

VAV Systems

Design, Performance and Commissioning Issues

Flow and Pressure Measurement



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Senior Engineer

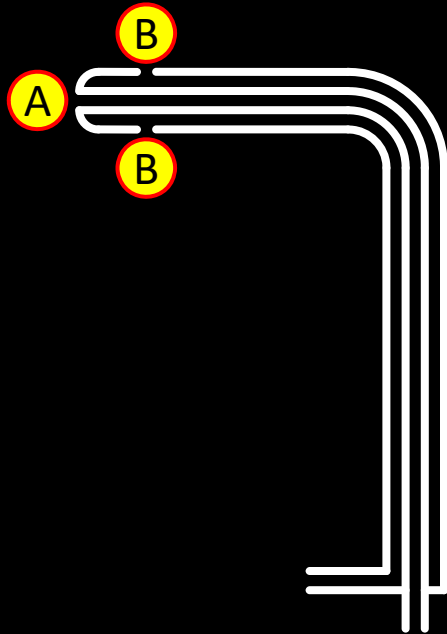
Facility Dynamics Engineering

March 7, 2018

What's In This Module?

- Static, velocity and total pressure; what they are and how we use them to measure flow
- Application considerations for measuring flow

Flow Sensors are Typically a Form of Pitot Tube



Pitot tubes are designed to measure velocity pressure

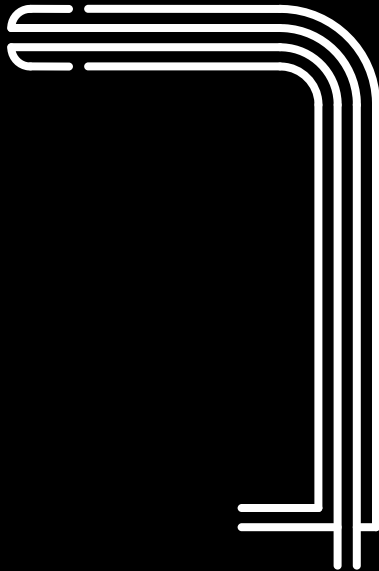
A tube inside a tube

- Inner tube open at the tip (A)
- Outer tube open through ports on the side (B)

In a moving air stream:

- The ports on the side (B) are exposed to only the ambient static pressure
- The port on the tip (A) is exposed to both the static pressure and the pressure created by the air being stopped; a.k.a. total pressure.
- The air is stopped because the tube dead ends on the measurement device
- The pressure associated with the moving air is called velocity pressure

Flow Sensors are Typically a Form of Pitot Tube



There is a specific relationship between velocity and velocity pressure

$$V = 4,005 \sqrt{p_{velocity}}$$

Where :

$p_{velocity}$ = Velocity pressure in inches water column

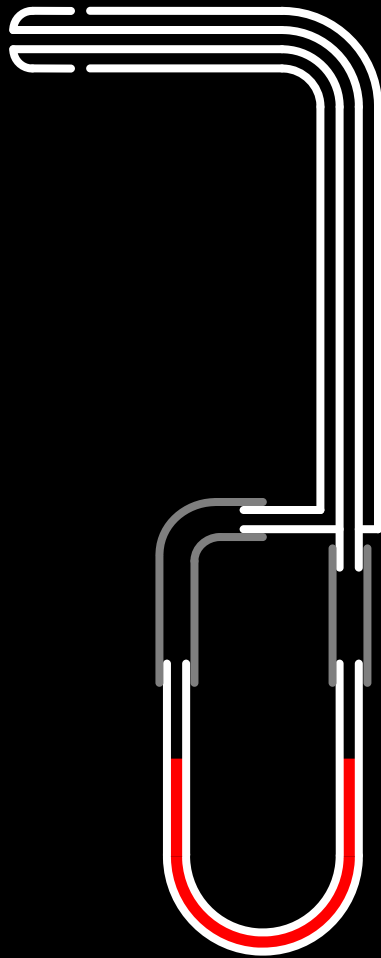
V = Velocity in feet per minute

4,005 = A units conversion constant

(Which depends on the state of the air!)

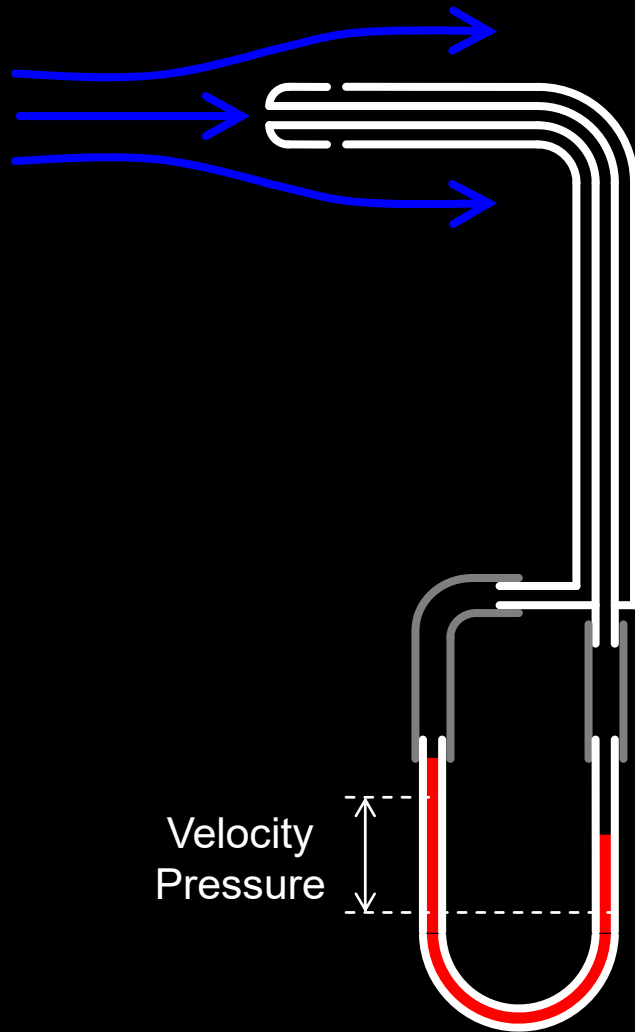
If you measure the velocity pressure, then you can calculate the velocity

Flow Sensors are Typically a Form of Pitot Tube



Connecting a U shaped glass tube filled with a liquid like oil or water – called a manometer – to the pitot tube allows velocity pressure to be measured

