LL Features in TAM

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I. Main LL Analysis Window

The primary ***Liquid Level (LL)*** analysis screen (Figure 1) shows the acoustic trace and results, such as distance to liquid, acoustic velocity, and fluid above pump at the top of the screen and a detailed wellbore schematic with the corresponding fluid distribution. At the bottom of the screen are buttons used for plot modification and analysis updates.

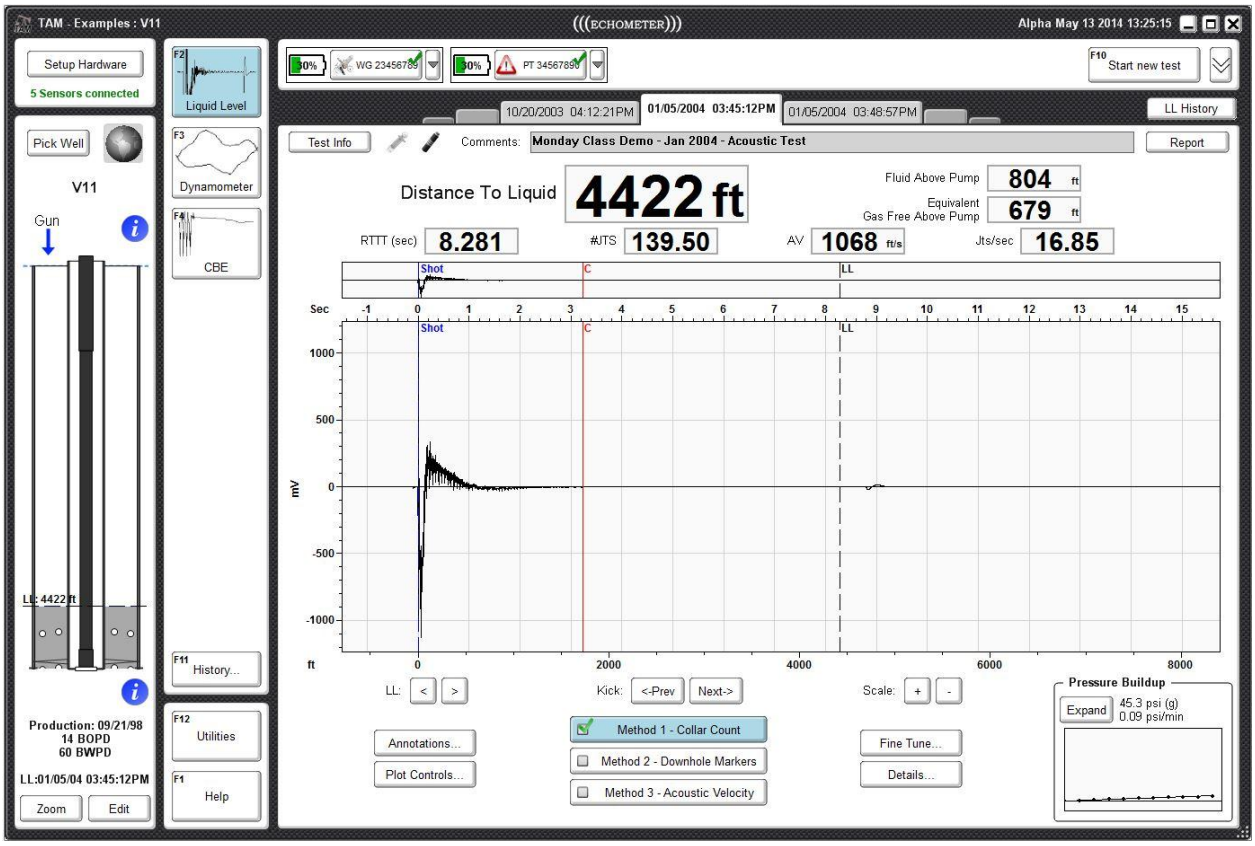

Figure 1: Main LL Analysis Screen

Navigation Sub-plot

Directly above the main shot trace plot, is a smaller sub-plot that can be used to adjust the horizontal and vertical region of interest displayed in the primary plot. Clicking and dragging in the middle of the white region of the sub-plot allows the user to pan the region of interest left and right. Dragging near the ends of this region box allows it to be resized. Figure 2 shows an example of how the sub-plot can be manipulated to get an expanded view of the liquid level echo for this particular example.

Figure 2: Adjusting the region of interest by manipulating the selection box of the sub-plot.

Adjusting Plot Scale

The scale of the vertical axis, in millivolts, of the shot trace plot can be increased or decreased using the **+/-** scale buttons directly below the plot. The scale of the plot can also be adjusted by manipulating the mouse wheel. Figure 3 shows the example shot trace after scaling down the graph to a 2400 mV range.

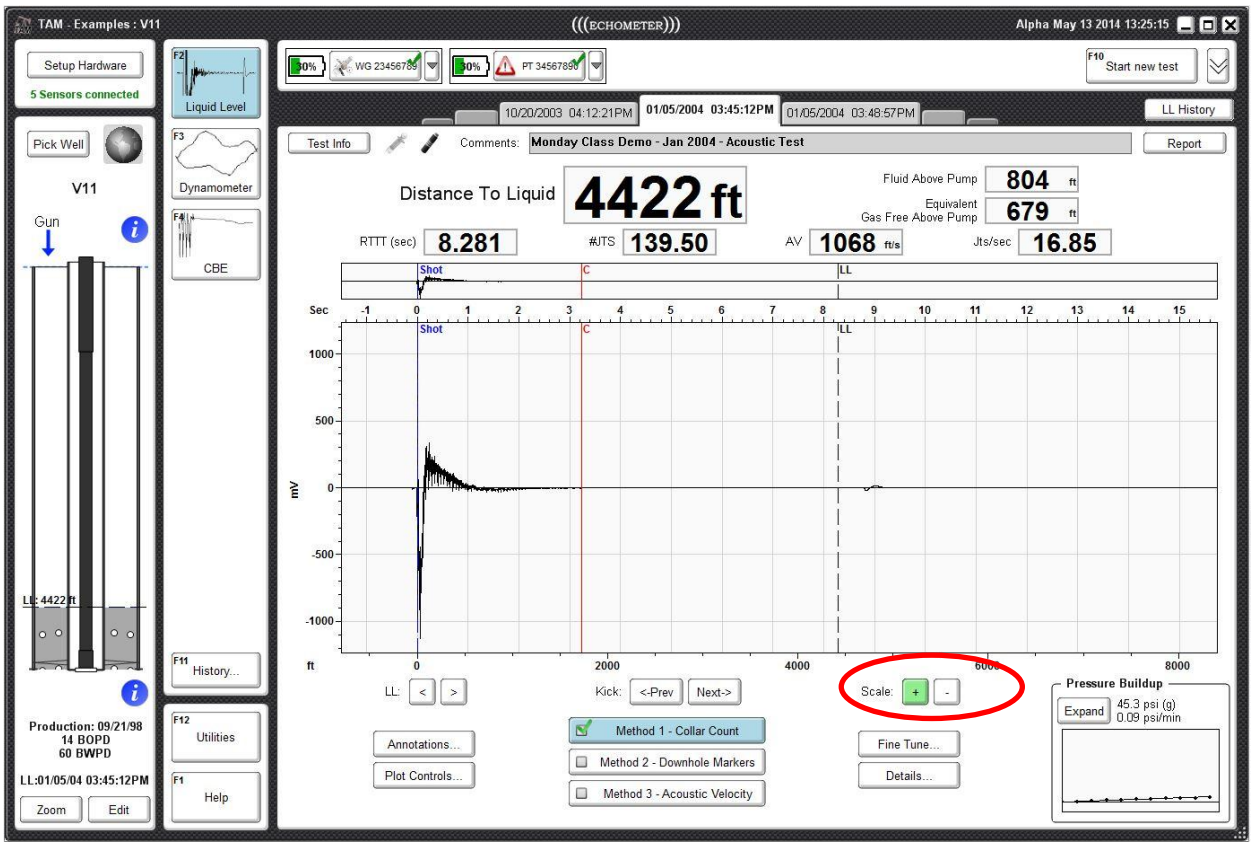

Figure 3: Shot trace after being scaled down

Adjusting Shot Beginning & Liquid Level

When hovering over the plot, users will notice that drag indicators appear at the ends of both the ***Shot*** beginning marker (blue) and liquid level ***LL*** marker (black) in Figure 4. Both of these markers can be clicked and dragged to adjust their positions along the shot trace. After adjusting these markers, the liquid level distance calculation analysis is automatically re-run and new results will appear.

NOTE: after manually adjusting the markers they can be reset to their original position using the ***Fine Tune*** button and selecting the ***Reset*** option for the corresponding marker.

