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# **Design Principles of Infectious Diseases Containment Facilities**

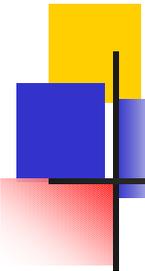
**Tim Lee**

**Leader of National Laboratory Knowledge Network**

**M.SC; P.Eng; PMP**

# Bio-Containment Facilities



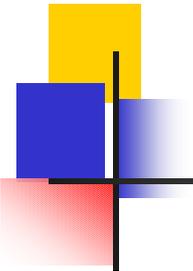


# Bio-Containment Facilities

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## Facilities

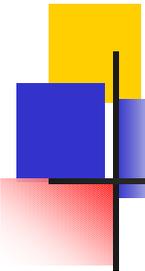
**Human or Animal Pathogens or  
Infectious Agents are grown  
for Research or Development  
Purposes**



# Infectious Agent Biosafety Levels

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- Biosafety Level 1 - Basic**
- Biosafety Level 2 - Basic**
- Biosafety Level 3 - Containment**
- Biosafety Level 4 - Maximum Containment**



# Risk Assessment

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**Probability**

**Severity**

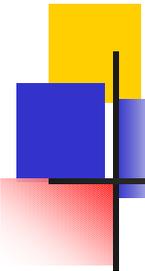
**Magnitude**

**Human**

**Animal**

**Plant**

**Environment**



# Selection of Biosafety Levels

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**Prudently Select Levels**

**Inflexibility and Inadaptability**

**Huge Cost Differentials Between  
Levels**

# Biosafety Level 2

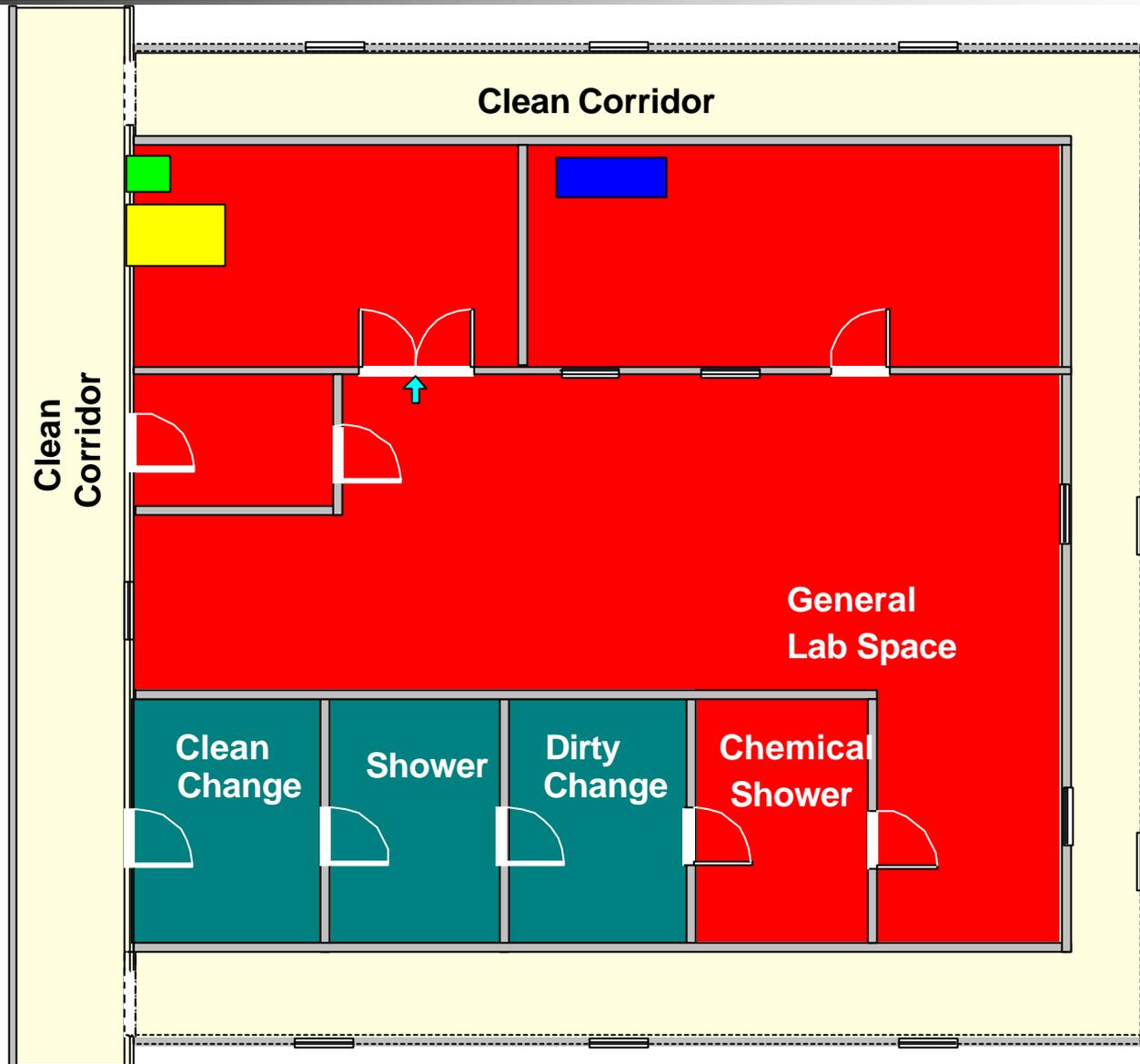




# Biosafety Level 3



# Biosafety Level 4

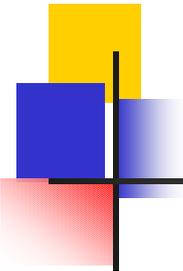


# Biosafety Level 4



# Biosafety Level 4





# Objectives of Containment

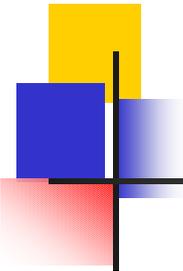
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**Minimize or Eliminate Potential  
Hazardous Agents to:**

