Diverter Gas Separator

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Basic Principles of Downhole Separator System

- Gravity separation is the governing principle for downhole gas separators.
Gas Bubbles flow upward in oil or water at a rate of approximately 6 inches per second. Thus, gas bubbles will be released from a liquid column if the downward liquid velocity is less than 6 inches per second.

A liquid column having an area of 1 square inch travelling at a velocity of 6 inches per second is a rate of approximately 50 BPD.
Natural Gas Anchor

The most efficient downhole gas separators locate the pump intake below the lowest gas entry point.

At least 8 feet from casing perfs to anchor perfs.
Improved Natural Gas Anchor

Maximum flow area in casing annulus below pump.
## Natural Gas Anchor

### Gas Separator Capacity – Pump Below Fluid Entry Zone

<table>
<thead>
<tr>
<th>Casing Size Inch</th>
<th>Dip Tube Size Inch</th>
<th>Description</th>
<th>Annulus Area* Sq Inch</th>
<th>Liquid Capacity BLPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3 ½</td>
<td>Perforated Tubing Sub</td>
<td>23.1</td>
<td>1150</td>
</tr>
<tr>
<td>7</td>
<td>2 7/8</td>
<td>Perforated Tubing Sub</td>
<td>26.7</td>
<td>1335</td>
</tr>
<tr>
<td>7</td>
<td>2 3/8</td>
<td>Perforated Tubing Sub</td>
<td>28.8</td>
<td>1440</td>
</tr>
<tr>
<td>5 ½</td>
<td>2 7/8</td>
<td>Perforated Tubing Sub</td>
<td>12.7</td>
<td>635</td>
</tr>
<tr>
<td>5 ½</td>
<td>2 3/8</td>
<td>Perforated Tubing Sub</td>
<td>14.8</td>
<td>740</td>
</tr>
<tr>
<td>4 ½</td>
<td>2 7/8</td>
<td>Perforated Tubing Sub</td>
<td>6.1</td>
<td>305</td>
</tr>
<tr>
<td>4 ½</td>
<td>2 3/8</td>
<td></td>
<td>8.2</td>
<td>410</td>
</tr>
</tbody>
</table>

**Higher Capacity if Needed**

<table>
<thead>
<tr>
<th>Casing Size Inch</th>
<th>Dip Tube Size Inch</th>
<th>Description</th>
<th>Annulus Area* Sq Inch</th>
<th>Liquid Capacity BLPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ½</td>
<td>1 ½</td>
<td>Perforated Line Pipe</td>
<td>16.4</td>
<td>820</td>
</tr>
<tr>
<td>4 ½</td>
<td>1 ¼</td>
<td>Perforated Line Pipe</td>
<td>10.4</td>
<td>520</td>
</tr>
</tbody>
</table>

*Annulus Area Between Casing and Perforated Tubing Sub (or Line Pipe)  

**Table 1**
"Poor Boy" 
Gas Separator above perforations

A small, long dip tube within a small diameter separator.

Very poor design with a small outer tube ID and long flow paths.

Only acceptable for low volume wells.
“Poor Boy” Gas Separator

Limited Flow Area and Small 3/8 inch holes in perforated sub limit gas exit flow and liquid entry thus reducing separation efficiency.

Tubing Collars prevent perforated sub from laying against casing wall where liquid accumulates.

Feb. 19 – 22, 2012
### Poor Boy Gas Separator

#### Liquid Capacity

<table>
<thead>
<tr>
<th>Outer Barrel Description and Size, Inch</th>
<th>Dip Tube Size Inch</th>
<th>Annulus Area SQ Inch</th>
<th>Liquid Capacity BPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 1/2 Perforated Tubing Sub</td>
<td>1.250</td>
<td>4.87</td>
<td>260</td>
</tr>
<tr>
<td>2 7/8 Perforated Tubing Sub</td>
<td>1.000</td>
<td>3.32</td>
<td>177</td>
</tr>
<tr>
<td>2 7/8 Perforated Tubing Sub</td>
<td>1.250</td>
<td>2.52</td>
<td>134</td>
</tr>
<tr>
<td>2 3/8 Perforated Tubing Sub</td>
<td>0.750</td>
<td>2.26</td>
<td>121</td>
</tr>
<tr>
<td>2 3/8 Perforated Tubing Sub</td>
<td>1.000</td>
<td>1.77</td>
<td>94</td>
</tr>
<tr>
<td>2 3/8 Perforated Tubing Sub</td>
<td>1.250</td>
<td>0.96</td>
<td>51</td>
</tr>
<tr>
<td>2 3/8 Perf Tub Sub &amp; 1.5” Pump</td>
<td>1.760</td>
<td>0.69</td>
<td>37</td>
</tr>
</tbody>
</table>
A good separator must strike a balance between annular flow area, separator flow area, dip tube diameter and pressure drop.

