MODULE 3 | AGENDA

- Equipment
- Decontamination
- Materials and Finishes
- Lessons Learned

MODULE 3 | TENETS OF BIOCONTAINMENT DESIGN

- Budget
- Risk Assessment
- Maintenance
- Biocontainment Plan
“All procedures involving the manipulation of infectious materials must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices”

– BMBL 5th ed. Section IV: Laboratory Biosafety Level Criteria: BSL-3 C.1

### MODULE 3 | BIOLOGICAL SAFETY CABINETS

**TABLE 1. SELECTION OF A SAFETY CABINET THROUGH RISK MANAGEMENT**

<table>
<thead>
<tr>
<th>BIORLOGICAL RISK ASSESSED</th>
<th>PROTECTION PROVIDED</th>
<th>BSC CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PERSONNEL</td>
<td>PRODUCT</td>
</tr>
<tr>
<td>BSL 1-3</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>BSL 1-3</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>BSL 4</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
**MODULE 3 | BIOLOGICAL SAFETY CABINETS**

**TABLE 2: COMPARISON OF BIOSAFETY CABINET CHARACTERISTICS**

<table>
<thead>
<tr>
<th>BSC CLASS</th>
<th>FACE VELOCITY</th>
<th>AIRFLOW PATTERN</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NONVOLATILE TOXIC CHEMICALS &amp; RADIQNCLUCIDES</td>
</tr>
<tr>
<td>I</td>
<td>75</td>
<td>In at front through HEPA to outside or into room through HEPA (fig. 2)</td>
<td>YES</td>
</tr>
<tr>
<td>II, A1</td>
<td>75</td>
<td>70% recirculated to cabinet work area through HEPA; 30% balance can be exhausted through HEPA back into room or to outside through canopy unit (fig. 3)</td>
<td>YES (minute amounts)</td>
</tr>
<tr>
<td>II, B1</td>
<td>100</td>
<td>30% recirculated, 70% exhausted. Exhaust cabinet air must pass through a dedicated duct to outside through a HEPA filter (fig. 5A, 5B)</td>
<td>YES</td>
</tr>
<tr>
<td>II, B2</td>
<td>100</td>
<td>No recirculation; total exhaust to outside through HEPA filter (fig. 6)</td>
<td>YES</td>
</tr>
<tr>
<td>II, A2</td>
<td>100</td>
<td>Similar to II, A1, but has 100 Lfpm intake air velocity and plenums are under negative pressure to room; exhaust air can be ducted to outside through canopy unit (fig. 7)</td>
<td>YES</td>
</tr>
<tr>
<td>III</td>
<td>N/A</td>
<td>Supply air is HEPA filtered. Exhaust air passes through two HEPA filters in series and is exhausted to outside via hard connection (fig. 8)</td>
<td>YES</td>
</tr>
</tbody>
</table>

**MODULE 3 | EQUIPMENT**

Class II / A2 BSC:

- Biological Containment / “Product Protection”
- 100 Lfpm Intake Air Velocity
- Negative Pressure to Room
- 70% Re-Circulated Air;
- 30% Exhausted Air – to Room or to Canopy (Thimble)
MODULE 3 | EQUIPMENT

Class II / B1 BSC:

• Biological Containment and Minute Chemical Quantities

• 100 Lfpm Intake Air Velocity

• Negative Pressure to Room

• 30% Re-Circulated; 70% Exhausted

• Hard-Ducted Exhaust


MODULE 3 | EQUIPMENT

Class II / B2 BSC:

• Biological and Chemical Containment

• 100 Lfpm Intake Air Velocity

• Negative Pressure to Room

• 100% Exhaust – thru HEPA Filter

• Hard-Ducted Exhaust
Class III BSC – “Glovebox”

- 100% HEPA Filtered Supply
- 100% (Double) HEPA Filtered Exhaust
- Hard-Ducted Exhaust
- “Isolator” – No Personnel Direct Contact with Work-Surface (Gloved Access)

Dimensions
Type II / A2 6'-0" Nominal Width:
- Manufacturer A – 77"-5/8"
- Manufacturer B – 71-3/4"

Exhaust Flow Rate
Type II / A2 6'-0" Nominal Width:
- Manufacturer A – 650 cfm @ 10” Sash Height
- Manufacturer B – 471 cfm @ 10” Sash Opening
• Process / Workflow Impact on Space Planning is Significant

• Equipment:
  – Class III Glovebox
  – Plethysmograph
  – Control Cart
  – Crash Cart
  – Anesthetic Cart

