Acoustic Liquid-Level Determination of Liquid Loading in Gas Wells

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(((ECHOMETER)))
OBJECTIVE:

1. Observe fluid level response in two loaded wells both in flowing and shut in conditions.

2. Confirm the accuracy of fluid level measurements in tubing via fluid level gun vs. gauges.

Quartz Pressure Gauge 1 second Readings

- EC Martinez No 4
  - Tested 05/22/2004 (8:46 AM – 2:25 PM)
  - Acquired 30 Acoustic Fluid Level Shots

- Bruni Mineral Trust “C” BMT C-35
  - Tested 05/23/2004 (9:17 AM – 2:17 PM)
  - Acquired 24 Acoustic Fluid Level Shots
Procedure:

1. Set up quartz gauges (.01 resolution) recording @ 1 pt / second.

2. Rig up fluid level instrument.

3. RIH with gauges.

4. Obtain acoustic fluid levels while making gradient stops.

5. Hang Gauges on bottom (shut in well if flowing).

6. Continue shooting fluid levels and monitor surface pressure.

7. Make additional gradient survey while retrieving gauges from well.
Well Information - EC Martinez No 4

Located near Laredo, TX

Current Production Rate:

- 55 Mscf/D Gas (Below Critical Rate)
- 0.72 BPD Oil & 0.62 BPD Water

Mono-Bore 2.875” Production Tubing (No Casing)

Multiple Zones Perforated: 7511 - 7687 feet

Current Production Method: Soap Sticks
Production Plot - EC Martinez No 4

Early Loaded

Daily Production Rates

Oil Production (bbl)

Water Production (bbl)

Flowing Pressures (psi)


- Oil Production (bbl) Daily
- Gas Production (mcf) Daily
- Water Production (bbl) Daily
- Historical Well Counts
- Flowing Pressures

305,663 mcf
2,224 bbl
LOBO CONS
ZAPATA
Chart - EC Martinez No 4
EC Martinez No 4 - Fluid Level and Gauge Survey

- Prior to Running Gauge at 8:51 AM - 05/22/04
  - Flowing BHP 554 Psi @ 7500 ft from Fluid Level Shot
  - Dropped surface pressure by 83 psi
- At 9:AM Shut-in well and Began Running in Gauges
  - Fluid Level Rose 3000’ during 1st hour After Shut-in
- Shot Fluid Level Periodically and at Each Gradient Stop
- Fluid Level Collapses 3664 Feet During Hours 2 & 3 while Running Gauges to Bottom
- Gauge Pressure Constant ~661 Psi During Hours 4 & 5 while Gauges at 7500 Feet
- At 1:24 PM there was a 79 Psi Difference between BHP Determined From Liquid Level and Quartz Gauge
Acquired using Fluid Level Instrument

Surface and BH Pressure + Liquid Level Depth

EC Martinez No 4

8:51 AM
554 Psi

Flow Shut-in

Dropped Casing Pressure 83 Psi

In 2 hours Height of Gaseous Liquid Level Collapses 3664 Ft.

BHP @ 7500' (Fluid Level)
Casing Pressure
Gaseous Liquid Height

Elapsed Time (DH Pressure Sensor) - Hours

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Denver, Colorado
Quartz Gauge Sensed Pressure Wave from Fluid Level Shot

- Pressure Wave from Shot Detected 1334 Feet Below Surface of Liquid
- 22nd Shot
- Gauges @ 7500'

Graph: EC Martinez No 4
- Sensor Pressure @ 7500 Ft - Psig
- Gaseous Liquid Column Height - Feet
- Elapsed Time (DH Pressure Sensor) - Hours
- Quartz Gauge Pressure
- Gaseous Liquid Height

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Compare Bottom Hole Pressure Acquired from Fluid Level and Quartz Gauge

BHP 79 Psi Difference From Liquid Level To Quartz Gauge

EC Martinez No 4

8:51 AM 554 Psi

662 Psi 1:24 PM

583 Psi

Flow Shut-in

Sensor Pressure
Fluid Level Pressure (7500")
Height Gaseous Liquid Level
EC Martinez No 4 - Observations

- Quartz Gauge @ 1334’ Below Liquid Surface, Detected Pressure Wave from Fluid Level Shots (Surprise)
- Expect Changes to Effect Flowing Bottom Hole Pressure
  - Dropping Casing Pressure Prior to Shut-in
  - Shutting in Well While Running Gauges in Hole
- Changing Fluid Levels During 0-3 Hours of Test “Suggests” BHP Conditions NOT Steady
- From 3.5-6.0 Hours Flowing Hole Pressure Remained a Constant ~661 Psi (Some What of a Surprise)
- Fluid Level Flowing BHP of 554 Psi “DIFFERENT” from Quartz Gauge ~661 Psi Shut-in BHP
Well Info for Bruni Mineral Trust (BMT C-35)

Located near Laredo, TX

Current Production Rate:

• 172 Mscf/D Gas (Below Critical Rate)
• 2.0 BPD Water

Mono-Bore 2.875” Production Tubing (No Casing)

Zones Perforated: 7180-94, 7199-7203, 7206-18, 7221-25, 7230-33 (Tagged Top of Sand @ 7150)