- Outer barrel OD same as collar OD.
- Thin wall outer barrel and dip tube.
- Short flow conduits.
- Large inlet ports.
To get gas capacity of a specific installation multiply the table value by the Pressure at the Pump Intake (psi) and divide by 14.7.

<table>
<thead>
<tr>
<th>Tubing Size Inches</th>
<th>Collar O.D. Inches</th>
<th>Liquid Capacity Bbl/Day</th>
<th>Gas Capacity MCF/D @ 1 Atm of Pump Intake Pressure *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 ½” Casing</td>
</tr>
<tr>
<td>2 3/8</td>
<td>3.0</td>
<td>229</td>
<td>35</td>
</tr>
<tr>
<td>2 7/8</td>
<td>3.75</td>
<td>413</td>
<td>11</td>
</tr>
<tr>
<td>3 ½</td>
<td>4.5</td>
<td>624</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>5.0</td>
<td>778</td>
<td>-</td>
</tr>
<tr>
<td>4 ½</td>
<td>5.6</td>
<td>1016</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 ½” Casing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7” Casing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>154</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>130</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>101</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>79</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>49</td>
</tr>
</tbody>
</table>

* Multiply Gas Capacity times Pump Intake Pressure in Units of Atms.
Packer Gas Separator

- Uses gravity separation like the “Poor Boy” except much more separation area and capacity.

- Higher cost and higher risk of mechanical and sand problems.
A concentric packer type gas separator offers additional liquid and gas capacities.
Diverter Gas Separator
Animation
The liquid falls to these ports and is directed into the pump inlet using large ports and short tube to minimize pressure drop from inlet ports to pump inlet.
Diverter Cups

The diverter cups are constructed from high temperature, flexible, wear-resistant, premium elastomer.
Diverter Cups

Multiple cups can be utilized as desired.
Shear pins are located below the diverter cups. The force required to shear the shear pins is operator selectable. Factory setting is 4000 pounds.

If the diverter cups are not retrievable with the gas separator, the cups will be left in the well with the shear pins and shear collar.
Sand Accumulation

Sand or debris may deposit above the swab cup flow diverter. If 5 inches of sand accumulates over the diverter between the gas separator and the casing wall, the flow of liquid into the gas separator will cease and production from the tubing will cease.

When sand or debris is blocking the gas separator liquid inlet ports, a fluid level test will indicate a high fluid level in the casing annulus and a dynamometer pump card will indicate low or no pump fillage. The well will require servicing.

The diverter cups can be located further from the inlet ports if desired.
Sand Accumulation

When the pump is unseated, liquid in the tubing will flow down the tubing and discharge out of the gas separator through the gas separator liquid inlet ports. The discharging liquid will be at high pressure. This will wash the sand and debris away from above the diverter. The discharging liquid will flow up the casing annulus and carry the sand. Probably ½ of the liquid and sand will flow down through the gas separator into the lower portion of the casing below the diverter. The discharging liquid should carry some of the sand from above the diverter to below the diverter.

Reseat the pump and pump the well. Perform the liquid level test and dynamometer test to insure the well is operating properly.
Sand can accumulate above the gas separator diverter and cause difficulty in removing the gas separator and diverter from the well.

