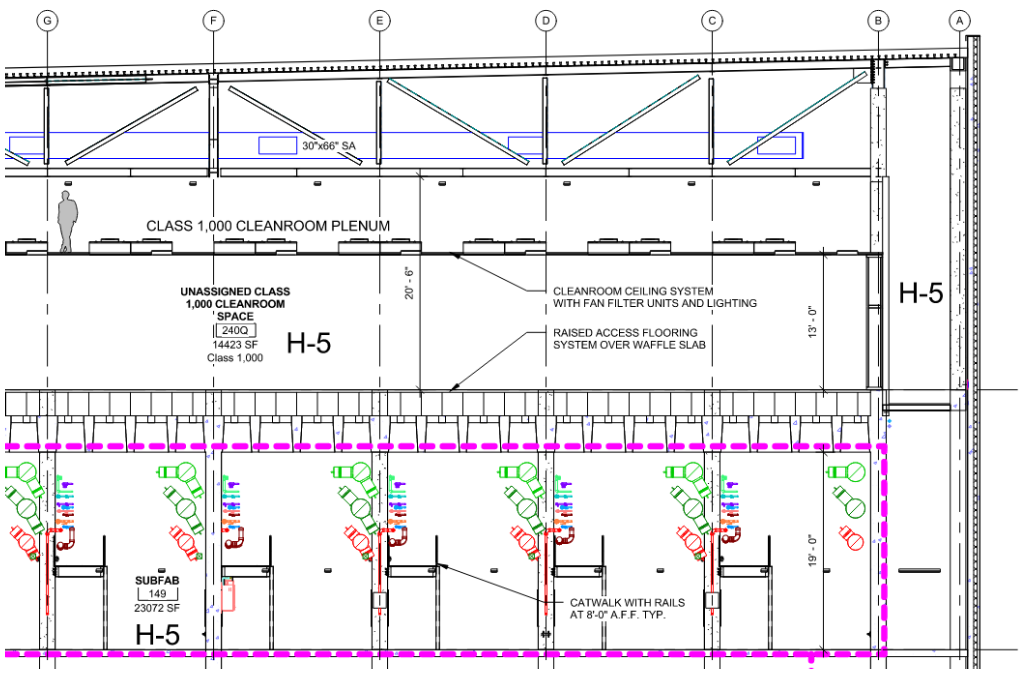


Figure 14- cross section at elevated fab with subfab with dedicated regularly spaced utility routings and catwalk access

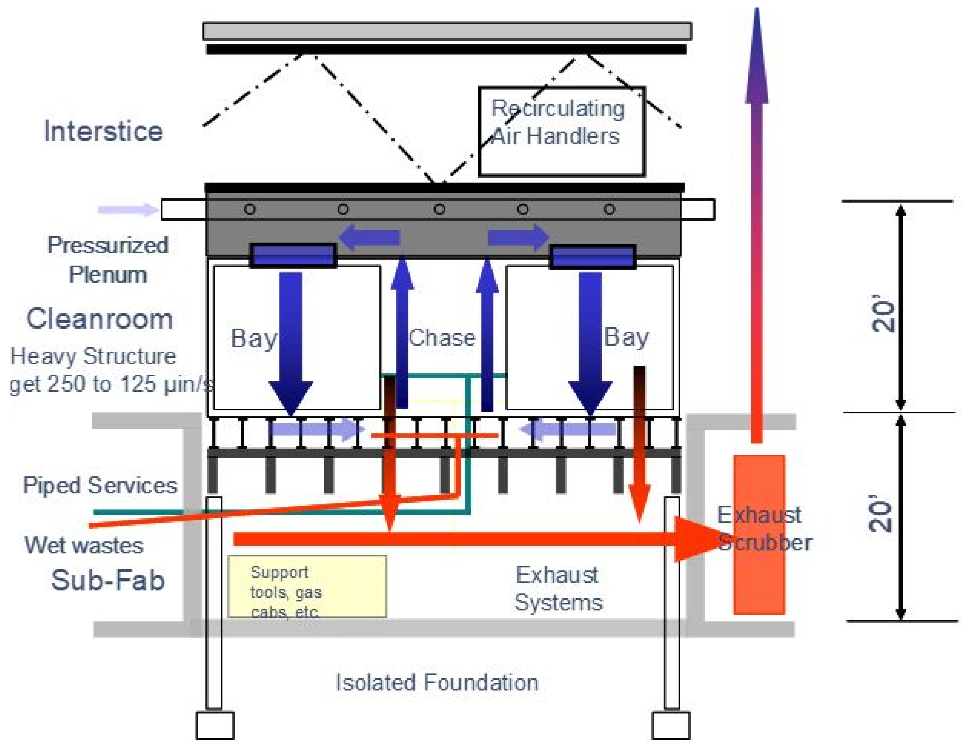


Figure 15- Typical elevated cleanroom with flow-through subfab (Note: Bay and Chase Arrangement as shown can be flow-through or utilize adjacent return air chases in fab areas)

4.3 Building Envelope- Exterior Wall Systems

4.3.1 The exterior cladding for the building is anticipated to be tilt-wall concrete construction attaching to the building framing for the first level and possibly including the second level. Form liners may be utilized for the tilt-wall construction.

4.3.2 The cladding on the upper extents of the building may be structural steel studs with metal panel cladding. Systems and extents will be reviewed by the design team and contractor for potential options.

4.3.3 Exterior wall systems shall be designed to meet minimum envelope requirements per ASHRAE 90.1-2022 or current adopted version for the climate zone where the building/facility is to be located.

4.3.4 All exterior walls will be provided with a moisture barrier specified by the designer that meets the assembly parameters for the building and is appropriate for the local climate conditions anticipated.

4.3.5 Rigid, spray foam or batt insulation systems are acceptable for vertical exterior wall assemblies, but all cellular or particulate generating insulation must be completely encapsulated from all clean environments.

4.4 Building Envelope- Roof Systems

4.4.1 The roof structure shall be designed to slope not less than 1/4" per foot and all drainage must account for pathways for water flow, including cricketing.

4.4.2 The roofing membrane may consist of the following available systems and materials, including single ply TPO or EPDM systems. Refer to the ASU Project Guidelines for additional information on roofing system requirements:

Project-Guidelines.pdf (asu.edu)

4.4.3 Exact roofing composition and structural support framing will be determined by the design team. The structural framing and decking will be a steel system that may include long span joists, built-up plate girders, or a combination of steel shapes.

4.4.4 The roof and structural framing will be designed for all anticipated vertical and lateral loads per local code requirements.

4.4.5 The roof system will be designed to accommodate mechanical loads (suspended air handlers, ductwork, piping racks, etc.) of 70 lbs/sf, plus other catwalk and potential walkable ceiling and ceiling load at 50 lbs/sf with the consideration of an extra % for future loads to the roof structure.

4.4.6 The roof system shall be provided with rigid polyisocyanurate or polystyrene insulation boards. The roof system shall be designed to meet the minimum requirements for envelope design per ASHRAE 90.1- 2022 version or current adopted version for energy code compliance and sustainability targets.

4.4.7 It is recommended that the number of roof penetrations be limited as much as possible over the cleanroom areas for drains, mechanical equipment, etc. to minimize the chances of roof leaks from damaging or contaminating the valuable tools and equipment below. Most rooftop equipment (exhaust fans, centralized scrubbers) should be located off of the locations where the fab/clean areas are located.

4.4.8 The roof system will include a parapet wall, railing system, or other fall protection mechanism designed to meet 29 CFR 1910, Subpart D. Refer to the ASU Project Guidelines for additional requirements for roof systems:

Project-Guidelines.pdf (asu.edu)

4.5 Interior Partitions and Separations

4.5.1 Cleanroom Perimeter Walls

A. All cleanroom envelopes must be tightly sealed against outside air and have a humidity or vapor barrier for any exterior perimeter walls.

B. Cleanroom perimeter partition construction shall be floor to deck with appropriate materials and systems meeting fire resistivity requirements.

C. While finishes on the non-clean side of perimeter partitions are flexible and do not need to be cleanroom compatible, the clean side of the partitions should be provided with cleanroom compatible coatings with an epoxy finish.

D. Perimeter hollow metal doors and windows will require the appropriate fire rating. Like the partition finish requirements listed above, all HM frames and doors must be cleanroom compatible with an epoxy finish.

E. All concrete or structural steel within the cleanroom envelope shall be epoxy painted, including all surfaces in the clean interstitial spaces above the fab areas. This is necessary and appropriate for a clean pressurized interstitial space.

F. Wall penetrations must be sealed providing a smooth finish and all materials utilized in fire-rated penetrations must be low VOC (x<50 grams/liter) and cleanroom compatible.

G. No cementitious fireproofing shall be used due to long term particulate contamination from this material. Intumescent paint shall be used, if needed.

Figure 16- clean interstitial area over cleanroom/fab area with appropriately specified epoxy and intumescent coatings

H. Perimeter walls will be provided with sound abatement via encapsulated batt insulation.

4.5.2 Cleanroom Interior Walls

A. Construction materials for clean spaces are to be non-shedding, non-porous, impervious to moisture, chemically resistant and bacterially inert. Walls are to be seamless and easy to clean.

B. Modular wall systems rated as cleanroom-compatible may be provided for interior walls in the cleanrooms and for liner panels over perimeter cleanroom walls. Note: Liner panels are typically not required for clean classifications of class 10,000 or higher.

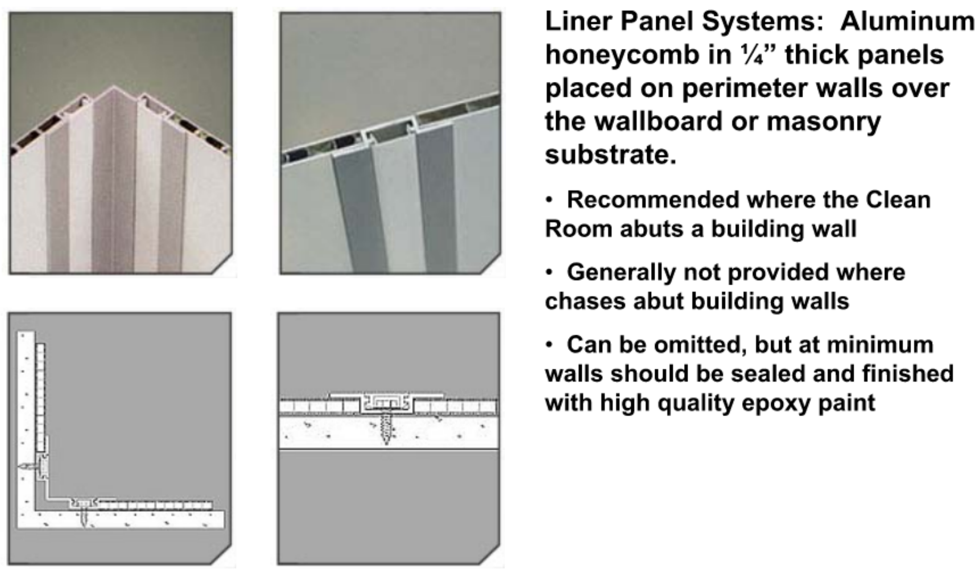


Figure 17- Modular Cleanroom Liner Panel Details

C. The surface can range from aluminum honeycomb wall panels with baked epoxy finish to epoxy painted walls for all clean classified areas.

D. Full or partial skinning of epoxy painted walls can be done with aluminum honeycomb wall panels and is recommended for areas with increased usage of carts and traffic.

E. For clean fab areas equipped with a subfab return air can enter the subfab through pop-outs in the waffle slab. Pre-penetrations in typical patterns shall be designed and procured in advance.

F. Walls can be either predrilled or drilled on site, or more often, a combination. Wireways can be installed below the raised floor and can provide general power outlets above the raised floor in predetermined locations. Bus ducts and other utilities will be fed from the subfab through openings in the waffle slab.

G. All surfaces of cleanroom walls and windows should be as flush as possible on the clean side (i.e., minimal to no sills or ledges for potential dust collection).

H. Any interior modular cleanroom wall system shall have the following features:

1.) Demountable construction.

2.) Panels consist of commercial grade aluminum honeycomb core sandwiched between two aluminum skins. Finishes shall be baked epoxy paint and static dissipative.

3.) Panels need to be lightweight and stiff for both easy handling and long-term wear.

4.) Pre-engineered head tracks, floor tracks, post, corners, battens, doors, and door frames are interchangeable to create single or double wall systems. Floor tracks shall be secured to the raised floor system where modular walls occur in the areas where this system is scheduled.

5.) Battens and post to have integrated T-grooves which run the entire length to allow connection of equipment, workstations, and similar items without the need to drill into the wall.

6.) Framed wall system to accommodate 0.25-inch panels without requiring post alterations.

7.) The framing members and mounting blocks shall allow horizontal posts to be installed anywhere along the wall's vertical plane.

8.) Windows, air return grilles, tool openings and similar items must be easily installed anytime with minimum disturbance to adjacent walls/partitions.

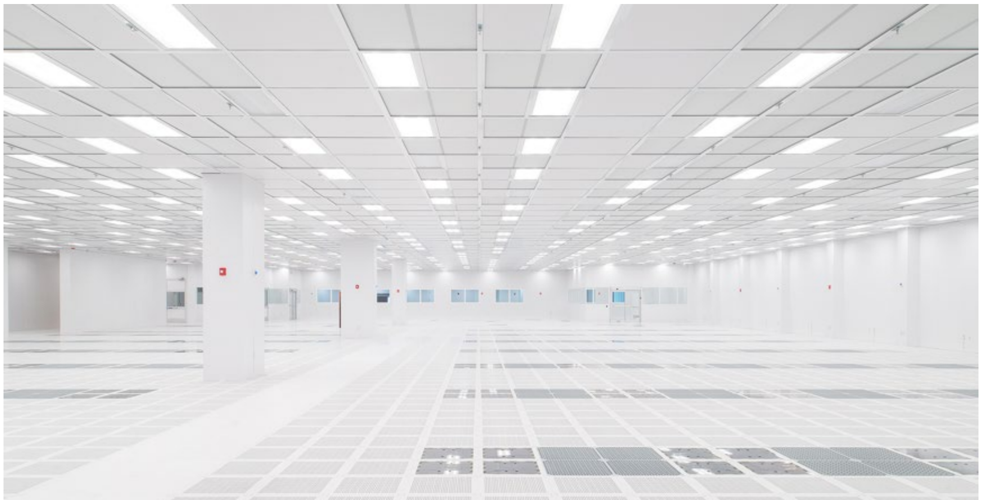


Figure 18- Open Ballroom Configuration Cleanroom with Raised Access Flooring and Recessed Elevated Waffle Slab- Note perforated RAF panels and Grated Panels for Airflow coordinated with Tool and Equipment Layouts

4.5.3 Subfab and Interstitial Perimeter Partitions

A. Subfab and Interstitial perimeter partitions must be tightly sealed against outside air and have a humidity or vapor barrier for any exterior perimeter walls.

B. Perimeter partitions must be rated stud wall and gypsum construction with epoxy paint finish where required by code. Epoxy paints are recommended for finish coatings like what is specified for the cleanroom areas above.

C. Perimeter hollow metal doors and windows will require the appropriate fire rating and hardware.

D. All concrete or structural steel within the subfab envelope will be epoxy painted. Wall penetrations must be sealed providing a smooth finish.

E. While the subfab volume is not specifically classified as a clean space, it should be treated as a clean area since the flow-through air from above is moving through the subfab volume to the recirculating air system.

4.5.4 Other Facility Partitions

A. All other interior partitions for any supporting labs, administrative areas, non-hazardous storage areas, common areas, and MEP support areas shall follow the guidelines set forth by ASU as follows:

[laboratory Guidelines (asu.edu)]

B. All other partitions as listed above shall follow appropriate code requirements for fire resistiveness for the occupancy classification and construction type.

4.6 Materials and Finishes

4.6.1 Floors/Flooring

A. The balance of floors (slab on grade, elevated decks) will be sealed concrete and all slabs on grade shall be provided with a continuous 8mm moisture barrier where in contact with the earthwork and subbase.

B. For all floors in non-clean areas such as supporting lab/maintenance areas, supporting MEP areas, and administrative and common areas, please follow appropriate guidance per the ASU Design Guidelines; see links below:

laboratory Guidelines (asu.edu)

Sustainable-Design-Guidelines.pdf (asu.edu)

Classroom-Design-Guidelines.pdf (asu.edu)

C. All concrete sealers specified are to be compatible with the specified surface-applied vinyl flooring or poured epoxy flooring systems.

D. Stiff and massive floors are preferable to achieve required vibration criteria where required by sensitive tools and equipment. The floor must be extremely flat to ensure stability of photolithography and measurement tools. Flatness of concrete will follow criteria guidelines in Section 3. The test method to confirm flatness (Ff) and levelness (Fl) measurements are within specified criteria ASTM-E1155. Semi rigid epoxy fillers are not needed over flooring joints.

E. Raised Access Flooring

1.) The raised access flooring system is to be used in elevated cleanroom areas where the recessed waffle slab occurs.

2.) The raised access floor system can be either heavy duty aluminum or steel construction.

3.) The raised access flooring system will be perforated aluminum or steel with pedestals aligning to the specified height.

4.) The system is to be provided with stringers and corner locks for maximum stability.

5.) Panel dimensions shall be 24" x 24" and very light in color so that any dirt, stain, or leak is immediately visible for correction.

6.) The flooring surface is to be anti-static (10-E6 to 10-E9 ohm). The system must accommodate all anticipated static and rolling loads for the heaviest tool and/or tool components, including intermediate support where needed.

Typically, the same vinyl tile flooring type used for slab on grade or elevated slab decks can be utilized for the top finish for all raised floor panels that aren't full grating or transparent tiles for service and utility access. See item 4.6.1.-F for additional information on the vinyl tile flooring.

7.) It is recommended to match finishes on the raised access flooring system with other static dissipative/chemically resistant flooring elsewhere in the cleanroom/facility. See below for vinyl flooring specifications.

8.) The floor system needs to be grounded to the building structure.

9.) Structural criteria are summarized as follows:

a. Concentrated Design load- 3,500 lbs.
b. Uniform Design load- 800 lbs.
c. Ultimate Load- 8,000 lbs.
d. Panel Size- 24" x 24"

Figure 19- Raised Access Flooring System with 24 x 24 in Panels and Grates with Corner Locks and Continuous Stringers

F. Vinyl Flooring

1.) Finished flooring will accommodate the type of cleanroom operation and shall be light in color so that any dirt, stain, or leak is immediately visible for correction.

2.) Flooring materials of chemical resistant, static dissipative, solid-vinyl sheet or tile materials with welded seams are recommended for all clean areas. Typically, 24" x 24" vinyl tiles are the minimum size; vinyl rolls are usually better (less seams, better conductivity). The vinyl flooring product should match appearance and performance for applications on concrete slabs and raised access flooring systems.

Figure 20- Raised Access Flooring with Static-Dissipative/Chemically Resistant Vinyl Flooring

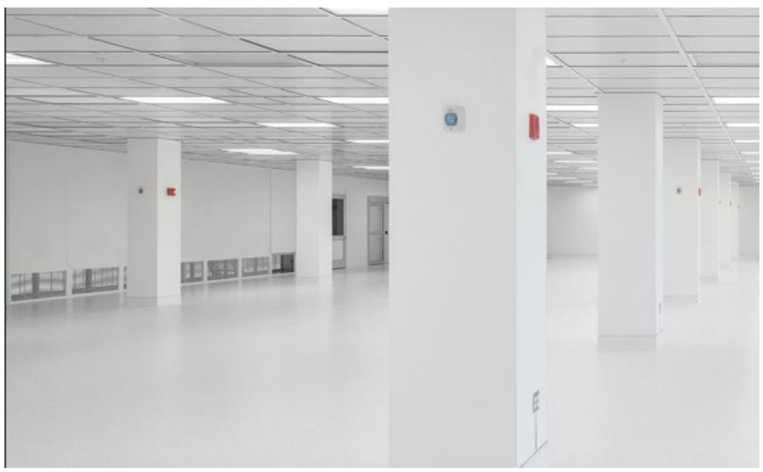


Figure 21- Static-Dissipative/Chemically Resistant Vinyl Flooring on Slab (No RAF or Subfab)

3.) Floor to wall covering is required on the far edges in the cleanroom, providing easy-to-clean surfaces. Vinyl flooring is static dissipative (10-E6 to 10-E9 ohm).

4.) The copper grounding strips for the flooring will be routed to selected electrical boxes for grounding.

G. Poured Flooring

1.) Chemical-resistant, wear-resistant, anti-slip, static dissipative resinous poured flooring is to be used.

2.) Flooring is to be a two or three-component system, self-leveling, epoxy formulation consisting of resin, curing agent and select graded aggregates that provide conductivity throughout the flooring system. This is a low-VOC epoxy flooring system (X < 50 grams/liter total VOC content).

3.) Floors are to be anti-static (10-E6 to 10-E9 ohm) and resistant to chemicals (solvents, acids, and bases).

4.) Where all poured flooring systems are provided, integral cove bases are to be provided for a minimum height of 6" above finished floor.

5.) Note: Where integral poured in place concrete trenches and/or pits are provided in the cleanroom or in MEP support spaces, the trenches and pits are to be constructed with the same poured flooring system on the bottoms and sides.

4.6.2 Ceiling Systems

A. Flat ceiling or suspended ceiling systems are common for cleanrooms to provide support for accessible HEPA filters, air distribution system, lights, and sprinklers.

B. If plenums with flush integral ceiling systems are specified or desirable, these can be provided by a sole source vendor/manufacturer that includes the plenum box construction, ceiling grids, flush in-grid lighting, blank panels, and HEPA filters. Leave-outs are provided for ceiling mounted devices and other appurtenances including fire sprinkler heads, particle monitors, ionization, etc. Plenum boxes need to be walkable on the top surfaces and provided with appropriate guardrails for fall protection.

C. For open ballroom cleanrooms, the ceiling system will be a modular T-Grid type, and contain modules suitable for HEPA filters, ULPA filters, clean blank panels, clean lighting, clean fire sprinklers, and possible Ionization for particle reduction (low voltage system distribution). The grid is to be specified to accommodate either 2' x 4' fan filter or 4' x 4' fan filter units for small cleanrooms.

