Not Just a Lot of Hot Air!

In-line calibrating an Annubar® Primary Flow Element in unconventional ductwork or plumbing.

Short Course: 6A-4890
Photography and audio/video recording is not permitted in any sessions or in the exhibition areas without press credentials or written permission from the Emerson Exchange Board of Directors. Inquiries should be directed to:

EmersonExchange@Emerson.com

Thank you.
Presenters

- Dave Winters
- Nate Kenyon
Dave Winters: Bio

- Field Service Engineer
- Based out of Rosemount DP Flow in Boulder, CO
- 35 years of service to Rosemount DP Flow
- Experience
  - Drafting
  - Design
  - Field Service: Experiences include flowmeter installations, start-ups, and in-line calibration
Nate Kenyon: Bio

- Product Development Engineer
- Also based out of Rosemount DP Flow in Boulder, CO
- Experience:
  - Skid design
  - Antifreeze/coolant processing plant
  - Flowmeter configuration management
  - Rosemount DP Flow projects outside standard product offering
In-Line Calibration - Introduction

- Focusing on air flow:
  - You will learn how an Annubar® Averaging Pitot Tube works.
  - You will learn how an S-Type (Stauscheibe) Pitot Tube works.
  - You will learn how to perform an in-line calibration.
  - You will learn how to obtain an accurate reading from an Annubar® APT installed in less than ideal conditions.
In-Line Calibration - Introduction

- We may inadvertently use the following terms interchangeably:

<table>
<thead>
<tr>
<th>In-Line Calibration</th>
<th>Flow Coefficient</th>
<th>Annubar® Primary Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitot Traverse</td>
<td>K-Factor</td>
<td>485</td>
</tr>
<tr>
<td>Flow Test</td>
<td>Blockage Coefficient</td>
<td>Annubar® APT (Averaging Pitot Tube)</td>
</tr>
</tbody>
</table>
Annubar® Primary Element Basics

3051SMV Transmitter w/ Pressure & Temperature Compensation

Direct Mount Transmitter Option Shown

RTD Connection Housing

Mounting Hardware

Annubar® Primary Element

High Pressure Side

Low Pressure Side

Duct Size & Area

Flow

Optional Opposite Side Support
Annubar® Primary Element Basics

- The Annubar® primary element creates a blockage in the process piping (Model 485 is shown).
- Process fluid accelerates to fit the same amount of fluid flow through the smaller area.
- Since energy must be conserved the process pressure decreases as velocity increases.
- The transmitter measures the difference in pressure and calculates flow rate.
Any Questions?
### Dream Conditions
- 8 upstream and 4 downstream diameters of straight pipe (or more)
- No valves, elbows, reducers, holes, expanders, etc. in front of measurement point
- Annubar® APT installed perpendicular to pipe axis within 3°
- Smooth wall pipe
- Fully developed flow profile
- No moisture, particulate or condensate
- Measured pipe ID (used for calculation)
## In-Line Calibration - Introduction

<table>
<thead>
<tr>
<th>Upstream/Downstream Condition</th>
<th>Recommended ‘A’</th>
<th>Recommended ‘B’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8D in plane 10D out of plane</td>
<td>4D</td>
</tr>
<tr>
<td></td>
<td>11D in plane 16D out of plane</td>
<td>4D</td>
</tr>
<tr>
<td></td>
<td>23D in plane 26D out of plane</td>
<td>4D</td>
</tr>
<tr>
<td></td>
<td>30D in plane 30D out of plane</td>
<td>4D</td>
</tr>
<tr>
<td></td>
<td>12D in plane 12D out of plane</td>
<td>4D</td>
</tr>
</tbody>
</table>

Table taken from the 485 QIG (Quick Installation Guide)
Why do you need an In-Line Calibration?

- Annubar® APT is installed in less than ideal conditions
  - Lack of straight run
  - Odd-shaped or large ducting
  - Non-standard mounting
  - Fan or dampers in close proximity
  - ‘Manifold’ of primary elements
  - Temperature gradient in flow
- Flow reading is not representative of actual flow
In-Line Calibration

- Introduction: An in-line flow calibration is used to adjust the K-Factor (or flow coefficient) of the Annubar® APT so that the DP reading from the bar matches the actual, non-standard flow through the pipe or duct.

