Yale University

Guidelines for Safe Laboratory Design

Prepared by Yale University
Environmental Health & Safety

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Contents

1. Introduction

This document provides basic design guidance for laboratory spaces at Yale University. As a generic document, it addresses features (and pitfalls to avoid) for most - but not all - potential laboratories. Please review designs with the proposed occupants as early in the process as possible, to ensure compatibility with anticipated research or teaching activities. Please also consult EHS for input on the specific renovation or construction project. As this is meant to be a "living" document, please forward any comments, suggestions, or questions to EHS so that we can address and incorporate them, as appropriate. We can be reached at 785-3550.

2. Pre-Construction/Renovation Work

A variety of potentially hazardous materials and/or conditions may exist in spaces or on property planned for renovation or construction. These range from issues relating to existing building systems (e.g., asbestos, lead paint) to materials left behind by former occupants (e.g., chemicals, contaminated piping), all of which require assessment and abatement prior to project commencement. Although these issues are generally identified and managed by EHS, cost responsibilities for structural abatement work (e.g., asbestos, lead paint, underground storage tank removal) are usually a project budget line item. Early interaction with EHS on these issues will help ensure that adequate lead-times and monies are allocated for the project.

<u>Infrastructure Issues:</u>

- Asbestos
- Lead/lead paint
- PCB-containing caulks
- Mercury fluorescent lamps and PCB ballasts
- Thermostat mercury switches
- Excessive mold/mildew, pigeon or other animal excreta, high dust accumulations, and other likely nuisance conditions
- Potentially contaminated waste plumbing, vacuum lines, and/or hazardous exhaust system ductwork (see below)
- Freon recovery from refrigerators and freezers
- Compressed gas cylinder returns
- Underground or above-ground storage tanks
- Potential soil/groundwater contamination
- Smoke detectors

<u>Operational Issues:</u>

- Historical use of hazardous materials (e.g., biological, chemical, radioactive materials) triggers area and equipment clearance by EHS before work begins
- EHS surveys must be performed on vacuum, waste plumbing, and hazardous exhaust fume hood ductwork where radioactive materials were previously used
- Hazardous wastes must be removed by EHS prior to start of construction work
- Laboratory sink traps and vacuum line traps and elbows often contain small amounts of mercury. Instruct all demolition and plumbing staff to collect initial drain effluent into a pail or bucket to inspect for mercury globules. If present, stop work, set pail aside and notify EHS to remove. Stop work and contact EHS in the event of a mercury spill or contamination.

- Implement dust control and general nuisance avoidance procedures prior to start of work. This includes preliminary assessment of potential impacts during design/ planning phase, evaluating need for an occupant's Community Meeting, and distribution of on-going project "look-aheads" to keep occupants and other relevant departments (e.g., Yale Fire Code Compliance, service/maintenance groups, EHS, Alarm Control Center, etc.) aware of work.

3. Laboratory Commissioning

Prior to officially opening a newly constructed or renovated laboratory space, it is important that EHS, Yale Fire Code Compliance, and Facilities staff have the opportunity to walk-through the area. This final walk-through gives these and other Yale service departments with long-term responsibilities for the space the opportunity to evaluate equipment and conditions, and to ensure that critical building and safety systems (e.g., emergency water, fume hoods, postings and signs) are properly installed before lab occupancy. On sensitive or higher hazard projects, please involve EHS and/or other pertinent support departments for periodic pre-completion site visits.

4. Laboratory Design

a. Basic Parameters:

- Fire/Life Safety Code compliance, NFPA 101, NFPA 45
- New Haven/State of CT Building Code compliance
- Maximize energy and materials conservation and processes throughout project (e.g., improved structural insulation, low electric consumption lighting, reduced water demand equipment, use of recycled products, etc.) within safety and comfort envelope.
- Determine nature of laboratory ventilation control systems and overall driver: fume hood exhaust, thermal load, or minimum air changes.
- Use of radioactive self-luminescent exit signs is prohibited
- Smallest fire rated spaces possible
- Provide direct and unobstructed paths to exits
- Modifiable to provide reasonable accommodations to workers with disabilities
- Provide adequate amount of separate break area(s) and separate dedicated food refrigerators to discourage eating and drinking in labs
- Avoid locating desks and study carrels in lab rooms. If not possible, include splash protection / separation from wet bench areas to reduce PPE requirements.
- Doors, hallways, and aisles of sufficient width for standard lab carts and equipment moves
- Provide dedicated storage areas, closets, and / or hanging areas for lab coats and for personal items and clothing. Lab coat hangers should be located near the entrance to the lab.
- Provide a safety station area near the door for the phone, fire extinguisher, safety postings, and holders for visitor safety glasses.
- Install at least one emergency eyewash station at a sink in the laboratory where hazardous materials may be used.
- An emergency eyewash and safety shower with tepid water should also be located in the laboratory, ideally near the safety station, where corrosive chemicals are handled.
- Emergency eyewashes not located at a sink should be plumbed to a drain.
- Provide adequate number of rated flammable storage cabinets.