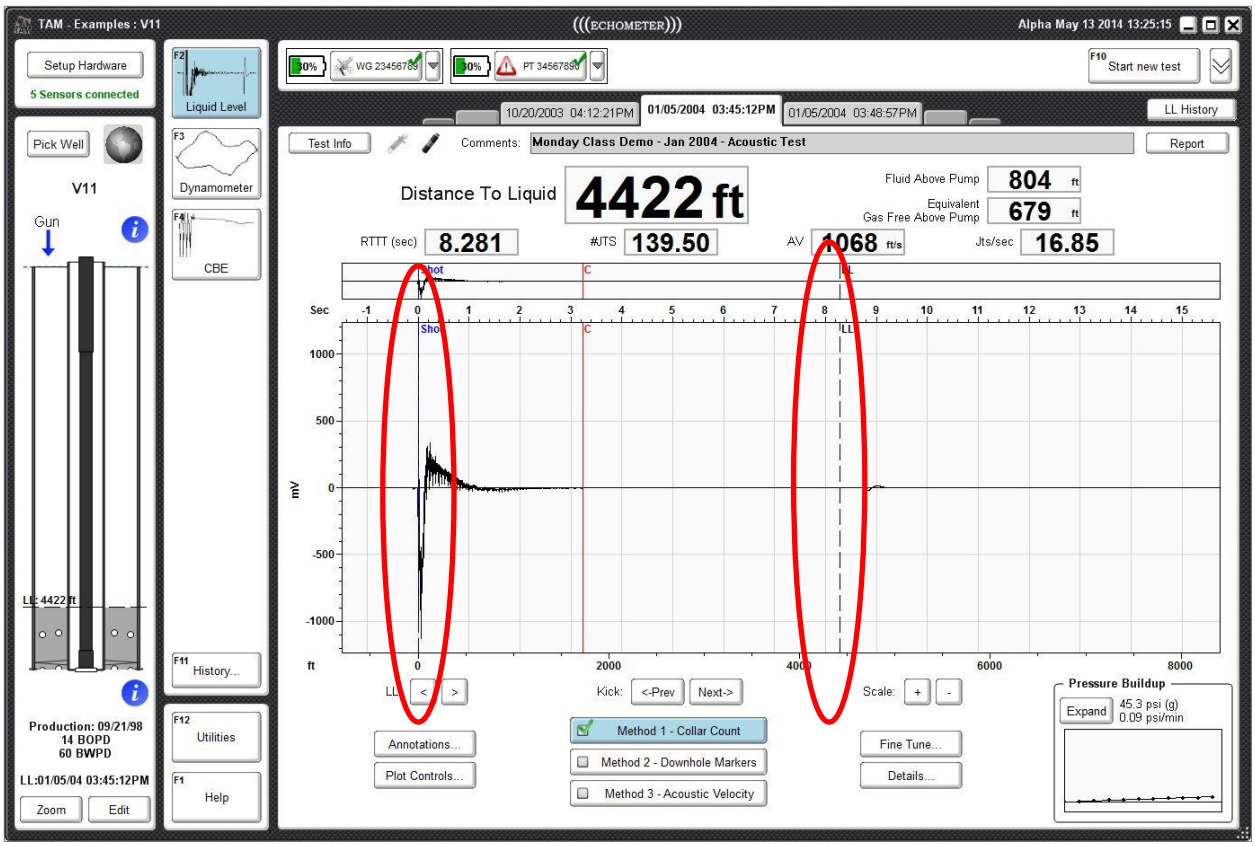

Figure 4: Drag indicators for shot beginning and liquid level cursors.

When multiple echoes, that satisfy the characteristics of a liquid level echo, are present, the user can investigate which echoes the software thinks that could also correspond to the liquid level by using the ***<- Prev*** and ***Next->*** kick buttons directly below the plot. Clicking these buttons will cause the ***LL*** marker to jump to the other possible echoes. When such additional echoes are not present in the trace, the ***LL*** marker will not move. The user can refine the ***LL*** marker position by using the ***"<"*** and ***">"*** buttons found just to the left of the kick candidate buttons.

II. Right Click Menu

Additional plot options can be accessed by right-clicking inside the plot area. This will bring up the popup menu seen in Figure 5 with the following options:

- ***Print Image***: sends an image of the plot to the printer
- ***Copy Image to Clipboard***: copies the plot image to the system clipboard
- ***Copy Data to Clipboard***: copies the shot trace data (time, mV) to the system clipboard
- ***Export Data to File***: saves the time/mV values of the trace to a text file (which can be loaded into spreadsheet programs like Excel)
- ***Add Note***: add a note/annotation to the plot (see details in **"Plot Notes"** in **"TAM Features"** document)

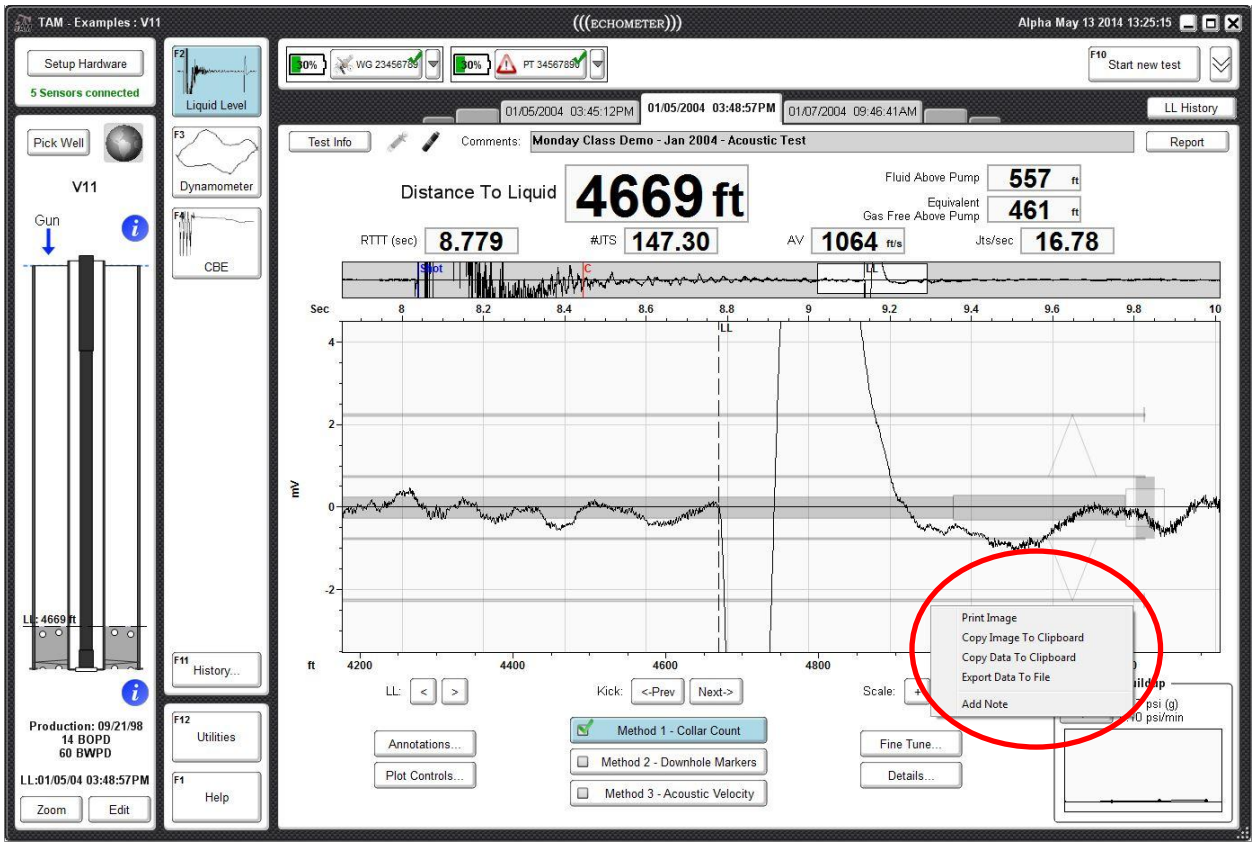

Figure 5: LL plot right click menu

III. Pressure Buildup Window

When wellhead pressure (casing or tubing, depending on where the gas gun is installed) is acquired alongside a shot, the pressure buildup window will appear in the bottom right-hand

side of the analysis window (Figure 6). Clicking on the ***"Expand"*** button will allow the user to see the full results of the pressure buildup record.

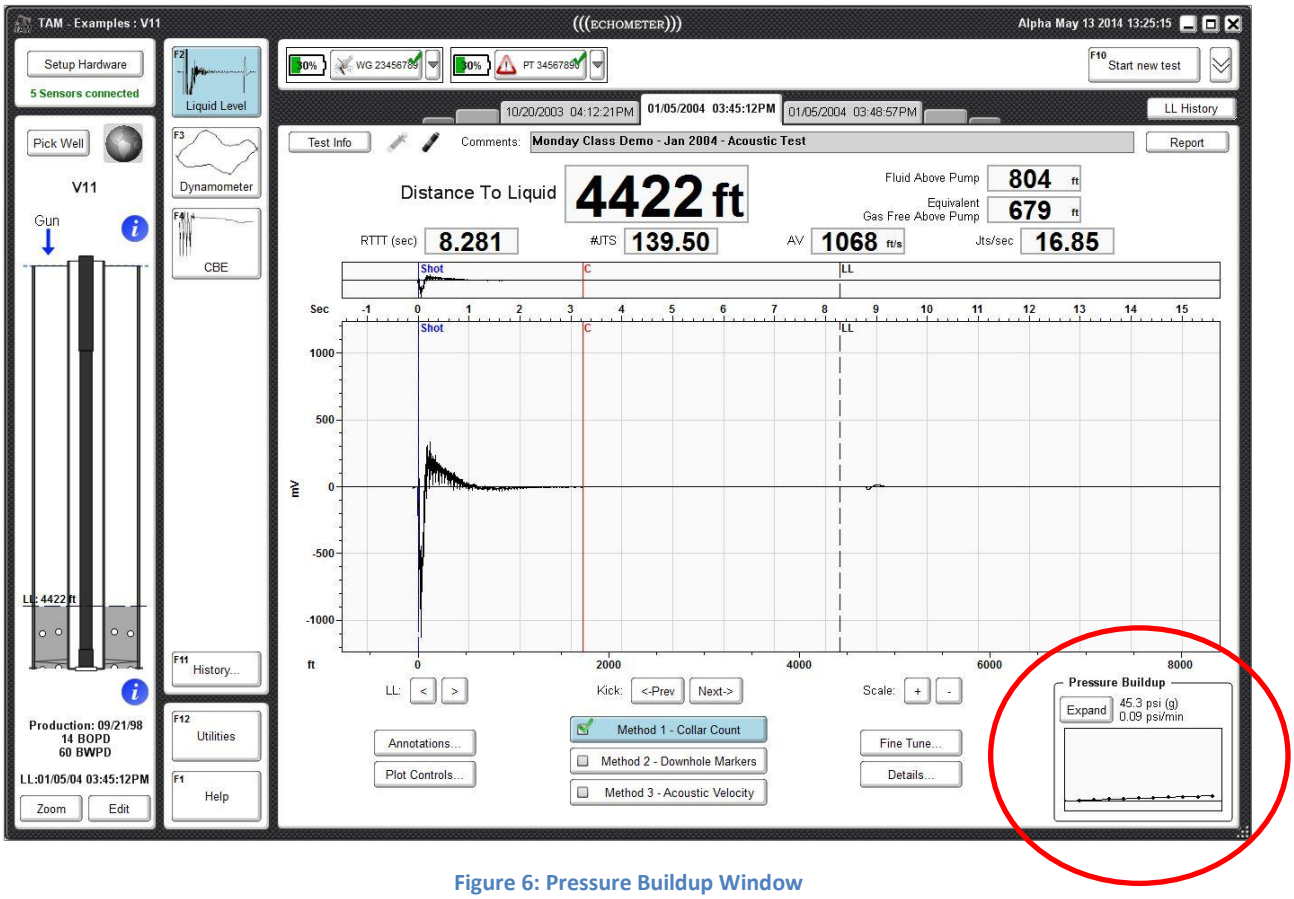

Figure 6: Pressure Buildup Window

Figure 7 shows a screenshot of the expanded pressure buildup window. This window shows the results of pressure buildup, including casing pressure, change in pressure/time, and gas flow. These calculations will automatically update if the user selects a different end point for pressure buildup (using the ***"<-- Left"*** and ***"Right -->"*** buttons). If the user wishes to bypass the automatically measured values and enter manually information for casing pressure, change in pressure, and change in time, it can be done by clicking the ***Modify Casing Pressure*** button. This will bring up a dialog where the user can manually enter the pressure and time values.

