Industrial Flow Meters: When is Accuracy Important

Alden Webinar Series
March 10, 2009

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- Webinar recording

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Agenda

• Introduction
• Flow meter types and when to calibrate
  – Richard Wakeland, Fluidic Techniques
• How calibration and accuracy affect the power industry
  – W. Cary Campbell, Southern Company
• Process industry perspective: a case study on steam delivery
  – Zach Hennig, Air Liquide
• How calibration works
  – Phil Stacy, Alden Lab
Introduction

• Current economic conditions
  – Make calibration of some meters more important than ever
  – Highlight the importance of deciding when not to calibrate

• The importance of industrial flow meters
  – Plant efficiency
  – Plant safety
    • Case in point: Feedwater in nuclear power plants
Example: Nuclear Safety

- Courtesy of Dr. John Bickel, Talisman International
- Secondary side $\Delta T$ calorimetric Power is used to calibrate reactor power
- If feedwater flow instruments become inaccurate over time, the reactor power determination will also be inaccurate
  - Some plants have unwittingly operated at power levels above what the license allows
  - Large allowances can be made for flow inaccuracies
    - Corresponds to lost revenue for the plant
- Reference:
- License Event Report (LER) Accession #8908310139, 1988
Introduction to Alden

- Flow Meter Calibration
  - All meter types: ¼” to 48” pipe size
  - Flows to 35,000 gpm
- Plant Hydraulics
  - ECCS sump strainer testing
  - Tank draw-down testing
- Drinking water and wastewater systems
- Cooling water intake evaluation
  - Hydraulics
  - Fish protection
- River mechanics studies
- Stormwater sediment removal testing
- Laboratory and pilot scale environmental studies
- Fish protection technology design
  - Upstream and downstream passage
- Air pollution control system optimization
- Sediment transport analysis
Flow Measurement

1. Background
2. Flow Meter Types
3. When to Calibrate

By Richard Wakeland, Chief Engineer
Flow Measurement Applications

• Power Plants
• Refinery
• Chemical
• Gas Production and Transmission
• Others
Flowmeter Considerations

- Line (Pipe) Size
- Type of Fluid
- Fluid State – Gas, Liquid, Vapor
- Meter Range
- Desired Accuracy / Repeatability
- Piping Configuration
- Costs – initial, installation, and operating
Flow Meter Types

1. Differential Producers

2. Ultrasonic

3. Insertion Pitot Devices

4. Coriolis

5. Others
Ultrasonic Flow Meter
Insertion Pitot Device
Verabar by VERIS
Differential Producing
Primary Flow Elements

1. The largest market share for Nominal Pipe Sizes, NPS, 3” and larger

2. A well established performance record
   - Proven Technology – Long history of usage
   - Simple by design – Durable
   - Wide range of applications
   - Accuracy
   - Economical

3. Differential Producers are typically only being replaced by other technologies because of poor performance in the specific application
Differential Producing
Primary Flow Elements

Orifice Plates

Flow Nozzles

Venturi Flow Meters

Proprietary Devices

High Head Recovery (HHR) Flow Tube

HHR *FlowPak*
Concentric Plate
Orifice Plate installed in Flange Union
AGA Orifice Meter Run
Flow Nozzles & Flow Nozzle Meter Runs
Venturi Flow Meters
High Head Recovery (HHR) Flow Tube
High Head Recovery (HHR) FlowPak
Flow Measurement Standards

- American Society of Mechanical Engineers, ASME
  - MFC Series, Measurement of Fluid Flow
  - PTC Series, Performance Test Codes

- International Organization for Standardization, ISO
  - ISO 5167

- American Gas Association, AGA
  - Report No. 3

- Others
Flow Measurement Standards

• Accuracy Statements
  a) Pipe Size
  b) Reynolds Number
  c) Beta Ratio
  d) Piping Requirements Before and After the Primary Flow Element
In each of the flow measurement standards, the Coefficient of Discharge, or the equation to calculate the Coefficient of Discharge, is stated with an uncertainty and conditions of use.

For example, ASME MFC-3Ma-2007 states that for a Long-Radius Nozzle...

- The coefficient of discharge equation is stated in terms of Pipe Reynolds Number and Beta Ratio
- With an uncertainty of 2.0%
- If the pipe diameter is between 2 and 25 inches, inclusive
- The beta ratio is between 0.2 and 0.8, inclusive
- And the Pipe Reynolds Number is between 10,000 and 10,000,000.
Factors Used to Meet Published Accuracies

1. Use actual dimensions for Pipe and Throat (Bore) Diameters.
   - Most pipe is subject to a 12.5% mill tolerance on the pipe wall thickness.

