Outline

- Important Aspects of Particulate Filters
- Particulate Filter Test Standards
- Local Codes & Requirements
- Application Summary

Discussion on Gaseous Contaminants and Gas Phase Filter Test Standards and Applications Are Saved For Another Time
Why Filter?

- Remove Dust, Dirt, & Microbials
  - Keep Equipment & Systems Clean
    - Reduce Maintenance Cost
    - Reduce Energy Cost
  - Keep the Indoor Environment Clean
    - Improve Health
    - Improve Cleanliness
What is This?
What is That?
### What To Filter?

<table>
<thead>
<tr>
<th>Particle</th>
<th>Particle Size (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Respirable Particles</em></td>
<td>&lt;5</td>
</tr>
<tr>
<td>Viruses</td>
<td>0.003 – 0.06</td>
</tr>
<tr>
<td>Individual Bacteria</td>
<td>0.4 – 5</td>
</tr>
<tr>
<td>Fungal &amp; Bacteria Spores</td>
<td>2 - 10</td>
</tr>
<tr>
<td>Pollen Grain</td>
<td>10 - 100</td>
</tr>
<tr>
<td>Dust</td>
<td>&lt;100</td>
</tr>
<tr>
<td><em>Human Hair (Diameter)</em></td>
<td>100 - 150</td>
</tr>
</tbody>
</table>

Excerpted from 2005 ASHRAE Handbook - Fundamentals, Chapter 12
Filtration Methods

- Straining
- Inertial Impingement
- Interception
- Diffusion
- Electrostatic

All Methods Are Used in Capturing Particles in Most Filters; However, Filters are Typically Designed with a Dominant Method
Straining

- The Particle is Larger Than the Opening Between Media Fibers
- A Dominant Method of Particulate Removal in Low Efficiency Air Filters (Pleated Prefilters)
Inertial Impingement

- A Large, Dense Particle Collides with the Fibers and Attaches to the Media
- Adhesives or Tackifiers Can Be Used to Enhance Capture Efficiency
- A Dominant Method of Particulate Removal in Low Efficiency Air Filters (Flat Panel Prefilters)
Interception

- Particle Follows Airstream at Lower Velocities and Contacts Fiber Through Weak Intermolecular attractions (Van Der Waals Forces)

- The Dominant Method of Particulate Removal in Medium Efficiency Air Filters (Bags and Extended Surface Final Filters)
Diffusion

- Small Particles Collide with the Air Molecules and Move in An Erratic Path (Brownian Movement) and Attaches to the Media Fibers

- The Dominant Method of Particulate Removal in High Efficiency Air Filters (HEPA Filters)
Electrostatic Effects

- An Electrostatic Charge is applied to the Fiber that Can Produce an Attracting Force if the Particle is of Opposite Charge
- Passive (One-Time, Initial) and Regenerative Charges
- The Dominant Method of Particulate Removal in Metal Panel Prefilters and Some Room Purifiers
Effects of Filtering

- Restricts Airflow
  - Added Pressure Drop Requires Energy
- Requires Space and Cost
  - Requires Additional Equipment / Frames
  - Replacement Additional Maintenance
Is It Worth It?

“60% of the Service Calls on Air Conditioning Units Could Be Reduced if the Dirt Was Removed From the Airstream Before The Components.”
How to Value Differences

- **Dust Removal Efficiency**
  - The Percentage of Airborne Particulate the Filter Will Remove (ASHRAE Standards 52.1 and 52.2 Handle this Differently and Both are Applicable)

- **Dust Holding Capacity**
  - The Amount of Dust the Filter Will Hold To a Maximum Resistance Value (ASHRAE Standard 52.1 Only)

- **Filter Resistance**
  - As a Function of Airflow & Dust Load
Test Standards

- Particulate Filter Test Standards
  - ASHRAE Standard 52.1 - 1992
  - ASHRAE Standard 52.2 - 1999
  - UL Standard 900 (Flammability)
  - US Military Standard MIL-STD-282 DOP Method for HEPA Filters
  - International (CEN EN 779:1993, Others)
ASHRAE Standard 52.1 - 1992

- Atmospheric Dust Spot Efficiency Test
- ASHRAE Dust Weight Arrestance Test
- ASHRAE Dust Holding Capacity Test
Atmospheric Dust Spot Efficiency Test

- The Dust Spot Test Measures the Ability of a Filter to Reduce Soiling of Fabrics and Building Interior Surfaces using Unconditioned Outside Air.

