DUAL SHOT ACOUSTIC TECHNIQUE

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ABSTRACT

The Dual Shot Acoustic Technique is used to troubleshoot Gas-lift Wells by looking for pressure communication between tubing and casing. One gas gun is fired, sending a pressure wave down the tubing. Simultaneously, a second gas gun listens to the casing. Both microphones are attached to the same input to record the acoustic signal. The tubing microphone is disconnected immediately after creating the traveling pressure wave at the surface of the tubing, and the microphone on the casing detects signals that pass through defective valves or checks or holes in the tubing. The acoustic signal is created in the tubing, then holes and malfunctioning check and gas-lift valves pass the pressure wave into the casing. To account for the pressure wave traveling down the tubing and up the casing, the average acoustic velocity of just prior tubing and casing shots is used for accurate depth determination to the detected communication.

INTRODUCTION

Efficient operation of artificial lifted wells normally requires the fluids moving to the surface in the tubing to be isolated from the casing annulus. Meaning, in a properly designed gas-lift installation, all gas-lift valves above an operating valve should be closed, and all valves below should be open. When upper valves are left open, or are open, inefficient multipoint gas injection can result, preventing unloading to the maximum lift depth for which the installation was designed. Leaks and pressure communication through the tubing usually results in failure of the Lift Method. Historically, there has not been a simple method to identify a leaky valve in a gas-lift well by shooting a traditional fluid level down the tubing or casing. The resulting analyzed shot does not show sufficient detail to determine if any communication exists between the tubing and casing as a result of a leaky gas-lift valve. Past in-depth analysis has shown that if high pressure and low noise conditions exist, a detailed study of the reflections across each valve may reveal an inconsistent reflection pattern on one valve that might indicate a problem valve, but using this acoustic approach is time consuming and unreliable. In unconventional reservoirs, many traditional sucker rod lift operators have made a significant shift toward gas-lift as the primary method. A simple method is needed to find and identify leaks or communication between the tubing and casing due to holes or faulty equipment.

The distance to the fluid level provides beneficial information throughout the life of a gas-lift well[1]. Typically, a traditional fluid level shot utilizes an acoustic gas gun to release a pressure wave into the tubing or casing, then analysis of the resulting reflections on a strip chart or computer software will determine the depth to the fluid level. In gas-lift wells, gas-lift mandrels are excellent downhole markers and are used to determine very accurate distances to the fluid level or other anomalies in a well.

THE DUAL SHOT METHOD

The Dual Shot Method is a newly discovered acoustic technique used to help diagnose problems with gas-lift wells by revealing communication points between the tubing and casing above the liquid level. The following is a step by step instruction on how to perform the Dual Shot Method.

Displace Fluid in the Tubing

It is first necessary to displace the fluid in the tubing down to the operating valve. Displacing the fluid to a level sufficient for effectively performing the Dual Shot test is a balancing act of Shut In time. The well needs to be Shut In long enough for the fluid to settle and noise to subside, but without being Shut In so long that the liquid level moves up the tubing enough to cover the gas-lift valves that could be leaking. It is not possible to see reflections below the liquid level in an acoustic shot. The liquid level should be sufficiently low so that the pressure wave fired from the acoustic gun is able to travel past all gas-lift valves down to the operating valve. As a reference, the shut in time of the gas-lift well in Example 1 was

24 hours. A repeat of the Dual Shot test 96 hours after shut in was not possible because the liquid level had moved up high enough in the tubing to cover the majority of the gas-lift valves.

Equipment Description

Two acoustic fluid level guns are used in conjunction with a well analyzer and laptop computer. The test is best accomplished if the user has at least gun with remote fire capability. The remote fire acoustic gun should be used as the gun that is firing the shot. The second acoustic gun can be either a manually fired or remotely fired gun and should be the same working pressure as the gun firing the shot. The test can be set up one of two ways. An operator can fire the shot down the tubing and observe the reflections or “listen” on the casing side, or the shot can be made down the casing and “listen” on the tubing side. Both options are illustrated in this paper. For the purposes of this procedure description, the gun firing the shot is connected to the tubing and the gun that will be recording the shot is connected to the casing.

