Pressure Transient Features in TAM

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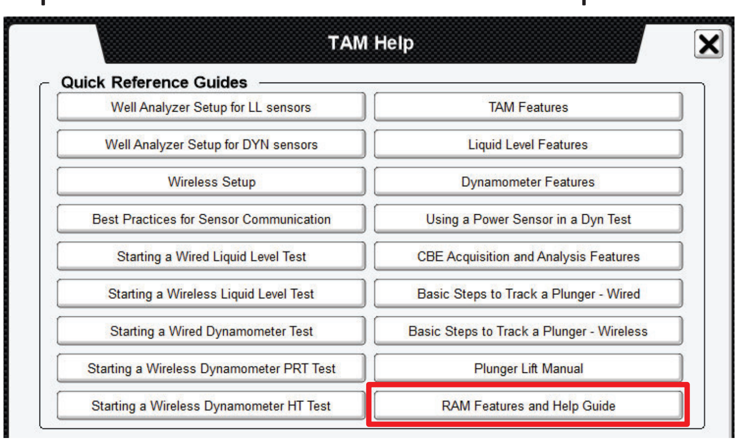
NOTE: This document assumes that the user is familiar with the "RAM Features and Help Guide" document in TAM Help.



Objective of Pressure Transient Acoustic Measurements

Flowing bottom hole pressure surveys, pressure buildup tests, pressure drawdown tests, and inflow performance analysis are the principal tools available to determine reservoir pressure, formation permeability, productivity index, pump efficiency, skin factor, as well as other indicators that can be used in the optimization of producing well operations. These techniques are widely used in flowing wells and in some gas lift wells, where the pressure information is easily obtained from wireline-conveyed bottomhole pressure recorders. The presence of the sucker rods in beam pumped wells essentially precludes practical, routine, direct measurement of bottomhole pressure, thus eliminating the single most important parameter for well analysis. Permanent installation of surface indicating bottomhole pressure gages have not become cost effective, nor have wireline measurements through the annular space.

The solution of this problem has been found through calculation of the bottom hole pressure from casinghead pressure measurement and determination of the annular fluid head from echometric surveys that yield the depth of the gas-liquid interface. [1,2,3,4,5]

The RAM System for Pressure Transient data Acquisition

The advent of the Internet and wireless communications has made it possible to develop a practical data acquisition system to remotely monitor and automatically acquire acoustic fluid level and other data during pressure transient tests [6].

The **RAM** system (**R**emote **A**sset **M**onitor), shown schematically in Figure 1, has several objectives:

- Automatically acquire data without user intervention.
- Monitor individual well performance trends over extended periods of time.
- Provide remote access to test equipment deployed in the field.
- Monitor acquired data remotely via Internet and download it to user's computer.
- Manual Data Acquisition override.
- Increase safety and productivity of field personnel by reducing travel requirements.

These objectives are satisfied by using a programmable system for stand-alone wireless data acquisition and communication via the Internet. Frequency of data acquisition is controlled by the operator and can be modified during the test. The RAM system is a general-purpose system for monitoring the performance of all types of oil and gas wells.

