Remediation of Mold Contaminated Ductwork

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The Problem

• Visible mold growth on interior of liner inside air handling unit.
• Visible mold growth on the interior surface of duct lining
• No Drain Pans (entire bottom of air handling unit used as pan)
• Complaints of musty odors
Steps in Remediating Mold in HVAC Equipment

• Correct maintenance problems
• Correct the specific situation that allowed the mold amplification
• Remove mold*
• Sanitize surface
• Coat with a fungistat coating
• Clearance inspection and sampling
• Set up an O&M program
Mold on Interior of Air Handling Unit
Mold Growth on Surface of Duct liner
Projections into air stream wetted
Mold followed water movement in direction of air flow
Surface of liner found to be wet
Interior of liner found to be relatively dry
### Liner in Supply Air Duct

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Surf Duct Liner (pinless)</th>
<th>Interior Duct Liner</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd Floor</td>
<td>22.5</td>
<td>16</td>
<td>(6.5)</td>
</tr>
<tr>
<td>9th Floor</td>
<td>23.8</td>
<td>12.7</td>
<td>(11.1)</td>
</tr>
<tr>
<td>11th Floor</td>
<td>17.2</td>
<td>13.5</td>
<td>(3.7)</td>
</tr>
<tr>
<td>Average</td>
<td>21.2</td>
<td>14.1</td>
<td>(7.1)</td>
</tr>
</tbody>
</table>
Stratification of Outside Air

OUTSIDE AIR

RETURN AIR

COIL
Fog in Ductwork

RETURN AIR
75° DB 50% RH

OUTDOOR AIR
92° DB/78° WB

65°/DEWPOINT 64°

48°

COIL -27°
TEMPERATURE DROP
Cause of Moisture

- Direct wetting of liner in AHU from condensate in bottom of unit
- Fog in air stream down the ductwork caused by improper mixing of outside air. Wetted surface of duct lining
First Step

• Correct causes of wetting
  – Bottom of AHU sloped to provide drainage
  – Outside air preconditioned to correct fog in ductwork
Determine Remediation Feasibility

• Determine if mold could be remediated
  – Mold on surface can be remediated.
  – Liner removed if mold penetrated into liner

• Determine extent of mold contamination down ductwork to determine the scope of the remediation
Can Mold be Remediated?

• Evaluated with Microscope in field
  – Face and interior inspected for hyphae
• Mold found to be on surface of liner
• Only penetrated to interior in first 10’ past air handling unit
Liner in AHU wetted by condensate in bottom of unit.

- Bottom of unit pitched to provide drainage.
- Liner removed from inside unit.
Chronically Damp Areas

- Interior of air handling units and first part of trunk ducts were chronically damp environments.
- Remove duct liner.
- Sanitize.
- Coat with fungistat coating.
- Initiate O&M program to clean and sanitize on a regular basis.
Duct Remediation Program 1

• Areas with mold inside liner
  – Interior of air handling unit and first 10’ of trunk duct
  – Remove liner, coat metal surface with fungistat coating,
  – Re-insulate on exterior
Duct Remediation Program 2

• Areas with mold only on surface of liner
  – Ductwork beyond trunk duct
  – Clean surface of liner
  – Sanitize surface with fungicide
  – Apply coating with fungistat to stabilize cleaned surface
Evaluating Fibrous Glass Surfaces

- Inspect to determine extent of contamination
- Determine food source for mold
- Test for cleanability with HEPA Vacuum
- Test effectiveness of sanitizers
Determine extent of Contamination

- Borescope inspection for initial determination
- Openings cut in duct to verify borescope information and to collect samples for examination with microscope
Extent of Contamination Mapped
Determine Food Source

- Sample of liner sent to materials lab
- Mold growing on drywall taping compound dust from original construction
- Filters in HVAC do not need to be upgraded
Test Cleanability

- Surface hand vacuumed to determine if mold and drywall taping compound dust could be removed
- Hand vacuuming used as reference method for evaluating success of contractor’s cleaning efforts and to resolve disputes
Sanitizers (Biocides) Tested