"The risk of infectious aerosols from infected animals or bedding can be reduced through the use of primary barrier systems. These systems may include solid wall and bottom cages covered with filter bonnets; ventilated cage rack systems; or for larger cages placed in inward flow ventilated enclosures or other equivalent systems or devices"
“Conventional” Rodent Caging

- Room is Exposed to Same Air as the Animal Models
- May Require the Room to become a Primary Barrier based on Agent Specific Risk Assessment
- Conventional Caging is Generally not Considered Primary Containment

Filter Bonnets can Provide Additional Protection from Aerosols and Allergens
- Filters are not Certified
- Filters are Prone to Mis-Seating and Human Installation Error
MODULE 3 | CAGING

Micro-Isolator / IVC Unit:

- Micro-Environment is Created at the Cage Level; Protection for Operators and Research Models
- Air is Supplied and Extracted through Positive Connection Ports – Shared Supply / Exhaust Plenums
- Minimizes Airborne Particulate, Pathogen and Allergens
- Prevents Gross Contamination of Secondary Barrier

MODULE 3 | CAGING

Biocontainment Caging

- Isolation at the Cage-Level – Completely Self-Contained
- Allows for Multiple Agents / Pathogens to be used in a Single Space
- Provides Maximum Personnel Protection
- HEPA Filtered Breather
- Gas/Liquid-Tight Assembly
Cages are washed in a mechanical cage washer. The mechanical cage washer has a final rinse temperature of at least 180°F. Cages should be autoclaved or otherwise decontaminated prior to removal from ABSL-3 space. The cage wash facility should be designed and constructed to accommodate high pressure spray systems, humidity, strong chemical disinfectants and 180°F water temperatures, during the cage cleaning process.

– BMBL 5th ed. – Animal Biosafety Level Three – Laboratory Facilities (Secondary Barriers) D.9
MODULE 3 | ABSS CAGEWASH

Space Planning Issues
- Waste Handling – Carcass Disposal
- Bedding Handling
- Housing Solutions
- Procedure Requirements
- Cage Processing
  Cage Change Rate
  Cage Change Process
  - Full Wash
  - Bottoms Only
  Room Turnover Rate
  Bottles or Auto-Watering System

MODULE 3 | MATERIALS AND FINISHES
• Durable

• Cleanable
  – Resistant to Cleansing Chemicals

• Decontaminatable
  – Ability to Withstand Decontamination Regimen

• Safe and Maintainable
  – Floor Texture

• Repairable
  – Damage can be Repaired without Significant Facility Shutdown

---

• Establish Performance Requirements
  • Barrier Integrity Test
  • Pressure Decay Test
  • Visual Inspection

• Understand the Cost Impact the Performance Requirements will have on the Project

• Ensure the Entire Assembly Meets the Testing Requirements; a Single Component Failure
Room Integrity – Ideology
• Smoke testing the integrity of a containment room can be done to detect leaks in the room perimeter. All joints, corner and sealed penetrations should be surveyed for leaks. Pressure decay testing the integrity of the provides an indication of the tightness of the room perimeter (i.e. the ability of gasses and liquids to move through the perimeter membrane and service penetrations).

Room Integrity Testing – Practice
• Integrity of containment surfaces to be tested visually and with a smoke pencil or other visual aid. Inspect floor, walls and ceiling for cracks, chips and wear. Verify integrity of wall/floor and wall/ceiling joints. Acceptance criteria: to confirm the integrity of all penetrations (i.e. equipment, services, etc.) and seals (i.e. around doors, windows, autoclaves, etc.) on the containment barrier.

Considerations
• Slip Resistance
• Clean-Ability / Decon
• VOC Off-Gassing
• Repairability
• Lifespan
Seamless Sheet Product - $ 

**Pros**
- Inexpensive
- Average Chemical Resistance
- User Comfort
- Pre-Formed Cove Base & Corners Available

**Cons**
- Susceptible to Damage
- Poor Resistance to Acids

---

Resinous Epoxy Flooring - $$

**Pros**
- Relatively Inexpensive
- Average Chemical Resistance
- Low / No VOC Application – 100% Solids

**Cons**
- UV Discoloration
- Substrate Cracking can Telegraph through System
- Poor Solvent Resistance
- Poor Acid Resistance
MODULE 3 | FLOORING

Methylmethacrylate (MMA) - $$$

Pros
• Excellent Chemical Resistance
• Good Acid Resistance

Cons
• High VOC – Repair or Recoating Requires Facility Shutdown
• Flake Finish Hides Dirt and Damage