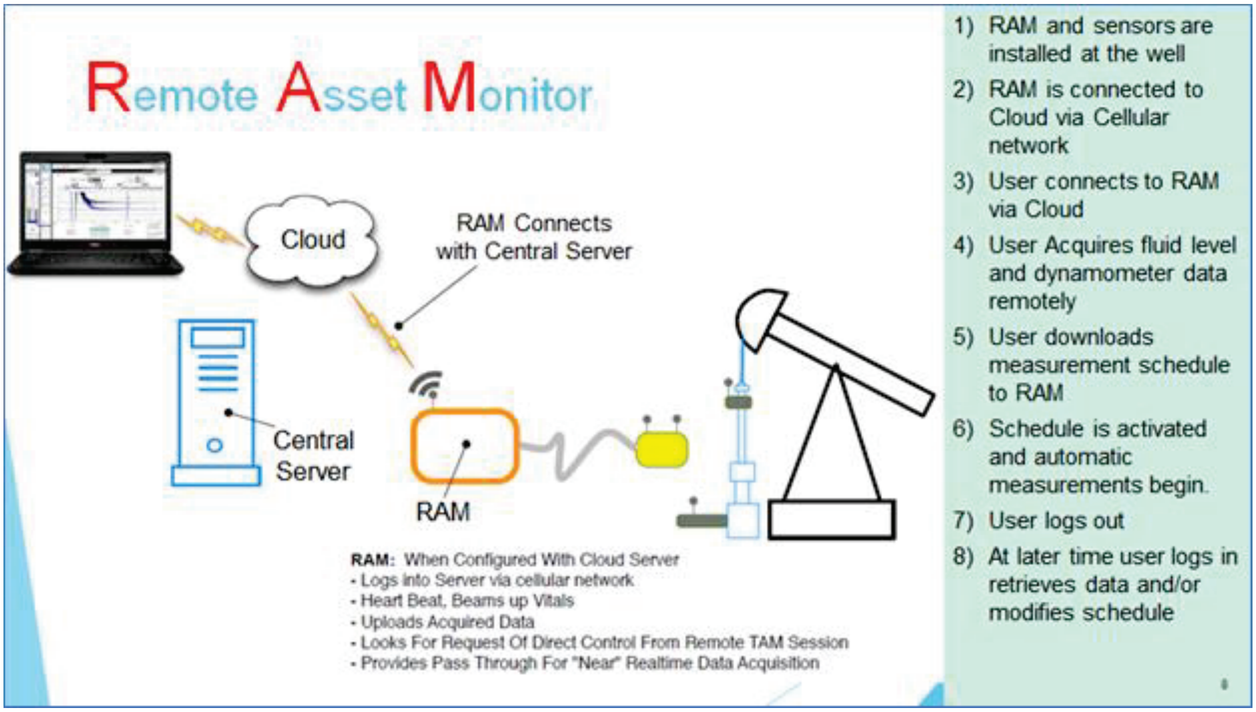


Figure 1: The RAM system schematic

For more details, please refer to the **RAM Features and Help Guide** and the **Liquid Level Features** in the TAM Help Tab:

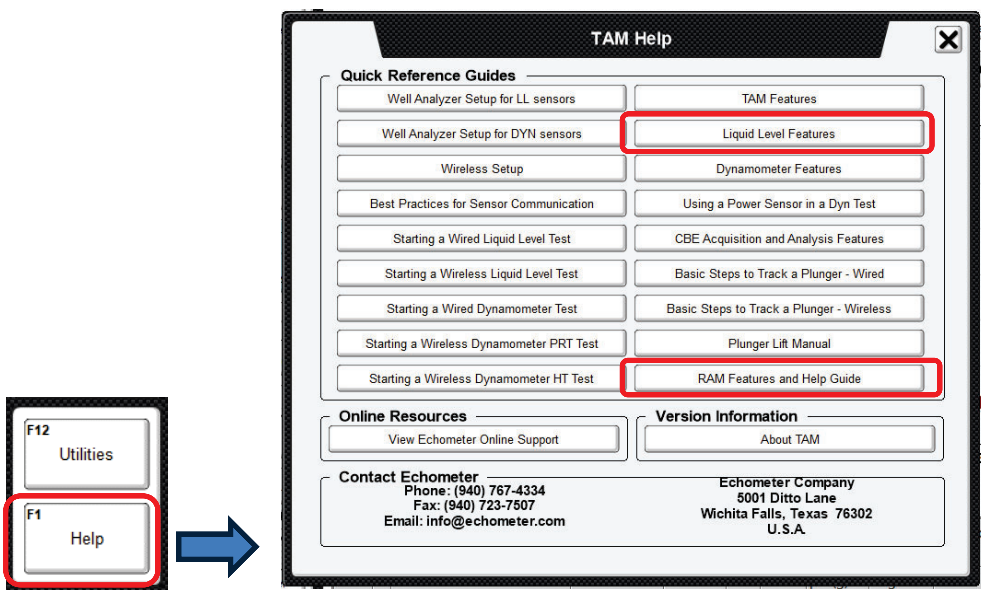


Figure 2: The TAM Help Menu

Hardware Setup for Pressure Transient Test Acquisition

A special version of the RAM system has been developed with the specific objective of acquiring and analyzing fluid level records during pressure transient tests in conjunction with version 1.9 or later, of the TAM software.