**Laboratory Workers**

**Outside Environment**

**Community**



# Containment Barriers

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**Primary Barrier**

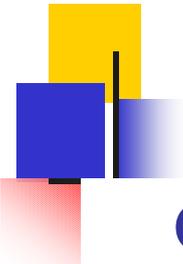
**Laboratory Equipment**

**Secondary Barrier**

**Engineering System Design**

**Tertiary Barrier**

**Building Envelope**

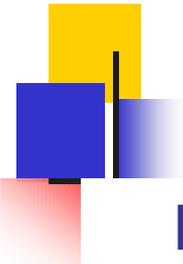


# Containment Barriers

## Containment Facility

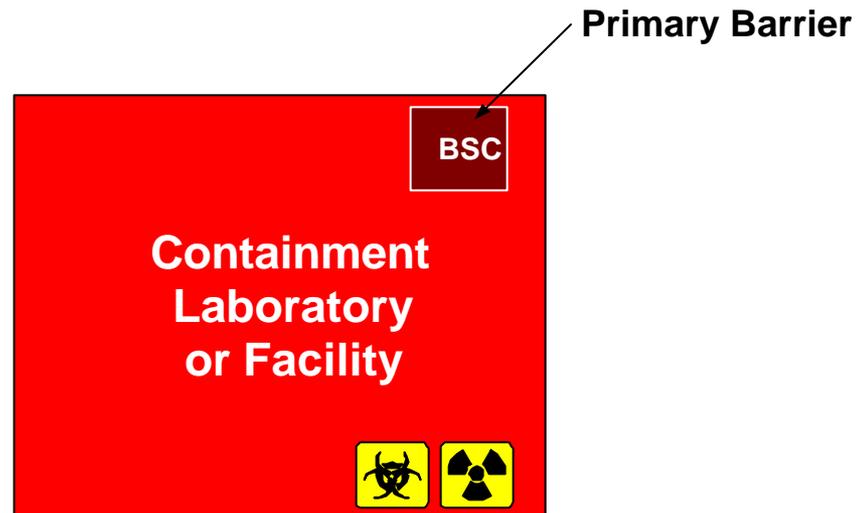


**Containment  
Laboratory  
or Facility**



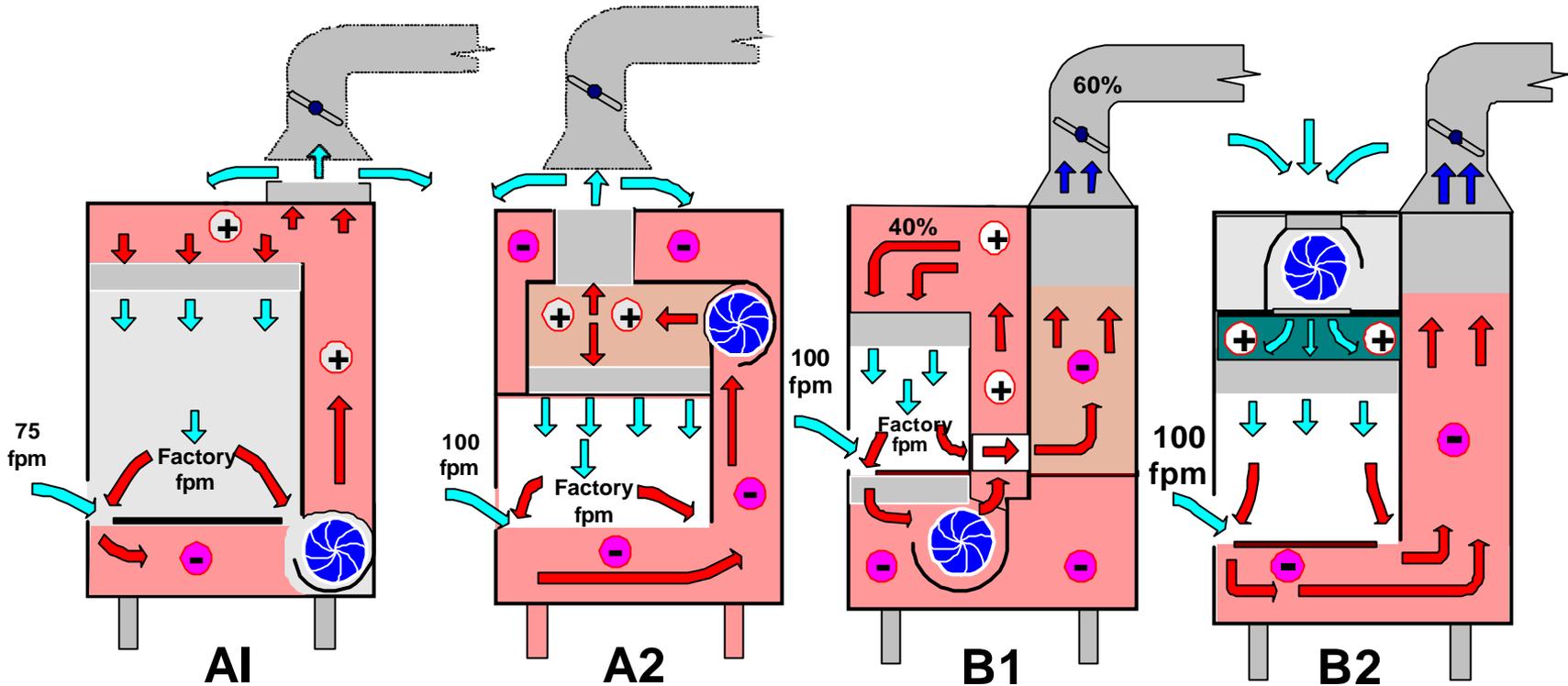
# Containment Barriers

## Primary Barrier



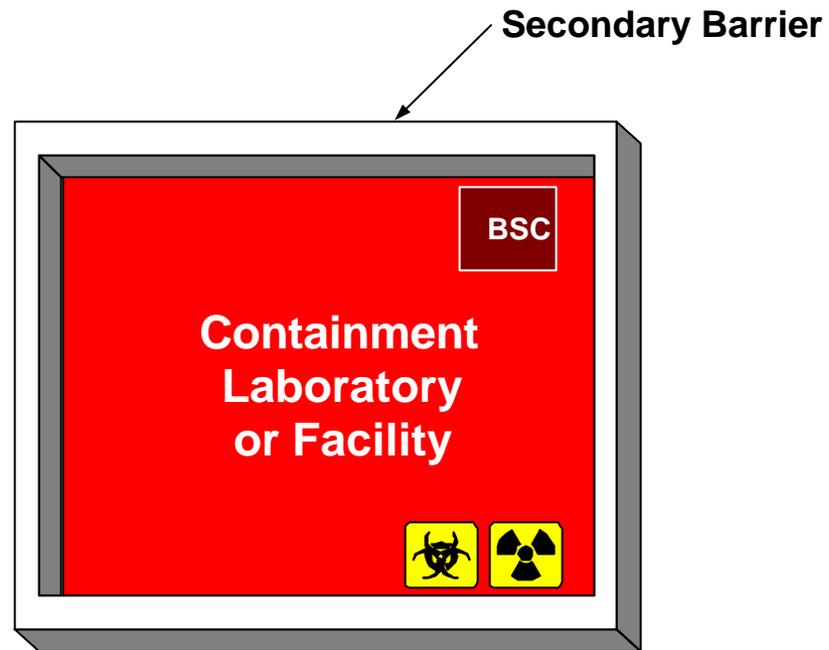
# Containment Barriers

## Primary Barrier – Biosafety Cabinets



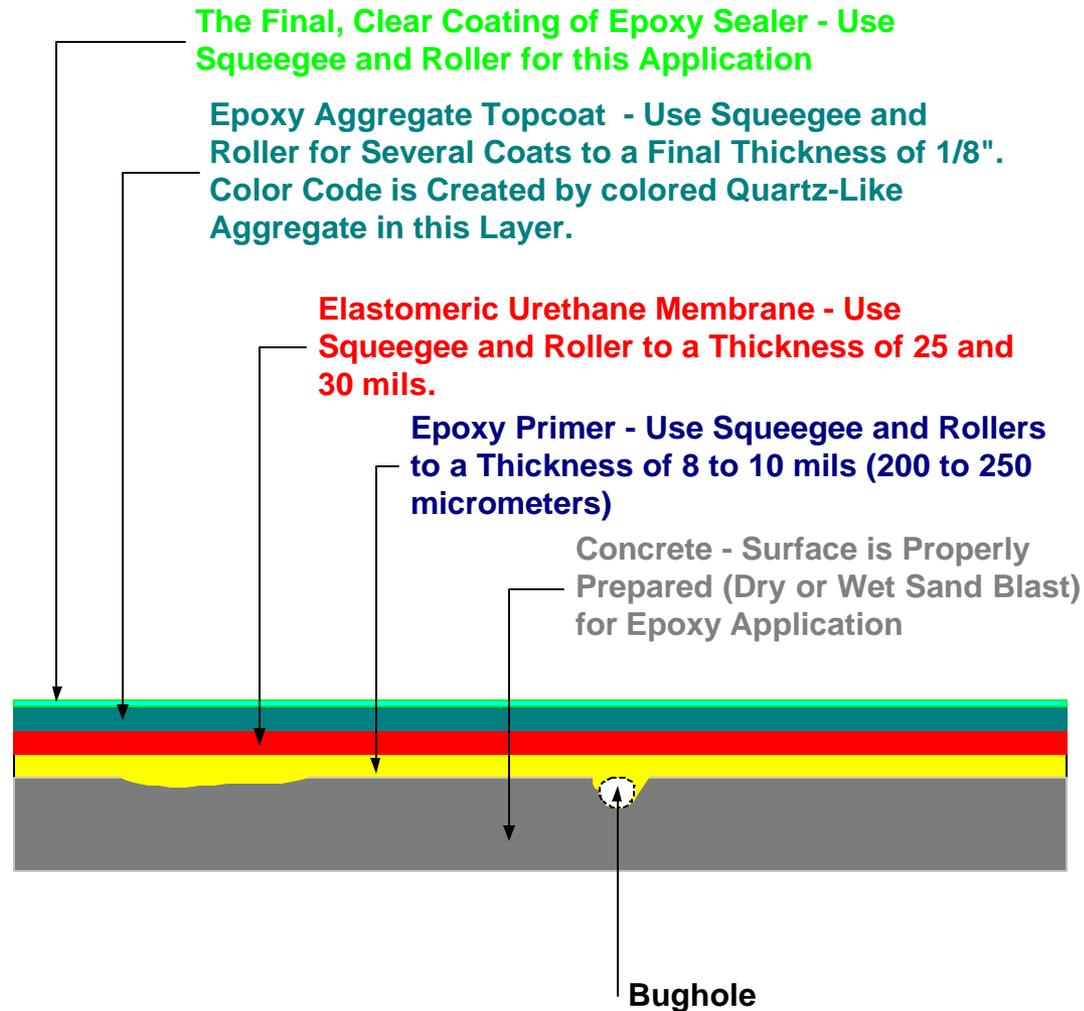
