Design, Build, and Validation for Infection Control Acceptance
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

“Trust but Verify”
Design, Build and Validation for Infection Control Acceptance

Andrew J. Streifel
Hospital Environment Specialist
University of Minnesota
strei001@umn.edu

Hosted by Dr. Lynne Sehulster
Centers for Disease Control and Prevention

Ventilation Management in Healthcare

- Temperature and Relative Humidity Control
  - ASHRAE
- Smoke Control
  - NFPA
  - Building Codes
  - ASHRAE
- Infectious Disease Control
  - Airborne spread-TB, Measles, Chicken Pox, Aspergillosis
  - AIA, CDC, OSHA, ASHRAE

Why Validate?

- Existing Conditions of Ventilation Systems
  - Area control
  - Comfort and moisture management
  - Fire management
  - Infection control needs for:
    - Surge of unknown infectious patients
    - Infectious disease event
    - Potentially infectious
    - Environmental microbes
  - Functional performance testing
  - Safety management
    - Patient
    - Employee
    - Visitor

CDC Environmental Infection Control Guidelines 2003

Emergent Diseases
- SARS
- Monkey Pox
- Antibiotic Resistant Microbes
  - Tuberculosis
  - Chicken Pox
  - Disseminating H. zoster
  - Measles
  - Smallpox

Droplet nuclei <5 µm particles

Infection Control Air Flow Management

- Airflow ventilation control with offset:
  - supply versus exhaust/return
  - clean to dirty airflow
  - greater exhaust = negative
  - greater supply = positive
- Pressure differential
  - airflow in or out of area (AIA 1996)
  - 0.01 inch water gauge (AIA 2001)
  - air flow velocity about 400 fpm
  - consistent airflow necessary for control

CDC Environmental Infection Control Guidelines 2003

Negative Pressure Room for Airborne Infection Isolation

Positive Pressure Room for Protective Environment

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
Design, Build, and Validation for Infection Control Acceptance
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Environmental Risk Factors for TB Transmission
- Exposure to TB in small enclosed places
- Inadequate local/general ventilation
- Recirculation of air containing infectious droplet nuclei
- Inadequate cleaning and disinfection of medical equipment
- Improper specimen handling procedures
- Unrecognized patient

(CDC MMWR, 12/30/05)

Airborne Infectious Diseases
- Patient/Visitor
  - TB
  - VZV
  - Measles
  - RSV
- Environmental
  - Aspergillus
  - Fusarium
  - Mucorales
  - Legionella
  - Bacillus sp.
  - Gram negative bacteria

Objective for sampling
- Interpretation guidelines
  - What are we trying to accomplish?
  - What should the data show?
- Baseline data
  - Functional performance of infection control system
- Epidemiology study
  - Determine if the environment source of disease
  - Source detection
- Validation of controls
  - Assure control systems are maintaining baseline

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
Design, Build, and Validation for Infection Control Acceptance
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Breaking the Chain of Infection

• Negative Pressure Isolation
  – Isolate infectious microbe to eliminate the mode of transmission

• Source Management
  – Direct removal of infectious pathogen from reservoir
  – Change of pathogenic reservoir environment in order to inhibit and prevent its growth

Hospital survey summary of Airborne Infection Isolation Capability

- 678 rooms surveyed using survey and site visit objective analysis
- Most rooms do not meet AIA/CDC criteria
- Inadequate pressures in a large % of rooms checked
- Filtration analysis less than specification in a high % of air handlers checked
- Lack of written plans for negative pressure machines and surge management


Airborne Infection Room Criteria

<table>
<thead>
<tr>
<th>Table 1. Critical parameters for benchmarking AII performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Air Inlet Airflow</td>
</tr>
<tr>
<td>Air Outlet Airflow</td>
</tr>
<tr>
<td>Whole Room Airflow</td>
</tr>
<tr>
<td>Airflow Balance</td>
</tr>
<tr>
<td>Airflow Balance</td>
</tr>
</tbody>
</table>

Performance Evaluation of Filtration in Air Handling Systems

- Filtration at 90% rating to consider evaluation of filter bank when the measured efficiency is below 80%

Common causes of filter leaks are:

- Loose filters
- Missing gaskets
- Missing or damaged filters
- Incorrect filters installed
- High air velocity
- Overloaded filters

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
**Design, Build, and Validation for Infection Control Acceptance**
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com

---

### Table I Ventilation in each location sampled

<table>
<thead>
<tr>
<th>Location</th>
<th>Filtering efficiency of fan (%)</th>
<th>ΔP</th>
<th>Air changes per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMT suite (32 rooms)</td>
<td>99.97</td>
<td>0.03</td>
<td>12</td>
</tr>
<tr>
<td>Patient care units</td>
<td>90–95</td>
<td>b</td>
<td>3</td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>90–95</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Indoor reference</td>
<td>65 NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Lobby</td>
<td>90–95</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

BMT, bone marrow transplant; NA, not applicable.