Flow Sensors are Typically a Form of Pitot Tube



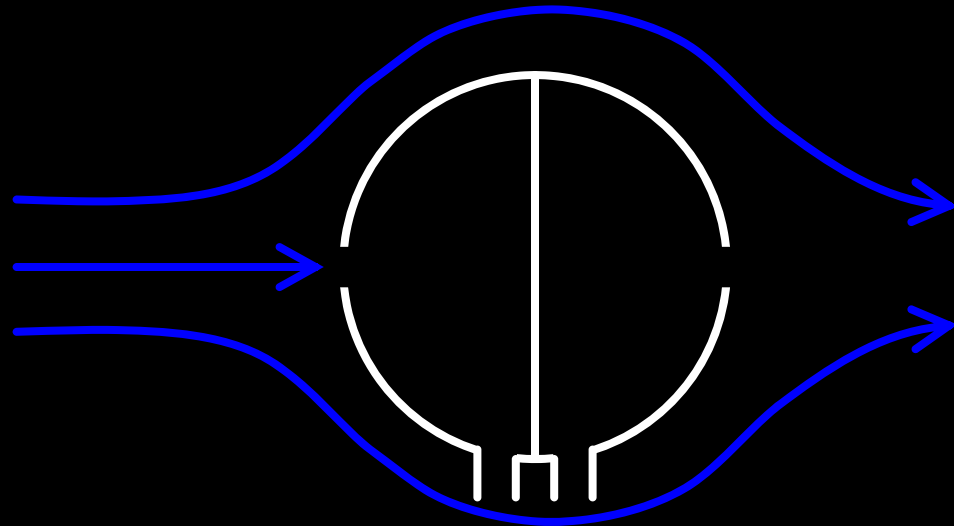
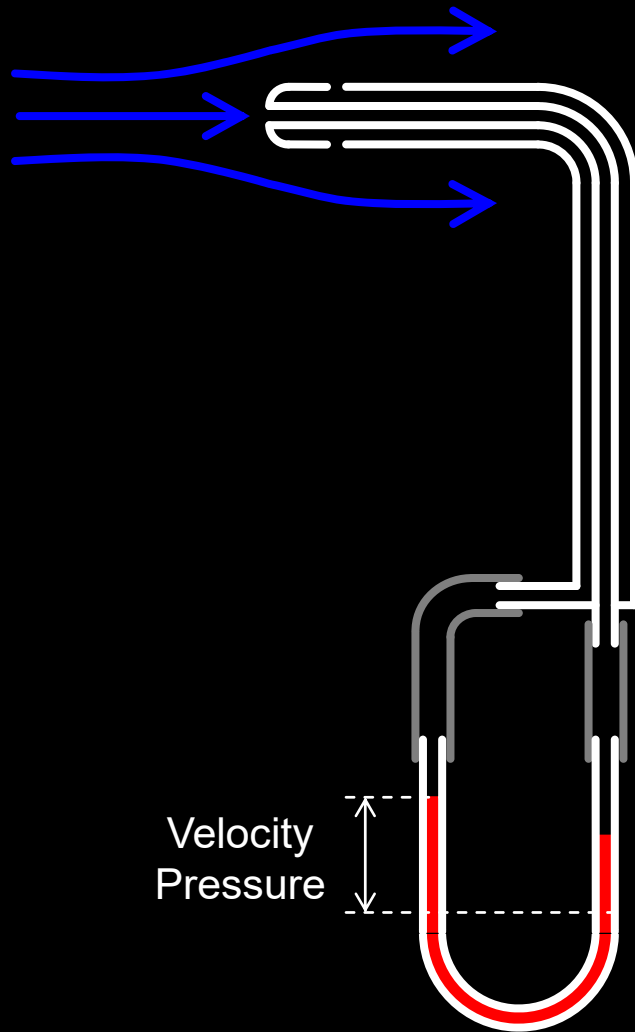
With no air flow, the pressure at both ports is the same and the level in each “leg” of the U tube is the same.

In a moving air stream, the total pressure port pushes the manometer liquid down in the tube it is connected to

But the static pressure pushes back, canceling out the static pressure portion of the total pressure signal

The resulting level difference is a measure of the velocity pressure

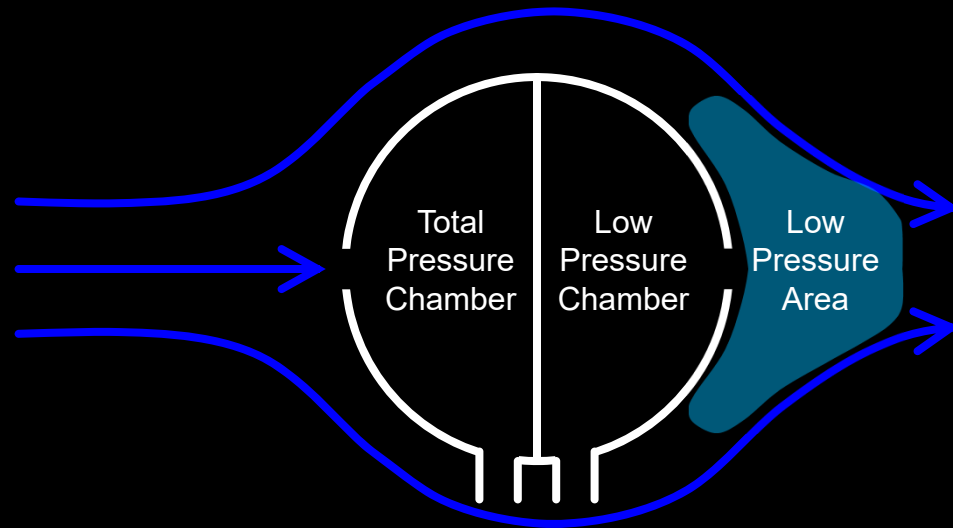
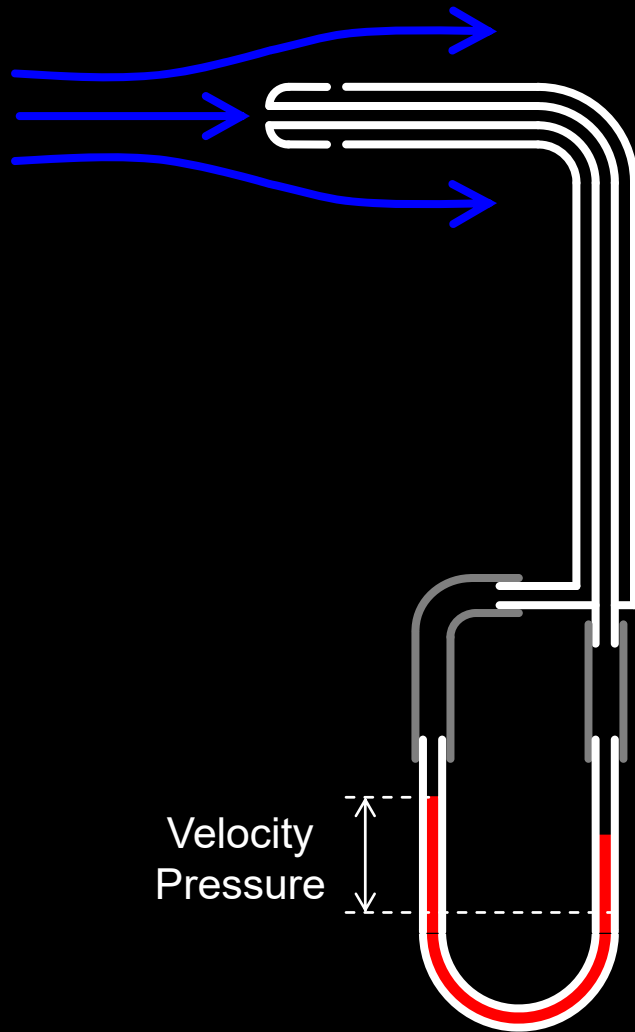
Flow Sensors are Typically a Form of Pitot Tube



Terminal unit flow sensors are typically tubes that are divided down the center, creating two chambers

- One chamber has a port facing into the air flow
- The other has a port facing away from the air flow