- Variety and Variability of Atmospheric Dust May Cause the Same Filter to Test at Different Dust Spot Efficiencies at Different Locations.
ASHRAE Standard 52.1 – 1992
Test Apparatus

Note: Units shown are mm (in.).

LEGEND
1. DUST FEEDER
2. DUST FEED PIPE
3. MIXING ORIFICE
4. PERFORATED DIFFUSION PLATE
5. STATIC TAP
6. MANOMETER
7. FILTER DEVICE AND TRANSITIONS (IF ANY)
8. MAIN FLOW MEASUREMENT NOZZLE
9. DUST-SPOT SAMPLER
10. FLOW STRAIGHTENER
11. VERTICAL MANOMETER FOR MEASUREMENT OF NOZZLE INLET PRESSURE
12. PERFORATED PLATE FOR FLOW DISTRIBUTION
ASHRAE Dust Weight Arrestance Test

- The ASHRAE Dust Weight Arrestance Test Measures The Amount of Dust (By Weight Fraction) The Filter Will Capture
- Requires High Degree of Standardization of Testing Apparatus
- More Suited for Low to Medium Efficiency Air Filters
ASHRAE Dust Holding Capacity Test

- Measured Amounts of ASHRAE Dust are Used to Artificially Load the Filters in Hours and Not Months.

- ASHRAE Dust is Not Atmospheric Dust; So, Results May Vary Greatly in Actual Installations.
### Test Results

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Air Flow Rate (CFM)/Velocity (FPM)</td>
<td>2000 cfm/500 fpm</td>
</tr>
<tr>
<td>Initial Resistance (in. WG)</td>
<td>0.224</td>
</tr>
<tr>
<td>Final Resistance (in. WG)</td>
<td>1.0</td>
</tr>
<tr>
<td>Initial Atmospheric Dust Spot Efficiency</td>
<td>37.1</td>
</tr>
<tr>
<td>Average Atmospheric Dust Spot Efficiency</td>
<td>40.6</td>
</tr>
<tr>
<td>Average Synthetic Dust Weight Arrestance</td>
<td>91.6</td>
</tr>
<tr>
<td>Ashrae Dust Holding Capacity</td>
<td>146.6 grams</td>
</tr>
<tr>
<td>Dust Feed Rate</td>
<td>2 grams/1000cfm</td>
</tr>
</tbody>
</table>
Why a 52.2?

- Needed a Means to Measure Removal Efficiency by Particle Size
- Needed more Mandatory (Code) Language
- Needed More Reliable and Verifiable Results
Figure 4-1  Schematic diagram of the test duct (notes and legend are below). Dimensions are in mm (in.).

LEGEND FOR FIGURES 4-1 and 4-2d

1. Blower
2. Flow control valve
3. HEPA filter bank
4. Transition, if any, from filter bank to 610 mm x 610 mm (24 in. x 24 in.) ducting. Maximum transition half angle = 45°.
5. Aerosol injection tube
6. Aerosol generator
7. Dust feed pipe
8. Dust feeder
9. Mixing orifice
10. Perforated diffusion plate
11. Location of sample probe
12. Static tap
13. Manometer
14. Air cleaner device and transitions (if any)
15. Final filter (installed only during dust loading)
16. Vertical manometer
17. Main flow measurement nozzle
18. Transition, if needed
19. Bend, optional
ASHRAE Standard 52.2 - 1999

- Twelve (12) Ranges of Particle Counts are Taken Over a Range of Particles Six (6) Times for a Total of Seventy Two (72) Data Points.