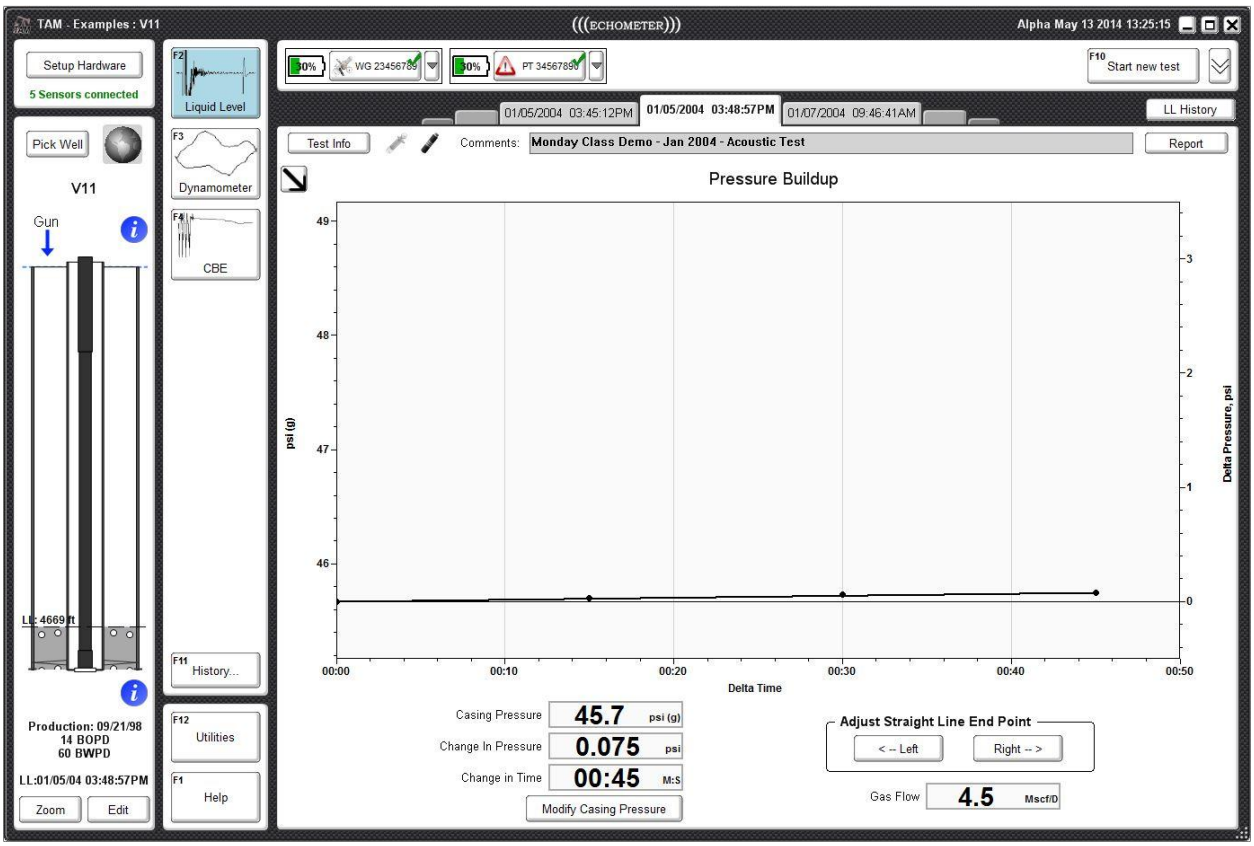

Figure 7: Pressure Buildup Window

IV. LL Annotations

Annotations can be added to the main ***LL*** plot by clicking the ***Annotations*** button in the bottom left-hand corner (Figure 8). Users can add multiple overlays including previous shot traces, a depth reference line, a trace folded about the LL marker and wellbore overlay. The "Opacity" slider can be used to modify the opacity of the wellbore overlay, when it is enabled.

Figure 8: Annotations dialog.

Trace Overlays

Clicking on ***Previous Shot*** opens an additional dialog that allows selecting up to five overlays from existing acoustic tests, for the specific well, and plotting them simultaneously with the trace being analyzed as shown in Figure 9 where the **black** trace is the signal being analyzed and the **blue** trace corresponds to the overlay. Traces for overlay are enabled or disabled by clicking the corresponding ***On/Off*** buttons in the ***Overlay Selection*** table. Clicking on one of the two ***Spread*** buttons will increase or decrease the vertical spread between the center lines of each trace. The ***Clear All*** button will deselect all traces currently turned on. The ***Swap Order*** button inverts the position of overlays relative to the current trace and "Show LL On Cursors" displays the liquid level depth for the overlays on their ***LL*** cursors. The user also has the option of lining up overlays based on ***Depth*** (default) or based on ***Time***.

NOTE: before applying overlays it is convenient to process each trace using the same vertical ***mV*** scale.

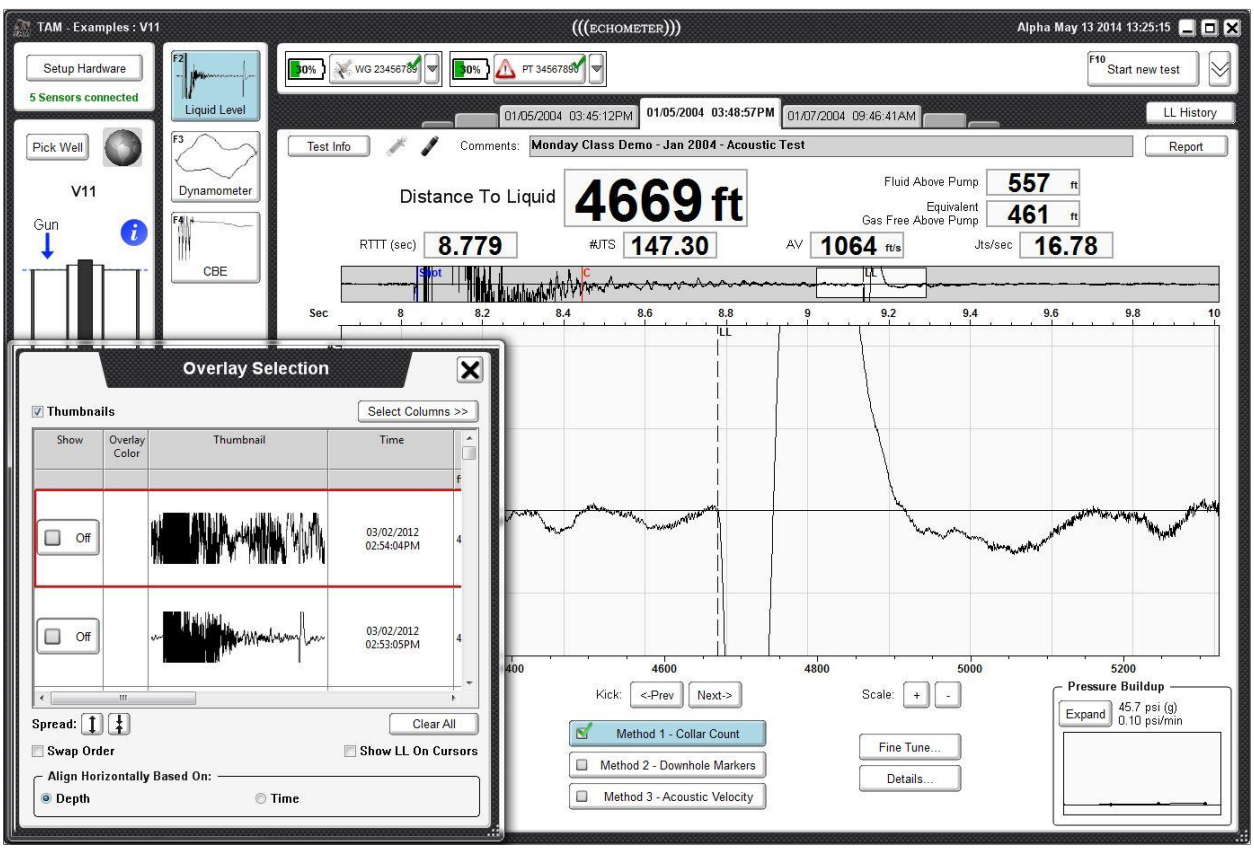

Figure 9: Overlay selection dialog.

Depth Reference Line

Clicking the ***Depth Reference Line*** button, places on the graph a moveable cursor that displays the time and depth of its current location. It is used to display the position (in time and depth)

of certain physical features of the acoustic trace. This marker can be dragged and moved with the mouse to any place along the trace. A corresponding dashed cursor will also appear on the wellbore diagram on the far left of the screen.

Figure 10: Depth Reference Line

Trace Folding

The ***Fold Trace*** option under ***Annotations*** allows the user to see a reflection of the data around the selected liquid level echo. This view may be helpful when aligning multiple reflected echoes found along the shot trace. When enabled, the folded shot trace appears in red. A "shadow" of the reflected part of the shot remains in a lighter gray color (see Figure 11).