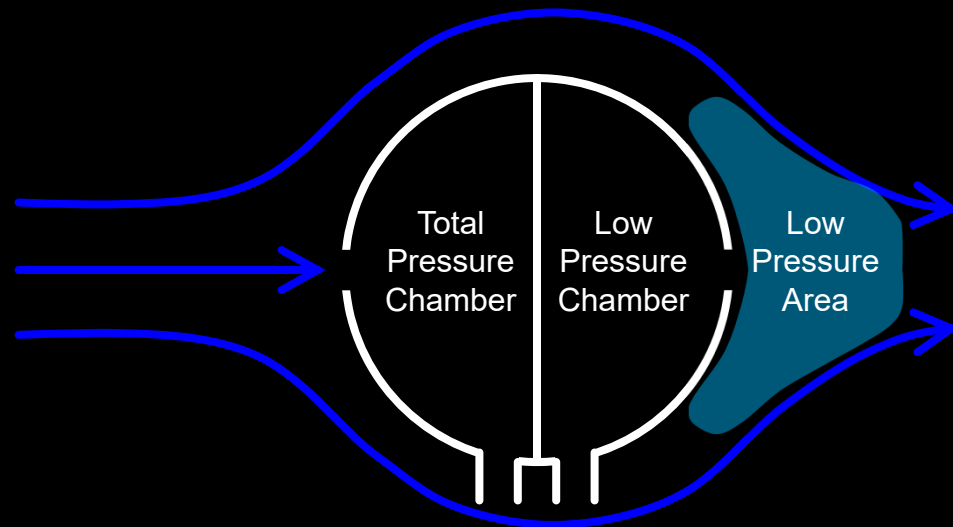
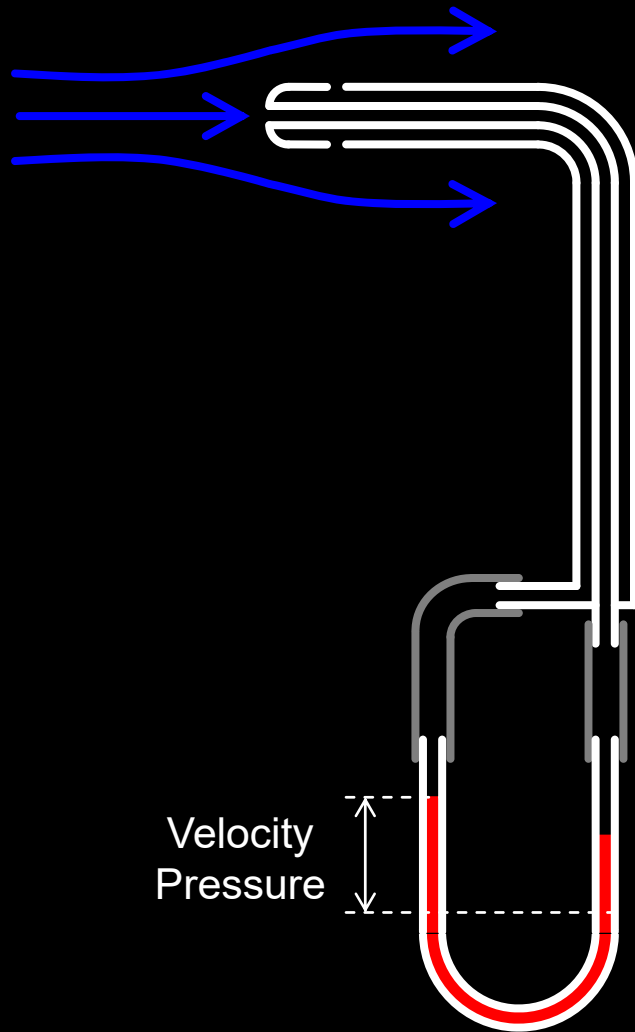
Flow Sensors are Typically a Form of Pitot Tube



The chamber facing the air flow sees total pressure

The chamber facing away from the air flow sees a **low pressure area** in the wake of the flow around the tube

Flow Sensors are Typically a Form of Pitot Tube



The difference between the two pressures is an “amplified velocity” pressure signal

The “amplification” allows the VAV box controller to work at lower flows than would be possible if actual velocity pressure were sensed

