WELLTEST SPECIALISTS

*i*REPORT

Welltest 103: **Acoustic Well Sounders**

Welltesting & Acoustic Well Sounders

Responsibility Chain Management	Petroleum Reservoir and Production Engineering teams initiate hydrocarbon welltests. Well testing is about measuring and recording flow rate and pressure data. Acoustic Well Sounders (AWS) help estimate bottomhole pressures. Responsibility chain management of data requires an integrated team: from wellsite acquisition or collection; to field-office processing, data validation, and technical reporting; to engineering analysis (PTA, AOF, IPR) and legal submissions (AER, SEC). Corporate directors, managers, and stakeholders depend on reliable, traceable, advice from tests.
Welltesting Team	Talented and experienced wellsite equipment operators are always appreciated for safe running, installation, and recovery of scientific instruments. Knowledgeable and particular field-office technicians are valued for accurate, timely technical reporting. Engineers need to know what standards to expect, and to do whatever data processing might be required to achieve professional acceptance.
Surface Team	Acoustic well sounders, and surface pressure recorders (Welltest 104), are installed, operated, and maintained by surface data crews.
Engineering Team	Engineering is quirky: words are different, acronyms are strange, expectations are high, accuracy and precision are standard protocols. All staff in the responsibility chain need an awareness of equipment, tools, and operations. Practical knowledge about quality control, data validation, and technical reporting ensures consistent, reliable deliverables. Literacy with oil patch nomenclature (words, acronyms, subscripts, superscripts) is requisite for effective communication and comprehension.
Bridging Technical Gaps	Welltest Specialists technical training material has been written to bridge technical gaps and help new staff get up to speed with welltest engineering workflow and workspace.
Pressure Data	This *i*REPORT will focus on topics related to deployment of acoustic well sounder technology for welltesting purposes.

Welltest 103: Acoustic Well Sounders

Acoustic Well Sounders

Welltesting Bottomhole pressures (BHP) are critical to reservoir and production engineering. However, it is not always possible, economic, or necessary to have wireline install subsurface pressure gauges (Welltest 101). Pressures can easily be measured at surface, but calculating the BHP requires knowledge of where gas and liquid levels are in wellbores or the annulus.

Sound Waves Acoustic well sounders (AWS) are sonar or sonic instruments designed to detect the annular fluid levels in oil wells with rods and pump – which block accessibility down tubing. Normally the well is pumped off and there is a gas head on top of the liquid column. Sound waves are generated at surface and a microphone picks up the echo. Return signal amplitude is recorded on an analogue paper strip chart or onto a digital computer hard drive. Example strip charts are provided below.

Reflections Sound waves are reflected to surface by variations in the path: ***constrictions*** such as tubing collars or anchors, or ***expansions*** such as perforations or the end-of-tubing (EOT). Reflection of the entire sound wave occurs when it hits a liquid (fluid) level or plug-back-total-depth (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 of detecting pumping liquid levels in oil wells to help with production optimization (keeping wells pumped off). Those are instantaneous ‘single shot’ tests, which are also used for pressure observation and regulatory Annual test purposes. Automated equipment can also be left on-site for longer pressure build-up welltests.

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).

Application Diversity

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: shots down an annulus with jointed, coiled, seamless, or endless tubing installed; casing shots only (no tubing installed); or shots inside tubing (jointed or coiled).

Safety & the Acoustic Impulse

Use Gas Guns Only

The Amoco Bigoray 08–08 casing failure and blowout taught us the perils of using blank gun powder charges (an ignition source) to produce the acoustic impulse. Air trapped in the annulus created a volatile situation that turned catastrophic when the 12 gauge 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 everybody still refers to the acoustic impulse as a 'shot' *please do not infer this to mean gun powder—**always use a gas gun** to generate the energy 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 (i.e. the entire sound wave returning). Some instruments run the two side-by-side on the same wide paper chart. If you have the single paper strip, 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 clip the edges. Even worse is the pen striking and sticking past the edge—the amplitude is too high!

Jointed Tubing & Casing

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, causing collar kicks.

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 (gas density decreases with increased temperature). The simplest, most accurate (expensive) method of counting is to use a purpose designed 11–point scissor caliper. Nevertheless, mark each 10 joint kicks with a pen for easy checking, adding, and quality control. Example strip charts are provided below.

Calculating Depth from Collar Count

Average Joint Length

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

Coiled Tubing

Acoustic Velocity

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

Calculating Depth with Acoustic Velocity

Acoustic Velocity

For paper charts use a ruler 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•v)÷2.

Echometer™

If you use an analogue Echometer™ their school notes include paper graphs with acoustic velocities for gas relative densities. Alternatively, download their free AWP2000 software from www.echometer.com.

Back Calculate Velocity

You can back-calculate the acoustic velocity (v) if you can identify kicks corresponding to items of known depth like a tubing anchor, end-of-tubing, or perforations. Use the formula: v = (d•2)÷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 paper chart speed 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 models place a tick mark every second, Sage™ machines mark charts every ¼ second. If you don't have marked charts, verify 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 microphone input port, turn on the machine, and run it for just over one second, before turning it off. Note the regular cycle of the pen trace (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. Example strip charts are provided below.

