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 = ((Vent Time – 30 min)*(1/1410)*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

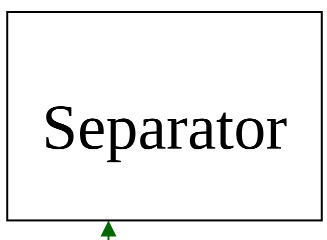
VOLUME Calculation	
altitude (feet above sea level)=	7000
site atmospheric pressure (psia)=	11.3
shut-in tubing pressure (psig)=	500
temperature of gas in pipeline (F)=	75
well depth (ft)=	10000
diameter of production casing (inches)=	7
diameter of vessel (ft)=	0.58
compressibility (z)=	0.87
corrected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

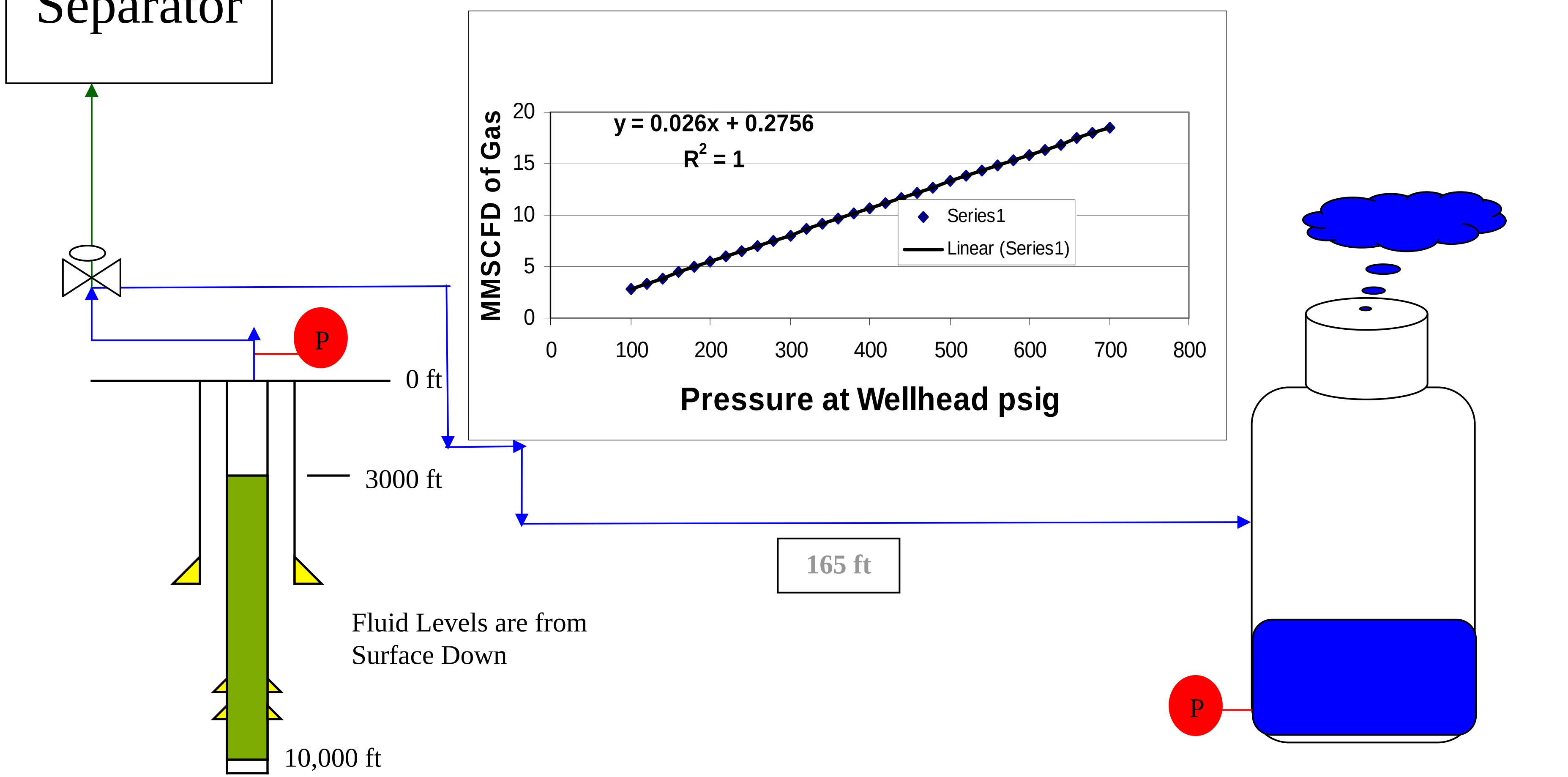
(depth*3.1416*(diameter/2*diameter/2))*((tubing pressure+atmospheric pressure)/14.7)*(520/(temp+460))/B19/1000