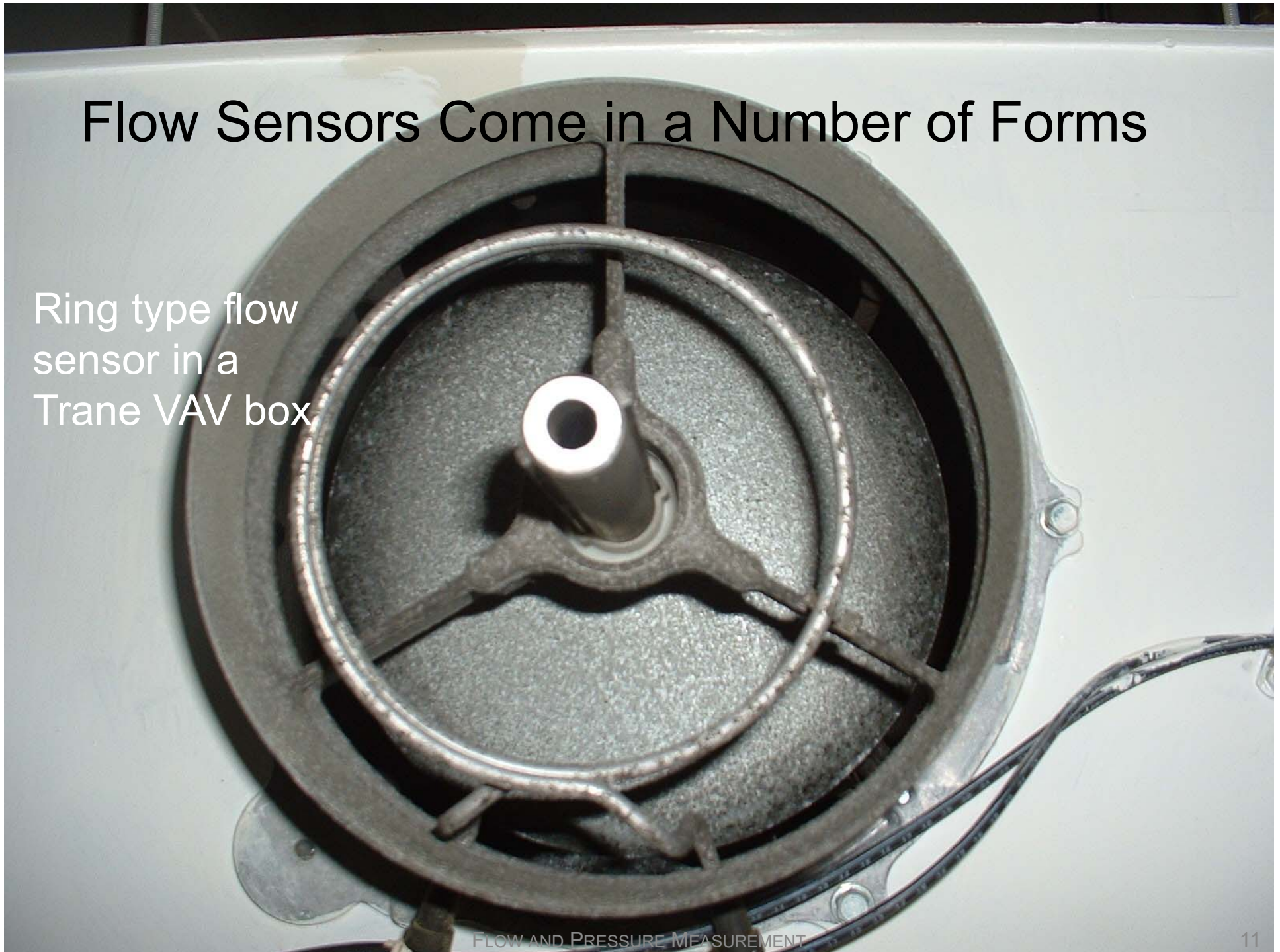
Flow Sensors Come in a Number of Forms

Titus Double Duct Box
with cross type flow
sensor



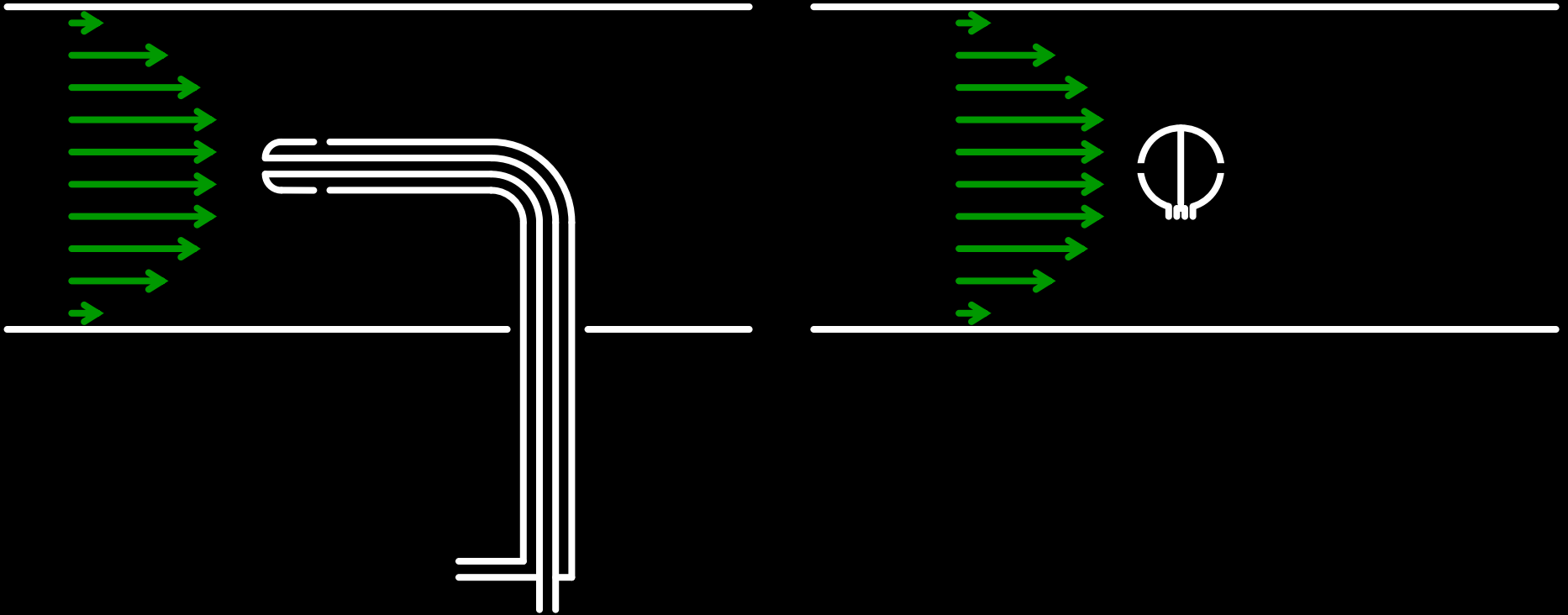
Flow Sensors Come in a Number of Forms

Ring type flow
sensor in a
Trane VAV box

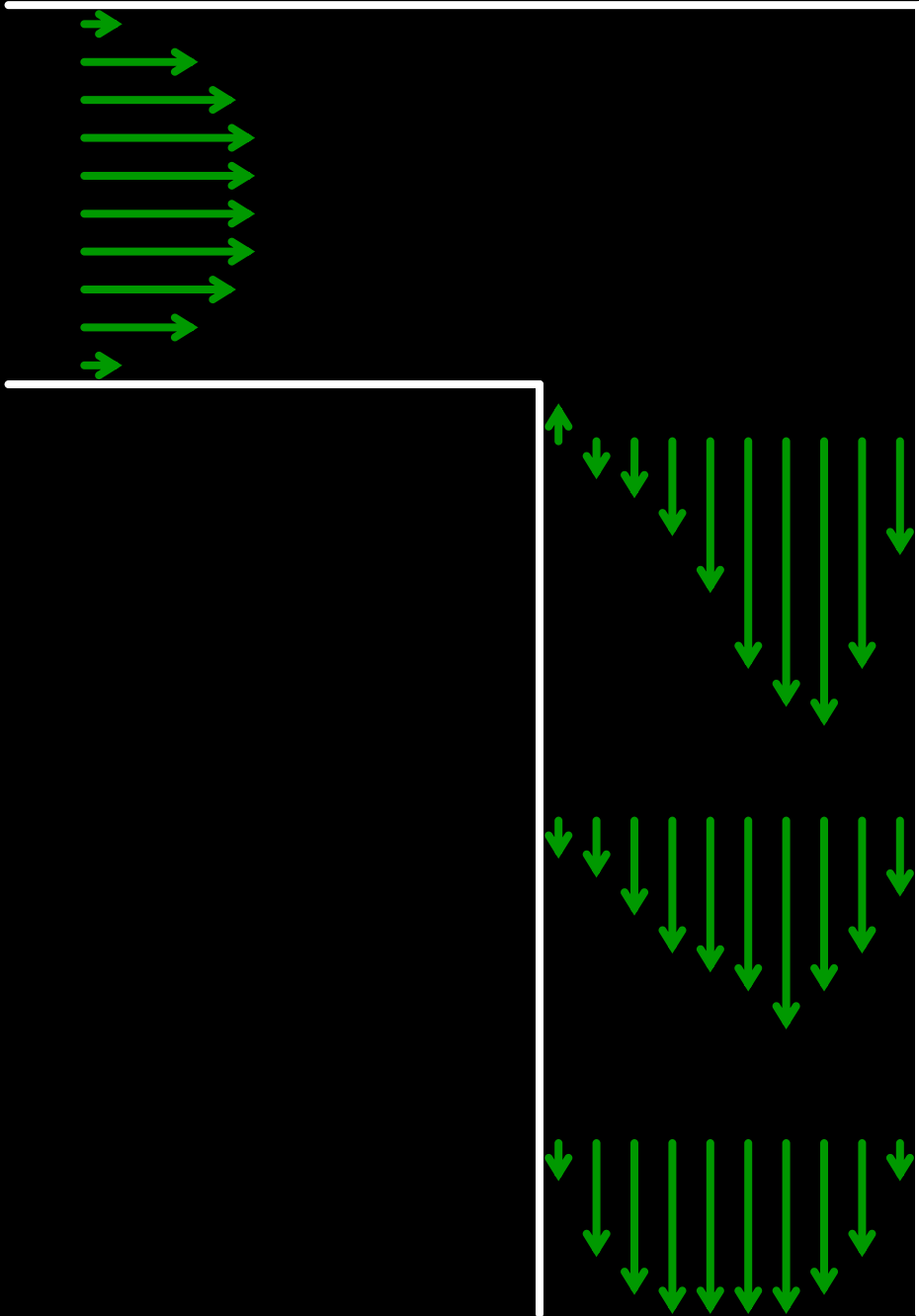


The Inlet Duct Size Is Usually Not the Duct Run Size for the Terminal Unit

- Based on generating a measurable DP at minimum flow
- May result in a very high static loss at maximum flow if used as the duct run size