Shot Setup

The remote fire acoustic gun is used to fire a shot, sending a pressure wave down the tubing (hereafter referred to as the Fire Shot Gun). The second gun is used as a listening device only to listen down the casing (hereafter referred to as the Listen Gun). As the pressure wave is released into the tubing by the Fire Shot Gun, and travels down the tubing annulus, the casing gun will only hear background noise for the duration of the shot unless there is a point in the casing that has communication with the tubing (i.e. a hole in the tubing, gas lift valve that is open or leaking). The point at which the casing gun microphone detects a pressure wave entry and records a downward kick reflection will be the point of communication.

Connect the Fire Shot Gun (remote fire gun) transducer/solenoid cable from the gun to the Well Analyzer, and a microphone cable from the gun to a BNC Coax T adapter on the Well Analyzer. Connect a second microphone cable from the Listen Gun to the other side of the tee on the Well Analyzer. As soon as the shot is fired through the automatic Fire Shot Gun, unplug the Fire Shot Gun microphone cable from the T at the well analyzer as shown in Figure 2. The software program does not start recording a shot until the software detects an acoustic signal (loud noise) that results in the microphone producing a large millivolt signal compared to the normal background noise microphone output. The acoustic signal created by the Fire Shot Gun must be registered by the software in order for the shot acquisition to begin. However, in order to isolate the casing reflection response of the Listen Gun and prevent multiple confusing reflections from being recorded down both the tubing and casing, it is necessary to remove the microphone cable from the tubing as quickly as possible once the shot has been fired and the beginning of the shot is registered as time 0.

Identify Points of Communication

The pressure wave from the Fire Shot Gun travels down the tubing. The pressure wave will expand or contract depending on any change in cross sectional area it encounters. If there is any communication between the tubing and casing, a portion of that pressure wave will pass through that point of communication and cross over into the casing. The Listen Gun connected to the casing will detect the pressure wave intrusion and record it as a downward reflection kick. If there is no communication, there will be no reflection kick registered and the casing side acoustic signal being recorded would remain silent. The resulting shot would be only continuous background noise.

Acoustic Velocity Calculation of Dual Shot

The resulting acoustic pressure wave fired from the Fire Shot Gun travels down through the tubing gas and up throught the casing gas as illustrated in Figure 2. Because the pressure wave is traveling down the tubing and up the casing, it is traveling through different pressures and temperatures and gas compositions on the inside and outside of the tubing. The acoustic velocity at which the pressure wave travels down the tubing is likely different than the acoustic velocity the wave encounters up the casing. When the software calculates a depth, it assumes the pressure wave’s Round Trip Travel Time occurs at one calculated average acoustic velocity[2]. In order to improve the depth calculation accuracy, the operator should use the average of the tubing and casing acoustic velocities. Therefore it is essential that separate pre-Dual Shot fluid level measurements be taken down both the tubing and casing and accurately analyzed before the Dual Shot is acquired. Acoustic velocities, that may be different because gas compositions are different, are known both for the tubing and for the casing. Then on the Dual Shot, use the average of the tubing and casing acoustic velocities to calculate the depth to the communication reflections. Note, any kicks/reflections seen in the pre-Dual Shots of the tubing and casing need to be properly identified as all kicks/reflections will be seen in the Dual Shot below the point of tubing/casing communication.

Determine Reason for Communication

Using the calculated depth to the point of communication, refer to a wellbore schematic or utilize a wellbore overlay to identify the location of the communication and determine whether the point of communication is occuring due to a malfunctioning gas-lift valve or a hole in the tubing.

EXAMPLE 1

Using a shot overlay feature, it is possible to see all three shots, the tubing pre-shot, the casing pre-shot and the Dual Shot, on one display as seen in Figure 3. In the background of the display, a wellbore overlay displays the location of gas-lift valves and other wellbore features. The casing pre-shot displays a downkick at the liner top at 11 seconds, followed by the Liquid Level downkick at 12 seconds and the up kick that follows is the wave going back past the liner top and expanding in the larger casing.

