Tubing Anchor Effect on Pump Fillage

Jim McCoy
Jim@echometer.com

Lynn Rowlan
Tony Podio
Ken Skinner
Gas Separator Overview

- Natural Gas Separators
- Poor Boy Separators
- Modified Poor Boy Separators (Collar Size)
- Packer Type Separators
- Special Separators (Twister, Cups)

Many gas separators are **too long** and are poorly designed and constructed (torch).
Gas Separator Liquid Capacity is Based on the Following Principle:

1/4 INCH DIAMETER 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 6 INCHES PER SECOND IS A FLOW RATE OF 50 BPD.
What Kind of Separator is Needed?

ESP is Producing 5MMCF/D  Well Measurements must be performed.
The most efficient downhole gas separators locate the pump intake below the lowest gas entry point.

Gas is not pulled down to the pump perforations unless the liquid velocity is greater than 6 inches per second.

Maximum capacity is obtained using casing annulus.
Gravity separation is the governing principle for downhole gas separators.

Insert Separator has less capacity than using the casing ID.

Downward Liquid velocity greater than 6 inches per second in separator pulls gas into pump.
Sorry “Poor Boy” Gas Separator

Limited Flow Area and Small Holes

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

Seating Nipple Collar Casing Perforated Sub Dip Tube Collar Joint of Tubing
Modified Poor Boy Separators

The outer barrel is commonly enlarged for greater liquid/gas separation capacity.

The space between the outer barrel and the casing should not result in fluid flow in the casing annulus past the ports greater than 10 feet per second.

The outer barrel ports should be machined so that the edges are smooth. Do not use a welding torch to cut the ports.

The dip tube should extend about 4 feet below the outer barrel perforations...excessive length will reduce efficiency.

The lower portion of the outer barrel is used for sand and debris collection...the bottom must be closed with orange peel or bull plug.

A collar on the bottom of the outer barrel can be removed to allow a joint of tubing to be placed below the outer barrel for additional sand collection capacity...the bottom must be closed.
A good separator must balance annular flow area, separator flow area, dip tube diameter and pressure drop.

Outer barrel OD same as collar OD.

Thin wall outer barrel and short dip tube.

Large inlet ports distributed around outer barrel facilitate entry of liquid.
The Collar-Size Separator

The 5 foot long collar-size separator is optimized for the separation of gas and liquid. More area between the outer barrel and the dip tube is obtained by using a larger ID outer barrel for additional gas and liquid separation capacity. Each square inch of area had a separation capacity of 50 BPD. A dip tube length is optimized that results in a free gas and liquid separation length that is long enough to separate most of the free gas from the liquid yet is not excessively long to cause excessive friction loss that results in solution gas being released from the oil. The internal diameter and short length of the dip tube results in a friction pressure drop of less than 1 psi so minimum gas is released from the oil. A joint of tubing can be run below the separator for a sand and debris catcher.
Poor Boy Separator  Franks #1

57% Liquid
~ 18 Mscf/D
Annular
Gas Flow Rate

34.4” Effective
Plunger Stroke
with 34%
Pump Fillage
Collar Sized Gas Separator  Franks #1

Production of 100 BPD with a Full Pump

22% Liquid
~ 161 Mscf/D
Annular Gas Flow Rate
Packer Gas Separator

Inner tube can hold a pump or simply be a long small dip tube to a pump landed above.

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

Higher cost and higher risk of mechanical and sand problems.

Page Oil Tools 1957
Fluids from the formation flow upward to the gas separator and then flow through a concentric annulus to an outlet at the top of the separator which discharges on one side into the annulus.

The gas rises and the liquid falls in the casing annulus.

Pump inlet located at the bottom of the gas separator causing the pressure drop from the liquid at the bottom of the separator to the pump inlet to be negligible.

Diverter Cups or a packer or tail pipe with packer is located below the Separator to force formation fluids into the separator.
The Packer Type Separator requires a Packer below the separator or some type of device to direct the formation fluid flow from below the separator into the bottom of the separator and then out of the top of the separator where the liquid will fall to the bottom of the separator and enter the pump.