Figure 22- Walkable Clean Interstitial Space with Defined Pathways, Utility Routings, and Fan Filter Units

D. The ceiling system must be leak-free and will have the same features as walls and floor. Medium duty gasketed T-Grid ceiling systems are recommended for large open ballroom cleanroom configurations as they have the following advantages over gel-sealed ceiling systems:

1.) Cheaper system for installation over gel-sealed ceilings

2.) Are typically used over gel-sealed options for cleanroom classes from Class 100 on up

3.) Offer more flexibility than gel-sealed systems which is a requirement for R&D and pilot production facilities

4.) Easier to maintain and replace than gel-sealed systems

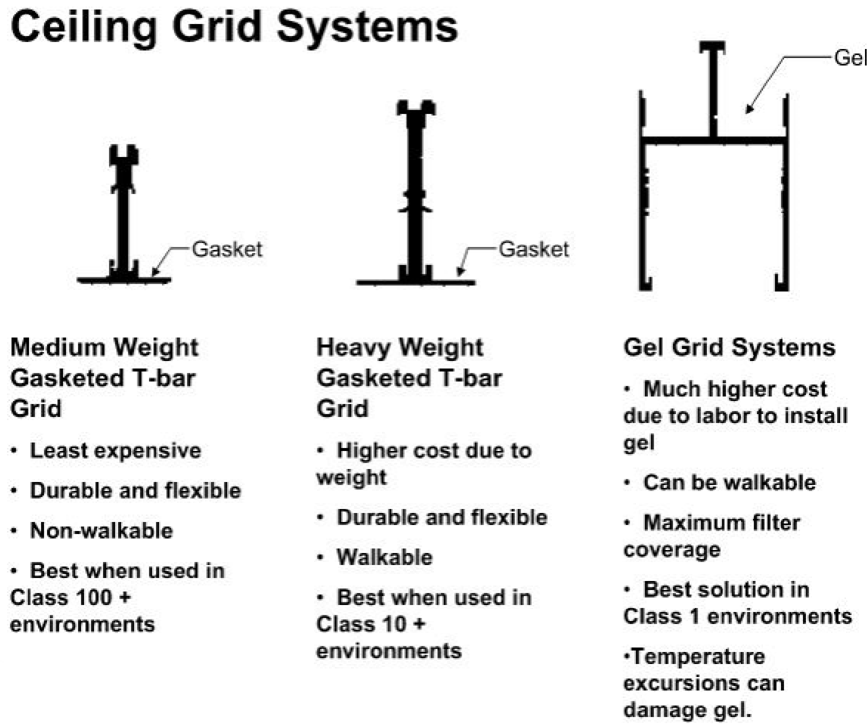


Figure 23- Cleanroom Ceiling T-Grid Options

E. HEPA filters will be adjustable from the cleanroom side of the ceiling assembly. HEPA filters will be easily replaceable, either from the room side or using walkable blank panels and catwalks above.

F. Lay-in/Drop-in LED lighting is to be provided in stick-built/T-grid ceiling assemblies within cleanrooms. Where cleanrooms require a more stringent classification, flush in-grid lighting is to be specified. If the T-Grid ceiling system is desired to be walkable for maintenance access in the interstitial spaces, lighting fixtures will be specified to be walkable-rated.

G. Lighting with cages or unbreakable fixtures will be suspended in the interstitial subfab areas, and HPM areas. Pendant lights in flammable storage areas that are electrically classified are to be specified accordingly, meeting requirements for those spaces.

H. Fire Sprinklers, ionization, and other ceiling accessories all will be surface mounted to blank panels for all clean areas. For cleanroom areas with 100% filter coverage, these items shall be grid mounted to make way for the HEPA filters between the ceiling grids.

4.6.3 Paint and Painting

A. All particle generating materials such as gypsum board, concrete, block, black iron piping will be painted. A water-based epoxy paint system shall be used to paint all surfaces and materials required.

B. The paint system shall include all required primers and sealers.

C. All paints used within cleanroom areas must be cleanroom compatible.

D. Painting the interstitial roof deck, structural framing, and all exposed walls with white epoxy paint is recommended for high visibility and contamination reduction.

E. Stainless steel ductwork, galvanized ductwork, copper piping, Polypropylene, PVDF and stainless-steel piping and valves, as well as other piping materials specified by the project team, is not painted.

4.6.4 Interface Between Ceiling and Roof

A. The hanging load capacity should be 70 lbs/sf for mechanical equipment and piping plus 50 lbs/sf for cleanroom live load and dead load for ceiling and, if specified, suspended overhead catwalks.

B. Intermittent steel may be needed in addition to the primary roof framing system, but this will be minimized, if possible. The total working design load shall be 120 lbs./sf.

C. For interstitial areas where specified, maintenance catwalks shall be constructed of baked epoxy coated steel or aluminum grid and with railing. Catwalks will be accessible from the mechanical mezzanine/fan deck to maintain equipment in the air plenum over cleanroom areas. Note: If any cleanrooms are specified with a walkable ceiling system, catwalks are not required but the suspended ceiling system must be specified to accommodate all anticipated vertical dead and live loads, including grid systems, HVAC equipment, sprinkler systems, electrical and data conduits, lighting, and maintenance personnel.

4.7 Openings- Doors and Windows

4.7.1 Perimeter Doors

A. Perimeter doors to the cleanroom spaces are to be hollow metal doors with vision panels. Vision panels are tempered safety glass and sized to fit window openings. Any vision panels in rated door assemblies will be laminated. Glass is clear unless the door is into a photolithography area. Photolithography area glass is tinted yellow or an amber film to meet UV wavelength requirements.

B. For all glazing into cleanroom bays, privacy tinting is allowable by the ASU fire marshal and tinting shall be provided where requested by the project users and stakeholders. As a definition, privacy tinting is typically totally opaque.

C. A perimeter “tool move in” door size is to be 10 feet clear in width with a removable center mullion. Equipment move-in doors for the cleanroom shall have a door height of 11 feet tall, using a 2-foot-high removable transom above a 9-foot door. Where tool move-in doors are provided, there should be an adjacent “staging/wipe-down” room that serves as an airlock for the cleanroom/fab areas as well as a place to unpack tools and prepare all items for movement into the cleanroom.

D. All cleanroom perimeter door assemblies shall be fire rated doors with crash-bar type egress hardware and door swings outward when exiting. Several doors along the perimeter of the cleanroom may exit only with no entry hardware to control ingress into those spaces. These openings are for emergency use only as required by code.

4.7.2 Interior Doors – Anodized Aluminum

A. Interior cleanroom doors in modular cleanroom walls are hollow anodized aluminum doors with vision panels. Vision panel is tempered safety glass and sized to fit window opening.

B. Glass is to be clear unless the door is into a photolithography area. Photolithography area glass is yellow tinted and must conform to “Cleanroom Windows and Glazing Specification.” The glazing side shall be shown on plans, on the chase side or on the corridor side.

4.7.3 Interior Doors – HPM Areas

A. Interior doors accessing moderate to high hazard storage and/or dispensing areas should be robust hollow metal assemblies for frames and leaves and be specified for appropriate partition ratings they are hosted within; ratings can be up to 2 hours for partitions typically.

B. In addition to frames and leaves, the hardware for doors into HPM areas need to be specified to meet appropriate life safety criteria depending on the materials being stored or handled in each space. For example, doors accessing flammable storage areas may need to meet electrically classified requirements such as Class 1-Division 1 or Class 1- Division 2 requirements as listed in the National Electric Code (NEC). Any electrically powered items for doors in spaces with C1/D1 or C1/D2 requirements may include but are not limited to specialty electric strikes or illuminated exit signage.

C. Door locations and quantities in moderate and/or high hazard HPM storage and dispense areas must also meet requirements for exit separation and travel distances per Chapter 4 in the IBC. All doors in HPM areas should be equipped with appropriate hardware which may include exit devices, closers, and smoke seals.

4.7.4 Interior Doors- Automatic Sliding Doors

A. Automatic sliding doors shall be cleanroom compatible and constructed of aluminum with full glass panels for visibility. Sliders will also be broken away for emergency egress purposes. This door will also be operated by a hand wave operator in lieu of proximity sensor. Note: full glass panels that require privacy or opaque tints is permitted for selected doors with glazing if requested by one of the cleanroom's tenants.

4.7.5 Interior Doors – General

A. For all door openings not listed above in the facility, ASU's guidelines for commercial door assemblies shall be followed.

4.7.6 Windows and Glazing

A. Cleanroom interior glazing shall be tempered plate or float glass for all windows. All glass in perimeter rated cleanroom walls is laminated and meets opening restrictions per the code. Glass in sensitive areas is coated with film that blocks UV light at specific ranges. Cleanroom glass must comply with ASTM-C1036 standards.

B. Transparent Yellow and Amber film shall be used on all windows that are required to eliminate 99.999% of UV light less than 470nm light levels (Photolithography- related areas).

Figure 24- Typical Photolithography Bay with Yellow/Amber Lighting and Window Tinting

C. Viewing windows should be provided where possible on cleanroom perimeter walls but total opening percentages should be applicable to fire resistivity requirements. ASU values the importance of viewing windows from non-clean areas and common corridors and the facility layout should make all reasonable efforts to maximize opportunities for guided tours around the cleanroom utilizing view windows where practical. Viewing corridors and windows into the clean fabrication areas should be in non-clean areas so visitors and staff do not have to gown in these areas.

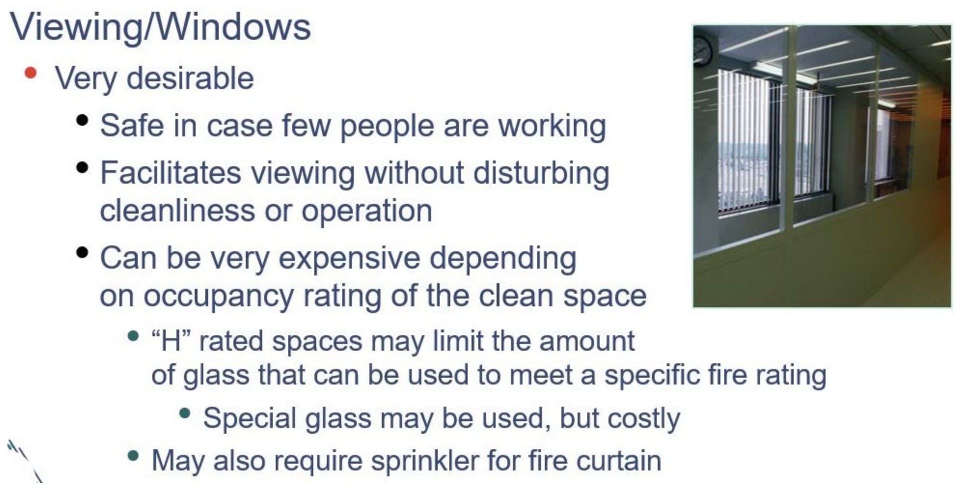


Figure 25- Viewing Window Criteria for Cleanrooms

4.8 Graphics and Signage

4.8.1 Graphics

A. Directional graphics and signage should be based on ASU signage Guidelines. Refer to the following website: https://www.asu.edu/fm/documents/project_guidelines/ASU-Signage-Design-Standard.pdf

4.8.2 Signage

A. All new signage shall be coordinated through OUA/CPMG to confirm that ASU signage standards are utilized and coordinated with EHS Standards. Refer to the following website for specific hazardous signage standards: https://cfo.asu.edu/chemicals

B. Signage should also comply with applicable OSHA and NFPA standards.

4.9 Acoustic, Electromagnetic Interference (Emi), and Vibration Mitigation

4.9.1 An EMI, Vibration and Acoustic site survey, measurement and analysis study should be conducted for interference and disturbances related to sensitive instruments and equipment. Sensitive instruments in microelectronic semiconductor facilities can include advanced metrology and lithography tools, such as E-beam lithography systems, Aberration corrected Transmission Electron Microscopes (ACEM), and Scanning Electron Microscopes (SEM).

4.9.2 Mitigation recommendations include, and are not limited to:

A. For optimization of performance of extremely sensitive tools, a location within the facility should be determined early in the design that incorporates recommended distance setbacks as determined by the design team for potential EMI, vibration, and acoustic sources. Such sources of interference may include but are not limited to:

1.) Elevators (EMI and vibration interference)

2.) Ground traffic from vehicles (vibration and acoustic interference)

3.) Large electrical equipment and gear (EMI interference)

4.) Mechanical house and support equipment (vibration and acoustic interference)

B. If the site allows, use the highest EMI and vibration isolation required by the most stringent tool as a requirement for vibration and EMI isolation for the entire area.

C. Increased slab thickness and raised floor structural platforms isolate instrument areas or rooms from known vibration disturbances.

D. Tools and equipment that vibrate can be isolated with thicker depressed slabs and dedicated "floating" slabs on jacks.

E. Selected services and support equipment shall be evaluated for additional mitigation for vibration and/or EMI, depending on the location, risk of interference, and severity.

F. Keep sensitive instruments at an optimal distance away from potential interference and disturbances from vibration, noise, and EMI sources, such as passenger and equipment elevators, mechanical and electrical rooms, process systems and other vibrating inducing equipment.

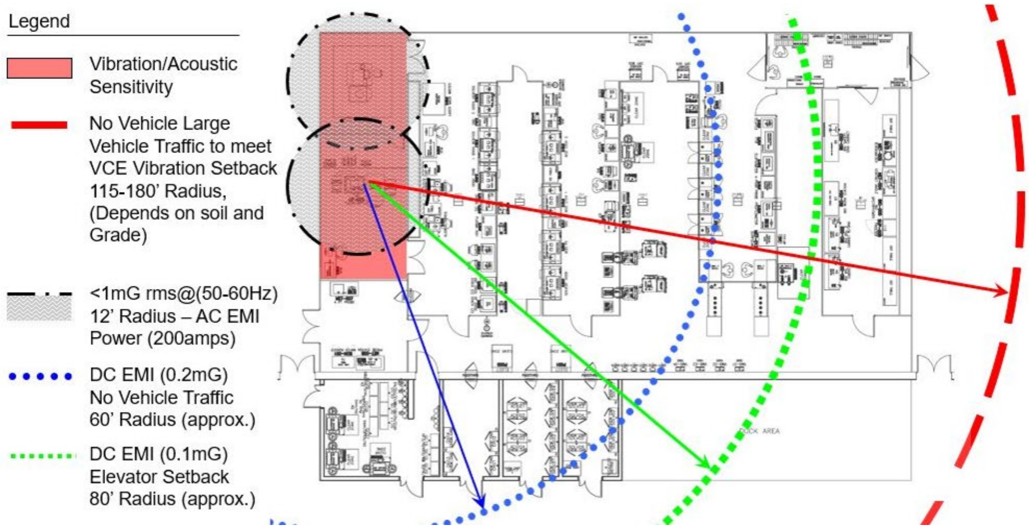


Figure 26- Sample EVA (EMI, Vibration, Acoustic) Study for Tool and Cleanroom Study

G. Place support equipment of sensitive instruments that may cause additional environmental interferences in separate room or chase.

H. Stiff and massive floors are preferable to achieve required vibration criteria. The floor in sensitive tool areas must be extremely flat to insure stability of photolithography and measurement tools.

I. Some processing equipment may be sensitive to acoustical noise. Noise control methods include the acoustically lined enclosures used to quiet the noisy HVAC equipment.

4.10 Cleanroom Lighting

4.10.1 Cleanroom

A. A level of 60-80 foot-candles at work surfaces can satisfy close assembly work and is considered as a higher limit of lighting in the white light areas of the cleanroom.

B. Adjustable lighting is recommended in metrology, characterization, and photolithography areas.

C. Light fixtures are compatible with the cleanliness requirements of the cleanroom and do not disrupt the laminar flow.

D. All fixtures are provided with internal fuse and transient voltage surge protection.

E. Lights embedded in the cleanroom ceiling grid are highly recommended for uniform, bright light.

F. Teardrop fixtures limit the height flexibility of the space and are not recommended for the cleanroom.

G. LED lighting is recommended for all luminaires within the cleanroom and supporting areas. Typical requirements for all LED lighting are as follows:

1.) CRI: 70 or better

2.) Color Temperature: 4,000 to 4,500 F

3.) Efficacy: 50 lumens/watt or better

H. Yellow/amber filters are required on all lights and glazing in photolithography related and adjoining areas (including chases and interstitial areas) to eliminate 99.999% of UV light of less than 470nm, which will prevent interference of photoresist processing.

I. The yellow light areas of the cleanroom typically have 50-70 foot-candles at the work surface with the amber/yellow lenses in place. Amber/yellow light areas may be further de-rated.

J. Chases should be provided with 60-foot candles for work on the support tools and piping.

4.10.2 Lighting Lenses

A. Light lens covers are clear acrylic ribbed diffusers that snap flush to the grid without external fasteners.

B. Lenses are available in clear, opaque white, and amber colors. Amber lens shall provide UV filtration up to a wavelength of 470 nanometers. Yellow sleeve filters are to be provided to insure UV filtration below 470 nanometers.

C. Yellow light areas should have both amber lenses and yellow sleeve filters to insure UV filtration less than 470 nanometers.

D. LED lights should be used and may not need filtration to comply with elimination of UV below 470 nm wavelength. Vendor shall provide data.

4.10.3 Flammable and Pyrophoric Chemical and Gas HPM Room Lighting

A. Lighting for flammable gas and chemical rooms must meet Class 1- Division 2 electrical requirements.

B. Lights are provided with protective cages or heavy-duty lenses to minimize the chances of accidental breakage.

C. Light Level: 40-60 fc at the work surface level.

4.10.4 Non-Flammable Chemical and Gas HPM Room Lighting

A. Lighting for non-flammable gas and chemical rooms is not required to meet Class 1- Division 2 electrical requirements. However, pendant lighting should still be provided with protective cages or heavy-duty lenses to minimize the chance of accidental breakage.

B. Light Level:40-60 fc at work surface

4.11 Loading Docks and Staging Areas

A. Loading docks are as close as possible to the cleanroom or HPM areas, as design permits. This ensures minimal travel of hazardous materials and equipment move-in through corridors to minimize accident risks. H occupancy spaces also require dedicated corridors for egress; no HPMs can be moved in these paths of travel. Alternative pathways for HPM movements from loading/unloading areas to HPM storage and dispense rooms may be required in the layout.

B. The loading dock facilities should also incorporate applicable guidance from the ASU standards:

Project-Guidelines.pdf (asu.edu)

C. A designated or temporary staging area should be considered for move-in/move-out (MIMO) of equipment and materials during construction phase of the cleanroom. This will ensure the cleanliness level of the cleanroom will be maintained during personnel and equipment entry.

D. There should be a large service elevator that has a capacity of 10-12 tons that is capable of moving large and heavy tool and equipment loads from the loading areas up to the fab areas that are on the second level. The elevator should have as short and direct path from the loading area as possible and should be adequately sized for floor area to accommodate large tools such as steppers, CMP tools, and furnaces. A typical tool and equipment service area can be 14 to 15 ft. square. This specialty elevator should be planned into the structural and architectural design and layout of the facility early on.

E. In addition to the large tool and service elevator, additional elevators should be planned for normal passenger and freight traffic. These elevators and their related machinery are large EMI and vibration sources which may affect sensitive tool operations and should be planned for accordingly with the facility layout to provide reasonable setbacks from sensitive tool areas.

5. Fit-Up Requirements and Considerations

5.1 Cleanroom Areas Fit-Up

5.1.1 Pre-gowning and Gowning

A. The gowning area will have a pre-gowning area for users entering the cleanroom to complete the first stage of gowning including garment items, bouffant, beard mask, shoe covers and gloves. Typically, many semiconductor facilities have designated areas for shoe covers at or near any pre-gowning areas. These may be located directly adjacent to any locker areas for visitors or staff preparing to enter the cleanroom areas.

B. The gowning area is the main entry to the cleanroom area. In the gowning zone, the remaining materials to complete cleanroom suit are provided before entering the cleanroom: jumpsuit, boots, head covering, face mask, and final gloves.

C. Appropriate storage and containers are provided such as cleanroom garment hamper for reusable garments, garment inventory storage shelves, and glove/ mask/ hairnet/ shoe covers dispensers. Other furnishings include stainless steel gowning benches, stainless steel gowning racks, and a full-sized gowning room mirror.

D. The gowning room needs to be the same clean classification as the cleanroom area it is providing access to. The pre-gowning area may be a lesser classification.

E. The gowning room will be used for gowning procedures for the clean bays, chases and interstitial spaces as the intent is to have the same clean garments and protocol throughout the entire cleanroom, including these spaces.

F. Cleanroom gowning and protocols are used when materials, products and people flow from room to room during normal processing and tool servicing. Typically, cleanroom garments are the same class of frocks but those for people accessing only maintenance chases are different colors and are laundered more frequently. In addition, ASU typically has differentiating colors for ASU personnel vs. tenant users in current existing cleanroom operations. This requirement may be required for any new facilities.

G. Contamination control methods required during construction are to be defined during the design phase.

5.1.2 Cleanroom

A. The cleanroom includes furnishings and equipment to support process flow. Materials of these items must cause minimal particle emission, be easy to clean, prevent electrostatic charges, and are expected to protect the work environment. Documentation will be provided to match and/or higher cleanroom classification requirements.

B. Chemical transportation carts are to be provided with recommended chemical resistant materials. These must be classified by chemical type. They must include a wash out drain, locking/swivel casters, handle, and drip tray with raised edge to contain spills within cart.

C. Labware racks and storage shelves are to be selected. They can be made of open wire, upright position standing or floor standing, but are required to have leveling feet.

D. Pass-through chambers for chemicals and wafers are to be rated to fit in a fire rated assembly and mounted the same fire rated wall. The unit shall have a mechanical interlock system, a 30-degree sloping top, and removable shelves. Doors shall be transparent and equipped with full-length piano hinge and 3-point latching device and lock. The unit will be provided with a nitrogen purge or a low-level CDA purge port and positive air pressure to the outside hallway.

E. Solvent Waste Receptacles that are impact, corrosion-resistant, and rustproof are to be provided. The units shall be red containers clearly marked "Solvent Waste Disposal Only." Containers require an elevated bottom to encourage circulation of air around receptacle to disperse heat and prevent spontaneous combustion. Foot levers shall be provided for automated lid control for hands-free operation.

F. Wafer and Reticle storage to be provided for cleanroom users with adjustable interior shelves to accommodate various wafer storage boxes. Each box should have a nitrogen purge meter, lockable doors with handles, and clear safety glass and/or static dissipative acrylic-PVC windows on front and back (sides optional).

G. Tote storage racks to accommodate tote boxes are to be made of ultra smooth surfaces that will not snag wipers or harbor contaminants. Tote boxes should be made of static dissipative polypropylene, sealed with fitting lid/cover.

H. Wafer box storage cabinets to accommodate wafer boxes are to be made of ultra smooth surfaces that will not snag wipers or harbor contaminants. Shall be of electro-polished stainless steel wire cage type construction to accommodate cleanroom laminar airflow. Slanted shelves with 12" vertical clearance will accommodate the most common wafer lot boxes.