- Verify with EHS whether flammable cabinets need to be vented. All cabinets used to store chemicals that are toxic by inhalation or have a very low odor threshold are required to be vented.
- Provide chemical storage areas with shelving below 5' high.
- Avoid placement of laboratories using flammable, corrosive, or highly toxic materials in limited access areas such as basements or penthouses.
- Comply with code requirements for volumes of flammable liquids, gases, and oxidizers. Note that these limits are very restrictive as you go up in floors.
- Automatic fire suppression is required for all new laboratory installations where flammable materials are used and/or stored.
- Gas cabinets are required for toxic gases.
- Install standard Yale telecomm systems so that emergency notifications and instructions can be made through ordinary channels
- Dual means of egress is often required by fire and building codes.
- Address personal and property security in overall building and area designs.

b. Ventilation:

- Locate supply air intakes distant from potential sources of contamination, including fume hood stacks, vehicle emissions, and exhaust from portable gas powered tools
- Separate general and fume hood exhaust systems, where feasible
- Design and balance systems so that lab rooms are slightly negative with respect to corridors and surrounding rooms
- Maximize the percentage of fresh air provided.
- Labs must be on 100% exhaust systems (no recirculation/re-use of lab exhaust)
- Design target is 8 - 10 room air changes per hour for occupied rooms, and 4 - 6 per hour for unoccupied rooms. All designs with air changes rates <8 must be approved by EHS.
- Air change rate occupancy setbacks for energy savings are allowed based on a combination of time of day and occupancy sensors.

c. Fume Hoods:

- Provide a life cycle cost comparison for fume hood types and control systems
- Hard-ducted systems only - so-called "ductless" fume hoods are prohibited except with special approval by EHS.
- Facilities Systems Engineering and EHS joint review and approval of type(s), siting locations, and all controllers to ensure that devices are appropriate to intended use, sited correctly, and interlocked to maintain spatial pressure differentials.
- Diversity should be considered to avoid over-engineering.
- For standard fume hoods, design to provide 100 feet per minute (fpm) linear air velocity into hood face (acceptable working range = 80 - 120 fpm, with sash height of 18" – not full open). Non-occupancy setpoints to 80fpm if applicable.
- For high performance fume hoods, design to 80 fpm +/- 20%. Non-occupancy setpoints to 60fpm if applicable. All high performance hoods must be approved by EHS prior to purchase. .
- ASHRAE 110 testing required for new fume hoods installations and for high performance hoods as part of commissioning.

- Design roof exhaust ejectors to good engineering practices, either 1.5 x building height or effective equivalent by high velocity release for good atmospheric mixing and dispersion
- Open-air rooftop access to fume hood fans preferred over mechanical rooms. Ensure passive fall protection (rails) from elevated heights and rooftops where routine mechanical maintenance work is conducted.
- Where ganged systems are used, provide redundant fans and means to ensure system maintains negative pressure during failures.
- New hoods must have permanently installed face velocity monitors, with local read-out/display and audible ~~or~~ alarm for off-normal conditions.
- Fume hoods should be appropriate for the control system being used. By-pass sash design required for constant air volume (CAV) systems, and hoods that are designed for variable air volume (VAV) systems should be selected when VAV systems drive the hood ventilation.
- Sash style should be either vertical or horizontal for constant volume systems, but can be combination vertical/horizontal operating sash with variable volume systems only.
- Sash should have hasp or similar means to permit locking sash in "closed" position for repairs and maintenance (at very least, an open-style grab handle through which a chain and lock can be fastened)
- Hoods should have chemically-resistant surfaces and finishes
- Locate hoods distant (i.e., ≥ 10 ft) from doors, pedestrian traffic ways, and overhead supply air diffusers to minimize deleterious effects of turbulence; front-to-front placement within the same room should be avoided
- Most hood installations will require water, electric, and drain connections. Where required by user, also install gas service connection and house vacuum.
- Lights must be easily accessible from outside of hood to facilitate timely replacement
- Installation and commissioning by certified air balancer; physically post written certification at hood face
- Notify EHS after hoods are certified by air balancer so that face velocity performance can be verified and the hood properly posted before placing into laboratory occupant service.
- Code and label fume hoods with consistent, standardized system (e.g., building code-room number-hood number); fan, ejector, and ductwork also so labeled to facilitate common language during repairs and maintenance
- Hood cabinetry/casework should include flammable cabinets and possibly corrosive storage cabinets below, depending on chemicals used in the laboratory. Generally, flammable cabinets are not required to be vented, however cabinets containing highly toxic compounds or highly odorous or stench chemicals should be vented.