Some packers have casing locking devices and other packers require a tubing anchor to anchor the tubing string.
The tail pipe with packer configuration is very effective and will increase production in a well when the pump is set a considerable distance above the formation. The tail pipe reduces the pressure required to push the formation fluids to the pump so a lower PBHP exists.
Tail Pipe Reduces Producing Bottomhole Pressure

![Graph showing the relationship between vertical distance below pump and bottomhole pressure for different pipe sizes.](image)
Acoustic and Dynamometer Analysis of Gas Separator Performance

- **Casing Pressure Buildup**: 3.1 psi, 0.75 min
- **Gas/Liquid Interface Pressure**: 123.1 psi (g)
- **Liquid Level Depth**: 1030.09 ft
- **Pump Intake Depth**: MD 7215.00 ft, TVD 7215.00

**Well State: Producing**
- **Annular Gas Flow**: 298 Mscf/D
- **% Liquid**: 20

**Liquid Below Tubing**
- **Oil**: 0%
- **Water**: 100%
- **% Liquid Below Tubing**: 47%

**Pump Submergence**
- **Total Gaseous Liquid Column HT (TVD)**: 6185 ft
- **Equivalent Gas Free Liquid HT (TVD)**: 1247 ft

**Load (K-Lbs) vs Position (in)**

- **88.6” Effective Plunger Stroke**
- **with 87% Pump Fillage**
Cobra wells northwest of Big Spring indicate that packer type separators with long dip tubes do not perform any better than no separator
(Rory Edwards)
Pump Fillage

- Chevron contacted Echometer to aid in the analysis of low pump fillage problems in wells having high fluid levels, even when the pumps were set below the perforations.
- Poor gas separation or restricted pump intake were initially believed to be the problem, that evolved to the concept of free gas confined below the TAC (analyzed by Dr. Tony Podio).
- Data from three Chevron wells exhibited the same behavior of gas confined below the TAC restricting production.
- Fluid Level Depression Tests were used to confirm that free gas can collect below a TAC and restrict production from a well.
- A TAC set above a pump can result in a low production rate and POC problems.
A field study was conducted using fluid level and dynamometer tests to determine why low pump fillage existed in wells with high fluid levels that had the pump set below the formation. 11 wells were analyzed. Following is the type of analysis that was performed on each well.
### Test Analysis Information

**Low pump fillage and blocked intake**

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Run Time Hours</th>
<th>Prod. BPD</th>
<th>Pump Cap. 24 hr.</th>
<th>Pump Fillage %</th>
<th>Pump Below Perfs</th>
<th>TAC Above Perforations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2504</td>
<td>10</td>
<td>13-9-63</td>
<td>120</td>
<td>28-100 varies</td>
<td>-14</td>
<td>Y</td>
</tr>
<tr>
<td>3104</td>
<td>3</td>
<td>14-7-52</td>
<td>145</td>
<td>15-100</td>
<td>+136</td>
<td>N</td>
</tr>
<tr>
<td>3502</td>
<td>4</td>
<td>6-24-59</td>
<td>130</td>
<td>30 constant</td>
<td>+75</td>
<td>N</td>
</tr>
<tr>
<td>3515</td>
<td>20</td>
<td>67-43</td>
<td>350</td>
<td>12-75 varies</td>
<td>+56</td>
<td>N</td>
</tr>
<tr>
<td>3711</td>
<td>11</td>
<td>48-23-150</td>
<td>200</td>
<td>22-100 varies</td>
<td>-5</td>
<td>Y</td>
</tr>
<tr>
<td>3912</td>
<td>24</td>
<td>95-95-210</td>
<td>185</td>
<td>100 constant</td>
<td>-136</td>
<td>N</td>
</tr>
<tr>
<td>3913</td>
<td>24</td>
<td>34-46-50</td>
<td>185</td>
<td>100 constant</td>
<td>-46</td>
<td>N</td>
</tr>
<tr>
<td>4112</td>
<td>10-24</td>
<td>38-44-512</td>
<td>200</td>
<td>37-100</td>
<td>-12</td>
<td>N</td>
</tr>
<tr>
<td>4114</td>
<td>4-6</td>
<td>18-8-189</td>
<td>200</td>
<td>PRT100-POC 30</td>
<td>+15</td>
<td>Y</td>
</tr>
<tr>
<td>4115</td>
<td>24</td>
<td>98-67-419</td>
<td>185</td>
<td>100 constant</td>
<td>-11</td>
<td>N</td>
</tr>
<tr>
<td>4316</td>
<td>24</td>
<td>2-73</td>
<td>130</td>
<td>100 constant</td>
<td>+27</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Varies:** indicates that the pump fillage periodically increases and decreases.
<table>
<thead>
<tr>
<th>Well</th>
<th>Proposed Well Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>2504</td>
<td>Perform Depression test</td>
</tr>
<tr>
<td>3104</td>
<td>Perform Depression test</td>
</tr>
<tr>
<td>3502</td>
<td>Pull pump and clean intake</td>
</tr>
<tr>
<td>3515</td>
<td>Pull pump and clean intake. Remove rod guides.</td>
</tr>
<tr>
<td>3711</td>
<td>Remove TAC. Remove mule shoe. Optional, run depression test.</td>
</tr>
<tr>
<td>3912</td>
<td>OK</td>
</tr>
<tr>
<td>3913</td>
<td>Test for Tubing leak.</td>
</tr>
<tr>
<td>4112</td>
<td>Remove TAC. Optional, run depression test.</td>
</tr>
<tr>
<td>4114</td>
<td>Check POC and Echometer data. The data varies.</td>
</tr>
<tr>
<td>4115</td>
<td>OK</td>
</tr>
<tr>
<td>4316</td>
<td>Test for tubing leak.</td>
</tr>
</tbody>
</table>
Lupin 3104 Well Characteristics

