Principles and Concepts of Laboratory Design
Purpose of Laboratory Design

- Protect the Workers
- Enable the Work
- Secure the Facility
- Protect the Environment
- Comply with Regulations
Objectives of Laboratory Design

• Provide a safe/secure workplace
• Facilitate workplace activities
• Efficient
• Cost Effective
Barriers to Good Lab Design

- Cost
- Poor Communication
- Lack of Scientific Knowledge
- Complicated Project
- Trade-offs
- Personalities
- Maintenance
Good Laboratory Design

Based on:

Containment

Maximize Containment

Minimize Contamination

Redundancy is the Key
Chemical Containment Concept

Facility

Chemistry Knowledge

Personnel

Engineering Controls

Operations

Storage

Environment

Facility

Facility

Facility

Environment
<table>
<thead>
<tr>
<th></th>
<th>Chemical Protection Depends on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chemistry Knowledge</td>
</tr>
<tr>
<td></td>
<td>Workers must have knowledge and understanding</td>
</tr>
<tr>
<td>2</td>
<td>Containment</td>
</tr>
<tr>
<td></td>
<td>Safe/Secure Storage</td>
</tr>
<tr>
<td></td>
<td>Proper Work Practices</td>
</tr>
<tr>
<td></td>
<td>Good Engineering Controls</td>
</tr>
</tbody>
</table>
Chemical Protection Depends on, cont’d:

3

Construction

How well the facility is built
Key Stakeholders

Architects
Engineers
Administrators
Builders
EHS Professionals

Laboratory Users
Laboratory Design is an Iterative Process
Design Phases

Definition
(problems and needs)
(iterative process)

Interpretation
(of requirements into design criteria)
(iterative process)

Design
(translates specifications into pragmatic reality)

Construction
(to accomplish goal)
Architectural Features Include:

- Layout of buildings and laboratories
- Space requirements
- Spatial arrangement of equipment and benches
- Emergency egress
- Storage requirements
- Waste requirements
- Access controls
- Security features
Lab Design Components

- **Spatial**
  - Floor plan
  - Location of rooms and equipment
  - Traffic flow of people and equipment
  - Access control
- **Mechanical**
  - Ventilation
  - Utilities
  - Effluent control
  - Control and monitoring
- **Safety and Security**
Factors in Laboratory Design

- Architectural
- HVAC*
- Safety and Security
  - Fire
  - Emergencies
  - Exposures
  - Access/exit control (facility, chemicals, equipment)

(* heating, ventilation, and air conditioning)
General Information Needed

- Number of occupants and their technical qualifications
- Space and storage requirements
- Utilities needed
- Equipment needs
- Time/duration of occupancy
- Anticipated changes in research/programs
- Sustainability (environmental, green initiatives)
- Security needs
Safety/Security Information Needed Before Design can Begin

Type of Work/Research

Type of Hazards

Type of Wastes

Chemical

Biological

Radiation

High Voltage
Safety/Security Information Needed for Lab Design, cont’d.

Types of Chemicals (based on physical state and properties)

- Flammable
- Corrosive (acid or base)
- Reactive
- Acutely Toxic (poisons)
- Regulated
- Chronically Toxic (e.g., carcinogens, repro-toxins)

Chemicals of security concern

- Controlled Drugs
- Wastes
Specific Chemical Laboratory Safety/Security Concerns

Include:

- Fire detection, alarms, and suppression systems
- Safety equipment (i.e. emergency showers, eyewash and contaminant control)
- Ventilation (i.e. laboratory hoods, glove boxes, ventilated enclosures)
- Management of chemicals and waste
- Access controls for facility and laboratories
Examples of Lab Design Considerations

- Sample preparation and storage area
- Segregate sample digestion using acid-specialized laboratory hoods
- Segregate solvent extraction to reduce vapor contamination
- Proper eyewash placement
- Adequate egress
- Waste storage area
- Gas bottle storage
Building Layout: Divide into Zones

- Zones or control areas may have different:
  - Types and degree of hazards
  - Amounts of hazardous chemicals
- Allows better control over:
  - Personnel access
  - Hazards using
    - Equipment
    - PPE
    - Administrative procedures
- Examples: Fire safety zones, HVAC zones, Building floors
Building Layout: Corridors

• Best practice is to separate movement of:
  – General population
  – Laboratory personnel
  – Chemicals and laboratory materials.