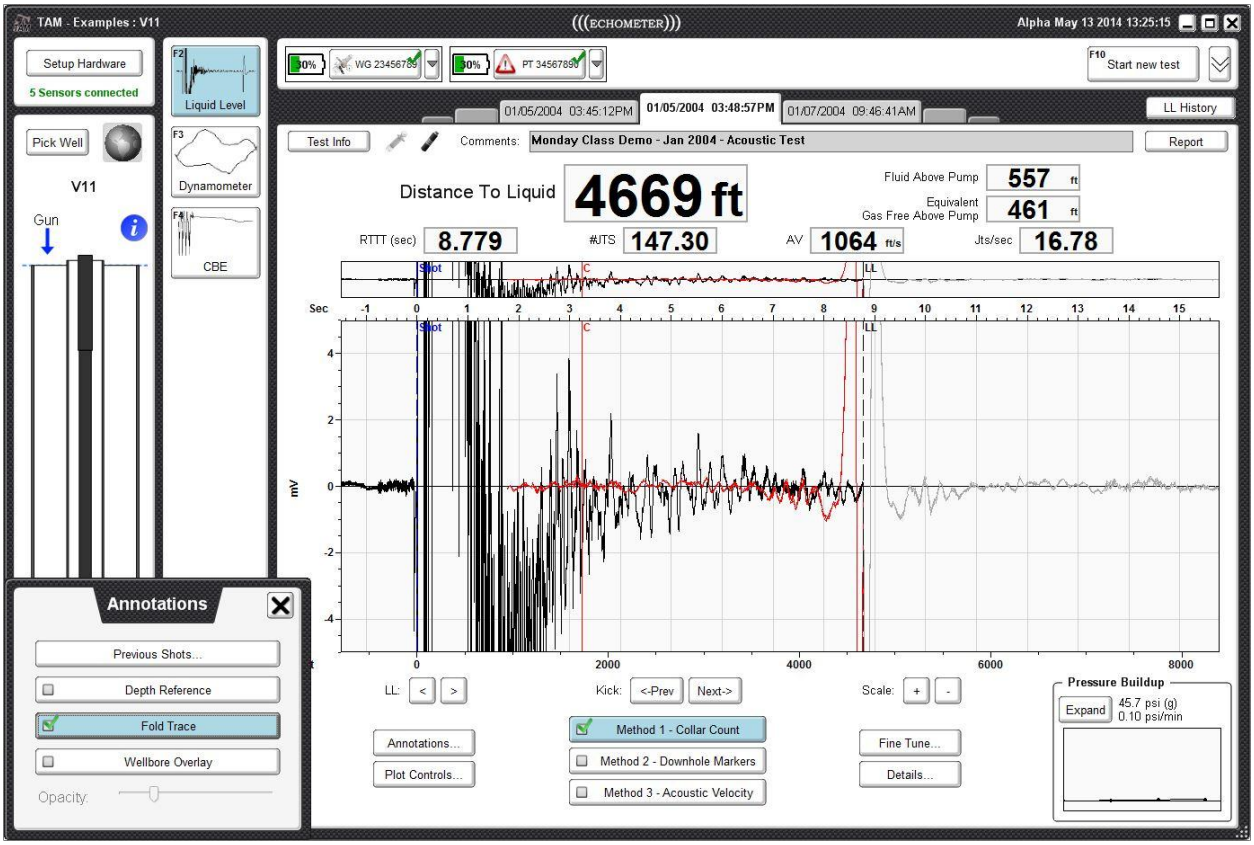

Figure 11: Example shot trace that has been folded.

Wellbore Overlay

The wellbore details shown on the wellbore schematic at the left of the screen can be displayed on the acoustic trace using the ***Wellbore Overlay*** button. The user will see a semi-transparent image of the well diagram on top of the acoustic trace. The opacity of this overlay can be adjusted using the ***Opacity*** slider at the bottom of the ***Annotations*** menu. This feature is very useful when it is difficult to identify the LL echo when the trace exhibits multiple echoes and to show the position of the liquid in relation to the perforations.

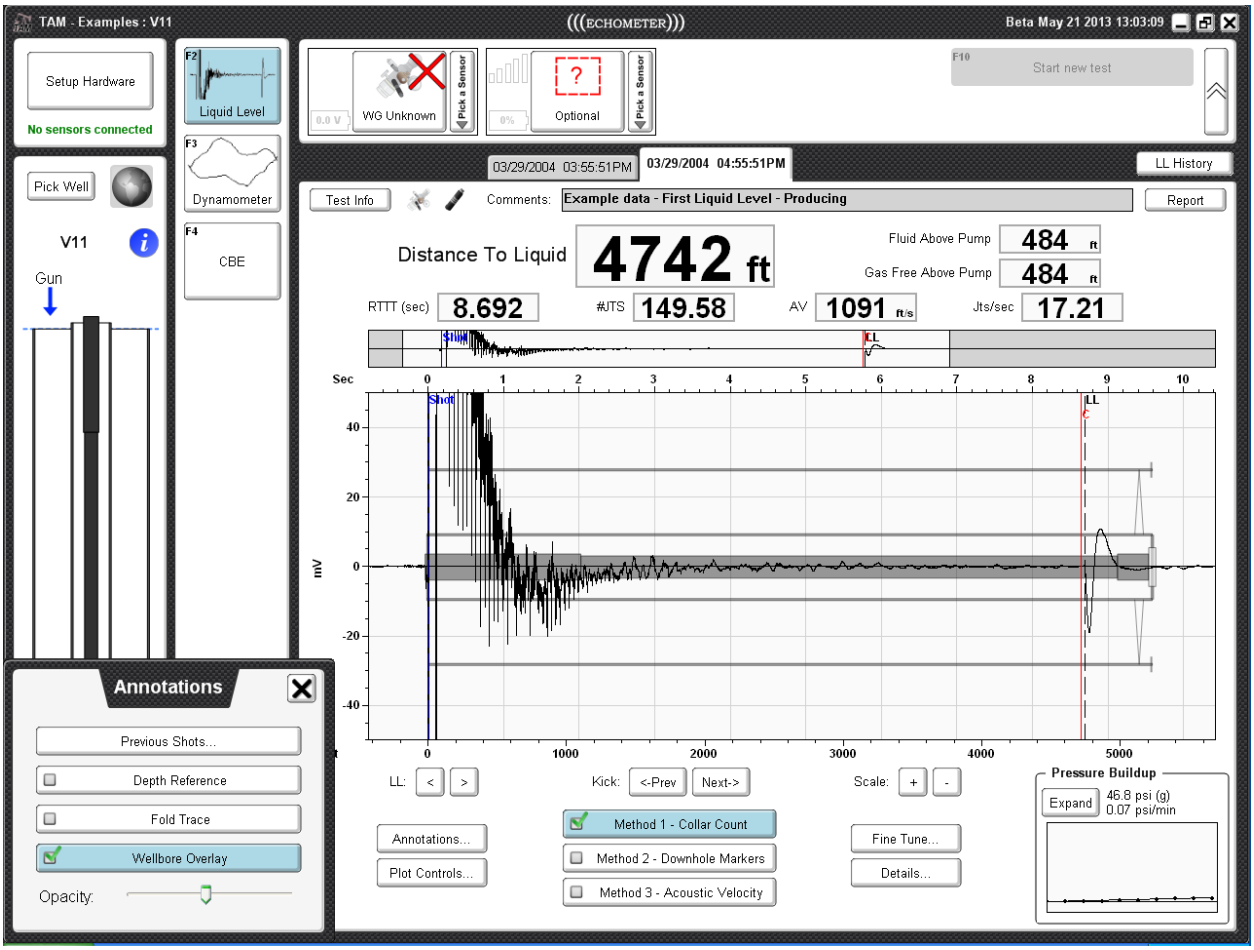

Figure 12: Wellbore overlay

V. LL Plot Controls

Clicking on the ***Plot Controls*** button on the main ***LL*** screen brings up a dialog with options for interacting with the shot trace plot (Figure 13). The options currently available include: ***Echo Zoom, Zoom All, Select, Pan,*** and ***Undo***.

- The ***Echo Zoom*** button is a smart-zooming feature that automatically adjusts the viewing region of the recorded trace to an optimum range. It determines this region based on the location of the shot beginning and liquid level cursors, as well as, the kick height at the selected liquid level.

- The ***Zoom All*** button allows the user to quickly adjust the viewing region such that the entire shot trace is visible.

Figure 13: Plot controls dialog

- Using the ***Select*** tool allows the user to draw a box around a region of interest directly on the main trace plot. After clicking the "Select" button, the user's mouse cursor will turn into a plus (+) sign when hovering over the main plot. Clicking and dragging on the

plot will allow the user to draw a red box (see Figure 14 left) over the trace section of interest to display the record with an expanded timescale as shown at right in Fig 14.

- The ***Pan*** tool coverts the mouse cursor into a four-way arrow. When in ***"Pan"*** mode the user can click and drag inside the main plot to adjust the viewing area horizontally.

- The ***Undo*** button allows the user to undo previous ***Select*** and ***Pan*** operations and return to the original viewing area and scale.

Note: Performing these operations will automatically adjust the region of interest shown on the navigation sub-plot.

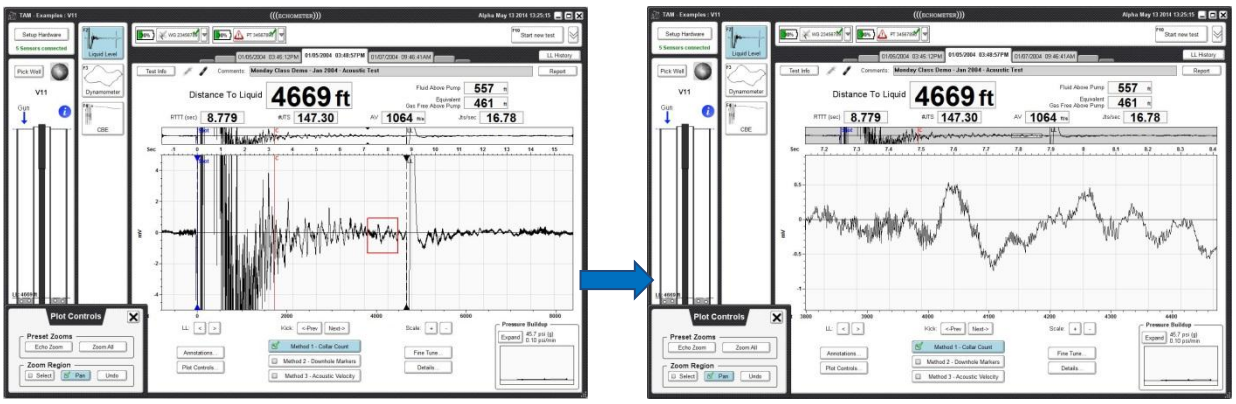

Figure 14: Selecting a new region of interest

VI. Liquid Level Fine Tune

As seen in Figure 15, the ***Fine Tune*** button on the main LL screen gives the user access to dialogs that are helpful when refining the location of the cursors. This button brings up a dialog with the options to fine tune the position in time of either the ***Shot Beginning*** or the ***Liquid Level*** cursor. There is also a checkbox that can be used to apply a low-pass filter to the shot trace data. The results of this filter will be present not only on the fine tune dialogs, but also the plot on the main ***LL*** screen.

