Agenda

Use of acoustic surveillance in gas well deliquification
Course instructor: L. Rowlan (Echometer Company)

- 8:00 – 9:00  General Liquid Level Presentation
- 9:00 – 10:00 Echometer Presentation
- 10:00 - 10:30 Break
Presentation content

- Echometer – Principle
- Data aquisition
- Data processing
- General types of Jobs
  - Transient liquid levels
  - Pumping jobs
  - Static conditions shots (tubing / annulus)
- FBHP calculations
- Summary
Echometer – Principle

- Generates acoustic pulse in the well and measures acoustic reflections
- Reflections are caused by changes in diameter
  - Reduction is seen as a down-kick
  - Increase is seen as an up-kick
  - Fluid level gives large kick and lets no energy through
- Traditionally done down an annulus where tubing collars are counted for depth measurement
- Acoustic liquid level tracking *typically* used for:
  - Beam pump optimization
  - Plunger tracking
  - Liquid loading diagnostics
Annulus Shot Set-up
Tubing Shot Set-up

WECO crossover to M-mas tree cap used to tie into 2” NPT thread
Data Acquisition and Processing
Data Acquisition (1/3)

- Setup Window
  - Coefficients from transducer entered (standard for well services)
  - Zero offset of transducer (standard for well services)
  - Choose implosion/explosion (always explosion unless using higher pressure rating gun)

- Base well file
  - For acquiring data, the only thing that is important is the formation depth
  - Tool uses this depth to determine how long it will “listen” and record reflections
  - Other details can be entered later during analysis
Data Acquisition (2/3)

- Shot is triggered when operator open the valve of the pressure chamber

- Acquire data window
  - Background noise measured by tool
  - Click button to fire shot (start recording)

- Acoustic reflections “heard” by microphone and displayed vs. time in window
Data Acquisition (3/3)

- Wellhead pressure is measured every 15 seconds until button is clicked to stop or 15 minutes elapses.

- Good to take at least 3-4 points to make sure that a good trend is established for THP build up.
Data Processing (1/6)

Select Liquid Level tab

- Move cursor to select feature of interest (liquid level or other equipment)
- Move cursor with buttons, vary step size with sliding scale
- Select the start of the kick
- Scale Up & Down
Data Processing (2/6)

**Depth Determination** tab

- **Select method**
  - *Automatic* - automatically counts tubing collars
  - *Manual* - manually identify tubing collars
  - *Downhole marker* - best option for a shot through tubing
  - *Acoustic velocity* - possible for tubing and annulus
Data Processing (3/6)

Automatic and Manual methods

- Possible for annulus shots only
- Automatic identifies collars response
- Can be fine-tuned with Manual
Data Processing (4/6)

**Downhole marker** method

- Window shown here pops up
- Liquid level mark from previous window is shown
- Move other cursor to approximate area of feature that will be used for correlation
- Select “show one second interval of shot trace”
- Move marker to knee of kick
- Select “enter depth to downhole marker”
- Enter in distance and provide comment for reference
- Important things:
  - Must take depth reference into account
  - Must take into account distance between microphone and depth reference used
- Hit “calculate” and then “done”
**Acoustic Velocity** method

Acoustic Velocity options:
- Manually entered
- Calculated based on SG of gas
- Calculated based on compositional analysis

(Manual gas velocity can be used for approximations or in case where velocity already determined by downhole marker correlation in other shot)

Acoustic velocity depends on:
- Gas gravity / composition
- Temperature along completion
- Pressure in the completion (automatically calculated from measurements taken during the shots)
Data Processing (6/6)

**Acoustic Velocity** method

- Enter Gas SG
- Enter Gas Composition from Analysis
- Enter Acoustic Velocity if Multiple shots are compared
- Make sure BHT has been input
General Types of Jobs
General Types of Jobs

- **Transient liquid levels**
  - Well is in production until gun is rigged up and ready
  - Well is shut-in on wing valve
  - Shots are taken and liquid level is tracked

- **Pumping jobs**
  - Pump something in the well (foam, corrosion inhibitor)
  - Track the top of the liquid slug down the tubing

- **Static liquid level/Shut-in tubing**
  - Well is not in production
  - Close in on wing valve and do a few shots in static conditions

- **Liquid level in Annulus**
Transient liquid levels

Typical program:

- Well is in production when crew arrives
- Swab valve closed
- X-mas tree cap removed
- Echometer rigged up, calibrated and computer interface established
- Chamber pressured up with N2
- Open swab valve
- Close in well on wing valve
- Take first shot a few seconds after shutting in
- Continue to shoot if interesting (if nothing is changing/moving, maybe call it quits, but be sure before you leave!)
Example- COV-53

- Liquid level begins around 1573 meters
- Falls over time until bottom of tubing and packer assembly are seen
- If packer is seen in later shots, may be best to use as downhole marker, then use acoustic velocity from that shot for other earlier shots
  → A 1 meter error on a SCSSV set at 100 meters could mean +/- 30 meters in a 3000 m deep well
- Generally difficult to see or make out features below the packer and accessories
Example- SCH-591

- Liquid level begins around 600 meters
  (Well produces stably at 50,000 m3/d ~ 1757 MscfD)

- Falls over time until bottom of tubing and packer assembly are seen

- Flowing pressure survey run at same time

- Shots carried out with tool string in hole at bottom of well

- Able to see tool string when pulling out of well in later shots (Nice for depth calibration)
Summary for transient liquid level shots

- Well must be in production until ready for shots
  - Gaseous liquid column can move quickly and go below packer
  - Requires good communication with operations for planning and can still be difficult

- Start with relatively high pressure in chamber for shots to have best chance of seeing deep in low pressure wells

- Use as good of data as possible for further analysis

- FBHP calculation is reasonably accurate, but good judgment is required (and further work)
Pumping jobs

- Typical program:
  - Well can be producing or shut-in
  - Rig up echometer along with T-piece for pumping if necessary (used for foam jobs, otherwise fluids can be pumped down kill wing)
  - Shoot baseline shot (or several) before pumping in order to get an acoustic velocity
  - Pump fluids
  - Shoot echometer shots down tubing
  - *Experience shows that fluids move very slow, so be patient and plan on being there for a few hours at least!*
Example – WYK-4 foam batch

- Shot level with no liquid in wellbore as a reference prior to pumping foam
- Easily recognizable features
- Several repeats of SCSSV always seen

Shot several levels after batch job to follow the slug fall

3 ½” X 2 7/8” crossover

Accessories & packer

Top of foam slug
Example – OSH-1 Corrosion inhibitor batch

→ Shut in time optimization
- Cover all tubing length
- Doesn’t reach formation

First, no reflections in well, very high liquid level

Eventually thins out

May fall quicker afterwards

OSH-1 Batch Corrosion Inhibitor Tracking

Depth (m)

Fall rate (m/min)

Fluid changed from plug to hollow cylinder (reflections of packer below were observed)
Summary for pumping jobs

- Take baseline shot to establish an acoustic velocity before pumping (helps to know depth while job going on)

- Plan on being there for at least a few hours if not all day

- Be patient, liquid level will not be clear at first

- High pressure in the gun is not required for the initial, high liquid levels.

- Fluid level is indication of top of liquid, bottom of liquid could be much lower depending on amount pumped and how much it spreads out in well
Static conditions shots

Typical program:

- **Tubing Tests:**
  - Well is not in production
  - Rig up echometer and shut-in wing valve
  - Take some shots down tubing and see results
  - Assuming nothing is moving, only a few shots are required to verify that data is consistent, then rig down

- **Annulus test:**
  - Rig up echometer to annulus
  - Shoot a couple of shots and rig down
COV-28

- SSSV with many Repeat Echoes
- Packer / EOT seen by clear reflection
- In 7” Casing 400 m below packer can see top of open Perfs
  → LL Below Top of Perfs 11347 Ft
MGT-1

- Used to see where fluid level was during well kill
- Difficult to see flapper reflections due to strong signal
- Flapper reflections did come at ~.25 seconds instead of normal ~.5
- Gas velocity was almost 2X as high due to Pressure in well of ~400 bar (5787 Psi)
  → Confirmed by using gas composition in acoustic velocity window
ENA-1 annulus shot

- Possible sometimes to use LNSV outer profile reflection as well for downhole marker method
Summary for static conditions shots

- For annulus shot, Automatic method should be fine.
- For tubing shot, Downhole marker method can also be used if reflections are available from LNSV or other features.
- Connections to annulus must be quite direct (Multiple bends or ID changes between tool and annulus can be impossible to shoot due to loss of signal and multiple reflections).
FBHP Calculation
FBHP calculation

1) Echometer FBHP OK for Dry Gas or when $Q_g < Q_c$
FBHP calculation \([Q_g > Q_c]\]

