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*i*REPORT

Information Report Acoustic Well Sounder Surveys an Important Tool for Testing Oil and Gas Wells

Sonar Instruments

Sound Waves

Acoustic well sounders are simply sonar or sonic instruments. A sound wave or impulse is generated at surface and a microphone records reflected sound waves, called 'kicks', on either a paper strip chart or digitally onto a computer hard drive. Sound waves are reflected to surface by variations in the path: *obstructions* such as tubing collars or anchors and *expansions* such as perforations or the end-of-tubing. Finally, the entire sound wave is reflected when it hits a liquid (fluid) level or PBTD.

Liquid Levels and Wellbore Anomalies

Fluid Levels

Sonic or acoustic well sounder (AWS) surveys are often referred to as simply 'liquid levels' because of the common application for detecting liquid levels in petroleum wellbores. This knowledge is necessary for completion and production operations, pump optimization and for determining sandface or bottom hole pressures from surface measurements.

Anomalies

Sonic surveys are also used to find wellbore anomalies such as holes in the casing or tubing, something plugging the wellbore (bitumen, wax, salt or sulfite deposits) casing patches or a fish (lost tool).

Sonic Surveys Useful for a Variety of Test Programs

Oil & Gas Well Tests

Application of the AWS for oil well pressure surveys is well documented and avoids pulling rods and pump. Sonic surveys are also useful in a variety of other testing circumstances, including clean-up operations, gas well testing and surface casing vent tests. Acoustic surveys can be utilized in a wide range of wellbore configurations besides shots down an annulus with jointed tubing. These include those with coiled, seamless or endless tubing installed, casing only (no tubing installed) or through tubing (jointed or coiled).

Safety & the Acoustic Impulse

Use Gas Guns Only

The Amoco Bigoray 8–8 casing failure and blowout taught us the perils of using blank gun powder charges to produce the acoustic impulse. Air trapped in the annulus created a volatile situation that turned catastrophic when the shot was fired during a 'routine' AWS survey. Compressed nitrogen (N_2) or carbon dioxide (CO_2) are inert and the only way to go for safety. While nearly everybody still refers to a fluid level 'shot' *please do not infer this to mean gun powder—always use a gas gun to generate the impulse or sound wave.*

Explosion vs. Implosion

Generating a Sound Wave

The most common method of creating the sound wave is to charge the gas gun chamber with compressed N_2 or CO_2. When this is released instantaneously into the wellbore an *explosion* impulse is created. An alternative method, in higher pressured sweet gas, is to allow well gas to instantaneously fill the empty chamber, causing an *implosion* impulse.

Interpretation of Kicks

The difference between explosion or implosion is critical to interpretation of strip chart kicks (either paper or digital). It is easily determined by the very first kick on the strip chart.

Explosion Shots

Explosion shot's first kick is *downward*. Obstructions (collars, anchors, liquid level) also kick *downward*. Expansions (perforation holes, end-of-tubing) kick *upward*.

Implosion Shots

Implosion shot's first kick is *upward*. Obstructions (collars, anchors, liquid level) also kick *upward*. Expansions (perforation holes, end-of-tubing) kick *downward*.

Amplitude

Settings

Most instruments have two amplitude (attenuation) settings: collars and liquid. This is analogous to a volume control, the collar setting is turned up listening for quiet reflections while the liquid setting is turned down listening for a loud reflection (of the entire sound wave returning). Some instruments run the two side-by-side on the same wide paper chart. If you have the other type, be sure to conduct shots using both settings and line them up for accurate and definitive interpretation.

Adjustment

Adjust the amplitude on a paper chart instrument so the pen does not strike the edges. Even worse is the pen striking and sticking on the edge—the amplitude is too high!

Jointed Tubing

Annular Shots

The most familiar application of an AWS is to shoot down the annulus and determine the liquid level depth by counting collars. Jointed tubing sections are screwed together with a collar which is an *obstruction* (thicker than the tubing). A small portion of the sound wave is thus reflected to surface at every collar.

Casing & Tubing

Sonic surveys can also be conducted down casing only (no tubing installed) and down jointed tubing. The joints in these cases are *expansions* (i.e. slightly larger than the pipe) thus their kick is opposite to the first kick (explosion or implosion). Sometimes, however, the kicks are too faint for accurate interpretation. When this happens use the acoustic velocity method, below.

Line up Kicks

To estimate a tubing-side shot with faint kicks, one can line up the annular shot with good collar kicks alongside the tubing shot (from the same well, of course).