The field setup of the equipment for a pressure transient test at a pumping well is illustrated in Figure 3. It includes a Wireless Remote Fire Gas Gun (WRFG), a RAM box, and a Nitrogen gas supply. Very often, especially in the case of a rod pumped well, additional equipment may include a wireless Polished Rod (WPRT) dynamometer and a wireless pressure sensor (WPT). These additional sensors are used to acquire well performance data before initiating the pressure transient test to verify that the performance of the well and the pump are in accordance with the planned test.

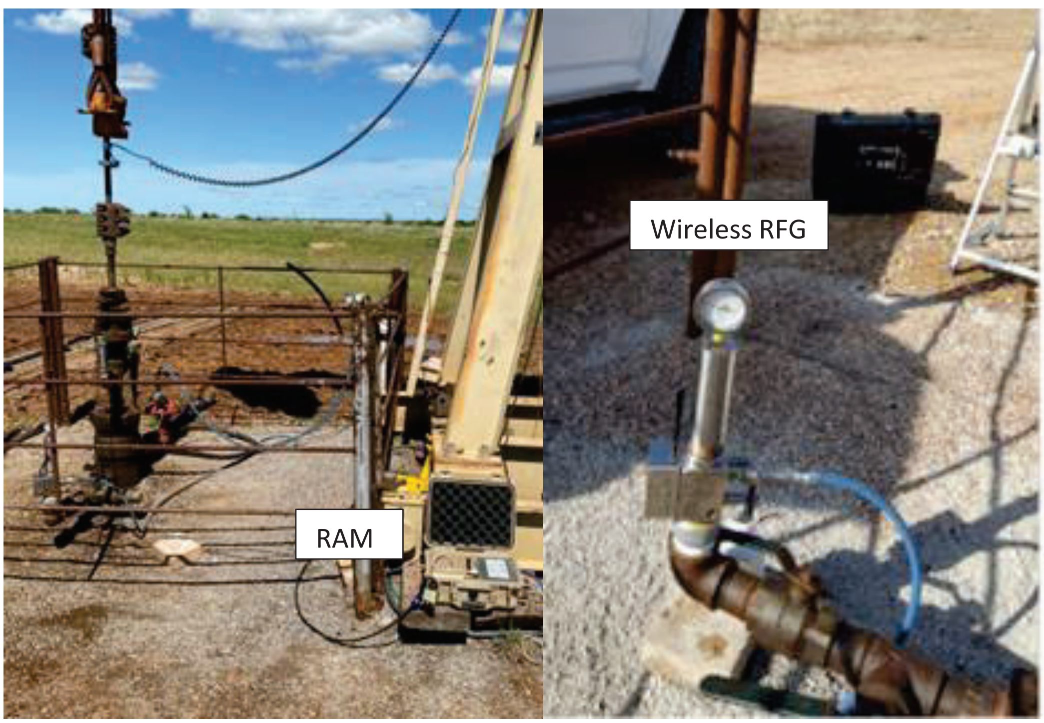


Figure 3: Field installation of the RAM system and Wireless Remote Fired sensor.

Wireless Remote Fire Gas Gun

The wireless remote fired gas gun (WRFG) consists of a microphone, solenoid gas valve, integral pressure sensor and volume chamber. During the several days of the typical pressure transient well test, the transducer's sensing element may undergo temperature variations of over 60 degrees F. Even though the transducer is built with integral temperature compensation this temperature change can cause periodic variations in the measurement of casinghead pressure that are reflected in the BHP record. In wells that exhibit low wellhead pressure it may be necessary to protect the WRFG from environmental temperature variations.

RAM Box

The RAM hardware, shown in Figure 4, communicates with the sensors via a standard Echometer base station and with a Cloud Server via a cellular network or connecting to internet available at location via Wi-Fi. It includes a single board computer system built to be deployed in the field (at the well). Contains just enough control firmware to acquire data unattended and communicate with an external laptop or with the cloud via internet connection. It utilizes existing wireless equipment for data acquisition and can run for around two weeks without external power such as solar panels or deep cycle batteries. The RAM's electronics are housed in an enclosure that withstands environmental conditions of temperature, wind, and rain.

Figure 4: RAM box connected to external battery and Nitrogen supply for long term operation.

For best results and reliable communication, the RAM box with the base and sensors should be placed in a location where there is cell coverage and a minimal level of wireless, SCADA and radio traffic. The system provides the necessary tools to identify and select radio channels with minimal traffic and interference.