The Tubing pre-shot displays reflections across several gas-lift valve locations. Two upkick reflections at approximately 10.4 and 10.5 seconds, located between gas-lift valves eight and nine are prominent, followed by the Liquid Level downkick just above the tenth gas-lift valve.

The Dual Shot is the top trace displayed in Figure 2. It was shot by the automatic gun down the casing and recorded by the manual gun listening on the tubing. The large reflection kick occurring just after 3 seconds occurred when the microphone cable was plugged into the tubing gun. There was no BNC T used on this particular shot, so the cable from the Fire Shot Gun was unplugged from the well analyzer just after the shot was fired, and the microphone cable from the Listen Gun was plugged into the well analyzer as quickly as possible. The well appears quiet until just after 9 seconds when the wave passes the seventh valve down and a downward kick is observed, suggesting that valve is open and there is communication into the tubing. Another downkick occurs at 10 seconds at the eighth valve with more amplitude than the previous valve. Two smaller down kicks occur at 10.4 seconds and 10.5 seconds that correspond with the two small up kicks from the tubing shot, supporting evidence that points to two small tubing holes. Once pressure communication occurs from the casing to the tubing, pressure waves are now traveling both in the casing and tubing, meaning additional kicks may display from both the tubing and casing further down the shot trace. This is evident at the next downkick at 10.9 seconds. This kick occurs at both the 9th gas-lift valve and the liner top, with greater amplitude than the previous two reflections across the gas-lift valves. The down kick at 10.9 seconds is caused by the pressure wave in the casing hitting the liner top and returning the signal back through the open 7^{th} and 8^{th} valves; to determine if the 9^{th} valve is also open is impossible because the liner top and the 9^{th} valve are too close together. The next kick at 11.6 seconds is the liquid level in the tubing, and the kick at 12 seconds is the liquid level in the casing.

The Dual Shot Method showed gas-lift valves 7, 8 and 9 were either stuck open or leaking (cut), and 2 small holes existed in the tubing between valves 8 and 9 at approximately 6,211 ft and 6,276 ft respectfully. The Dual Shot procedure also works well to definitively verify the presence of very small holes in tubing.

Physical Evidence after Pulling Tubing String

Shortly after these testing results the tubing string was pulled and the valves inspected. Externally, the valves looked to be in good shape with little to no scale build up on the exterior. Upon inspection of the valves at the valve manufacturing facility, the manufacturer's representative determined that valves 7, 8, 9 and 10 were all defective. Valves 7 and 8 were packed full scale and 9 and 10 contained a mixture of dehydrated paraffin and scale. Had valve 9 not been so close to the liner top and valve 10 not been under the fluid level, this procedure would have very likely also shown these valves also to be stuck open. The Dual Shot acoustic trace analysis determined the distance to the holes in tubing were at a depth of

6,211 ft and 6,276 ft. The depth determined from the analysis of the Dual Shot was within 5 feet of the measured depth to the holes at 6,216 ft and 6,281 ft.

EXAMPLE 2

The resulting Dual Shot is shown with the casing pre-shot overlay in Figure 4. The casing pre-shot has been properly analyzed. Upkick reflections are evident across each gas-lift valve on the casing pre-shot and a clear liquid level is identified. The depth to the liquid level is calculated using the 10^{th} gas-lift valve. The Dual Shot shows a shot fired at 0 seconds. There is only background noise from the time the shot is fired until a clear downkick appears at the location of the 8^{th} gas-lift valve, verifying the point of communication is due to the malfunctioning valve.