* Pressure differential of patient’s room, with the door closed.
  b Open door, no ΔP maintained.

### Table II Colony-forming units per cubic meter sampled from fan-specific locations (10 years)

<table>
<thead>
<tr>
<th>Location (Fan #)</th>
<th>Samples (n)</th>
<th>Total colony counts at 35°C fungi</th>
<th>Total fungal counts at 37°C fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult BMT (S-11)</td>
<td>122</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Pediatrics BMT (S-3)</td>
<td>127</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>BMT (S-3)</td>
<td>137</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>BMT (S-3)</td>
<td>137</td>
<td>24</td>
<td>16</td>
</tr>
</tbody>
</table>

**Highlights**
- Range of cfu from 0 to 1008 for 37°C fungi.
- Control of sources more effective than searching for burst.

---

### Air Quality Surveillance
University of Minnesota Medical Center-Fairview

**Airborne Fungi and Ventilation Parameters**

- **Filtration local cfu/m³**
  - U of MN 1962: 706 (35C) none
  - U of MN 1982: 82 (35C) 40
  - U of MN 2002: 3.6 (35C) 90

**Infection Control Ventilation Parameters**

- Air exchanges
- Pressure differential
- Airflow direction
- Particle management

---

### What is a burst of fungal spores?

A burst is >3 standard deviations above the average?
1243 SAMPLES INDOORS WITH 48 "BURSTS" EVENTS

---

### Functional Performance Testing of Special Ventilation Rooms

- **Optical particle counters**
  - Microbial sampler high volume portable

- Air sampling devices need interpretation guidelines before sampling begins.
- Providing existing conditions information for ventilation is essential.
- Performance testing should be conducted where ventilation critical for infectious disease management. The parameters include: location, monitoring, offset, air exchanges, pressure, room size and filtration. This data serves owner with baseline information.

---

### Filtration Efficacy

- Impaction occurs due to inertia collision of particle with fibers
- Interception occurs due to size and the collision of particles with fibers
- Diffusion occurs from random motion causes particle contact with fiber
- Electrostatic attraction due to electrostatic force
Are aerosols preferentially removed?

Collection of biological and non-biological particles by new and used filters made from glass and electrostatically charged synthetic fibers, Raynor, P., et al., Indoor Air 2008; 18: 51-62

Removal Efficiency In-Situ by Particle Size and Resistance to Flow

Depiction of particle counts before and after filtration in air handling system

DATA DEMONSTRATE PERCENT REDUCTION OF AIRBORNE PARTICLES

<table>
<thead>
<tr>
<th>Optical PC</th>
<th>Before filter PC</th>
<th>After filter PC</th>
<th>Percent reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERV 12 filters</td>
<td>120000</td>
<td>120000</td>
<td>80</td>
</tr>
<tr>
<td>MERV 14 filters</td>
<td>120000</td>
<td>120000</td>
<td>60</td>
</tr>
<tr>
<td>MERV 16 filters</td>
<td>120000</td>
<td>16</td>
<td>99.87</td>
</tr>
</tbody>
</table>

Note: Optical Particle Counts are Report As Particles Per Cubic Foot. * PC = particle counts **MERV = minimum efficiency rating value (current ASHRAE rating system)

Rank order reduction of particles from Clean to Cleanest will demonstrate the efficacy of local filtration.

How the door swing affects pressure?

Door swing shows pressure flux depending on the seal on the room. How much air is moved with each swing?

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention

www.webbertraining.com
Room Leakage Areas

- Airflow leakage occurs around:
  - plumbing connections
  - medical gases
  - electrical/video connection
  - lighting
  - ceilings
  - windows/doors
  - door cracks
  - in wall mounted fixtures

Room Seal Necessary for Special Ventilation Management

- Cracks can result in room air leakage.
- Supply air volume differential allows for airflow direction control.
- Low pressure differential can result in airflow reversal.
- Substantial room pressure design should provide a sealed “vessel”.
- Design criteria are necessary for control.

Causes of Ventilation Deficiencies

- Plugged Filters
- Plugged Temperature Control Coils
- Duct Leakage
- Dust on Fan Blades
- Fan Belt Slippage
- Uncalibrated Control Equipment
- Digital Controls
- Pneumatic Controls
- Plugged sensors

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
Design, Build, and Validation for Infection Control Acceptance

Andrew Streifel, University of Minnesota

A Webber Training Teleclass

Ventilation deficiencies can affect airflow direction

Flexible duct not properly installed caused condensation & mold

What is wrong with this picture??