• Internal “service corridors” between labs
  – Allow transport of chemicals away from public
  – Provide access to utilities and other support equipment
  – Provide additional lab exits with emergency doors to main corridors
Building Layout: Entrance/Exit Doors

- Good safety: two or more exits from each lab/room/building
- Good security: control who can enter a lab/room/building
- Emergency exit doors:
  - Lack handles or are locked on outside
  - Have “panic bar” on inside
  - May set off alarm when opened
Building Layout: Chemical Stockrooms

• Multiple, specialized stockrooms rather than one central storeroom
  – Chemicals dispensed across counter
  – Access restricted to stockroom personnel
  – Locked when unattended

• Teaching stockroom
  – High traffic
  – Only keep ~1 week supply of chemicals needed for student experiments

• Central Stockroom
  – Wide variety of chemicals and materials
  – Additional controls and containment for regulated, attractive, or dual-use chemicals

• Chemicals stored in compatible groups
Building Layout: Compressed Gases

• Install tanks outside building and pipe into lab
  – Long-term, frequent use of same gas
  – Highly hazardous gases
  – Restrict access
  – Out-building or outdoors, depending on conditions
Building Layout: Compressed Gases

• Tanks inside labs
  – Wide variety of gases
  – Low use rates
  – Strap to wall or bench
  – Transport safely
Building Layout: Chemical Waste

- Large volumes of chemical waste should be stored in areas with fewer people
  - Access restricted to responsible personnel
  - Locked when unattended
  - Divided into chemically compatible groups
  - Provide safety equipment and alarms
Building Layout: Chemical Waste

• Waste collection area in teaching/research labs:
  – Convenient student use
  – Emptied/moved frequently
  – Divided into chemically compatible groups
  – Provide safety equipment
Open vs. Closed Laboratories

Open Laboratory

Closed Laboratory
**Open vs. Closed Laboratories**

**Open laboratories**
- Support team work
- Facilitates communication
- Shared:
  - Equipment
  - Bench space
  - Support staff
- Adaptable and flexible
- Easier to monitor
- Cheaper to design, build and operate
- The trend since mid 90’s

**Closed laboratories**
- Specialized, dedicated work
- More expensive
- Less flexible
- Easier to control access
- Needed for specific work
  - NMR
  - Mass spec
  - High hazard materials
  - Dark rooms
  - Lasers

Consider using both or having connected access:
Energy Conservation, Sustainability and Green Chemistry Concerns

- Design leading to increased productivity
- Energy conservation and efficiency
- Centralized heat-generating equipment
- Manifolded hoods and ventilation
- Reduction/elimination of harmful substances and waste
- Efficient use of materials and resources
- Recycling and reuse
Ventilation Considerations Include

- Heating and cooling needs
- Maintaining directional airflow
- Type of hoods
- Single vs. manifolded hoods
General Laboratory Hood Considerations

- Determine minimum exhaust requirements.
- Communicate hood limitations to users.
- Label restrictions e.g., no perchloric acid.
- Alarm systems
- Consider future needs.
Hood Manifold Considerations

Single Hood - Single Fan

1000 CFM

H

1000 CFM

H

1000 CFM

H
Hood Manifold Considerations

Manifold: 3 Hoods, 1 Fan

H1  H2  H3

3000 CFM
Hood Manifold Considerations

Hood Diversity = 33%

1000 CFM

H1  H2  H3
Ventilation Design: Avoid Exhaust Recirculation
Lab Layout

• Try to locate hoods, utilities and safety equipment in the same relative position in all labs.
• Locate sinks centrally
• Space between benches should allow people to pass each other (≥1.5 m).
• Details given in later presentations on:
  – Lab hoods
  – Safety showers / eyewashes
  – Chemical management
Lab Layout