Production Method: Soap Sticks
BMT C-35 - Fluid Level and Gauge Survey

• Well Flowing while Running Gauge to Bottom - 05/23/04
• Shot Fluid Level Periodically and at Each Gradient Stop
• Good Agreement with Measured Gradients (Psi/Ft)
  – Flowing: Gauge 0.075 Versus Fluid Level 0.085
  – Shut-in: Gauge 0.437 Versus Fluid Level 0.437
• During 24.5 Minutes of Time Immediately After Shut-in
  – Casing Pressure Increased 63 Psi
  – Quartz Gauge Pressure Increased 89 Psi
  – Height of Gaseous Liquid Level Collapses 3585 Ft.
• At 9:17 AM Flowing BHP 371 Psi From Liquid Level
• At 11:25 AM Flowing BHP 313 Psi From Quartz Gauge
• From 9:17 to 11:25 Liquid Level Rose 1318 Feet
Stops with Quartz Gauge
Recorded Pressure and Temperature

- Sensor Pressure - Psi
- Sensor Temperature - Deg F

Gaseous Liquid Gradient
Liquid Gradient

Flow Shut-in

Elapsed Time (DH Pressure Sensor) - Hours

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Acquired using Fluid Level Instrument
Surface and BH Pressure + Liquid Level Depth

Pressure @ 7150' from Liquid Level
Casing Pressure
Height Gaseous Liquid Level

Flow Shut-in
In 24.5 Min. Height of Gaseous Liquid Level Collapses 3585 Ft.
63 Psi Pressure Increase

9:17 AM 371 Psi
2:17 PM 385 Psi

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Quartz Gauge Sensed Pressure Wave from Fluid Level Shot

- Pressure wave from Shot Detected 651 Feet Below Surface of Liquid
- Gauges @ 7500'
- Quartz Gauge Pressure
- Gaseous Liquid Height

20th Shot

Quartz Gauge Sensed 0.27 Psi Pressure Wave from Fluid Level Shot

9.736 Seconds is RTTI for Acoustic Shot @15.1944 Hrs

10.0 Seconds Between Peaks One Gauge Reading per Second

0.27 Psi Pressure Wave From Shot Detected 651 Feet Below Surface

20th Shot 12:54 PM
Compare Bottom Hole Pressure
Acquired from Fluid Level and Quartz Gauge
BMT C-35 - Observations

- Quartz Gauge @ 651’ Below Liquid Surface, Detected Pressure Wave & Repeats from Fluid Level Shots
- Bottom Hole Pressure INCREASED when Well Shut-in
- RIH while Flowing from 9:17 – 11:25 AM, the 1218’ Rise in Fluid Level “Suggests” BHP Conditions NOT Steady
- Flowing BHP @ 7150 Ft during Gauge Run in Hole
  - 371 Psi from Fluid Level @ 9:17 AM
  - 313 Psi from Quartz Gauge @ 11:25 AM
- After 24.5 min. Casing Pressure Stopped Building, then Flowing BH Pressure Remained a Constant ~402 Psi
- 655 Feet on Liquid in well @ 12:54 PM Agrees with Corrected Gas Free 685’ Height determined @ 9:17 AM
Acoustic Shots

Initial Shot
Well Flowing

Shot @ 9:17 AM
BMT C-35
Liquid Level @ 3627’
685’ of Gas Free Height

20th Shot
Well Shut-in

Shot #20 @ 12:54 PM
Casing Psi
Not Building

Liquid Level @ 6525’
655 of Liquid in Well
Initial Acoustic Shot @ 9:17 AM

Initial Shot
Well Flowing
Measured 3427.4 Feet of Gaseous Liquid in Well
Calculated 685.4 Feet of Gas Free Liquid in Well

BMT C-35
Gas flowing into well

Closed Casing Valve 1.5
Min. to Determined Gas Flow Rate and % Liquid

PBHP = 373.9 psi

Tested Gas Production = 172 MCF/D
Flowing Gradient Profile from Fluid Level

Shot Liquid Level @ 3753’ From Surface Feet Measured

3427.4’ of Gaseous Liquid Above Formation

297 Psi Back Pressure From Liquid Loading

172 Mscf/D Gas Production

Current
Tubing ID: 2.441”
Turner's Minimum 432 Mscf/D Gas Flow Rate for Continuous Water Removal NOT POSSIBLE

If Unloaded
Tubing ID: 1.25”
206 Mscf/D Gas Continuous Flow Rate.

34 Mscf/D Incremental
Assumptions/Limitations

• Data Requirements
  – Gas Gravity, API Oil Gravity, and Water Specific Gravity
  – Average Joint Length is known

• Gas Cut Fluid Level is based on SPE 14254 (McCoy, Podio, Huddleston)

• Fluid Level detected is not a Liquid Pocket/Slug (Fluid is continuous)

• Well should be in normal conditions
Summary

• Production in Both Wells is Reduced by Liquid Loading

• Any Disturbance (Shut In or RIH) can effect the fluid levels and BHP’s in loaded wells
  – Shutting In Well Changes BHP causes the FL to fall
  – Opening up a well will changes the BHP and the fluid level (think how this affects swabbing)
  – Running Gauges in Hole can result in fluid levels rising (breaking fluid pockets)
Conclusion

Acoustic Fluid Level Shots thru the Tubing can Predict:

- Gas Cut Fluid Level
- Equivalent Amount of Fluid in the Well
- BHP
- Amount of Back Pressure due to Liquid Loading
- Behavior of the Fluid Level as Well Dynamics Change (Optimize Choke Sizes)

Acoustic Fluid Level Shots can be:

- Acquired Simply and Quickly
- Obtained without any Well Intervention (Low to No Risk)
- Used to Identify and High Grade Liquid Loaded Wells