Pitot tubes and VAV flow sensors rely on a uniform velocity profile for accurate measurements



- Turns and other obstructions distort the flow profile
- Interactions between the air and the duct wall will eventually restore the uniform flow profile
- Generally takes 5-10 equivalent duct diameters of distance



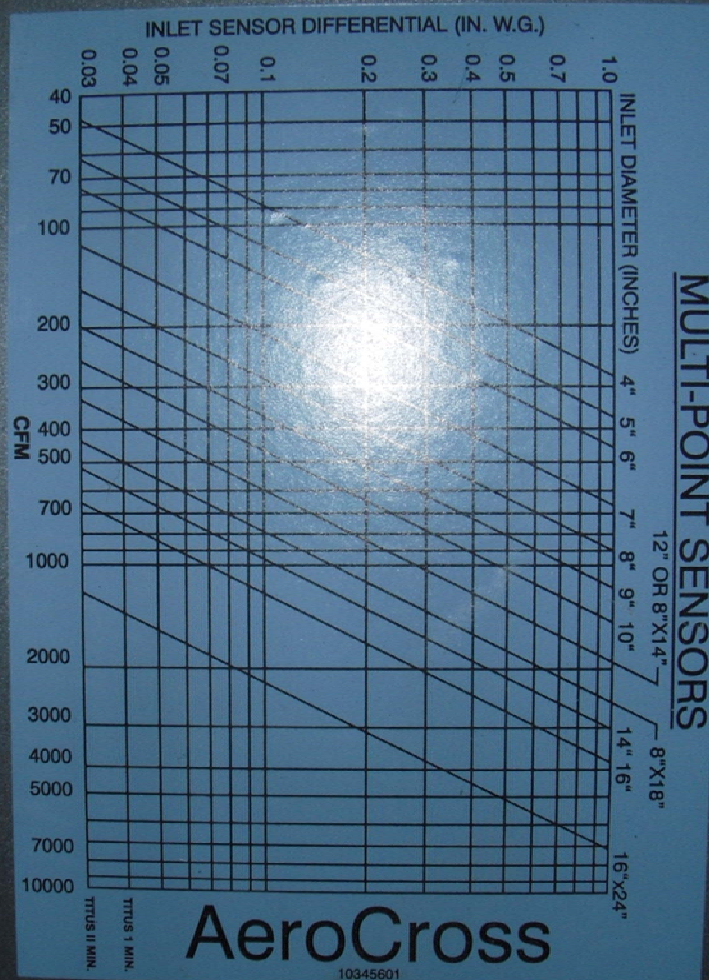
Typical Terminal Unit Inlet Duct

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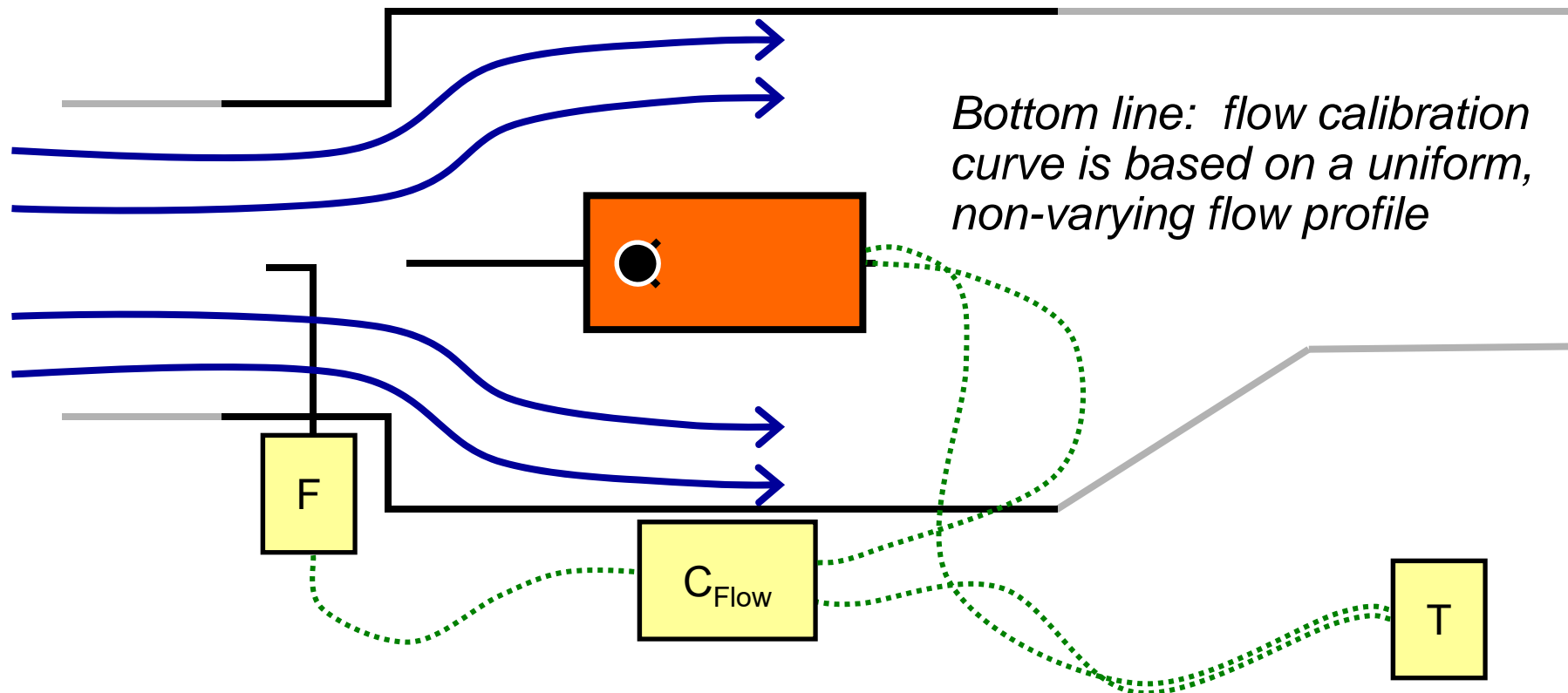