Nitrogen Supply with Pressure regulator

The chamber of the Wireless Remote Fire gun is charged automatically with gas at a regulated pressure in excess of the well's casing head pressure. Nitrogen gas should be used (not CO2 because its pressure is dependent on the ambient temperature, it will freeze the flow restrictor in the automatic fill attachment and CO2 pressure regulators are unreliable). The size of the Nitrogen bottle should be sufficient to supply gas for the duration of the testing. The graph, shown in Figure 79, can be used to estimate the number of fluid level acquisitions that can be performed with a given standard size Nitrogen bottle and a given chamber pressure. Normally the pressure regulator is set around 150 psi over normal operating casing pressure but since during the buildup test the well pressure will increase, the regulator setting should be adjusted as necessary based on the quality of the remotely monitored acoustic records.

External Power Supply

For extended operation of the RAM system and sensors it is recommended to provide auxiliary electrical power using external batteries as shown in Figure 4, or solar panels or direct connection to AC power if available at the wellsite.

Acquisition of Pressure Sensor Zero

Zero Offset Acquisition must be performed, this can be done before installing the guns on the wellhead to ensure the pressure sensors are at atmospheric pressure when the offset pressure value is acquired. See the “Starting a Wireless Liquid Level Test” of the TAM Help Quick Reference Guides.

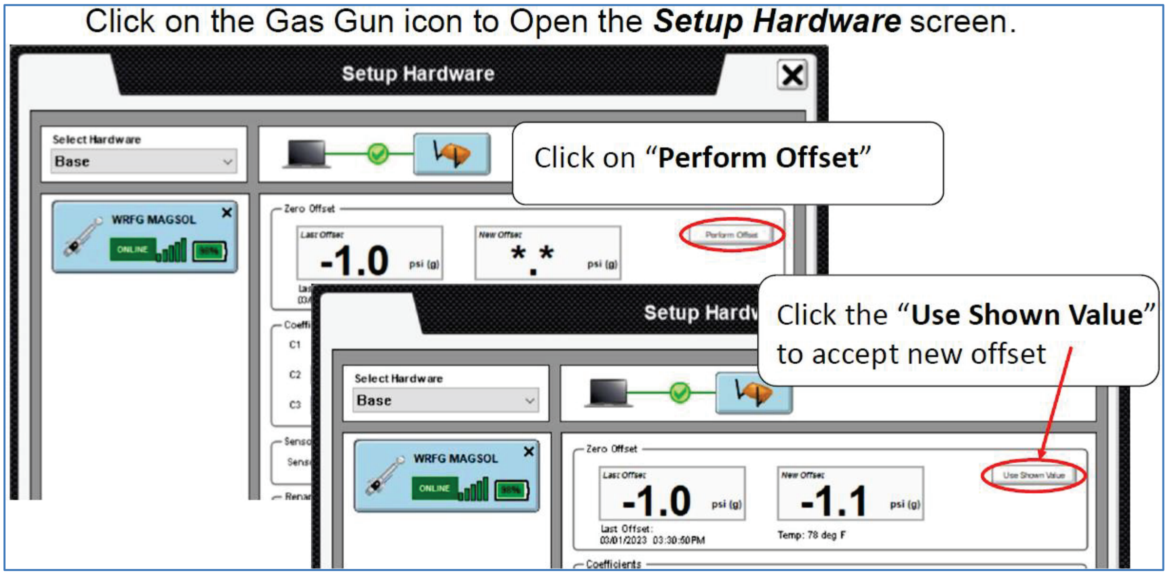


Figure 5: Zero Pressure Sensor Procedure

The zero-offset test information is saved as part of the **Session Test Info** tab

