TESTING AND TROUBLESHOOTING OF VENTILATION SYSTEMS
TESTING AND TROUBLESHOOTING OF VENTILATION SYSTEMS

While this lecture is mine in thought, I have borrowed from these individuals:

• Marty Schloss, P.E.
  Schloss & Associates, LLC

• Jonathan Hale, MAPA
  Air Systems Corporation
Testing and Troubleshooting
Monitoring a Ventilation System

There are 6 reasons for Monitoring a Ventilation System:

1. Commissioning: Recording initial performance of system and determining if it meets design criteria

2. Proof of Performance: Determining the degree of compliance with codes and standards (EPA, OSHA)

3. Balancing Systems: Adjusting airflows to match desired distribution. Done at commissioning, after alterations and after blast gates have been tampered with
Testing and Troubleshooting
Monitoring a Ventilation System

There are 6 reasons for Monitoring a Ventilation System:

4. Baseline Maintenance: Obtaining data through periodic checks to determine when maintenance or repairs are needed

5. Troubleshooting: Determine where and why system components have changed and adversely impacted system air flows

6. Change Management: Data to assist in the design or alteration of future systems
Testing and Troubleshooting Monitoring a Ventilation System

• Hoods
  – Air flow pattern disturbed
  – Adequate air flow and velocity profile
  – Contaminant capture

• Duct Work
  – Adequate conveying velocity
  – Duct airflows disturbed

• Collector
  – Differential pressure
  – Sub systems operating at base condition

• Fan
  – Airflow as intended (shaft speed, motor amps)
Hood Measurements

Face velocity measurements:

- **What/Where:** Airflow Through Controlled Openings
- **Units:** Feet per minute (fpm)
- **Instruments:** Rotary Vane Anemometer Thermal Anemometer Smoke
Hood Measurements
Rotary Vane Anemometer

Vane blade rotations counted by tachometer
- Must be calibrated
- Should not exceed 5% of cross sectional area
- Measures air velocity over time period over probe area
- Range 50 fpm – 3,000 fpm
Hood measurements
Thermal Anemometer

Measures cooling of wire as air passes probe
- Probe orientation is key
- Must be calibrated
- Range 30 fpm – 6,000 fpm
- Wire easily fouled by contaminants
Hood Measurements
Measuring Face Velocity

AEROSOL HOOD OPENING

\[
\frac{150 + 200 + 170 + 190}{4} = 180 \text{ FEET PER MINUTE}
\]

FILLER ACCESS DOOR

\[
\frac{100 + 130 + 130 + 140 + 140 + 150}{6} = 131 \text{ FEET PER MINUTE}
\]
Hood Measurements
Measuring Face Velocity (cont.)
Hood Measurements
Smoke visualization
Hood Measurements
Smoke Generators

Smoke tubes

Theater smoke generator – “DJ Fogger”
Duct Measurements
Static Pressure

• **What/Where:**
  – Vacuum or Pressure Exerted on the Inside of a Duct and measured perpendicular to air flow (SP)
  – Constant across a cross sectional area of a duct
• **Units:**
  – Inches or mm of Water, Pascals
• **Instruments:**
  – Slack or U-tube Manometer
  – Manometer
Duct Measurements
U-tube Liquid Filled Manometer

Primary standard – no calibration needed
Duct Measurements
Slack or U-tube Manometer

- Measures: Vacuum or Pressure
- Units: Inches or mm of Water
- Fluids: - Water with Green Coloring
  - Red Oil
  - Mercury
Duct Measurement
Manometer
Fluid
Comparison

Pressure Source of 13.6" Water

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Oil</td>
<td>0.826</td>
</tr>
<tr>
<td>Water</td>
<td>1.0</td>
</tr>
<tr>
<td>Mercury</td>
<td>13.6</td>
</tr>
</tbody>
</table>

(The scale on the manometer lists its intended liquid.)
Duct Measurement
Measuring Static Pressure
Duct Measurements
Magnehelic Gauges

- Measures Pressure or Vacuum (< 15 psig rated)
- Must be routinely calibrated – hard bump can change reading
- Calibrated in mm WC, in WC, in Hg, PSI
Duct Measurements
Velocity Pressure (VP)

- **What/Where:**
  - In the linear flow of the airstream – measured parallel to the airflow (VP)
  - VP changes across the cross sectional area of a duct (velocity profile)
  - Air volume can be calculated from VP, \( Q=VA \) and \( V= 4005 \left( \frac{VP}{df} \right)^{0.5} \)

- **Units:**
  - Inches or mm of Water, Pascals

- **Instruments:**
  - Pitot tube &
    - Inclined Manometer
    - Slack or U-tube Manometer
    - Manometer, Magnehelic gage
Remember TP = VP + SP?