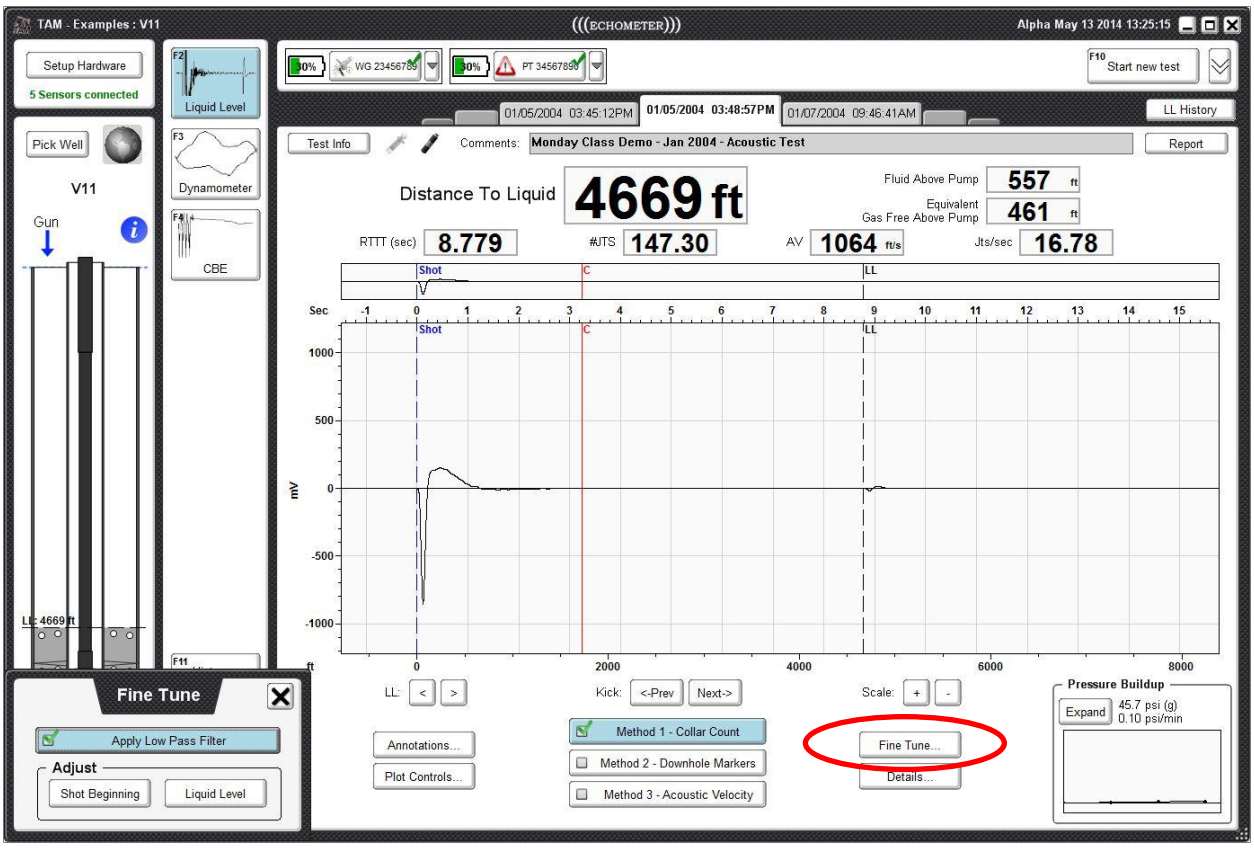

Figure 15: LL fine tune dialog (after applying low pass filter)

Shot Beginning

The shot beginning dialog displays a plot similar to the one on the main ***LL*** screen (see Figure 16). Like the main trace plot, the shot beginning dialog plot has a sub-plot that can be used to adjust the viewing region of interest. It also contains scale buttons that can adjust the millivolt range. The ***Shot*** cursor can be moved directly on the plot or by using the ***Move*** arrow buttons, labeled ***"<<", "<", ">", ">>"***. The ***Reset*** button at the top of the plot is used to return to the shot beginning time automatically detected by TAM.

In very noisy wells, where the automatic shot detection fails to correctly locate the start of the pulse, rather than moving the shot beginning cursor manually, the user can adjust the threshold voltage used by TAM's automatic shot detection algorithm by editing the value in the ***Threshold Voltage*** box and pressing **Enter.** If necessary it is possible to apply an offset to account for gun noise by clicking the ***Account for gun noise*** checkbox. The ***Defaults*** button will return the threshold voltage value and gun noise checkbox value back to their normal values.

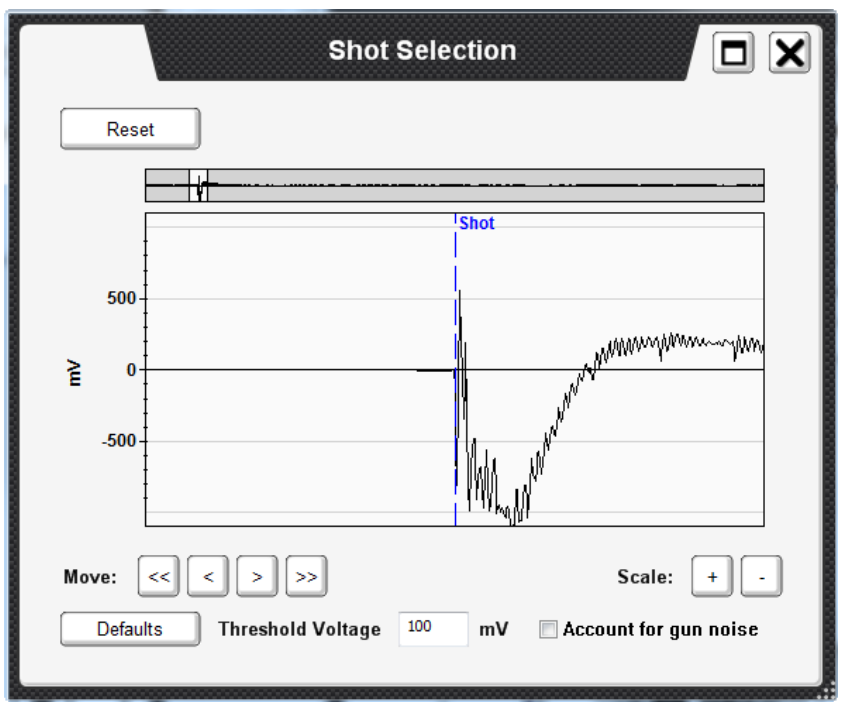

Figure 16: Shot beginning dialog

Liquid Level

Although the liquid level cursor can be moved on the main ***LL*** analysis screen, a user may wish to refine the value even further. Clicking on the ***Liquid Level*** button in the ***"Fine Tune…"*** menu brings up the ***Kick Selection*** panel showing a zoomed-in region around the current liquid level indicator (Figure 17). Here the user can refine the cursor position by dragging it directly on the plot or by using the ***Move*** buttons in the bottom left-hand corner. The ***Reset*** button at the top will return the ***LL*** indicator to the original time picked automatically by TAM.

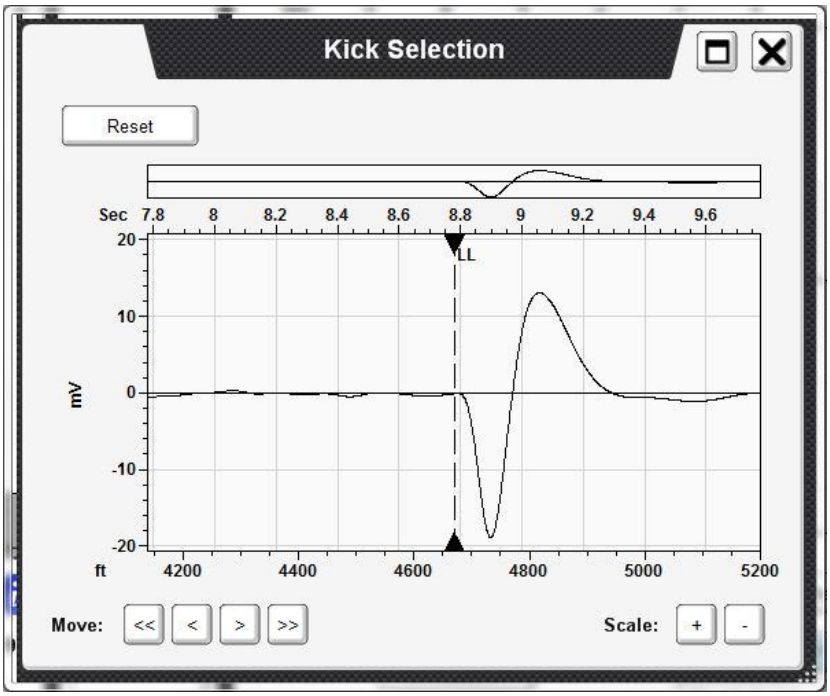

Figure 17: Refining the liquid level position

VII. LL Details

The ***Details*** button on the main LL screen will bring up a dialog that allows the user to indicate the pulse type used for the shot (explosion or implosion), the position where the gun is installed – either on the casing or the tubing, as well as the state of the well. Adjusting these options will automatically trigger a re-analysis on the ***LL*** test. Changing the pulse type from explosion to implosion inverts the polarity of the acoustic trace so it is very important to indicate to the program the actual pulse type used.

NOTE: Implosion shots can only be done when using manually operated gas guns such as the Echometer Compact Gas Gun or the 5000 psi and 15000 psi gas guns.