- First, we determine the actual flow through the pipe.
- Then we adjust the K-Factor that has been programmed into the transmitter (or customer’s control system) to account for the non-standard flow profile.
In-Line Calibration

- **Where did it come from?**
  - The actual Pitot Traverse is done following the guidelines of Code of Federal Regulations (CFR) number 40, part 60

- **Where does the Pitot Traverse take place?**
  - At or near the location of an existing Annubar® primary element, the Pitot tube is used to determine the actual flow rate, compensating for any special conditions.

![Preferred Flow Testing Location](image-url)
In-Line Calibration

Any Questions?
What are the steps to an In-Line Calibration?

- Split the pipe or duct into numerous equal area segments near the Annubar® APT
- Use an S-type Pitot tube to measure the DP (flow) through each segment
- Adjust the Annubar® APT flow coefficient to make the flow or DP reading match the total flow determined from the Pitot Tube measurements
Divide the duct interior into numerous equal area segments.

Section A-A from previous slide.
In-Line Calibration - Introduction

Add access ports for the S-type Pitot Tube

Section A-A from previous slide
Insert the S-type Pitot Tube into the access port
In-Line Calibration - Introduction

Record DP readings at each segment of the pipe from the Pitot Tube

Section A-A from previous slide
In-Line Calibration - Introduction

- Use area, temperature, pressure, blockage and recorded DP from the S-type Pitot Tube in each segment to determine actual flow
- Compare to Annubar® APT’s reading
- Adjust the primary element’s flow coefficient to match

**Diagram:**
- Pitot Tube DP Readings
- Temperature & Pressure
- Annubar APT DP Readings
- Actual Duct Flow Rate
- Annubar APT Flow Rate Reading
- Annubar APT Flow Coefficient Adjustment
In-Line Calibration - Introduction

- Pipe or Round Duct

- Pitot Tube Taps

- Equal area segments

- DP measurement points
In-Line Calibration - Introduction
Prior to In-Line Calibration

- Obtain customer information
  - Fan curve
  - Line/Duct size and wall thickness
  - Mounting information
  - Fluid information
    - Type of fluid: Air, natural gas, steam, etc.
    - Temperature of fluid
    - Process pressure on fluid

- Enter this information into a quoting and calculation program called “Instrumentation Toolkit” to predict the DPs and K-factor
Prior to In-Line Calibration

- **Instrument Toolkit Calculation Datasheet**
  - Customer inputs
  - Calculated outputs
  - Warnings, structural failure information
Prior to In-Line Calibration

- Sizing the Annubar® Primary Element in Instrumentation Toolkit:

---

**ROSEMOUNT INC.**

**485 - Annubar Primary Element**

**CALCULATION DATA SHEET**

<table>
<thead>
<tr>
<th>GENERAL DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer:            Various</td>
</tr>
<tr>
<td>Project:             Nate Kenyon and Dave Winters</td>
</tr>
<tr>
<td>S. O. No:</td>
</tr>
<tr>
<td>P. O. No:</td>
</tr>
<tr>
<td>Calc. Date:         August 20, 2013</td>
</tr>
<tr>
<td>Model No:           485G080ZSHPS1T100R7RL / 3051SFA1G080ZSHPS1T100T31DA1A5RLQ4M5</td>
</tr>
<tr>
<td>Tag No:             EMEX-DEM-O-AIR-430F</td>
</tr>
</tbody>
</table>

**PRODUCT DESCRIPTION**

- **Product Type:** 485 Duct Mount
- **Sensor Size:** Sensor Size 1
- **Wetted Material:** 316 Stainless Steel
- **Transmitter Conn.:** Remote-Mount NPT Connections
- **Mounting Conn. Material:** 316 Stainless Steel
- **Mounting Type:** Duct Flange
- **Instrument Valve:**
  - **Valve Material:**
  - **Line Size:** 8.25" X 4.75"
  - **Pipe Sch.:**
  - **Pipe Orientation:** Horizontal
Prior to In-Line Calibration

- Sizing the Annubar® Primary Element in Instrumentation Toolkit:

We field verify duct dimensions prior to in-line calibration

From Customer’s Original Order

<table>
<thead>
<tr>
<th>INPUT DATA</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Type:</td>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid Name:</td>
<td>Air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe I.D. (Span):</td>
<td>8.250 inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body I.D.:</td>
<td>8.250 inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duct Width:</td>
<td>4.750 inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at Flow:</td>
<td>0.200 inH2O @ 50°F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature at Flow</td>
<td>430.00 °F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute Viscosity</td>
<td>0.02660 cP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isentropic Exponent</td>
<td>1.390</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressibility at Flow</td>
<td>1.0002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density at Flow:</td>
<td>0.0446 lb/ft³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum:</td>
<td>400.00 ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal:</td>
<td>600.00 ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum:</td>
<td>800.00 ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Scale:</td>
<td>800.00 ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prior to In-Line Calibration

- Sizing the Annubar® Primary Element in Instrumentation Toolkit:

  Customer’s original flow coefficient from initial Toolkit sizing calculation. This is the flow coefficient in the transmitter “out of the box”.