Counting Collars

Count Every Collar

Be sure to *count every collar*, the field method of marking the first 10 on a cigarette pack and quickly extending the measurement to the liquid level can result in significant errors! The sound wave actually speeds as it descends and the joint reflections become slightly closer together. The simplest and most accurate method of counting (and most expensive) is to use a purpose designed 11-point scissor caliper (marked 0–10). Nevertheless, mark each 10 joint kicks with a pen for easy checking, adding and quality control.

Calculating Depth from Collar Count

Average Joint Length

To turn joint counts into depth measurements one requires a wellbore description with the number of tubing joints and length (i.e. 168 joints of 60 mm 6.85 kg/m J55 EUE, 1587.6 m). One divides the length by the number of joints to get an average m/joint measurement (i.e. 9.45 m/jt for the example). An average casing joint length can be more difficult to obtain or figure out from a wellbore schematic.

Coiled Tubing

Acoustic Velocity

Sonic surveys can be conducted down casing only, down an annulus with coiled, endless or seamless tubing installed and down the coiled tubing itself, using the acoustic velocity method. This method requires an accurate knowledge of the paper chart speed (cm/s) and the speed-of-sound in a natural gas or acoustic velocity (v, m/s). Computerized AWS units have these calculations internally.

Calculating Depth with Acoustic Velocity

Acoustic Velocity With this method a ruler is used to measure the distance from the first kick to the fluid level kick (cm). Divide this by the chart speed (cm/s) to yield sonic travel time (t, s). Depth (d) is then determined by the formula: $d = (t \bullet v) \div 2$.

Echometer™ If you use an Echometer™ their school notes include paper graphs with acoustic velocities for select gas relative densities. Alternatively, download their Total Well Management™ software from www.echometer.com and one can fudge the example into use for more rigorous calculations with any gas relative density.

Back Calculate Velocity You can back-calculate the acoustic velocity (v) if you can identify kicks that correspond to items of known depth such as a tubing anchor, end-of-tubing or perforations. Use the formula: $v = (d \bullet 2) \div t$.

Velocity Formula In simple terms the acoustic velocity formula is: $v = \sqrt{g_c ZnRT}$. Please refer to SPE 2579.

Calibrating Paper Chart Speed

Know Your Chart Speed Factory setting for an Echometer™ model D is 9.2075 cm/s. This can change with age, environment, level of use and battery charge. Don't pull on the chart as it comes off the machine. Some Echometers™ place a tick mark every second, Sage™ machines mark charts every ¼ second. If you don't have one of these, check your chart speed near an electrical source (i.e. in the office, not out on a lease). Stick something metal (pen knife or paper clip) into the input port, turn on the machine and let it run for more than a second before turning off. Note the regular cycle of the pen (60 Hz in North America). Count off 60 spikes, that's exactly one second, measure the length with a ruler (cm), that's the chart speed (cm/s).

Interpreting Deflections

Or Misinterpreting Depending on wellbore configuration and where the liquid level is, one may observe kicks besides collars and fluid level. Some of these kicks have the potential to be misinterpreted as the liquid level. Please review the examples in appendix 1 for different scenarios.

Double the Recording To be sure your interpretation is correct, run the chart or computer at least twice as long as it takes to observe the liquid level. In other words, run the chart until the impulse hits surface again. This way the paper chart can be folded in half and your interpretation can be verified (on a computer a doubling of the travel time can be confirmed).

Required Data

Liquid Level Only — If a liquid level is the only requirement then tubing data (for collar counts) or gas properties (for velocity calculations) are sufficient. An appropriate gas relative density is critical for accurate velocity calculations. If a wellbore has been purged with air and you are assuming a gas relative density of 0.6 your liquid level will be below PBTD!

Bottom Hole Pressures — If bottom hole pressures are required, appendix 2 is a convenient form outlining the data necessary for calculations as per AEUB G-5 and AEUB.pas file submissions. Note oil, water and gas rates are important for fill-up ratios.

Go to School!

Learn from the Source — Echometer™ holds short courses around the world on acoustic well sounder technology. Their course includes far more detailed information than this brief report. This course is highly recommended for anybody using an AWS. www.echometer.com.

Sonic Survey Qualifications

Qualify Your Application — This information report on AWS surveys is provided as a means of disseminating thoughts, information, knowledge and experience. The very nature of well testing is interpretative, as much art as science, such that there are no definitive answers. The magnitude of impact on quantitative results must also be qualified. Open discussion of the topics presented herein are encouraged.

Selected References

Basic Reference — "Calculating Subsurface Pressure via Fluid Level Recorders" Alberta Energy and Utilities Board Guide 5, 1978. www.eub.gov.ab.ca.

Good Overview — "Well Analysis & Echometer School", including "Analyzing Well Performance XV" (SPE).