For example: 12” Sch 40
- Nominal Pipe Internal Diameter (ID): 11.938”
- Nominal Wall Thickness: 0.406”
- Maximum Pipe ID: 12.040”
- Minimum Wall Thickness: 0.355”
Factors Used to Meet Published Accuracies

2. Use actual Flow Rates to calculate the Coefficient of Discharge (C) and Gas Expansion Factor (Y)

3. Use Pressure and Temperature Compensation to determine the Density as system conditions vary

4. Use Corrosion Resistant materials for the primary element throat
Factors Which Improve Published Accuracies

1. Laboratory Flow Calibrate
   a. When less uncertainty is required than stated in Flow Measurement Standards
   b. When used outside the criteria stated in these standards
   c. When the upstream and downstream piping requirements cannot be met
      i. Calibrate the flow meter with the upstream and downstream configuration
HHR FlowPak Flow Calibration with Two Elbows Out of Plane
Factors Which Improve Published Accuracies

2. Use Alignment Pins for Orifice Plates and Flanges
Orifice Plate Alignment with Flange Bolts
Factors Which Improve Published Accuracies

3. Know your Manufacturer

- Design and manufacturing methods may produce better accuracy

- In some cases, different methods of design and manufacture may be implemented for laboratory flow calibrated meters and those which are not flow calibrated parts.
Coefficient of Discharge vs. Pipe Reynolds Number

12" Sch 40 Flow Nozzle Meter Run, FN-1

PIECE REYNOLDS NUMBER *10^6
COEFFICIENT OF DISCHARGE
THEORETICAL VALUE (TV)
TV + 1%
TV - 1%
TV + 0.5%
TV - 0.5%
Tap Set B
Tap Set A

Manufactured by Fluidic Techniques
Flow Calibrated by Alden Research Laboratory
Coefficient of Discharge vs. Pipe Reynolds Number

12" Sch 40 Flow Nozzle Meter Run, FN-2

Manufactured by Fluidic Techniques
Flow Calibrated by Alden Research Laboratory
Case Study
12” Sch 40 Flow Nozzle Meter Run

• Sizing Parameters
  – Fluid: Steam
  – Nominal Pipe ID: 11.938 Inches
  – Maximum Flow Rate: 74000 Pounds Per Hour (lb/h)
  – Normal Flow Rate: 51800 lb/h
  – Maximum Differential Pressure: 250 inches of Water Column (in WC)
  – Pressure: 90.00 PSIG
  – Temperature: 643°F
  – C: 0.99346, calculated @ Normal Flow Rate
  – Y: 0.973554, calculated @ Normal Flow Rate
Case Study
12” Sch 40 Flow Nozzle Meter Run

• Calculating the maximum flow rate \((Wm)\) @ the maximum differential pressure \((dPm)\)
  – \(C = 0.994072\)
  – \(Y = 0.945606\)
  – \(Wm = 71920 \text{ lb/h}\)
  – \% Error = 2.81
Case Study
12” Sch 40 Flow Nozzle Meter Run

And then, changing the Pipe ID to the maximum allowed with the mill tolerance, 12.040”, the maximum flow rate at 250 in WC becomes...

- Wm = 71863.7 lb/h
- % Error = 2.89
Case Study
12” Sch 40 Flow Nozzle Meter Run

• Similarly...
  – A 5% change in pressure creates a 2.4% error in flow.
  – A 5% change in temperature creates a 1.5% error in flow.
  – A five thousandths (0.005”) change in the bore diameter creates a 0.18% error in flow.
SUMMARY

• Using a flow element which has not been correctly designed, manufactured and installed for the appropriate application is like expecting a performance car to meet expectations with no maintenance, improperly inflated tires and low octane fuel.