EXAMPLE 3

The Dual Shot is displayed between the tubing and casing pre-shots. The upkick from the end of the tubing on the tubing pre-shot appears at 12.2 seconds followed by the liquid level kick at 12.6 seconds. The casing pre-shot shows reflection kicks across the gas-lift mandrels with the liquid level located just above the operating valve. The Dual Shot in the middle of Figure 5 shows only background noise in the casing until the Listen Gun detects the pressure wave passing through the communication leak from the Tubing at the 10^{th} valve. If there had not been communication at the 10^{th} valve, the Dual Shot would have shown only background noise for the entire duration of the shot. The Liquid Level marker is placed at the point of communication for depth calculation purposes. The software automatically calculates the depth to the position of the liquid level marker.

Figure 6 shows the Acoustic Velocity calculations for each shot. The acoustic velocity of 1255 ft/sec down the tubing was calculated using the end of the tubing as the downhole marker. The casing acoustic velocity of 1177 ft/sec was calculated using the 9^{th} gas-lift valve as the downhole marker. For the Dual Shot depth calculation, the average of the tubing and casing acoustic velocities, 1216 ft/sec, was manually entered into the software program to determine the depth to the communication leak.

EXAMPLE 4

The Dual Shot application for wireless equipment is achieved using plunger tracking software. Multiple channels of acoustic and pressure data are simultaneously streamed from the wireless sensors into the software. Acquisition is started before the shot is fired. Once acquisition has begun and the pressure and acoustic data from the Fire Shot gun on the Tubing and the Listen gun on the casing are displayed as shown in Figure 7, the Fire Shot gun is manually fired, and the acquisition will run until it is manually stopped once the fluid level reflections are evident. Annotations within the software are used to mark the events from the tubing shot, such as the shot being fired (A1), the upkick at the end of the tubing (A2), and the liquid level in the tubing (A3). These annotations can now be overlaid onto the casing trace that was obtained using the Listen Gun on the casing as shown in Figure 8. The point of communication, as well as subsequent reflections kicks, is identifiable on the Dual Shot Listen Gun acoustic trace.

CONCLUSION

The Dual Shot Method is used to find leaky or malfunctioning check valves and gas-lift valves. Passing a pressure wave from one pipe into an adjacent pipe allows identification of points of unwanted pressure communication and unwanted loss of integrity of the tubing string. Knowing the acoustic velocity profile of a well and having an accurate gas-lift wellbore schematic provide critical information for depth calculation accuracy needed for determining depth and likely cause of communication between the tubing and casing. The physical evidence shown in the examples in this paper proves the Dual Shot to be an invaluable tool to efficiently diagnose gas-lift valve problems without having to use expensive outside services.

References

1. Taylor, C., Rowlan, L., McCoy, J. : “Acoustic Techniques to Monitor and Troubleshoot Gas-Lift Wells,” paper SPE-169536-MS presented at the SPE Western North American and Rocky Mountain Joint Regional Meeting held in Denver, Colorado, USA, 16-18 April 2014.
2. Rowlan, O., McCoy, J., Becker, D., Podio, A. : “Advanced Techniques for Acoustic Liquid Level Determination,” paper SPE-80889-MS presented at the SPE Production and Operations Symposium held in Oklahoma City, Oklahoma, 23-26 March, 2003.

