VAV AIRFLOW CONTROL

Reliable Without Limitations?

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.
Presentation Description

1.  VAV Airflow Station...
2.  …testing at Factory Facilities
3.  …testing on projects
4.  …inaccuracy AFTER calibration
5.  Medical Research facility example
6.  Energy usage implications
7.  Suggestions
Learning Objectives

At the end of this session, participants will be able to:

1. Apply practical methods for evaluating VAV systems for proper operation and possible excessive energy use at minimum airflow.

2. Communicate with HVAC professionals about VAV terminal units regarding performance and minimum airflow verification methodology.
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VAVs...What’s the big deal anyway?

...review project documents...

Building Automation System (BAS) guys...

...enter the VAV data into BAS application...

...upload BAS to each VAV controller
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Testing Adjusting Balance (TAB) guys...

...review project information...

...proportionately balance the outlets...

...connect to the VAV...

...calibrate the airflow station...
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...the VAV operates happily ever after...THE END...

...umm...isn’t that true???

Why is it so COLD in here!!!

Why is it so LOUD in here!!!

Why are these electrical & gas bills so EXTREME?!?!
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Pitot Tube Airflow Measurements

TOTAL PRESSURE

STATIC PRESSURE

TP

SP
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Pitot Tube Airflow Measurements

TOTAL PRESSURE
- STATIC PRESSURE
= VELOCITY PRESSURE (VP)
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VAV Airflow Measurement... similar but different...

TOTAL PRESSURE

LOW PRESSURE

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VAV Airflow Sensor Measurements

TOTAL PRESSURE
- LOW PRESSURE
= DIFFERENTIAL PRESSURE (ΔP)
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Examples of VAV airflow velocity sensors…

Examples of VAV Airflow Sensor Types
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ΔP Measured at sensor...

Sensor Airflow (CFM)...

VAV Airflow Sensor Chart
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VAV Airflow Sensor Chart

Minimum measureable (Controllable) $\Delta P$. 
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VAV Airflow Sensor Chart

$\Delta P / \text{CFM}$ relationship...

...4-inch VAV Inlet size...
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VAV Airflow Sensor Chart

...through 16-inch VAV Inlet size...
1. No VAV Damper

2. Airflow modulated by a fan with a VFD

3. Airflow measured at calibrated AFS.

4. Airflow pattern across sensor very laminar & consistent

F = Flow Sensor
C = VAV Controller
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VAV Manufacturers refer to ASHRAE 130-2008 for VAV testing Procedures…

Standard for Testing VAV Terminal Units

Methods of Testing Air Terminal Units
Paragraph (5.6.1): “This test is intended to measure terminal unit air flow sensor output at various airflows (or velocities) for a specified duct static pressure. Its purpose is to determine the effects of the throttling device on flow sensor performance.”
Question 1: Is there a completely open VAV damper in test unit while creating the published airflow sensor chart?

In correspondence I have been told “...no damper...” is present.

Question 2: No VAV damper means ASHRAE 130-2008, 5.6.1 testing is not performed?

No answer yet, still corresponding...

Question 3: Where is ASHRAE 130-2008, 5.6.1 testing data published?

No answer yet, still corresponding...
Airflow pattern across airflow sensor of field installed VAV fairly laminar...

...Unfortunately...
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VAV Field Testing: Chart
comparisons with Measured CFM

Field tests are perplexing...

Maximum CFM

12” VAV…

![Diagram showing airflow control and field testing results.](image-url)
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Field tests are perplexing...

Maximum CFM

12” VAV, 1800 CFM @ 0.80 in. W.G.

Works, makes sense!
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VAV Field Testing: Chart comparisons with Measured CFM

Minimum CFM

12” VAV, 800 CFM @ 0.08 in. W.G.

Why does the Minimum CFM plot on the 14” VAV curve?
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VAV Field Testing: Chart comparisons with Measured CFM

Attempted CFM / ΔP comparisons many times…
LIMITED success…

...very LIMITED success…

CAUTION for the faint of heart…

“Traumatic” project experience follows…

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VAV Field Testing:
Accelerated Project Schedule

3 buildings…
...each building had 5 floors...