Fluidic Techniques – The Source for Precision Primary Flow Elements

www.fluidictechniques.com

When Performance Counts...
Benefits of Calibrating Flow Meters Used in Electrical Generating Plants

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March 10, 2009
Typical Applications of Fluid Flow Meters in an Electric Power Generating Plant

- Condensate Flow (Low Temperature and Pressure)
- Boiler Feedwater Flows (High Temperature and Pressure)
- HP, IP & LP Steam Flows
- Desuperheating Flows
- Natural gas Flow
- Fuel Oil Flow
- Circulating Water Flow
- Reactor Power Calculations
Sources of Flow Meter Uncertainty

1. Flow Measurement Technique
2. Meter Design and Manufacture
3. Variations in Surface Roughness from Std. Equations
4. Dimensional Errors
5. Installation and Orientation Effects
6. Upstream Flow Disturbances
7. Change in Meter Condition (Fouling or Damage)

Note: Discharge Coefficient only corrects for Items 1-4
Reasons to Calibrate Flow Meters

• May be Required by ASME Performance Test Codes
• Verify Meter was Manufactured Properly
• Confirm Expected Meter Characteristics
• Determine and Document Actual Characteristics
• Establish Trends for Interpolation or Extrapolation
• Determine Effect of Fouling, Cleaning, or Damage
• Reduce Uncertainty of Flow Measurements
• Reduce Uncertainty of Overall Test Results
Example Calibration of an AGA Report 3
Natural Gas Flow Orifice Meter Tube

Goatrock 1 GTA
Comb. Turbine Gas Flow Orifice (Flange Taps)
Calibration Data

\[ C = 0.598462 + 112.68981 \times \text{Re}^{-0.75} \]

Difference is suspected to be due to pipe surface roughness (Stainless vs. Carbon Steel)
ASME PTC 6 Feedwater Flow Nozzle Design
Example Calibration of a ASME PTC 6 Flow Nozzle Meter Tube (Evaluated Using PTC 6-1976 Procedure)
Example Calibration of a ASME PTC 6 Flow Nozzle Meter Tube (Evaluated Using PTC 6-1996 Procedure)

<table>
<thead>
<tr>
<th>Throat Reynolds Number (Millions)</th>
<th>Calibration Points</th>
<th>Cx Regression Line</th>
<th>Average Cx</th>
<th>Lower 95% Confidence Interval</th>
<th>Upper 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0020</td>
<td>1.0020</td>
<td>1.0020</td>
<td>1.0020</td>
<td>1.0020</td>
<td>1.0020</td>
</tr>
<tr>
<td>1.0045</td>
<td>1.0045</td>
<td>1.0045</td>
<td>1.0045</td>
<td>1.0045</td>
<td>1.0045</td>
</tr>
<tr>
<td>1.0070</td>
<td>1.0070</td>
<td>1.0070</td>
<td>1.0070</td>
<td>1.0070</td>
<td>1.0070</td>
</tr>
<tr>
<td>1.0095</td>
<td>1.0095</td>
<td>1.0095</td>
<td>1.0095</td>
<td>1.0095</td>
<td>1.0095</td>
</tr>
<tr>
<td>1.0120</td>
<td>1.0120</td>
<td>1.0120</td>
<td>1.0120</td>
<td>1.0120</td>
<td>1.0120</td>
</tr>
</tbody>
</table>

Average Cx = 1.007533
Cd (Actual) = Cx - 0.185 *Rd^(-0.2) * (1 - 361239/Rd)^0.8

Case 1
Case 4
ASME PTC 6 LP Condensate Flow Nozzle Design

NOTES —
1. DIMENSIONS IN INCHES.
2. PIPE SIZE: 12 INCH SCH 40.
3. TEST SECTION SHALL BE CONSTRUCTED IN ACCORDANCE WITH ASME PTC-6, 1996 AND ASME B31.1.
4. INTERNAL SURFACES SHALL BE CLEANED AND COATED WITH A LIGHT OIL.
5. EXTERNAL SURFACES SHALL BE COATED WITH STANDARD PRIMER, 3 MIL O.F.T.
6. STAINLESS STEEL TAG SHALL BE PERMANENTLY ATTACHED WITH THE FOLLOWING INFORMATION: P/N NUMBER, MANUFACTURER, DATE OF MANUFACTURE, FTI JOB NUMBER, "AS BUILT" BORE DIAMETER, "AS BUILT" BETA RATIO, AND DIRECTION OF FLOW.
7. 20 POINT FLOW CALIBRATION REQUIRED FOR ALL FOUR TAPSETS FROM R4 OF 2x10^-6 TO MAXIMUM OBTAINABLE BY ARL CUSTOMER WILL WITNESS CALIBRATION AND ACCEPTANCE CRITERIA PER ASME PTC-6, 1996.
8. NOZZLE ALIGNMENT TO BE PERFORMED WITH BUILT IN DOWELS.
LP Condensate Flow Nozzle Inserted in Pipe
LP Condensate Flow Nozzle Installation Arrangement
LP Condensate Nozzle Meter Run Installation
LP Condensate Flow Orifice Meter Tube Design