I. The computer and general tables shall be electro-polished, 304 stainless steel and require cylinder square tube construction with C frame style and adjustable leveling feet. Tables will have a rounded bullnose front to enhance worker comfort and provide footrest bar. Must meet ASU's accessibility requirements and be ESD safe. Ideally, ASU should equip the tables with holders for vacuum wands and nitrogen blow off guns.

J. Chairs and stools shall be made of material that mitigates particulate generation, is non-shedding, and designed to easily maintain cleanliness by reducing airborne particle generation and surface contamination. Seating material will be either polyurethane or vinyl as cloth materials are to be avoided. Material should be antistatic-ESD safe.

K. Personal protective equipment racks for items such as, face shields, goggles, acid gowns, chemically resistant gloves and glove dispensers, and boots to be provided.

L. Cleanroom waste receptacles, with foot lever for automated lid control for hands-free operation, are to be provided. Receptacles must be raised 18" above finished floor elevation to provide air circulation and minimize particle accumulation.

5.2 Non-Clean Lab and Support Areas

5.2.1 Non-clean laboratory and support areas are to include wet and dry laboratories, testing spaces, maintenance shop, receiving/material handling area, and offices.

5.2.2 A dedicated area for lockers for either full time or rotating personnel for the facility should be considered for secure storage for staff utilizing the cleanroom/fab areas and for staff who don't have dedicated office space within the facility.

5.2.3 Fit-up in non-cleanroom and HPM areas for modular and non-modular furniture and casework should be modular and follow standards as outlined for these systems in the ASU lab and general facilities guidance- links below:

laboratory Guidelines (asu.edu)

Project-Guidelines.pdf (asu.edu)

5.3 Specialty Hoods and Wet Benches

5.3.1 Specialty Hoods

A. All specialty hoods in the cleanroom, such as horizontal and vertical laminar flow clean benches, are to be built with a work surface that is compatible with the chemicals in use. Hoods that are used with solvent chemicals to be 316 stainless steel and those with acid/base chemicals to be constructed with FM 4910 approved materials. Side walls and view screen/sash shall be static dissipative PVC, tempered safety glass, or stainless steel. Systems must not introduce contamination to the cleanroom and be easy to clean and maintain.

B. The cabinet is expected to have an exterior enclosure of stainless-steel panels. Each cabinet component is to be adhesive-sealed, welded, gasketed, or assembled with air-tight, hermetically sealed joints. This is to provide a leak free, soap bubble-tight gas sealed assembly. All cabinet components shall be cleanroom compatible.

C. Enclosures will have dual sensor alarms to provide warning, in the event of an airflow failure, to ensure operator safety.

D. Hoods are to have removable anodized aluminum or stainless-steel screen to protect filters.

E. Hoods will meet or exceed both UL (Underwriters Laboratories) and FM Global Guidelines. Work zone surface need to meet desired ISO air cleanliness as per ISO 14644.1

F. Laminar flow clean benches shall also comply with the design outlined in the ASU Laboratory Standards & Design Guidelines, Lab Ventilation, and Division 11 technical guidelines located at the following links:

Project-Guidelines.pdf (asu.edu)
https://www.asu.edu/ehs/design-guidelines/laboratory-ventilation.pdf

5.3.2 Wet Benches

A. Wet Benches are to meet or exceed both UL (Underwriters Laboratories) and FM Global Guidelines. Benches will follow SEMI S-2 and S-15 standards.

B. Wet Bench design and utility requirements will vary by process and be outlined during the design phase based on facility and users' needs.

C. Benches are constructed out of non-combustible materials and must be compatible with the chemicals that they will encounter. These materials must not outgas any amines, ammonia, or other molecular contamination. Systems must not introduce contamination to the cleanroom.

D. Leg levelers and/or casters are to be provided at each corner of each wet bench. The selection of which to use can be location specific (as needed).

E. Perforated decks shall be used where possible.

F. Side and face shields shall be fabricated from a clear FM 4910 material. Face shields shall be hinged, sloped, or vertical so that no items can be "stored" on them.

G. Each bench will be constructed to provide spill containment and overflow protection. The drip pans shall be fabricated from the same material as the wet bench shell. The materials of construction need to be resistant to the chemicals used in the bench. Secondary spill containment areas are typically driven by specific vendor requirements depending on expected bench use.

H. Must allow clean air flow on the wet bench surface, as well as fume collection via deck exhaust, lip exhaust and rear panel exhaust. This is to ensure a clean work surface and complete removal of fumes.

I. All decks are to be modular. The modular design will allow the decks to be separated into 3 pieces and allowing for easy removal for maintenance and potential reconfiguration.

J. Fire suppression systems are to be supplied and connected to the fire alarm system as needed per Factory Mutual FM 7-7. This should be assessed by the design team dependent on the chemical processes being performed.

K. Acid/base Wet Benches

1.) All materials of construction are to be FM 4910 approved materials.

2.) Shell material meets the 25/50 flame / smoke index rating per the ASTM E 84 standard and deck fabricated from PVDF, unless otherwise noted.

3.) Perforated work deck areas must drain to specified drains as described in Section 7.4.1- Wastewater and other liquid waste treatment systems.

4.) Exhausted and water flushed plenum provided for all non-solvent benches.

5.) Aspiration at wet benches is determined by what each bench would be used for and what chemicals will be run. Chemical quantities for ASU facilities are typically limited to keep control. However, if specific tenants require larger quantities of chemicals at wet benches this would need to be discussed with ASU Facilities and EHS.

L. Solvent Wet Benches

1.) Constructed with 316 stainless steel for horizontal surfaces and satin finishes for vertical surfaces.

2.) Meet Class I, Division 2 compliance, for all wet benches. NOTE: Class 1, Division 1 is typically not required for most wet bench uses but this should be checked on a case-by-case basis.

3.) Include a UV/IR sensor for flame detection and be connected to TGM and Fire Alarm.

4.) Constructed in a way that will allow carboys to collect the solvents. All carboys must be within an exhaust supported enclosure and integrated with the wet bench exhaust's connections to facility.

5.) Provide CO_2 extinguisher system for wet benches handling materials above their flash point.

5.4 Casework

5.4.1 Cleanroom furniture including casework (if included) is to be constructed with 316 stainless steel for horizontal and vertical surfaces or equivalent anti-static cleanroom compatible material. Furniture and casework surfaces are smooth and do not generate particulates or allow dust. Surfaces shall be easy to clean and chemically resistant.

5.4.2 Casework cabinet doors and drawers are designed without handles and easy to operate to minimize contamination. Furniture design will allow airflow under the cabinets to avoid accumulation of particulates and dust.

5.4.3 All casework must be modular and mobile to allow flexibility for future reconfiguration with a fitting process that will minimize gaps to prevent bacteria growth and contamination.

5.4.4 Non-clean laboratory casework outside of the cleanroom and support areas in the MTW facility are to follow the design outlined in the "ASU Laboratory Standards & Design Guidelines" located online at:

laboratory Guidelines (asu.edu)

5.5 Safety Cabinets

5.5.1 Chemical storage cabinets will be required for storage of chemicals not distributed through a centralized chemical distribution system. All chemicals will be poured directly into the wet bench tanks or tool chemical storage systems that require changing/filling.

A. Depending on the users' needs, there are different types of chemical cabinets required.

1.) Solvent cabinets

2.) Explosion proof refrigerators, typically for photoresist

3.) Acid Cabinets

4.) Base Cabinets

5.) Oxidizer Cabinets

B. Each chemical cabinet shall be connected to the specific exhaust stream. Each chemical cabinet will also have spill containment of at least 110% of the largest container in the cabinet. Each cabinet to be lockable for restricted access.

Typical exhaust streams will likely be tied to acid exhaust distribution but may need separate exhaust for solvents.

1.) Solvent cabinets do not require ventilation if the dispensing is not done in the cabinet.

C. Chemical cabinets must have double-wall construction, dual vents, grounding wire connections, adjustable shelves, leak proof sills, three-point self-latching doors and leveling feet. Self-closing door(s) shut and latch automatically when a fusible link melts at 165°F (74ºC) under fire conditions. Unique, concealed self-closing mechanism offers obstruction-free access to contents.

D. Chemical cabinets include polyethylene trays that sit on top of galvanized steel shelves and a separate polyethylene liner for the bottom sump to resist aggressive chemicals. Provides an easy to remove liner for quick cleaning of drips and leaks. An all epoxy baked-on powder-coat finish, inside and out, provides increased chemical resistance.

E. Cabinets to comply with NFPA 1, NFPA 30, NFPA 400 Hazardous Material Code, and the International Fire Code.

F. Explosion proof refrigerators need to have steel encased electrical components, spark proof components and door gaskets. They will be designed to meet NFPA and OSHA standards for safe storage of volatile, flammable, and combustible materials.

G. Storage cabinets to also comply with guidelines “Facilities Development and Management Project Guidelines” found at:

Project-Guidelines.pdf (asu.edu)

5.6 Acoustic, EMI, and Vibration Mitigation

5.6.1 Environmental design considerations should be considered during master planning for the new facility, specifically the areas which will be housing sensitive instruments. If structural, isolation, or location design criteria cannot be met, mitigation tools or third-party mitigation technologies such as passive or active environmental abatement systems may be considered as an alternate solution. Viable options may include but are not limited to:

A. Vibration and noise cancellation pads for support equipment, including MEP systems, designed to achieve, at a minimum, VC-E vibration criteria for vibration sensitive instruments.

B. EMI shielding such as Magnetic Active Cancellation Systems (MACS)

C. Passive and Active Vibration Isolators

D. Insulation or acoustic panels to walls, ceilings, and floors. Acoustic barriers such as partitions and doors if the design allows.

E. Acoustic enclosures

5.7 Hazardous Materials Storage Areas

5.7.1 A gas and chemical analysis, with their specific hazardous classifications and consumption rates, will be required during the design phase for planning of the hazardous material storage areas and allowable limits. Users should provide a list of all gases and chemicals being used and stored. A benchmark list of gases and chemicals can be combined with the user supplied list of gases and chemicals for programming storage spaces and occupancy rating of the cleanroom and other areas.

5.7.2 HPM storage areas will be defined during the design phase for the new facility. These areas may be separated by chemical types and designated occupancies such as Flammables, Corrosives, Specialty Chemical Dispense, Oxidizers, etc.

5.7.3 HPM storage exhaust is hazard dependent. Incompatible exhaust streams must be kept separate. Exhaust streams are outlined in Section 6 with their associated constructed material.

5.7.4 Depending on the new facility requirements, hazardous materials storage areas may house chemical storage cabinets, gas cabinets, VMBs, manifolds, and chemical abatement systems. Refer to Sections 5.5 Safety Cabinets, 6.4 Scrubbers and 7.6.12-15 Gas/Chemical Distribution Equipment for additional details on this equipment.

5.7.5 Hazardous Materials Storage shall also follow guidelines outlined in the "ASU Laboratory Standards & Design Guidelines" located online at: Laboratory Guidelines (asu.edu). The AE shall notify ASU of any conflicts between this guideline and the ASU EHS Laboratory Standards and Design guidelines. AE shall follow the more stringent guideline unless approved by ASU.

5.8 Safety Equipment

5.8.1 Cleanroom and HPM safety showers and eyewash

A. Showers with eyewashes shall comply with the following codes and standards:

1.) ASU Standards for Eyewashes and Safety Showers: www.asu.edu/ehs/design-guidelines/eyewash-shower-standard.pdf

2.) ANSI Standard Z358.1

3.) OSHA Requirements

4.) FM approved Materials

5.) Local Laws, Codes, and Ordinances

6.) International Fire Code

7.) SEMI S-2 and S-15 Standards

8.) Underwriters Laboratories (UL)

B. Safety showers with cold potable water are required anywhere there is a risk of exposure to hazardous chemicals. This includes, but is not limited to, the cleanroom, chemical rooms, or support labs. NOTE: Tempered water for safety showers and eyewashes is not required at ASU Facilities.

C. Safety showers and eyewash stations are to be constructed with stainless steel or equivalent. All exposed pipes and fittings are to be furnished with powder coated epoxy finish or all stainless steel. A monthly test schedule must be performed to ensure operation while in service.

D. When activated, these showers will send a signal to the facility command center or central station and the campus Emergency Control Station (ECS).

5.8.2 Emergency Response Equipment (ERT)

A. A dedicated ERT room/area would require additional staffing by ASU facilities. If this is to be included in any new facility, this should be coordinated with ASU EHS accordingly.

5.8.3 Fire extinguishers

A. Fire extinguishers in the cleanroom shall be built of cleanroom compatible materials.

B. The AE team to specify appropriate fire precautions based on the chemicals used in the cleanroom during the design phase.

C. Fire Extinguishers to be provided as required to meet the code, including specialty fire extinguishers as required.

D. Applicable standard: NFPA 10 – Standard for Portable Fire Extinguishers.

E. Provide fire extinguisher cabinets as required.

5.8.4 Safety equipment shall also comply with the outlined in the “ASU Laboratory Standards & Design Guidelines” and the ASU Project Guidelines located online at:

Project-Guidelines.pdf (asu.edu)

laboratory Guidelines (asu.edu)

6. Mechanical Requirements and Considerations

6.1 HVAC Design Strategies

6.1.1 HVAC systems design strategy for the cleanroom and support areas is based on a large-ballroom type configuration with an elevated fab/clean level with a raised access flooring system over a recessed waffle slab and a flow-through subfab below for all support equipment.

6.1.2 Cleanroom standards are generally met or maintained by control or installation of the following equipment or systems.

A. Filtration System

1.) Filtering or removing particulates is the primary means of maintaining cleanroom operations. All airflow to the cleanroom shall be delivered to the space via an air terminal device with filtration.

2.) HEPA (High Efficiency Particulate Air)/ULPA (Ultra-low Particulate Air) filters provide capture or containment of particles that can contaminate, interfere, or damage proper operation of the clean space.

3.) Other airborne contaminates (molecular) may not be efficiently or properly removed with HEPA or ULPA filtration. Where these molecular level components are potentially present, additional special filtration will be required.

B. Airflow

1.) Design should follow Federal Standard 209E (Fed 209E) for the required airflow and room air change rate necessary to maintain the respective cleanroom cleanliness.

2.) Fed 209E defines airflow movement and interaction within the cleanroom. In most cases, this airflow movement should be “laminar” in nature. HEPA/Filter location must be designed to maintain laminar flow adjacent to tools, equipment, and features of the proposed space.

3.) A study or test data by computational fluid dynamic (CFD) model is required or recommended for areas where laminarity may not be possible.

4.) Space pressurization, relative to adjacent spaces, limits contamination or intrusion by additional particulate. Design of makeup/outside air and air distribution shall pressurize the clean space such that the proposed space has higher pressure to all adjacent spaces and the exterior.

5.) Placement of pressure sensors and reference pressure devices are to be installed with and maintained by the BAS system for this pressurization strategy. Must be coordinated during the design of the BAS system or controls strategy.

6.) Return paths shall include architectural and construction features to meet cleanliness requirements. The following exhibit represents an example of a typical return path and airflow configuration.

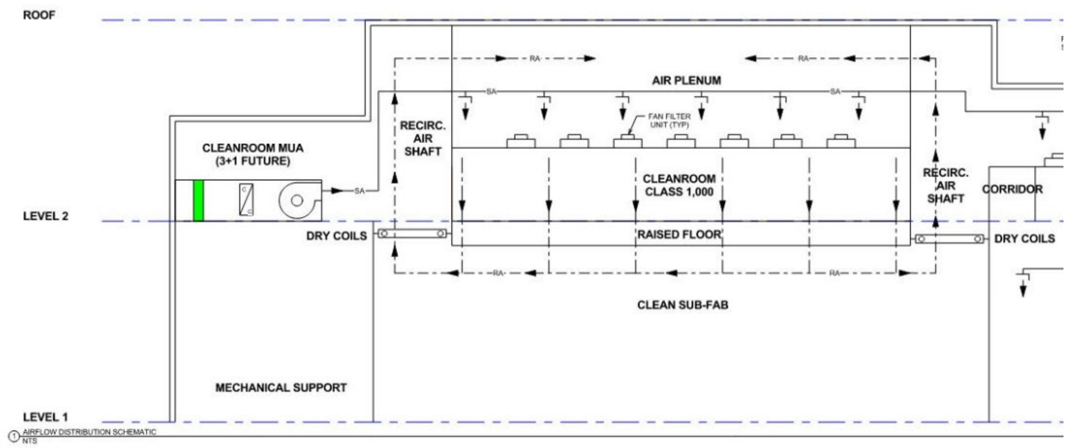


Figure 27- Sample Cleanroom Air Flow Diagram

C. Protocol and Construction

1.) Proper operation and cleanliness of the cleanroom depends upon proper isolation and control of the clean space. Additional details can be found in section 4.5.2 and the ASU MTW cleanroom protocols.

6.1.3 Design criteria to be based on the local codes and ordinances, industry and ASHRAE standards for the Phoenix Metropolitan area. Exterior or outdoor-rated equipment shall be capable of operation to 125 degrees F minimum.

6.1.4 The new facility shall support and provide flexibility and adaptability to keep pace with the rapid changes continually occurring in semiconductor R&D facilities and be designed to allow research space to be converted and/or renovated with minimal disruption.

6.1.5 Design for the building Central HVAC Systems, such as chillers, cooling towers, and boilers, in conjunction with areas outside of the cleanroom and HPM areas, shall follow the ASU guidelines “Engineering Design Guidelines” and “Technical Guidelines, Division 25” found in the following link. AE firm must coordinate these central systems with the HVAC systems outlined for cleanroom and HPM areas.

[Project-Guidelines.pdf (asu.edu)]

6.1.6 All alternate design proposals that do not explicitly follow this guideline will require a comparison analysis between the guideline baseline requirement and the proposed scheme for the relevant criteria as agreed with ASU Facilities. Explicit approval would be obtained from ASU's CPMG Engineering for experimental designs before commencement.

6.1.7 To adequately plan for accessible building systems, space should be reserved in the utility corridors, ceilings outside the cleanroom and support areas, and subfab for future HVAC, plumbing, and electrical needs.

6.1.8 Facilities management and control system for operation and maintenance of systems and equipment should be robust and entirely automated to maintain the environmental standards of the HVAC cleanroom systems. Additional details outlined in Section 9 – Controls & Monitoring.

6.1.9 The HVAC systems shall be energy efficient. Motors are to comply with NEMA MG.1 and IEEE 112.

6.1.10 Temperature and Humidity Control

A. Design for outdoor air conditions should be followed per the ASU Engineering Guidelines.

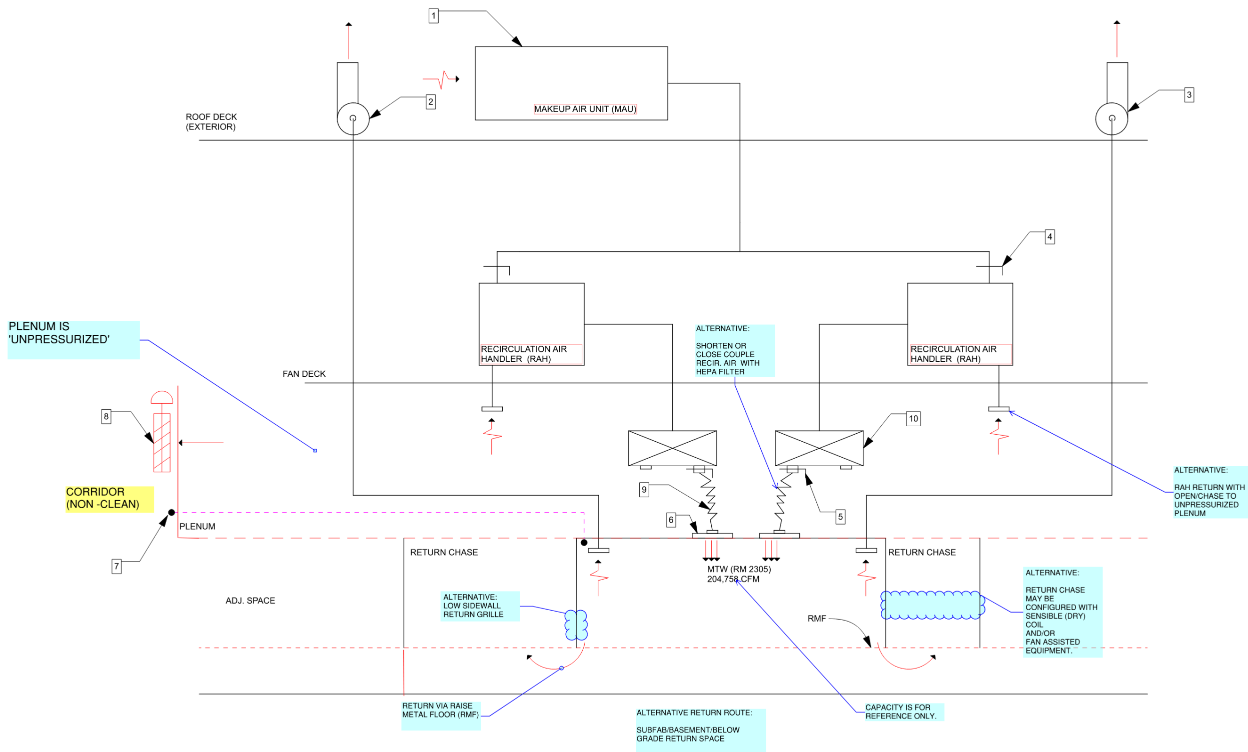
B. Cleanroom or interior conditions shall be based on the benchmark design of tool or process requirements.

6.2 HVAC Supply Equipment

6.2.1 The cleanroom airflow strategy outlined is based on the following combination of a typical central station air handlers system for this type of facility. This includes 100% dedicated outside/make-up air unit (MAU) and recirculation air units (RAH), HEPA filters, process and pressurization exhaust.

6.2.2 All equipment, ductwork, and piping to be identified and labeled per the MTW labeling standards.

6.2.3 An example of the orientation and configuration of MAU, RAH, and HEPA equipment for the typical cleanroom arrangement at MTW is depicted below in *Figure 28- ASU MTW Cleanroom – Current HVAC Cfg.* Alternatively, *Figure 27 – Cleanroom Air Flow Diagram* shows an example of a cleanroom with fan filters and pressurized plenum(s).



1 CLEANROOM AIRFLOW DIAGRAM (PARTIAL)

NOT TO SCALE

SHEET NOTES:

1. EXISTING MAKEUP AIR (MAU) UNITS.
2. EXISTING SOLVENT EXHAUST
3. EXISTING ACID EXHAUST
4. BALANCE EXISTING RAH UNITS FOR MAKEUP AIR VALUE AS INDICATED.
5. BALANCE FLEX CONNECTION TO HEPA FILTER (FIELD VERIFY)
6. NEW HEPA FILTER BALANCE TO 576 CFM EACH. SEE FLOOR PLAN FOR LOCATION(S) AND QUANTITY.
7. EXISTING PRESSURE SENSOR(S)/CONTROLS IN EXISTING CORRIDOR (CLEAN WEST). BALANCE SYSTEM SUCH THAT CLEANROOM PRESSURE IS 0.10" WG. ABOVE CORRIDOR.
8. EXISTING SMOKE CONTROL DAMPER AND DUCTWORK.
9. CLEANROOM SUPPLY DUCTWORK - MAIN DUCT
10. FLEX DUCT FROM SUPPLY DUCT TO HEPA FILTER.