Retrieval of the gas separator and diverter may still be a problem even after flushing sand from above the diverter. A shear pin is located at the bottom of the swab cup diverter on the gas separator so that the gas separator can be removed from the diverter and retrieved from the well. The shear pin holds the diverter swab cups to the gas separator. When the shear pin is sheared, the gas separator can be separated from the diverter swab cups and removed from the well. The shear pin will shear at 4000 # (pre-set or as desired).
Fluid Pressures Surrounding Separator

- 58 psi  Fluid Discharge Pressure
- 60.5 psi  Liquid Inlet Pressure
- 60 psi  Separator Inlet Pressure
Producing BHP Recommendation

PBHP 10% of SBHP insures producing 97% of Well’s Max Rate
Producing BHP Recommendation

PBHP 25% of SBHP produces 90% of Well’s Max Rate

Vogel's IPR Curve

Producing Rate as a percentage of the maximum (100*Q/Qmax)
Echometer Test Equipment

- 5000 psi gas gun
- 15,000 psi gas gun
- 1500 psi Compact Gas Gun
- Liquid Level Tracking
- Pressure Transient Testing
- Plunger Lift Analysis
- Plunger Tracking
- Pump Animation
- Wireless Equipment
Insufficient Gas Separator

A good Gas Separator will separate the gas from the liquid in the casing annulus and cause the liquid to enter the pump if sufficient liquid exists in the casing annulus.

If a well has a high fluid level and the pump is not full, the separator capacity is not sufficient for the well.
The pump is not at fault when gas is present in the pump and liquid exists in the casing annulus. Do not blame the pump.

The gas separator capacity is not sufficient for the well.

This is a common error of many operators.

However, the gas and liquid capacity of the well may exceed the separation capacity of the available space in the Casing/Tubing combination.
High Fluid Level
High Casing Gas Flow Rate
Fo max  Fo from fluid level  Fo Plunger

TWM - Russell Brown: Wagonhound 13-1H <Surface Card> acq-[11/10/11 14:50:56] 0.00 - 30.00: Dyna Cards

Load (K-Lbs) vs Position (in)

Calculated Fluid Load Max 4566 lb
Polished Rod Power 11.4 HP
Polished Rod / Motor Eff. %
Pumping Speed 6.742 spm @ 30 Hz
Pump Card HP 5.5 HP
Pump / Motor Eff. %
Pump Displacement 266.1 BBL/D
Pump Intake Pressure... 1645.6 psi [g]

Damp Up 0.05115
Damp Down 0.05115

Effective Plunger Stroke

Tubing Head Pressure 150.0 psi [g]

Stroke 83
# Fluid Level Test and Analysis

**Cobra Oil and Gas**

**Feb. 19 – 22, 2012**

### Production

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Current</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>96</td>
<td>BBL/D</td>
</tr>
<tr>
<td>Water</td>
<td>73</td>
<td>BBL/D</td>
</tr>
<tr>
<td>Gas</td>
<td>378.0</td>
<td>Mscf/D</td>
</tr>
</tbody>
</table>

### Casing Pressure

<table>
<thead>
<tr>
<th>Casing Pressure</th>
<th>77.1 psi (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing Pressure Buildup</td>
<td>6.9 psi</td>
</tr>
<tr>
<td></td>
<td>1.00 min</td>
</tr>
</tbody>
</table>

### Gas/Liquid Interface Pressure

<table>
<thead>
<tr>
<th>Gas/Liquid Interface Pres.</th>
<th>77.9 psi (g)</th>
</tr>
</thead>
</table>

### Wellbore Depth

<table>
<thead>
<tr>
<th>MD</th>
<th>287.50 ft</th>
</tr>
</thead>
</table>

### Pump Intake Depth

<table>
<thead>
<tr>
<th>MD</th>
<th>7268.00 ft</th>
</tr>
</thead>
</table>

### Formation Depth

<table>
<thead>
<tr>
<th>MD</th>
<th>10400.00 ft</th>
</tr>
</thead>
</table>

### Acoustic Velocity

<table>
<thead>
<tr>
<th>1150 ft/s</th>
</tr>
</thead>
</table>

### Pump Submergence

<table>
<thead>
<tr>
<th>Total Gaseous Liquid Column HT (TVD)</th>
<th>6981 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Gas Free Liquid HT (TVD)</td>
<td>1306 ft</td>
</tr>
</tbody>
</table>

**Annular Gas Flow**

<table>
<thead>
<tr>
<th>511 Mscf/D</th>
</tr>
</thead>
</table>

**% Liquid**

<table>
<thead>
<tr>
<th>19</th>
</tr>
</thead>
</table>

**Reservoir Pressure (SBHP)**

<table>
<thead>
<tr>
<th>1178.2 psi (g)</th>
</tr>
</thead>
</table>

**Pump Intake Pressure**

<table>
<thead>
<tr>
<th>521.4 psi (g)</th>
</tr>
</thead>
</table>

**Equivalents**

<table>
<thead>
<tr>
<th>BHP</th>
<th>77.1 psi (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBHP</td>
<td>1178.2 psi (g)</td>
</tr>
</tbody>
</table>