...dedicated AHU on each floor...
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VAV Field Testing:
Large DDC VAV Project with an Accelerated Project Schedule

...each AHU served 20-30 VAVs...
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No Down-Duct Static control ...

...BUT...

...TAB needed to start to meet project schedule commitments!

VAV Field Testing:
“Unusual” Problem...
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VAV Field Testing:
How TAB proceeded…

Closed 50% of VAVs on the floor we were working on…
...building down-duct static for other floor VAV calibration...
...calibrated & proportionately balanced VAVs...
...set completed VAV to control temperature (72°) moved to next VAV...
...until entire floor was completed.
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VAV’s are “Pressure Independent”.

Set final AHU down-duct static @ Operator Work Station (OWS)
Kill two birds with one stone at OWS:

Identify hydraulically hardest to satisfy VAV(s) on each AHU...

Adjust AHU Down-Duct-Static setpoint to satisfy this VAV(s)
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VAV Field Testing:

What we failed to take into account...

VAV dampers @ Minimum CFM were 5-15% open...

...VAV dampers @ Maximum CFM were 20-30% open...
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After 2 days at OWS...

...VAVs controlled Maximum Airflow with dampers 70-90% Open.

Concluded that it was time to:
Set AHU Minimum Outside Air...
Measure & document final AHU operational data...
...mere hours from project completion!
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VAV Field Testing:
...Spot check VAV airflow...

Zone airflow verification revealed...

Most VAV actual CFM was 20-30%...

HIGHER or LOWER than Design & BAS CFM!
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VAV Field Testing:
HUGE PROBLEM

WHAT HAPPENED?!?!!
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Airflow in a duct is a lot like cars on a freeway...
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...add a traffic counting device...

F = Traffic Flow Counter

...traffic moves at a measurable rate...

...but what happens when...
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...big rig spin-out = traffic backup...

F= Traffic Flow Counter

...creating a freeway “Dead-Zone”
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Airflow through airflow sensor with open VAV damper...no problem
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VAV damper closing is similar to the big rig spin-out...

...how far the “Dead-Zone” extends depends on the “traffic” or duct pressure behind the damper.
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Is this really THAT big of a deal?
How do you diagnose this issue?

EXAMPLE:

- 397,000 Square Foot Medical Research facility
- We’ll look at 1 AHU (of many) supplying 100% OA through…
- Hot Deck (Steam Coil) and Cold Deck (CHW) at AHU down to…
- 62 Dual Duct VAVs, constant outlet airflow serving…
- Laboratories & Lab Support Administration areas
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Our initial approach...

- Using the BAS, we began to evaluate zone performance.
- Rebalance had occurred 6-months earlier so...
- ...TAB report was in our hands.
- Began to look for “Targets of Opportunity” to allow us to...
- ...move to zone level with our instruments to verify system operation.
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Typical VAV:
Design Flow Total = 3,015 CFM

TAB calibrated Hot & Cold VAV controllers at 2,380 Max CFM but…
...did not document Minimum airflow calibration in the TAB Report…
...Max CFM discrepancy and lack of Min CFM documentation…

...in other words…

NOBODY KNEW ANYTHING…
VAV AIRFLOW CONTROL  Discharge Air Temperature…
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- 85 °F
- 68.5 °F
- 52 °F

Should be on the 85° side of 68° rather than the 52° side…
VAV AIRFLOW CONTROL  Discharge Air Temperature…
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Discharge Air Temperature (DAT) Calculation:

$$\text{DAT} = \left[\frac{1,087 \text{ CFM}}{1,808 \text{ CFM}} \times 85^\circ \text{F}\right] + \left[\frac{721 \text{ CFM}}{1,808 \text{ CFM}} \times 52^\circ \text{F}\right]$$

$$\text{DAT} = 71.8^\circ \text{F}$$
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**AT BAS:**

- Repeated DAT calculation (Spreadsheet) for each VAV…
- …found many VAVs with identical issue.

**In Field @ three random VAVs:**

- Verified DAT sensor location; GREAT location!
- BAS Temperature indication within ½° calibrated instrument
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Actual VAV damper position vs. BAS indication...
...matched...

+2.04-in. W.C.