Typical Terminal Unit Flow Calibration Chart

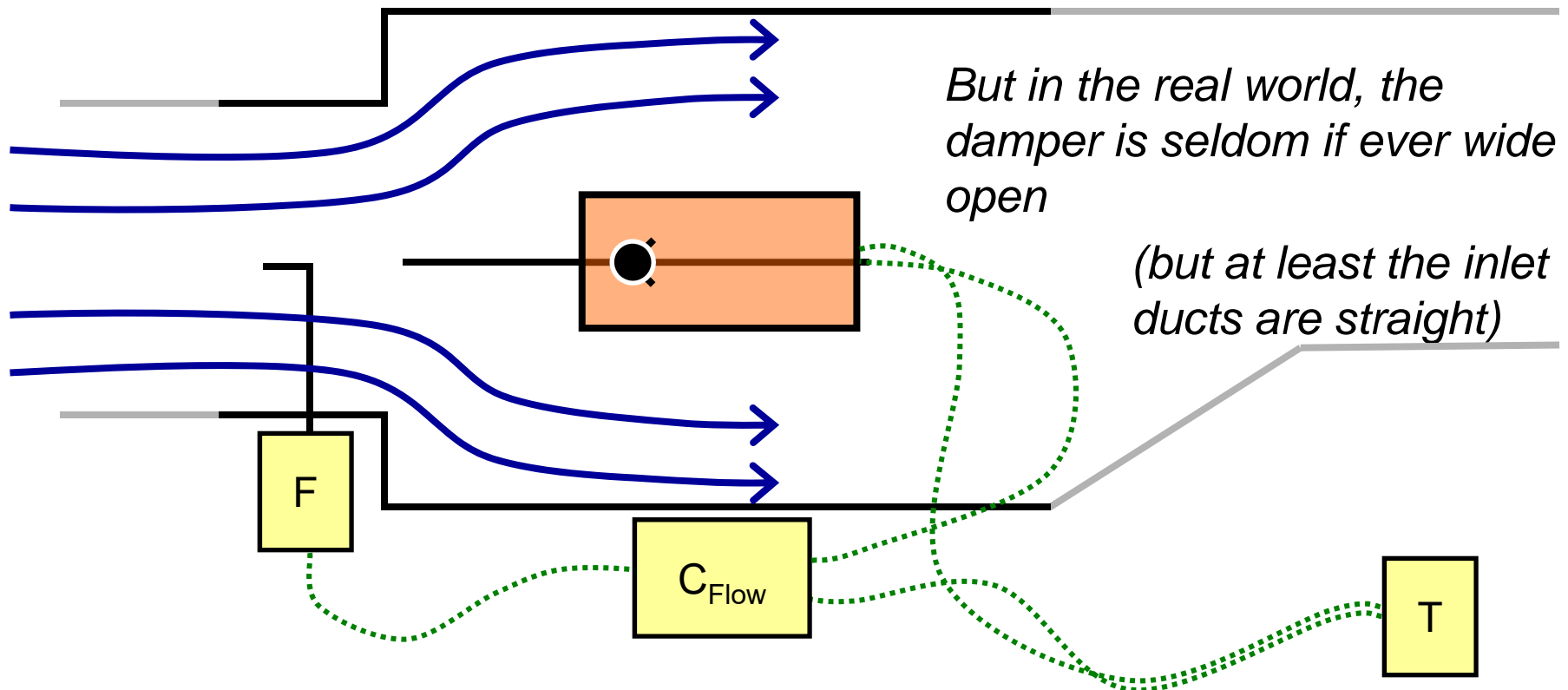
Typical Terminal Unit Flow Calibration Chart