# Containment Barriers

## Secondary Barrier



# Containment Barriers

## Secondary Barrier – Concrete Surface Preparation



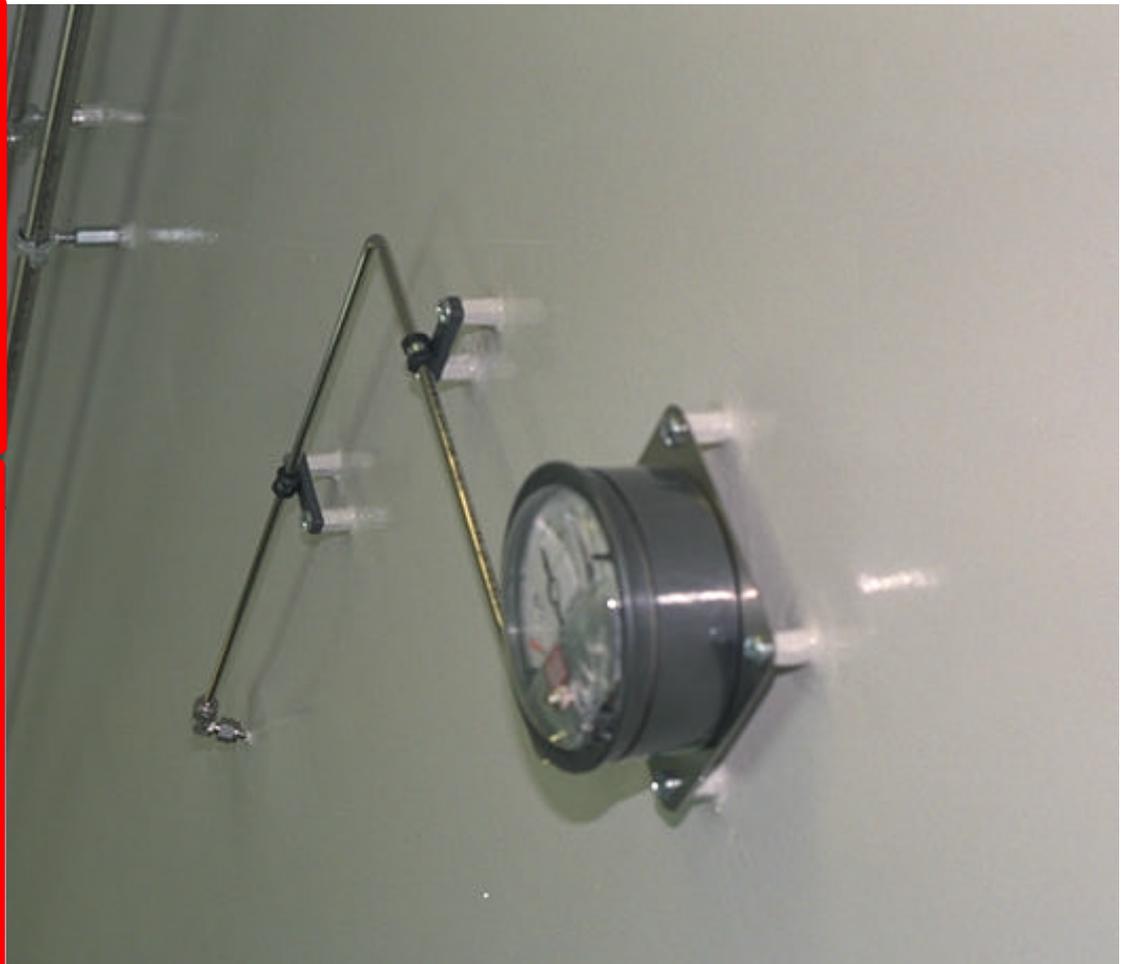
# Containment Barriers

## Secondary Barrier – Concrete Surface Preparation



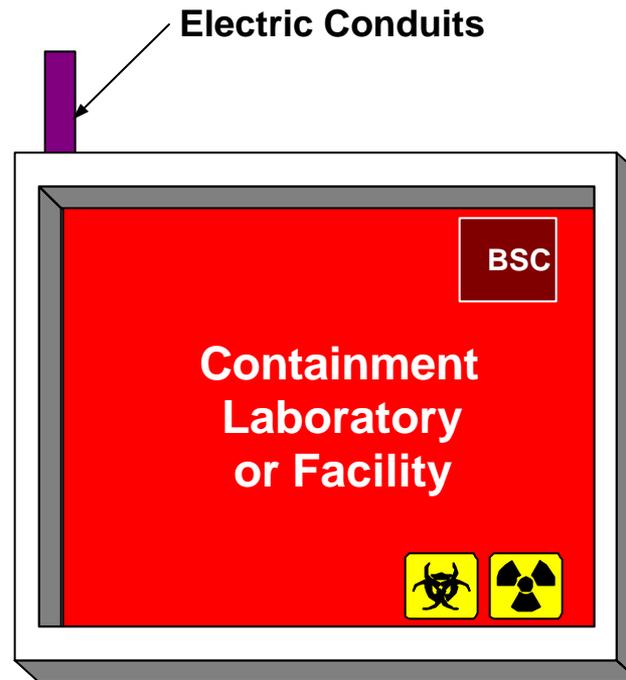
# Containment Barriers

## Secondary Barrier – Concrete Surface Preparation



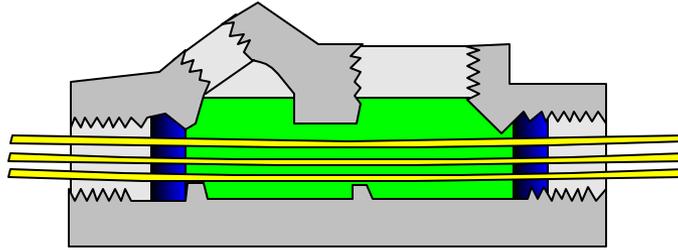
# Containment Barriers

## Conduits

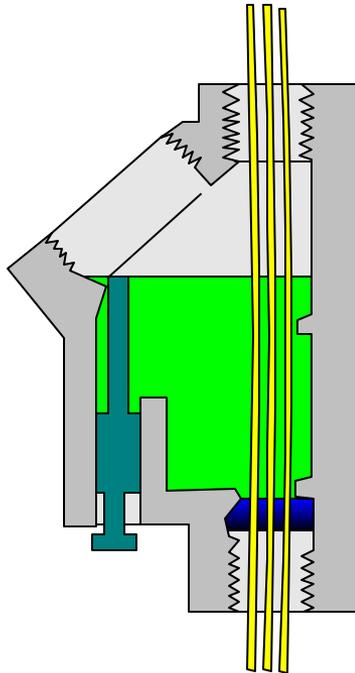


# Containment Barriers

## Conduits



Horizontal Conduit



Vertical Conduit



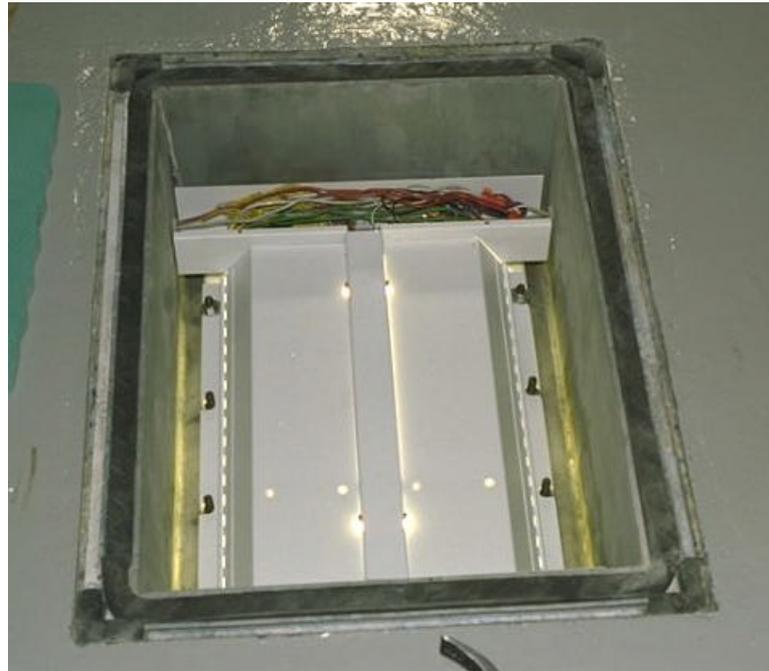
# Containment Barriers

## Conduits



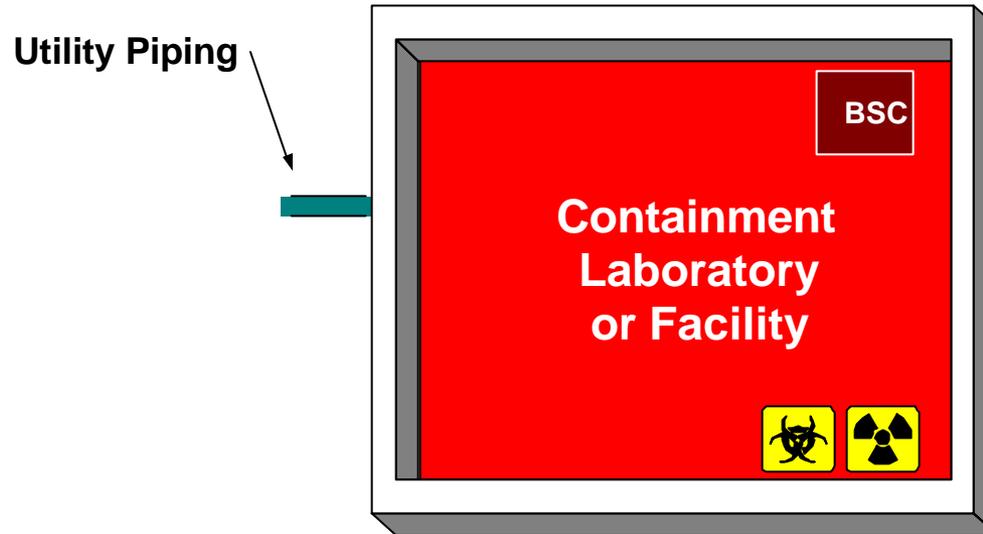
