Wait a minute...I thought this was a Workshop on Smokestack Gas Measurement?

It just so happens the same flow meters that measure smokestacks also measure flare gas.
Comparative Flare Gas Flow Measurement Study

Smokestack vs. Flare How Are They Different:

- Smokestacks are usually larger.
  - Full-bore meters are not an option.
- Smokestacks have smaller flow ranges:
  - Flare gas can range from 0.1 to 500 feet/sec.
- Smokestacks have more stable flows.
- Flare gas can have transient flow with wide flow swings.
- Flare gas can have large gas composition & density changes.
Smokestack vs. Flare How Are They Similar:

- Very little or no straight run of piping.
- Lots of distorted velocity profiles, skews & swirls.
In 2011, Chevron contracted a blinded study to test various flow meters used in flare gas measurement. The goal was to shed some light on different flare gas flow measurement technologies.

Improve:
- API-14.10 (Measurement of Flow to Flares)
- API-22.3 (Testing Protocol for Flare Gas Metering)

Data presented at the GPA (Gas Producers Association), April, 2013, San Antonio, Texas.

Thank you:
Steve Baldwin, Chevron
Houston, Texas, U.S.A.

Thank you:
Eric Estrada, Targa Resources
Houston, Texas U.S.A.
The comparative blinded study ran from 2011 to 2013 and included the following meters:

- USM (4-path Chordal)
- USM (2-path, Diametral)
- USM (1-path, Diametral)
- USM (1-path, Partial Insertion)
- Optical Flow Meter
- Tracer Gas Dilution Methodology

Wanted to test Pitot Tube Technology but time & money didn’t allow it.
### Rules of the Game:

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>70°F (Ambient)</td>
</tr>
<tr>
<td>Pressure</td>
<td>12 PSIA (Ambient)</td>
</tr>
<tr>
<td>Velocity</td>
<td>1 to 150 FPS (feet/second)</td>
</tr>
<tr>
<td>Pipe size</td>
<td>10” (6” pipe for 4-path chordal USM)</td>
</tr>
<tr>
<td>Pipe orient</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Piping Config</td>
<td>Ideal straight-run</td>
</tr>
<tr>
<td></td>
<td>Swirling flow after an elbow</td>
</tr>
<tr>
<td></td>
<td>In-Plane &amp; Out-of-Plane</td>
</tr>
</tbody>
</table>
Manufactures were expected to:

- Supply, install, operate, zero and record meter outputs.
- Must be present during testing.
- Blinded from reference data.

- Had an opportunity to review their data prior to submission.

...many nervous manufacturers.
Warning!
Test results based on:
• Limited testing with a small sample size in 6” and 10” pipes.
• Extreme caution should was exercised when extrapolating these results to other
  – Pipe sizes
  – Different piping configurations
  – Different fluids
  – Different meters types
Comparative Flare Gas Flow Measurement Study

Consider Flare Gas & Smokestack Velocity Profiles:

- Typical/Classical Velocity Profile
- Atypical Velocity Profile
- Atypical Velocity Profile
Consider How a Meter Senses the Flow:

- **Optical Meter (Single Point)**
- **USM 2-Path (Diametral)**
- **USM Partial Path**
- **USM 4-Path (Chordal)**
- **USM 1-Path (Diametral)**
- **Tracer Gas Dilution**
- **Fully Developed Velocity Profile**
- **Swirling Velocity Profile**
- **Skewed Velocity Profile**
Comparative Blinded Flare Gas Flow Measurement Study
USM Meter #4, 4-Path Chordal
Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane

Comparative Flare Gas Flow Measurement Study

Meter #4, Straight Pipe
Meter #4, Elbow In-plane
Meter #4, Elbow Out-of-Plane
Comparative Blinded Flare Gas Flow Measurement Study
USM Meter #3, Two-Path Diametral, Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane
CEESI, 10" Pipe, April 13, 2013, CE-18074