- Stop flow at surface
- Start shooting every 3-5 minutes
- Observe depression of gas/liquid interface and THP increase
- Use pressure at top of multiple gas/liquid interfaces to establish the gaseous column gradient
- Extrapolate FBHP
FBHP calculation

Qg > Qc

- Fluid level measurement after shut-in
- Shots taken 5 minutes apart

First: mist flow → no liquid level

After a few minutes → liquid level appears and is push down along the tubing
Qg < Qc: 1st shots best for FBHP; Gradient may Change.
FBHP calculation

- Well details (tubing, depths, deviation, etc.) entered in
- THP build-up is measured after each shot

Gas flow rate into well calculated

Gradient of gaseous liquid column is calculated

BHP is calculated

Begin of liquid level is identified

![Graph showing Delta Pressure vs Delta Time]
FBHP calculation

- BHP window
  - Gives calculation of BHP at moment of shot
  - Also some other information on gaseous liquid column
FBHP calculation

Pressure-Depth Traverses After Shut-in

Source: Lynn Rowlan, Echometer, Denver workshop 2007
Summary: FBHP calculation

- Cheap way to get a Rate-FBHP-THP point
- Initial acoustic fluid levels most accurate in determining Flowing BHP
- After well is shut-in for a period of time:
  - Flow regime in the tubing is disturbed
  - Liquid falls back toward the bottom of the tubing.
Additional Testing
Liquid Level Near Surface

0.27 Sec ~ 165 Ft.

0.105 Sec ~ 63.5 Ft.
Liquid Soap Treatment – Acoustic Shots
Surfactant Initially Fell @ 18 Ft/min

After 22 Min. Top of Soap 316 feet from Surface

After 23.4 Min. See thru Soap 359 feet from Surface
Fluid Level Results on Gas Well Treated with Surfactant – Foam 1/3 of Gaseous Liquid Gradient

Tubing Pressure
- 89.4 psi (g)
- Pressure Buildup: 4.3 psi in 2.00 minutes
- Gas/Liquid Interface Pressure: 95.6 psi (g)
- Liquid Level Depth: 2149.55 ft
- Tubing Intake Depth: 6040.00 ft
- Formation Depth: 6197.00 ft
- PBHP: 607.6 psi (g)

Well State: Producing
- % Liquid: 24

Casing Pressure
- 150.9 psi (g)
- Pressure Buildup: -0.060 psi in 1.50 minutes
- Gas/Liquid Interface Pressure: 179.5 psi (g)
- Liquid Level Depth: 6044.83 ft
- Casing Gas Flow: 0 Mscf/D
- % Liquid: 100

Well State: Producing
- % Liquid: 82

Tubing Intake
- 548.7 psi (g)

Casing
- 248.7 psi (g)
Holes in Tubing

▪ DO NOT be surprised if more than 10% of your liquid loaded gas wells have holes in the tubing.
▪ Hole Causes Significant Drop in Gas Production.
▪ Tubing and Casing Pressure are Not Equal with Hole
▪ When flow up tubing; High Fluid Level in Casing Likely Indicates a Hole in the Tubing
▪ High Cost of using a wire-line to set a standing valve and pressure test the tubing may be avoided
▪ Using an acoustic fluid level instrument is a low cost, quick method to troubleshoot a gas well and to identify the presence/location of a hole.
Can’t be a Hole ~ Tubing is New

Hole @ Depth 4325 Ft from Surface
Time 12:12:27  
Csg 125.9 Psi 
Shot Casing/ Flowing Up Tubing

Time 12:24:15  
Csg 135.5 Psi 
Shot Casing/ Tubing Flow Shut-in

Time 12:29:14  
Csg 138.8 Psi 
Shot Casing/ Tubing Flow Shut-in

Time 12:35:58  
Tbg 143.1 Psi 
Shot Tubing/ Flow Shut-in

Time 13:09:38  
Tbg 150.8 Psi 
Shot Tubing/ Flow Shut-in

516  Hole @4325 Ft
Packer Integrity Testing w/ Acoustic Instrument

1. Identify Wells w/ Increased Annulus Pressure
2. DO NOT BLEED OFF PRESSURE
3. Acquire 2 shots on both Tubing and Annulus thru Fully Opening Valve
4. Shoot Fluid Levels on Tubing
   a) Calculate Pressure at Packer
5. Connect Acoustic Instrument to Annulus and Shoot Fluid Level
   a) Determine distance to Liquid Level
   b) Calculate Pressure at Packer
6. Bleed off Annulus Pressure and Shoot Fluid Level to Determine Gas Leakage Rate
Determine Pressure at Packer