• Construction materials should be appropriate for chemicals
  – Benchtops
  – Cabinets & shelving
  – Flooring
  – Avoid metal drainpipes
• Store chemicals and waste securely – not easily spilled or knocked over.
• Keep bulk chemicals in stockroom - not lab.
• Control access to labs, especially during off-hours
Laboratory Modifications or Decommissioning

• When a laboratory is modified or vacated, ensure that:
  – Chemicals have been safely moved to another lab, returned to the stockroom, or properly disposed of.
  – Any contamination has been removed from the:
    • Room (floor, ceiling, walls)
    • Furniture
    • Equipment and fixtures
    • Plumbing system
    • HVAC ductwork
Questions & Answers, Homework
Chemical Safety and Security Program

Organization and Responsibilities
<table>
<thead>
<tr>
<th>Crisis Management: Prevention &amp; Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facility crisis</strong></td>
</tr>
<tr>
<td>– Fire</td>
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<tr>
<td>– Explosion</td>
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<tr>
<td>– Chemical release</td>
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<tr>
<td><strong>Natural disaster</strong></td>
</tr>
<tr>
<td>– Earthquakes</td>
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<tr>
<td>– Hurricane/typhoon</td>
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<tr>
<td>– Tsunami</td>
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<tr>
<td><strong>Disgruntled personnel</strong></td>
</tr>
<tr>
<td>– Employees</td>
</tr>
<tr>
<td>– Ex-workers</td>
</tr>
<tr>
<td>– Students</td>
</tr>
<tr>
<td><strong>Demonstrations, protests</strong></td>
</tr>
<tr>
<td><strong>Evacuation / reoccupancy</strong></td>
</tr>
<tr>
<td><strong>Terrorism</strong></td>
</tr>
</tbody>
</table>
Chemical Safety and Security Program
Ideal Roles

• Culture of Chemical Safety and Security should exist at all levels of the organization.
• Top management sets policy, provides resources.
• Workers, students, researchers must understand and implement.
• Many organizational interactions are important for chemical safety and security
  – After Fig 1-1 in Prudent Practices in the Laboratory, NRC 1995

- Executive Officer or President
- Institutional Safety Officer and Institutional Security Officer
- Senior Manager
  - Research director, Department chairperson
- Supervisor
  - Project manager, Principal investigator
- Laboratory Worker
  - Student, Technician
- Chemical Safety & Security Officer
  - Designated by the department
Faculty/Principal Investigator

has the responsibility
to *teach, model* and *encourage*
good Chemical Safety and Security practices
Principal Investigator
CSS Responsibilities

• Develop procedures with CSSO for unique hazards and chemicals (e.g. carcinogens)
• Develop proper control practices with CSSO
• Participate in developing CSS Plan, CSS Committee, accident investigations
• Ensure CSS documents and records are maintained
• Maintain local chemical inventory for their lab
• Ensure (M)SDS are available in the laboratory
• Facilitate compliance with policies, guidelines and regulations
CSS Responsibilities
Principal Investigator, cont’d.

• Ensure students/workers know and follow policies and practices
• Ensure equipment and controls are properly maintained
• Ensure all students/workers received proper training and refreshers
• Ensure new students/workers receive proper training before starting work
• Inform CSSO of any accidents and incidents
• Follow-up on accidents and incidents
Employees and students have a responsibility to *actively* support and participate in the CSS Program.
Employee/Student CSS Responsibilities

• Follow policies/rules
• Wear Personal Protective Equipment (PPE)
• Report accidents, incidents/near misses, problems
• Learn about hazards of specific chemicals
• Suggest changes and improvements
• Work safely
• Do not put others at risk
• Encourage good safety and security
• Behave responsibly
Employee/Student CSS Responsibilities

- Understand and act in accordance with policies and practices
- Wear and maintain proper PPE
- Use engineering controls properly
- Follow good chemical safety practices
- Participate in required training
- Read & understand CSS related documents
- Report accidents, incidents
- Suggest improvements and changes to the CSS Program
- Participate in the CSS Program
Chemical Safety and Security Officer

has the responsibility
to provide expertise and information
so that
a safe and healthy workplace is present
CSSO
Training, Experience, Skills