VP = TP – SP; V = 4005

\((VP/df)^{0.5}\)
Duct Measurements
Inclined Manometer

- **Range:**
  - 0-2 inches of Water
  - 0-50 mm of Water
- **Uses** “0.826 Red Oil”
- **Being level is critical!**
Duct Measurements
Pitot Tube & Inclined Manometer
Duct Measurements
Measuring Airflows

• Equipment set-up
• Location of Test Port
  – 7 D upstream
  – 4 D downstream
• Traverse Pattern
• Recording Data
• Proper Calculations
Pitot tube tip Parallel to Duct Wall

Pitot tube shaft Perpendicular to Insertion Point
Duct Velocity Profile

Duct Traverse Points – Equal Concentric Areas – Good Averaging
## Equal Area Traverse Points

<table>
<thead>
<tr>
<th>Traverse Point/ % diameter</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
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<td>1</td>
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<td>6.7</td>
<td>4.4</td>
<td>3.2</td>
<td>2.6</td>
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<tr>
<td>5</td>
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<td>67.7</td>
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<tr>
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<td>X</td>
<td>89.5</td>
<td>77.4</td>
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<tr>
<td>8</td>
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<td>X</td>
<td>X</td>
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</table>
Dry air at 70 F is flowing in a 6” diameter duct at sea level. Calculate Volumetric Flow Rate.

<table>
<thead>
<tr>
<th>Points</th>
<th>VPh</th>
<th>Vh</th>
<th>VPv</th>
<th>Vv</th>
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<tr>
<td>0.19”</td>
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<td>0.78</td>
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<tr>
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<td>0.95</td>
<td></td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>4.07”</td>
<td>0.94</td>
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<td>0.79</td>
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<tr>
<td>5.81”</td>
<td>0.64</td>
<td></td>
<td>0.61</td>
<td></td>
</tr>
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</table>
Calculate Air Flow

• Convert Velocity Pressures to Velocity
  – \( V=4005(VP/df)^{1/2} \)
  – \( df = 1 \) for sea level and 70 F

• For first value:
  – \( V=4005(0.55/1)^{1/2} = 2970 \text{ ft/min} \)
Dry air at 70 F is flowing in a 6” diameter duct at sea level. Calculate Volumetric Flow Rate.

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<td>21126</td>
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<td>20869</td>
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Complete Calculation

- Average velocity:
  - \((21126 + 20869)/12 = 3500 \text{ ft/min}\)
- \(Q = V \times A\)
- \(A_{6'' \text{ duct}} = \pi \times 6^2/4 \times (144) = 0.1963 \text{ sq.ft.}\)
- \(Q = 3500 \times 0.1963 = 687 \text{ ft}^3/\text{min}\)
The actual air temperature was 150 F. What is the corrected flow rate for the 6” diameter duct at sea level.

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<thead>
<tr>
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<tr>
<td>1.93”</td>
<td>0.95</td>
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<td>0.90</td>
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<td>0.79</td>
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<tr>
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<td>0.64</td>
<td></td>
<td>0.61</td>
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</table>
Pitot Tube Traverse

- The Pitot Tube and monometer are calibrated at standard air
- Standard Air is dry air at 70 F and 29.92 (ins HG) barameter. The density of air at STP is 0.075 lb/ft³ and the df is 1.0
- Therefore, under non-standard conditions the measured VPs taken with a pitot tube must be corrected by:

\[ V = 4005 \left( \frac{VP}{df} \right)^{\frac{1}{2}} \]

In order to determine Actual Cubic feet per minute (ACFM)
## Pitot Tube Traverse

### Density Factors

Air Density Correction Factors ($df$):