MODULE 3 | FLOORING

Urethane - $$$$$

Pros
• Low / No VOC Application
• Good Resistance to Acids
• Good Solvent Resistance
• Low VOC
• High Abrasion Resistance

Cons
• Highest Cost
• Limited Experienced Installers
MODULE 3 | PARTITIONS

Considerations
• Performance
  – Can the Substrate
• Durable
  – Impact Resistance
  – Puncture Resistance
  – Animal Species Appropriate
• Repairable
  – Can the Partition be Repaired
• Acoustics
  – Sound Transmission
  – Sound Absorption

MODULE 3 | WALLS

CMU Substrate - $

Pros
• Inexpensive
• Low-Skill Installation
• Multiple Finish Options

Cons
• Difficult to Seal to “Smooth” & Pin-Hole Free
• Cracking Issues
MODULE 3 | WALLS

IR-GWB Substrate w/ High-Performance Coating $$: - $$ - $ 

Pros
- Inexpensive Substrate
- Multiple Finish Applications Available
- Good Impact Resistance
- Low-Skill Installation
- Fast

Cons
- Limited Puncture Resistance
- Many Components Increases Application Error Probability

Panelized System - $$$$$

Pros:
- Finish and Substrate in One System
- Completely Seamless when Cured
- Excellent Impact Resistance (Large Animal Use)

Cons:
- Limited Installers
- Limited Products to Specify
MODULE 3 | CEILINGS

Considerations

• Accessibility

• Appropriate to the Lab Environment

• Withstand Dynamic Pressures

GWB Substrate w/
High-Performance Coating- $

Pros

• Inexpensive Substrate
• Multiple Finish Applications Available
• Low-Skill Installation
• Fast

Cons

• Limited Puncture Resistance
• Many Components Increases Application Error Probability
Fiber Resin Polyester (FRP) $$$

Pros

- Moderate Cost
- Allows Access for Service
- Factory Finished Surface

Cons

- Many Components to Seal / Ensure are Sealed
- Field Modification Difficult

Liner Panel Ceiling - $$$$

Pros

- Substrate and Finish in One System
- Seamless System (when Compound Cures)

Cons:

- Relatively Expensive
- Limited Manufacturers and Installers....
  ....but getting better!
Casework Considerations

- Durability
- Seamless / Smooth
- Compatible with Surface / Room Decontaminants
- Compatible with Procedures

**Epoxy: $**

**Pros**
- Durable
- Variety of Suppliers and Colors
- Repairable

**Cons**
- Staining
- Scoring
- Must be Cast; Used for Bench-Tops Only
Phenolic Resin: $$
Resin Impregnated Kraft Paper to form Epoxy like Dense Material

Pros
• Liquid Impervious
• Accommodates Wide Variety of Decon Agents

Cons
• Edges Susceptible to Damage
• Non-Uniform Material (Face and Body Sheets Differ)

Stainless Steel: $$$$$
Welded Construction Required

Pros
• Surgical Quality Surface
• Durable
• Longevity

Cons
• Expensive
• Chloride Degradation
• Exposed Surfaces Scratch Easily
• Seams on Exposed Surfaces Difficult to Weld Smoothly
MODULE 3 | CASEWORK - HYBRIDS

MODULE 3 | DOORS

Types:

$ - Hollow-Metal with High-Performance Coating

$$ - Fiber Resin Polyester (FRP)

$$$$ - Stainless Steel

$$$$$ - Air Pressure Resistant
Hollow Metal w/ High-Performance Coating – $

Pros
- Inexpensive
- Common
- Short Lead Time

Cons
- Susceptible to Damage
- Damaged Doors Rust
- Many Seams and Areas for Pathogen to Hide / Vermin Harborage

Fiber Resin Polyester -$$

Pros
- Sealed Door Assembly
- Chemically Resistant
- Easily Cleanable
- Hydrophobic

Cons
- Moderate Cost
- Long Lead Time
- Damage Difficult to Repair in Place
- FRP Frames are “Frangible”
MODULE 3 | DOORS

Stainless Steel -$$$$

Pros
• Excellent Wear
• Chemically Resistant
• Extremely Durable

Cons
• High-Cost
• Chloride Degradation
• Scratches / Dents

MODULE 3 | DOORS

Air Pressure Resistant-$$$$$
• Compressible Seal
• Pneumatic

Pros
• Excellent Wear
• Chemically Resistant
• Extremely Durable
• Gas-Tight

Cons
• Extremely High-Cost
• Frequent Maintenance
MODULE 3 | SEALANT

Sealants

• Compatible with Decontamination Means and Methods

• Occurs at all Material / Surface Transitions (Dissimilar Materials or Seams)