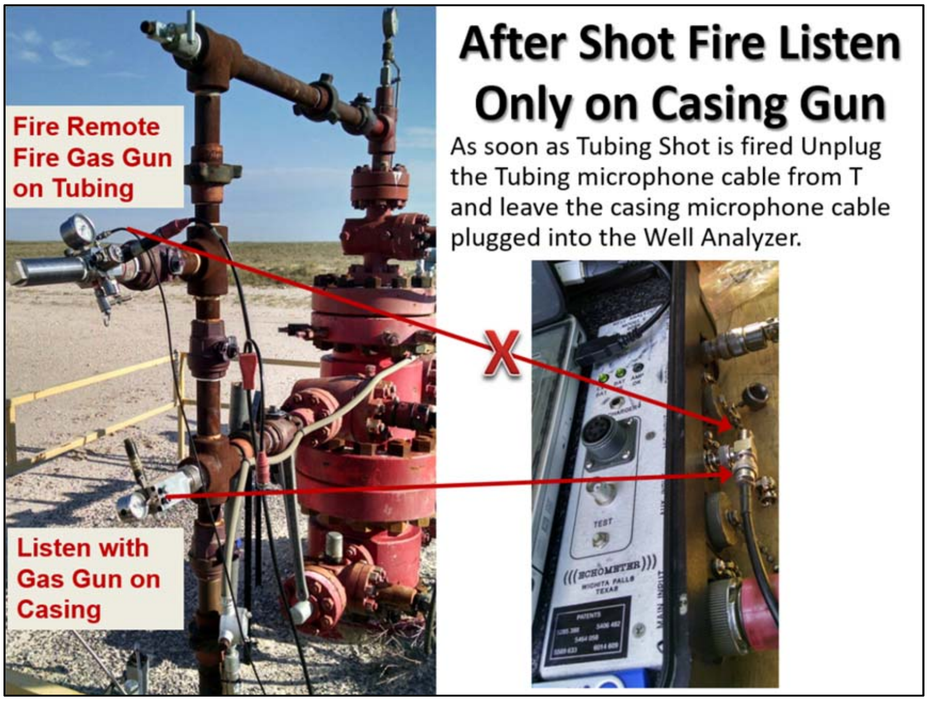

Figure 1 – Equipment Setup with well analyzer and BNC T

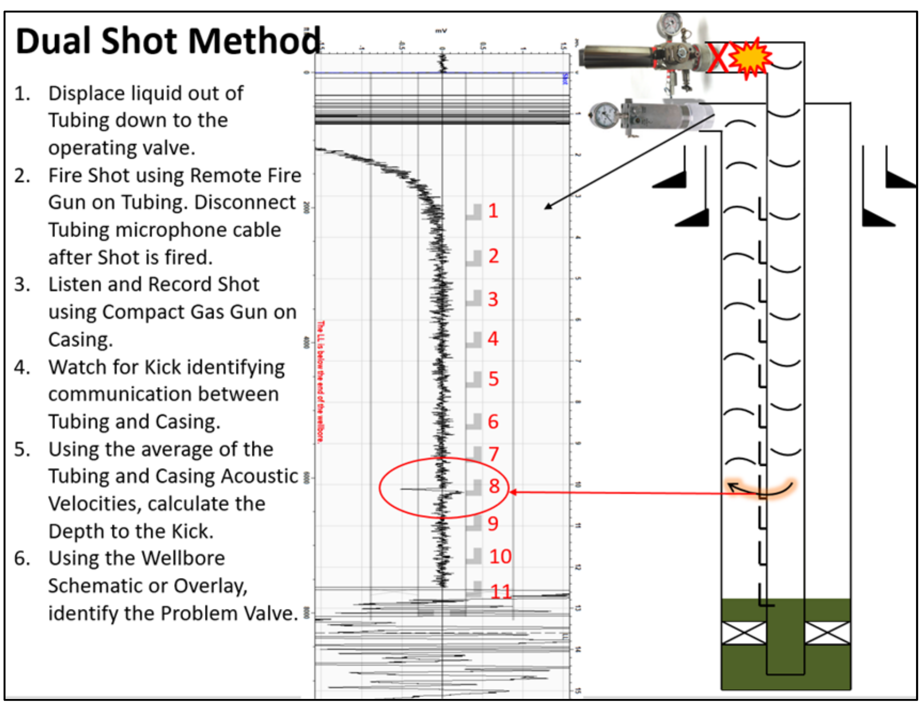

Figure 2 – Dual Shot Method Communication through Leaky Valve Illustration