Acoustic Velocities — "Determination of Acoustic Velocities for Natural Gas" (SPE 2579).

david@welltestspecialists.com — **David Leech, BTech, Welltest Specialists Inc. 403–256–5767**

≡	***Appendices***
Appendix 1 ⇒	Example Strip Charts Required Data Sheet

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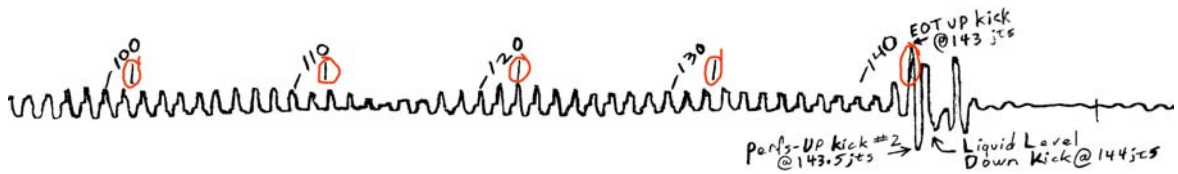
Appendix 1 Examples of Paper Strip Charts and Interpretation of Liquid Levels

1 *Explosion Shot Down Annulus, Jointed Tubing*

- Cigarette Pack Count [1]
- Field Count Out 40 m
- End-of-Tubing (up kick)
- Perforations (up kick)
- Liquid Level (down kick)

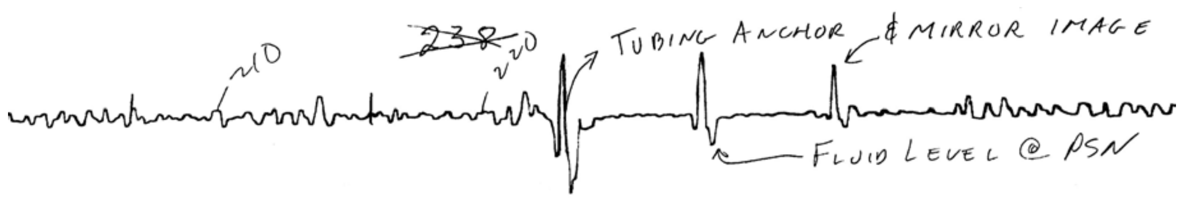
The field cigarette pack count was 140 joints to the liquid level (down kick) which was picked incorrectly anyway. Using a caliper for precise counting got 144 joints, about 40 m difference. Having a wellbore schematic confirmed the end-of-tubing (EOT) count at 143 joints and perforations at 143.5 joints (both up kicks). Fluid was below the perforations.



2 *Explosion Shot Down Annulus, Jointed Tubing*

- Poor Quality Collars
- Field Count Out 100 m
- Tubing Anchor (down kick)
- Liquid Level (down kick)
- Reflection of Tubing Anchor

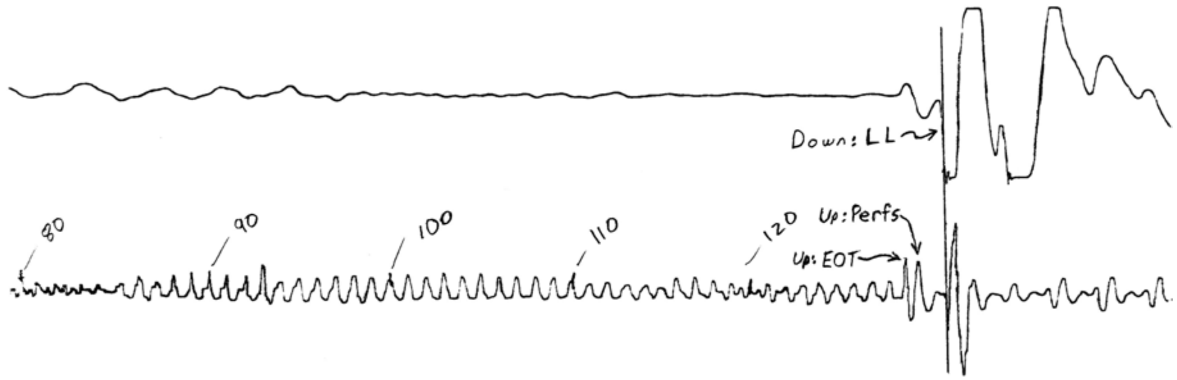
Note the tubing collars are not very well defined and the field count was out by 10.5 joints (about 100 m). Calipers allowed for more careful interpretation. Again, having a wellbore schematic confirmed joints to the tubing anchor. Note the anchor is reflected again after the sound wave hit the liquid level: what you see going down must be reflected coming up, good reason for running the recording (strip chart) twice as long as it takes to hit bottom.