<u>d. Biological Safety Cabinets (BSC):</u>

- Purchase only in consultation/approval with EHS (Clean Air Device Program).
- All BSCs must be added to EHS-managed service/certification contract
- Locate distant from doors, pedestrian traffic ways, and overhead supply air diffusers to minimize deleterious effects of turbulence; back-to-back BSC placement within the same room should be avoided
- Per National Sanitation Foundation Standard 49, provide the following clearances around BSC's: 3" - 12" on all sides; 1.5" - 12" back; and ≥ 8" above highest point.

- Provide vacuum, water, and electric service to units (use flexible connections where possible to permit limited re-positioning of BSC). Gas service discouraged but permitted at specific request of user.
- Thimble or hard-ducted exhaust connections may be warranted depending upon nature and hazard of materials used. Contact EHS for assistance with design, installation, and certification of these connections.

e. Lab and Hall Doors:
- Maximum appropriate fire rating possible
- Provide glass panels or viewing ports to facilitate interior observation in event of accident
- Do not provide integral door chock hardware - lab doors kept open to the hallway defeat lab HVAC and fume hood systems. If doors must be kept open between labs, use fusible links or a magnetic catch system interconnected with fire/smoke alarm systems.
- Hallway doors should be installed on infrared or other automatic opening door systems to facilitate movement of materials and carts along halls

f. Lab Door/Entry Signage:
- Provide standard 8.5 x 11 inch clear plastic sign holders outside door, to accommodate lab safety door id sign (required per NHFD agreements).

g. Walls and Ceilings:
- Surfaces should be smooth and easily cleanable
- Avoid friable ceiling tile styles, as they liberate dust, are difficult to clean, and make an excellent habitat for mold and bacteria when water leaks from above
- Recessed lighting preferable over suspended styles, but avoid placement directly above lab benches to facilitate bulb replacement and repairs
- Incorporate energy efficient lighting designs whenever possible
- Windows should generally be non-openable to avoid defeating HVAC, fume hood, and biological safety cabinet systems.
- Provide a restraining system(s) for securing compressed gas cylinders appropriate to anticipated occupant's needs.

h. Flooring:
- Easily washed, non-porous, coved, spill/leak resistant (i.e., seamless sheeting preferred over vinyl tile)
- Ensure new flooring materials are asbestos-free
- Carpeting prohibited in lab, lab support, clinical, and related work areas. Carpeting is hard to clean/disinfect/decontaminate, serves as a reservoir/source of dust and microorganisms, and once wetted becomes excellent habitat for mold and bacteria.
- Caulk/seal all floor penetrations to retard migration in the event of spill or flood.

i. Plumbing:
- Back-flow prevention (anti-siphon) devices required by Regional Water Authority on all sink installations and fixed water consuming equipment.