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. Paper charts can then be folded in half to verify your reading and 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) and 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 could be below PBTD!

Bottom Hole Pressures

If bottom hole pressures are required, Appendix 2 is a convenient form outlining data required for calculations as per AER G-5 and AER.pas file submissions. Note oil, water, and gas rates are used 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 *i*REPORT. This course is highly recommended for anybody using an AWS. www.echometer.com.

Sonic Survey Qualifications

Qualify Your Application

This *i*REPORT 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 is encouraged.

Selected References

Basic Reference	"Calculating Subsurface Pressure via Fluid Level Recorders" Alberta Energy Regulator (AER) Guide 5, 1978. www.aer.ca.
Good Overview	"Well Analysis & Echometer School", including "Analyzing Well Performance XV" (SPE).
Acoustic Velocities	"Determination of Acoustic Velocities for Natural Gas" (SPE 2579).

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Examples

Paper Strip Charts

1

Explosion Shot Down Annulus, Jointed Tubing

Cigarette Pack Count ○

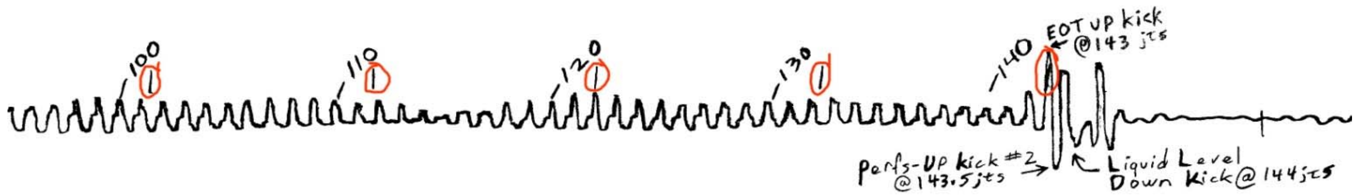
Field Count Out 40 m

End-of-Tubing (up kick)

Perforations (up kick)

Liquid Level (down kick)

Field cigarette pack count (○)was 140 joints to fluid (down kick due to a contraction of space), which was picked incorrectly anyway. Using a caliper, a precise liquid level count was 144 joints, about 40 m difference. Having a wellbore schematic confirmed the end-of-tubing (EOT) at 143 joints, and perforations at 143.5 joints (both up kick signatures due to an expansion of space). Fluid was below perforations.



2

Explosion Shot Down Annulus, Jointed Tubing

Poor Quality Collars

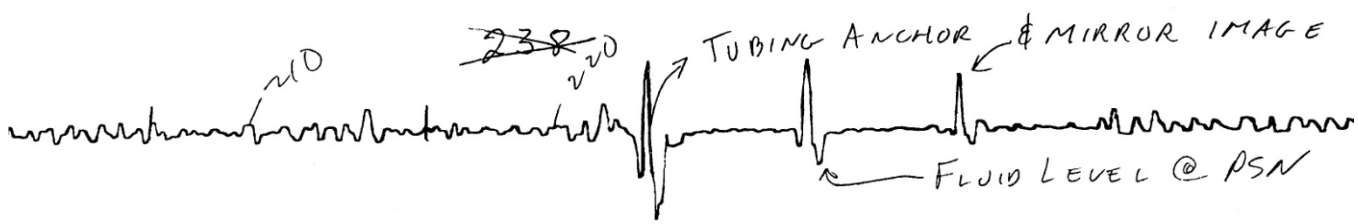
Field Count Out 100 m

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

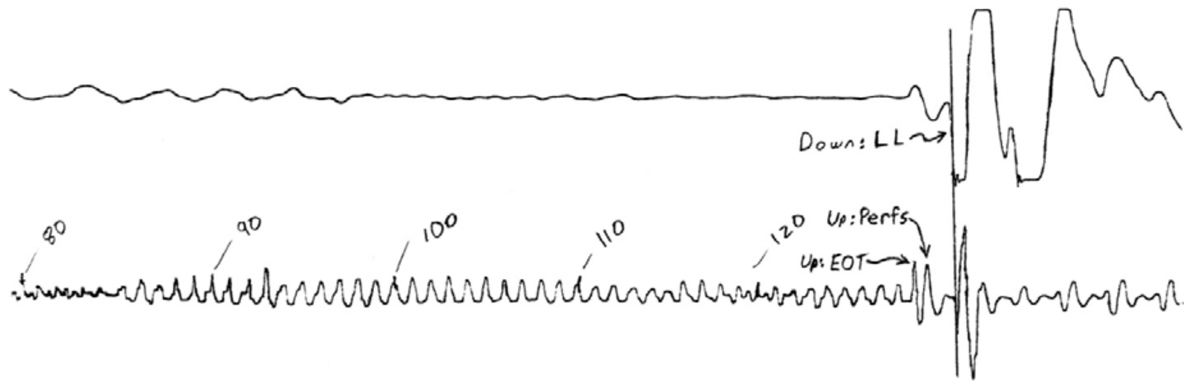
Fluid Level Trace

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 expansion up kicks) with the liquid level below the perforations (a constriction down kick).