• Facilitates Gaseous or Vapour Decontamination of Room

MODULE 3 | SEALANT

Partition Penetrations must be Sealed to Facilitate Decontamination via Gas or Vapor

Typical Penetrations
• Electrical Devices
  - Receptacles
  - Switches
  - Tel-Data
• Plumbing Penetrations
• HVAC
  - Pressure Monitors
  - VPIs
• Sealants must be Applied in a Clean Environment. The Site Must be Kept Free of Dirt, Debris, Airborne Contamination.

• Smooth, Uniform Surfaces are Required for all Sealant

• Rough Edges, Broken Beads, and Incomplete Areas Should be Rejected.

• All Sealants Should be Integrity Tested
Common Threads:

- Lack of understanding of bio-safety principles affecting construction decisions
- SOP’s not developed during design
- Constructor (In)experience
- Detail (mis)interpretation
- Inappropriate Schedule / Sequencing
- Improperly defined performance and quality expectations
• High Performance Coatings Must be Applied in a Clean Environment. The Site must be Kept free of Dirt, Debris, and

• Work that will not Receive High-Performance Coatings must be Protected

• Pot-Time Limitations must be Adhered to Strictly

• Technique to be Developed for Fiberglass Mat Application – Training

• Pinhole Free Application is Absolutely Critical
MODULE 3 | LESSONS LEARNED

• Ductwork must be protected during high-performance coating application

• Surface tension is unacceptable / intolerable for bio-seal dampers

• Bio-seal dampers are rated at a minimum for 2,000 cycles before the gasket must be replaced.

• Damper at 25 cycles

MODULE 3 | LESSONS LEARNED

Access to the laboratory is restricted to entry by a series of two self-closing doors.
**MODULE 3 | LESSONS LEARNED**

\[
F = F_{dc} + [5.20WA \delta p/2 (w - d)]
\]

Where
- \( F \) = total door-opening force, lb
- \( F_{dc} \) = force to overcome door closer, lb
- \( W \) = door width, ft
- \( A \) = door area, sq.ft
- \( \delta p \) = pressure difference across door, in of water
- \( d \) = distance from doorknob to edge of knob side of door, ft
- 5.20 = coefficient

**MODULE 3 | LESSONS LEARNED**

Recessed Electrical Device Detail
- Cast or Welded Back-Box
- Perimeter Sealant for Smooth Cleanable Surface
- Conduit Sealed
- Weathertight Faceplate
- Stud Anchorage
- Foam Sealant
Recessed Electrical Device Detail

- Cast or Welded Back-Box
- Perimeter Sealant for Smooth Cleanable Surface
- Conduit Sealed
- Weathertight Faceplate
- Stud Anchorage
- Foam Sealant

Sequencing is the Key to Many Details in Biocontainment

- Sequences are Oftentimes the Opposite of Non-Containment Projects
- Suggestion to Hold Tradesmen Educational Seminars to Deliver Design Intent to the Actual Constructors
• Mock-Ups
• Barrier Integrity Testing
• Structured Contractor Education
• SOP Development Scope
Mock-Ups:
- Sealant(s)
- Penetrations:
  - Electrical
  - Controls
  - Plumbing
  - HVAC
- Finishes:
  - Wall
  - Floor
  - Ceiling
- All transitions

*Ensure the mock-up is included in the trade packages and contracts!*
• Establish barrier integrity testing requirements for the project during design phase

• Establish acceptance criteria for the testing methodology selected

• Incorporate the requirements (and re-work until acceptance) in the trade-contractors contracts!
Structured Constructor Education:

- Biosafety Overview
- Facility Design Overview
- Performance Expectations
- Quality expectations
- Sequencing
- Detail Review
- Technique

*Frequent review and re-instruction is helpful!*

SOP Development:

- Draft SOP’s during the design process

- Don’t think you can “get” SOP’s from another facility….they are unique!

- SOP’s are an iterative process…. It’s OK!
MODULE 3 | TOOLS FOR SUCCESS

MODULE 3 | TENETS OF BIOCONTAINMENT DESIGN
<table>
<thead>
<tr>
<th>Date:</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session:</td>
<td>Tools</td>
</tr>
<tr>
<td>Presenters:</td>
<td>Resources</td>
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<tr>
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<td>Innovative Ideas</td>
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