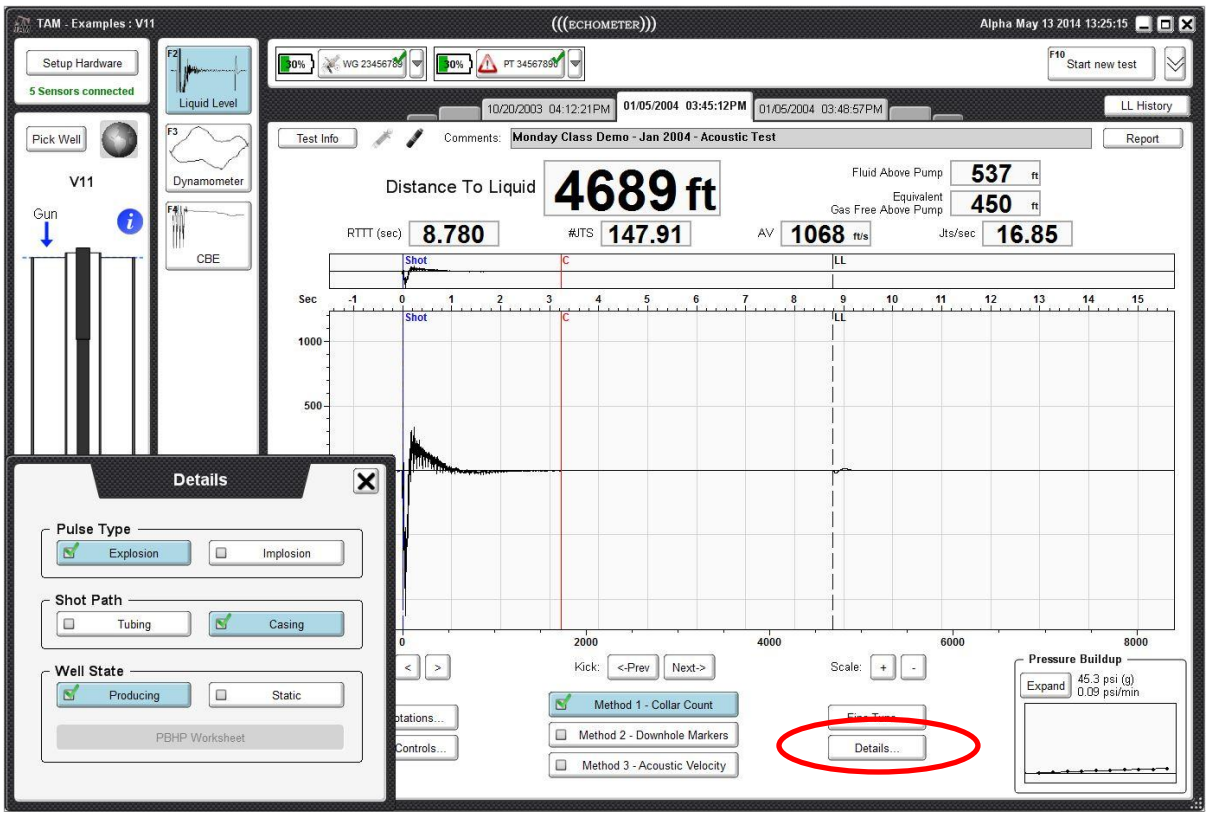

Figure 18: LL details dialog, results after changing pulse type

VIII. LL Analysis Methods

TAM currently provides three different methods for determining acoustic velocity, and consequently, the distance to the liquid level. TAM, by default, applies the ***Collar Count Method*** but the user can toggle between the analysis methods by clicking on one of the three buttons at the bottom of the main LL analysis screen, as seen in Figure 19. Clicking on a given method button will bring up the corresponding dialog allowing the user to manually adjust the parameters used for depth determination. The three methods include:

- *Method 1 - Collar Count Method*
- *Method 2 - Downhole Marker Method*
- *Method 3 - Acoustic Velocity Method*

Figure 19: Method toggle buttons

Collar Count Method

No action by the user is normally required since the TAM program follows a very efficient method to identify and count collar echoes automatically to the deepest part of the record. In those cases where the collar count marker line **"C"** is located significantly above the liquid level echo it may be appropriate for the user to intervene manually to attempt to obtain a deeper collar count.

Clicking on the ***Method 1 – Collar Count*** button displays the collar analysis dialog (Figure 20) which is in the ***Auto Collar Selection*** mode by default. The user can override the automatic mode by interacting with this dialog by a two-step process. To ***Manually Adjust Collars*** the user selects a one second region from the top plot indicating the section of the record where the collar echoes will be identified. This one second region is indicated by a yellow selection box that can be clicked and dragged to any position along the top plot.

Once the area of interest has been selected, the bottom plot automatically updates to show a zoomed-in view of the region. Here, dashed red lines appear bounded by solid red marker lines ▲▼ which can be dragged to align collar markers to the corresponding echo positions along the trace. The move buttons ***"<<", "<", ">", ">>"*** can be used to move all markers left or right. The spread buttons "***--", "-", "+", "++"*** can be used to spread or shrink the spacing between cursors. The markers can also be adjusted by dragging the first and last collar lines.

To return to the collar analysis used by TAM initially, click the ***"Auto Collar Selection"*** button in the top-left corner. This dialog also contains filter buttons that can be used to filter the trace displayed in the bottom plot. ***Raw*** displays the trace data without applying any filter, ***HP*** applies a high-pass filter, ***BP*** applies a band-pass filter, and ***HBP*** applies a high band-pass filter before plotting the trace. After performing collar analysis, the user will notice a red cursor labeled ***C*** on the main LL analysis screen. This indicates the position of the last collar counted.

Figure 20 – Collar analysis dialog

By default the ***Apply Automatic Collar Count*** box is checked so that the program processes the collar echoes using a digital filter to identify the echoes as deeply as possible. The result of the automatic count is displayed by clicking the ***All Collars*** button to display the screen shown in Figure 21 where the acoustic trace has been subdivided in 2 seconds intervals and the collar echoes have been identified by the tick marks. Un-checking this box forces the program to use the number of collars per second for the section highlighted in yellow to estimate the number of joints to the liquid level echo.

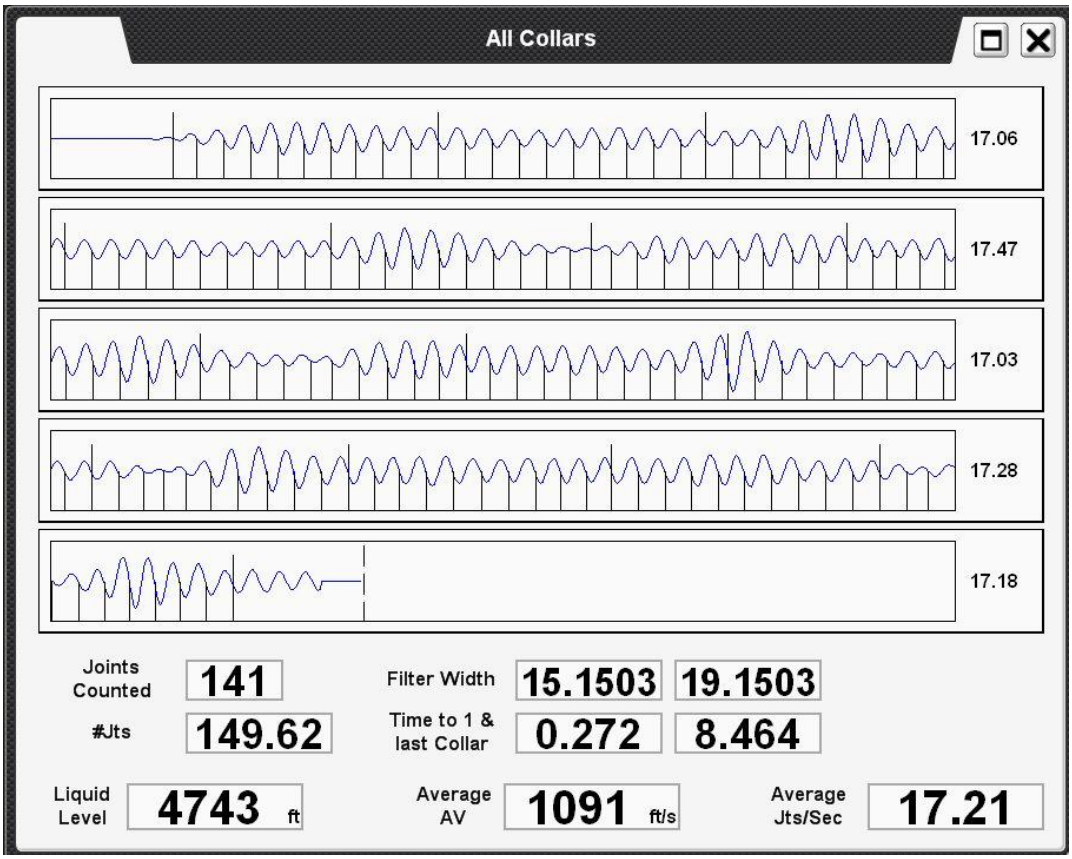

Figure 21 – Total Collar Count

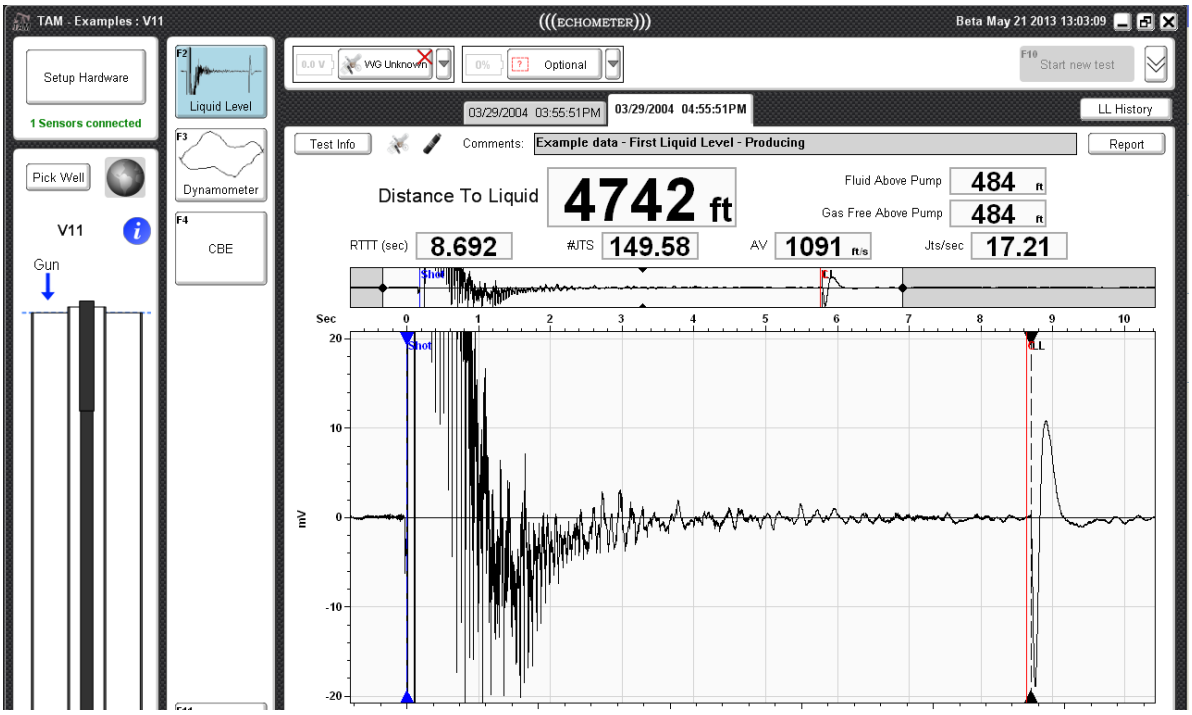

Figure 22 – Automatic Collar Count

Downhole Marker Method

Wellbores that include downhole features that cause acoustic reflections, such as a tubing anchor shown in Figure 22, that can be used to determine the average acoustic velocity of the gas and calculate the distance to the liquid level.