**Comments**

- Acoustic Test
Stabilized Surface Dynagraphs
Surface Dynagraphs and Pump Card

Feb. 19 – 22, 2012
Diverter Gas Separator Laboratory Test System

Available for demonstration on request On Memory Stick
No Gas at Pump

No gas was flowing with the water in this slide. The liquid enters the separator and falls to the diverter water inlet to the pump.

The rate is 600 BPD with no gas.
The top of the gaseous column at 1 to 3 feet above the top of the diverter gas separator was used to determine maximum gas flow rate for a certain water rate in these tests and these numbers were used in the calculation of the Diverter Performance Calculator.

The water rate was 400 BPD with a gas rate of 45 MCF/D in this slide.
High Fluid Level

The casing above the diverter separator is full of gaseous liquid column up to the top of the test fixture. This rate is 400 BPD with 90 MCF/D.

The gas rate is greater than is used in the Performance Calculator Spreadsheet.
Pressure Across Diverter Cups

At 400 BPD and 75 MCF/D
Diverter Gas Separator Performance Calculator

**ECHOMETER Co.**

**Downhole Diverter Gas Separator Performance Calculator**

**INPUT VARIABLES**

- Liquid_rate: 200 Bbl/day
- Casing_ID: 4.7 inch
- Tubing_OD: 2.5 inch
- Pump_Intake_Pressure: 100 psig
- Pump_Intake_Temperature: 140 Deg F

**OUTPUT**

- Max Gas Rate: 700 MCF/D

Read Maximum Gas Rate in Green Box

**Release**

Diverter Gas Separator Performance Calculator

**Performance Graph**

- Minimum Liquid Rate: 125 Bbl/day
- Maximum Liquid Rate: 700 Bbl/day
- Number of points: 10

<table>
<thead>
<tr>
<th>Liquid Rate Bbl/day</th>
<th>Liquid Velocity ft/sec</th>
<th>Gas Velocity ft/sec</th>
<th>Gas Rate MACF/D</th>
<th>Gas Rate MSCF/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>0.094</td>
<td>15.106</td>
<td>113</td>
<td>114</td>
</tr>
<tr>
<td>182.5</td>
<td>0.137</td>
<td>10.209</td>
<td>76</td>
<td>77</td>
</tr>
<tr>
<td>240</td>
<td>0.180</td>
<td>7.689</td>
<td>57</td>
<td>58</td>
</tr>
<tr>
<td>297.5</td>
<td>0.224</td>
<td>6.156</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>355</td>
<td>0.267</td>
<td>5.127</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>412.5</td>
<td>0.310</td>
<td>4.389</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>470</td>
<td>0.353</td>
<td>3.834</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>527.5</td>
<td>0.396</td>
<td>3.402</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>585</td>
<td>0.440</td>
<td>3.057</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>642.5</td>
<td>0.483</td>
<td>2.774</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>700</td>
<td>0.526</td>
<td>2.538</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

**NOTE:**
Assumes no change in Z factor

**Separator Performance at 100% Efficiency**

**Additional Computed Values**

- Annular_area: 12.44071 sq. inch
- Liquid_velocity: 0.150313 ft/sec
- Gas_velocity: 9.286078 ft/sec
- Gas_rate: 69315 Actual cu ft/D

Liquid rate less than 50 bbl/day per square inch. 622 Bbl/day
**Diverter Calculator Input and Analysis**

<table>
<thead>
<tr>
<th>Input Variables</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid_rate</td>
<td>300 Bbl/day</td>
</tr>
<tr>
<td>Casing_ID</td>
<td>4.7 inch</td>
</tr>
<tr>
<td>Tubing_OD</td>
<td>2.5 inch</td>
</tr>
<tr>
<td>Pump_Intake_Pressure</td>
<td>1500 psig</td>
</tr>
<tr>
<td>Pump_Intake_Temperature</td>
<td>140 Deg F</td>
</tr>
</tbody>
</table>

**Output**

- Max Gas Rate: 4239 MSCF/D

Type desired values in yellow boxes.