NOTES:
(1) ALL WELDING PER ASME B31.1, UNLESS SPECIFIED
(2) MIC. INTERNAL DIAMETER PER CALIBRATION FORM #: MTCAL
(3) STAMP CALIBRATION AVERAGE AND SERIAL NUMBER
(4) IN I.D. GRIND WELDS TO MATCH PIPE I.D. AND FINISH
(5) CALIBRATE METER RUN PER MFC-3M-1989; 2 SETS OF TAPS 20 PTS. PER TAP SET, INCLUDING REPEAT TEST POINTS
   25%, 50%, & 75%
(6) PIPE ID FINISH TO BE STANDARD FINISH NO HONING
**LP Condensate Flow Orifice Meter Calibration**

**McIntosh 10A, SN 4540**

**LP Condensate Flow Orifice Calibration Data**

\[
C = 0.60283 + 36.00236 \times Re^{-0.75}
\]

- **Calibration Data**
- **Actual Data Regression**
- **ASME MFC-3M-1989**
- **PTC 19.5 Extr.**

**Pipe Reynolds Number (x 10^5)**

**Discharge Coefficient**

- **Base Load**
- **Peak Load**

**ALDEN**

Solving Flow Problems Since 1894
LP Condensate Flow Orifice Meter Location
## Uncalibrated LP Condensate Orifice Flow Uncertainty

<table>
<thead>
<tr>
<th>Test Value</th>
<th>Units</th>
<th>Sensitivity</th>
<th>Systematic</th>
<th>Random</th>
<th>Systematic Uncertainty Contribution</th>
<th>Random Uncertainty Contribution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Meter Error (Cd)</td>
<td></td>
<td>1.0000</td>
<td>0.5784</td>
<td>0.0000</td>
<td>0.08363664</td>
<td>0</td>
<td>Cd Uncertainty = Beta</td>
</tr>
<tr>
<td>Beta Ratio Range</td>
<td></td>
<td>0.5784</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code range of 0.3 to 0.6</td>
</tr>
<tr>
<td>Straight pipe upstream length</td>
<td>Dia</td>
<td>123</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code requirement of &gt; 18 Dia</td>
</tr>
<tr>
<td>Straight pipe downstream length</td>
<td>Dia</td>
<td>8.4</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code requirement of &gt; 7 Dia</td>
</tr>
<tr>
<td>d - Bore Dia.</td>
<td>Inches</td>
<td>5.7948</td>
<td>2.2978</td>
<td>0.0313</td>
<td>0.0000</td>
<td>0.001289028</td>
<td>0</td>
</tr>
<tr>
<td>D - Pipe Dia.</td>
<td>Inches</td>
<td>10.0190</td>
<td>0.2978</td>
<td>0.0313</td>
<td>0.0000</td>
<td>2.16507E-05</td>
<td>0</td>
</tr>
<tr>
<td>h - Differential Pressure</td>
<td>&quot;H2O</td>
<td>81.47</td>
<td>0.5000</td>
<td>0.6255</td>
<td>0.1063</td>
<td>0.0244550</td>
<td>0.0028262</td>
</tr>
<tr>
<td>P - Static Pressure</td>
<td>psia</td>
<td>336.53</td>
<td>0.0005</td>
<td>0.1253</td>
<td>0.0171</td>
<td>9.8145E-10</td>
<td>7.32252E-11</td>
</tr>
<tr>
<td>T - Flowing Temperature</td>
<td>Deg F</td>
<td>102.95</td>
<td>-0.0081</td>
<td>0.2871</td>
<td>0.0420</td>
<td>1.35245E-06</td>
<td>1.15957E-07</td>
</tr>
<tr>
<td>Coefficient Extrapolation</td>
<td></td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>None since test value within cal range.</td>
</tr>
</tbody>
</table>

### SINGLE ORIFICE TAP RESULT:

- Average Value: 551,011 lbm/hr
- Degrees of Freedom: \( v = 238 \)
- Student's t: \( t = 1.97 \)
- Relative Systematic Uncertainty: \( B_r = 0.6615 +/- % \)
- Relative Random Uncertainty: \( tS_r = 0.1047 +/- % \)
- Total Relative Uncertainty: \( U_{95} = 0.6698 +/- % \)
### Calibrated LP Condensate Orifice Flow Uncertainty

