Well Venting and Completion Emission Estimation

2009 Natural Gas Star Annual Workshop
Emission Estimation
Well Venting and Completion

• Difficult Sources to Characterize with Multiple Variables and Complex Physics
• Well Venting
  – Calculation Methodology
  – Pressure Transient Analysis
  – Orifice Measurement of Three Phase Flow
• Completion Flow-back
  – Pressure Drop Across Choke Flow Model
• None of These are “Accurate” in an Absolute Sense
• All of These are Accurate Enough to Enable Management
Well Venting - Calculation

- **Vent Volume** = \((\text{Vent Time} - 30 \text{ min}) \times (1/1410) \times \text{MCFD}\) + (Well Blowdown Volume)
  - Function of Vent Time, Normal Production Rate, and a Blow-Down Value
  - Limitations of Method
    - Post Blow-Down Value is Under the Assumption of Line Pressure
    - Does Not Account for Well-bore Fluid Column Weight or Volume

- **Well Blowdown Volume**

  **VOLUME Calculation**
  \[
  \text{corrected volume (mscf)} = \frac{\text{depth} \times 3.1416 \times (\text{diameter}/2 \times \text{diameter}/2) \times ((\text{tubing pressure} + \text{atmospheric pressure})/14.7) \times (520/(\text{temp}+460))/B19/1000}{10}
  \]

  (Please note: "z" factor changes with composition, pressure & temperature)

  - altitude (feet above sea level) = 7000
  - site atmospheric pressure (psia) = 11.3
  - shut-in tubing pressure (psig) = 500
  - temperature of gas in pipeline (F) = 75
  - well depth (ft) = 10000
  - diameter of production casing (inches) = 7
  - diameter of vessel (ft) = 0.58
  - compressibility (z) = 0.87
  - corrected volume (mscf) = 103.9
Venting Estimation
Pressure Analysis

- 17 Wells Studied
- Used Relation Between Pressure & Flow
- Utilized Relief Valve Calculation to Develop Linear Expression
- Choke Flow is Accounted Using this Method

Wamsutter Vent Estimates

\[ y = 0.026x + 0.2756 \]

\[ R^2 = 1 \]

Fluid Levels are from Surface Down

Separator

Pressure at Wellhead psig

MMSCFD of Gas

Series 1
Linear (Series 1)
Follow-up Pressure Analysis

- Same Pressure Data
- Evaluated Using “Visual Flow” and “Flarenet” Model Systems
- Results:
  - Flow up pipes ≤1.875” diameter:
    \[ \text{Vent volume (MCF)} = 0.49 \times \text{time} + 8.5 \]
  - Flow up pipes with >1.875” diameter:
    \[ \text{Vent volume (MCF)} = 1.5 \times \text{time} + 21 \]
- Enabled Funding for Automation Approach

Limitations
- Population Size and Representativeness
- Does Not Account for Reservoir Influx
Orifice Metering of Blowdown

- Quite Depleted Reservoir Energy Area
- 4 Distinct Production Horizons
  - Picture Cliff (Sand)
  - Mesa Verde (Sand)
  - Dakota (Sand)
  - Fruitland (Coal)
  - Dual Completed Comingled Wells
- Approximately 30 Wells In Study Population
  - Split Between Formation/Well Types
  - Orifice Meter Installed on Vent Line
    - Multiple Blowdown Runs per Well
    - 3 Phase Flow
- Limitations
  - 3 Phase Flow Accuracy
  - Representativeness of Study Population
Orifice Metering Results

- Formation Specific Vent Volume per Minute

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<thead>
<tr>
<th>Vent Rates</th>
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<tbody>
<tr>
<td>Dakota</td>
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<tr>
<td>Mesa Verde</td>
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<td>Fruitland</td>
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<td>Picture Cliff</td>
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<td>Cmgl</td>
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- Minutes of Venting are Tracked – Automation Based
- Agreement With Other Data

<table>
<thead>
<tr>
<th>Company X Vent Rate Comparison</th>
<th>BP Vent Emissions Methodology</th>
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<tbody>
<tr>
<td>Well</td>
<td>Vent time</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>6.8</td>
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<tr>
<td>3</td>
<td>7.7</td>
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<tr>
<td>3</td>
<td>5.3</td>
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<td>3</td>
<td>5.3</td>
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<td>13</td>
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<td>7</td>
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Orifice Metering – Outcome

Southern San Juan Quarterly Vent Volumes

Automation Based Well/Vent Control
• ~2,300 Wells
• ~$12 MM Investment
• ~99% Vent Reduction
• >21 BCF Cumulative Volume Reduction
Completion Flow-back Estimation

- Post Frac Well Clean-up
  - Flared or Vented
- Volume Calculated Based on Pressure Drop Across Choke
- Very Complex Calculations
  - Subcritical and Critical Velocity Handling
  - Fluid Properties and Z Factor Handling
  - Thermodynamics Handling
- Various Models are Available; HySys; AspenTech; Etc. Type Models Include Modules for Choke Flow
- Conservation of Mass is the Fundamental Principle
- Limitations
  - “Slugging” Flow
  - Variable Composition Fluids
  - 2 Phase Flow w/Sand
  - Amount and Frequency of Data Capture and Handling
Completion Flow-back - Simple

Rawlins – Schellhardt Approach

- Dependent On Only Upstream Conditions

\[ q_g = \frac{C_f (14.4 / P_{sc}) P_1}{1000 \sqrt{Y_g Z_1 T_1}} \]

- Limitations
  - Simplifying Assumptions

- \( Q_g \) = Gas Flow Rate
- \( C_f \) = Choke Flow Coefficient
- \( P_{sc} \) = Standard Pressure
- \( P_1 \) = Upstream Pressure; psia
- \( T_1 \) = Upstream Temperature, degrees Rankin
- \( Y_g \) = Gas Specific Gravity; (air=1.0)
- \( Z_1 \) = Gas Compressibility Factor at Upstream Conditions