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

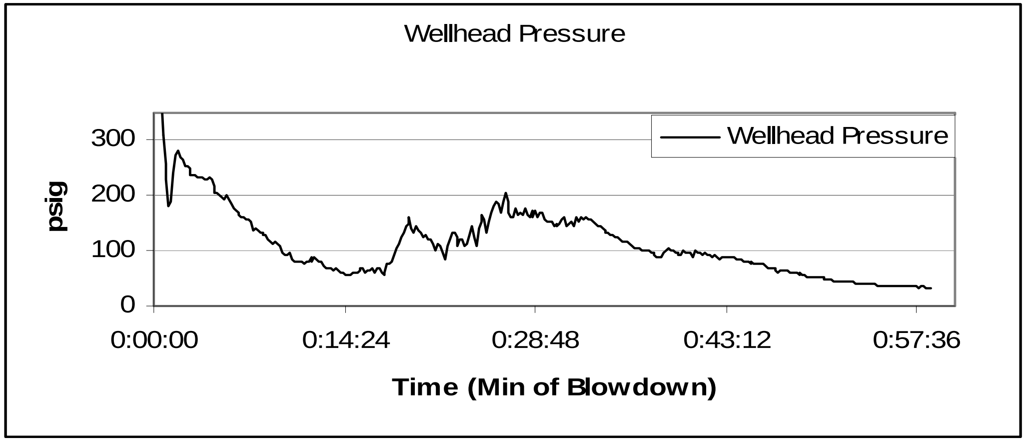
Venting Estimation
Pressure Analysis

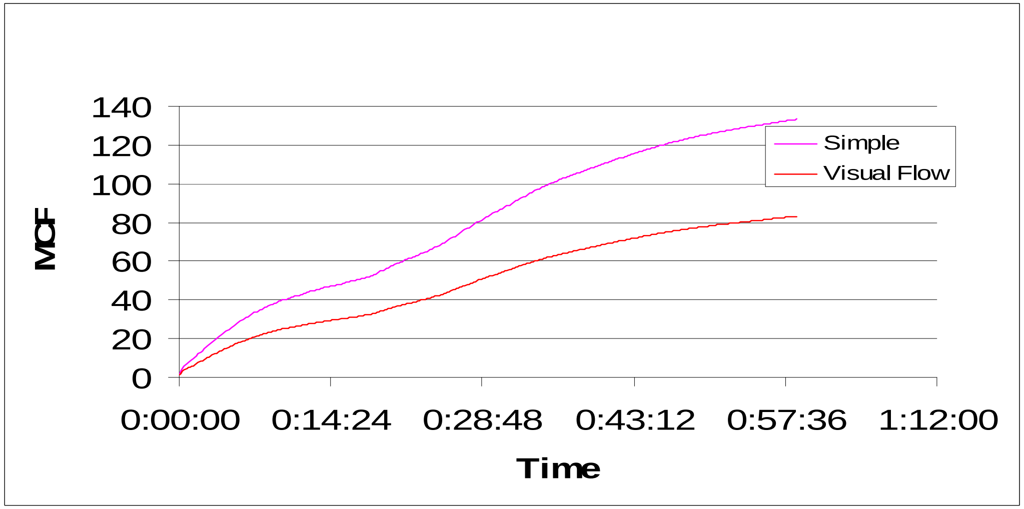
- 17 Wells Studied
- Used Relation Between Pressure & Flow
- Utilized Relief Valve Calculation to Develop Linear Expression
- Choke Flow is Accounted Using this Method





Follow-up Pressure Analysis





Limitations

- **Population Size and Representativeness**
- **Does Not Account for Reservoir Influx**

- Same Pressure Data
- Evaluated Using "Visual Flow" and "Flarenet" Model Systems
- Results:
- **Flow up pipes ≤1.875" diameter:**