Formations:
- Bryson: 4934'
- Caddo: 5894'
- Chappel Lime: 6183'

Wellbore Schematics

Surface Pipe set at 126'

Casing: 5-1/2", 15.5#, Range 2, 8 r. thd., J-55, set @6359'
Top of Cement: 5266'
Hole Size: 8-3/4"

Logs: Electric Log, MicroLogging
Temperature GR CCL
Casing Inspection Lugs

2-7/8" O.D. Tubing set @6140'
J-55, 4.7 ULTRA FG
W/ Baker Retrieval-De Lok Set Packer

P.B.T.D. 6340'
High Fluid Level in Annulus Difficult

Fluid Level = 0.021 Sec  YES

Ringing on Acoustic 0-8 Sec.

Fluid Level = 2.799 Sec?  NO

1. Kick @ 2.799 sec looks like LL
2. 4300 ft/sec AV Packer Fluid
3. 1391 ft/sec AV annulus gas
1. 7.825 sec RTTT from Surface to Liquid Level.
2. Distances down Tubing Calculated Using up-kick from end of the tubing Down Hole Marker at the depth of 6140 ft
Pressure on Tubing Did not Change

1. Tubing pressure was 2425.2 Psi(g)
2. Pressure Buildup Test showed no increase in pressure (no flow of gas into the annulus) over a 1.0 minute interval.
3. The tubing appears to be in a static condition.
1. **Surface pressure measured at 2425.2 Psig**
2. **Pressure calculated at Packer is 2832 psig.**
Static Fluid level acquired down the Casing

1. 0.172 sec RTTT from surface to Liquid Level.
2. Tubing collars not present because of the premium flush joint connections.
3. Distances calculated using 1425.21 ft/sec acoustic velocity from Gas SG of 0.6136.
Pressure on Annulus Did not Change

1. Casing pressure was 92 Psi(g)
2. Pressure Buildup Test Showed no increase in pressure over a 2.25 minute interval. (no flow of gas into or out of the annulus)
3. The Annulus appears to be in a static condition.
1. Surface pressure measured at 92.0 Psig
2. Pressure calculated at Packer is 2802 psig.
Pressure Approximately Equal at Packer

1. Pressures down the tubing at the packer is 2832 psi while pressures down the annulus at the packer is 2802 psi.

2. These two pressures being equal is a good indication that the leak in this well is at the packer.

3. If hole exist in the Tubing, then liquid level should be at hole and the pressures should be equal at hole.
Both the tubing and casing pressure change were measured for a 15 minute time interval after the annulus venting was completed. The tubing pressure decreased by 0.1 psig during the same 15 minute period.
Both the tubing and casing pressure changes were measured for a 15 minute time interval after the venting was completed. The casing pressure increased 3.2 psig during the 15 minute time interval.
Annulus Re-charging through Leak

Casing Annulus pressure buildup rate of 3.2 psi in 15 minutes is due to an average of 15 Mscf/D of gas flowing through the pressure leak over the 15 minute time interval.
Observations/Conclusion

1. Pressure at the packer was equal from the fluid level shot down the Tubing and Annulus.
2. Equal pressure at the packer indicates that the packer assembly is the likely cause of the gas leak from the tubing into the casing annulus.
3. Leak recharge rate through the packer is 15 MscfD, when the casing pressure was dropped from 92 psi to zero (resulted in a 92 psi pressure differential across the packer.
4. 15 MscfD is a slow recharge rate and this leak through the packer may be considered minor.
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<th>Current Process</th>
<th>Advantage</th>
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<td>Determine liquid Level and BHP in Liquid Loaded Gas Well</td>
<td>Flowing Pressure Gradients on Slickline</td>
<td>Save Day(s) of Wireline, crew, and equipment</td>
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<tr>
<td>Flowing Gaseous Column Gradient</td>
<td>Flowing Pressure Gradients on Slickline</td>
<td>Save Day(s) of Wireline, crew, and equipment</td>
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<tr>
<td>Static BHP and Fluid Level ~ Maximum tubing set Depth</td>
<td>Slickline / not done</td>
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<td>Locate Holes in Tubing/Casing</td>
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<td>Monitor Effectiveness of Batch Treatment</td>
<td>Not previously possible</td>
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<td>Track fall rate of plunger, batch corrosion and foam jobs</td>
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<td>Gain understanding of liquid loaded well behavior</td>
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<tr>
<td>Confirm SSSV Close/Open Operation</td>
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Questions