

## Title: Fluid Flow Metering

### FLUID FLOW METERING

#### I. Measurement

- A. Purpose is to determine
  - 1. Dimensions
  - 2. Capacity
  - 3. Amount
- B. Ruler
  - 1. Length - Measurement job
  - 2. Two lines separated by an unknown distance.
  - 3. Will use a number of different length devices - Each team arrives at a number. Keep answer to yourselves. Report length in inches and decimal fractions of an inch.
  - 4. Usefulness depends on job to be done
    - a. Mile
    - b. .001 inches
  - 5. Basic principle

#### II. History of Flow Meters

- A. Chinese over 4000 years ago
  - 1. Salt from salt water
- B. Romans (2000 years ago)
  - 1. Aqueducts control
- C. 1730's
  - 1. Pitot Bernoulli Equation
- D. 1790
  - 1. Venturi
  - 2. Pipes, Nozzles, Constricted pipes
- E. 1800 -1810
  - 1. London - Fuel Gas business started
- F. 1810 - 1820
  - 1. U.S. - Baltimore Gas Light Co. (All gas used for lights) 5 lights - 10 lights per house
  - 2. England
    - a. Clegg first PD Meter - Wet Meter
  - 3. U.S. First PD in 1820 - Hill
    - a. Rogers & Stanley, Fathers of U.S. Meter Industry, improved wet meter
- G. 1840's
  - 1. U.S. - First dry PD Meter
- H. 1880's
  - 1. First head type meters in U.S. Professor Robinson Pitot for gas well measurement
- I. 1890's
  - 1. U.S. other head meters investigated for gas measurement.

#### II. History of Orifice Meters

- A. 1903's Weymouth began orifice testing, Completed in 1912 with an ASME paper.
- B. 1913 - 1915 U.S. manufacturers ran parallel programs testing orifices by universities, Manufacturers and independent gas co. tests.

C. Manufacturer's included

1. Pittsburgh Equitable (which became EMCO later
2. Rockwell and now Equimeter)
3. Metric Metals (which became Westcott and then
4. American Meter)
5. Foxboro (who took data from Ohio Fuel Gas)

(Note: All of these manufacturers had their own coefficients and requirements of manufacture in their own books.)

D. Around 1920, request to the Bureau of Mines and the National Bureau of Standards for a recommended procedure for measuring gas produced on Indian land in Oklahoma led to tests run by the NBS in 1922-25 4, 6, and 8 inch to a pressure of 250 psig.

E. 1923 - The American Gas Association was formed and began its own tests in cooperation with the NBS

F. 1925 - The Natural Gas Association formed the first Measurement Committee who were to determine:

1. Correct installation of orifice meters
2. Correct calculations and operating requirements for orifice meters
3. Interface with NBS and Bureau of Mines for assistance

G. First report 1927 of committee

H. Report revised 1929

AGA No 1 issued in 1930. Had 4 sets of coefficients: Foxboro Flange taps, Metric Flange taps, Pittsburgh Equitable Flange taps, and Metric Full Flow (Pipe) taps

I. 1931 ASME joined to form a joint committee of AGA - ASME

J. AGA No 2 issued in 1935 (supplement to AGA-1) based on Ohio State coefficient tests

K. AGA No. 3 in 1955 was a further supplement, which expanded the application.

L. Further work resulted in Revisions in 1969

M. 1975 became an API standard 14.3

N. 1977 became an ANSI standard

O. 1985 revised to presently used report

P. 1990-1992 revised to standard whose printing will be completed in 1992 (Sept estimate)

More revisions in the future as knowledge is gained.

IV. Length Exercise

A. The answer is . inches

1. Prove it
2. Authority statement
3. Customer questions Daniel meters accuracy
4. Decimals in answer (.1 inch line thickness)
5. Digital read out to 4 decimals accurate to unit place only.

B.