<table>
<thead>
<tr>
<th>Test Value</th>
<th>Units</th>
<th>Sensitivity θ</th>
<th>Systematic Bᵢ</th>
<th>Random Sᵢ</th>
<th>Systematic Contribution (Bᵢθ/2)²</th>
<th>Random Contribution (Sᵢ²)²</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Meter Error (Cd)</td>
<td>1.0000</td>
<td>0.2000</td>
<td>0.0000</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>Calibration Lab Uncertainty</td>
</tr>
<tr>
<td>Beta Ratio Range</td>
<td>0.5784</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code range of 0.3 to 0.6</td>
</tr>
<tr>
<td>Straight pipe upstream length</td>
<td>123 Dia</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code requirement of &gt; 18 Dia</td>
</tr>
<tr>
<td>Straight pipe downstream length</td>
<td>8.4 Dia</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Meets Code requirement of &gt; 7 Dia</td>
</tr>
<tr>
<td>d - Bore Dia.</td>
<td>5.7948 Inches</td>
<td>2.2978</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Any error is embedded in Cd cal.</td>
</tr>
<tr>
<td>D - Pipe Dia.</td>
<td>10.0190 Inches</td>
<td>0.2978</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0</td>
<td>0</td>
<td>Any error is embedded in Cd cal.</td>
</tr>
<tr>
<td>h - Differential Pressure</td>
<td>81.47 °H2O</td>
<td>0.5000</td>
<td>0.6255</td>
<td>0.1063</td>
<td>0.0244550</td>
<td>0.0028262</td>
<td>Includes an assumed 0.5 °H2O water leg error.</td>
</tr>
<tr>
<td>P - Static Pressure</td>
<td>336.53 psia</td>
<td>0.0005</td>
<td>0.1253</td>
<td>0.0171</td>
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<td>0</td>
<td>0</td>
<td>None since test value within cal range.</td>
<td></td>
</tr>
</tbody>
</table>

**SINGLE ORIFICE TAP RESULT:**

- Average Value: 551,011 lbm/hr
- Degrees of Freedom: ν = 238
- Student's t: t = 1.97
- Relative Systematic Uncertainty: Bᵣ = 0.3712 +/- %
- Relative Random Uncertainty: tSᵢ = 0.1047 +/- %
- Total Relative Uncertainty: Uᵣ = 0.3857 +/- %
HHR Nozzle Calibration Data

McIntosh LP Steam Flow
Fluidic HHR Flow Tube Calibration Data

Cx = 0.996568 + 4.9947e-10 * Rd
C = Cx - 0.185*Rd^(-0.2)*(1-361239/Rd)^0.8

Base Load
Peak Load

Cx = 0.997935
C = Cx - 0.185*Rd^(-0.2)*(1-361239/Rd)^0.8
Wall Tap Nozzle Calibration Data

McIntosh Superheat Spraywater Flow
Tag DS-FE-702A, Ser #J011735-1 Calibration Data
ASME Long Radius Nozzle (Wall Taps)

\[ C = 1.00434 - 4.46302 \cdot Re^{(-0.5)} \]

Difference between std. equation and actual is 0.7%
Conclusions

- Calibration transfers the uncertainty of a flow meter to the uncertainty of the calibration lab and the repeatability of the meter
- Use meters with predictable and repeatable characteristics
- Verify meter was manufactured properly by its performance
- Determine actual meter characteristics by calibration
- Curvefit calibration data using theoretical equation shapes
- Install meters with required upstream and downstream piping requirements (Duplicate lab flow conditions)
- Maintain meter condition as during calibration
Air Liquide Pipeline Operations

Zach Hennig

Why we calibrate meters
Air Liquide

• Product Pipelines
  – Oxygen
  – Nitrogen
  – Hydrogen
  – Steam
  – Water
• 400+ Billing meters
Why we calibrate meters

• Best measurement possible needed
  – for venturi meters this means calibrating to reduce the uncertainty of the discharge coefficient

• Assurance we have a properly built meter

• Customer confidence in our metering
Case Studies

• Case 1: Pipeline Balance

• Case 2: Steam venturi meter calibration

• Case 3: Failed venturi meter calibration
Case 1: Pipeline Balance

• Problem
  – Four mile steam line had ~ 7% balance discrepancy between inlet and outlet venturi meters