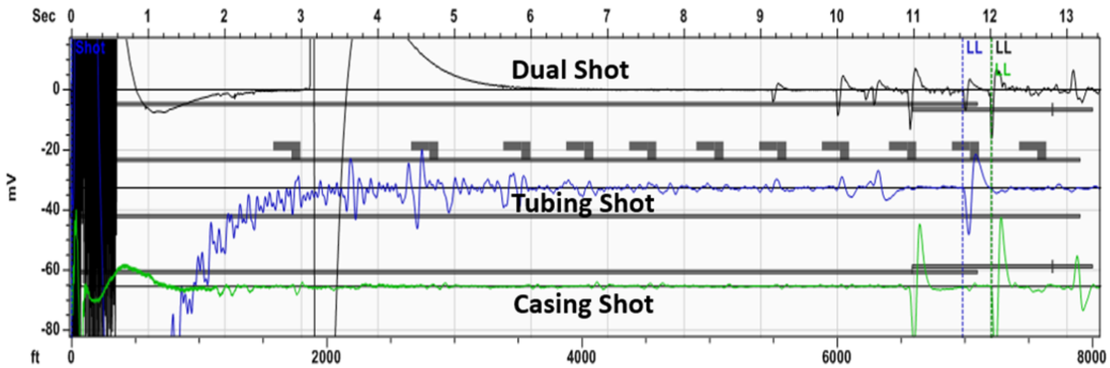

Figure 3 – Example 1 Four Bad Valves and Two Holes in Tubing

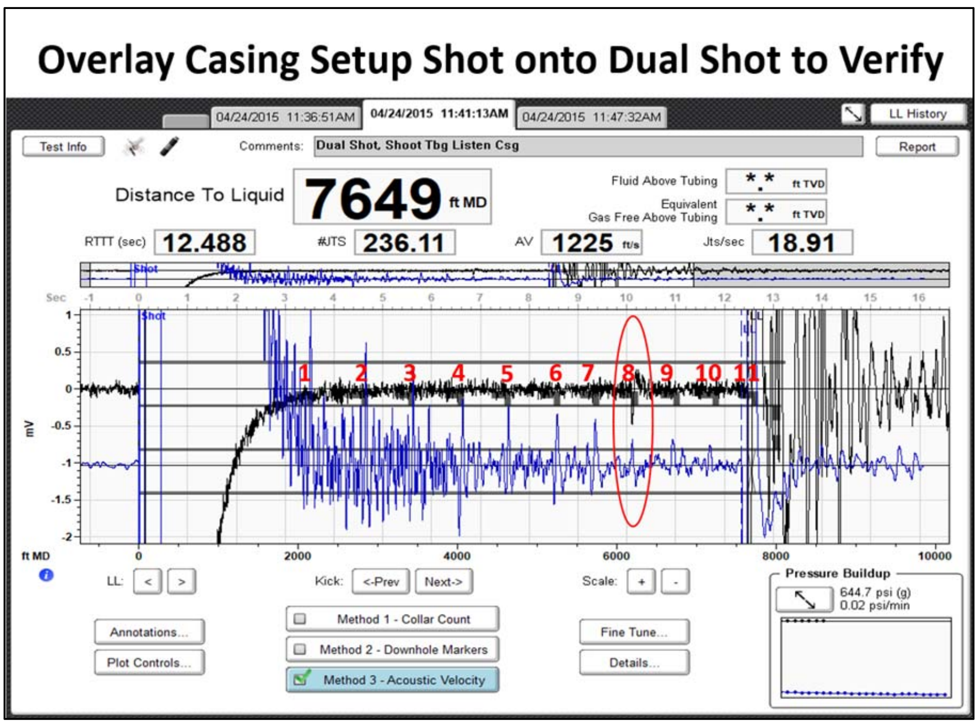

Figure 4 – Example 2 Casing Pre-shot and Dual Shot Overlay