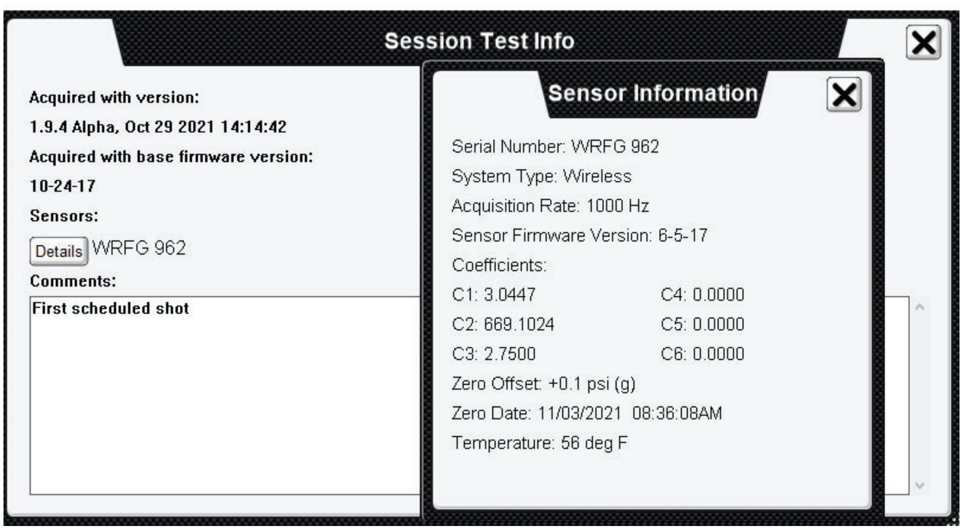


Figure 6: Advanced Analysis Session Test and Pressure Sensor Information

Software Setup for Pressure Transient Acquisition

In addition to the description of the well and the completion system, **the formation and fluid properties** must be entered in the **Reservoir Properties** tab of the TAM well data Detail View. This is not a requirement for acquisition of the records but these data are necessary to be able to perform preliminary pressure transient analysis while the test is still in progress.

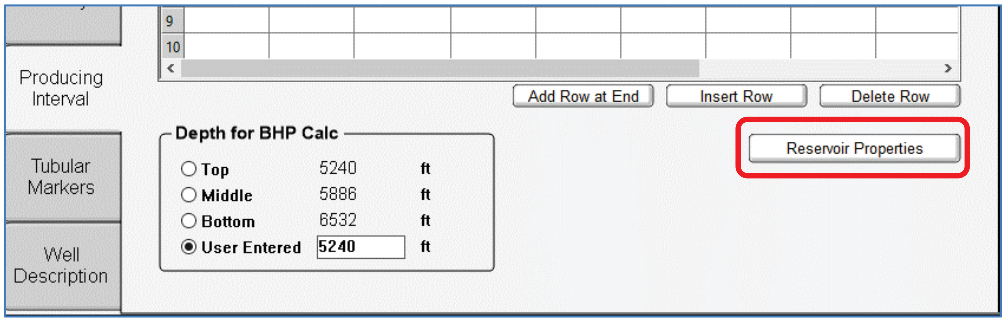


Figure 7: Reservoir Properties Button in Producing Interval Tab

Clicking that button opens the following dialog for entering the data used for pressure transient analysis.