GENERAL NOTES:

THIS ILLUSTRATION IS A DIAGRAMMATIC REPRESENTATION SUBJECT TO CHANGE OR MODIFICATION AS REQUIRED BY EACH PROJECT.
ALL SIZES, CONFIGURATION AND DETAILS ARE SHOWN AS A 'REPRESENTATIVE' EXAMPLE OF POTENTIAL CLEANROOM LAYOUT AND AIRFLOW SCHEME.

Figure 28- ASU MTW Cleanroom - Current HVAC Configuration

6.2.4 Pressurizations schemes (pressurized plenum, etc.) can also be viewed in the exhibits above.

6.2.5 Central Station Air Handlers

A. General Requirements

1.) Central station air handlers shall be defined per AHRI Standard 430.

2.) Performance ratings shall follow ASHRAE Std 90.1, EER and COP, as applicable.

3.) Regulatory requirements shall be AHRI 270 rated, NFPA 70, and UL (DIR) listed.

B. Redundancy for equipment to be provided as outlined in the table below.

Table 3- Equipment Redundancy

Unit Quantity (including N+1/ZUD*)	% System Capacity per unit	Remarks
2	100%	Both Fans shall run at 50% load
3	66%	ZUD fan shall run at 50% load
4	50%	
Other	TBD	Subject to MTW design review

** ZUD: The redundant or "Zero Unscheduled Downtime" Unit*

C. Dedicated Make-Up Air Unit (MAU)

1.) Properly designed MAU units shall meet the design condition of the cleanrooms and provide make up air to the recirculation air units. MAUs provide all humidity control by controlling the Relative Humidity percentage of the make-up air to maintain the setpoint measured in the cleanrooms.

2.) MAU to condition the incoming outside air to maintain the setpoint temperature measured, all fresh make-up air and required filtrations for the air introduced into the cleanrooms.

3.) Generally, MAU's should be located as far from planned exhaust points as possible to avoid exhaust re-entrainment. Although code minimums exist for separations of supply inlet and exhaust points it is recommended a wind/wake consultant be engaged on the project team for any new facility to provide analysis based on the working site and facility plan and micro-climate, including prevailing winds and other potential sources of concern such as exhaust flows from adjacent sites.

4.) MAU provides sufficient air to maintain minimal positive pressurization in the cleanroom relative to surrounding spaces.

5.) Additional details and alternative make-up air arrangements can be found in the exhibits above.

6.) Redundancy shall follow *Table 3 – Equipment Redundancy* outlined above.

D. Recirculation Air Unit (RCU)

1.) The RCU unit will be sized to maintain the cleanroom classification requirement, per Fed 209E Cleanroom Standards, and set point temperature of cleanrooms.

2.) Cooling and heating (tempered) air to be provided must meet calculated cleanroom supply temperature, including RAH fan heat. While typically most

RCUs don't require heating cools in the Phoenix Valley area this should be looked at for any sites at higher elevations that may have different climatic conditions.

3.) RCUs to provide the required filtration for return air from the return air chases up to the pressurized plenum above.

4.) Additional details and alternative RCU configurations can be found in the exhibits above.

E. HEPA/ULPA (HEPA) Terminals

1.) The HEPA filter rating shall be at 99.99% efficient at 0.3 micron.

2.) The HEPA terminals to be located at the ceiling panel for each space.

3.) HEPA modules are to be matched and rated for the cleanroom ceiling.

4.) HEPA modules will be sized and framed to form a permanent 'air-tight' seal with the cleanroom ceiling.

5.) HEPA seals are gasketed with neoprene gaskets suitable for cleanroom application.

6.) For ceiling grid system, refer to Section 4.6.2.D.

6.3 HVAC Exhaust Equipment and Management Strategies

6.3.1 Exhaust Fans

A. The exhaust system shall be equipped with redundant (N+1) exhaust fans as shown in *Table 3 – Equipment Redundancy*.

B. The exhaust system shall be vertical discharge units. The minimum discharge velocity to be 3,000 fpm at exterior termination of duct.

C. Avoid discharge at or near ventilating system or building intakes. See guidance above on recommendations for wind/wake analysis for any new facility designs. High velocity fans may be required if recommended due to the site design and climate conditions.

D. For specific minimum distances between exhaust stacks and building fresh air intakes reference applicable building and safety codes and standards such as IMC and IBC or ASHRAE Standards. Refer to the CPMG Project Guidelines and the EHS Laboratory Standards & Design Guidelines for additional requirements.

https://cfo.asu.edu/ehs

Project-Guidelines.pdf (asu.edu)

6.3.2 Exhaust Management Strategies

A. Incompatible chemicals shall be in separate exhaust streams.

B. Exhaust materials of construction shall be compatible with the chemicals handled in the exhaust system.

C. All exhaust must comply with annual emission limits.

D. Cleanroom abatement and exhaust guidelines to be coordinated with the ASU MTW Exhaust Management strategy.

6.3.3 Exhaust streams are hazard dependent and a chemical analysis will be required for design and configuration. All ducts to be rated for use without sprinklers when possible:

A. Corrosive Exhaust – Required for venting hazardous materials storage areas and process equipment exhaust per code. Examples of corrosive exhaust include acid exhaust and high concentration acid exhaust.

1.) Material – Teflon/Halar Coated Stainless Steel (Bolted/Welded/Flanged) Note: FRP not allowed as this would require sprinkler protection.

B. Flammable Exhaust – Required for hazardous materials storage areas and process equipment exhaust per code. Examples of flammable exhaust include solvent exhaust.

1.) Material – Stainless Steel (Bolted/Welded/Flanged) without Teflon/Halar lining.

C. Corrosive and Flammable (High Static Pressure) Exhaust – Will require localized absorption abatement scrubbers in case of catastrophic release of hazardous gas or liquid metal precursors. These abatement unit(s) will be close to the dispensing cabinet exhaust output. Appropriate unit type and size to be determined during design. The cabinet exhaust will be ducted as a dedicated system. This system requires a high static exhaust fan to overcome the pressure drop of the absorption media (6” w.c. minimum) and may require explosion resistant fans. This type of system is required for gases that have both flammable/pyrophoric and corrosive properties and very low emission limits due to toxicity. The low emission limits cannot be met with a wet scrubber or other abatement.

1.) Material – Teflon/Halar Coated Stainless Steel (Bolted/Welded/Flanged)

D. Corrosive and Flammable Exhaust – Will require localized wet abatement scrubbing that does not require high static pressure exhaust fans. High static pressure exhaust fans are not required because the wet scrubber pressure drop is much lower than absorption media. These unit(s) will be close to the output of the corrosive gas cabinet exhaust. Appropriate unit type and size to be determined during later design stages. The Corrosive Gas cabinet exhaust will be ducted as a dedicated system. Gases in this exhaust stream must be capable of being wet scrubbed below emission limits. Ammonia is an example of a flammable corrosive gas that can be wet scrubbed.

   1.) Material – Teflon/Halar Coated Stainless Steel Bolted/Welded/Flanged)

E. Pyrophoric/Silane Exhaust – This is a dedicated exhaust that sends the release of a pyrophoric and or flammable material directly out of the building through an explosion resistant exhaust fan. This service is not connected to any type of abatement system and is most common for Silane.

   1.) Material – Stainless Steel (Bolted/Welded/Flanged) **without** Teflon/Halar lining.

F. Specialty exhaust systems for hazardous production materials that are both highly toxic and flammable/pyrophoric require abatement and an explosion resistant exhaust fan. Examples of specialty HPMs include phosphine and arsine. Exact abatement and exhaust methodology depends on the concentration and species of gases used. Refer to abatement section for abatement options.

G. A high temperature / heat exhaust system made of materials compatible with process temperature and process chemistry may be required. Depending on process variables, high temperature exhaust may consist of a dedicated exhaust system, or a portion of ductwork incorporated into the systems above that are designed to be compatible with local high temperatures.

6.4 Scrubbers and Abatement Options

6.4.1 Central and Point of Use (POU) Abatement systems are required due to code requirements, EPA/AHJ discharge limit requirements, local air quality district mandates, and air permit requirements for specific gases being used. A chemical analysis should be performed to evaluate the abatement type during the initial phases of design. The following general design requirements should be considered.

A. Abatement systems must consider the maximum credible leak scenario and be capable of abating the worst-case scenario while complying with local code and air permit for the purpose they are provided.

1.) POU abatement may be used for catastrophic release protection in order to limit the size of centralized abatement systems.

B. Chemical analysis considers types of gases and flow rate in waste stream.

C. Emission limits of the gas components must be calculated.

D. An abatement system that is equipped with a bypass duct shall be avoided, if possible.

E. Destruction and Removal Efficiency (DRE) must meet applicable requirements. Typical recommendation is greater than 99%.

6.4.2 POU Abatement

A. Required for processing tools emitting hazardous exhaust and can be used to target specific containments.

B. Should consider whether a centralized scrubber is part of the exhaust system. POU abatement systems may not need wet scrubbing if a central scrubber is upstream.

C. Should be located close to the source of emissions. Each will treat the unreacted effluent from the tool locally before it enters the scrubbed exhaust system.

D. Effluent from POU abatement may require wet scrubbing prior to releasing to the atmosphere.

E. Must include a closed loop feedback system that prevents tool usage if the abatement system is offline or requires maintenance. Each system must have both audible and visible warnings on the front panel, such as a LED stack light visible from a distance, to indicate an offline status or maintenance fault prompt.

F. Maintenance and service preference of the owner/tenant vs cost.

G. Typical POU abatement systems include:

1.) Dry resin systems

2.) Water scrubbers

3.) Thermal/wet systems

4.) Plasma systems

5.) Plasma/wet systems

6.) Water cooled traps for precipitation of particulates

6.4.3 Catastrophic Release Abatement is required to contain a leak of a gas source's full contents.

A. Each abatement system will produce an exhaust that meets local code and EPA regulatory requirements. Gas concentrations must be lower than ½ IDLH and/or 25% of the lower flammability limit levels at the system outlet.

B. No abatement system shall depend on the gas properties to initiate combustion. All abatement systems must have internal gas sensors (including toxic, corrosives, flammables, and pyrophorics). Each system must have both audible and visible warnings on the front panel to indicate that the abatement system is inadequate to meet the required detection levels.

C. Systems shall be equipped with a connection to interface with the gas monitoring system. The abatement system's controller will be able to send a signal indicating the system status and/or a trouble alarm for gas concentrations above ½ IDLH limits or 25% of LEL limits.

D. Abatement type depends on the chemical or mixture of chemicals being abated. Abatement selection shall be evaluated for any changes to gas sources. Typical options for abatement include:

1.) Resin-based systems are used for the treatment of gases released from a bottle malfunction, system leak, or open bottle.

2.) The wet scrubber system may be a doped water-based system that will be used for treatment of gases that may be released from a bottle malfunction, system leak, or open bottle.

3.) The thermal wet system will contain a thermal oxidation unit and a wet scrubber.

6.4.4 Centralized Scrubber

A. Effluent abatement will be dependent on local air quality statutes and regulations (Applicable County, Arizona State, and Federal EPA requirements).

B. Centralized scrubber type depends on the HPMs used and the POU abatement strategy. The design team shall coordinate with the owner on the best methodologies.

C. Typical centralized scrubbers include:

1.) Acid or Caustic Exhaust to pass through an appropriately sized local wet scrubber with the appropriate chemistry.

a. AWN system sizing needs to account for this stream.

2.) Thermal oxidizers

3.) Regenerative thermal oxidizers

4.) Concentrators/thermal oxidizers

6.5 HVAC Distribution- Dry Systems

6.5.1 Ductwork

A. Ductwork shall fall under the latest SMACNA standards.

B. Consult ASU Project Guidelines (23 31 00 - HVAC Ducts and Casings) for specific ductwork type and construction materials.

C. Ductwork flow and sizing shall meet the following design criteria.

1.) Minimum flowrate: 500 fpm (Feet/Min)

2.) Size of ductwork to meet Noise and Vibration criteria as outlined in *Table 1* in Section 2 – Civil and Site Requirements and Considerations.

6.5.2 Air Terminals

A. Critical Environments/Cleanroom Diffusers

1.) Diffuser construction material to comply with ASTM E84, UL 723, UL 2518, NFPA 90A, and NFPA 90B.

2.) Laminar Flow Diffusers are to be constructed of stainless steel and framed according to the manufacturer's recommendations.

3.) Radial Flow Diffusers are to be constructed of stainless steel and framed according to the manufacturer's recommendations. Damper shall provide volume control in accordance with manufacturer's recommendations.

B. Fan Filter Units (FFU)

1.) Units must comply with UL 507, 586, and 900.

2.) Units shall have the following performance ratings.

a. Unit factory sealed and tested.
b. Filter efficiency should be 99.99 percent (HEPA) at 0.30 microns or higher particle size when tested in accordance with DOP-smoke (Dioctyl Phthalate) penetration test on MIL-STD-282.

3.) Air velocity to have a minimum capacity of 500 fpm.

4.) Resistance to be within the range of 0.5 in-wc (124.3 Pa) to 2.0 in-wc (497.9 Pa).

5.) Media will be a pleated, water-resistant glass fiber with aluminum separators.

6.) Face gasket to be construction of silicone.

7.) Media will be bonded to frame side with silicone.

8.) HEPA filters will be attached to the ceiling system as indicated in Section 4.6.2-E.

9.) See *Figure 27 - Cleanroom Air Flow Diagram* for application of FFU in a typical cleanroom configuration.

6.6 HVAC Distribution- Wet Systems

6.6.1 Hydronic Piping

A. Consult ASU Project Guidelines (23 21 13 - Hydronic Piping) for specific guidelines and construction materials.

B. Piping flow and sizing shall follow the following design criteria.

1.) Minimum pipe flowrate: 2 fps (Feet/Sec)

2.) Maximum pipe flowrate: 5 fps

3.) Size ductwork to meet Noise and Vibration criteria as outlined in *Table 1* in Section 2 – Civil and Site Requirements and Considerations.

6.7 Energy Efficiency

6.7.1 The HVAC system shall be designed for optimal energy efficiency while not compromising the basic requirements of the cleanroom areas for air changes and environmental controls.

7. Plumbing and Piping Requirements and Considerations

7.1 Plumbing Systems and Design Strategies

7.1.1 System Sizing

A. For any planned renovations or tool installations, a gap analysis shall be performed to verify any planned changes will not impact existing system capability.

B. All plumbing systems should be sized to meet peak and average flow demands from a benchmark utility analysis.

   1.) The average and peak flow demands can be compiled by adding up the expected peak and average demand using a benchmark list of process tools. Additional expected loads for facility equipment must also be accounted for.

C. Pipe and pump sizing shall be supported by calculations, which may require a fluid system modeling software depending on system complexity. Systems that require multilevel or a closed loop recirculating distribution can be difficult to balance without software. ASU may require report-outs to confirm system performance meets design intent.

   1.) Component reliability and redundancy required must be considered.

   2.) Projects may include a phased design and construction approach and a software model can be used to simulate multiple scenarios.

D. Chemical source sizes should be capable of meeting benchmark peak / average flow demands with an additional safety factor for future expansion or modifications.

E. Chemical sources should be sized to ensure a reasonable changeover frequency that can be met by a chemical supplier and site staffing. This frequency is chemical specific and must be verified during design.

   1.) Appropriate storage for the chemical inventory needed to meet changeover frequency is required.

   2.) Redundancy of chemical sources and effects of system downtime should be considered at this stage.

      a. Two sources on an automatic changeover system can offer system redundancy.
      b. Specialty gases and chemical distribution systems must be automatic changeover capable.

   3.) Maximum allowable quantities for the control area / occupancy should be followed for existing construction. New construction exceeding maximum allowable quantities shall contain all code required engineering features.

      a. AE firm shall notify the owner of any exceedance. Resolution of exceedance may result in significant changes to facility design or changes to inventory of chemicals to preserve current occupancy.

b. The owner is responsible for having a hazardous material inventory statement to provide the project team with current quantities per control area in existing facilities.

4.) Chemical sources should be stored/used as close to where they are delivered to the building as possible to limit the transport of them within the building.

5.) When a high frequency of delivery is required to meet demand, consideration for sufficient unloading/loading dock access availability shall be considered.

a. A delivery dock capable of controlling an accidental release may be required. Provisions for accidental release are dependent on the form and quantity of HPM and must be considered during design.

F. Collection tanks must be sized to receive the anticipated waste volumes that require collection.

1.) Size must be coordinated with the waste collection/disposal frequency or waste treatment system they are associated with.

2.) Must be interlocked to prevent overfill from upstream equipment.

3.) Intermediary day tanks are permitted if required to meet capacity.

G. Abatement Systems

1.) Must be designed to abate the maximum credible scenarios for a leak and discharge emissions in compliance with all applicable codes and air permitting. Refer to Section 6.4 for additional details.

H. Plumbing Points of Use (POU)

1.) Need to provide the required pressure and flow for the application and perform to the design pressure and flow without impacting other connections to the system.

2.) Must be designed to provide lock out tag out capability.

3.) Is accessible without excessive ergonomic strain or ladders when possible, to ensure they are accessible for regular use.

a. Facility valves in the distribution system may be located in less accessible areas / overhead.

4.) Must be labeled.

5.) Needs to be sized based on benchmark peak and average flows.

6.) Do not affect the quality of the chemical. Provide filters as required to ensure purity.

7.) Should be located away from or protected from mechanical impact and tampering.

I. System sizing should include a safety factor exceeding the calculated flows for each utility to enable future expansion or modification of equipment.

J. Modifications to the existing facility systems require approval of the owner and affected tenants. Modifications will be designed to reduce downtime/impact on other tenants. The owner shall be notified as soon as possible of any impacts to areas out of scope.

7.1.2 Provide piping system riser diagrams for multi-level projects.

7.1.3 Ensure maintenance and accessibility provisions for servicing and replacement.

7.1.4 Where plumbing units are roof mounted or require roof openings, verify that all structural provisions are made to assure adequate capacity for load bearing and diaphragm capacity.

7.1.5 Do not route piping over any electrical rooms.

7.1.6 Identify and label all equipment and piping per ASU MTW facility specifications. Match existing site standards where possible. Follow CGA C-7 and / or SEMI F34-0998 labeling guides when no site standard exists.

7.2 House Equipment

7.2.1 Bulk gas systems can be provided as required. The tenant or the owner will be procuring or leasing all the bulk gas equipment required for House and Process N2, as well as any specialty gas supply as required. Scope boundaries between the chosen bulk gas vendor and the Design Build Contractor will be established during design when new systems or modifications are required.

7.2.2 The project team to evaluate whether bulk liquid source, pipeline, or onsite generation is required. The demand for the facility, quality requirements for N2, how many grades of N2 are required, and location of the facility will determine which approach is most suitable.

A. All sources of N2 will require filtration before distribution. The particle removal rating will be dictated by the sources' initial quality compared to POU quality requirements.

7.2.3 A bulk nitrogen system for both house and process nitrogen shall be provided.

A. Refer to CGA P-18 Standard for Bulk Inert Gas Systems

B. This system is to be accessible outside the building for bulk fill from truck service.

C. A bulk purifier for Process N2 will be part of the bulk gas yard equipment. From the bulk purifier, there should be analytical equipment to show purity of the Process N2 entering the main supply valve before it branches to sub-mains that supply the different areas of the cleanroom and labs. The gas vendor/supplier shall provide the footprint and utilities of the analytical equipment to the design team.

D. The House N2 supply from the vaporizers will bypass the analytical equipment and bulk purifier and will be plumbed directly to redundant filters and feed into the main House N2 pipe supplying the various parts of the cleanroom and labs.

E. The design includes a trestle or outside structural requirements, valve connection to the main pipe inside the building envelope, peripheral equipment, including analytical equipment of Process N2, from the bulk gas yard to the building penetration.

7.2.4 Bulk Gas System Components:

A. Vaporizers are required when flow will result in liquid flow into the piping network.

1.) Redundant vaporizers may be provided when a risk of freezing a single vaporizer exists. Redundant vaporizers are auto switched so that when one is frozen the other vaporizer can be online.

B. A concrete pad for tank and all system components. The concrete pad should be grounded.

C. Redundant bulk gas storage tanks to avoid downtime during refilling.

1.) The bulk gas vendor shall provide sufficient redundancy in the system to avoid downtime during maintenance or refilling of the bulk gas tanks. If the tanks cannot be refilled while online, a second tank or approved redundancy strategy is required to provide continuous flow of gases.

D. A bulk purifier may be required as part of the bulk gas yard contract. Purity will be defined by the owner’s/tenant’s client’s awarded contract. Analytical equipment, if needed, (post bulk purifier) shall be defined by the owner/tenant in the contract to be awarded to the bulk gas yard vendor/contractor.

1.) The purity of the liquefied gas sources will be determined when gas suppliers are engaged in the project lifecycle. The incoming purity of the liquid supply will be determined by the bulk gas yard vendor and tenant. They will determine if a bulk purifier is needed before the gas supply enters the building envelope to make it suitable for the user processes.

7.2.5 Additional considerations for the bulk gas yard:

A. This system is considered a long lead time item.

B. It is advised that the contract with the chosen gas bulk yard vendor/contractor should include a temporary connected nitrogen source at a ramped schedule if the bulk gas yard is not ready and operational by RFE (Ready for Equipment) date.

C. The bulk gas yard vendor shall own and comply to deadlines, code required setbacks, permits, certificates, and safety requirements as set forth by the local AHJ (authorities having jurisdiction), applicable CGA requirements and building codes, including NFPA and local/ jurisdictional codes set forth by the town, the local fire marshal, the county, and state of Arizona. If gaps in battery limit and/ or scope of work exist, the owner/tenant, bulk gas yard awardee and Design Builder shall ensure that battery limits and scope of work are re-defined to ensure that all gaps are closed and owned.

D. The project contractor will calculate the required ramp schedule for temporary House N2, Process N2 and specialty gases when:

1.) The tenant provides spec gas commissioning schedule.

2.) The tenant provides the tool move in schedule.

3.) A project schedule to RFE date is completed by the project team, more specifically, the timeline when gas lines will require supply of House and/or Process N2 for purging and commissioning.

E. A clearly delineated battery limit of piping and cost of bulk gas systems between the chosen bulk gas supplier/contractor and the cleanroom piping distribution contractor shall be defined in the contract awarded to the bulk gas yard supplier/contractor.