- For Each Measurement, the Filtration Efficiency is Stated as a Ratio of Downstream-to-Upstream Particle Count.
Result? MERV

- The Lowest Values then Determine the Composite Minimum Efficiency Curve
### TABLE 12-1
Minimum Efficiency Reporting Value (MERV) Parameters

<table>
<thead>
<tr>
<th>Standard 52.2 Minimum Efficiency Reporting Value (MERV)</th>
<th>Composite Average Particle Size Efficiency, % in Size Range, μm</th>
<th>Average Arrestance, %, by Standard 52.1 Method</th>
<th>Minimum Final Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range 1 0.30 - 1.0</td>
<td>Pa</td>
<td>in. of water</td>
</tr>
<tr>
<td>1</td>
<td>n/a</td>
<td>$E_3 &lt; 20$</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>n/a</td>
<td>$E_3 &lt; 20$</td>
<td>65 ≤ $A_{avg}$ &lt; 70</td>
</tr>
<tr>
<td>3</td>
<td>n/a</td>
<td>$E_3 &lt; 20$</td>
<td>70 ≤ $A_{avg}$ &lt; 75</td>
</tr>
<tr>
<td>4</td>
<td>n/a</td>
<td>$E_3 &lt; 20$</td>
<td>75 ≤ $A_{avg}$</td>
</tr>
<tr>
<td>5</td>
<td>n/a</td>
<td>20 ≤ $E_3 &lt; 35$</td>
<td>n/a</td>
</tr>
<tr>
<td>6</td>
<td>n/a</td>
<td>35 ≤ $E_3 &lt; 50$</td>
<td>n/a</td>
</tr>
<tr>
<td>7</td>
<td>n/a</td>
<td>50 ≤ $E_3 &lt; 70$</td>
<td>n/a</td>
</tr>
<tr>
<td>8</td>
<td>n/a</td>
<td>$70 ≤ E_3$</td>
<td>n/a</td>
</tr>
<tr>
<td>9</td>
<td>n/a</td>
<td>$E_2 &lt; 50$</td>
<td>85 ≤ $E_3$</td>
</tr>
<tr>
<td>10</td>
<td>n/a</td>
<td>50 ≤ $E_2 &lt; 65$</td>
<td>85 ≤ $E_3$</td>
</tr>
<tr>
<td>11</td>
<td>n/a</td>
<td>65 ≤ $E_2 &lt; 80$</td>
<td>85 ≤ $E_3$</td>
</tr>
<tr>
<td>12</td>
<td>n/a</td>
<td>80 ≤ $E_2$</td>
<td>90 ≤ $E_3$</td>
</tr>
<tr>
<td>13</td>
<td>$E_1 &lt; 75$</td>
<td>90 ≤ $E_2$</td>
<td>90 ≤ $E_3$</td>
</tr>
<tr>
<td>14</td>
<td>75 ≤ $E_1 &lt; 85$</td>
<td>90 ≤ $E_2$</td>
<td>90 ≤ $E_3$</td>
</tr>
<tr>
<td>15</td>
<td>85 ≤ $E_1 &lt; 95$</td>
<td>90 ≤ $E_2$</td>
<td>90 ≤ $E_3$</td>
</tr>
<tr>
<td>16</td>
<td>95 ≤ $E_1$</td>
<td>95 ≤ $E_2$</td>
<td>95 ≤ $E_3$</td>
</tr>
</tbody>
</table>

**NOTE:** The minimum final resistance shall be at least twice the initial resistance, or as specified above, whichever is greater. Refer to 10.7.1.1.45

45 The minimum final resistance specified is for test purposes to determine minimum efficiency, not as a recommendation for actual use. For example, air cleaners used in residences may be changed or cleaned at a lower final resistance than that required by this standard. Also see Appendix A3.1.