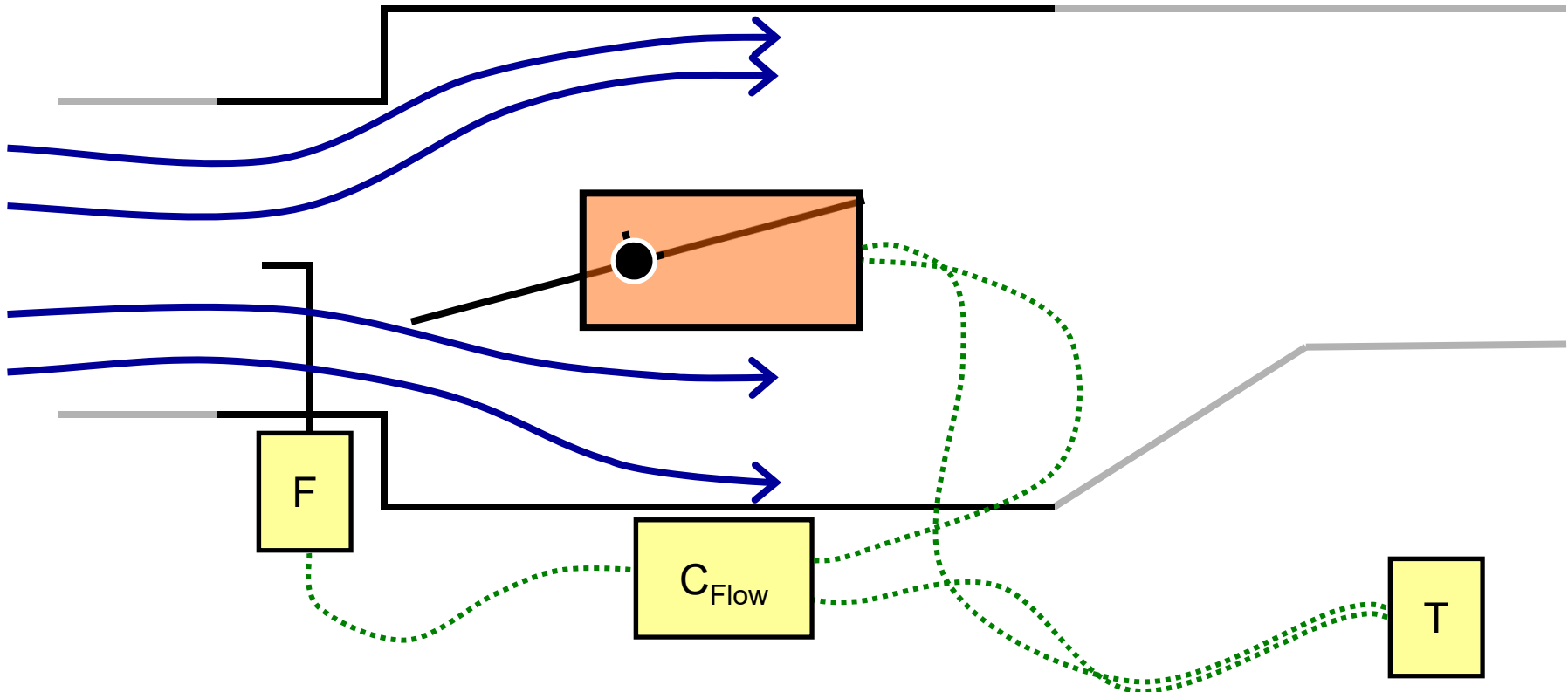




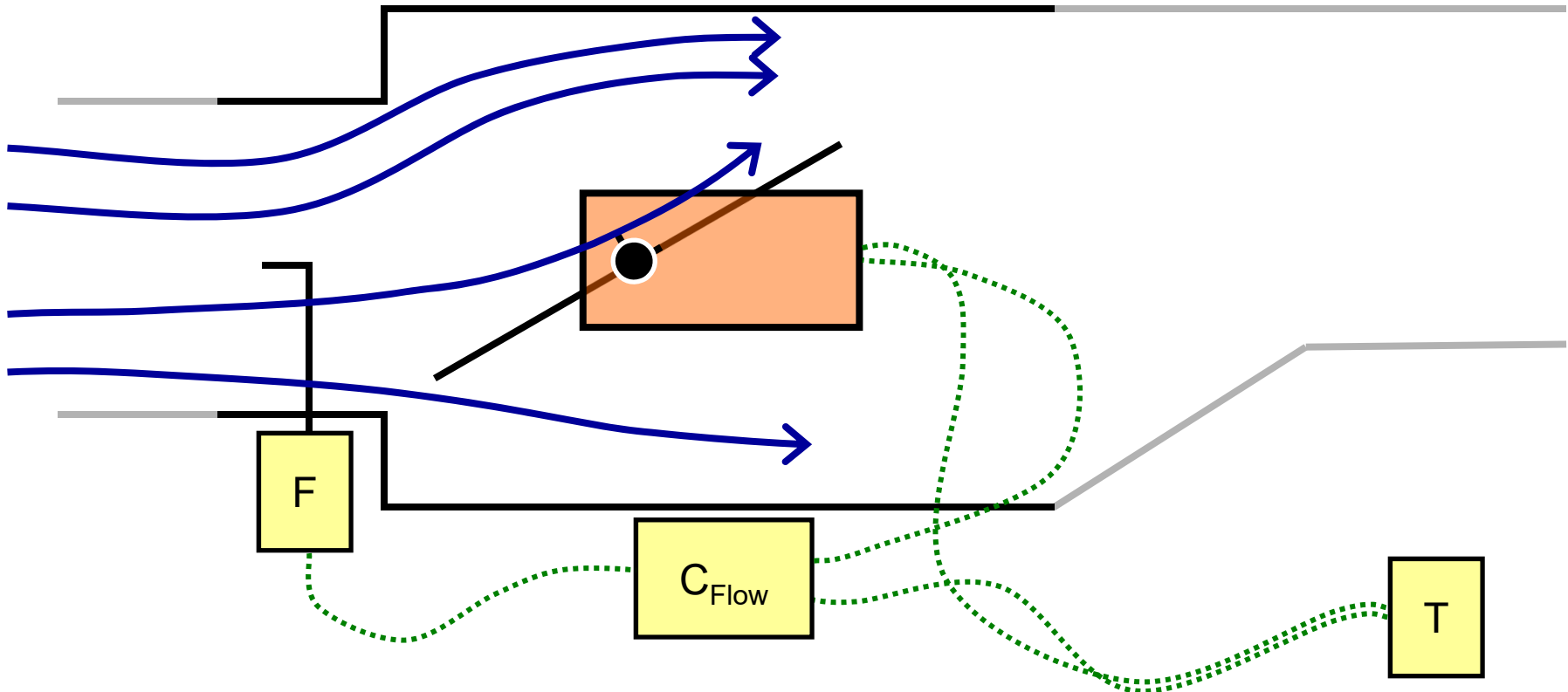
Flow sensors calibration curves established by factory test
 Damper held fully open for the entire flow range
 Flow varied by varying fan speed on the fan in the test rig



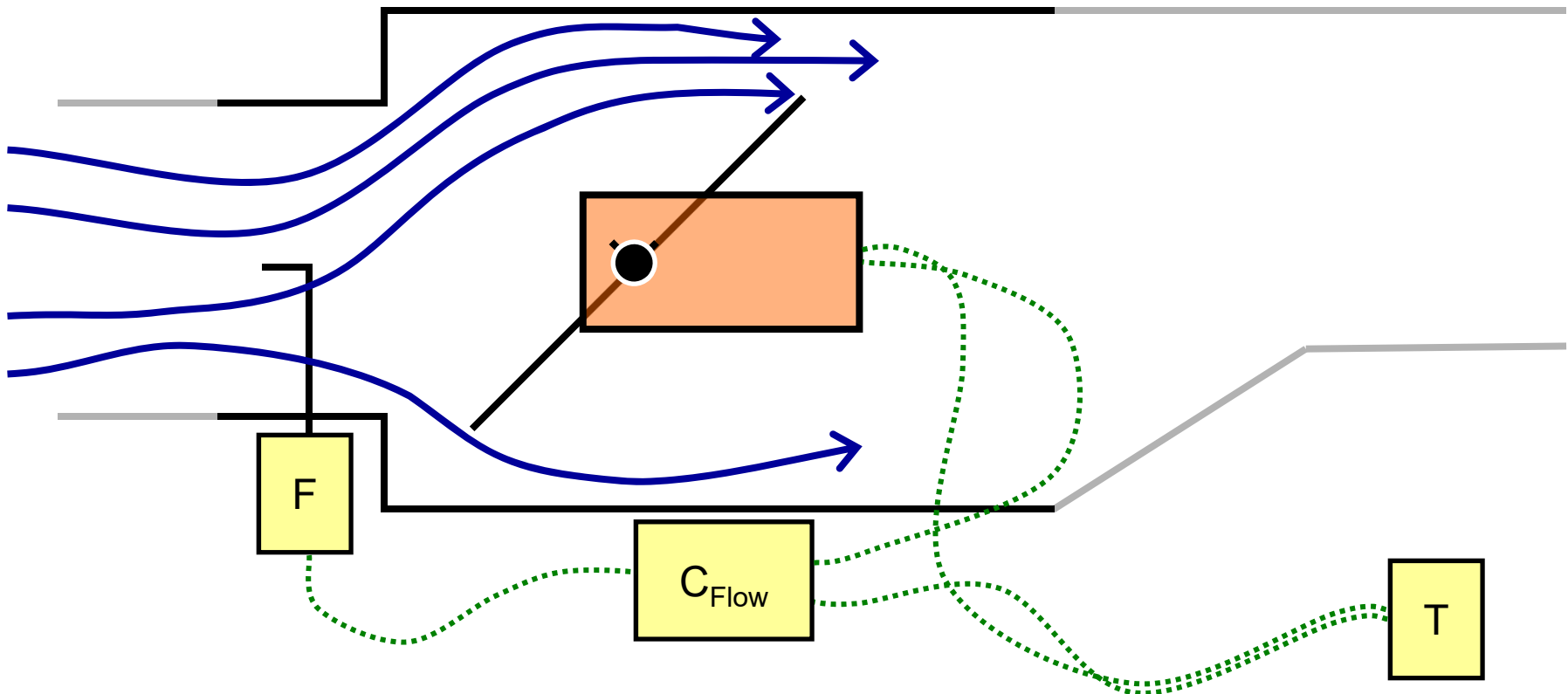
In the real world, with a good inlet condition and a wide open damper, things tend to match up pretty well