- Laboratory drain wastes general maintain pH 6.5 - 8.5 and are little different from residential/domestic greywater. Requests for wastewater neutralization systems should be challenged – contact EHS.
- Where house natural gas is needed, design and install so that each lab can be shut-off by valving located just outside lab. This makes emergency shut-off during fires or other accidents safer. Use clear glass/plastic cover and label shut-off location prominently.
- Deionized water plans should be discussed with user prior to design, and may require registration with EHS for wastewater discharge permitting.
- City water may not be used for equipment or space cooling. Instead, use chilled water or install point-of-use recirculating chiller.
- Cup sinks rarely used in modern laboratories outside of fume hoods, and often serve only as a source of sewer gas odors from dry traps. Challenge requests to verify need.
- Avoid below-slab piping.

j. Emergency Deluge Water:

- Provide emergency eyewash and shower safety devices per ANSI Z358.1 requirements (i.e., tepid water, within 10 sec travel distance, or about 55 ft unobstructed travel distance). Eyewashes are used far more frequently than showers, so one should be placed in every lab. Emergency showers should be placed in laboratories where corrosives are handled.
- Water source for emergency water devices must be potable.
- Eyewashes may be sink-mounted style or stand-alone, or combined with a shower as a separate emergency water station. Eyewashes must be hard-drained or located at a sink to promote regular testing.
- Eyewashes must be capable of activation in a single motion within 1 second, remain "on" once activated in a hands-free operation mode, and provide flushing to both eyes simultaneously.
- Each shower installation must have a secondary shut-off (ball) valve just upstream from unit. It should be located out-of-view where possible and installed with a lock-out mechanism. This shut-off is to facilitate periodic shower testing, and prevent flooding in event that primary shower valve fails open. Shut-off valve must be in "open" position at time of lab commissioning.
- Floor drains for safety showers are beneficial to avoid floods, but tend to dry out and become and on-going source of sewer gas odors unless trap primers are installed. Consult Facilities Operations for advice.
- Emergency water stations must be posted with large, high visibility signs.
- Installing an additional emergency shower in the handicapped accessible stall of at least one men’s and one women’s restroom (per floor) has proven highly effective in promoting shower use.

k. Medical and Veterinary Gas Systems

- Gas storage and delivery systems for medical or veterinary applications (e.g., medical oxygen, anesthetic gas) must be designed, built, and certified to NFPA 99.
- Contact EHS to evaluate any leak detection requirements.

l. Compressed Gas Systems

- Fixed CO_2 and nitrogen gas systems should generally be manifolded with multiple bottle racks to provide extended gas service and integral back-up. Manifolds must meet EHS requirements.
- All gas cylinder storage and use areas much have adequate accessibility and permanent securing means by chains or strapping.
- Hydrogen gas generation should be considered instead of cylinders for large users. In some building locations, fire code may require local generation. Contact EHS for assistance.
- Large installations have the potential to displace oxygen if significant quantities are released without adequate ventilation. Contact EHS in advance for review of location and potential oxygen monitoring needs. Laboratory group is responsible for on-going maintenance or calibration of any required personal or fixed area monitors.

m. Cryogens

- Large cryogen systems have the potential to displace oxygen if significant quantities are released without adequate ventilation. Contact EHS in advance for review of location and potential oxygen monitoring needs. Laboratory group is responsible for on-going maintenance or calibration of any required personal or fixed area monitors.

n. Lab Furniture and Furnishings:

- Smooth, non-porous, easily cleaned surfaces
- Low volatility/off-gassing to minimize odors upon occupancy
- Prefer bench-tops of chemical resistant, non-porous black epoxy tops with splashblocks, and all seams caulked and sealed
- Accessibility below furniture for cleaning in event of accident/spill
- Lab chairs - 5 leg style, non-porous fabric coverings to facilitate cleaning and prevent absorption of infectious, hazardous chemical, or radioactive materials
- Provide flammable-rated storage refrigerators/freezers as warranted by proposed occupant's operations and chemical inventory needs
- Incorporate good ergonomic designs into furniture and furnishings selection. Contact EHS for additional information.
- Review planned operations with proposed occupants to consider any special equipment requirements (e.g., adequate floor load ratings, vibration sensitivity or dampening needs, awkward worker:equipment interfaces requiring special design considerations, etc.)

o. Chemical Storage:

- Provide basic chemical storage features in all labs. These include separate below-hood or below-bench flammable and caustic chemical storage cabinets, and a sufficiency of shelving above work benches. Shelving should have chemical resistant finish surfaces, and be designed to reduce or eliminate accidental falls of containers off the shelves (i.e., either use of shelf edge lips or designed to prevent pass-through forces from other bench side to "push" a bottle off.
- Flammable storage cabinets must meet NFPA or FM approval as “rated flammable storage.”
- New labs should also be equipped with at least one explosion-protected refrigerator/freezer unit capable of meeting rated flammable storage.

p. Solvent Distillation:

- Traditional heated / thermal distillation for routine solvent purification or drying is strongly discouraged. Instead, users should select a cold solvent purification system. Contact EHS for recommendations on systems currently in use on campus.

q. Electrical Issues:

- Maximize number of separate circuits to avoid overloads
- Breaker boxes well marked, circuits coded, and centrally located for quick access
- Abundance of grounded 110V, 20 A outlets, on multiple circuits to minimize needs for power outlet strips and extension cords
- Outlets coded back to circuit number
- 220V power available, and supplied as needed especially in equipment rooms
- Emergency/back-up power - provide a basic backbone service as feasible.
- Emergency generator installations must be registered with EHS for air discharge permitting with the State of CT DEP.

r. Freezers

- Recognize the high heat loads generated from most freezers, and place accordingly. Freezer-farm rooms may require additional local cooling.
- Shared ultra-low temperature freezers should be of the style with multiple interior insulated sub-compartments to avoid long door open periods.
- Users interested in temperature monitoring alarms and off-hours notification calls need to arrange for such services individually. The following services are available at present:
    - Maintenance Contracts and 24-Hour Alarm Monitoring
        - Alert Scientific, 800-872-2028
        - Airflow Laboratory Services, 800-720-9807
    - 24-Hour Alarm Monitoring Only
        - Minus80 Monitoring, 804-502-4604 (Highly flexible, cloud-based system – successful pilot program at Yale Pathology 2014)
        - ADT, 203-741-4073
        - Nationwide Security, 203-785-0300

s. Darkrooms:

Although most traditional wet darkroom work has been supplanted by dry digital processes, the following criteria still apply for wet darkrooms:

- Provide additional ventilation to either dilute contaminants or capture locally (especially if wet tray work or using processing equipment with dedicated exhaust)
- Silver recovery system required for effluent from automatic film processors
- Automated film or photograph processors must be registered with EHS for wastewater discharge permitting with City of New Haven. Such equipment must also be on service contract to ensure regular maintenance.
- DWV pipes should be at least one diameter larger than standard drainage required due to periodic solids loading and recognized tendency of such installations to clog.
- Constant temperature equipment typically needed to maintain water temperatures within 2 degrees of 68 F for wet tray/black and white work, and within 0.5 degrees of 95 F for color work. Confirm with end users.
- Provide footprint/space for waste collection containers.

t. Tissue/Cell Culture Rooms:

- Under negative pressure relative to corridors and surrounding spaces.
- Separate from surrounding areas with door, preferably inward opening.
- Seamless sheet flooring, raised wall:floor edging
- Floor penetrations caulked/sealed to prevent liquid migration in emergency
- Handwashing sink inside room, preferably near door
- Ceilings at least 8 ft high to accommodate biological safety cabinets and stacked incubators
- Avoid placing biological safety cabinets below air supply vents
- Hard-plumbed, manifolded gas delivery system for incubators as required by occupants.

u. Hallways:

- Non-carpeted, non-porous., easily cleaned surfaces (i.e., seamless sheet flooring, vinyl tiling)
- Avoid door/threshold saddles and carefully evaluate expansion joint designs to prevent pedestrian and lab cart accidents
- Sufficient width and height to accommodate pedestrian, cart, and equipment traffic

v. Shelving:

- Wall and above bench shelving to maximize accessible storage space
- Chemical resistant finish surfaces
- Shelf lips - not required in Connecticut, but are recommended as their use greatly reduces accidental slides/pushes of bottles off shelves. Alternatively, include a center shelf partition on back-to-back lab bench shelving systems.

w. Waste Collection and Storage Areas:

- Dedicate adequate space within each contiguous lab for waste storage, preferably near the front of the lab.,

5. Special Operations

The following kinds of areas and operations carry higher or unusual hazards, and must be designed in conjunction with EHS and other applicable departments:

- Animal research
- Autoclave/glassware washing rooms
- Automated film processors
- Biological safety level 3 (or higher) labs and tissue culture rooms
- Cleanrooms
- Clinical spaces and areas adjacent to related patient care areas, especially those with potential respiratory disease cases, tuberculosis patients, and infectious agent isolation rooms
- Flammable storage rooms
- High magnetic field generating equipment
- Irradiators
- Large teaching laboratories
- Perchloric acid fume hoods
- Radioactive iodine fume hoods

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