- Sodium hypochlorite (Bleach)
  - 25% solution
  - 10% solution
- Chlorine Dioxide (Oxine HVAC)
- Quaternary Ammonia (Aegis Microbe Shield)
- Hydrogen Peroxide
Biocides tested for Effectiveness

- Biocides applied to sample of surface of mold contaminated liner
- Observed under stereo microscope to determine effectiveness
- Rated based on ability to destroy hyphal growth
Biocides

• Registered by EPA under FIFRA
• National Antimicrobial Information Network (http://nain.orst.edu)
  – Oregon State University and the EPA
  – (800) 447-6349
• Fungicide (destroys fungi and inhibits growth) vs. fungistat (inhibits growth without destroying fungi)
• Mildewcide vs. mildewstat
• Bactericide vs. bacteristat, etc.
Effectiveness of Biocides

• Highly effective
  – Bleach 25% solution
  – Bleach 10% solution
  – Aegis Microbe shield

• Effective (lost effectiveness in ~ 30 sec.)
  – Oxine HVAC (Chlorine Dioxide)

• Poor effectiveness
  – Hydrogen Peroxide
Effect on Strength of Liner

- The effect of biocides on the strength of the liner face was evaluated to determine if there was a potential for fiberglass release after the remediation.
Test Integrity of Liner Surface

• Visual inspection
• Tensile strength test
  – “ASTM D 5035 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)” adapted to test tensile strength of strips of liner face
Effect on Strength of Liner

• All biocides, except hydrogen peroxide, found to have minimal to no effect on tensile strength of liner.

• Hydrogen peroxide visibly deteriorated liner
Biocide Selected

- Aegis Microbe shield (quaternary ammonia) selected for the project (Note: no longer registered for this use)
- Oxine HVAC only biocide registered for use in HVAC equipment
  - Oxine HVAC not registered for porous surfaces
  - Currently no biocide registered for use on porous surfaces in HVAC equipment
  - Many manufacturers of bleach all of whom register their product with EPA. It is possible that a bleach manufacturer has filled the void. Check FIFRA website
Fungistat Coatings

- Portersept – HVAC - 3830
- Fosters 40-20¹
- Aegis Microbe Shield
- Duct Liner Repair Coatings²

1. Yang, C., PhD. & Ellringer, P., PE, CIH Antifungal Treatments and their effect on Fibrous Glass Liner – ASHRAE Journal, April, 2004

2. Coating color is typically dark
Fungistat Selected

• Portersept HVAC 3830
  – Lower paint odor
  – Heavy enough coating to stabilize surface of liner
  – White to provide an easily inspected surface for future monitoring
Duct Cleaning Preparation

• Access openings
• Access hatches
• Frequent enough to permit access for cleaning and inspection of all surfaces
• Hatches promote good hygiene in the future and allow periodic inspections
Cleaning Fibrous Glass Surfaces

- NAIMA – North American Insulation Manufacturers Association

  – Cleaning Fibrous Glass Insulated Air Duct Systems, Recommended Practice
Duct Cleaning Procedures - NAIMA

- Place duct system under negative pressure
- Clean from clean end toward dirty end
- Move dust down duct to be collected by HEPA filtered vacuum
  - Contact Vacuuming
  - Air Washing
  - Power Brushing
Clearance Testing

• Visual inspection

• Comparison test for fibrous glass
  – Tape lift
  – NADCA Vacuum test
  – Modified Microvacuum technique (ASTM D 5755)
    • Analyze by PCM
    • Compare remediation area to clean area

• Clear if remediation area as clean or cleaner than criterion area (discounting fiber glass)
Post Remediation

- Revisit site to insure that damp conditions or mold amplification are not re-occurring
- Monitor to determine if there are any health complaints after re-occupancy
- Periodically inspect the interior of HVAC units and ductwork

No mold amplification re-occurrence in past 24 months
Operations & Maintenance

- Monitor interior of ductwork
- Change filters regularly
- Clean coils periodically
- Clean drain pan – install biocide strips
- Guards on belts
- Cleanliness of interior of equipment
- Calibrate temperature controls
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