4 Explosion Shot Down Annulus, Coiled Tubing

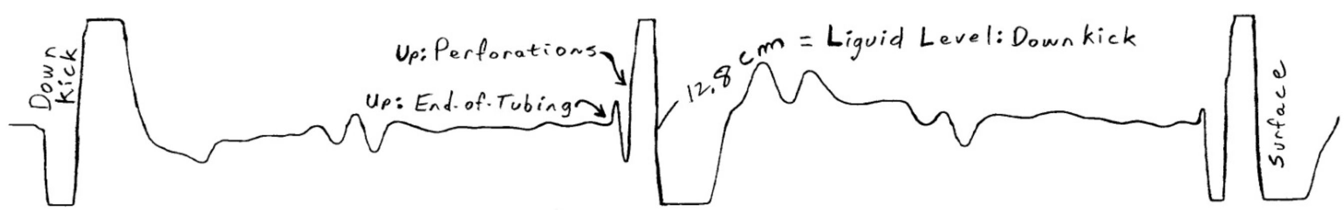
Acoustic Velocity

End-of-Tubing (up kick)

Perforations (up kick)

Liquid Level (down kick)

A shallow well illustrating the complete acoustic 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

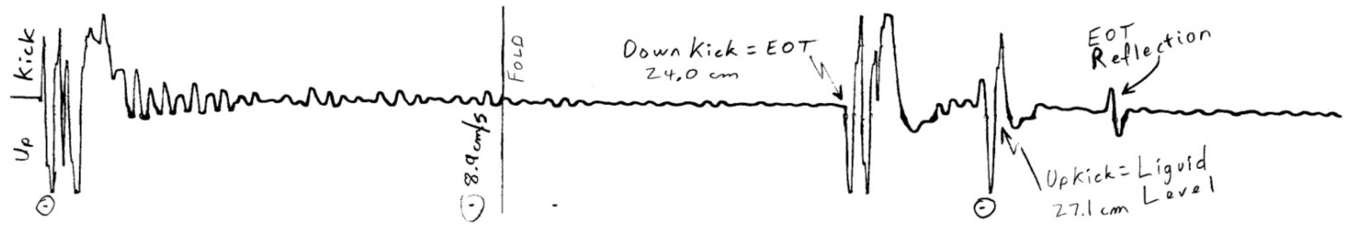
Second Marks ⊙

Chart Folded @ |

End-of-Tubing (down kick)

Liquid Level (up kick)

Note the initial up kick of an implosion shot—kicks are opposite to an explosion shot. Chart is marked with ticks every one-second, chart speed 8.9 cm/s (chart was folded for illustration).



Welltest 103: Acoustic Well Sounder Data Collection Sheet

Company:____

Engineer:____

Location:____

Well Name:____

License #:____

Field:__________________ Pool or Formation:____________________

Oil Rate:__________ m^3/day Water Rate:________ m^3/day

Gas Rate:_________ e^{3}m^3/d Water Cut:________ %

Shut-in Date & Time:______________________________________

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

Notes:____

____

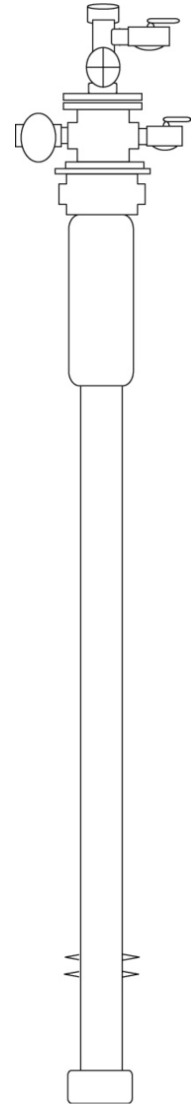
____

Data required to calculate Bottomhole Pressures (BHP) as pre AER G5.

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

Elevation (KB):____________ m

Elevation (CF):____________ m



Tubing Size:_____________ mm

Depth:_____________ mKB CF

Casing Size:_____________ mm

Depth:_____________ mKB CF

Number of Tubing Joints:_________

Length:__________________ m

Average Joint Length:____________ m

or ❑ Assume 9.45 m/jt

Perforation (top):__________ mKB CF

Perforation (bot):__________ mKB CF

Open Hole (top):__________ mKB CF

Open Hole (bot):__________ mKB CF

Pump Depth:____________ mKB CF

Known Obstructions in Annulus:

Tubing Anchor:_________ mKB CF

Other:________________ mKB CF

Conforms with AER electronic Digital Data Submission (DDS) of AWS.pas files.

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