1. First ruler in centimeters
2. 6 inch ruler
3. 12 inch ruler
4. 36 inch ruler
5. 72 inch ruler
6. 50 foot tape
7. An unmarked stick

Some of you should have preferred to use one other meter

C. Let's list some good and bad characteristics of your meters (chalkboard)  
Good Bad

D. Good Meter for Length

1. Inexpensive (Cost)
  2. Accurate
  3. Accepted
  4. Repeatable
  5. Low Maintenance
  6. Easy to use and service
  7. No moving parts
  8. Proper size for job
  9. Stable
  10. Rugged
  11. Traceable
  12. Long life
  13. Convenient & Familiar Units
- E. Good Meter for Flow
1. Linear with flow (computers make this less important than repeatable.)
  2. Rangeability
  3. Few fluid properties limitations
  4. Construction materials with stand high pressure and corrosion.
  5. Power required (Quality of Power)
  6. Electrical safety requirements
  7. High resolution
  8. Ease of Installation and Removal for cleaning
  9. Line size limitations (small and large)
  10. Is power required? Available?
- F. Low pressure drop caused by meter
1. Calibrateable
- G. Tolerances
- V. Accuracy
- A. Indicated versus true
  - B. No golden cubic foot at standards agency to check meter
- Some limits (standards and their use)
- C. Used in specmanship
  1. No control agency
  2. Usage and experience give some idea
  - D. Orifice in accordance with standard
  - E. New AGA-3 requirements
- VI. The standards define the orifice meter
- A. Orifice Plate and Meter Run
  1. Construction
  2. Installation
  3. Equation
  4. Computation
  5. Uncertainty
  - B. Straw Hat
  1. No standard
  2. Construction limitations
  3. No equation (coefficient)
  4. Uncertainty (too large)
- VII. Basic Considerations for all meters - fluid
- A. Gas Measurement Basics of Orifice Meter
  1. Gas in pipeline under pressure
  2. Uses Bernoulli's equation as a basis
- Pressure drop on known device (orifice)
- B. Gas Laws

1. Reduce to Base Conditions
- C. Requires other measurements
  1. Pressure
  2. Temperature
  3. Composition (Natural Gas a mixture)
- Specific gravity
- Methane
- Carbon dioxide
- Nitrogen
- Others
- Ethane
- Propane
- I-butane
- N butane
- Pentane
- Hexanes plus
4. What is to be measured? Gas, liquid, mixture
- D. Flow
  1. Flow movement of fluid upstream of meter to have a proper pattern when entering meter
- C. Measurement
  1. Primary - Meter part in line in contact with fluid
  2. Secondary - Auxiliary equipment out of pipeline usually not in contact with flowing stream.

#### VIII. Further Breakdown of these concerns

- A. Fluid
  1. Compressible - Gas
  2. Incompressible - Liquids
  3. Single phase
  4. Homogeneous across pipeline
    - a. Composition
    - b. Temperature
  5. Pressure
  6. Temperature
  7. Corrosive
  8. Erosive
  9. Corrections from effects of flowing to base conditions.
- Pressure
- Temperature
- Composition
- Compressibility
- Density
- Stream Example
- Saturated
- Super heated
- Quality
- Non vaporizing liquids
- Non condensing gases
- Near critical conditions
- Pressure
- Temperature
- B. Flow
  1. Fluid flow pattern arriving at meter
    - a. Distortion
    - b. Swirl

2. Installation piping of standards
    - a. Lengths
    - b. Diameters
    - c. Roughness
    - d. Roundness
  3. Required for all head and turbine meters
    - a. Possible exception for PD's
  4. Shorter lengths make no predictions on accuracy
  5. Daniel makes meter installations to the standards
  6. Length shortness can be done with:
    - a. Flow profile generators
    - b. Straightening vanes
  7. Distortions & swirl cause inaccuracies
    - a. Distortions 0 - 5% slow, length
    - b. Swirl 0 - 30% slow, straightening vanes
  8. Turbulent not Laminar flow in industrial applications
  - C. Measurement - Many kinds of meters
    1. Primary Devices \* The asterisks indicate the meters that Daniel Makes for gas.
      - a. \* Orifice
      - b. \* Nozzle
      - c. \* Venturi
      - d. \* Turbines
      - e. Positive Displacement
      - f. Others
      - g. \*Ultrasonics
      - h. Vortex Shedding
      - i. Targets
      - j. Wedge
    2. Secondary Devices
      - a. Formerly Mechanical
- Charts
- Indicators
- b. New Electronic
- Long stable life
- Customer confidence
- Better trained customers (field personnel)
- General acceptance of electronics in every day life (Can't program VCR)
- Little or no wear

