Investigation of Gas Carryover with a Downward Liquid Flow

SPE 103151

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Objectives

• Quantify the amount of gas carryover as function of downward liquid velocity
• Examine the effect of pipe geometry
• Examine the effect of gas velocity
• Establish operability guidelines for wells and pumps
## Observed Field Results

<table>
<thead>
<tr>
<th>Well</th>
<th>Water Velocity, ft/sec</th>
<th>Gas Carry Over, Vol %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.32</td>
<td>29.2</td>
</tr>
<tr>
<td>2</td>
<td>0.34</td>
<td>8.8</td>
</tr>
<tr>
<td>3</td>
<td>0.60</td>
<td>12.3</td>
</tr>
<tr>
<td>4</td>
<td>0.64</td>
<td>4.2</td>
</tr>
<tr>
<td>5</td>
<td>0.73</td>
<td>1.7</td>
</tr>
<tr>
<td>6</td>
<td>0.83</td>
<td>17.4</td>
</tr>
<tr>
<td>7</td>
<td>0.88</td>
<td>4.6</td>
</tr>
<tr>
<td>8</td>
<td>1.17</td>
<td>11.9</td>
</tr>
<tr>
<td>9</td>
<td>1.43</td>
<td>7.4</td>
</tr>
<tr>
<td>10</td>
<td>2.51</td>
<td>1.8</td>
</tr>
</tbody>
</table>
CSM Flowloop
CSM Flowloop
CSM Flowloop Schematic
Centrilift Test Facility
Centrilift Test Facility Schematic
Flow Pattern Map – Downward Flow

4 x 2-3/8-in Flow Pattern Map (90° Downward)

- SL-SA
- SL-DB
- SL-BU
- Observed

SL - Slug
SA - Stratified or Annular
DB - Dispersed Bubble
BU - Bubble

Dispersed Bubble
Stratified / Annular
Slug
Annular Flow Video

CCF
Annular Flow Example

4 x 2.375-in Flowloop
Flow Pattern Observations

- Stratified/annular flow prevails for liquid rates less than 5,500-10,000 BLPD (4x2-3/8 in annulus) unless liquid column is maintained.

- Desired flow pattern must be liquid or bubble to maintain pump operability.

- Desired flow patterns can only be achieved by regulating withdrawal rates not “pumping off” the well.
Downward Liquid Flow with Suspended Bubbles
CCF Video

CCF
4 x 2.375-in Flowloop

3.5 SCFM Gas & 0.5 ft/sec Water
Effect of Loop Size

1.0 SCFM Gas Rate

% Gas Carryover vs. Liquid Velocity, ft/sec

- 4.0-in Loop
- 6.0-in Loop
CCF Video

4 x 2.375-in Flowloop

1.0 SCFM Gas & 1.0 ft/sec Water
Effect of Gas Rate in 6-in Loop

6-in Loop
Effect of Gas Rate
(104 °F & Vliq=0.92 ft/sec)

% Gas Carryover

Gas Rate, SCFM

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Effect of Gas & Liquid Rate in 4-in Loop

4-in Loop
Effect of Gas Rate

% Gas Carryover

Liquid Velocity, ft/sec

- 1.0 scfm
- 0.5 scfm
- 3.6 scfm
- 4.3 scfm
Effect of Submergence & Liquid-Gas Entry Point

4-inch Loop
Distance from Water Entry Point

% Gas Carryover vs. Liquid Velocity, ft/sec

- 10 ft Loop 4.8 ft
- 20 ft Loop 4.8 ft
- 10 ft Loop 2.5 ft
- 20 ft Loop 2.5 ft
- 20 ft Loop 13 ft
Effect of Flowloop Temperature

6-in Loop
Effect of Temperature

% Gas Carryover vs. Loop Temperature, °F
Comparison of CSM & Centrilift Results

Effect of Loop Size
1.0 SCFM Gas Rate

<table>
<thead>
<tr>
<th>Liquid Velocity, ft/sec</th>
<th>0.0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Gas Carryover</td>
<td>0.0</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

- 4.0-in Loop
- 6.0-in Loop
- Centrilift
Performance of Centrilift Flowloop with Depressed Liquid Level
Conclusions

• Effective gas separation can be attained by locating the pump inlet below the perforations.

• The 0.5 ft/sec velocity rule of thumb is conservative. Effectively no gas will be carried over in a liquid filled annulus at this liquid velocity.

• The distance between the water entry and gas entry points affects gas carryover.

• Increasing flowloop temperature acts to reduce gas carryover.
Conclusions

• Multiphase flow pattern maps indicate the predominate downward flow pattern is stratified/annular. In order to maintain a filled liquid column, pump intake must not exceed reservoir inflow minus liquid carried up the well.

• Failure to maintain the liquid level in the well will result in excess gas carryover regardless of downward liquid velocity.

• Depressing the liquid level to the pump requires the pump rate to be significantly reduced in order to reestablish a liquid level.