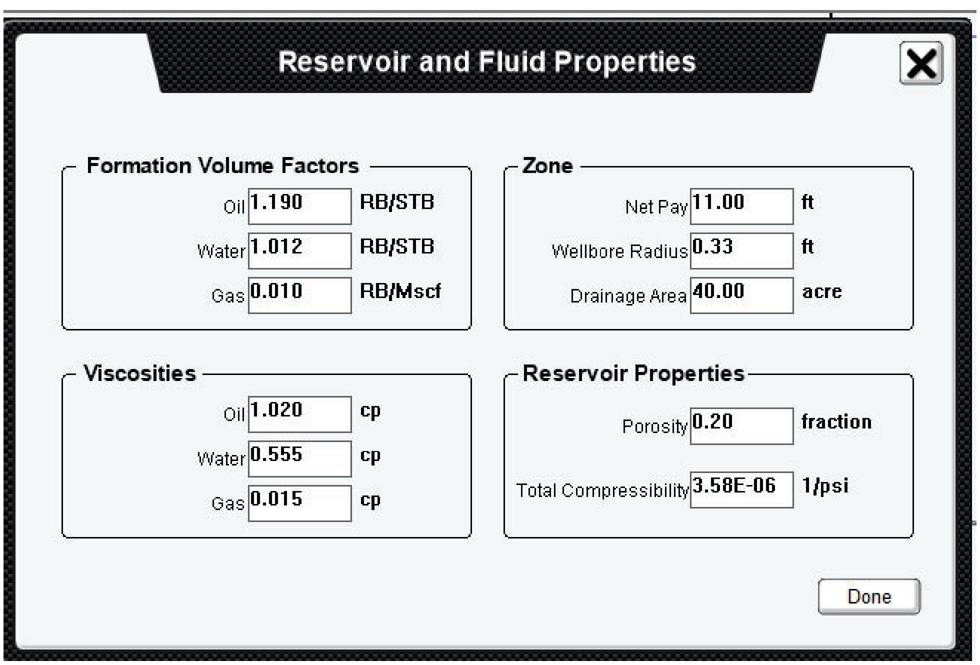


Figure 8: Reservoir and Fluid Properties Tab

NOTE: These data are not required for acquisition of the acoustic pressure transient records. They are required to generate the analysis graphs illustrated in Figures 39,40 and 42.

Advanced Analysis Schedule

A special schedule for Advanced Analysis, shown in Figure 9, specifies the frequency of data acquisition and the start time of the test. Fluid level records can be programmed to be acquired at constant time intervals or according to a logarithmic schedule to be consistent with the normal graphical presentation of pressure transient tests. The length of acquisition of the acoustic record and the duration of pressure monitoring are also specified.

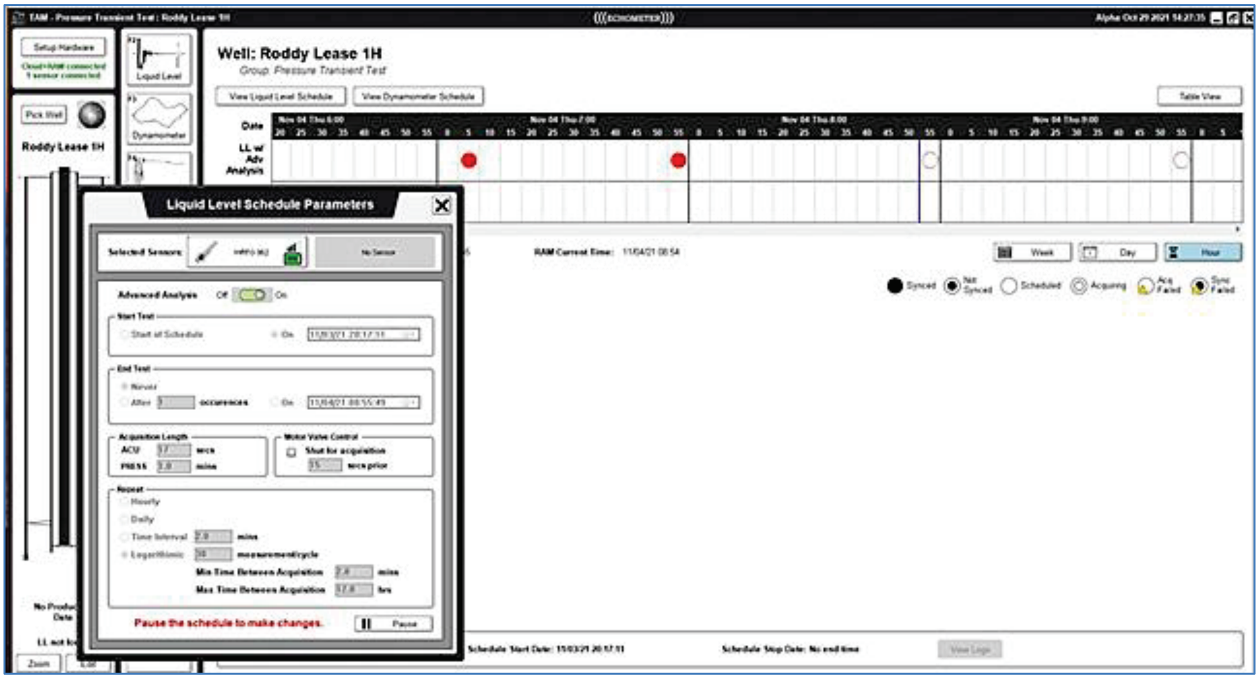


Figure 9: –Schedule for Liquid Level Record Acquisition for Advanced Analysis Pressure Transient.

Once the schedule has been activated the progress of the acquisition is monitored on a timeline where there is indication of the current date and time, which records have been completed (closed circles), which records are pending (open circles), which records have failed to be recorded, etc.