Comparative Flare Gas Flow Measurement Study

-25.0
-20.0
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
0.5 5.0 50.0
Percent Error
Velocity (ft/sec)

- Meter #3, Straight Pipe
- Meter #3, Elbow In-plane
- Meter #3, Elbow Out-of-Plane
- Meter #3, Elbow-45-Degree
Comparative Blinded Flare Gas Flow Measurement Study

USM Meter #2, Single-Path Diametral, Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane
CEESI, 10" Pipe, Oct 4-6, 2011, CE-14275

- Comparative Blinded Flare Gas Flow Measurement Study
- USM Meter #2, Single-Path Diametral, Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane
- CEESI, 10" Pipe, Oct 4-6, 2011, CE-14275
Comparative Blinded Flare Gas Flow Measurement Study

USM Meter #1, Single-Path, Partial Insertion

Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane

CEESI, 10" Pipe, Oct 4-6, 2011, CE-14275
Comparative Blinded Flare Gas Flow Measurement Study

Optical Meter

Straight Pipe, Elbow In-Plane, Elbow Out-of-Plane

CEESI, 10" Pipe, June 4-6, CE-14275

Percent Error vs. Velocity (ft/sec) graph showing:
- Optical Meter, Straight Pipe
- Optical Meter, Elbow In-Plane (Inside Radius)
- Optical Meter, Elbow Out-of-Plane
Comparative Blinded Flare Gas Flow Measurement Study
Tracer Gas Dilution Method
CEESI, 10" Pipe, May 7-8, 2013, CE-18143

Percent Error vs. Velocity (ft/sec)

-25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0 25.0
-25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0 25.0

Tracer Gas Data

Comparative Flare Gas Flow Measurement Study
Comparative Flare Gas Flow Measurement Study

A Few Pictures:

Test Facility & Test Piping
Comparative Flare Gas Flow Measurement Study

Test Facility & Test Piping
USM (1-Path & Partial Path) Installation
Comparative Flare Gas Flow Measurement Study

USM (2-Path) Installation
Comparative Flare Gas Flow Measurement Study

USM (4-Path Chordal) Installation
Comparative Flare Gas Flow Measurement Study

Tracer Gas Dilution Installation
Comparative Flare Gas Flow Measurement Study

Optical Meter Installation
Comparative Flare Gas Flow Measurement Study

CONFIGURATION #1

CONFIGURATION #2

CONFIGURATION #3

6" USM Pipe Configurations
CEESI Job# CE-15627

DRAWN BY: EJH
PRINT APPR: EJH
REV: B
PAGE: 1 OF 1
Comparative Flare Gas Flow Measurement Study
Results:

USM (4-path Chordal)
- Straight: ±1%
- Elbow: ±2%

USM (2-path, Diametral)
- Straight: ±5%
- Elbow: ±10%

USM (1-path, Diametral)
- Straight: ±3 to 7%
- Elbow: ±25%

USM (1-path, Partial Insert.)
- Straight: ±3-7% (3-150 FPS)
- Straight: ±7-22% (1-3 FPS)
- Elbow: ±20%

Optical Flow Meter
- Straight: ±35%
- Elbow: ±35%

Tracer Gas Dilution
- All Installations: ±6-10%
Consider How a Meter Senses the Flow:

- **Optical Meter (Single Point)**
- **USM 2-Path (Diametral)**
- **Fully Developed Velocity Profile**
- **USM Partial Path**
- **USM 4-Path (Chordal)**
- **Swirling Velocity Profile**
- **USM 1-Path (Diametral)**
- **Tracer Gas Dilution**
- **Skewed Velocity Profile**
Conclusions:

- Chordal 4-Path best.
- Diametral USM’s struggle.
- 2-Path USM’s better than 1-Path in elbow.
- Optical Meter not a viable meter.
- Tracer Gas Dilution a viable solution when there is no straight pipe.

The more non-diametral paths the better!
Comments & Questions?

Thank you!