<table>
<thead>
<tr>
<th>CALCULATED DATA</th>
<th>DP at Min Flow: 0.258 inH2O@68F</th>
<th>Flow Coefficient:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP at Normal Flow: 0.581 inH2O@68F</td>
<td>Rod Reynolds Number (Minimum): 3005</td>
</tr>
<tr>
<td></td>
<td>DP at Max Flow: 1.034 inH2O@68F</td>
<td>Rod Reynolds Number (Normal): 4507</td>
</tr>
<tr>
<td></td>
<td>DP at Full Scale Flow: 1.034 inH2O@68F</td>
<td>Gas Expansion Factor: 0.9999</td>
</tr>
<tr>
<td>Resonant Frequency:</td>
<td>404 Hz</td>
<td>Permanent Pressure Loss:</td>
</tr>
<tr>
<td>Wake Frequency:</td>
<td>149 Hz</td>
<td>at Normal Flow: 0.07 inH2O@68F</td>
</tr>
<tr>
<td>Blockage:</td>
<td>0.12</td>
<td>at Maximum Flow: 0.13 inH2O@68F</td>
</tr>
<tr>
<td></td>
<td>Velocity at Max Flow: 48.65 ft/sec</td>
<td></td>
</tr>
</tbody>
</table>

| GUIDELINES | Primary Element Min Limit: 885.37 ACFM | Recommended Min Rod Reynolds Number: 6500 |
|           | Structural Limit (Flow): 13984.11 ACFM | Recommended Min DP: 0.100 inH2O@68F |
|           | Structural Limit (DP): 315.8 inH2O@68F | Max. Allow. Temp.: 850 F |
| Max. Allow. Pressure@Temp.: | 27818.1 inH2O@80F-3 | 430 F |
| Design Pressure/Temperature: | 0.20 inH2O@60F-3 | 430.00 F |
Any Questions?
Annubar® APT Installation: Real Condition 1

Annubar® installed directly after Fan in Windbox Expansion/Transition Duct
Annubar® APT Installation: Real Condition 2

Hot Air Ducting

(2) FORMER “VENTURI” SECTION
63” WIDE X 24” TALL
(5’-3” X 2’-0”)

FLOW TO BOILER

FLOW

FLOW

“FORGOTTEN” 12” TALL
“RESTRICTOR PLATE”

600°F AIR
FLOW FROM
F.D. FAN

NORTH DUCT

SOUTH DUCT
Annubar® APT Installation: Real Condition 2

General Arrangement

Venturi Section
Retro-Fit Project (1)

DSI Artwork No. 81-49123-008
Annubar® APT Installation: Real Condition 4

- Downstream of dampers and elbows
- Upstream of conditioners and elbow
- Unknown velocity profile
Annubar® APT Installation: Real Condition 5
 Conditions:
  - Upstream dynamic dampers
  - Structural supports both up and down
  - Measurement in reducing accelerator
  - Downstream turning vanes
Any Questions?
Are you sure?
Demonstration Unit

- 3-Pitot Tube Test Ports
- Expanding Width Duct
- Decreasing Height Duct
- Annubar®
- 3051S D.P. Transmitter For Pitot Tube
- 3051SMV D.P. Transmitter For Annubar® APT
- Viewing Windows
- Annubar® & Pitot RTDs
- Mitered Elbow
- Actual or Adjustable Temperature (0-1000°F) Continuous for both RTDs
- Inside:
  - Diverter Plate
  - Structural Support
  - Turning Vane
- Fan with Speed Control
Demonstration Unit

Top View:

- Expanding Duct Width
- Annubar® Primary Element
- Pitot Test Ports
Demonstration Unit

Side View:

- Mitered Elbow
- Turning Vane
- Decrease in Duct Height
Demonstration Unit

RTDs

Diverter Plate
Demonstration Unit

Looking Inside:

Duct Area at Annubar® 485 = Width at Annubar® 485 Center Line x Height of Duct

Duct Width at Annubar® 485

Duct Height
Demonstration Unit

Looking Inside:

Duct Area at Pitot Test Ports = Width at Test Port Center Line x Height of Duct

Structural Support Creates Additional Disturbance

Duct Height

Duct Width at Test Ports

Test Port Center Line
Any Questions?
Live In-Line Calibration

Traverse Set-Up:

- Duct dimensions at Annubar® Primary Element are verified to match the original customer order:
  - Annubar® APT is a Rosemount Model 485/T1 size installed in a 8.25”(209.6mm) Wide x 4.75”(120.6mm) Tall Duct
  - Duct area at the Annubar® APT is 39.2in² (25,277.8mm²)

- Duct dimensions at Pitot test ports:
  - Duct size at the Pitot tube test ports is 7.75”(196.8mm) x 4.75”(120.6mm) Tall
  - Duct area at the Pitot tube test ports is 36.8in² (23,748.3mm²)
Live In-Line Calibration

- Traverse Set-Up Continued:
  - For the Pitot traverse the duct area is divided into 15 equal areas
  - The Pitot traverse will take place with the fan speed set at maximum
  - Factory Fan Rating, 747 SCFM
  - Process temperature will be set at 430°F
  - All transmitter calibrations, output and signal loops are verified
### Data Collection Sheet Ready for test

<table>
<thead>
<tr>
<th>Plot</th>
<th>Plot Dim, Parts</th>
<th>Primary 485, 1/2”</th>
<th>Pilot 960, 3-TYPE</th>
<th>Temp.</th>
<th>Press.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apps / Opposite</td>
<td>4/5”</td>
<td>INCHES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1/4” / 1/2”</td>
<td>2.485 / 1/3”</td>
<td>2.385 / 2.385</td>
<td>34.56 / 2.385</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1/4” / 1/2”</td>
<td>2.485 / 1/3”</td>
<td>2.385 / 2.385</td>
<td>3.385 / 3.385</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- 3051 AVM Output to SA-DUCT Set @ 0 - 4” W.G.
- 4” EQUIVALENT FINE INSIDE DIAMETER: 2.064” INCHES
- AREA @ MAIN BAR 39.2” INCHES
- DUCT INSIDE DIMENSIONS @ PITOT: 2.75” x 4.75” (36.854” INCHES)
Live In-Line Calibration

- **Almost Ready**
  - Now, plant operations will hold fan speed/damper to desired flow rate
  - Avoid discharge end of duct for safety reasons
  - For this demonstration some assumptions or simulations may be made such as barometric pressure, process temperature, etc.
  - If we start running out of time we will use pre-prepared data
  - **ANY QUESTIONS?**
  - Don’t throw objects in the fan!
  - Finally! . . . Let’s turn the fan on and record some numbers!

“CLICK...”

“WIRRRRR....”
## Live In-Line Calibration

### Completed Traverse in Axis 1

<table>
<thead>
<tr>
<th>No.</th>
<th>OPPOSITE CALL</th>
<th>INCHES</th>
<th>TEMP °F</th>
<th>PRESS. INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.56/1/2”</td>
<td>.56</td>
<td>430°</td>
<td>.875</td>
</tr>
<tr>
<td>2</td>
<td>1.43/1/2”</td>
<td>.56</td>
<td>430°</td>
<td>.875</td>
</tr>
<tr>
<td>3</td>
<td>2.38/2/3”</td>
<td>.56</td>
<td>430°</td>
<td>.875</td>
</tr>
<tr>
<td>4</td>
<td>3.38/3/3”</td>
<td>.56</td>
<td>430°</td>
<td>.875</td>
</tr>
<tr>
<td>5</td>
<td>4.28/4”</td>
<td>.56</td>
<td>430°</td>
<td>.875</td>
</tr>
</tbody>
</table>

**Axis 1**

**Notes:**
- SMV output to SA duct set @ 0”.
- Equivalent pipe inside diameter: 9.66” dia.
- Duct inside dimensions @ Pitot: 7.75” x 4.75” (36.88 sq. in.)
### Completed Traverse in Axis 2

**DIETERICH STANDARD - PITOT TRAVERSE DATA JOB**

- **Customer:** EMERSON EXCHANGE, 2013
- **Date:** OCT 27 2013
- **Tech:** DS Tech