*This Table Excerpted from ASHRAE Standard 52.2 - 1999*
# Table E-1
## Application Guidelines

<table>
<thead>
<tr>
<th>Std. 52.2 Minimum Efficiency Reporting Value (MERV)</th>
<th>Approx. Std. 52.1 Results</th>
<th>Application Guidelines</th>
<th>Typical Air Filter/Cleaner Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>n/a</td>
<td>≤0.30 μm Particle Size Virus (unattached)</td>
<td>Cleanrooms, Radioactive materials, Pharmaceutical manufacturing, Carcinogenic materials, Orthopedic surgery, HEPA/ULPA Filters</td>
</tr>
<tr>
<td>19</td>
<td>n/a</td>
<td>Carbon dust, Sea salt, All combustion smoke, Radon progeny</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>n/a</td>
<td>All combustion smoke, Radon progeny</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>n/a</td>
<td>All combustion smoke, Radon progeny</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>n/a</td>
<td>0.30–1.0 μm Particle Size All bacteria, Droplet nuclei (sneeze)</td>
<td>Hospital inpatient care, General surgery, Smoking lounges, Superior commercial buildings, Bag Filters</td>
</tr>
<tr>
<td>15</td>
<td>&gt;95%</td>
<td>Most tobacco smoke, Cooking oil, Most smoke</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>90–95%</td>
<td>Most smoke, Copier toner, Most face powder, Most paint pigments</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>80–90%</td>
<td>Insecticide dust, Copyer toner, Most face powder, Most paint pigments</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>70–75%</td>
<td>1.0–3.0 μm Particle Size Legionella, Humidifier dust, Lead dust</td>
<td>Superior residential buildings, bag Filters</td>
</tr>
<tr>
<td>11</td>
<td>60–65%</td>
<td>Legenella, Humidifier dust, Lead dust</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>50–55%</td>
<td>Milled flour, Coal dust, Auto emissions</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>40–45%</td>
<td>Neubelzer drops, Welding fumes</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>30–35%</td>
<td>3.0–10.0 μm Particle Size Mold, Spores, Hair spray</td>
<td>Commercial buildings, Better residential, Industrial workplaces, Paint booth inlet air, Pleated Filters</td>
</tr>
<tr>
<td>7</td>
<td>25–30%</td>
<td>Spores, Hair spray, Dusting aids</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>&lt;20%</td>
<td>Fabric protector, Dusting aids, Cement dust</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&lt;20%</td>
<td>Cement dust, Pudding mix, Smuff, Powdered milk</td>
<td></td>
</tr>
</tbody>
</table>

This Table Excerpted from ASHRAE Standard 52.2 - 1999
52.1 and 52.2 Coexist

- **52.1**
  - Used for MERV 1-4 filters
  - Many Local Standards Reference 52.1 and Dust Spot Efficiency Tests
  - Dust Holding Capacity Has Merit

- **52.2**
  - Gaining Popularity
  - Some Manufacturers Test New Products Only Using 52.2
  - Table E-1 is a Good Crossover Reference Chart
  - Now You Have Met MERV
Next Steps for Filter Testing

- ASHRAE Standard 52.2
  - Addendum A: Reference Filter Check; (Approved and Included)
  - Addendum B: Incorporating Elements of 52.1 Into 52.2 (Waiting for More Data...)
  - Addendum C: Conditioning Step (Waiting for More Data...)

- Global Standards for Filter Testing (ISO)?
  - ASHRAE Journal Article, August, 2006, Page 58
UL Standard 900

- The UL 900 Standard is Designed to Determine Combustibility and the Amount of Smoke Generated for Air Filter Units Under Test

- A Methane Flame is Ignited on the Upwind Side of the Filter, Resulting in a Direct Flame Against the Filter, Which is Maintained For Three (3) Minutes
UL Standard 900 (Cont.)