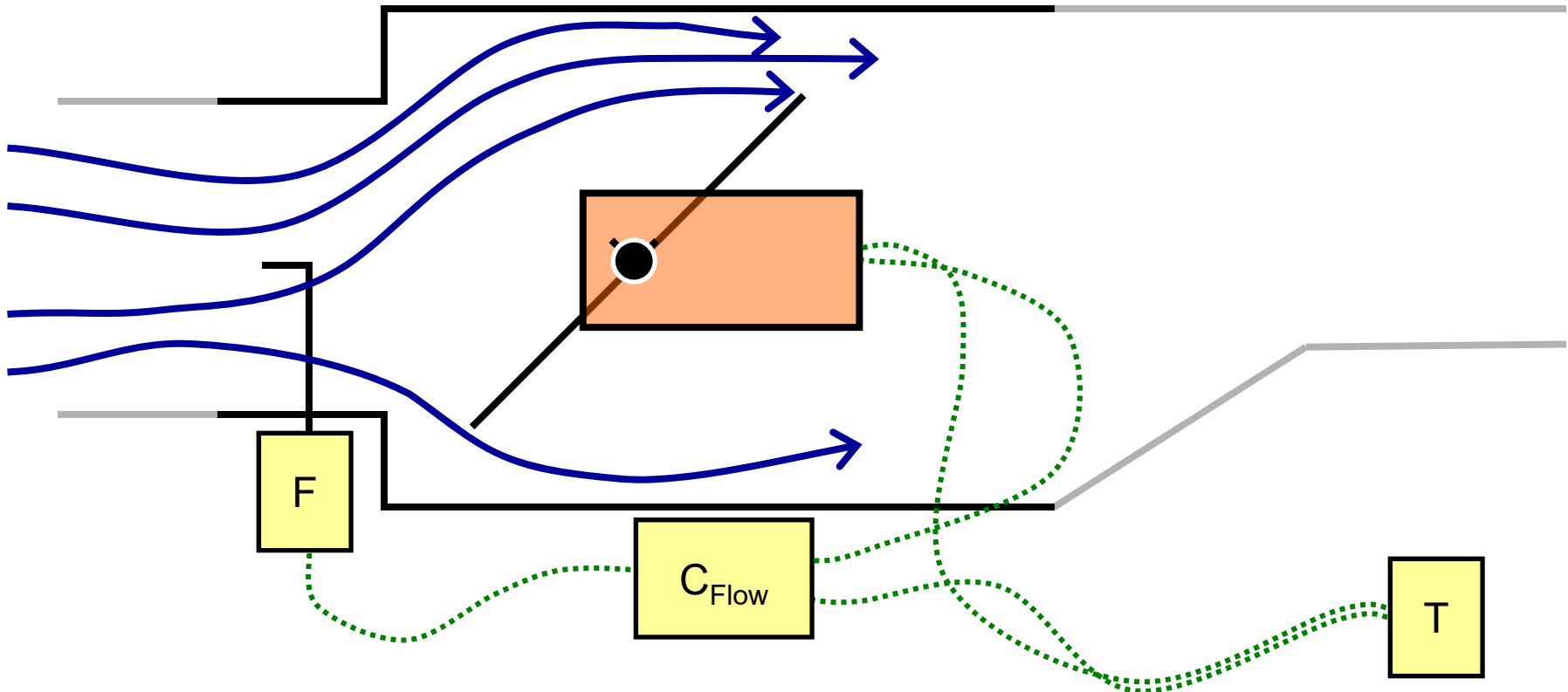
As the terminal unit damper begins to throttle the flow profile upstream of it begins to distort because the air is directed towards the sides of the box and accelerated by the closing damper



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Calibrations based on at least two data points representative of the actual extreme operating conditions of the terminal unit will generally provide better results vs. a one point calibration

Field Data from the “Show Me” State

Building Control System Data

Set point 1,800 cfm

Indicated Flow 1,835 cfm
(102% of set point)

Set point 700 cfm

Indicated flow 717 cfm
(102% of set point)

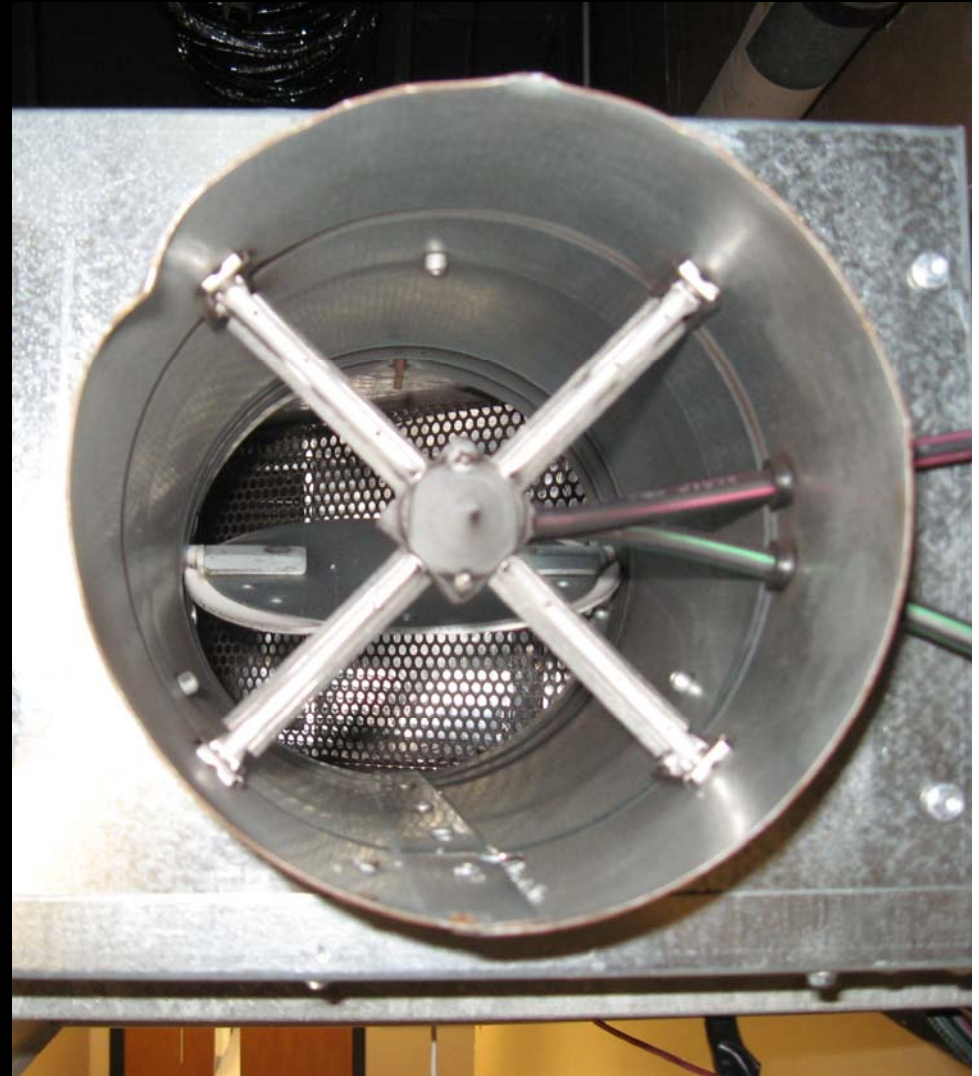
Field Test Data (Traverse basis)

Set point 1,800 cfm

Traversed flow 1,962 cfm
(107% of indicated)

Set point 700 cfm

Traversed flow 1,125 cfm
(157% of indicated)



Field Data from the “Show Me” State

Read the paper and the presentation from NCBC 2013 at <http://tinyurl.com/RonNCBC2013Presentation> and <http://tinyurl.com/RonNCBC2013Paper>

Bottom Lines

1. Accurate flow measurement is crucial to VAV system operation
2. Accurately measuring flow is not as easy as you might think