Clicking the ***Method 2 – Downhole Markers*** will give the dialog shown in Figure 23. At the top of this screen is a list of possible markers, based on the information entered in the ***Detailed*** well description, with their corresponding depths. Faint red lines show their corresponding positions on the acoustic trace and the small zoomed-in window displaying the section of record near the liquid level. Clicking the button of the marker to be used (tubing anchor in this example) thickens and highlights its corresponding indicator that can then be moved directly on the main plot to its correct position or using the smaller plot showing the zoomed in area around the selected marker. Here the marker can be further refined as needed. This screen also provides buttons for adjusting the millivolt scale, adjusting the window size of the sub-plot (the width of the yellow region on the main plot), adjusting the wellbore overlay's opacity, and buttons to provide quick zooming.

The result of the marker analysis is shown in Figure 24 with the annotation Tubing Anchor displayed on the record to indicate which marker was used for the calculations.

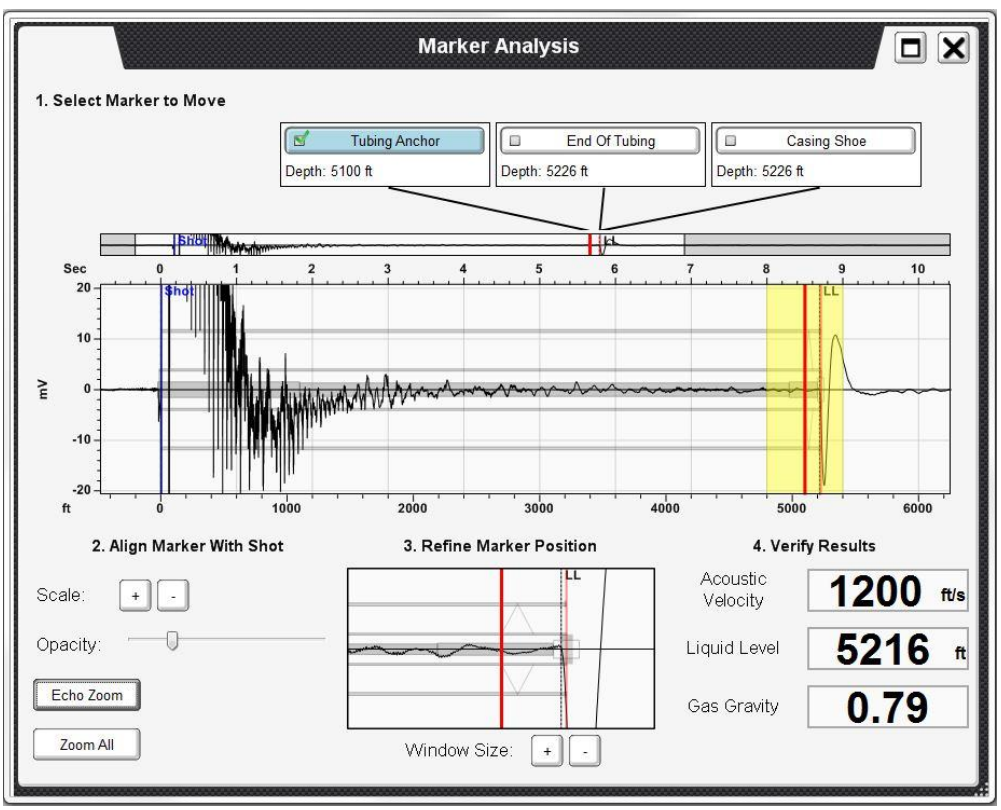

Figure 23 – Marker analysis dialog

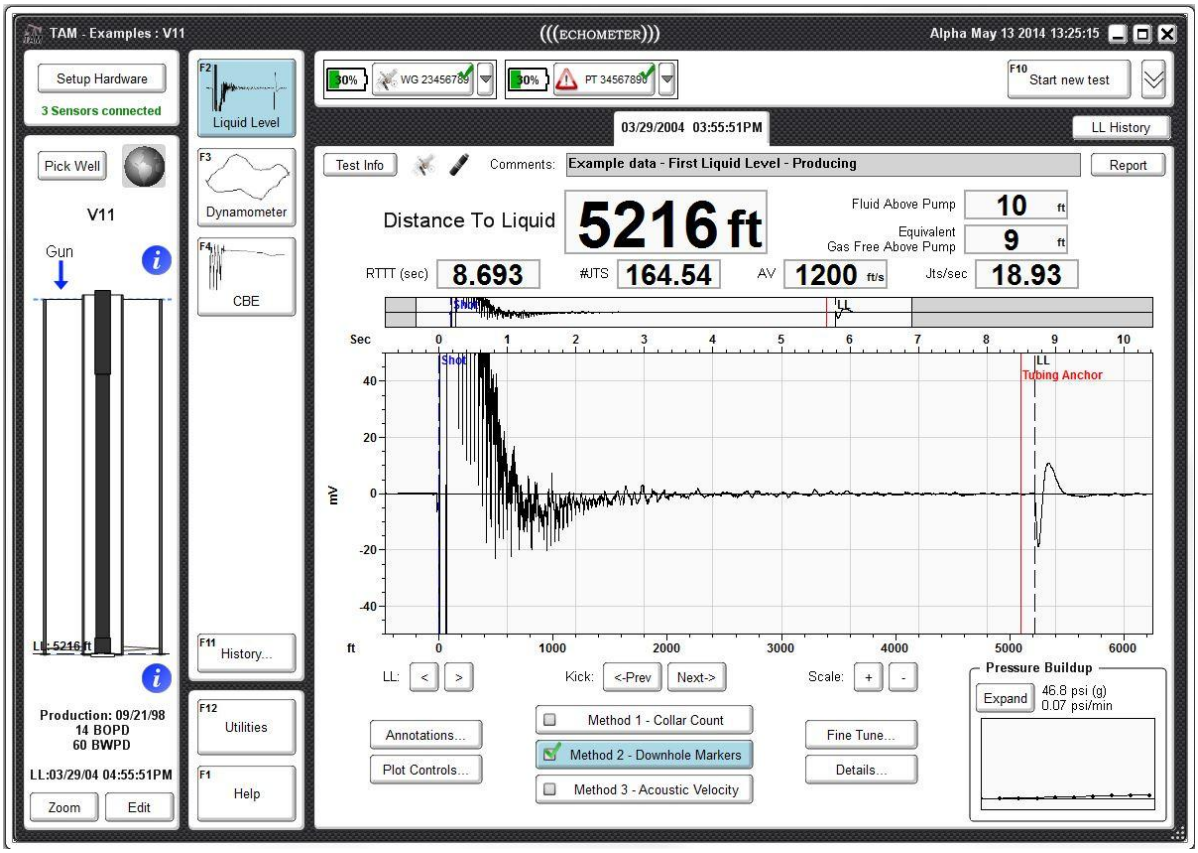

Figure 24 – Marker analysis results

Acoustic Velocity Method

This method is used whenever the record does not show echoes from tubing collars or downhole markers such as for acoustic measurements inside internally flush tubing or cased holes without tubing. Clicking on ***Method 3 – Acoustic Velocity*** allows the user to manually enter a known acoustic velocity (Figure 25) or have the program calculate a velocity by manually entering a value for gas gravity or a detailed gas composition. To enter gas properties select the ***Compute from Gas Gravity*** button to derive an acoustic velocity based on entered gas gravity (Figure 26) or computed from gas composition(Figure 27) . The fluid level analysis based on acoustic velocity is shown in Figure 28.