At any time, the user can connect to the RAM, via Internet, and view the progress of the schedule. The schedule can be interrupted and the frequency of acquisition can be modified to fit more accurately the expected future performance of the pressure and fluid level variation as a function of time.

Clicking on the **Scheduler** button at the lower left of the main screen:

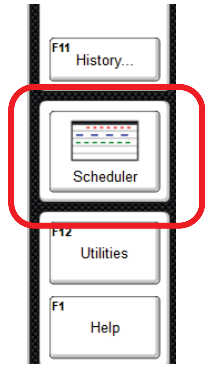


Figure 10: Scheduler Opening Button

Opens the RAM's scheduler window to display a timeline of all the acquisitions that have been completed or are scheduled in the future.

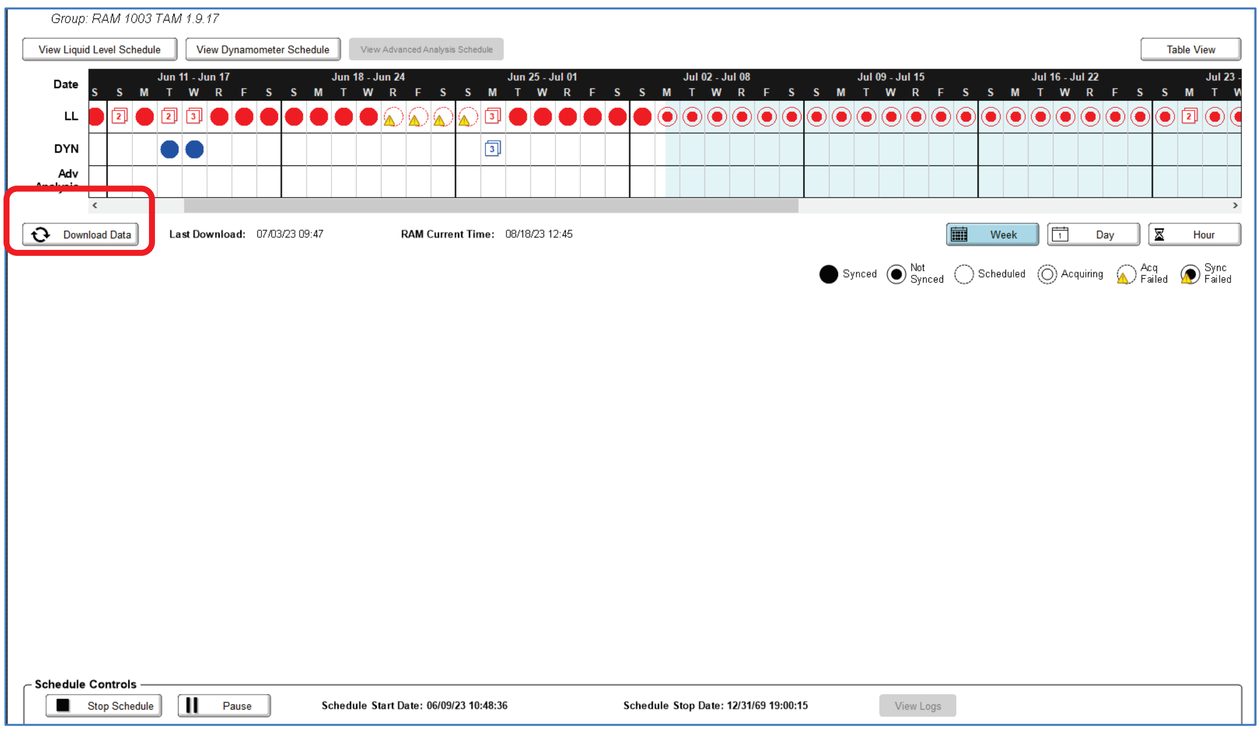


Figure 11: Scheduler Timeline View

The records can be downloaded to the user's computer by clicking the **Download Data** button.

Solid circles indicate records that have been already downloaded from the RAM to the user's specific computer. Circles with partial filling indicate records that have been acquired but have not been downloaded. Open circles indicate records that are scheduled for acquisition.

While the RAM is online and connected to the user's computer, the acoustic transient records that have been acquired up to that time can be downloaded for visualization and analysis.