Top of Perforations 8020
Bottom of Perforations 10046
Tubing Anchor 9140
Seating Nipple 10182
Cavins Desander 10182-10190
Bull Plug Mud Anchor 10222

2.875
PBTD 10317

Run time 3 Hours
Oil Production 14 BPD
Water Production 7 BPD
Gas Production 52 MCF/D

Does mud anchor have perforations? Dip tube?

Area between casing ID and TAC OD is <2.9 square inches.
Fluid Level Test

- Fluid level is about 1000 feet above top of perforations at 8020
PRT Dynamometer Data at Start-up

- Full
- Partial fillage

Graphs showing data over time with labels for LOAI (kWh) and TV (MHz).
PRT Dynamometer Data after 9 Strokes

- Full
- Partial fillage
The gaseous liquid column above the TAC restricts gas flow from below the TAC and causes high pressure gas to accumulate between the bottom of the TAC and the pump. This accumulation of high pressure gas causes a back pressure against the formation that restricts production from the formation. The gas is drawn into the pump on the upstroke because insufficient liquid exists to fill the pump on the upstroke.

Feb. 23 - 26, 2014
1. Confirm the liquid level is above the TAC and the pump chamber is not filled with liquid when pumping.

2. After the well has been shut down for 10 minutes, if the pump is full for only a few strokes plus the fluid level is above the TAC, then the fluid level depression test should be run on the well.

3. Close the casing valve to build casing pressure and depress the liquid level. Continue to pump the well.

4. Shoot fluid levels every 15 minutes as the casing pressure builds-up and the liquid level is being depressed.

5. Acquire 4-5 additional shots after the fluid level is pushed below the TAC and stabilized.

6. The fluid level depression tests verified that a gaseous liquid column existed above the TAC with a free gas (no liquid) between the TAC and pump. The high pressure gas below the TAC restricted liquid production from the well.
The gaseous liquid column above the TAC restricts gas flow from below the TAC and causes high pressure gas to accumulate between the bottom of the TAC and the pump. This accumulation of high pressure gas causes a back pressure against the formation that restricts production from the formation. The gas is drawn into the pump on the upstroke because insufficient liquid exists to fill the pump on the upstroke.

Feb. 23 - 26, 2014
Lupin 3104

The TAC caused a high BHP due to the collection of gas below the TAC and reduced the liquid inflow from the formation into the casing annulus. The problem is not an inefficient gas separator. The problem is lack of production from the formation to fill the pump due to the accumulation of gas below the TAC causing back pressure against the formation.

This collection of free gas below a TAC that restricts production from the formation is not known to the industry.
Lupin 3114

TAC: 7908 Feet  
Perforations: 7978 to 10542 Feet  
Pump Depth: 10559 Feet

Fluid Level 2599 feet above TAC
Lupin 3114 Fluid Level 259 Feet Above TAC
Summary of Lupin 3114 Pressure Transient
Liquid Level Depression Test