1.) The design considerations shall include subgrade trenching or overhead trestle to contain and support piping from the bulk gas pad to the building penetration point.

2.) Structural requirements

3.) Valve connection to the main pipe inside the building envelope

4.) Peripheral equipment, including analytical equipment, from the bulk gas yard to the building penetration.

5.) Distribution within the subfab

6.) Toxic gas leak detection and alarms

7.) Toxic and highly toxic gases: Entire length of pipe shall be double contained, and the bulk tank shall be double contained.

8.) Heat Tracing as required: Piping from the bulk tank will be heat traced until it penetrates an environmentally controlled area in the building and then throughout distribution close to point of use.

F. Setbacks for the bulk tanks are required for code compliance.

G. Limiting quantities on site to below OSHA Process Safety Management Program threshold limits.

7.2.6 Bulk Silane Components:

A. Refer to CGA G-13 – Storage and Handling of Silane and Silane Mixtures.

B. Silane use rate, including different mixtures of silane, shall be evaluated during design phase. Typically, ASU limits the amount of silane used for existing facilities but some tenants of future facilities may require this in their processes and chemistries. Some options for silane storage and distribution are as follows:

1.) Redundant silane sources sized based on demand.

2.) N+1 redundancy by silane mix type.

3.) 2-hour fire rated walls are required in between individual bulk gas source and between each gas source and their gas panels, as required by CGA-G13 publication.

4.) A 15-foot separation distance is required between each silane gas panel and their respective control panels, as required by CGA-G13 publication.

5.) Emergency shutoff buttons (ESO/EMO) must be placed near the silane sources and their process and control panels, as required by CGA-G13 publication.

6.) Provisions to maintain a minimum quantity of silane in the system.

7.3 Water Systems – Supply

7.3.1 DI Water System:

A. DI Water System will consist of a Reverse Osmosis plant producing 1 megohm water, a DI water make up system producing approximately 18 Megohm ASTM Grade E1.2 water and a DI water recirculation loop circulating E 1.2 grade water throughout the cleanrooms and labs. RO 1 Megohm water may be provided to some other systems in the building including cleanrooms and labs, and clean steam system for humidification of cleanroom air. RO/DI cast off water may be used to feed cooling towers and water-based scrubbers. Parts of the RO/DI water system may be in a building separately operated from the cleanroom building if required.

B. The DI water will be provided to the specifications listed below. The DI Water system shall deliver 18 meg-Ohm water. The DI System shall be capable of recirculating with redundant pumps and final filters. The system shall also be equipped with 2 buffer/return tanks constructed of polypropylene with a Nitrogen blanket. DI water quality requirements will need to be defined based on processes and will drive the need of components such as the N2 blanket. The size of tanks will be determined during design.

1.) SEMI F61, Guidelines for Ultrapure Water System used in Semiconductor Processing

2.) SEMI F63, Guidelines for Ultrapure Water used in Semiconductor Processing

3.) ASTM D-5127, Standard Guide for Ultrapure Water Used in the Electronics and Semiconductor Industry – E1.2 type water.

4.) ASU Laboratory Guidelines section 6. FF

C. System size is based on the expected demand plus a safety factor. Minimum consideration for system sizing is:

1.) Recirculation Flow and Velocity

2.) Make-Up Rate

3.) Pressure drops across the system and all individual components

4.) Supply pressure

5.) Tank Sizes

6.) Flow and Pressure Requirements

7.) Water quality needs to support each process at point of use (POU).

8.) Length of travel from source to POU to maintain process required water quality.

D. System configuration should be reviewed by the AE team during the design phase.

E. RO grade water will be distributed to cleanroom humidification system- as part of make-up air system.

7.4 Water Systems – Waste Treatment

7.4.1 Specialty or Hazardous Wastewater and other liquid waste treatment systems

A. All waste treatment and waste collection systems shall comply with local codes including but not limited to:

1.) Environmental Protection Agency (EPA)

2.) EPA Resource Conservation and Recovery Act (RCRA)

3.) ADEQ requirements

4.) Local POTW Requirements

5.) ASU Laboratory Guidelines section B.6.I, B.6.T, 6. FF.3

6.) Site waste permit

B. All hazardous production materials shall have a plan from cradle to offsite disposal.

1.) A gap analysis is required when new materials are introduced to the site to determine if new waste treatment systems or modifications to waste permitting are required.

C. Peak drain capacity for each system will be determined in design.

D. All collected waste shall be accumulated in the Material Accumulation Area according to the RCRA standards. (90-day maximum storage).

E. Waste streams are process specific. The size and type of waste treatment systems shall be evaluated during the design phase. Define additional waste streams as required to comply with all waste requirements. Typical semiconductor waste streams include but are not limited to:

1.) Acid Waste Neutralization (AWN)

2.) Solvent wastes

3.) Fluoride wastes

a. New sites must determine if the concentrated fluoride waste can be discharged to the AWN system and meet any discharge limits.
b. Square footage should be set aside for future system needs such as fluoride waste treatment and/or concentrated HF collection. While HF is not currently in ASU's existing facilities, this may be a requirement for future facilities and should be planned for and considered.

4.) Metal containing waste

5.) Slurry wastes

6.) III-V wastes

7.) Examples of waste sources

a. Rinse water from wet processing stations, developer and developer rinse water, effluent from wet local and house scrubbers, diluted concentrated acids and bases from wet processing stations that are not required to be collected. They may be collected in lift stations and sent to the pH neutralization system, pending confirmation that each waste is treatable by AWN.

F. Lift station redundancy shall be considered in the design to provide continuity of operations. Lift station redundancy may include redundant lift pumps and tanks depending on space, budget, and anticipated flow rates. Where zero down time is required, provide full lift station redundancy.

G. AWN System

1.) A centralized pH adjust only AWN system will be utilized for the entire site and may be located off site. The project team should recommend the most cost-effective, compliant options.

2.) All acid and base waste, both concentrates and rinse water, will be drained from the tool to a common waste drain in the subfab using gravity drains. From the subfab, a lift station may send the waste to an AWN system for neutralization.

3.) System design and operation may be provided by a third-party source.

4.) Total average water-based waste streams and peak demand will be determined during design. Additional waste treatment systems may be required if metal and "other" contaminant removal is required.

5.) The main AWN lift station will require a sump pump, tanks, and lift station in a fully lined pit (double containment) that will be lower than the floor and have capacity for peak flow x 15 minutes or 1 hour of average flow = 60 minutes x of average flow.

H. Solvent waste collection system - Solvent based chemicals and solvent base developers from wet processing stations and tracks:

1.) Shall be a grounded stainless steel drain system coming through the popouts to the subfab and connected to one or more solvent collection tank sets (auto switched) in a flammable cabinet with fill sensors, auto switch, and alarms. A solvent waste collection and accumulation area will be evaluated in Design.

2.) Tenants may opt for carboys to collect small volumes of solvent waste, which will require a carboy pump out station. The footprint of the carboys and the size of the solvent waste accumulation containers will require space in the cleanroom, sub-fab, labs, and in the flammable chemical room or waste accumulation areas.

3.) Bulk Solvent Waste Collection is required where the volumes of waste are too large for carboys or drums. Bulk solvent waste collection consists of day tanks which are emptied via vacuum pump trucks. Lift stations may be required to reach the bulk solvent waste collection tanks.

I. Concentrated HF wastes- HF (Fluoride) Waste collection system

1.) The current site does not have a need for or a system to handle concentrated HF waste. The design team must evaluate which method is feasible for the site when this waste stream is present.

2.) Evaluate if HF wastes can be treated and discharged back to the POTW. This is a highly unlikely process as the volumes of HF in academic and user fabs is low and very highly controlled. Need to discuss volumes of HF use and handling in fab to determine the best waste handling flow.

J. Metal Containing Waste from Plating systems - collection system:

1.) Copper and possibly nickel plating will generate metal contaminated liquid waste. The metal contaminated waste stream will collect concentrated plating baths that contain copper and other precious metals used in plating layers, such as nickel, tin, or gold. This waste stream shall be collected separately from other wastes since it can be collected and sent out for reclaim.

K. Slurry Waste Collection system

1.) The system will include a slurry collection tank and piping system coming from tools. Piping shall be used for the slurry drain, connected to an auto switch slurry drain drum system. This waste stream can be shipped out as hazardous waste.

L. III/V Drain collection.

1.) The system is required to collect waste from wet processing stations used to process GaAs-based wafers and/or other III-V-based wafers or wafer layers. This system will include a set of III/V drain collection tanks (auto switched with level sensors) connected to a liquid drain system. This waste stream needs to be evaluated since it may be part of other waste streams. If it is not part of another waste system, it may be possible to have the waste stream go through an Arsenic removal process. The effluent from the Arsenic removal process can be sent to the waste neutralization system before being discharged to the POTW. Evaluations will be needed to determine if this would be feasible and how many and what types of Arsenic, Gallium, and Indium containing waste will be collected and disposed of directly as hazardous waste, versus processed or filtered on site. Arsenic is heavily regulated so any effluent (concentrate or rinsewater) will likely have to be collected, then disposed of as hazardous waste OR treated by a filtration system.

M. All onsite waste treatment systems shall include double containment (pipe and trench inside building, double walled piping outside in leak proof trench sloped appropriately) and liquid spill sensors tied to the Gas monitoring and Control system and the Facilities monitoring system.

N. All gravity waste streams, except for solvent containing wastes, will be single wall Fuseal polypro to the lift station or collection tanks. Pressurized waste from lift station or filtration system discharge will be double wall Fuseal polypro to the pH neutralization system which may be in another building.

1.) Note: Sending corrosive waste off site to a third-party neutralization system could subject the ASU facility to be classified as a large waste generator under the provisions of the RCRA program. All lift station discharge lines will be required to have meters so that volumes can be tallied and tracked to meet RCRA requirements.

O. Pressurized corrosive waste will be coming from local wet scrubber systems. The waste stream will be distributed overhead and connected to the appropriate waste stream, identified above, for treatment and/or collection. Pressurized corrosive waste streams shall be plumbed in double contained Fuseal piping.

P. Industrial Waste lines shall be plumbed in single wall Fuseal polypro when under gravity flow. Industrial waste lines under pressure or overhead shall be double contained Fuseal polypro.

Q. Solvent containing waste stream will be single wall grounded 304 stainless steel tubing to the waste collection system.

R. For all drain piping, assumption is 1/8 inch per foot slope for gravity drains.

S. Design team to determine if the non-solvent based wastes can be treated on site and discharged through a neutralization system and discharged back to the POTW.

7.4.2 Waste Collection Systems

A. Central drum collection systems that automatically fill 55-gallon drums which are then hauled away as hazardous waste are required for waste streams using offsite disposal. The individual waste systems designated for collection will be connected to individual drum collection systems.

1.) Drum changeover frequency shall be estimated during the design and approved by owner/tenant. Excessive changeover frequency may drive the need for larger collection tanks.

B. The individual drum collection systems will have the following components:

1.) 2 x 55-gallon drums, auto-switched

2.) 110% spill containment

3.) Drum sensors that will sense if the drums are full and will trigger an auto switch to the next empty drum.

4.) Basic PLC for controls

7.5 Process Equipment

7.5.1 Process Vacuum System

A. Process Vacuum system will consist of a minimum of two pumps. Pumps are to be dry running, featuring two screw-type, non-contacting rotors and not require any sealing fluid, assuring virtually maintenance-free operation. Scroll pumps are also permitted.

B. System to be skid mounted when possible. Skid includes all components and receiver tank. Cooling media for the system will be evaluated as part of the design.

C. Compressed air at 80 psig to be supplied for controls and purge. The base should be pre-drilled, and the manifold pre-piped to accept additional pumps. The entire system is to be factory assembled and tested by the vacuum pump manufacturer to ensure that all performance specifications are met.

7.5.2 Clean Dry Air System

A. Clean Dry Air (CDA) system provided needs to meet ISO 8573.1 – Quality Class 1 requirements. CDA is air generated by a direct drive compressor. Redundancy for the CDA compressor is required.

1.) Evaluate the need for a separate Process Clean Dry Air (PCDA) system that has additional air purification for sensitive tools. This can be accomplished by adding additional purification equipment to the existing CDA system and/or POU filtration at the individual tool hook up.

B. System will consist of Compressor, Receiver, Air Dryers, and Filters to meet quality specification. System to be skid mounted when possible. Skid should include all components and receiver tank.

7.5.3 Process Cooling Water System

A. The Process Cooling Water (PCW) System will consist of redundant pumps and heat exchangers break tank, and final filters. Nitrogen blanket may be required for open tank system design to maintain water quality. The PCW system is to be skid mounted to minimize overall system footprint.

B. Water quality will be tool and process driven dependent. Water quality will be dictated by the most sensitive, or least resistant materials in the system. AE team should evaluate all tools and support equipment wetted materials for compatibility and to determine the highest purity that can be provided without causing corrosion.

C. The system shall be constructed of stainless steel for high quality water.

D. Redundancy to be N+1 OR 0.75 Nx2.

7.6 Piping Distribution

7.6.1 Refer to the ASU Laboratory Guidelines and Project Guidelines for additional piping requirements.

[Project-Guidelines.pdf (asu.edu)]

[Engineering-Design-Guidelines.pdf (asu.edu)]

[Laboratory Guidelines (asu.edu)]

7.6.2 Domestic and non-potable plumbing water systems (CW)

A. CW shall be distributed using copper piping with ball valves for isolation.

7.6.3 Hot Water (HW)

A. HW is to be distributed using copper piping with ball valves for isolation.

B. Insulation Required

7.6.4 Process Cooling Water (PCW)

A. PCW up to 4-inch diameter piping is distributed using type L or type K copper piping cleaned for Oxygen service, with ball valves for isolation. The entire system is 304 stainless steel, if use rate dictates larger than 4-inch piping. Any transitions in the system and distribution between Stainless steel and copper will require dielectric isolation of the metals.

7.6.5 Corrosion resistant corrosive waste and vent piping (AWN).

A. AWN needs to be distributed using PVDF Fuse-Seal piping- Note that detailed piping descriptions for other related systems are shown above.

B. Buried AWN piping is not permitted. All below grade AWN piping must be in trenches.

C. Vent piping can be polypropylene except in return air plenums outside of H-5 occupancy where it shall be PVDF.

7.6.6 House Nitrogen (HN2)

A. HN2 is to be distributed using type 304 or 316 stainless steel piping cleaned for oxygen service, using brass ball valves for isolation and balancing valves, up to 4-inch diameter. If demand requires greater than 4-inch diameter piping in any area, the entire piping system needs to be 304 stainless steel piping with stainless steel ball valves.

7.6.7 Process Nitrogen (PN2)

A. PN2 is distributed high purity stainless steel (316L) piping, using high purity diaphragm valves for isolation.

B. Where needed, POU filtration at tool hook up can be installed.

7.6.8 Clean Dry Air (CDA)

A. CDA is distributed using type L or type K copper piping, cleaned for oxygen service, using brass ball valves for isolation, up to 4-inch diameter. If demand requires greater than 4-inch diameter piping in any area, the entire piping system needs to be 304 stainless steel piping with stainless steel ball valves.

B. If CDA is to be used as part of any process, appropriate piping, conditioning, and filtration will be designed in accordance with the tool/process requirements.

7.6.9 Process Vacuum (PVAC)

A. PVAC is distributed using copper piping, using brass ball valves for isolation.

7.6.10 DI Water Supply and Return (DIS/R) 18 Megohm ASTM Grade E1.2 Water.

A. Piping materials must be of an acceptable grade for production of Electronics Grade Water GRADE E1.2, 18 MEGOHMS, as specified. Piping of the required grade needs to be available such that the deterioration of water quality from that type of material is minimal. Polyvinylidene fluoride (PVDF) supply and return piping contains no additives that could leach out and contaminate the high purity water. Piping materials will be verified in design for value engineering design alternatives such as polypropylene for the DI water return loop.

B. The internal surface finish on all PVDF pipes and fittings will have a smooth finish. Surface finish shall have a mean roughness value (Ra) of 5 microns or less. All pipe and fittings shall have a uniform appearance. Pipe and fittings with a dull surface finish are not acceptable. The intent of the smooth finish requirement is to minimize both pressure drop and bacterial growth.

C. Pipes and Fittings: Material: Virgin, natural Polyvinylidene fluoride as specified above, using no antioxidants or pigments. Schedule: 80. Fittings: Socket type, same material as pipe Joints: Butt Fusion – Bead and Crevice Free

D. Valves shall be diaphragm and must be ZERO dead leg.

E. Provide pressure reducing valves for balancing the system.

F. RO (reverse osmosis- 1 Megohm) water will be distributed in CPVC piping.

G. As an option to be developed during design, DI water return may be distributed in Polypropylene piping with verification that grade E1.2 water can be successfully produced.

H. Hot DI water may be needed for some process tools. A Hot DI Water distribution system in PVDF is to be provided, if required.

7.6.11 Specialty Piping

A. High Purity 316L Stainless Steel Single or Double Wall Piping for specialty gases

1.) Double Wall Piping for Hazardous/Toxic gases: Between the double wall containment -- a (carrier) tube within an isolated tube --, there is an inner wall isolation volume (IWIV) that is to be pumped down to 5 x 10-3 torr minimum and isolated. The pressure of the IWIV will be monitored with a pressure sensor, as specified for each gas type, by the TGM system. A rise in pressure will result in a signal being sent to the gas monitoring system, and response initiated per the TGM response matrix.

2.) The Single or Double Wall hazardous piping systems need to be constructed of high purity and consist of the following items:

a. Direct lines from gas cabinets or other dispense locations to valve manifold boxes, following piping routing.

3.) No valves or un-welded fittings in the double or single walled stainless lines that are external to gas cabinets and/or VMB's. Only welded single or double walled fittings will be permitted outside of the gas cabinets and/or VMB's. The entire line of single or double walled stainless is continuous and welded. Most VMBs for the cleanroom should be located in the subfab near the process equipment above.

4.) Process piping cannot add more than 0.5 ppm total hydrocarbons and add less than 8 particles (larger than 0.12 µm per CF) downstream of the filter, between tank and output of point of use. All carrier tubing shall be seamless, 316L stainless steel, ASTM A 214, ASTM A 269, ASTM A 632; hydrogen bright annealed, with a 0.00% to 0.017% maximum Sulfur content.

5.) All tubing meets ASTM A-262 Practice E for intergranular corrosion resistance.

6.) The project team must submit a matrix indicating which type of hazardous gas lines will be single walled, double walled, heat traced or not heat traced.

B. The Single Wall non-hazardous gas piping systems are constructed of high purity and consist of the following items:

1.) Direct connections from gas manifolds or other dispense locations to gas distribution system.

2.) Each non-hazardous gas distribution system consists of mains, sub-mains, and laterals in the subfab. Points of connection on the laterals may be connected to floor valve boxes and/or distributed to any cleanrooms on the raised access floor. In other cleanrooms and labs, as well as in the subfab, laterals may be extended to drops or racks near to individual tool locations requiring the system gas type. 10% spare valves, minimum of 1 valve, shall be included on each lateral. Each sub-main, lateral, and drop or floor valve box shall start with a valve. The entire line of single walled stainless is to be continuous and welded.

3.) Process piping will not add more than 0.5 ppm total hydrocarbons and add less than 8 particles (larger than 0.12 µm per CF) downstream of the filter, between tank and output of point of use. All carrier tubing is to be seamless, 316L stainless steel, ASTM A 214, ASTM A 269, ASTM A 632; hydrogen bright annealed, with a 0.00% to 0.017% maximum Sulfur content.

4.) All tubing meets ASTM A-262 Practice E for intergranular corrosion resistance.

5.) A Gas cabinet/VMB matrix should be developed during the design phase AE Designer to submit schedule indicating which gas lines shall be heat traced or not heat traced for nonhazardous gases.

C. All high purity stainless steel piping systems are to be helium leak tested and tested for purity as well as particles and certified before any tool is connected to any system.

D. The awarded contract for the owner's/tenant's chosen gas vendor/supplier includes temporary Helium and weld Argon supply and must meet the requirements of the site during the installation of spec gas and bulk gas piping distribution work, installation, and commissioning.

7.6.12 Gas/Chemical Distribution Equipment

A. Items for consideration:

1.) If the bulk gas yard contract and spec gas supply is awarded to the same supplier, the probability is high that the same vendor can offer discounted or "bundle pricing" for gas cabinets, gas manifolds and VMBs (valve manifold boxes).

2.) Most of these vendors also offer the additional capability of offering maintenance contracts for gas cabinets, gas manifolds and VMBs even if the gas manifolds, gas cabinets and VMB's are not their own manufactured equipment. This service can be priced separately or can be bundled with the bulk gas yard contract.

7.6.13 Gas Manifolds:

A. Supplier needs to design and carefully fabricate equipment in accordance with specifications, local codes, and shall use only highest quality materials to assure maximum structural, chemical, electrical reliability, and minimum particulate/contamination generation.

B. Manual manifolds are to be used for non-hazardous gas manifolds that are not in gas cabinets. Manifold components should be independently replaceable without the need to remove manifold from the manifold mounting plate. All manifolds must meet the quality requirements as specified. House nitrogen will not be used as purge gas; an on-board nitrogen bottle shall be supplied. Manual manifolds shall be manually operated, 4 valve manifolds.

C. Auto-switching refers to Automatic-Duomatic manifold control; it eliminates the need for reversing the regulator settings when one cylinder bank is emptied. Gas Manifolds that will auto switch to the full cylinder or full bank of cylinders are required to eliminate downtime.

7.6.14 Gas Cabinets and VMB's

A. Refer to the ASU Project Guidelines and Laboratory Guidelines for gas equipment requirements:

Project-Guidelines.pdf (asu.edu)

laboratory Guidelines (asu.edu)

www.asu.edu/ehs/design-guidelines/pressure-vessels-and-compressed-gas-cylinders.pdf

B. Cabinet Walls, door, and roof are to be constructed of 11 gauge, cold-rolled sheet steel. The deck is to be built of heavy, non-skid, corrosion-proof rubber flooring installed flush with the threshold and capable of resisting deformation by cylinder impact. The height of the cabinet accommodates cylinder scales, where required. Seams are welded, ground, and filled to match base material; sharp edges and corners shall be eliminated. Interior and exterior surfaces primed, and spray painted with a textured, readily cleanable, solvent-resistant, 2-component, cross-linked urethane gray finish capable of withstanding 500 hours of severe salt spray. Recessed holes in deck corners provided for anchoring enclosure to facility floor with 3/8-inch diameter screws. All four corners must have seismic bracing and be bolted to the floor and adjacent walls. Suitable interior lighting provided. A window should be provided. Air operated valves are to have their current status visible through the window.