• Chemistry
  - Nomenclature
  - Physical properties
  - Reactivities
  - Chemical compatibilities

• Health and Safety (industrial hygiene)

• Security
  - Facility
  - Chemicals
  - Equipment
  - Personnel

• Psychology
  - Dealing with people

• Physics
  - Ventilation
  - Radiation (ionizing/non-ionizing)
  - Electrical

• Biology
  - Biosafety
  - Recombinant DNA
  - Blood borne pathogens

• Administration
• Writing
• Speaking/presentations/training
CSSO Responsibilities

- Report directly to higher management
- Provide leadership in safety and security
- Draft a budget
- Ensure Plans and Manuals are written and updated
- Advise administration, staff, employees, students
- Conduct inspections and audits
- Investigate accidents and incidents
- Respond to problems and concerns
- Participate in Chemical Safety and Security Committee(s)
- Ensure documentation, records and metrics are maintained
- Develop CSS Training plans
- Know legal regulations and ensure compliance
The Function of the CSSO is to Act as a Co-Worker, *NOT* as a Policeman
Chemical Safety and Security Committee

has the responsibility

to oversee and monitor the CSS Program
for management so that
a safe and healthy workplace
is maintained
Chemical Safety and Security Committee Responsibilities

• Reports directly to senior management
• Endorses policies
• Meets regularly (2 – 4 times/yr) with agendas
• Reviews accidents and incidents, may investigate, write reports with recommendations
• Establishes appropriate subcommittees on specific topics
Chemical Safety and Security Committee Composition

- Chaired by committed staff
- CSSO is ex-officio member
- Includes representatives from:
  - Facilities Management
  - Security
  - Administration
  - Faculty/Staff
  - Teaching Assistants/Graduate Students
  - Shops/Unions
- Representatives should rotate after a few years
# Management CSS Responsibilities

<table>
<thead>
<tr>
<th>Commitment:</th>
<th>Support:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Establish a formal CSS Program</td>
<td>• Financial support (budget)</td>
</tr>
<tr>
<td>• Announce formation of a CSS Program</td>
<td>• Staffing</td>
</tr>
<tr>
<td>• Create a written policy statement</td>
<td>• Response/.resolution of problems by</td>
</tr>
<tr>
<td>• Designate a Chemical Safety and Security Officer</td>
<td>– Establishing a CSS Committee</td>
</tr>
<tr>
<td>• Endorse a written CSS Plan (Manual)</td>
<td>• Stipulates CSS is part of everyone's job</td>
</tr>
<tr>
<td>• Participate and intervene as needed</td>
<td>– CSS applies to everyone</td>
</tr>
<tr>
<td></td>
<td>– Specifies CSS orientation for new employees</td>
</tr>
<tr>
<td></td>
<td>• Supports CSS staff</td>
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</tbody>
</table>
Management
CSS Responsibilities

POLICY STATEMENT

Documents and describes the commitment and support from the highest management level for the Chemical Safety and Security Program
Policy Statements

- By senior management
- Typically brief
- Clear goals
- Commitment
- Defines employee role
- Identifies resources and staff
- Signed by person in authority
Director/President
CSS Responsibilities

• Establish an effective CSS Program
• Provide for a budget
• Endorse written Policies, Plans and Manuals
• Appoint CSS Officers
• Ensure CSSO has responsibility, authority and accountability to perform assigned duties
• Establish a CSS Committee
• Maintain support and endorsement
• Timely response to Safety Committee recommendations
• Follow and set example, e.g., wears PPE
CSS
Program Evaluation

• Management leadership
• Employee involvement
• Administrative controls
• Security controls
  – Access to buildings, materials
• Engineering controls
• Accident/incident investigation
• Training
• Use of Personal Protective Equipment (PPE)
• Emergency Response Program
• Medical Surveillance Program
• Work site analysis
  – Inspections, surveys, hazard analysis
Questions and Answers
Homework- Describe your Lab