Read Maximum Gas Rate in Green Box.
Analysis at 300 BPD – 4.7 ID – 150 psig PIP
A 2 foot sub is needed below the seating nipple if a short strainer nipple is run below the pump.
The Diverter Gas Separator was run to 7500 feet. The pump and rods were installed. The rods unscrewed from the pump. The tubing and separator were pulled to retrieve the pump. Shown are the diverter cups in good shape.

Water was discharged at a show rate into the casing annulus while the separator was run into and out of the well. The liquid level was at 3000 feet.
Negligible free Gas at Pump
Full Pump – Limited Free Gas

![Graph showing pump performance metrics and calculations.](image-url)
Grantham 12 Fluid Level Test

Select Liquid Level | Depth Determination | Casing Pressure | Collars
Production
- Current: Oil 40 BBL/D, Water 130 BBL/D, Gas 73.0 Mscf/D
- Potential: Oil 47.6 BBL/D, Water 154.9 BBL/D, Gas 87.0 Mscf/D
Casing Pressure
- BHP: Oil 119.0 psi, Water 3.8 psi, Gas 1.00 psi, Buildup
Well State:
- Producing
- Annular Gas Flow: 285 Mscf/D
- % Liquid: 20%
- Liquid Below Tubing: Oil 0 %, Water 100 %, % Liquid Below Tubing 47 %
- Pump Intake Pressure: Oil 541.6 psi, PBHP 1180.6 psi, Reservoir Pressure (SBHP) 3500.0 psi (g)

Acoustic Velocity: 1233.18 ft/s
IPR Method: Vogel
PBHP/SBHP: 0.34
Producing Efficiency: 83.9%

Fluid Densities
- Oil 40 deg API
- Water 1.05 Sp.Gr. H2O
- Gas Gravity 0.72 Air = 1

Total Gaseous Liquid Column HT (TVD): 6088 ft
Equivalent Gas Free Liquid HT (TVD): 1235 ft

Feb. 19 – 22, 2012
2012 Gas Well Deliquification Workshop
Denver, Colorado
Grantham 12  Casing Pressure Buildup
Gas Flow 285 MCF/D in Casing Annulus and at Pump
Gas Flow at Pump (Volume)
285 * 15 / 491 = 8700 CF/D
Strainer nipple (64 - 3/16 inch holes) and 2 standing valves may cause excessive pressure drop and cause free gas to be in pump. Maximum Rate is 1258 BPD.
Pump Rate During a Stroke

![Graph showing pump rate during a stroke](image)

- **Plunger Velocity In/sec**
- **Instantaneous Rate - BPD**

**Elapsed Time for 1 Stroke - Seconds**
Grantham 12 Dynamometer
Grantham 12 Fluid Level Test

**WG Unknown**

- Fluid Above Pump: 6088 ft
- Liquid Level: 1395 ft

**Production**

- Date Entered: 02/10/12
- Current: 0 BBL/D
- Potential: 0 BBL/D
- Oil: 0 Mscf/D
- Gas: 0 Mscf/D
- Water: 0 Mscf/D
- Producing Efficiency: 0.00%

**Casing Pressure**

- Pressure: 119.0 psi (g)

**Annular Gas Flow**

- Gas Flow: 284.6 Mscf/D

**Fluid Properties**

- Gas Free Above Pump: 1235 ft
- % Liquid Above Pump: 20.29%
- % Liquid Below Pump: 47.18%

**Wellbore Pressures**

- PIP: 685.5 psi (g) @ 7483 ft
- SBHP: 1324.5 psi (g) @ 10462 ft

**Collar Analysis (Automatic)**

- Acoustic Velocity: 1233 ft/s
- Joints Per Sec: 19.45 Jps/sec
- Joints To Liquid: 44.00 J

**Casing Pressure Buildup**

- Casing Pressure: 119.0 psi (g)
- Buildup: 3.8 psi (g)
- Buildup Time: 1 min 0 sec
- Gas Gravity: 0.7218 Air - 1

**Comments and Recommendations**

- 650#
Use Efficient Downhole Gas Separators to

- Increase oil and gas production
- Improve efficiency of the lift system
- Correct artificial lift problems caused by incomplete pump fillage due to gas interference
- Reduce operating cost
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