C. Each gas cabinet needs to be equipped with a suitable-rated and approved wax-coated 68 degrees C (155 degrees F) fire sprinkler. A ½ inch male NPT fitting external to the enclosure shall be provided for connection to facility sprinkler water supply.

1.) Refer to NFPA 318 section 11.2.4 for requirements and exceptions.

D. Exhaust Port: A single 6-inch ID (one- and two-cylinder enclosures) or two 6-inch ID (three-cylinder enclosure) exhaust port (s) for connection to facility central exhaust provided on the enclosure's top surface. (Vendor may propose alternate exhaust ports)

E. All gas cabinets and hazardous gas dispense systems will have the capability of being fitted with a gas detection system as needed for the specific gas contained in the cabinet.

F. All gas cabinet manifolds, at a minimum, must conform to requirements listed.

   1.) All gas cabinet manifolds must be automatic manifolds.

   2.) All gas cabinet manifolds must have an RFO (flow restricting orifice) sized as specified and welded within the manifold as close to the cylinder connection as possible.

      a. Abatement units shall be sized to handle the maximum credible release from the RFO.

   3.) Each gas manifold will be equipped with 2 independent outlets.

   4.) Each outlet must have an independent shut off valve within the gas enclosure.

   5.) Each outlet must be capped with a welded cap exterior to the cabinet.

   6.) Each outlet must have an independent purge.

   7.) Heat tape will be used between the gas cabinet and point of use for low vapor pressure gases as required.

   8.) Heat tape will be used for gases that come from the bulk gas yard until it penetrates the climate and temperature-controlled building envelope as required.

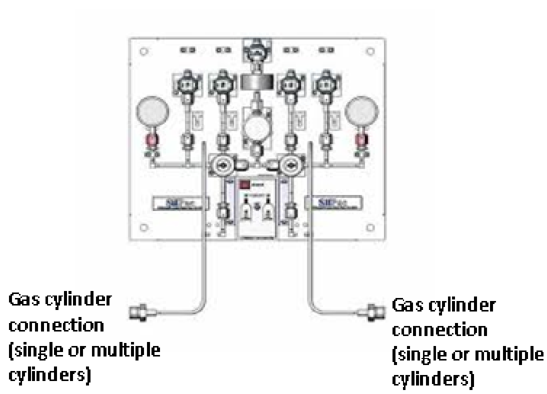


Figure 29- Gas Cylinder Manifold

Figure 30- Valve Manifold Boxes (VMBs)

7.6.15 Chemical Distribution Systems

A. The solvent dispense drum cabinet consists of a self-contained chemical cabinet with control area and pump area.

B. Cabinet to hold two 55-gallon drums, for supplying fresh liquid chemicals to a process tool.

C. The control area is mounted to the side and is to provide all the power and air services required for the chemical cabinet. This contains dry contact relays that communicate between the drum cabinet and process tools.

D. The dispense chemical will be pumped from each dispense drum to the process station(s).

E. Chemical distribution cabinets must be constructed of materials compatible with the chemicals being dispensed. Flammable chemicals must be in non-combustible cabinets.

F. Chemical distribution cabinets must have self-closing doors and integrated spill containment equal to 120% of the largest container.

G. Cabinets must have liquid level and alarms controlled through a PLC.

H. Cabinets must have Emergency Power Off (EPO), exhaust pressure monitoring, fiber optic leak detection in the spill containment, and hazardous location design if required based on chemical hazards.

8. Electrical Requirements and Considerations

8.1 Electrical Design Strategies

8.1.1 Power Design Strategies

A. As can be expected, semiconductor facilities require a large amount of power to run on a day-to-day basis for house and process systems, and while actual demand historically will be less for a facility with limited production capacity and R&D than a full production facility with 24/7 operations, the electrical system must be right-sized for expected loads for the foreseeable future, including emergency, redundant power, and future renovations and expansion.

B. The facility power systems shall be designed to also consider and include, as appropriate, applicable engineering standards as published by ASU for design guidelines. These guidelines include the following:

asu.edu/fm/documents/project_guidelines/Project-Guidelines.pdf
Engineering-Design-Guidelines.pdf (asu.edu)
Construction Manual for Architects, Engineers (asu.edu)

8.1.2 Power Categories

A. Normal Power

1.) The normal power for a semiconductor manufacturing facility or research center will be provided by a local utility.

2.) Normal power will supply energy to all components in the facility that use electricity as the normal power source, such as tools, tool supporting equipment, heating, ventilation, air conditioning, lighting, building receptacles, and other house loads.

B. Standby Power

1.) If normal power is lost (such as a utility outage), then standby power will be engaged.

2.) Legally Required Standby Systems are required by codes to illuminate pathways, or to power equipment that is not categorized as requiring emergency power, but whose failure could create hazards, hinder rescue, or hamper firefighting operations. These systems are known as Level 2, or less critical systems [NEC Article 701].

3.) Optional Standby Systems are not required by code and serve equipment whose failure will not impact life safety. These systems may be specified and installed to protect against economic loss or business operations. The optional standby system is less stringent from a code standpoint but can be "business critical." End users may choose to voluntarily apply the more stringent emergency and legally required standards, depending on their tolerance for downtime in the event of a utility outage [NEC Article 702]. Examples:

a. Facility equipment such as process cooling water, chilled water, waste treatment and collection, for supporting tools or process equipment or emergency power systems (e.g., chilled water supplying HVAC).
b. Building management system or applicable facility controls not already on emergency power.

4.) Standby power systems to use natural gas as a standby source. Use of diesel generators or other fuels as the prime mover for the standby generator shall comply with applicable ASU standards.

5.) A stand-by generator may be provided for non-mandated emergency loads identified by the project team during design. Any distribution system should accommodate potential standby systems for initial construction or for potential addition at a later date.

C. Emergency Power

1.) Emergency systems are lifelines for people; therefore, life safety systems must be supplied by emergency power. These systems include fire pumps, smoke detection, gas monitoring, fire alarms; elevators; public safety communication; exit lighting; as well as air handling units (AHU), makeup air units (MAU), exhaust fans; and processes where power interruption would produce serious life safety or health hazards.

2.) Upon loss of normal power, emergency power must be available within 10 seconds [NEC Article 700.12].

3.) In an emergency, it is difficult to control loads administratively. Thus, the emergency system must be able to supply all emergency loads simultaneously.

4.) If the emergency power source also supplies standby power or other nonemergency loads, the emergency loads take priority over the other loads. Consequently, the system may drop other loads to support the emergency loads (load shedding).

5.) An emergency system power source must have adequate capacity to safely carry all emergency loads expected to operate simultaneously [NEC Article 700.5]. If an alternate power source has adequate capacity, it may be used to supply emergency loads [NEC Article 700], legally required standby loads [NEC Article 701], and optional standby system loads [NEC Article 702]. However, if the alternate power source lacks adequate capacity to carry the entire load, it must have automatic selective load pickup and load shedding to ensure adequate power — in this order of priority:

a. Emergency circuits
b. Legally required standby circuits
c. Optional standby circuits

6.) Emergency power systems commonly employ uninterruptable power supply (UPS) units, storage batteries, flywheel generators, fast-starting generators, or similar devices as a power source.

7.) A portable or temporary alternate source of power must be available whenever the emergency source is out of service for major maintenance or repair [NEC Article 700.4]. The alternate source may be another back-up generator, a storage battery set, fuel cells, or another alternate power source capable of supplying the emergency loads for the duration of the maintenance or repair.

8.) Emergency systems will need power transfer equipment. Transfer equipment must be automatic [NEC Article 700.6]. Therefore, an emergency panel which supplies emergency loads must be connected to an Automatic Transfer Switch (ATS) which will normally receive power from the utility but switch to the emergency power source if the utility power is lost.

9.) Transfer equipment must supply only emergency loads. Multiple transfer switches must be used if a single generator supplies emergency loads and other loads.

10.) Individual unit equipment such as emergency lighting with battery packs may be used but must have:

a. Rechargeable battery and charging means.
b. Provisions for one or more lamps mounted on the equipment, or terminals for remote lamps (or both).
c. Relaying device arranged to energize the lamps automatically upon failure of the supply to the unit equipment.

D. Mission Critical Power

1.) Systems that require both uninterruptable power (UPS) and standby or emergency power are mission critical.

2.) Provide Mission Critical power for the following:

a. Tools, process equipment, manufacturing equipment, support equipment (e.g., chillers, heat exchangers, pumps) as defined by the owner
b. Makeup air units (MAU), exhaust fans

c. Mission Critical Receptacles

8.2 Electrical Systems

8.2.1 Power Sources

A. Utilities

1.) Normal power is provided by a local electric utility. A voltage level of 13.8kV, 12.47kV, 4,160V, 2,300V, or 480V 3-phase may be provided. If 480V is provided by a utility owned transformer, the power is connected to the facility switchgear. If higher voltage is provided by the utility, a step-down transformer will be needed to reduce the voltage for connection to the facility switchgear.

2.) The utility should provide a fully redundant switching arrangement within the utility substation. Switches and transformers should be loaded to 50% max, which would allow the entire facility to run safely on a single transformer during maintenance and unexpected outages.

3.) The feeds to the onsite substation should be from two separate upstream distribution substations offsite to provide the means to run the facility if one offsite substation experiences an outage.

4.) Standard voltage swing by the utility is +/-5%. Confirm what local utility will provide. All infrastructure needs to accommodate this swing, else provide power conditioning.

5.) The power factor should be kept above .95 for equipment to use the power efficiently. If the power factor falls below certain limits, usually 0.95 or 0.9, the utility may include extra demand charges via fees, penalties, or other methods.

6.) The distribution system design needs to include capacitor banks in the event the power factor is too low. The capacitors pull the electric current back into phase with the voltage. After the necessary calculations, a cabinet containing the required capacitors can be installed at a convenient location in the electrical system. This solution is comparatively inexpensive and needs no maintenance. The goal for the facility design is to maintain operations and demand around 5% above the utility power factor that would incur penalties on power demand bills.

B. Generator

1.) If power from the utility is lost, selected components and/or systems will need power restored quickly, so back-up generators can be included for emergency or standby power. The distribution system for emergency power must be set up to comply with all code requirements for equipment identified to be on emergency power.

2.) A generator (sized per NEC Article 700.5) must automatically start the prime mover when the normal service fails.

3.) Any onsite generators shall be sized for code-required loads at the minimum. Where internal combustion engines are prime movers, an on-site fuel supply must provide not less than 2 hours of full-demand operation of the system per the NEC; however, industry best known method for semiconductor manufacturing facilities is to have fuel for 24, 48 or 96 hours (about 4 days).

4.) If an outdoor-housed generator has a readily accessible disconnect within sight (and within 50 feet) of the structure, an additional disconnect is not required at the structure for the generator feeder conductors that serve or pass through the structure.

5.) Two generators may be considered for required standby loads and optional standby loads.

6.) Roll-up Generators can be considered for special building conditions - Some buildings install a permanent exterior connection so it is easy to roll up a temporary (campus owned or rented) generator and plug it into the emergency circuits - however, an adequately sized breaker, meant to accommodate the critical loads in a building, must be provided within the main switchgear. A separate section with key interlocks can be provided, or a remote disconnect can be provided to allow for the safe and efficient connections of a temporary generator. Options on where the breaker is located and how connections are made should be determined on a project-by-project basis.

C. Uninterruptable Power Source (UPS)

1.) When tools, support equipment, data servers, or other facility equipment must not have an interruption of power, an uninterruptable power supply must be employed to provide constant (continued) power even during a utility outage.

2.) UPS should be provided for any main server rooms and IDF rooms within the facility.

3.) When a UPS (with storage batteries) is provided, the UPS must be of suitable rating and capacity to supply and maintain the total load for 90 minutes, without the voltage applied to the load falling below 87.5% of the normal level [NEC Article 700.12(A)].

a. UPS supporting specific tools or process equipment may require longer durations. Coordinate with owner on specific requirements.

4.) The UPS units should be located in the main electrical room or in another secondary electrical room closest to the point of use.

5.) Provide lithium-ion battery type.

a. Valve Regulated Lead Acid (VLRA) type will require justification and special approval by the owner.

D. Power Conditioning

1.) Provide power conditioning based on tool vendor requirements. Determine if central or point of use is required based on project needs. UPS may be used in lieu of power conditioner.

8.3 Major Electrical Equipment

8.3.1 Switchgear

A. Planning redundancy in the design will help ensure a reliable system. As noted above, the design should provide two independent feeds from the utility attach to independent buses or two sections of a bus with a normally open tie breaker between. If one power source is lost, the tie breaker will connect the redundant source.

B. ASU-owned switchgear shall be fully redundant with design loads to be no greater than 50% capacity typically. Matched switchgear and substations shall be connected via a manual tiebreaker in the event of an outage to one substation with its associated feed from offsite. Physical separations to be incorporated for potential maintenance that comply with NFPA 70E.

C. All distribution substations for 480V and 208V power will be completely redundant with manual tie breakers. They should also include power monitoring and software for analysis. Software should be similar to Square D's PowerLogic as a basis of design.

D. The Main Distribution Panel (MDP) will receive the incoming voltage from the utility, as described above from a redundant and independent source system. The MDP will distribute power to one or more panelboards and to motor control centers. The incoming voltage is provided in three phases; the building loads (downstream including tools, supporting, and house loads) to be diversified evenly across the three phases. Balance load to within 5% between phases. MDP must only be loaded up to 50%.

E. The MDP will include a main circuit breaker or an automatic/manual interrupter switch for the incoming power, plus circuit breakers for the branches.

F. The MDP to also include instruments for monitoring voltage, current, power, and frequency, as a minimum. Memory or graphs are useful for recording the history of power characteristics. These instruments to be IP addressable to be useful for data collection.

G. Panelboards distribute power to smaller electrical panels and step-down transformers. This power is used to energize tools, supporting equipment, and other house loads, including small (less than ½ HP) motor loads. Compliance with the NFPA 70E guidelines is critically important for companies and their workers, as lack of compliance has resulted in many workplace accidents.

H. Motor Control Centers (MCC) supply power to larger motor driven loads such as fans and pumps.

8.3.2 Transformers

A. Electrical power can be provided at different voltage levels. Most semiconductor process tools and support equipment require supply voltages of 120V, 208V, 240V, 277V, and 480V, which are common in industry. Provide a step-down transformer to bring the utility voltage down to 480V. The facility will also require additional transformers to make available the other lower voltages required by the tools and building equipment. The usual transformers required are:

1.) 480Y/277V to 240V/120V

2.) 480Y/277V to 208Y/120V

B. The above are common transformers, however, lead time from order to delivery may vary depending on the size (power) of the unit.

C. Some tools require voltage levels different than the common levels, which will require a special-order transformer, usually with long lead times.

D. Transformers to be of explosion resistant, fire resistant, air insulated, dry type construction, cooled by the natural circulation of air through the windings. Only copper windings are permitted.

8.3.3 Panels

A. Electrical panels provide power distribution to tools, support equipment and other house loads such as lighting and receptacles. Panels are grouped according to the voltage level distributed and can be varied sizes according to maximum power capability in kilovolt-amps (kVA).

B. Usual panel voltages are:

1.) 208V/120V

The 208V/120V panels are 3-phase panels, fed by four wires: all three phases in “wye” configuration plus a neutral at the common connection point. The voltage from a line to neutral is 120V, and from line to line is 208V. They may include 1-pole breakers for 120V single-phase loads, 2-pole breakers for 208V single-phase loads, and/or 3-pole breakers for 208V 3-phase loads. These panels normally distribute power to a receptacle or directly to equipment.

2.) 240V/120V

A 240V/120V panel is fed by two hot lines and a neutral (center tap), such that the voltage between either of the lines and neutral is 120V single-phase, and between the two lines is 240V single-phase. A 1-pole breaker is used to supply 120V loads, and a 2-pole breaker is used to supply 240V loads. The distribution design may connect either of these voltages directly to equipment, a disconnect switch, or to a receptacle.

3.) 480V/277V

The 480V/277V panels are 3-phase panels, fed by four wires: all three phases in “wye” configuration plus a neutral at the common connection point. The voltage from a line to neutral is 277V, and from line to line is 480V. They may include 1-pole breakers for 277V single-phase loads, 2-pole breakers for 480V single-phase, and/or 3-pole breakers for 480V 3-phase loads. These panels normally distribute power directly to equipment, to a disconnect switch, or to a receptacle.

C. There may be an occasion that will require a specially made electrical panel. Example: 400V for international equipment.

D. A lighting panel may be as simple as an electrical distribution panel designated for lighting, or purpose-built panels for indoor/outdoor lighting to include a main circuit breaker, switches, short-circuit protection, and may include batteries, timers, LED indicators and other features customized per the owner requirements.

E. Emergency and/or standby panels supplying emergency loads must be separated from the normal power panels, with only emergency loads connected. These panels may consist of all the previously mentioned voltage levels.

F. All distribution panels shall have a main breaker provided in the panel per ASU standards.

G. The electrical distribution panels are to be named and labeled as per the ASU standards.

H. Ground fault protection should be provided at the building's main breaker(s) as well as on any breakers larger than 480V 1000A.

I. An Arc Flash study and resulting label to be applied to all the electrical panels. The Arc Flash study may be performed by the responsible engineer, the installation contractor, or a third-party consultant.

J. Provide software for calculating and modeling loads, and include normal, overload, and short-circuit calculations. The same or additional software to include arc flash calculations. The basis of design needs to state that the software must be as non-proprietary as possible and that it has broad industry-wide acceptance.

8.3.4 Cabling

A. All cable should be constructed of copper wire.

B. Medium voltage (13.8kV to 480V) cables to withstand at least 15kV with stranded copper conductor and ethylene-propylene polymer (EPR) insulation.

C. Low voltage (480V and less) cables to withstand at least 600V with stranded or solid copper conductor and THHN/THWN 90°C insulation for indoor applications; THWN-2 or XHHW-2 90°C insulation for exterior, wet, or damp locations; or RHW-2 90°C insulation for areas subjected to temperatures exceeding 60°C.

D. All cables will be sized by the electrical engineer on the project team, however the minimum cable size for power circuits should be 12 AWG.

E. For EMI sensitive areas, twisted pairs of conductors are required for loads larger than 20A.

8.3.5 Raceways:

A. Trays

1.) Cable tray systems shall be permitted to support the service-entrance conductors. Cable trays used to support service-entrance conductors shall contain only service-entrance conductors [NEC 230.44].

2.) Install corridor cable trays with sufficient clearance from ducts, beams or other obstructions that will hinder access.

3.) Any penetration of fire rated walls shall use intumescent pillow penetration device for cable tray installations.

4.) It is recommended that cable tray capacity does not exceed 40%.

5.) Cable trays for power conductors are not permitted within 50 linear feet of any EMI sensitive areas.

B. Conduits

1.) The best conduit for manufacturing facilities is Electrical Metallic Tubing (EMT) or Intermediate Metal Conduit (IMC).

2.) Flexible metal conduit (FMC/LFMC) is acceptable for up to 6-foot maximum for final terminations to light fixtures and vibrating equipment, or vibration-isolate equipment.

3.) A minimum of ¾” conduit required for interior applications and 1” minimum for exterior applications.

4.) No more than 6 current-carrying conductors (3-hot and 3 neutral) allowed in a common conduit.

5.) Conduit routed within 50 feet of EMI Sensitive areas require Rigid Galvanized Stell (RGS) or Rigid Metal Conduit (RMC).

8.3.6 Electrical Rooms

A. Main service equipment inside the building to be located in a space designated as the Main Electrical Room. The main electrical room must have at least two points of exit, one must be a double door minimum of 6 FT clear opening. The main electrical room must have direct access to the corridor(s). All doors must swing in the path of egress. Consider acoustics including the partition walls sound insulation ratings.

B. Within the main electrical room's design, consideration should be taken to maintain proper clearances of all equipment. The minimum clearance for most equipment is 4 feet in front. Equipment containing heavy maintenance parts should be provided with additional clearance.

C. Electrical rooms to be sized to include a minimum of 20% usable space for future electrical equipment.

D. Provide a path to remove and replace large equipment. All equipment, regardless of size and lifespan, should be assumed to require replacement at least once in the building's life.

E. Locate the main electrical room in an area with no kitchen, café, or any type of cooking/warming establishments; no restrooms or water closets; or no waste or waste disposal rooms located above.

F. The main electrical room should not have water or waste pipes running through it, regardless of the height at which such pipes are located.

G. Leak detection should be provided in the main electrical room if located at or below grade.

H. Provide EMI shielding when electrical room is located within 200 FT of an EMI Sensitive space. EMI shielding requirements to be evaluated and may include a combination of welded aluminum and steel.

8.4 House Power Requirements and Considerations

8.4.1 Consider the following loads when sizing electrical distribution.

8.4.2 Heating, Ventilation, and Air Conditioning (HVAC)

A. The HVAC requirement will consume a substantial percentage of the building power.

B. The systems will be designed in the mechanical section; however, power will need to be supplied.

C. Most systems use 480V, 208V or 120V.

8.4.3 Lighting

A. Overhead room lighting typically uses 277V.

B. New buildings to be designed using LED fixtures typically.

C. Exit signs to be LED fixtures.

8.4.4 Receptacles

A. General purpose receptacles: 120V duplex or quadplex.

B. Special purpose receptacles for tools and supporting equipment may be required. These can include locking receptacles or custom provided by equipment vendors. Evaluate individual tool or equipment requirements.

C. Flammable or combustible gas, liquid, and solid storage HPM rooms require Class 1, Division 2 rated receptacles.

9. Controls and Monitoring

9.1 General Requirements and Considerations

9.1.1 All controls and monitoring provided for the facility's Building Automation System (BAS) should be a modern robust system that can provide statistical process controls.

9.1.2 The system will be a complete control and automation system capable of maintaining the environmental standards of each space of the facility. The system is to be composed of microprocessor based direct-digital controllers and associated devices.

9.1.3 Alarms, setpoints and conditions will be monitored and controlled via operator software and workstation with graphical interface. The controllers and equipment hardware are to be either industrial programmable logic controllers (PLC) or commercial grade HVAC building automation controllers. All devices shall be capable of communicating on industry standard protocol via TCP/IP and internet connections. The system should be able to receive signals (hardwired) from the TGM and Fire Alarm system.

9.1.4 Products requiring electrical connection shall be UL listed and classified as suitable for the purpose specified and indicated.

9.1.5 AE team to coordinate cleanroom controls requirements with the building system referred to in Division 25 of the ASU project guidelines.

Project-Guidelines.pdf (asu.edu)

9.2 HVAC Controls Requirements

9.2.1 Cleanroom controls of HVAC equipment are critical to keep the fab environment running correctly and will be monitored at multiple locations.

9.2.2 Temperature and Humidity Controls

A. Temperature and humidity sensors shall be located and orientated to monitor all critical temperature requirements.

B. Tolerance and accuracy to be equal or better than the most stringent tool or process requirement.

C. In general, the cleanroom space sensor should be located at or near the cleanroom return. Cleanroom size (area) and orientation may require averaging temperature sensors.