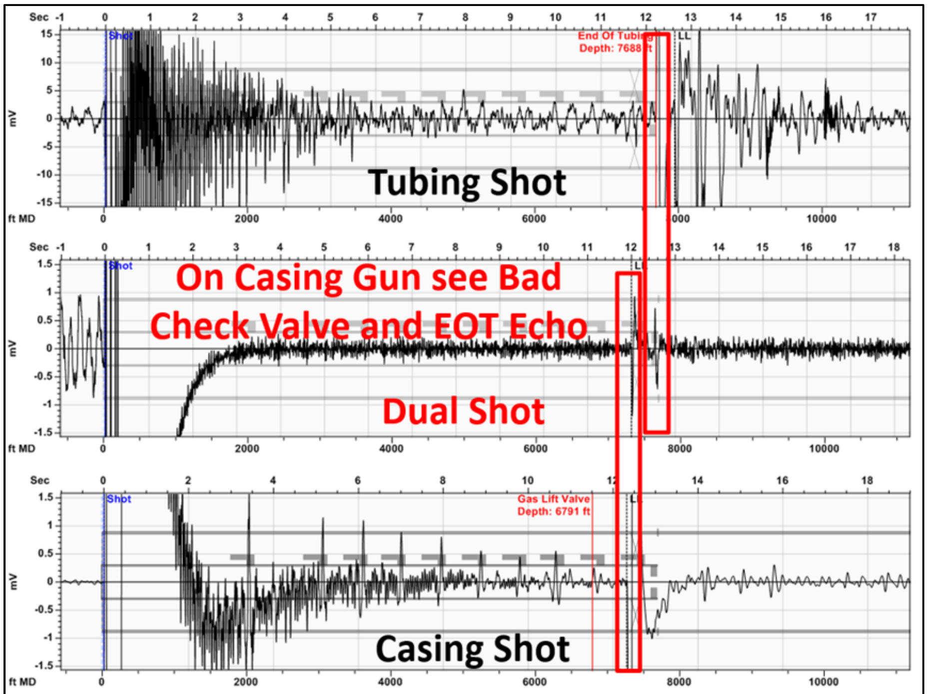

Figure 5 – Example 3 Dual Shot shows communication at 9th valve

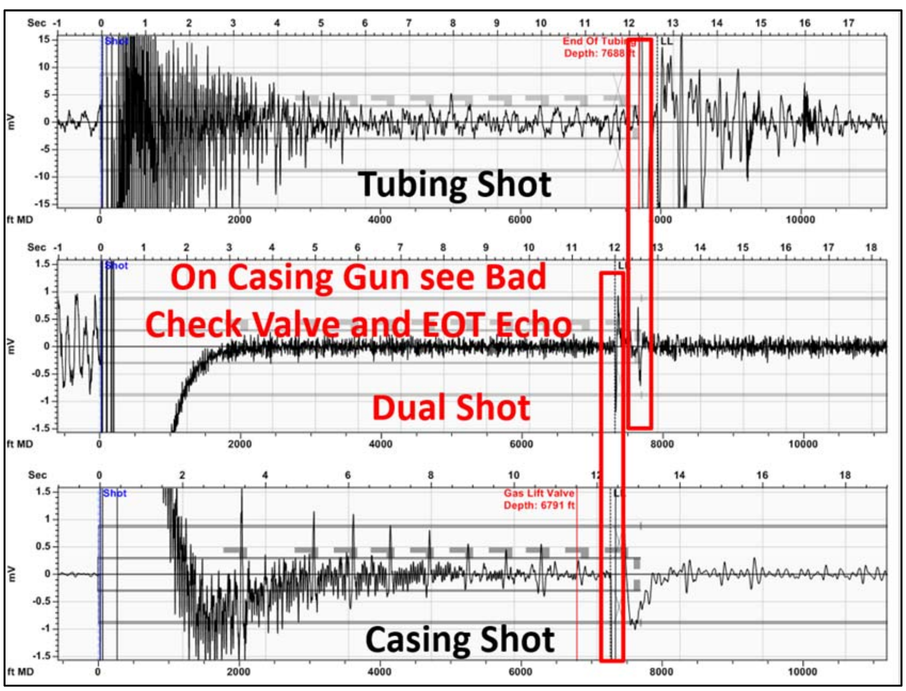

Figure 6 – Example 3 Acoustic Velocity Calculations for Dual Shot Depth Accuracy

