Optical Flare Gas Flow Meter

RANGE OF 0.33 TO 492FPS [0.1 TO 150M/S]
EPA Statement for Flare Gas Meters

Mr. Kenneth R. Comey, III
BP Products N.A., Inc.
Environmental Compliance & Advocacy Team
12317 Aralia Ridge Dr.
Austin, TX 78739-1940

Dear Mr. Comey:

The Environmental Protection Agency approved your previous request dated August 2, 2010, to use an ultrasonic flow meter in place of Method 2, 2A, 2C, or 2D to measure the flow rate for determining flare exit velocity at facilities subject to the general flare requirements of 40 CFR 60.18 and 63.11(b). This approval was broadly applicable and extended to other similar flares subject to these requirements. In your March 25, 2013, letter you ask that we include optical flow meters in this approval.

Your company would like to install optical meters in the future, and you note that they will be installed, calibrated, operated, and maintained according to the manufacturer’s specifications. These monitors will also meet the flare flow monitoring requirements of 40 CFR 60.107a(1) of Subpart Ja, Standards of Performance for Petroleum Refineries For Which Construction, Reconstruction, or Modification Commenced After May 14, 2007, which has location, sensitivity, inspection, and recalibration requirements.

Your request to use ultrasonic flow meters that are calibrated and maintained to measure the flare flow rate is an acceptable alternative to Method 2, 2A, 2C, or 2D. This letter expands the prior approval of ultrasonic flow meters to include optical flow meters. Optical and ultrasonic flow meters are acceptable for measuring flare gas flow rate under the provisions of 40 CFR 60.18(l)(4) and 63.11(b)(7)(i), provided the calibrations are maintained within the manufacturer’s recommended frequency. For documentation purposes, calibration sheets must be included in test reports to verify that meter calibration is current. Since this alternative method approval is applicable to other similar facilities in this source category, we will be posting this letter on our website at http://www.epa.gov/ttn/emc/approal.html for use by other interested parties.

If you have questions or would like to discuss the matter further, please call Foston Curtis at (919) 541-1063, or you may e-mail him at curtis.foston@epa.gov.

Sincerely,

Connie Oldham
Connie E. Oldham, Ph.D., Group Leader
Measurements Technology Group
EPA Statement for Flare Gas Meters

Your company would like to install optical meters in the future, and you note that they will be installed, calibrated, operated, and maintained according to the manufacturer’s specifications. These monitors will also meet the flare flow monitoring requirements of 40 CFR 60.107a(f) of Subpart Ja, Standards of Performance for Petroleum Refineries for Which Construction, Reconstruction, or Modification Commenced After May 14, 2007, which has location, sensitivity, inspection, and recalibration requirements.

Your request to use ultrasonic flow meters that are calibrated and maintained to measure the flare flow rate is an acceptable alternative to Method 2, 2A, 2C, or 2D. This letter expands the prior approval of ultrasonic flow meters to include optical flow meters. Optical and ultrasonic flow meters are acceptable for measuring flare gas flow rate under the provisions of 40 CFR 60.18(f)(4) and 63.11(b)(7)(i), provided the calibrations are maintained within the manufacturer’s recommended frequency. For documentation purposes, calibration sheets must be included in test reports to verify that meter calibration is current. Since this alternative method approval is applicable to other similar facilities in this source category, we will be posting this letter on our website at http://www.epa.gov/ttn/emc/approalt.html for use by other interested parties.

If you have questions or would like to discuss the matter further, please call Foston Curtis at (919) 541-1063, or you may e-mail him at curtis.foston@epa.gov.
What a 300fps Flare Looks Like & The L2F Probe
Optical Flare Gas Flow Meter

- ANSI 150 1”(in) flange
- L2F probe inserted into Flare Line
- PROBE FLOW TUBE PARALLEL TO FLOW DIRECTION
- ORIENTATION REFERENCE SURFACE
- Y CHAIN AND QUICK-LINKS
What Flare Flow at a nominal 300fps Looks Like (FS)
What Flare Flow at a nominal 300fps Looks Like
Optical Flare Flow Meter probe
THEORY OF OPERATION

The operating principle of the laser 2 focus optical flow meter is explained in Figure 1. Two laser beams are projected through optical windows and focused by the illuminating optics to form two thin sheets, separated by a known fixed distance along the direction of flow.

Naturally occurring microscopic particulate, entrained in the gas flow, pass through the focused laser sheets and scatter some of the light. The detecting optics collects the scattered light and direct it on to photodetector P1, which generates a signal pulse. A moment later, the particle crosses the second focus sheet, and the detecting optics directs the scattered light it on to a second photodetector P2, generating a second electrical pulse. By measuring the time interval between pulses, \( \tau \), the gas velocity is calculated as \( V = D/\tau \), where D is the distance between the laser beams.
Optically Measuring Particles In Flare Gas
Optical Flare Flow Meter Optics Effects Of Particles
Optical Flare Flow Meter Optics Detecting The Particles
Optical Flare Flow Meter Optics Matching The Particles