9.2.3 Pressurization

A. Multiple cleanroom spaces or large cleanroom areas are typically pressurized by “cascade” pressurization. Cascade pressurization is a system or strategy by which pressure sensors in physically separated or distinguished spaces are measured and monitored such that each space has a higher or lower pressure than the adjacent space(s).

B. Cascade Pressurization Requirements

1.) "Zero Reference" sensor is required for the 'non-clean' area as reference pressure. The space and sensor should be located such that pressure is constant or nearly constant without fluctuation or influence from outdoor air or drafts. Elevator shafts will not be acceptable for the Zero Reference sensor/location.

2.) "Most Critical" sensors are required for the most critical space. Typically, this space will have the highest or most stringent cleanliness.

3.) The most critical sensor will cascade, for example, to 0.5" wg above the "Zero Reference" space. The exact value should be calculated by the AE team to meet the design requirements.

4.) All other clean spaces with lower cleanliness ratings will cascade, for example, by 0.1" wg below the most critical space/sensor. The exact value should be calculated by the AE team to meet the design requirements.

9.3 Electrical Controls Requirements

9.3.1 All control equipment and devices associated with normal operations and/or life safety systems must be provided with appropriate power (low voltage or higher) and circuited accordingly.

10. Life Safety Requirements and Considerations

10.1 Facility Life Safety Principles and Goals

10.1.1 Any new facility must place the principle “Design for Life Safety” as a major priority and criteria for evaluating all design decisions and making appropriate selections.

10.1.2 Due to the expected and nature of the materials needed in the semiconductor manufacturing process, even in limited production or R&D, it is critical that facilities be designed to be as robust as possible and consider the safety of the occupants in addition to preserving the facility and all associated products and research. The building codes and standards typically utilized in the semiconductor industry must be understood and incorporated to provide a safe working environment that minimizes risk to persons and property.

10.1.3 The following responsible parties are typically part of the decision-making team that works with any design team for reviewing and providing guidance and boundaries that inform any new facility design:

1) Users- Facility Maintenance Team, Researchers, Students, Tenants, Visitors

2) Faculty- Department Chairs, Deans, Adjacent Researchers, Provosts

3) CPMG/OUA- Project Managers, Architects, Engineers

4) EHS- Environmental, Health, and Safety

5) FM- Facilities Management

6) AHJ- Authority Having Jurisdiction

7) FD/FMO- Fire Department/Fire Marshal

8) DEQ- Department of Environmental Quality

10.1.4 Hazardous Process Materials (HPMs) as noted in the sections above, must be all considered and evaluated per the following criteria:

1) Types- Gas, Liquids, or Solids

2) Hazard Categories, Maximum Allowable Quantities (MAQs)

3) In-Use vs. Storage

4) Point of Use or Bulk Storage and Required Abatement

5) Storage and Dispensing Locations (In-Building or Separate Buildings)

10.1.5 HPMs also need to be considered carefully for their measures of hazard (PEL, TLV, IDLH, LFL, and STEL) and their SDS or Safety Data Sheets

10.1.6 Additional design features may need to be incorporated into the facility design depending on the wide variety of HPM hazards such as:

1) Gases- C1/D1 or C1/D2 for Flammable Gases Required?

2) Liquids- Spill Containment and/or Liquid Leak Detection Required?

3) Solids- Dry Fire Protection System for Pyrophoric Dust Required?

10.1.7 Identifying either confirmed or predicted HPMs that can be expected to be needed for the typical semiconductor processes early in any new facility design drives safety and key decisions- “Planning for the Future” is paramount.

10.2 Fire Alarm Requirements and Considerations

10.2.1 The fire protection systems shall be provided by a fire protection designer/installer licensed in the authority having jurisdiction for the project.

10.2.2 The fire alarm system must be a robust and modern addressable system that meets all local code requirements and applicable ASU standards in the following guidelines:

Project-Guidelines.pdf (asu.edu)

Engineering-Design-Guidelines.pdf (asu.edu)

10.2.3 One goal for all fire alarm systems specified is to extend its end-of-life (EOL) out as much as possible into the future. Alarm systems that are easy to expand and/or upgrade should be considered to minimize future downtimes to the facility.

10.2.4 Very Early Smoke Detection System (VESDA) located to detect smoke in very high air change conditions such as those which exist in Class 10 and better cleanrooms should be added. This system will be in an accessible area and will be connected to the Fire Alarm and Fire protection system. Typically, VESDA is located in return air streams such as in return air chase inlets, at return air filter locations for recirculating air handling equipment, and/or in the subfab in return air streams in the high bay areas.

10.2.5 The following NFPA codes and standards are applicable for semiconductor facilities-see below:

National Fire Protection Association (NFPA) codes & standards

- ONLY specific articles out of 100's of code sections are law.
    - NFPA 13 - Standard for the Installation of Sprinkler Systems
    - NFPA 30 - Flammable Material Storage
    - NFPA 70 - National Electrical Code®
    - NFPA 72 - National Fire Alarm and Signaling Code
- Not all NFPA articles are law but can be used as guidelines.
    - NFPA 318 - Standard for the Protection of Semiconductor Fabrication Facilities
    - NFPA 484 and 654 – Fire protection combustible metals

Figure 31- Typical NFPA Standards for Cleanroom and Fab Facilities

10.3 Fire Suppression System Requirements and Considerations

10.3.1 The fire suppression system for a new facility should be sufficiently sized and specified to meet applicable code requirements as well as all established ASU standards per the guidelines below:

Project-Guidelines.pdf (asu.edu)

Engineering-Design-Guidelines.pdf (asu.edu)

10.3.2 The existing available water pressure to any new project site shall be evaluated with flow tests for domestic and/or fire water flows to determine if dedicated fire water booster pumps may be required to meet flow and coverage requirements for the facility.

10.3.3 If existing water pressure flows from the utilities are determined to be not meeting requirements, onsite fire water tanks with dedicated pumps will need to be provided. Dedicated pumps shall be diesel-powered and shall be on emergency power.

10.3.4 Fire piping distribution between buildings needs to include any post indicator valves (PIV) at the facility site.

10.3.5 The fire suppression system shall comply with NFPA 1 – Fire code, NFPA 13 – Standard for the Installation of Sprinkler Systems and all other applicable codes in the jurisdiction.

10.3.6 While it is standard practice and typically required by most codes to provide dedicated sprinkler drops to this equipment, ASU has a variance granted with the City of Tempe Fire Marshal that allows non-sprinklered gas cabinets and VMBs per the cited code reference IFC 5003.8.5. NOTE: if any new facility is located outside the city of Tempe, gas cabinets and VMBs will be required to be provided with dedicated sprinkler drops per code section IFC 5003.8.5.3 unless a similar agreement is reached with the appropriate AHJs in any jurisdictions outside of Tempe, AZ.

10.3.7 Suppression systems are not required in the specialty exhaust ductwork since all materials for these systems shall be non-combustible and/or approved flame/smoke retardant materials for ASU standards.

10.3.8 A separate pre-action system may be provided for the cleanroom for protection of expensive tools in this space. This may be single or double interlock, depending on budget and requirements of/tenant and/or insurance carriers.

A. Alternative methods may include carbon dioxide, water mist, and clean agent extinguishing media. Designs shall comply with applicable codes:

1.) NFPA 750 Standard on Water Mist Fire Extinguishing Systems

2.) NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems

3.) NFPA 12 – Standard on Carbon Dioxide Extinguishing Systems

10.4 Gas Monitoring Systems

10.4.1 Toxic Gas Monitoring Systems (TGMS) shall comply with IFC Chapter 27, NFPA 318, NFPA 55, and all other applicable codes in the jurisdiction.

10.4.2 Refer to the ASU Laboratory Guidelines additional requirements.

Laboratory Guidelines (asu.edu)

10.4.3 This system will be a complete toxic gas monitoring system that can detect toxic gas leaks, including those for corrosive, VOC, pyrophoric, and/or flammable systems and equipment. In addition to monitoring for hazardous gas leaks, the system will be capable of detecting inadequate exhaust conditions in gas dispensing equipment and monitoring for spills in specified locations. Exhaust loss or inadequate exhaust is monitored by exhaust switches on VMBs, TIBS, gas cabinets, and purifiers. The system will be able to take the appropriate actions to notify the appropriate personnel and to initiate the appropriate evacuations. It will be tied into the Fire Alarm System and Facilities management and control system. All Gas detections above the programmed alarm setpoints are gas system shutdowns to the specific piece of equipment.

10.4.4 Gas monitoring in the Breathing Zone/Ambient locations are building evacuation Horn/Strobe programmed with gas system and/or VMB shutdowns. Exhaust locations are supervisory notifications with gas system and/or VMB shutdowns.

10.4.5 The preferred system shall be a TCP/ICP POE based electro-chemical system or match existing site system.

10.4.6 The system must be flexible and expandable to allow for the phasing of equipment and changes as gas detection requirements change. Gas monitoring identification matrix and equipment shutdown matrix must be maintained as well as site maps of building monitoring locations.

10.4.7 Materials must be compatible with the contact chemicals within the specific system. Specify the exact size of sensors and access needed (through walls, in chase, wiring, etc.). Sampling points are to be separated from the display unit so that the gas level reading can be viewed from outside of the detection zone.

10.4.8 System components must be cleanroom compatible if it is located within the cleanroom envelope. Systems must not introduce contamination to the room.

10.4.9 All electrical components that are installed in the HPM pyrophoric/flammable rooms must meet the NEC Class I, Division 2 electrical requirements. This includes all annunciation devices, manual pull stations, sensors, sensor transmitters, sampling pumps, input modules, output modules, and power supplies that are located inside these rooms.

10.4.10 All TGM components installed outdoors, such as on the roof or around the dock and bulk gas areas, must be rated for outdoor use.

10.4.11 All connections must be in English units unless otherwise specified. All gas monitoring units must be clearly marked and identified as to location of monitoring.

10.4.12 Uninterruptible power supplies (UPS) shall be provided for the toxic gas monitoring and Alarm system, to include the controller and all PC's associated with the system. UPS shall provide sufficient power to provide two hours of monitoring and control or sufficient time to transition to emergency power from an emergency power generator.

10.4.13 Emergency power for the TGMS is required by code.

10.4.14 Flammable and pyrophoric gas cabinets and VMBs and solvent wet hoods will include a UV/IR sensor for flame detection and will be connected to TGM and Fire Alarm.

10.5 Other Life Safety Systems and Considerations

10.5.1 Signage

A. Refer to the ASU Standards for signage contained in the links below:

Laboratory Guidelines (asu.edu)

Project-Guidelines.pdf (asu.edu)

code-required-building-signage-checklist.pdf (asu.edu)

ASU-Accessibility-Standards.pdf

www.asu.edu/ehs/design-guidelines/hazardous-material-storage.pdf

www.asu.edu/ehs/design-guidelines/flammable-liquid-storage-cabinets.pdf

B. Gas monitoring units shall be labeled to indicate the building identifier, alarm type, gas type, equipment ID, location, and owner.

11. Telecommunication Requirements and Considerations

11.1 Information Technology System Requirements

11.1.1 The facility should incorporate applicable ASU standards for information technology (IT) and communications from the following guidelines:

Project-Guidelines.pdf (asu.edu)

Engineering-Design-Guidelines.pdf (asu.edu)

Enterprise Technology Telecommunications and Design Standards

11.1.2 Backup power must be provided to all IDF and data closets for the facility for utilizing VOIP phones during emergency events.

11.1.3 A number of “hard” lines should be provided to the facility front desk and security/command station. Refer to the ASU standards for additional information.

11.1.4 The facility should have sufficient network coverage to provide sufficient cellular coverage throughout the facility in all areas.

11.1.5 The cleanrooms and supporting spaces shall be provided with appropriately located and a reasonable degree of dedicated and convenient data ports for use by equipment and any other items requiring access to the customer networks and hubs. The cabling types and port quantities needed typically must be discussed with customer's leads during the design phase. Routings of conduits and ladder racks for cabling need to be coordinated for main and distribution runs.

11.1.6 The facility should include provisions to accommodate wireless radio vendors with sufficient space and power and IT infrastructure to have complete coverage for 2-way radios throughout the facility, including all points on the site. The facility shall also consider and include applicable code requirements for allowing first-responder radios to function completely and normally throughout the site in an emergency. This may include working with local wireless radio vendors during the design phases.

11.2 Security System Requirements

11.2.1 Security standards shall follow the applicable guidance denoted in the ASU Design Guidelines as follows:

Project-Guidelines.pdf (asu.edu)

11.2.2 Security systems include but are not limited to the following systems, components, etc.

A. Live monitored cameras

B. Motion Sensors

C. Card Readers

D. Door Position Switches

E. Audible Alarms

11.2.3 Security systems shall be coordinated with the building's fire alarm and automation systems to meet code requirements for safe egress of all areas and designating key openings in barriers as either FAIL OPEN or FAIL SECURE.

12. Sustainability

12.1 Sustainability Targets and Goals

12.1.1 ASU's current mandate is all new construction shall be designed to meet the criteria to achieve LEED Silver certification at the minimum as defined by the guidelines set forth by the US Green Building Council (USGBC).

12.1.2 Sustainability design measures for new facilities should be incorporated as applicable per the following ASU guidelines:

Sustainable-Design-Guidelines.pdf (asu.edu)

Solar-Alternative-Energy-Design.pdf (asu.edu)

12.1.3 The LEED Lab criteria as defined on www.usgbc.org provide useful guidance on appropriate methodologies for lab facilities. While the semiconductor facility with its cleanrooms and supporting spaces is not beholden to the ASU lab guidelines it is recommended the LEED Lab criteria be reviewed and considered for all new facilities for ASU. These are presently offered as an education course by USGBC at the link: LEED Lab | U.S. Green Building Council (usgbc.org)

12.2 LEED Requirements and Considerations

12.2.1 The latest applicable LEED rating system can be at the link below:

https://www.asu.edu/fm/documents/project_guidelines/Sustainable-Design-Guidelines.pdf

12.2.2 A LEED-accredited professional with a BD+C rating and familiar with the applicable standards for new construction should be on all project teams for the planning, design, and construction phases.

12.2.3 Any new facility newly LEED certified may be required to maintain the awarded certification through the Operating and Maintenance (O&M) rating criteria outlined by the USGBC.

13. Facility Certification and Commissioning

13.1 Facility Certifications

13.1.1 It is required the cleanroom and supporting areas be certified by an independent qualified 3rd party agency to observe, measure, and record all data obtained from the new facility and confirm it is completed, operating within defined parameters, and is ready to be occupied by the Client and all tenants.

13.1.2 The following standards are recommended for cleanroom certification:

A. ISO Standards: Institute of Environmental Sciences and Technology (IEST):

1.) 14644-1: Cleanrooms and Associated Controlled Environments (Including Part 1: Classification of Air Cleanliness).

2.) 14644-2: Specification for Testing and Monitoring to Prove Continued Compliance with ISO 14644-1

3.) 146443: Metrology and Test Methods (including Annex A, B, and C)

4.) 146444: Design, Construction and Startup

5.) 146446: Terms and Definitions

B. IES-RP-CC006.2 – Testing Cleanrooms

C. IES-RP-CC-002.1 – Laminar Flow Clean Air Device

D. IES-RP-CC-013-86T – Equipment Calibration or Validation Procedures

E. IES-RP-CC-001-86 – HEPA Filters

F. "Procedural Standards for Certified Testing of Cleanrooms." National Environmental Balancing Bureau (NEBB)

G. ESD Association Standard ESD-S-7, 1-9941

H. SEMI S2 Safety Guidelines for Semiconductor Manufacturing Equipment

I. SEMI 178 0998 Electrostatic compatibility guide to assessment and control of ESD and electrostatic attraction for equipment

J. NEBB- Procedural Standards for Measuring Sound and Vibration

13.2 Facility Commissioning Requirements and Considerations

13.2.1 It is recommended that the cleanroom and supporting areas be commissioned by a qualified and independent commissioning authority (CxA) upon substantial completion and all certifications are confirmed to be completed and accepted by all parties.

13.2.2 Commissioning is a prerequisite for LEED certification (see Sustainability Section above) and Enhanced Commissioning is recommended which will require a qualified CxA to be engaged by ASU to review the facility design during the design phases of the scope of work.

13.2.3 Applicable SEMI guidelines shall be followed for the commissioning of all items to be covered by the project team and CxA.

13.2.4 During the commissioning process, all systems shall be provided with the following by the project team and shall be turned over to ASU upon completion:

A. Final P&ID diagrams (updated with all field changes)

B. Written Sequences of Operations

C. Maintenance Manuals

D. Warranties in compliance with State of Arizona requirements

E. Copies of all software utilized, including copies of software licenses

13.2.5 The following systems should be included for commissioning:

A. Cleanroom Envelope (Modular partitions, doors, ceiling systems)

B. Cleanroom Make-Up Air Units and related ductwork

C. Cleanroom Recirculating Air Handling Units and/or Fan Filter Units with HEPA Filtration

D. Lighting Systems and Fixtures

E. General Exhaust Systems (Equipment and Ductwork)

F. Specialty Exhaust Systems (Equipment and Ductwork)

G. House Gas Systems (Equipment and Distribution)

H. Process Gas Systems (Equipment and Distribution)

I. Bulk Gas Systems (Equipment and Distribution)

J. Process Vacuum Systems (Equipment and Distribution)

K. Clean Dry Air Systems (Equipment and Distribution)

L. Ultrapure Water Systems (Equipment and Distribution)

M. Waste Treatment and Acid Waste Neutralization Systems (Equipment and Distribution)

N. Electrical Power Systems

O. Fire Protection Systems- Alarm and Sprinklers (Equipment and Distribution)

P. Toxic Gas and Gas Monitoring Systems (Equipment and Distribution)

14. APPENDICIES

14.1 FACILITY CHECKLISTS

14.1.1 Site Selection Checklist

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SITE SELECTION CHECKLIST

During the first meeting, the client should be prepared to provide as much information as possible on the following points:

(If existing equipment, process, or facilities are to be used, a TOUR is also needed.)

Background information on Project:

A. Project Overview

1. General purpose of facility:

   ☐ One or ☐ Two Fab Site, ☐ Other ______________________________

   Wafer Sizes: ☐ Pieces ☐ 4" ☐ 6" ☐ 8"

2. Operating unit(s) that will occupy facility:

   List wafer process types:

   ☐ CMOS, ☐ BiCMOS, ☐ Bipolar
   ☐ Other ____

3. Support Areas:

   ☐ Test, ☐ Assembly, ☐ Failure analysis, ☐ Chem mix, etc.

4. Desired dates for:

   a. Initial operations: ________________________________

   b. Peak production: ________________________________

5. What is the type of location desired?

   Examples might be: 5 miles of a Central Business District/ Standard Metropolitan Statistical Area/Small town or rural area?

B. General Building

1. Description of technology; Detail analysis will be performed via programming phase checklist:

   ☐ ____
   ☐ ____
   ☐ ____

2. List of facilities required:

   ☐ ____________________ ☐ ____________________
   ☐ ____________________ ☐ ____________________
   ☐ ____________________

☐ ______________________ ☐ ______________________
☐ ______________________ ☐ ______________________
☐ ______________________

C. **Personnel Requirements for your facility**

1. Staffing of the facility will be detailed out using the programming phase checklist and the benchmarking comparison:

☐ Director ____
☐ PI ____
☐ PI Staff ____
☐ Facilities ____
☐ Technical ____
☐ Other ____

CHECKLIST

A. Climate:

The following climate parameters will impact your building design, construction and operations:

1. For each month of year provide following data:
   a. Monthly average temperature
   b. Average maximum temperature
   c. Average minimum temperature
   d. Maximum temperature ever recorded
   e. Minimum temperature ever recorded
   f. Heating degree days
   g. Cooling degree days
   h. Number of days over 90 degrees F
   i. Number of days under 32 degrees F (freezing)
   j. Average precipitation, inches
   k. Average relative humidity
   l. Average wind velocity
   m. Prevailing wind direction
   n. Number of clear, partly cloudy, cloudy days
   o. Percent of time instrument flight rules prevail
   p. Maximum rainfall in 24 hour period
   q. Maximum snowfall in 24 hour period

2. Discuss the impacts of these climatic effects on costs and time to construct:
   a. On building design, construction and maintenance
   b. On cost of heating and air conditioning (first and ongoing operations costs)
   c. On transportation to and from plant
   d. On operations within plant, including technical processes
   e. On employee recruiting

3. Does this area have a history of natural disasters, special weather hazards?

   ☐ YES, ☐ NO

   ☐ Hurricanes
   ☐ Tornados
   ☐ Earthquakes
   ☐ Volcanic eruptions
   ☐ Tidal waves
   ☐ Floods
   ☐ Mud slides
   ☐ Forest fires
   ☐ Drought, dust storms
   ☐ Thunderstorms, lightning, hail
   ☐ Blizzards

B. Specific Site Questions

1. Is there a site currently under consideration for this project: ☐ YES, ☐ NO

2. Are there other building(s) on the site: ☐ YES, ☐ NO
   a. Will building(s) be demolished: ☐ YES, ☐ NO
   b. Will building(s) be retrofitted for this project ☐ YES, ☐ NO
   c. Do the existing building(s) contain hazardous materials: ☐ YES, ☐ NO

   d. What is the classification and use of the existing building(s)?

   e. What is the distance between the existing building(s) and the new building?

3. Are there adjacent building(s) to the site: ☐ YES, ☐ NO
   a. Will access to these adjacent buildings be required between the new building and adjacent buildings: ☐ YES, ☐ NO

      ☐ Bridge way
      ☐ Tunnel
      ☐ Pedestrian Walkway

   b. How close are adjacent buildings to new building?

   c. What is the classification and use of the existing building(s)?

d. Where are the intakes for the existing and adjacent building(s)?