# Containment Barriers

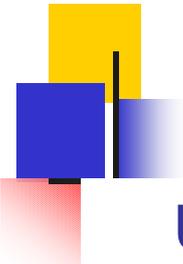
## Lighting Fixture



# Containment Barriers

## Utility Piping



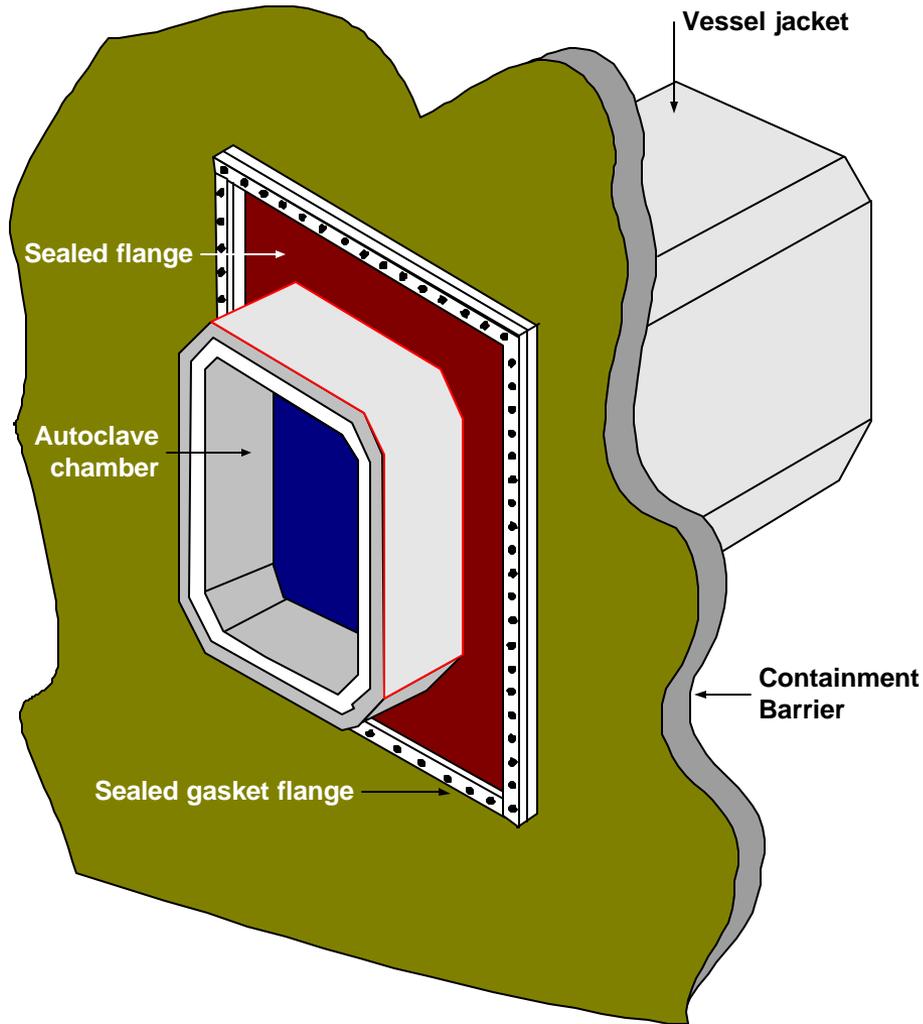


# Containment Barriers

Utility Piping

# Containment Barriers

## Pass-through Equipment



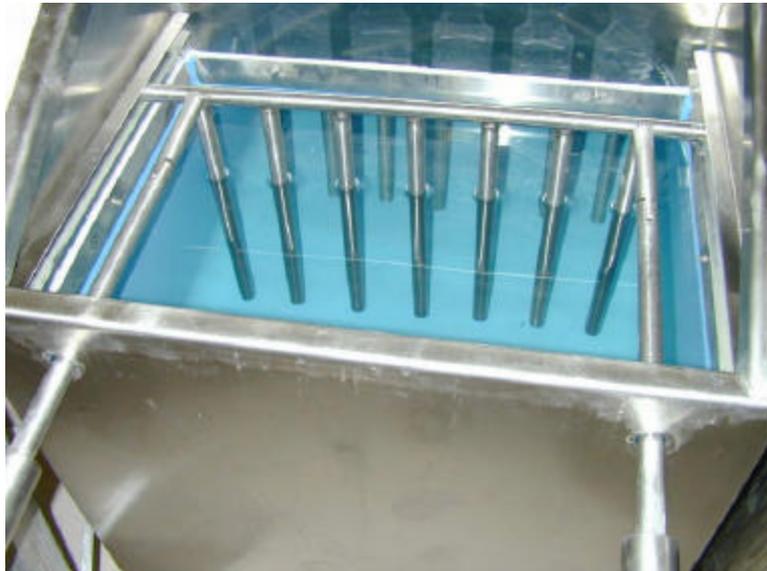
# Containment Barriers

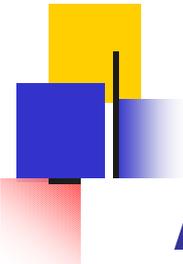
## Pass-through Equipment



# Containment Barriers

## Pass-through Equipment





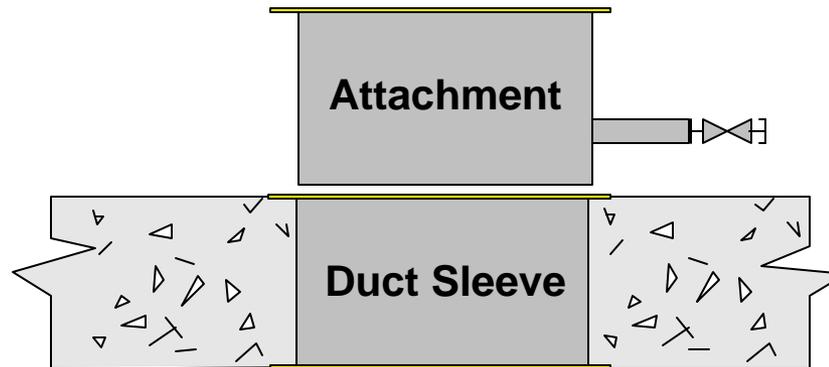
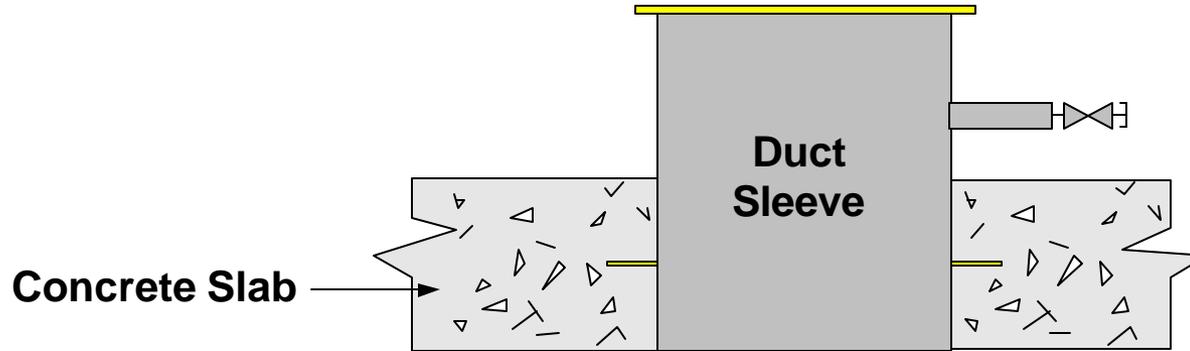
# Containment Barriers

## Air Ducts and Filters



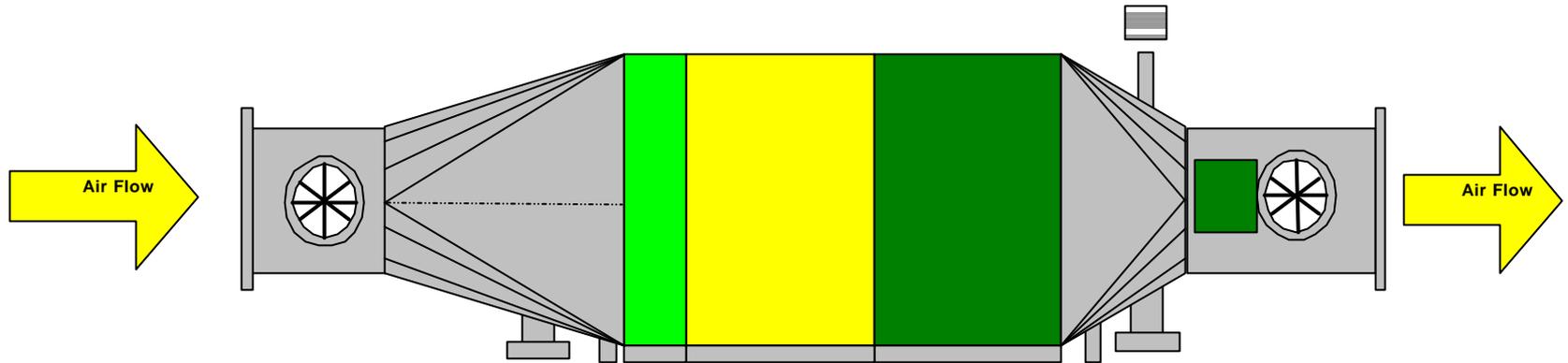
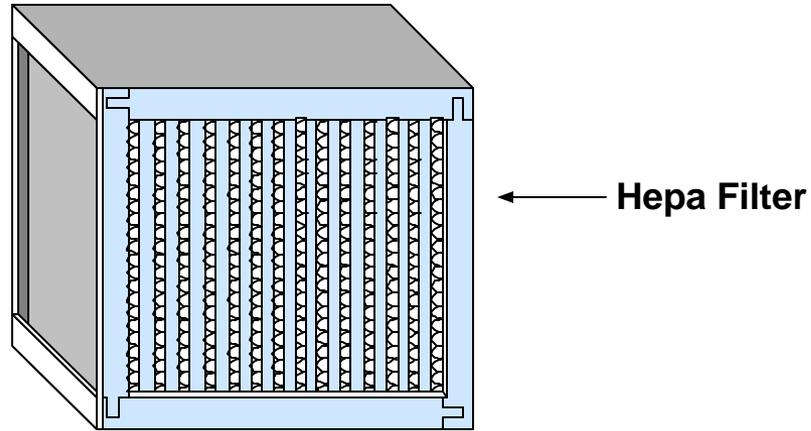
# Containment Barriers