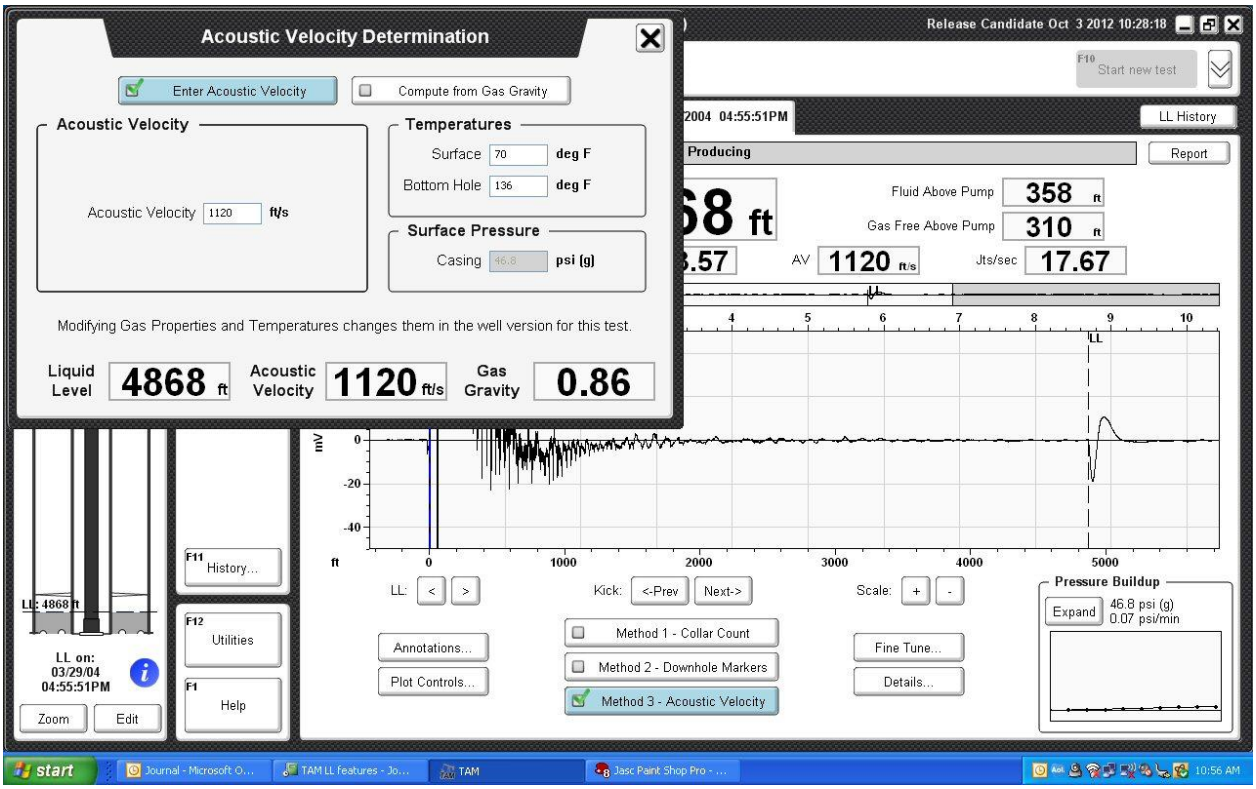

Figure 25 – Acoustic velocity dialog

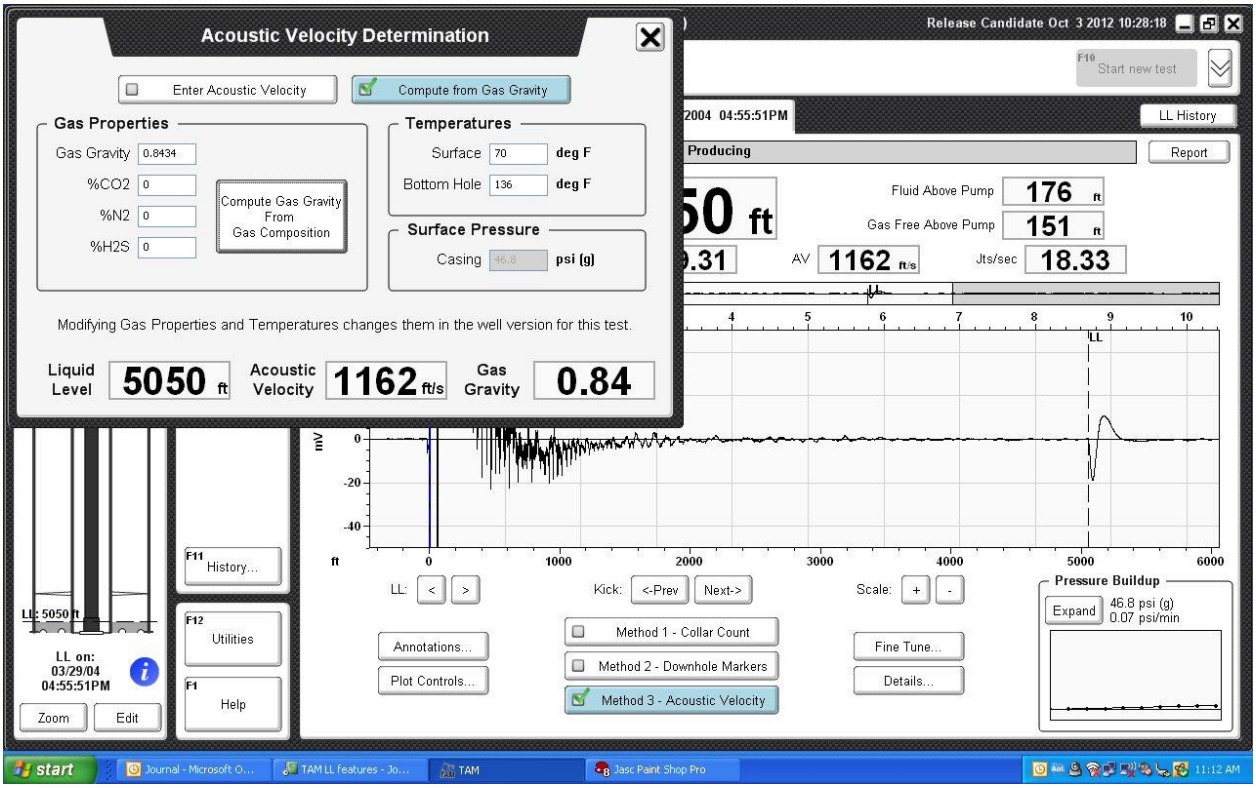

Figure 26 – Velocity from Gas Gravity Dialog

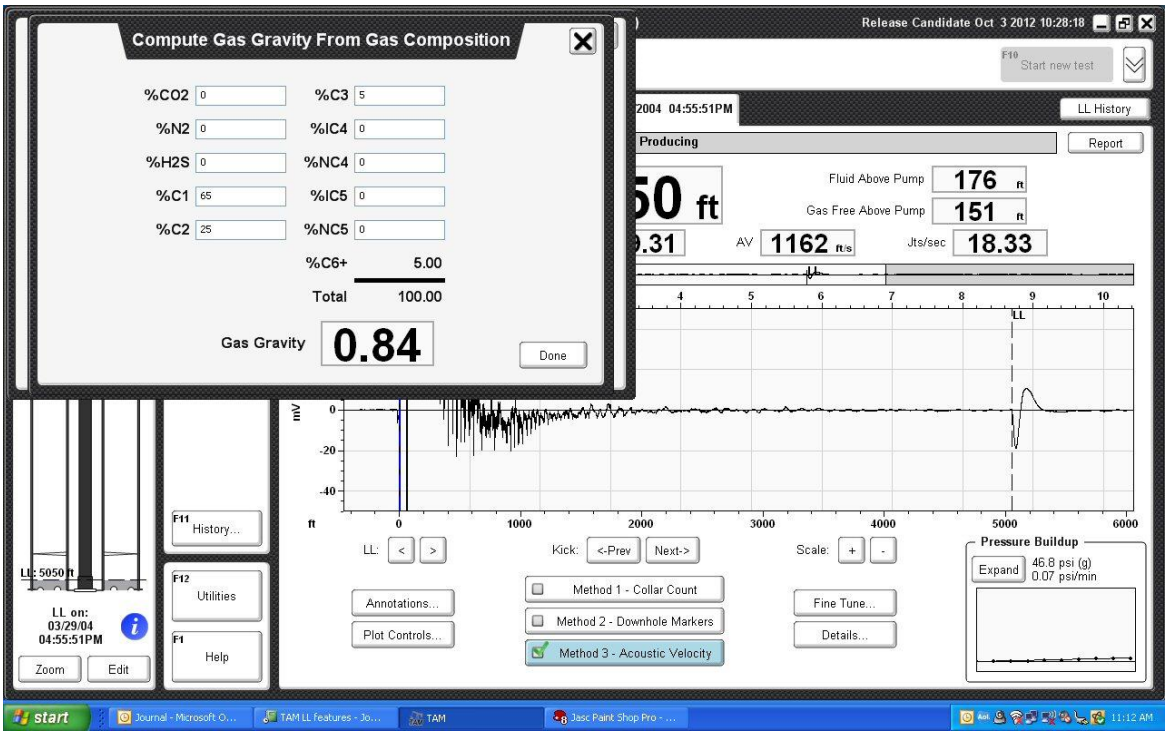

Figure 27 – Velocity from Gas Composition Dialog

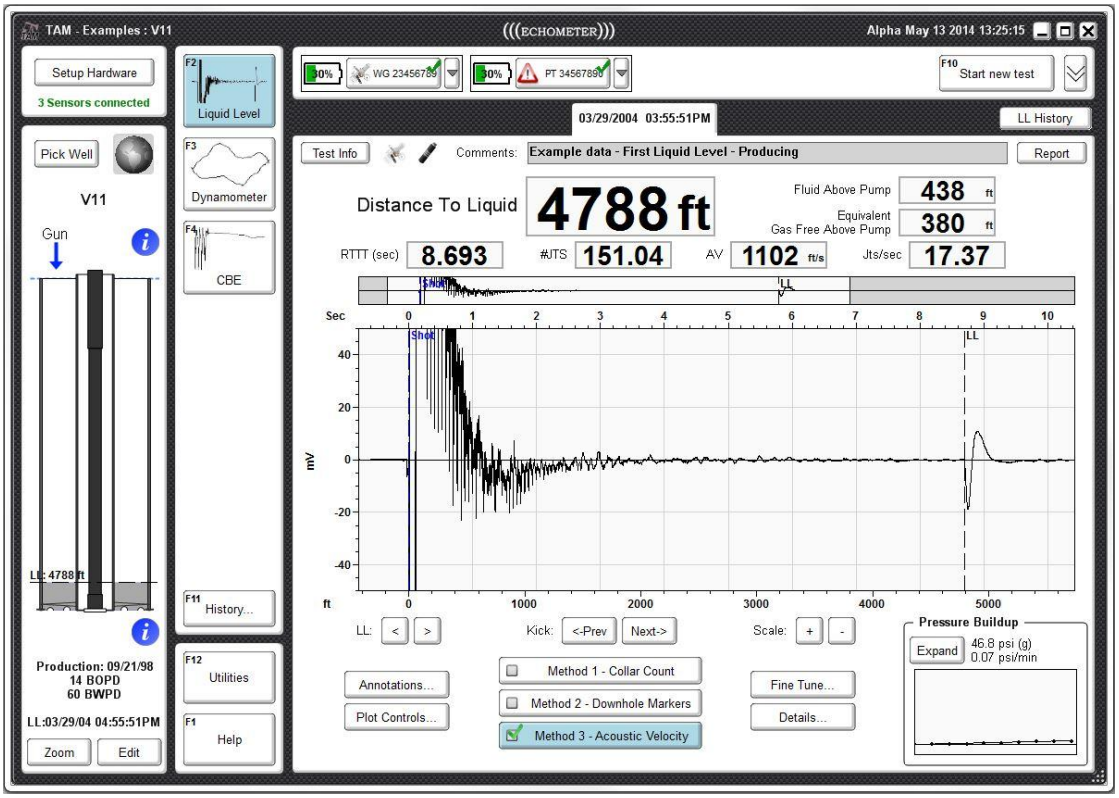

Figure 28 – Acoustic velocity result