Correlated - InBin = 2

valid correlations

crosscorrelations

www.cosaxentaur.com
Calculating the Velocity From The Particles

(1) \[ v = \frac{D}{t} \]

\[ v \quad [m/s] \quad \text{Velocity (m/s) of media at measuring point} \]

\[ D \quad [m] \quad \text{Distance (m) between centers of laser beams (0.001m)} \]

\[ \Delta t \quad [s]: \quad t_1-t_2 \text{ measured time (s) between logged electronic pulses} \]

\[ v \quad [ft/s] \quad \text{Velocity (m/s) of media at measuring point} \]

\[ D \quad [f] \quad \text{Distance (m) between centers of laser beams (0.001m)} \]

\[ \Delta t \quad [s]: \quad t_1-t_2 \text{ measured time (s) between logged electronic pulses} \]
Calculating Flow Rate From The Velocity

\[ (2) \quad B = A \times v = (\pi r^2) \times v \]

B: Bulk Flow \([m^3/s]\)
A: Cross section area of pipe \([m^2]\)
\(v\): Bulk (average) velocity of the flow which is measured \([m/s]\)
\(r\): Radius of pipe where flow is measured

B: Bulk Flow \([cf/s]\)
A: Cross section area of pipe \([ft^2]\)
\(v\): Bulk (average) velocity of the flow which is measured \([ft/s]\)
\(r\): Radius of pipe where flow is measured
Installation of the L2F probe is to be horizontally and at the three o'clock position to a depth of one quarter of the pipes inner diameter (I.D.).

Optimum location for the installation of the L2F probe is twenty pipe diameters downstream from any elbows, tees or angular offsets.

(source: University of California Cooperative Extension, Stanislaus County September 21, 2000 and Photon Control 2011)
In a straight run of pipe, gas at the edges of the pipe moves slower than the gas towards the center because of friction along the walls. In this drawing, areas in the pipe with similar velocities are depicted as concentric rings. The fastest moving gas is in the ring in the center and this is representative of a fully developed laminar flow profile. The L2F was designed to be inserted into a pipe to the depth equal to \( \frac{1}{4} \) (0.250) of inner pipe diameter. This to \( \frac{1}{4} \) (0.250) of inner pipe diameter is also the point in a fully developed flow profile that is the average between the fastest and slowest part of the gas flow.

This drawing depicts the distortion in the velocity cross section that occurs just after the flow has gone through an elbow or a tee junction. Thus the gas flow in the pipe is no longer laminar and has a fully developed flow profile for the L2F to measure and report the average gas flow velocity. The gas on one side of the profile is moving much faster than in the rest of the pipe. An L2F flow meter placed in the \( \frac{1}{4} \) (0.250) portion of inner pipe diameter will not give an accurate flow measurement and will require a mapping of the flow to determine optimum placement or correction factor.
FOCUS™ Probe Verification Test Results (0.1 to 35 m/sec and 80 to 100 m/sec)

- Combined Meter Error
- 2 σ Flow Instability of 100 Second Sample
- Meter Repeatability

Velocity (m/sec)

Meter Operating Accuracy %

- NPS6 1/4R Verification Test Results
- NPS6 1R Verification Test Results
- NPS12 1/4R Verification Test Results
Effects Of Installing On An Elbow – CEESI Test Data

NPS 6 - Two Elbows Out of Plane Installation Effect
(1 to 100 m/sec)

% Error (Meter-Reference)/Reference

Velocity (m/sec)

-16%
-14%
-12%
-10%
-8%
-6%
-4%
-2%
0%

40D
20D
10D

Linear (40D)
Linear (20D)
Linear (10D)

y = -6E-06x - 0.0301
R² = -0.1571

y = -3E-05x - 0.0686
R² = 0.0054

y = -1E-05x - 0.0916
R² = 0.0008
CEESI Installation Effects Test Data

NPS 6 - 45 Header Installation Effect
(1 to 100 m/sec)

NPS 6 - Two Elbows Out of Plane Installation Effect
(1 to 100 m/sec)

NPS 6 - Single Elbow Installation Effect
(1 to 100 m/sec)

NPS12 45 Header - 0.25R Probe Location
(Average and Individual Tests Points for 3 Probe Orientations Shown)

NPS 12 Two Elbows Out of Plane
(Average and Individual Tests Points for 3 Probe Orientations Shown)
## SwRI Test Data

### Meter Results from Preliminary Test

<table>
<thead>
<tr>
<th>File</th>
<th>Date</th>
<th>Time</th>
<th>P (psia)</th>
<th>T (F)</th>
<th>rho (lb/ft³)</th>
<th>Time (sec)</th>
<th>md (lb/s)</th>
<th>Umd (%)</th>
<th>Vavg (ft/s)</th>
<th>ReD</th>
<th>Vmeter (ft/s)</th>
<th>Cal</th>
<th>%error</th>
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<tr>
<td>F032315.001</td>
<td>150323</td>
<td>145750</td>
<td>256.37</td>
<td>70.25</td>
<td>0.8025</td>
<td>30</td>
<td>11.6317</td>
<td>0.21</td>
<td>11.8111</td>
<td>1552814</td>
<td>11.663</td>
<td>1.0127</td>
<td>-1.25</td>
</tr>
</tbody>
</table>