  Vent volume (MCF) = 0.49 * time + 8.5
- **Flow up pipes with >1.875" diameter:**

  Vent volume (MCF) =

  1.5 * time + 21
- Enabled Funding for Automation Approach

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

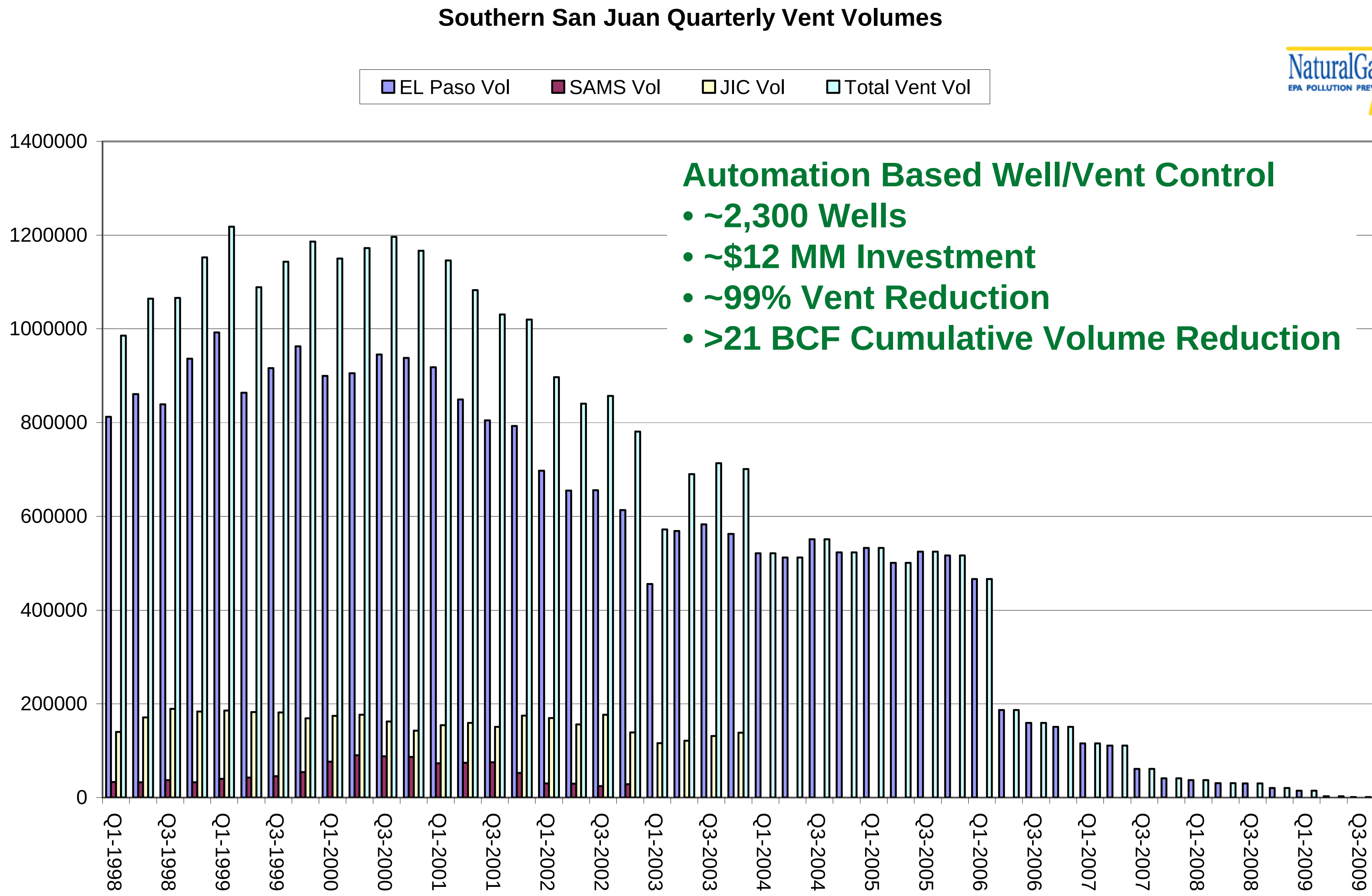
- Formation Specific Vent Volume per Minute

Vent Rates		
Dakota	0.26	mcf/minute
Mesa Verde	0.4	mcf/minute
Fruitland	0.26	mcf/minute
Picture Cliff	0.18	mcf/minute
Cmgl	0.275	mcf/minute

- Minutes of Venting are Tracked – Automation Based
- Agreement With Other Data

Company X Vent Rate Comparison				BP Vent Emissions Methodology				
Well	Vent time	Measured Volume	Co. X Calculation	Dakota	Mesa Verde	Fruitland	Picture Cliff	Cmgl
1	30	4.6	0.6	7.8	12.0	7.8	5.4	8.3
2	6.8	2.6	1.1	1.8	2.7	1.8	1.2	1.9
	7.7	2.7	1.1	2.0	3.1	2.0	1.4	2.1
3	5.3	1.5	1	1.4	2.1	1.4	1.0	1.5
	5.3	1.5	1	1.4	2.1	1.4	1.0	1.5
	7	1.62	1.2	1.8	2.8	1.8	1.3	1.9
4	6	3	1.3	1.6	2.4	1.6	1.1	1.7
	13	4.5	1.3	3.4	5.2	3.4	2.3	3.6
5	7	3	1.02	1.8	2.8	1.8	1.3	1.9

Orifice Metering – Outcome



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

$$q_g = \frac{C_f (14.4 / P_{sc}) P_1}{1000\sqrt{\gamma_g z_1 T_1}}$$

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

- Limitations
  – Simplifying Assumptions