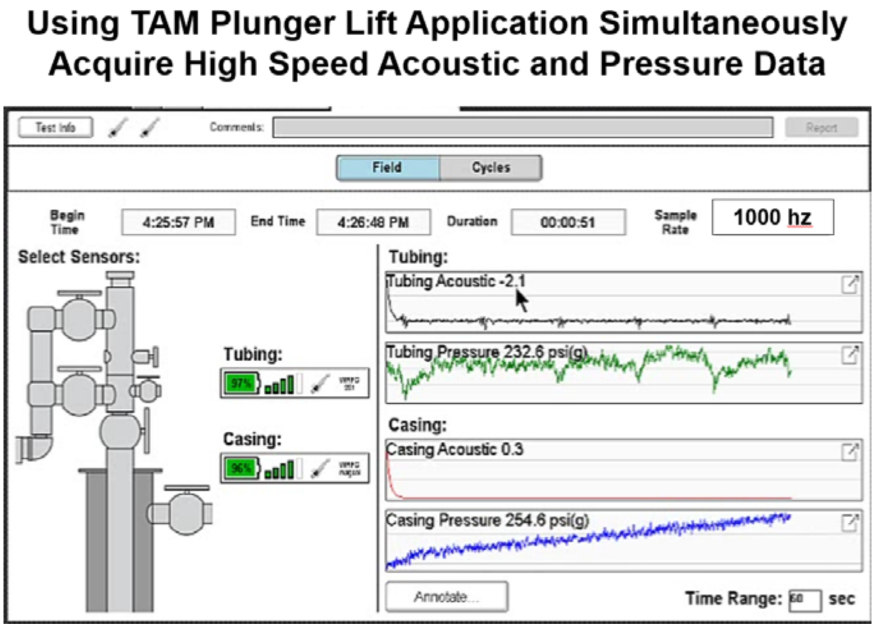

Figure 7 – Wireless equipment streaming data in plunger tracking software

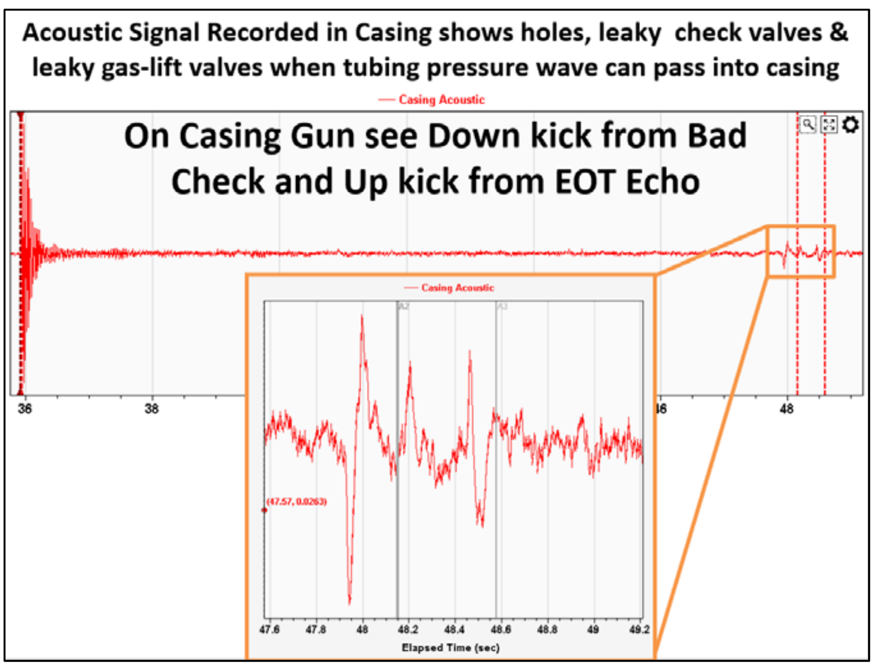

Figure 8 – Annotations help identify reflections and point of communication