**Description:**
- **In-Line Calibration of 8.25" model:** Tag No: EE-060-31
- **Axis:** Axis 2

<table>
<thead>
<tr>
<th>Pts</th>
<th>Axis</th>
<th>Time (Start/Finish)</th>
<th>P/ID Span</th>
<th>Primary Span</th>
<th>Pitot Type</th>
<th>K =</th>
<th>Barometer</th>
<th>Maximum Flow (MW/Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/8&quot;</td>
<td>40°</td>
<td>496°</td>
<td>0.075</td>
<td></td>
<td></td>
<td></td>
<td>148°F</td>
</tr>
<tr>
<td>2</td>
<td>3/4&quot;</td>
<td>.56</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>148°F</td>
</tr>
<tr>
<td>3</td>
<td>3/4&quot;</td>
<td>.56</td>
<td>.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>148°F</td>
</tr>
<tr>
<td>4</td>
<td>3/4&quot;</td>
<td>.56</td>
<td>.82</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>148°F</td>
</tr>
<tr>
<td>5</td>
<td>3/4&quot;</td>
<td>.56</td>
<td>.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>148°F</td>
</tr>
</tbody>
</table>

**Notes:**
- Job No: SWN OUTP 75 (6" Duct Work) @ 0-4°F. C.
- Equivalent pipe inside diameter: 7.064 Dia.
- Duct inside dimensions @ Pitot: 7.75" x 4.75" (36.8 sq. ft.)
### Live In-Line Calibration

- **Completed Traverse in Axis 3**

---

**DIETERICH STANDARD - PITOT TRAVERSE DATA**

**Customer:** Emerson EXCHANGE 2013  
**Date:** OCT 2012  
**Tech:** DS Tech EC  
**Site:** SOMEWHERE, TX  

**Description:** IN-LINE CALIBRATION OF B.25 MODEL  
**Tag No:** 5ENDTX-31  
**Location:** ANGOLA, IND  
**K:** 0.5

<table>
<thead>
<tr>
<th>No. of Axes</th>
<th>Pipe/Duct Dimensions</th>
<th>Time (Start/Finish)</th>
<th>Ref. Flow Rate/Load</th>
<th>Test Port/Axis</th>
<th>Test No.</th>
<th>Averaging %</th>
<th>O2</th>
<th>CO2</th>
<th>AIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4.28&quot;/4.94&quot;</td>
<td>1.58&quot;/1.92&quot;</td>
<td>2.28&quot;/3.06&quot;</td>
<td>12/13</td>
<td>3,213</td>
<td>3,195</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- 305 PSI AVG.
- STANDARD SET @ 0.483" NPT.
- EQUIVALENT PIPE INSIDE DIAMETER: 7.42" O.D.
- ANGULAR EFFECT: 39.25" O.R.
- DUCT INSIDE DIMENSIONS @ PITOT: 4.75"x4.75" (36.044 A)

---
Live In-Line Calibration

- Acquisition of “raw-test-data” is now complete

- At this point, plant operations would be notified to adjust fan to another speed or return to normal operations.

- Raw data will be entered in to the calibration spreadsheet

- The calibration spreadsheet will calculate new “K-Factor”
Live In-Line Calibration

Original K-Factor (From Toolkit): 0.5567
New K-Factor (From Pitot Traverse): 0.6727
% Change in K-Factor: 21%
Flow Profile

- Different fan settings, damper settings, and all around flow conditions could result in different associated K-Factors.

- Full Scale Flow: K = 0.672
- Normal Flow: K = 0.646
- Minimum Flow: K = 0.593
Almost Finished!

- Need to reconfigure the transmitter
  - Using Engineering Assistant (E.A.) the new Corrected Flow coefficient “K-Factor” will be entered in the 3051SMV multi-variable transmitter
  
  OR
  
  • Using a Field Communicator (like a 475 Handheld) the output signal (HART, 4-20mA, etc.) signal can be reconfigured to match the new Flow Coefficient.

  OR
  
  • If the customers data acquisition system is performing the flow calculation from the transmitter output, the new corrected Flow Coefficient will simply be provided to the customer.
Summary

You have now learned:

- Annubar® primary element basics
- Many of the real Annubar® 485 duct installation challenges
- The process of an in-line flow calibration
- Performing an in-line flow calibration on an Annubar® allows for repeatable and accurate flow measurement in otherwise impossible to measure process situations
Any Questions?
More information on Annubar® Primary Elements and Flowmeters can be found:

- Annubar Flow Handbook
  - [http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00809-0100-1191.pdf](http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00809-0100-1191.pdf)

- Annubar® Flow Test Data Book
  - [http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00821-0100-4809.pdf](http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00821-0100-4809.pdf)
Thank You for Attending!
Enjoy the rest of the conference.