### Diagram

- **Flow**
- **12x16 Reducer**
- **Probe Location**
- **Temperature**
- **Pressure**

Installation Diagram of Test Meter in High Pressure Loop
Calibration Test Data Given With Each L2F Probe

<table>
<thead>
<tr>
<th>No.</th>
<th>Base Velocity [m/s]</th>
<th>Measured Velocity [m/s]</th>
<th>Error As Found [%]</th>
<th>Error As Left [%]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.496</td>
<td>0.506</td>
<td>+0.691</td>
<td>+1.917</td>
</tr>
<tr>
<td>2</td>
<td>1.652</td>
<td>1.662</td>
<td>-0.619</td>
<td>+0.568</td>
</tr>
<tr>
<td>3</td>
<td>5.025</td>
<td>5.038</td>
<td>-1.430</td>
<td>+0.256</td>
</tr>
<tr>
<td>4</td>
<td>7.304</td>
<td>7.233</td>
<td>-2.157</td>
<td>-0.966</td>
</tr>
<tr>
<td>5</td>
<td>9.947</td>
<td>9.916</td>
<td>-2.260</td>
<td>-0.313</td>
</tr>
<tr>
<td>6</td>
<td>12.140</td>
<td>12.106</td>
<td>-1.251</td>
<td>+0.197</td>
</tr>
</tbody>
</table>

CAL-ASY-0238C-SN-80014044-6IN-1R

AVERAGE ERROR: +0.197%
METER FACTOR: 0.968 mm
Calibration Against a “Master” Meter

- **EPA METHOD 2** - DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

![Diagram of Type S Pitot Tube](attachment:image.png)
Field Calibration; Making New L2F Calibration Table

STEP 1

Variables
• BV = bulk velocity at OFM’s location; recalculated from master meter’s actual flow rate
• CV = filtered centerline velocity from OFM
• Reynolds number = Reynolds number at OFM’s location; recalculated from master meter’s bulk velocity
• Pressure = pressure sensor needs to be connected to OFM
• Temperature = temperature sensor needs to be connected to OFM

Reynolds calculation
Re = pvD/u or
Re = vD/k

Where:
p= density
v = bulk velocity
D = inside diameter of pipe
u = dynamic viscosity
k= kinematic viscosity of the fluid
STEP 2

Formatting Reynolds, cv/bv table:

(Note: COLUMN “B” is the Extrapolation Data Point)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
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<tbody>
<tr>
<td>re:</td>
<td>10000000</td>
<td>1293300</td>
<td>1210500</td>
<td>1125500</td>
<td>1038800</td>
<td>945380</td>
<td>859900</td>
<td>688010</td>
<td>430730</td>
<td>218110</td>
<td>84969</td>
<td>42617</td>
<td>17106</td>
<td>8330.6</td>
<td></td>
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<tr>
<td>cv/bv:</td>
<td>1.2</td>
<td>1.219166</td>
<td>1.239073</td>
<td>1.240429</td>
<td>1.24141</td>
<td>1.233105</td>
<td>1.226238</td>
<td>1.231107</td>
<td>1.247908</td>
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<td>1.21853</td>
<td>1.203393</td>
<td>1.197711</td>
<td>1.032166</td>
<td></td>
</tr>
</tbody>
</table>

- Save values in excel as above
- Enter in first column “B”, Re=10 million and cv/bv = copy of first cv/bv data
- Enter subsequent data points from highest to lowest Reynolds number from left to right
- Append Re=1 and cv/bv=0.3 at the right-most column
- Export the excel worksheet as “tab-separated” text file
- Upload the text file to OFP using OFM Monitor
Field Calibration; Making New L2F Calibration Table

STEP 3

- Verify calibration in OFP matches excel file data

<table>
<thead>
<tr>
<th>Reynolds No</th>
<th>Vcl/Vbulk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000000</td>
<td>1.2</td>
</tr>
<tr>
<td>1293300</td>
<td>1.219166116</td>
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<td>1210500</td>
<td>1.239073208</td>
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<td>832.37</td>
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<td>1</td>
<td>0.3</td>
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<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Perform calibration verification
- If verification some don’t match, then increase/decrease Vcl/Vbulk value in calibration table then re-upload
- Repeat verification
L2F Software Overview – Configuration Page
L2F Software Overview – Configuration Page
L2F Best Applications To Date

Wet & Dry Natural Gas Flare Flow Measurement

• High H2S
• High CO2
• Oil and Hydrocarbon Condensate (light aerosols)
• Vacuum to 300psig
• “Dirty Applications”

Natural Gas Custody Transfer Flow Measurement

• Dirty and high particulate measurement locations
• Downstream of oil compressors

Biogas (Landfill) Gas Custody Transfer Flow Measurement

• Dirty and high particulate measurement locations
Portable Version Also Available
Optical Flare Flow Meter Portable Version

- L2F Optical Flow Processor (OFM-XP)
- L2F Optical Heater Power Supply
- Battery & Case (24F) w/Charger
- L2F Probe
- ToughBook (PC)
- USB - RS-232
Questions