## Air Ducts



# Containment Barriers

## Air Filters and Housing



# Containment Barriers

## Air Filters and Housing



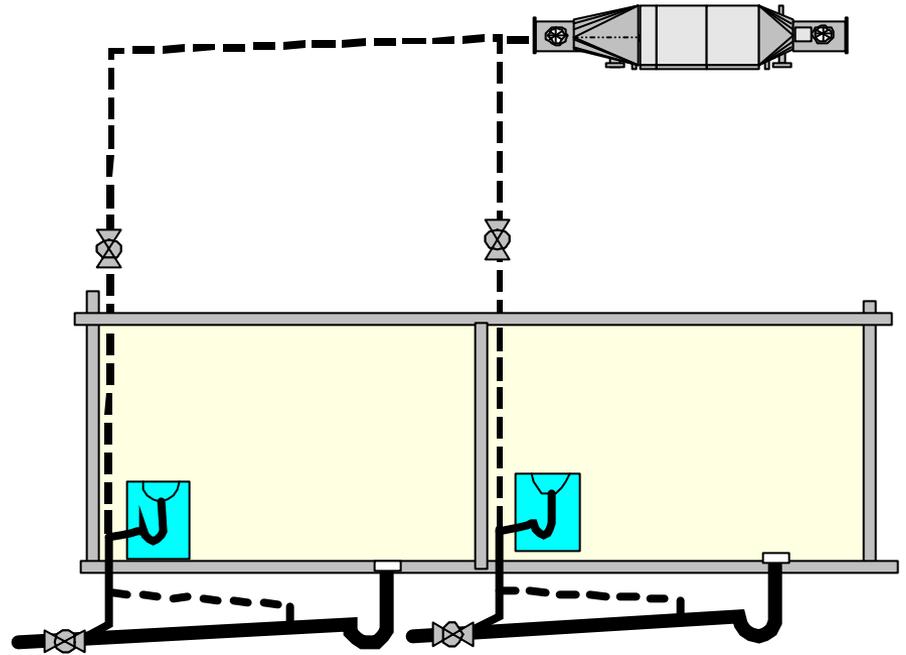
# Containment Barriers

## Air Filters and Housing



# Containment Barriers

## Air Filters and Housing



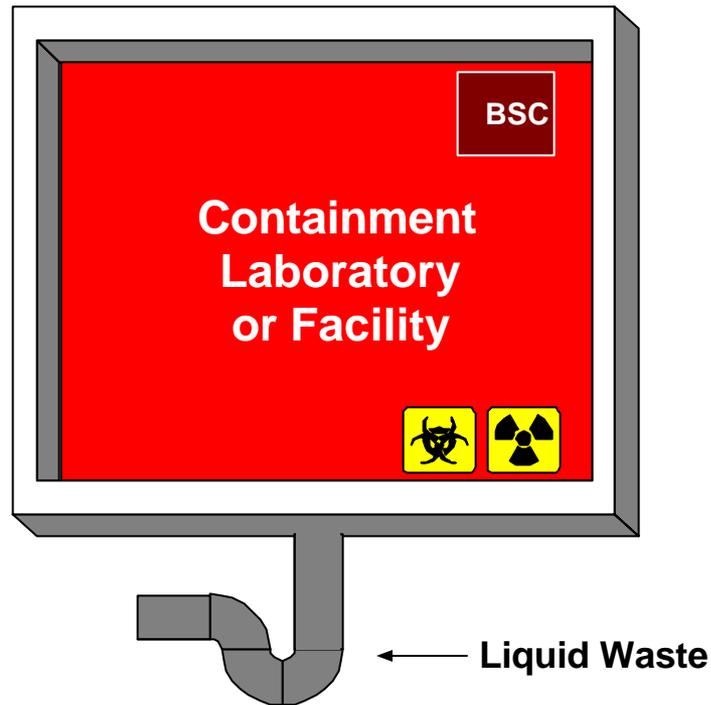
# Containment Barriers

## Air Filters and Housing



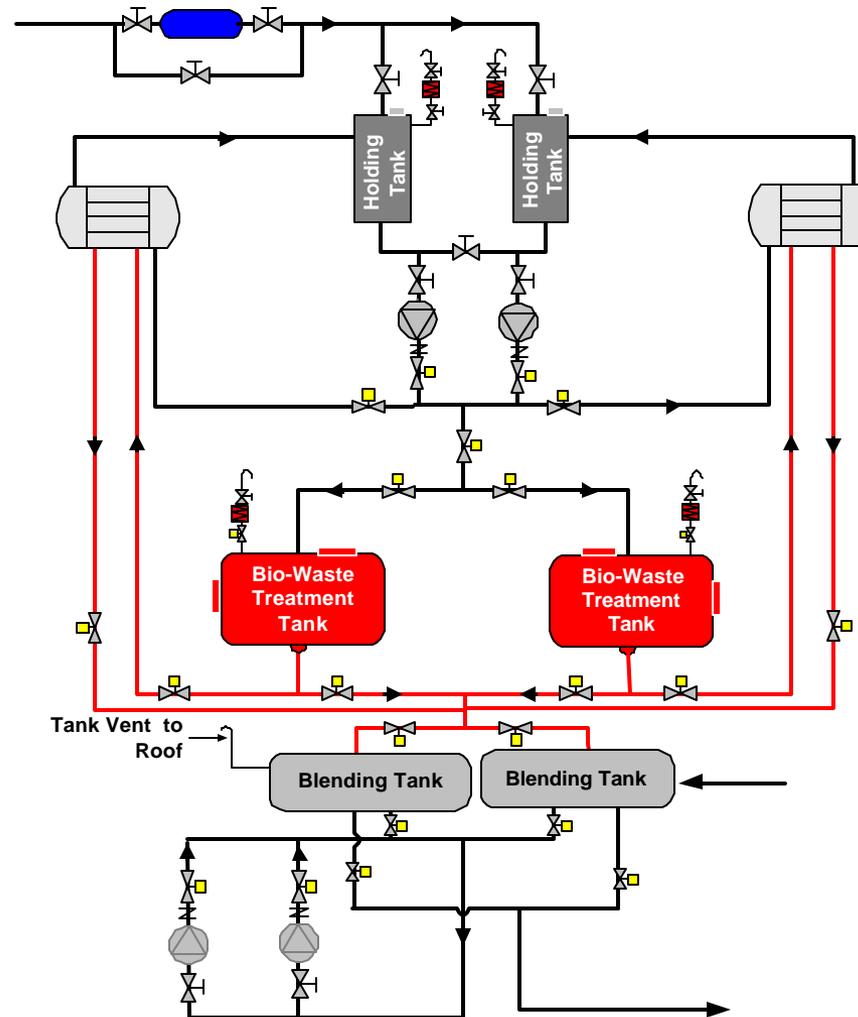
# Containment Barriers

## Liquid Waste



# Containment Barriers

## Liquid Waste Piping Schematic



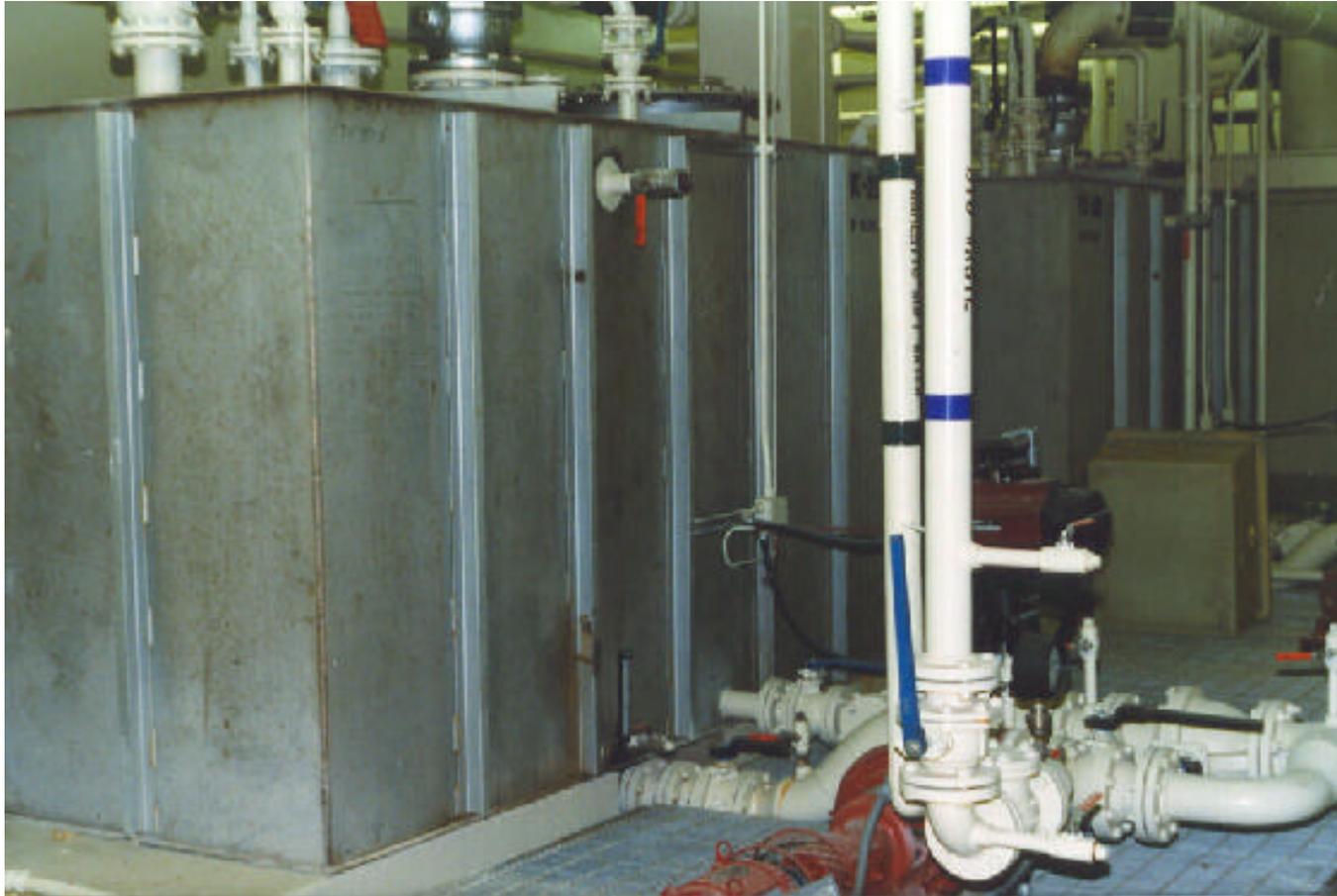
# Containment Barriers

## Liquid Waste without Steam Agitation



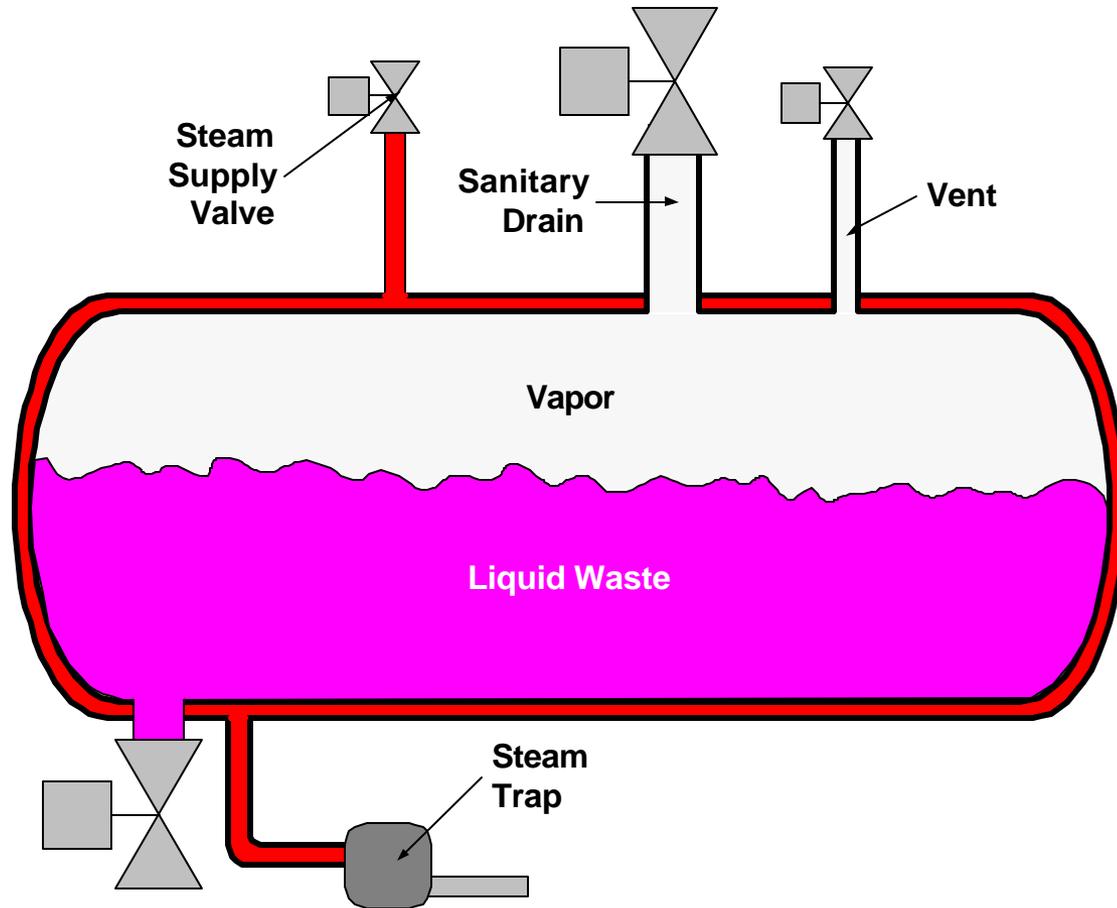
# Containment Barriers

Liquid Waste without Steam Agitation



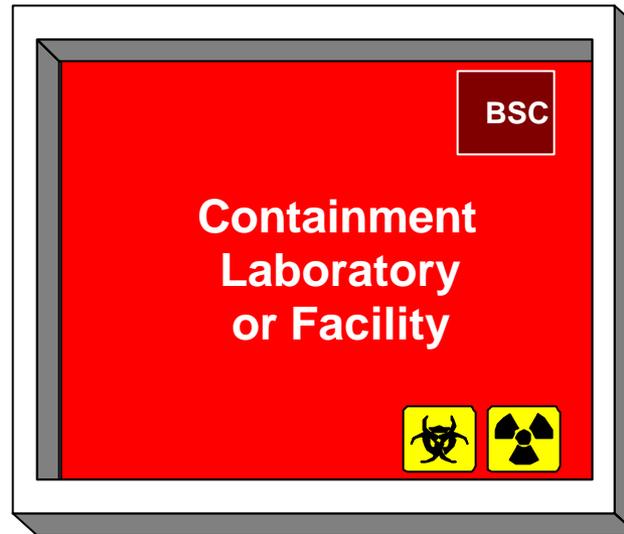
# Containment Barriers

## Liquid Waste without Agitation



# Containment Barriers

## Animal Carcass or Solid Wastes

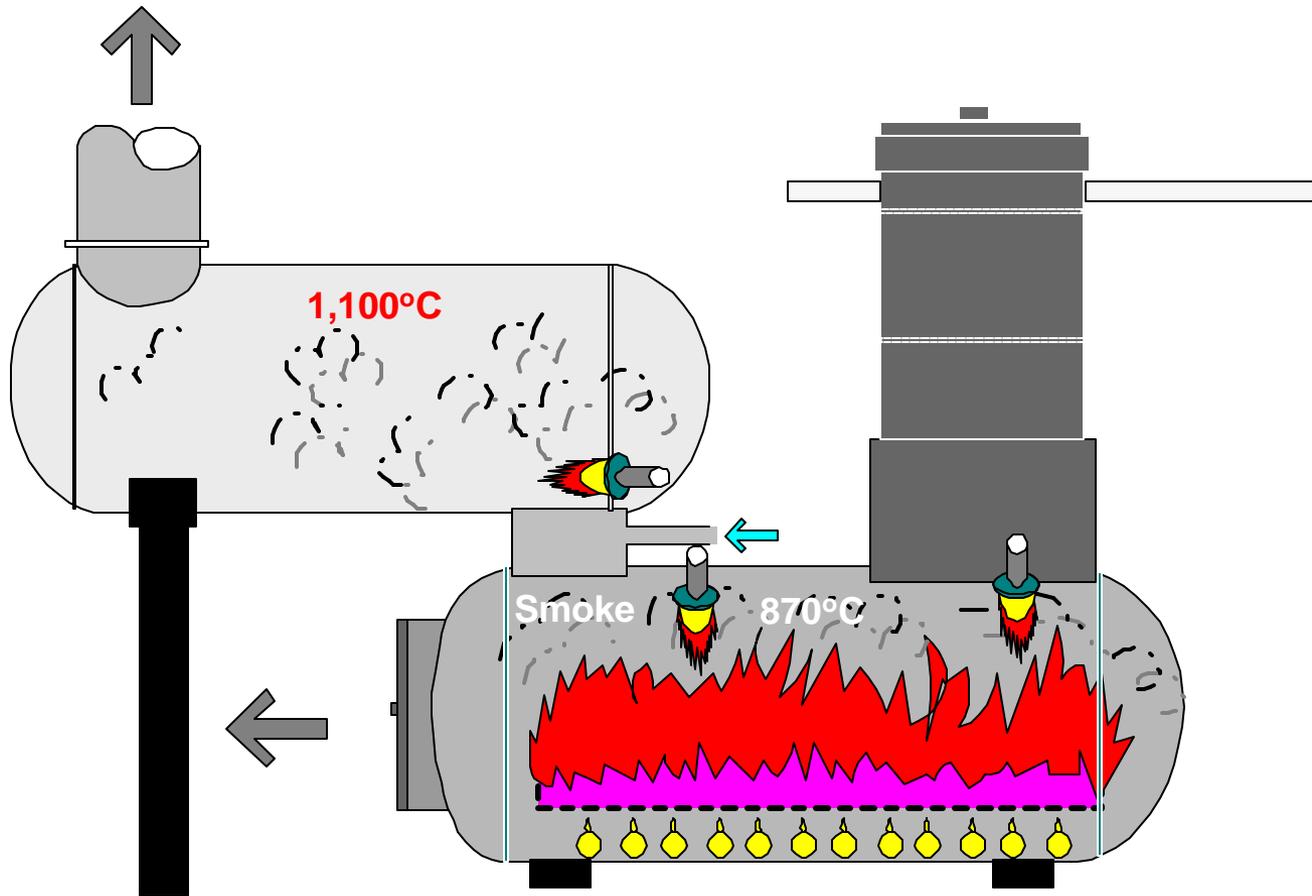


Animal Carcass →



# Containment Barriers

## Biowaste or Pathological Incinerator



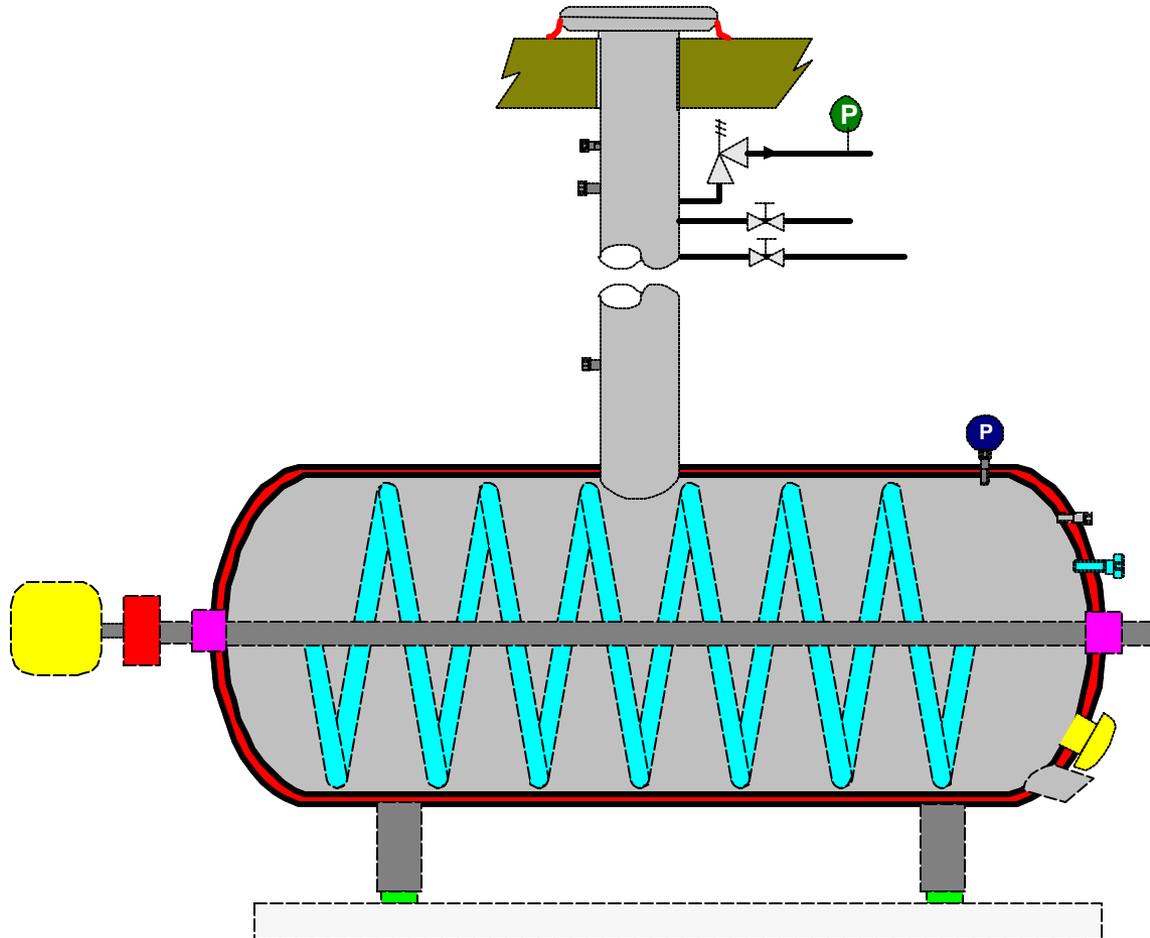
# Containment Barriers

## Biowaste or Pathological Incinerator



# Containment Barriers

## Solid Waste Rendering Tank



# Containment Barriers

## Solid Waste Rendering Tank – Alkaline Hydrolysis



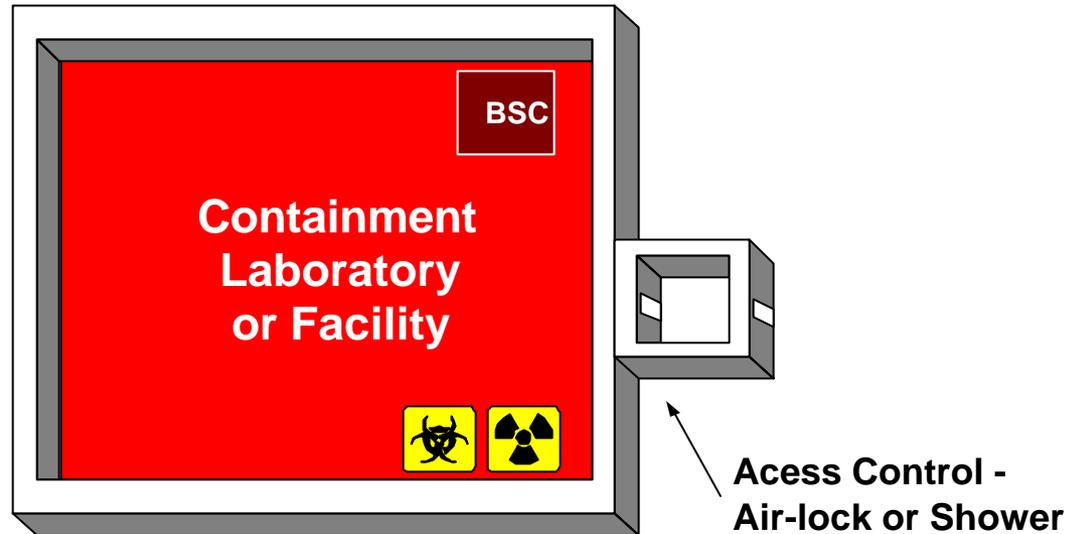
# Containment Barriers

## Solid Waste Rendering Tank – Alkaline Hydrolysis



# Containment Barriers

Air Lock or Shower or Change Room