3 *Explosion Shot Down Annulus, Jointed Tubing*

Good Collar Reflections
Fluid Level Trace
End-of-Tubing (up kick)
Perforations (up kick)
Liquid Level (down kick)

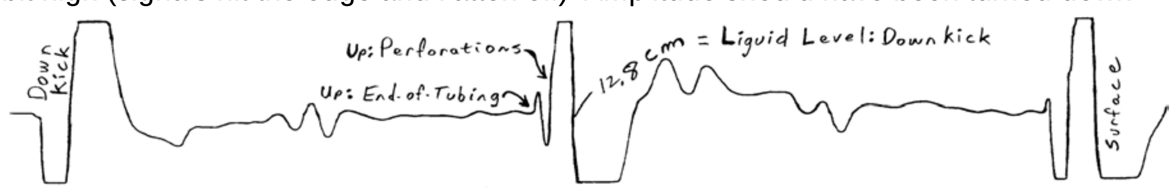
Another conventional example but lined up with the 'fluid level' trace (a lower sensitivity amplitude). Note again, having a wellbore schematic confirmed the EOT and perforations (both up kicks) with the liquid level below the perforations (down kick).



4 *Explosion Shot Down Annulus, Coiled Tubing*

Acoustic Velocity
End-of-Tubing (up kick)
Perforations (up kick)
Liquid Level (down kick)

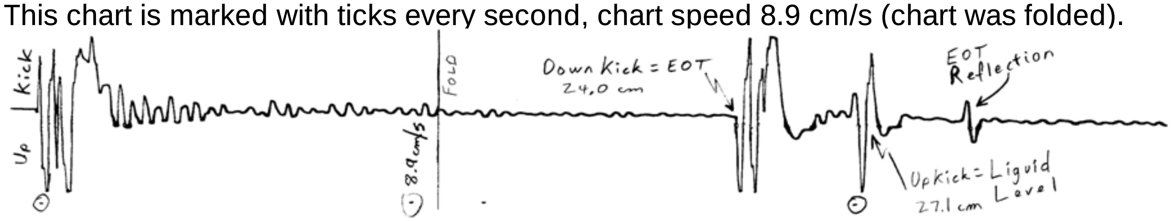
A shallow well showing the proper complete cycle; wave moving down, EOT, perforations (up kicks), liquid level (down kick), wave moving up, surface. Note the amplitude was up a bit high (signals hit the edge and flatten off). Amplitude should have been turned down.



5 *Implosion Shot Down Annulus, Coiled Tubing*

Second Marks [1]
Chart Folded @ |
End-of-Tubing (down kick)
Liquid Level (up kick)

Note the initial up kick of an implosion shot—everything is opposite of an explosion shot. This chart is marked with ticks every second, chart speed 8.9 cm/s (chart was folded).



≡	***Appendices***
	Example Strip Charts
Appendix 2 ⇒	**Required Data Sheet**

Acoustic Well Sounder (AWS) Data Sheet

To Calculate Bottom Hole Pressure as Per AEUB G-5 and Submit AWS.pas file

Company: ____

Engineer: ____

Location: ____

Well Name: ____

License #: ____

Field: ______________________ Pool or Formation: ______________________

Elevations: (KB) ______________________ (CF) ____________________ m

Perforations: ____ mKB CF

or Open Hole: ____ mKB CF

Deviation survey required if whipstocked, deviated, horizontal or multi-lateral. ☐

Tubing Size: ____________________ mm Depth: ____________ mKB ☐ CF ☐

Casing Size: ____________________ mm Depth: ____________ mKB ☐ CF ☐

Number of Tubing Joints: ____________________ @ ______________ m

Average Joint Length: ___________ m or ☐ Assume Joint Length of 9.45 m/jt

Pump Depth: ____ mKB ☐ CF ☐

Any Known Obstructions in Annulus: Tubing Anchor @ ______________ mKB ☐ CF ☐

Other: ____ mKB ☐ CF ☐

Bottom Hole Temperature: ____________________ °C or ☐ Assume 0.036 °C/m

Gas Relative Density: ____________________ or ☐ Assume 0.600

Mole Fraction of N_2: ____________ CO_2: ____________ H_2S: ____________

Oil Relative Density: ____________ or ______________ kg/m^3 or ___________ °API

Water Relative Density: ____________________ or ☐ Assume 1.05

Oil Rate: ________________ m^3/day Water Rate: ______________ m^3/day

Gas Rate: ________________ e^3m^3/d Water Cut: ______________ %

Shut-in Date & Time: ____

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