- IX. Customer is interested in entire system accuracy
- A. Errors can come from areas Daniel has no control over
    1. Fluid
    2. Flow
  - B. Operation in proper range
  - C. Maintenance
    1. All pipelines dirty
    2. All equipment eventually requires checking, repairs, or replacement.
  - D. Accuracy
    1. Used as sales tool
    2. Usually not all facts known required to make proper statement
  - E. In Summary
    1. We sell meters capable of accuracies  
(Warn sales people)
    2. Measure once for measurement
    3. Measure twice for argument
    4. Cost of accuracy

- a. Meters, low reading
- b. Meters, high reading
- 5. New Meters measurement

- a. Same
- b. Lower
- c. Higher
- d. Economics

6. Justified for reason other than accuracy

- a. Real time measurement
- b. Operating control on proper flow measurement
- c. Customer accuracy based on present meters
- 7. Competitors attack orifice accuracy

- a. Old, must be better way
- b. Trained personnel know how to use (operating maintenance)
- c. Accuracy reconfirmed by new data
- d. No comparable data available on other meters
- e. Pipeline using orifice balance to .1%
- f.

X. Orifice Products - Daniel major product

- A. Made to meet standards with great knowledge and care
- B. Precision measuring device can be destroyed by improper handling
- C. Standards lengths are minimum
- D. Most accurate in upper range with stabilized temp & pressure with no change in composition
- E. "New quality" condition must be maintained any time meter is used to obtain accuracy.
- F. Inspection should be easily done (Senior fittings)
- G. Meter tube usually made to exceed standards worse case requirements
- H. Alignment of tube to prevent flow distortion required.
- I. Use extreme requirements for all tubes
- J. Equations accuracy based on physical requirements being met
- K. Differential measurement most critical to accuracy
- L. Static pressure and temperature less critical
- M. Range may be restricted by flow conditions
- N. Design with multiple differentials and or multiple tubes can extend range
- O. Proper operation and maintenance required

XI. Turbine Meters - Gas Turbine Meters - Measures Natural Gas equally accurately as an orifice

A. Principle of Operation

- 1. Velocity measuring device
    - a. Constricted opening increases velocity
    - b. Free turning rotor (minimum friction)
    - c. Angular velocity of rotor proportional to d. linear velocity in meter
    - e. With area factor, volume is measured
    - f. Measure rotor speed
    - g. Determine area by flow calibration (not mechanical area)
    - h. Minimum speed to over come friction from retarding forces
- Bearing Friction (retarding forces)  
Fluid Friction (aerodynamic forces)  
Bypass of gas

j. Theoretical rotor speed is not actual, therefore calibration is required.

B. Construction

- 1. Flow deflector (2/3's area of meter opening) increase forces on rotor
  - a. Velocity

- b. Lever arm
- c. Accuracy at low flow rates
- d. Lessons thrust loads on rotor and bearings
- 2. Rotor
  - a. Lexan (light weight)
  - b. Available in aluminum for special gases (ethylene)
  - c. Machined to specific angle
  - d. Not able to predict calibration from machined rotor
- 3. Bearings
  - a. Lubricated shielded ball bearings
  - b. Turn with rotor
- 4. Magnetic pickup system
- 5. Oil - bearings
- 6. Preamplifier
  - a. Signal protection
- 7. Installation and Operation (specified in AGA-7)
  - a. Lengths
  - b. Straightening vanes
  - c. Filters
  - d. Strainers
  - e. Control orifice
  - f. Temperature
  - g. Pressure
- 8. Sizes of gas turbines
  - a. 2, 4, 6, 8, 12
- 9. Computing
  - a. Electronic readout (2235, 2500, 2707, 2480)
  - b. Solves gas law equation to reduce from line to base conditions
- 10. Proving
  - a. Spin tests
  - b. Transfer Power (Master Meter)
  - c. Pipe Prover
  - d. Critical Flow devices