<table>
<thead>
<tr>
<th>Altitude (Ft)</th>
<th>TEMPERATURE (Degrees F)</th>
<th>70</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
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<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>0.95</td>
<td>0.80</td>
<td>0.70</td>
<td>0.62</td>
<td>0.55</td>
<td>0.50</td>
<td>0.46</td>
<td>0.42</td>
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<tr>
<td>1000</td>
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<td>0.77</td>
<td>0.67</td>
<td>0.59</td>
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<td>0.44</td>
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<td>0.65</td>
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<tr>
<td>3000</td>
<td>0.90</td>
<td>0.85</td>
<td>0.72</td>
<td>0.62</td>
<td>0.55</td>
<td>0.49</td>
<td>0.45</td>
<td>0.41</td>
<td>0.38</td>
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<tr>
<td>4000</td>
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<td>0.82</td>
<td>0.69</td>
<td>0.60</td>
<td>0.53</td>
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<td>0.39</td>
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<td>0.67</td>
<td>0.58</td>
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<td>0.42</td>
<td>0.38</td>
<td>0.35</td>
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</tr>
<tr>
<td>6000</td>
<td>0.80</td>
<td>0.76</td>
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<td>0.56</td>
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<td>0.44</td>
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<td>0.37</td>
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<td>9000</td>
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<tr>
<td>10000</td>
<td>0.69</td>
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<td>0.55</td>
<td>0.48</td>
<td>0.42</td>
<td>0.38</td>
<td>0.34</td>
<td>0.31</td>
<td>0.29</td>
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</tr>
</tbody>
</table>
Air with different density

• Convert Velocity Pressures to Velocity
  – \( V = 4005 \left( \frac{VP}{df} \right)^{\frac{1}{2}} \)
  – \( df = 1 \) for sea level and 70 F
  – \( df = \frac{70+460}{150+460} = \frac{530}{610} = 0.87 \)

• For first value:
  – \( V = 4005 \left( \frac{0.55}{0.87} \right)^{\frac{1}{2}} = 3184 \) versus 2970 ft/min
The actual air temperature was 150°F. What is the corrected flow rate for the 6” diameter duct at sea level. df=0.87

<table>
<thead>
<tr>
<th>Points</th>
<th>VPh</th>
<th>Vh</th>
<th>VPv</th>
<th>Vv</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td></td>
<td></td>
<td>22648</td>
<td></td>
<td>22372</td>
</tr>
</tbody>
</table>
Complete Calculation

• Average velocity:
  
  \[-(22648 + 22372)/12 = 3752 \text{ ft/min}\]

• \( Q = V \times A \)

• \( A_{6'' \text{ duct}} = \pi \times 6^2/4 \times (1/44) = 0.1963 \text{ sq.ft.} \)

• \( Q = 3752 \times 0.1963 = 736 \text{ versus 687 ACFM (7\% greater volume)} \)
Fan Measurements

• Shaft speed: (check against fan curve)
  – hand held tachometer

• Fan motor current: (rough estimate of total airflow)
  – Clamp on ammeter
Troubleshooting

If an existing ventilation system appears to not be functioning properly, the following simple checks can be made without extensive measurements or expert help:

- Is the fan belt broken or slipping?
- Is the fan wired backward (reversed polarity)?
- Is ductwork clogged with dust?
- Is there holes, cracks or openings in the ducting?
- Is the air cleaner clogged?
- Are any dampers in the ductwork closed?
- Is there insufficient makeup air?
Troubleshooting

• Has ductwork been changed to include more length, more or sharper bends, or abrupt diameter changes?

• Have additional hoods and ductwork been added? Without proper airflow balancing, some hoods in a multiple system may have inadequate flow. Or the fan may be too small to handle the additional resistance.

• Has the contaminant source been moved further away from the hood opening?
Troubleshooting

• Is more contaminant being generated at the source?

• Are cooling fans causing cross drafts?

• Have employees modified the hood because it interferes with their job tasks?

Many of these problems can be avoided by periodic maintenance and measurements of air velocities or pressures of ventilation systems.
TESTING AND TROUBLESHOOTING OF VENTILATION SYSTEMS

Questions?