# Containment Barriers

Air-tight Doors – Gasket Inflated and Mechanical



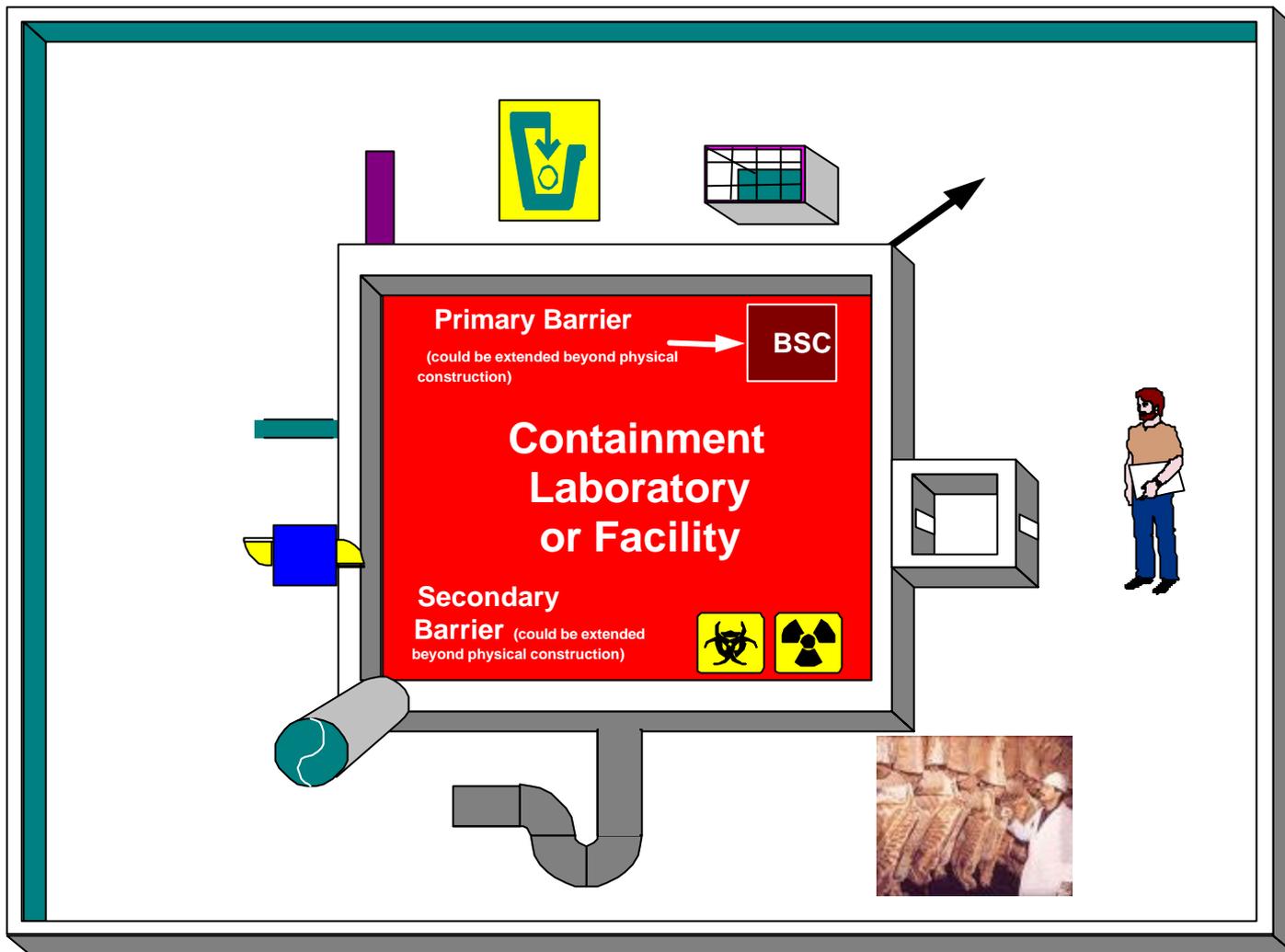
# Containment Barriers

## Air-tight Doors – Gasket Inflated and Mechanical

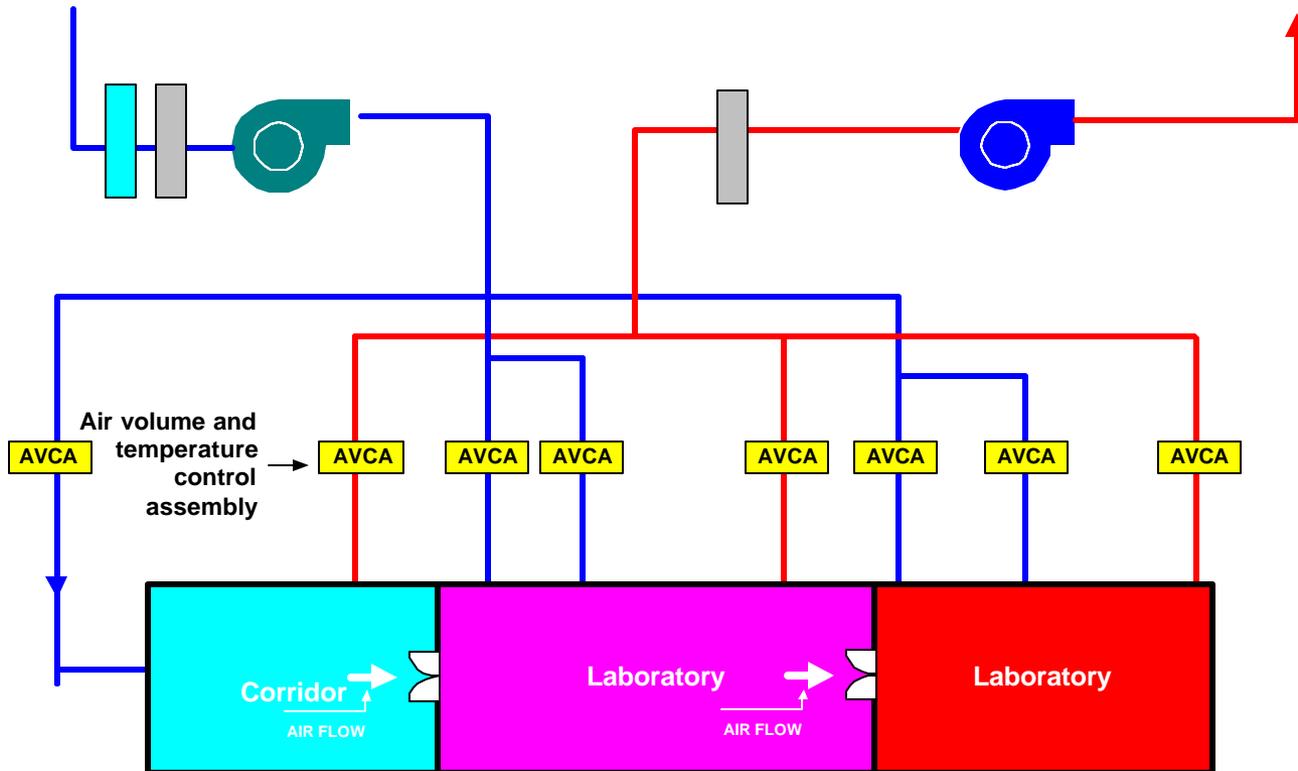


# Containment Barriers

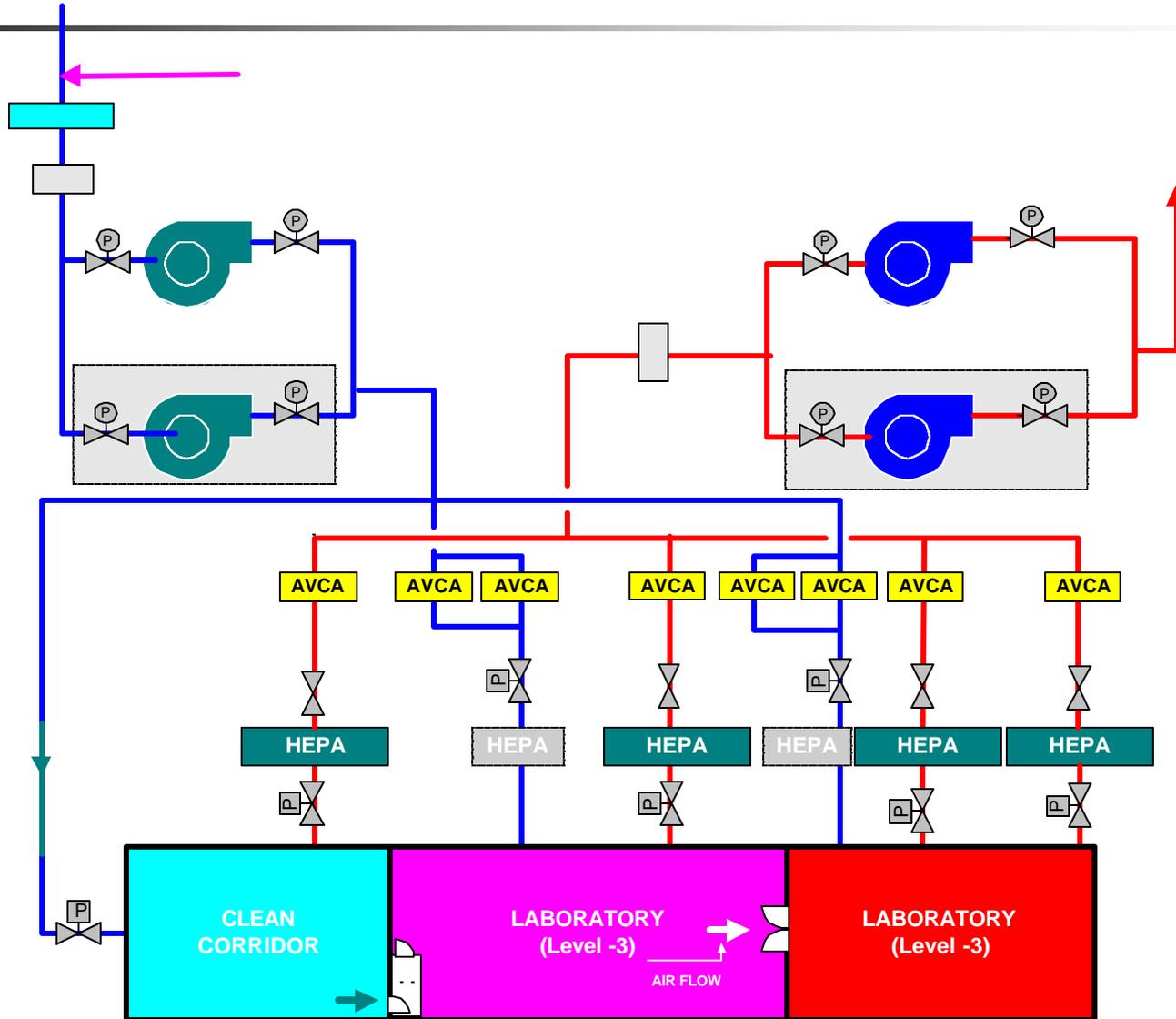
## Tertiary Barrier



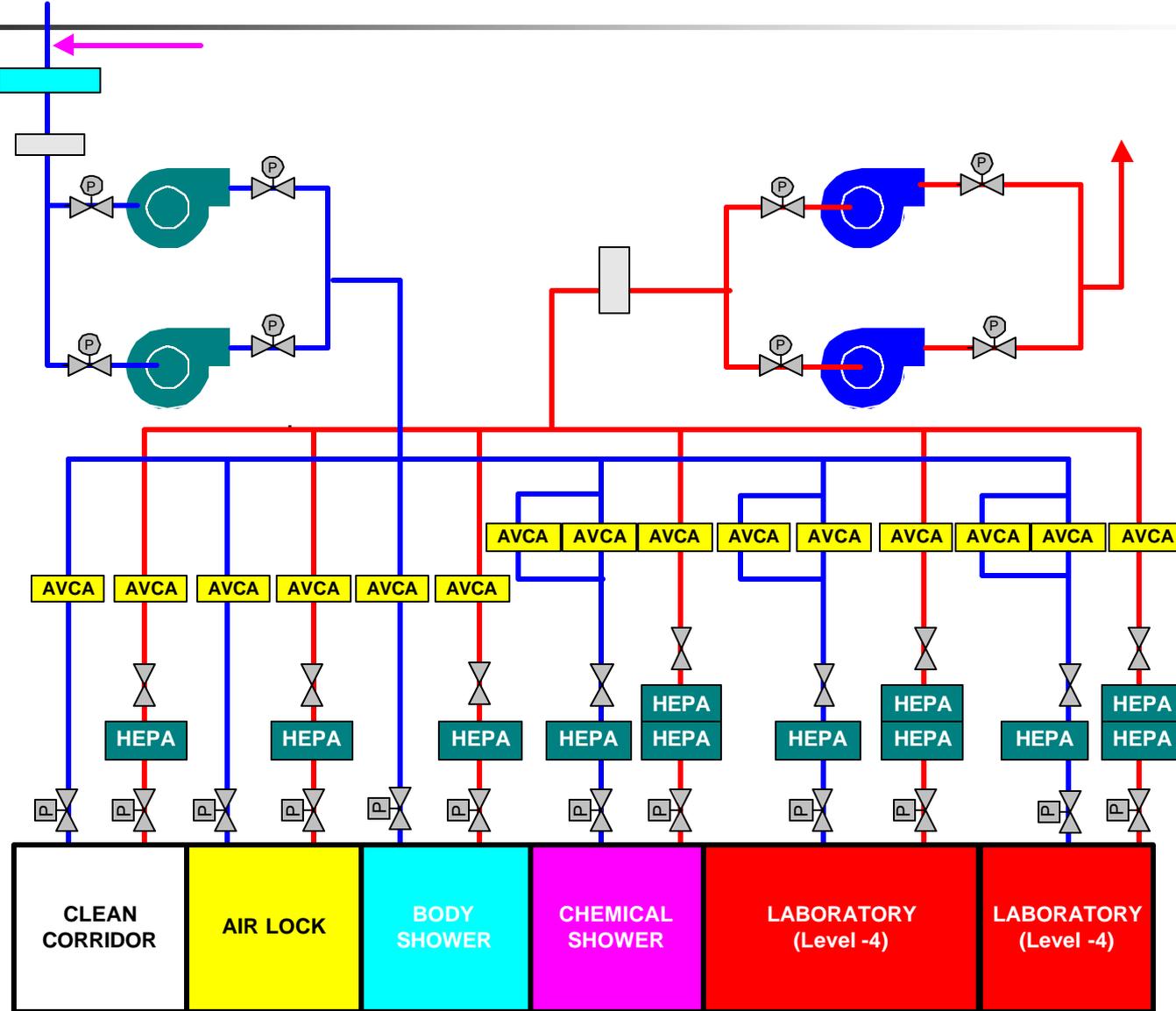
# BL- 1/2 - Ventilation

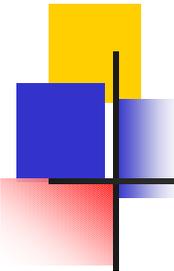


# BL- 3 - Ventilation



# BL-4 - Ventilation





# Design Considerations

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**Operation Protocols**

**Equipment Operation**

**Simplicity**

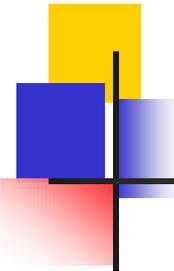
**Directional Air Flow**

**Pressure Differentials**

**Constant Building Pressure**

**Reference**

**Number of Penetration through  
Barrier**



# Design Considerations

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**Redundancy**

**Monitoring**

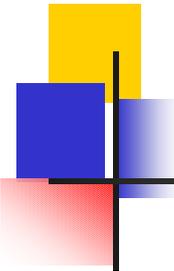
**Decontamination**

**Liquid**

**Gases**

**Compatibility of Materials**

**Sterilization of Liquid and Solid  
Wastes**



# Design Considerations

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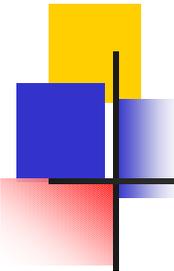
**Indoor Environment**

**Equipment Performance**

**Emergency**

**System Operation in Response to  
Power Failure, Alarm,  
Malfunction of Components**