- **Class 1 Air Filters**
  - No Flames or Sparks May Pass Through the Filter and Only a Small Amount of Smoke Can Be Generated

- **Class 2 Air Filters**
  - Limited Flaming and Sparking are Acceptable and a Larger Amount of Smoke May be Generated
US Military Standard MIL-STD-282 For HEPA Filters

- Reserved For a Later Date
Codes and Requirements

- 2003 Arkansas Mechanical Code
- 2005 Arkansas Hospital Rules & Regulations
- American Institute of Architects (AIA) Guidelines for Design and Construction of Health Care Facilities
- Joint Commission: A Guide To Managing Indoor Air Quality in Health Care Organization
- ASHRAE Standard 62.1 - 2004
- Proposed ASHRAE Standards 170P & 180P
Section 605 Air Filters Requires:

- Heating and Air Conditioning Equipment to be Provided with Approved Air Filters
- Filters to Be Installed in the Return Air System, Upstream of Any Heat Exchanger or Coil
- Filters to be Listed and Labeled
2005 Arkansas Hospital Rules and Regulations

- References ASHRAE Standard 52.1 Values & AIA Guidelines for Design and Construction of Health Care Facilities
### TABLE 1

**Filter Efficiencies for Central Ventilation and Air Conditioning Systems in Health Care Facilities**

<table>
<thead>
<tr>
<th>Area Designation</th>
<th>No. Filter Beds</th>
<th>Filter Bed No.1 (%)</th>
<th>Filter Bed No.2&lt;sup&gt;1&lt;/sup&gt; (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All areas for patient care, treatment, and diagnosis, and those areas providing direct service or clean supplies such as sterile and clean processing.</td>
<td>2</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Protective Environment Room</td>
<td>2</td>
<td>30</td>
<td>99.97</td>
</tr>
<tr>
<td>Laboratories</td>
<td>1</td>
<td>80</td>
<td>-</td>
</tr>
<tr>
<td>Administrative, Bulk Storage, Soiled Holding Areas, Food Preparation Areas, and Laundries</td>
<td>1</td>
<td>30</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>1</sup>These requirements do not apply to small outpatient clinics or outpatient clinics that do not perform invasive applications or procedures.

Notes: The filtration efficiency ratings are based on average dust spot efficiency per ASHRAE 52.1 – 1992.

Additional roughing or prefilters should be considered to reduce maintenance required for filters with efficiencies higher than 75 percent.
AIA Guidelines for Design and Construction of Health Care Facilities

- References ASHRAE Standard 52.1
- Requires a Manometer across each filter Bed Having a Required Efficiency of 75% or more
- For Individual Room Units, a Minimum of 68% Weight Arrestance Filters Are to Be Used (ASHRAE 52.1)
NFPA Standard 90A

- Requires Filters To be Renewed or Cleaned when the Resistance to Airflow has Increased to Two Times the Original Resistance or When the Resistance Has Reached a Value of Recommended Replacement by the Manufacturer.

- Avoid Gaps Between Filter Sections,

This Information Excerpted from Annex B: Maintenance of the 2002 Edition of NFPA Standard 90A
Joint Commission: A Guide To Managing Indoor Air Quality in Health Care Organization

- Composite Filter Banks with a Final Filter Efficiency of at Least 95%
  Removal of Particles of 1 Micron Size is the Critical Quality Target

- Does This Contradict Current 2005 Arkansas Hospital Rules and Regulations?

This Information Excerpted from A Guide To Managing Indoor Air Quality in Health Care Organization, 1997
ASHRAE Standard 62.1-2004

- Section 5.9 States That the Minimum of a MERV 6 Filter Must Be Used and It Should Be Located Upstream of Cooling Coils and Wetted Surfaces

- Section 7.1 States That During Construction Measures Should be Taken to Prevent Construction-Generated Contaminants From Spreading to Occupied Spaces
Proposed ASHRAE Standards 170P and 180P

- 170P: Ventilation of Health Care Facilities
- 180P: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
Application – Apply Right Filter

- Minimum MERV 6 Prefilter Rating In Non-Health Care Settings
- Minimum MERV 8 Prefilter Rating In Health Care Settings
Application - System Efficiency

System Efficiency Starts With the Frame / Housing
Application – System Efficiency (Cont.)

System Efficiency Continues With Eliminating Bypass
Application – System Efficiency (Cont.)
Application – Consider New Technology
Contact Information

John Carter, PE

Jack T. Carter Company

6701 West 12th Street, Suite 17
Little Rock AR, 72204

Toll Free: (888) 299-9272

john@jcarterco.com