Buildings age when the ventilation is turned on.

Which side moves more air??

Aree of Air Concept for particle movement

Figure 5: Diagram to illustrate the concept of “age of air.” Particle of air entering at the supply (0%) air after the patient’s 100% by many possible routes and take different times to get there. As the age of individual parcel of air moving, it may be described by a statistical distribution function.

Vertical airflow 30 to 40 lpm at surgery site

Operating room issues:

- Smoke from:
  - electro-cautery
  - laser
- Aerosol from:
  - saws
  - blood spatter

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention

www.webbertraining.com
Design, Build, and Validation for Infection Control Acceptance
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Advances in airflow evaluation in operating rooms

Airflow can be demonstrated when timing the release of gas or particle to the extractor grill. Then covering extractors and allowing gas to build to higher concentration and when extractors uncovered measure rate of decrease.

Interpretation of Data
Particle Counters & Construction

- Particle counts compared to outside
  - Per cent reduction approximation
  - Particle size and construction
  - Stop work guidance
- Local controls when sampling
  - Set up levels of project expect high counts
  - Know the aerosol
  - Critical to operation rooms, bone marrow transplant, oncology, neonates, burn unit
  - Lowest levels before and after
- Ventilation management controlling dirty air
  - Exhaust ventilation out of space
  - Recirculation of HEPA filter
  - Negative pressure

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
Design, Build, and Validation for Infection Control Acceptance
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Functional Performance Testing
Baseline Data for Future Reference

- patient care unit
- room number
- type of room
- monitoring system
- local display monitor
- HVAC
- differential pressure
- airflow
- airflow direction
- room size square feet
- supply volume
- return/exhaust volume

Contaminated air must be controlled

Training manual for temporary negative pressure isolation can be found at:
http://www.health.state.mn.us/oep/training/bhpp/airbornenegative.pdf

Proof of Containment

- Barriers for containment must show pressure differential (sides pull in as if under a vacuum)
- Differential pressure check with digital pressure gauge

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention
www.webbertraining.com
How to Validate: Tools

- **Pressure Gauges**
  - Airflow management
- **Test locations**
- **Intensity of airflow**
- **Direction consistency**
- **Interpretation**
- **Velocity and pressure**

IC CONSIDERATION EXAMPLES

**Construction Management & Commissioning issues**

**Interpretation of Data Pressure**

- Develop baseline information
  - before, during and after construction
- Airflow direction and intensity
  - clean to dirty airflow into construction site
  - air velocity and pressure
  - >0.01 inch water column about 400 linear feet per minute
  - Ideal around 0.02 to 0.03 in. WC harder to achieve
  - Pressure gauge sensitive to 0.001 inch water column
- Airflow control in Surgery Projects
  - keep operating rooms pressurized
  - maintain consistent airflow
  - know existing conditions
  - Return airflow and pressure to pre construction testing
  - cooperation between contractor and user

**Particle counters tell the rank order**

These parameters should be kept stable and should be checked when changes or adjustments in the HVAC system occur.

**These parameters demonstrate existing ventilation conditions**

**Biological testing in USP 797 Pharmacy Manufacturing**

<table>
<thead>
<tr>
<th>Location</th>
<th>25C fungi</th>
<th>35C bacteria + fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoors</td>
<td>700</td>
<td>80</td>
</tr>
<tr>
<td>Ante area</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>BSC</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Fill area</td>
<td>18</td>
<td>8</td>
</tr>
</tbody>
</table>

**Data Interpretation Guidelines**

- rank order (clean to cleanest)
- Comparison data
- qualitative
- temperature

**Realities:**
- culture results are too late
- emphasis on training & asepsis
- unusual event protocols

**Interpretation of Owner’s Acceptance Criteria**

**Air quality**
- clinical application
  - bone marrow, operating rooms, pharmacy
**Water quality**
- clinical application
  - laboratory, dialysis, stagnant reservoirs
  - drinkable
  - not sterile

These require specific objective information for TJC and Baseline data

**Control of the environment for patient safety**
- Interdisciplinary team overview includes issues from slips to infectious diseases

Hosted by Dr. Lynne Sehulster, Centers for Disease Control and Prevention

www.webbertraining.com
Pressure Management in Healthcare

- Airborne infectious disease
  - Patient & procedure rooms
  - Surge capacity for emerging infectious diseases
- Fire & smoke
  - Will IBC affect ID management?
- Building pressure
  - Infiltration of moisture and other...
- Construction zone
  - Dust aerosol control
- What is an appropriate pressure gradient?
  - Air velocity to control particle movement.

Questions?

Amplatz Children’s Hospital University of Minnesota-Fairview
March 26, 2011