Liquid Level = 7659.76 ft
Tubing Anchor 7908 Ft
7/25/13 6:33:40 PM

Liquid Level above
Tubing Anchor 7908 Ft
7/25/13 7:01:24 PM

Liquid Level Below Tubing Anchor
at Pump 10599 Ft 7/25/13 7:10:34 PM

Surface Casing Pressure - Psig

Elapsed Time - HH:MM:SS

Depth to Liquid Level - Ft
Lupin 2513

TAC       7939 Feet       TAC above formation
Perforations  7960 to 10091 Feet
Pump       10553 Feet
Run Time   7 Hours

Fluid Level above TAC
Lupin 2513
Displace the Fluid Level with High Casing Pressure Does Not Solve the Problem of Low Productivity
Unanchored Tubing Prevents Production Reduction

- Casing
- Tubing
- Casing Perforations
- Pump
- No Tubing Anchor
Heavy-Wall Collar-Size Separator for use above TAC

A fluid level depression test obtained by closing in the casing valve and continuing to pump the well is shown near the end of this presentation. The well has free gas accumulation below the TAC which is where the pump was located. This depression test proves that sometimes the pump and separator should be set above the TAC because the TAC restricts liquid flow and causes free gas to accumulate below the TAC. This mechanically strong separator can be run above a TAC.

Two 1 ¼ inch holes at the top of the heavy wall outer barrel allow gas to flow out of the separator.

Two 1 ¾ inch liquid inlet holes are located 5 inches below the upper vent holes.

The outer barrel is heavy wall to allow a TAC to be placed below the separator and pump and seating nipple.

A TAC or mud anchor or bull plug attaches to bottom of separator.
The heavy wall collar size separator is above the tubing anchor and the casing perforations.
The heavy wall collar size separator is above the tubing anchor and above the casing perforations.
The heavy wall collar size separator is above the tubing anchor and above the casing perforations. A dip tube is not needed below the pump.
This presentation and other presentations including videos of gas/liquid separation in laboratory models obtained at the University of Texas in addition to downhole pump animations showing gas compression, pump chamber pressure and pump fillage and also descriptive papers on the different gas separators discussed are available on memory stick from Lynn Rowlan or Jim McCoy or from info@echometer.com.
Copyright

Rights to this presentation are owned by the company(ies) and/or author(s) listed on the title page. By submitting this presentation to the Gas Well Deliquification Workshop, they grant to the Workshop, the Artificial Lift Research and Development Council (ALRDC), and the Southwestern Petroleum Short Course (SWPSC), rights to:

- Display the presentation at the Workshop.
- Place it on the www.alrdc.com web site, with access to the site to be as directed by the Workshop Steering Committee.
- Place it on a CD for distribution and/or sale as directed by the Workshop Steering Committee.

Other use of this presentation is prohibited without the expressed written permission of the author(s). The owner company(ies) and/or author(s) may publish this material in other journals or magazines if they refer to the Gas Well Deliquification Workshop where it was first presented.
Disclaimer

The following disclaimer shall be included as the last page of a Technical Presentation or Continuing Education Course. A similar disclaimer is included on the front page of the Gas Well Deliquification Web Site.

The Artificial Lift Research and Development Council and its officers and trustees, and the Gas Well Deliquification Workshop Steering Committee members, and their supporting organizations and companies (here-in-after referred to as the Sponsoring Organizations), and the author(s) of this Technical Presentation or Continuing Education Training Course and their company(ies), provide this presentation and/or training material at the Gas Well Deliquification Workshop "as is" without any warranty of any kind, express or implied, as to the accuracy of the information or the products or services referred to by any presenter (in so far as such warranties may be excluded under any relevant law) and these members and their companies will not be liable for unlawful actions and any losses or damage that may result from use of any presentation as a consequence of any inaccuracies in, or any omission from, the information which therein may be contained.

The views, opinions, and conclusions expressed in these presentations and/or training materials are those of the author and not necessarily those of the Sponsoring Organizations. The author is solely responsible for the content of the materials.