**Pressure Decay**



# Commissioning

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**Commissioning is a quality assurance process:**

**Provides a framework for a systematic, documented, collaborative, and a logical procedure in conducting inspection, testing, and verifying:**

**System components**

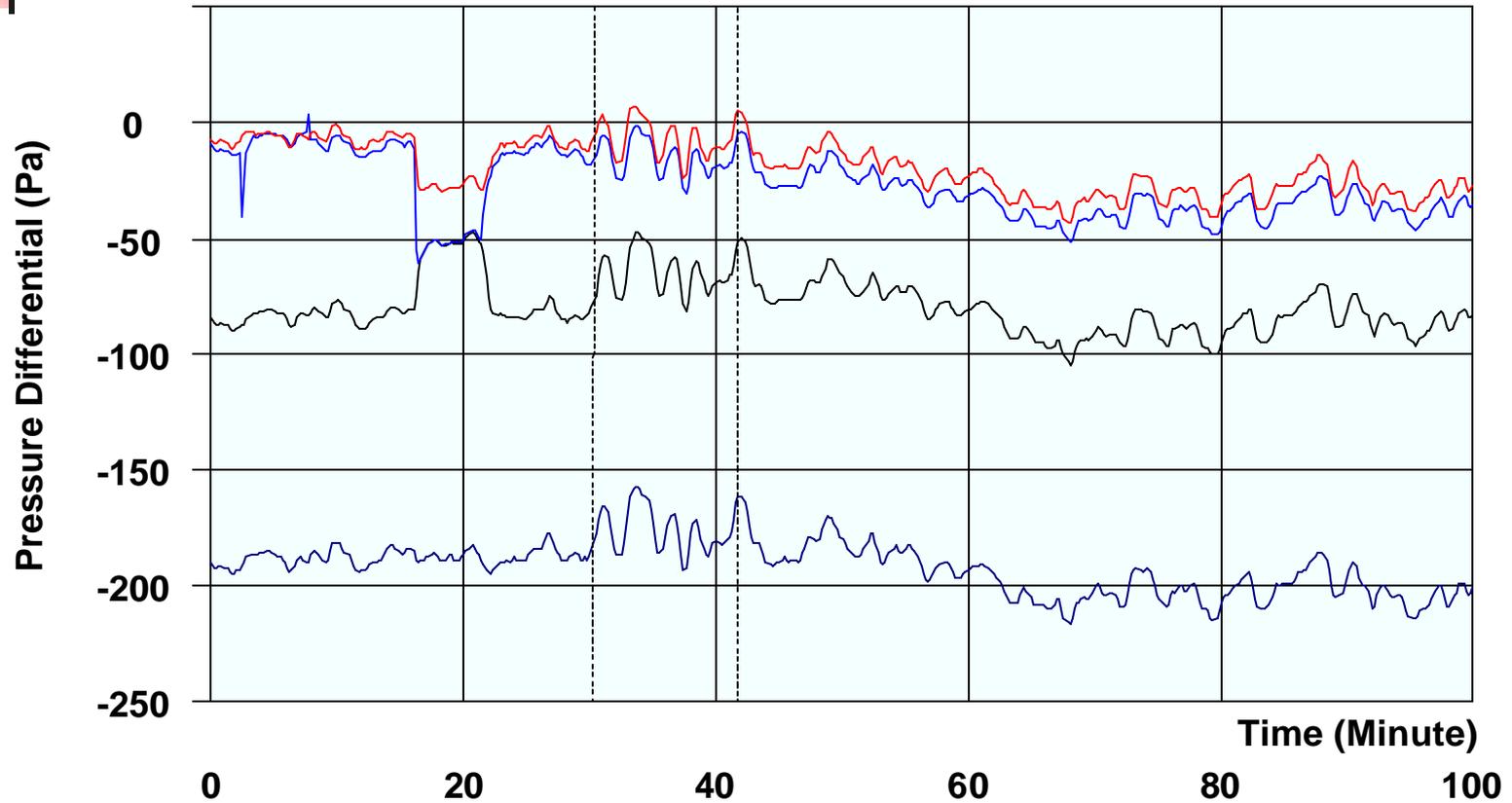
**Sub-system**

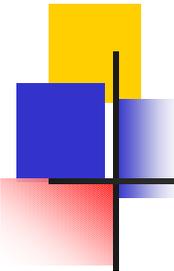
**Integrated system performance**

# Commissioning

<b>1.2.3. CEILINGS:</b> Verify by visual inspection that the ceilings are constructed of reinforced steel frame and gypsum, filler primer and paint finish to prevent release of agent into any adjacent spaces.	Project Manager	YES/NO/NA
<b>1.2.4. FLOORS:</b> Verify by visual inspection that the floors are monolithic and slip-resistant and the continuity of seal is maintained between the floor and wall (a continuous cove floor finish up the wall is required).	Project Manager	YES/NO/NA
<b>1.2.5. JOINTS AND SEAMS:</b> Verify by visual inspection that joints and seams are permanently sealed to prevent passage of air and liquid and that all joints between fixed cabinetry and the floor or wall are smooth coved and sealed to ensure joints and seams can be easily and effectively cleaned.	Project Manager	YES/NO/NA