• Solution
  – Inlet meter had not been calibrated or maintained well for many years
  – Replace inlet meter with calibrated meter
Case 1: Pipeline Balance

• Results
  – Imbalance of daily totals of the pipeline were reduced from ~ 7.0% prior to ~ 0.3%
Case 2: Steam Venturi Calibration

• Problem:
  – Plant balances indicated we might be under billing customer steam flow
  – Steam meter uncalibrated
  – Discharge coefficient assumed to be 0.985

• Solution:
  – Install new calibrated venturi meter
Case 2: Steam Venturi Calibration

- Calibration results of new meter
Case 2: Steam Venturi Calibration

• Results:
  – Mass balances following steam meter replacement indicated an ~ 3.9% increase in steam sales
  – Project paid for within a matter of weeks
Case 3: Failed Venturi Calibration

• Problem
  – Poor meter performance at the calibration lab
  – Difference of 3% between tap two pairs of taps

• Solution
  – Meter returned to vendor
Case 3: Failed Venturi Calibration

20 inch Venturi calibration

- Tap set A, avg. 96.3
- Tap set B, avg. 99.3

Throat Re# vs. Cd graph showing the deviation from expected values.
Case 3: Failed Venturi Calibration

• Lesson
  – Meter manufactures can make mistakes
  – Defects may not be visible to the eye
  – Proving the meter assures you know the characteristics of your meter
Conclusion

• Case studies show the necessity of flow testing meters
What is Calibration?

Calibration is used to determine the meter’s deviation from an accepted standard.

Accepted Standard = traceable to internationally agreed reference values, e.g., the National Institute of Standards and Technology (NIST).

Philip S. Stacy, Director
ALDEN RESEARCH LABORATORY INC.
Flow meters are calibrated by relating a “known” or traceable flow to the meter’s reading.

The first step to Calibration is to determine the meter’s deviation from an accepted standard.
Gravimetric Method

Measuring the fundamentals:

Weight, Time, Temperature

Weight*/Time = Mass Flow

Mass Flow/fluid Density = Volumetric Flow

* Corrected for bouyancy and local gravity.
Alden’s Meter Calibration Facilities

High Reynolds:
- NVLAP registered with best uncertainty +/- 0.1%
- using water at 95F flows to 20,000 gpm
- Gravimetric systems, 1,000 lb, 10,000 lb, 100,000 lb capacities

Low Reynolds:
- Best uncertainty +/- 0.2%
- Pond water (seasonal temperature variation)
- Gravimetric systems, 1000 lb, 10,000 lb, 50,000 capacities
- Secondary standard (venturi) to 35,000 gpm
Gravimetric Facility

- Manifold
- Pumps
- Sump
- Breakdown Valves
- Switchway
- Scale
- 100,000 lb Weighing Tank
- 10,000 lb Weighing Tank
- Return Pump
Meter Installation

Differential Pressure Transmitters

Meter Under Test
Weight System
Typical Calibration Data

Pipe Reynolds Number

ASME Predicted Coefficient

Test Results

+/- 0.5% Prediction
Why Calibrate?

• Meters used in performance testing are required to be calibrated.

• Reduce uncertainty – increase confidence in the meter performance.

• Confirm wear and tear - Recalibration
Calibration vs. Prediction

How well do meters perform with respect to predictive equations?
Calibration vs. Prediction

From a data set of several hundred of the following meters:

- Throat tap nozzle
- Orifice plate sections
- Wall Tap sections
- Classic Venturi sections
Calibration vs. Prediction

Illustrating the measured average coefficient of discharge (Cd) versus predictive equation Cd.
Throat Tap Nozzle Cd

~ 85% w/in +/- 0.25%
Orifice Plate Cd

~ 50% w/in +/- 0.25%
Venturi Cd

~ 30% w/in +/- 0.25%
Wall Tap Nozzle Cd

Acceptance Limits

~ 30% w/in +/- 0.25%
Conclusions

• Calibration reduces uncertainty

• Links the meter performance to Accepted Standards

• Often the only way to account for design and manufacturing tolerance that can significantly affect meter performance with respect to predictive equations.
Summary

• Flow meter accuracy and the current climate of industry concerns
• An overview of flow meter types, the accuracy standards, and how to know when to calibrate
• Flow meter accuracy importance in the power generation industry
• Increasing revenue in the process industry by calibrating flow meters measuring a product
• Methods of calibration
Questions?

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