The Sponsoring Organizations cannot and do not warrant the accuracy of these documents beyond the source documents, although we do make every attempt to work from authoritative sources. The Sponsoring Organizations provide these presentations and/or training materials as a service. The Sponsoring Organizations make no representations or warranties, express or implied, with respect to the presentations and/or training materials, or any part thereof, including any warranties of title, non-infringement of copyright or patent rights of others, merchantability, or fitness or suitability for any purpose.
## Test Analysis Information

### Pump Intake Blockage

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Run Time Hours</th>
<th>Prod. BPD</th>
<th>Pump Cap. 24 hr.</th>
<th>Pump Fillage %</th>
<th>Pump Below Perfs</th>
<th>TAC Above Perforations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2504</td>
<td>10</td>
<td>13-9-63</td>
<td>120</td>
<td>28-100 varies</td>
<td>-14</td>
<td>Y</td>
</tr>
<tr>
<td>3104</td>
<td>3</td>
<td>14-7-52</td>
<td>145</td>
<td>15-100</td>
<td>+136</td>
<td>N</td>
</tr>
<tr>
<td>3502</td>
<td>4</td>
<td>6-24-59</td>
<td>130</td>
<td>30 constant</td>
<td>+75</td>
<td>N</td>
</tr>
<tr>
<td>3515</td>
<td>20</td>
<td>67-43</td>
<td>350</td>
<td>12-75 varies</td>
<td>+56</td>
<td>N</td>
</tr>
<tr>
<td>3711</td>
<td>11</td>
<td>48-23-150</td>
<td>200</td>
<td>22-100 varies</td>
<td>-5</td>
<td>Y</td>
</tr>
<tr>
<td>3912</td>
<td>24</td>
<td>95-95-210</td>
<td>185</td>
<td>100 constant</td>
<td>-136</td>
<td>N</td>
</tr>
<tr>
<td>3913</td>
<td>24</td>
<td>34-46-50</td>
<td>185</td>
<td>100 constant</td>
<td>-46</td>
<td>N</td>
</tr>
<tr>
<td>4112</td>
<td>10-24</td>
<td>38-44-512</td>
<td>200</td>
<td>37-100</td>
<td>-12</td>
<td>N</td>
</tr>
<tr>
<td>4114</td>
<td>4-6</td>
<td>18-8-189</td>
<td>200</td>
<td>PRT100-POC 30</td>
<td>+15</td>
<td>Y</td>
</tr>
<tr>
<td>4115</td>
<td>24?</td>
<td>98-67-419</td>
<td>185</td>
<td>100 constant</td>
<td>-11</td>
<td>N</td>
</tr>
<tr>
<td>4316</td>
<td>24</td>
<td>2-73</td>
<td>130</td>
<td>100 constant</td>
<td>+27</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Varies:** indicates that the pump fillage periodically increases and decreases.
The purpose of the depression tests is to determine if liquid or only high-pressure gas exists below the TAC when the TAC is set in or above the perforations and the pump is set below the perforations.

These liquid level depression tests prove that high-pressure gas can collect in the casing annulus below the tubing anchor and down to the pump. Very little liquid is present below the tubing anchor. The high-pressure gas below the TAC causes a high producing bottomhole pressure and reduces liquid flow from the reservoir into the wellbore that causes very low pump fillage because of the restricted liquid flow into the wellbore.

Low production rates and low pump fillage are due to restricted inflow into the casing annulus and not by poor gas/liquid separation.
Pump Intake Blockage

Do not use a Strainer Screen that causes resistance to liquid flow and low pump fillage when blocked by well debris. This is just one example of liquid flow blockage into the pump intake. Long and small dip tubes can also restrict liquid flow into the pump chamber. When the pump plunger moves upward at a rate of 80-100 inches per second, the liquid flow through the pump intake and dip tube often approaches 250-400 inches per second. Large pressure drops occur releasing free gas and causing low pump fillage.
The heavy wall collar size separator is above the tubing anchor and below the casing perforations.
Trash in Strainer Screen Can Stop Liquid Flow

The debris shown was pulled out of the interior of a separator.

The Teflon tape and rubber wiper parts can collect on a strainer screen and completely block liquid flow into the pump.

Probably, letting the debris get into the pump so that the standing and traveling valves can hopefully pulverize the debris is a better plan than to have the debris block the strainer screen which requires that the pump be pulled in order to clean the strainer screen.
Wireless Dynamometer and Gas Gun for acquiring data remotely and unattended

The wireless fluid level gas gun and the wireless dynamometer offer an easy method for acquiring data on a well for an extended time while unattended. The casing valve can be shut in and the fluid level and dynamometer data can be acquired on a regular periodic basis. This allows the acquisition of fluid level data when the fluid level is above a TAC, and the depression of the fluid level to determine if free gas exists below the TAC. Simultaneously, dynamometer data can be acquired. This is a powerful new tool for acquiring well data so that the well’s behavior can be monitored. The equipment can be left on a well in the afternoon and retrieved the next morning to obtain data overnight.