<b>1.2.6. PENETRATIONS:</b> Verify by visual inspection that all penetrations into the BSL3 are sealed with a smooth finish or non-shrinking sealant at the BSL3 Containment barrier (or capable of being sealed) to facilitate decontamination and cleaning and to assure isolation of the BSL3 Containment (e.g., light fixtures, fire sprinklers, electrical and telecommunication conduits, water and utility lines, HVAC ductwork, utility access panels, condensate return lines, air supply lines, etc.)	Project Manager	YES/NO/NA
<b>1.2.7. INTERIOR SURFACES, COATINGS, AND FINISHES:</b> Verify by visual inspection that the interior surfaces, coatings, and finishes are smooth, continuous, impermeable to liquids, detergents, disinfectants, and decontamination gases normally used in the laboratory.	Project Manager	YES/NO/NA

# Commissioning





# **Operation and Maintenance**

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**Distribution - Interstitial Space**

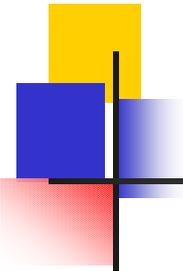
**Decontamination and  
Certification of Equipment**

**Accessibility of Ductwork and  
Piping, Equipment**

**Isolation of Piping and Ductwork**

**Location of HVAC Equipment  
Outside Lab Space**

**Minimum Number for Floor Drain**



# **Guidelines and References**

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**CDC-NIH – Microbiological and  
Biomedical Laboratories**

**Health Canada – Laboratory  
Biosafety Guidelines**

**CFIA – Containment Standards  
for Veterinary Facilities**

**World Health Organization –  
Laboratory Safety Manual**