4. Does the site currently have Fire Truck/Man Access: ☐ YES, ☐ NO

   Where: ____

5. Does the site currently have Fireman Access: ☐ YES, ☐ NO

   Where: ____

6. Are there current conditions or issues related to the property line of the site?

   ☐ YES, ☐ NO

7. Will the new building be using any campus facilities or services: ☐ YES, ☐ NO

   ☐ Chilled Water
   ☐ Steam
   ☐ Sewer
   ☐ Other ________________

8. Define the Site Conditions:

   ☐ Raw land, undeveloped
   ☐ Zoned office/industrial
   ☐ Planned office/industrial park
   ☐ Urban
   ☐ Suburban
   ☐ Rural
   ☐ Waterfront
   ☐ Airport frontage
   ☐ Redevelopment area
   ☐ Drained or reclaimed land
   ☐ Cleared, graded land
   ☐ Site in large-scale PUD (Planned Urban Development)
   ☐ New town
   ☐ Previous land use
   ☐ Toxic waste risk (avoid)
   ☐ Adjacent land use______________

   ____

9. Define the Topographic Considerations

- ☐ Slope and grade (minimize)
- ☐ Potential aesthetic problems
- ☐ Legislation restricting construction due to topography

- ☐ Height above sea level
- ☐ "Look window" for satellite antenna

10. Define the Geologic Conditions:

- ☐ Depth of solid rock and character of intervening soil strata

- ☐ Bearing loads as compared with requirements

- ☐ Soil analysis- needed to predict costs and vibration performance

- ☐ Variation in ground water level

- ☐ Flood risk and flood plains of surface bodies of water

- ☐ Drainage pattern after plant construction

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☐ Earthquake risk

11. Define the Site from Ecological Viewpoint
    a. Bedrock/foundation
       - ☐ Support quality
       - ☐ Type of material
       - ☐ Depth of material
    b. Soil analysis effects on vibration
       - ☐ Agricultural quality
       - ☐ Structure support quality
       - ☐ Depth
       - ☐ Erosion characteristics
       - ☐ Soil types
       - ☐ Drainage
    c. Existing vegetation
       - ☐ Vegetation types
       - ☐ Landscape design potential
    d. Wildlife
       - ☐ Wildlife habitats
       - ☐ Existing wildlife
       - ☐ Range
       - ☐ Sensitivity
       - ☐ Effect of development
       - ☐ Endangered Species
    e. Description of watershed or drainage basin
       - ☐ Ground water/ hydrology
    f. Surface water
       - ☐ Lakes/ponds/pools (size, quality, accessibility)
       - ☐ Rivers/ streams
       - ☐ Navigation characteristics
       - ☐ Use of domestic water
       - ☐ Pollution problems
       - ☐ US Government wetlands to be preserved/exchanged
12. Are there existing transportation services on/near the Site? (See also "Transportation")

- ☐ Airport at site
- ☐ Taxiway access
- ☐ Rail siding
- ☐ Truck dock
- ☐ Deepwater dock
- ☐ Barge dock
- ☐ Rapid transit stop
- ☐ Streets

13. What are the transportation services in area?

______, Approximate miles to closest Interstate highway access
______, Approximate miles to closest air carrier airport
______, Approximate miles to closest general aviation airport
______, Approximate miles to closest deepwater port
______, Approximate distance to main rail-line
______, Approximate distance to public transport (subway, light rail)

14. What are the impacts of other considerations, such as?

- ☐ Natural surroundings ______________________________
- ☐ View of building ______________________________
- ☐ Neighbors ______________________________
- ☐ Security ______________________________

15. Is enough land available for current and future needs and is it configured in a way that it is fully useable?

☐ Vibration: ____

Ideally (although not an absolute) a lab building is typically set back 500 to 1,000 feet from major roads to achieve the vibration criteria. Photolithography and imaging tools are sensitive to low levels of vibration. The site must be capable of achieving VC-E standard vibration criteria, typically less than 125 micro inches per second velocity, between 8 and 100 Hertz, and less than 250 micro inches per second between 4 and 8 Hertz. Imaging spaces may required VC-F,G,H or NIST-A and below grade conditions should be evaluated.

☐ Acoustical Noise: ____

Typically the site should achieve less than 55dBA during the day and 45dBA at night at the property line during routine operations.

☐ Electromagnetic Fields:

These stray fields (from electrical lines, generators etc…) can Interfere with imaging systems used to examine microelectronics devices.

From .001 Hz to 6,000 Hz the milligauss values may not exceed 10 at the perimeter of the facilities (wall) boundary. Some tools may be sensitive to as little as 1.0 mG. TEMs and some Ebeam lithography systems may be sensitive to 0.1 milligauss RMS (0.3 milligauss peak to peak).

From 150 kHz to 40 GHz the electric field in both horizontal and vertical polarization shall not exceed 3 volts per meter for some sensitive tools. Imaging tools are sensitive to both AC EMI and changes in DC Fields.

☐ Other disturbances to be avoided within a 1 mile radius:

a. Fire and explosives
b. Smoke or heat
c. Illumination or glare
d. Particulate matter, dust and dirt generators
e. Electrical disturbances, as noted in electrical section
f. Odors, toxic and noxious matter
g. Radiation

17. What are the site development costs?

a. Cost of water line, who pays?: ______________________________
b. Cost of sewer line, who pays?: ______________________________
c. Cost of electric line, who pays?: ______________________________
d. Cost of rail line, who pays?: ______________________________
e. Cost of access road, who pays?: ______________________________
f. Clearing and grading cost: ______________________________
g. Cost of campus utilities (steam, chilled water, etc..), Who pays?:______________

18. Does established fire and police protection exist?
    a. Emergency response personnel per 1,000 population:

    b. Fire insurance classification:

    c. Extent of protected area:

    d. Stations-location and time to outer limits of protected area:

    e. Equipment, including that for chemical fires:

    f. Water pressure for fire fighting

    g. Fire inspection of local industry / university

h. Sprinkler system requirements

i. Surveillance of industrial areas / university

j. Crime rates

k. Performance during strikes or labor disputes

19. What are the needs for physical security?
    a. Availability of private security agent protection, if needed

    b. Other

C. **What are the impacts of zoning, permitting, and regulations?**

1. What are the requirements for space allocations or dimensional standards for this site?
   a. Building-to-land ratio

   b. Minimum building size

   c. Minimum lot size

   d. Set-backs

   e. Uses permitted

   f. Off-street parking, bus access

   g. Percent of site that may be utilized

h. Control of nuisances (smoke, dust, noise, etc.)

i. Sign control

j. Height Restrictions –*Note: Building Height can be up to 110 feet with scrubber units mounted 18 feet above the roofline.*

- ☐ Will the height of the building violate any zones, permits?
- ☐ Is there a high rise code in this jurisdiction?
- ☐ Does high rise start at 75 feet above lowest fire department vehicle access, per IBC, or other (eg. Number of stories)?

2. Identify the local/regional equivalents of the following US regulations:

a. Impact of any type of Clean Air Act programs on facility

1. Air quality maintenance plans

2. Indirect source controls

3. Transportation controls

4. Parking management regulations

5. Significant deterioration regulations

b. Impact on the US equivalent of Federal Water Pollution Control Act programs on facility

1. National Pollution Discharge Elimination System

2. EPA 208 Water Quality Management programs

3. Non point source control

4. Dredge and fill permits

5. Waste water treatment facilities planning: data collection, fail safe requirements, operator requirements.

c. Identify the Village, Regional etc…applicable regulations

1. Names and jurisdiction of regulatory bodies

2. Scope of regulatory power

3. Water pollution

4. Air pollution

5. Noise

6. Solid wastes

7. Visual or aesthetic pollution

8. Land use regulation

9. Power plant siting

10. Coastal resources protection

11. Radiation

12. Hazardous wastes

13. Other

14. Criteria/standards for measuring pollution

d. Are there any additional regulations pending that might impact your facility?

e. What is the permitting and planning process, and what is the typical timing?

1. Planning approval

2. Licensing or construction/operating permit

3. Police power, law enforcement

4. Penalty for non-compliance with pollution control regulations

f. Are there financing programs or tax incentives for pollution control?

- ☐ Available Real property tax exemption ____________________
- ☐ Personal property tax exemption ____________________
- ☐ Sales/use tax exemption on pollution control facilities ____________________
- ☐ Sales/use tax exemption applicable to lease of pollution control facilities ____________________
- ☐ Credit against corporate income tax ____________________

- ☐ Maximum dollar limit of credit
- ☐ Accelerated depreciation of pollution control equipment
- ☐ Exclusion of pollution control investment from corporate franchise tax
- ☐ Exemption applicable to cost of operating pollution control facility
- ☐ State financing program for purchase and installation of pollution control facilities

3. What is the attitude of General Public in this area toward new development?
   - ☐ Action groups with history of opposition to development
   - ☐ Major projects stalled by opposition
   - ☐ News media treatment of such issues

D. What are the availability and adequacy of energy and utilities such as electric, gas, and fuels?

1. What is the current power source to this site?
   - ☐ Thermal- coal, natural gas, propane, fuel oil
   - ☐ Hydroelectric
   - ☐ Other- nuclear, geothermal, solar
   - ☐ Tax credit available for use of specific equipment or fuel to generate power
2. What is the current form of Electric Power supply?
   a. Company or public agency serving area

   b. Interconnection with other systems

c. What is the capacity at present and future planned?

d. Recent record of shortages or interruptions (History of "glitches", brownouts, voltage deviations, "power off" events for the past 3 years)

e. Vulnerability to natural disasters

f. Location of nearest electric substations and whether interlocking

g. Voltage, phase and cycle available

h. Size of connection at proposed site

i. Two-way feed is desired, trace back to origin for each.

j. Cost/timing of extending service

k. Typical residential and corporate power rates

l. Off-peak possibilities

m. Fuel adjustment provisions

n. Current fuel generation mix

o. Ongoing power plant construction

p. Planned power plant construction

q. Fuel generation mix when the new capacity is on line

r. Present and projected reserve margins

s. Record of service reliability to local manufacturers

t. Rate relief granted in last few years

u. Amount of the next rate hike request

v. Composition of the state public utility commission

w. Is the electrical power capacity (start and peak) sufficient for this plant/facility?

3. Do pipelines exist for the following commodities

- ☐ Nitrogen
- ☐ Natural Gas
- ☐ Oil
- ☐ Refined products

4. Natural Gas Service

   a. Suppliers

   b. Capacity, present and planned, as compared with peak requirements

   c. Allocation for industrial use

   d. Type (natural, mixed, manufactured) and Btu value

   e. Storage facilities

   f. Recent record of shortages and interruptions

g. Size of connection at proposed site

h. Two-way feed

i. Industrial and residential rates, including interruptible rate.

5. Will this Natural gas supply be sufficient to support this facility (average and peak)?
   Typical demand might be cf/year at 20 – 25 psi: 50K cubic feet per year (at 20-25 psi) for a large fab (avg.); 90K (peak)

6. Is there a supply for ☐ Coal, ☐ Oil? Fuel is used for back up generators, typical #2 diesel.
   a. Suppliers

   b. Cost of coal delivered, per million Btu's

7. What is the availability and adequacy of Motor Fuel?
   a. Availability

   b. History of shortages in area

   c. Cost of fuel

8. Is there a potential for On-Site Independent Energy Source? ☐ YES, ☐ NO
   - ☐ Gas Well
   - ☐ Other ______________________________
   - ☐ Ecological permits required
   - ☐ Available infrastructure of skilled workers

9. Nitrogen Pipeline Service
   a. Suppliers

   b. Capacity, present and planned, as compared with expected peak requirements

   c. Main purpose of pipeline

d. Semi-Grade available (4.8, 5.0, 5.5, 6.0)

e. Recent record/concerns of shortages and interruptions

f. Size of connection at proposed site

g. Industrial rates, including interruptible rate.

E. What is the availability, adequacy and quality of the water supply?

1. Assess the regional water situation
   a. Trend of consumption as compared with developed supplies, planned developments

   b. Watershed development proposals for export of water to or import from other watersheds

2. Assess the local water supply
   a. Agency and source of supply

b. Pumping and storage supply

c. Pressure at site

d. State health department rating of supply

e. Method and extent of treatment, including fluoridation

f. Industrial and residential rates

g. Cost of extending service

h. Likelihood of restricted use

i. Supply vs. projected demand

NOTE: Approximately 1.5 to 2.0 million gallons per day typically required for a large fab.

j. Is the water supply predictable?

NOTE: A predictable quality of water allows the water treatment system to be designed to the composition of the incoming water. Typically, Fabs evaluate the incoming water quality; and then design a specific, robust, RO/DI system to treat the specific water composition to ensure they can clean the water to meet their needs. Cost of operation and maintenance increase with high concentrations of minerals and organics but can be addressed with proper water treatment system design.

k. Is there an alternate supply for water?

NOTE: Ideally, a Facility will have access to two redundant water sources. However, storage can be used to satisfy the back up water need, should the primary delivery system fail. An ideal system design would allow each source capable of providing 100% supply. On-site storage is not a desired scenario but is used if the site and design dictate.

l. What is the chemical analysis of the water?

NOTE: The preferred water source would have:

- *Low Total Dissolved Solids (TDS) of 500ppm or less.*
- *Low organic content without seasonal fluctuations.*
- *Total hardness below 500 mg/l, softer water (Ca, Mg, Si) is desired.*
- *Low Total Organic Compounds (TOC).*

3. Are there other water sources such as surface water from streams and lakes?

☐ YES, ☐ NO

a. Daily, seasonal and long-term flow variations

____

b. Upstream use

____

c. Temperature

____

d. Chemical analysis (same as above)

____

e. Distance to site

____

f. Feasibility of dam or pumping station

____

4. Are there other water sources such as ground water wells?

☐ YES, ☐ NO

a. Recent trend of water table elevation

b. Recharge rate

c. Regulations on use

d. Pumping cost

e. Temperature, chemical analysis

5. Are there other water sources such as sea water
    a. Cost of desalination

    b. Potential corrosion problems

F. **What is the availability and adequacy of wastewater management and sewage and waste disposal?**

1. Direct waste water discharge
    a. Proximity of stream

    b. Size of stream

    c. Stream classification

    d. Existing discharges

    e. Total cost of disposal via this method

2. Is land application, spray irrigation possible? ☐ YES, ☐ NO
   a. Soil characteristics

   b. Elevation of water table

   c. Precipitation pattern

   d. Area on site for lagoon, lines

   e. Septic tank regulations

   f. Total cost of disposal via this method

3. Does a municipal treatment system exist? ☐ YES, ☐ NO
   a. Proximity to sewer line

b. Size of line

c. Excess capacity of existing treatment plant

d. Is there a moratorium on new users?

e. Separate sanitary and storm sewers

f. Secondary treatment

g. Total cost of treatment via this method

4. Are the sewage and waste treatment adequate to support the start and peak demands?

☐ YES, ☐ NO

NOTE: Typically, a Fab will have a dedicated wastewater effluent system that directs the "used" ultra-pure water (UPW) to the off-site, Publicly Owned Water Treatment Works (POTW) plant. The POTW further treats the water through a reverse osmosis process.

Daily wastewater discharges for a typical Fab can reach 0.8 – 1.2 million gallons per day. During the construction of a Fab peak daily discharges can be as high as 2.5 million gallons per day (MGD) when the systems are being flushed.

Ideally, the wastewater treatment plant should design systems such that the Fab(s) is not more than 20% to 40% of its input source. Fabs, however, can be as much as 60% to 70% of an input source with adequate demand planning by municipal wastewater authority and the Fab owner.

5. Does a public agency exist for solid waste disposal? ☐ YES, ☐ NO
   a. Agency and nature of collection system-incineration, landfill or dump, transfer stations, resource recovery

   b. Methods and frequency of collection

   c. Capacity compared with present and projected load

   d. Total cost of disposal via this method

6. Solid Waste Disposal On Site
   a) Regulations which must be complied with

b) Public relations aspects

c) Staff requirements for special personnel

d) Total costs via this method

7. Solid Waste Disposal Off Site

a) Availability of private service

b) Legal liabilities

c) Limitations on materials handled

d) Total cost via this method

8. Solid Waste Disposal via Recycling

e) Economic feasibility

a) Regulations which must be complied with

b) Staff requirements

c) Total cost via this method

9. Can this site support the volume of hazardous waste removal?

NOTE: A single Fab can generate up to 1,500 – 1,800 US tons/yr of hazardous/regulated waste.

10. Can this site support the volume of Solid Waste removal?

NOTE: Solid waste generation is estimated to be approximately 4,000 tons per year, per fully ramped Fab facility. Examples of solid waste generated include concrete, metals and wood, cardboard, paper plastic and glass. During construction efforts, solid waste can be expected to reach 15,000 tons per year.

G. **What is the availability and adequacy of the communications systems?**

1. What is the local telephone supplier?

2. Are they capable of supplying your needs? ☐ YES, ☐ NO

   a. Number of instruments in use vs. capacity

   b. Capability of handling large installations

   c. Private wire system

   d. Range of toll free area

NOTE: The Fab will require divergent routes into the facility for telecommunications connections and will desire access to two unrelated telecommunications service providers (such as ATT, GTE, Verizon etc…). This dual provider and dual access requirement supports a risk reduction/emergency back up plan to ensure uninterrupted service in the event one telecommunications provider experiences a failure or the connections are compromised.

T - 1 Line: *The Fab should have access to multiple T - 1 lines. On site banking services, supported by a T-1 line, are also often offered.*

Fiber Optic Cable: *Fiber Optic cable is required for voice and data. Copper is only required from the local carrier for emergency lines that don't come through a local system.*

3. Will your communication needs exceed the existing service in terms of the following?

☐ YES, ☐ NO

- ☐ Digital transmission service
- ☐ Microwave and satellite transmission service
- ☐ Telecommunications

4. Is there postal service? ☐ YES, ☐ NO
   a. Nearest post office

   b. Frequency of deliveries

   c. Proximity of a Bulk Mail center

14.1.2 Tool Installation Project Checklist

Tool Installation Project Checklist

During the first meeting, the client should be prepared to provide as much information as possible on the following points:

(If existing equipment, process, or facilities are to be used, a tour is also needed.)

Product Description:

- Device Type(s)
- Substrate Type(s)
- Substrate Size(s)
  -Transformations during process, including warpage, back grinding, etc.
- Process Technology
  - Minimum Feature Size
  - Number of Mask Levels/Process Steps
  - Key Processes
  - Lot Traveler or Process outline
- Test Technology (if applicable)
  - Temperature Range
  - QC Requirements
- Assembly Technology (if applicable)
  - Key Processes
  - Lot Traveler or Process Outline
- Quantity to be Produced per Week (Starts)
  - Production
  - Engineering/Development

Tool Installation Project Checklist, Continued

Equipment List:

- Existing Equipment and Future Equipment by Phase and Quantity.
- Tool List must include:
  - Description, Purpose, Vendor, Model Number, Dimensions or CAD footprint, Tool "Owner".
- Utility Matrix must include the following:
  - Required Utilities: volume, pressure of influent and effluent liquids and gases, exhaust.
  - Electrical Requirements: Volts, Amps, Phase, KVA during operation, Clean or UPS.
  - Chemical, gas, purity and cross contamination issues.
  - Vibration ambient condition requirements.
- Process Sequence:
  - Where each piece of equipment is used in a typical product flow.
- "Home Built" Tools
  - Documentation
  - Owners

Tool Installation Project Checklist, Continued

Facility Conditions:

- Layouts of Fab, Subfab and Support Areas:
    - Complete set of Design CAD Drawings (to scale) of Tool Layout in Building Background Drawing.
    - Tour of existing space, including the floor above, floor below, and facility area.
    - Available square footage for each intended use (Gas Cabinets, Chem Distribution, Piping routes, etc.)
- Vibration Issues
    - Sources such as HVAC equipment, traffic, trains, etc.
- Tool move-in path.
- “House” Utilities: Quantity, Quality, and Location - LIST ALL.
- Schedule of when utilities will be ready for tool installation by area.
- Location for Prefab of drops
    - Outsource?

Tool Installation Project Checklist, Continued

Process Environment:

- Temperature and Humidity control conditions, and when available.
- Cleanliness Control, by clean class, and when available.
- Mini-environments and SMIF.
- Raised Floor or Side Wall Return, raised floor utility ports std.
- Walls, doors, chases, elevations, penetrations, std. ports
- Interior design and layout issues affecting installation (bulkheading, etc.).
- Ceiling – height, configurations, ionization, and lighting.

People Issues:

- Gowning
- Communication
- Supervision
- Access
- Security
- Union or Non-Union and Matrix of Trades

Tool Installation Project Checklist, Continued

Material Handling and Storage:

- Product Movement and Storage (currently in use, preferences for future)
    - Tool Automation
        - SMIF/FOUP
        - Pods
        - Cassettes
    - Intrabay Automation
    - Interbay Automation
        - Pass-thrus
        - Stockers
        - MGV
        - AGV
        - Monorail
        - Conveyor options
    - WIP Storage
    - Chemicals and Gases - Automatic or manual distribution, philosophy
        - Chemical List
        - Gas List
    - Production Supplies
        - Location and Distribution method
    - Equipment Staging
        - Wipe down
        - Rigging and Tool Placement
        - Floor Labeling
        - Wall Labeling
    - CIM Interface
        - Links
        - Programming
        - None
        - MES
        - Recipe Control

Tool Installation Project Checklist, Continued

Project Management

- Preferred Software (Microsoft Project)
  - Other________________________________
- Preferred level of detail
- Installation Checklist
  - Short form____________
  - Other______________________________________
- Equipment Vendor interface responsibility
- Procedure for changes to tool dimensions/utilities by vendor
  - Source inspection of tools (included)?
- Procedure for changes to Facilities by A & E Constructor?
- EHS Requirements/Management of:
  - Environmental
  - Safety
  - Health

Tool Installation Project Checklist, Continued

Process Support for Tool Startup

- Getting wafers, materials
- Tool Operation, Sequence Validation
- Validate Vendor handoff
- Establish Recipes
- Run Experiments

Documentation

- Typical/General or Tool Specific Specs and Drawings
  - Materials Specifications
  - Drawings for installation?
  - Drop Drawings
- Facilities QA – Ready for installation sign off?
- Status Reports
  - E-mail
  - Format (Microsoft Project)
- Books on site –
- Purchase Order Documents and Sign-off Loop

Tool Installation Project Checklist, Continued

Tool Installation Project Agenda: 1-Day Visit

1. Discussion of Client Goals: for this session and for the project
2. Review of Drawings & Facility Tour, presentation of client product, process, goals for the new Facility.
3. Review of Tool Installation Project Checklist
4. Discussion of Key Issues and Possible Solutions
5. Action Plan

14.1.3 Cleanroom Pre-Certification Checklist

Pre-Certification Checklist

	ACTIVITY	YES	NO	DATE	COMMENTS
1	Walls installed and complete?				
2	Ceiling installed and complete?				
3	Floor installed and complete ?				
4	All HEPA /ULPA filters installed ?				
5	All services connected and functional?				
6	All Air handlers installed, supercleaned and running at specification?				
7	Preliminary Airflow balancing performed for HEPA/ULPA filter leak test ?				
8	Final Airflow balancing performed for final certification?				
9	Room pressures set to specification?				
10	Temperature and humidity controls in place and operating?				
11	Area supercleaned before particle counts are performed ?				
12	For "As Built" no Production equipment or personnel in area.				
13	For "At Rest" Production equipment installed and operating, no personnel in area.				
14	For "Operational" Production equipment and personnel present and working normal.				

Notes:

PROJECT

LOCATION

COMPANY

DATE