+1.98-in. W.C.

Measured Hot and Cold Duct inlet pressure...
...pretty high for VAVs without coils...
## VAV AIRFLOW CONTROL

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### Tested Airflow at VAV inlets...

<table>
<thead>
<tr>
<th>Hot Duct Traverse Results @ As-Found Maximum CFM Setpoint:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS: 1,835 CFM</td>
</tr>
<tr>
<td>BAS: 963 CFM</td>
</tr>
</tbody>
</table>

### Hot Duct Traverse Results @ Design Minimum CFM Setpoint:

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS: 963 CFM</td>
</tr>
</tbody>
</table>
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Comparison of data plot on airflow chart (Typical of 3)...

Plotting sensor ΔP on this chart were disturbing...

...actual airflow is NEVER on the curve but in the area between the Maximum & Minimum CFM
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Thoughts...Next Steps...

Just how big was this issue?

Verify airflow for entire AHU...
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- Measure Fan Operational Data (RPM, Volts, Amps, TSP), plot on fan curve and fan tables...

- Traverse Hot & Cold Deck Coils...
  - Shortridge VelGrid at discharge with 6-inch stand-offs
  - Unit free area @ traverse point calculate airflow

- Traverse all Supply Air ducts (4 Hot ducts & 4 Cold ducts)...

AT AHU...
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AHU CFM vs. BAS CFM

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- AHU airflow comparisons…
  - All three sets of airflow data ±2% of one another which is…
  - …WELL within acceptable instrument error…

- BAS Hot & Cold VAV CFM summary vs. measured CFM:
  - Actual Hot Deck airflow 122% of BAS indication
  - Actual Cold Deck airflow 118% of BAS indication
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Points of Energy Saving

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- **Fan Energy:**

- **Down-Duct Static AND CFM reduction (VFD or Sheave Change)**  
  = SIGNIFICANT kW/hour reduction

- **Heating Coil Steam load...**
  - 100% Outside Air, winter would require significant steam...

- **Chilled Water production and distribution costs:**
  - 100% OA Sensible & Latent cooling
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...significant energy expenses due to inaccurately calibrated, Pressure Independent VAV Terminal Units.
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• **Educate MEP, TAB & Cx Personnel**

1. Project schedule/completion dates drive project activities instead of logic…
   - Sometimes this works…
   - Other times, it can be catastrophic
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WHAT TO DO?

2. TAB with incomplete AHU control system cannot be overlooked without consequences.

   • Educated & diligent TAB personnel can overcome this…

   • …and make it right at the end of the project but…

   • …this is a LOT of extra work requiring compensation.
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• Educate MEP, TAB & Cx Personnel (continued)

2. NEBB, AABC & TABB Procedural Standards require fully operational control systems to commence TAB activities.

Proceeding with system TAB without completed BAS control compromises the NEBB, AABC & TABB process...

...will compromise the guarantee of accuracy by these bodies which is often paid for by the owners.
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WHAT TO DO?

- Educate MEP, TAB & Cx Personnel (continued)

3. Calibrate VAV near operational static pressure.

4. ALWAYS be aware of hydraulically hardest to satisfy VAV.
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WHAT TO DO?

5. **Educate MEP, TAB & Cx Personnel (contined)**

6. **Cx personnel need to support TAB personnel...**

5. **Cx personnel must educate clients, introduce intelligence into the process, ENERGY LATER vs. Project Schedule gain now.**
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**BAS Applications for DDC VAVs Need Additional Calibration Capability**

7. Most DDC VAV programs reconcile inlet duct airflow sensor $\Delta P$ with actual airflow using a form of the algorithm below…

$$\text{Current CFM} = (\sqrt{\frac{\Delta P \text{ Current}}{\Delta P \text{ at Calibration}}} \times \text{CFM at Calibration} \times \text{Correction Factor})$$

8. Add additional calibration points into the VAV application
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Request Publiction of ASHRAE 130-2008, Section 5.6 Test Data

Something is going on, let’s hear from the experts!
NOT a “Silver Bullet” for energy reduction in every building with pressure independent VAV systems.

DOES represent potential energy waste.

SHOULD be investigated and understood.
THANK YOU

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