After clicking the “Download Data” button, remaining records are downloaded one at a time and the progress of the download process is displayed at the bottom of the screen.

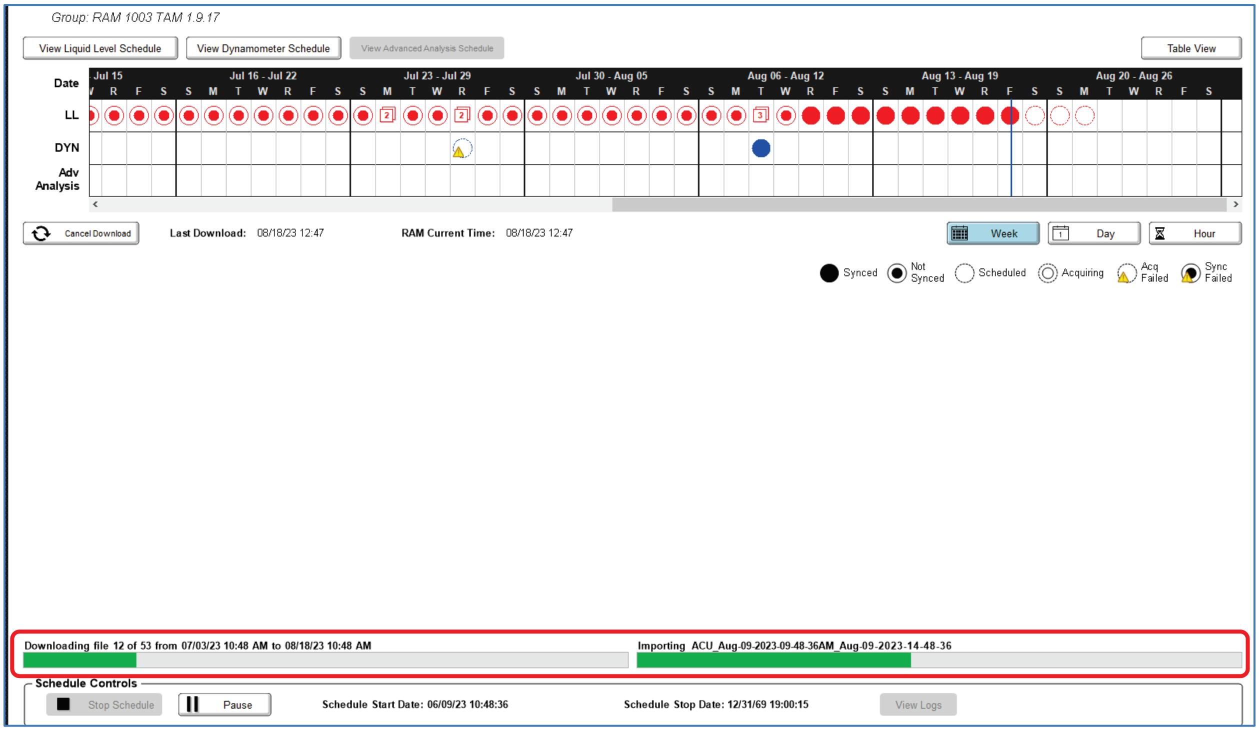


Figure 12: Scheduler shows that Records Download is in progress

Once all the available new records have been downloaded, they are stored on the user’s computer and can be viewed and analyzed. Depending on the progress of the test and the results obtained so far, the schedule can be continued or can be modified. Then the user’s computer is disconnected from the RAM and from the Cloud.

NOTE: Detailed discussion of operation of the RAM are included in the TAM help document: “**Ram Features and Help Guide**”

Presentation of Records from Transient Acquisition

The downloaded Pressure Transient records are grouped in a **<u>Session</u>** that is identified by the date and time when the test was initiated and is accessed by clicking on the **F6 "Advanced Analysis**" button:

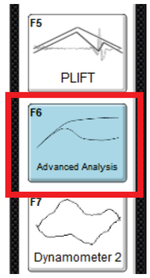


Figure 13: Advanced Analysis Session Opening Button

This will open the **Advanced Analysis Session** screen that gives the user a graphical and tabular presentation of the complete data set and the calculated results as shown in **Figure 14** where data points for all the records acquired during the past 471 hours are plotted. The **<u>Shots</u>** tab is selected by default.

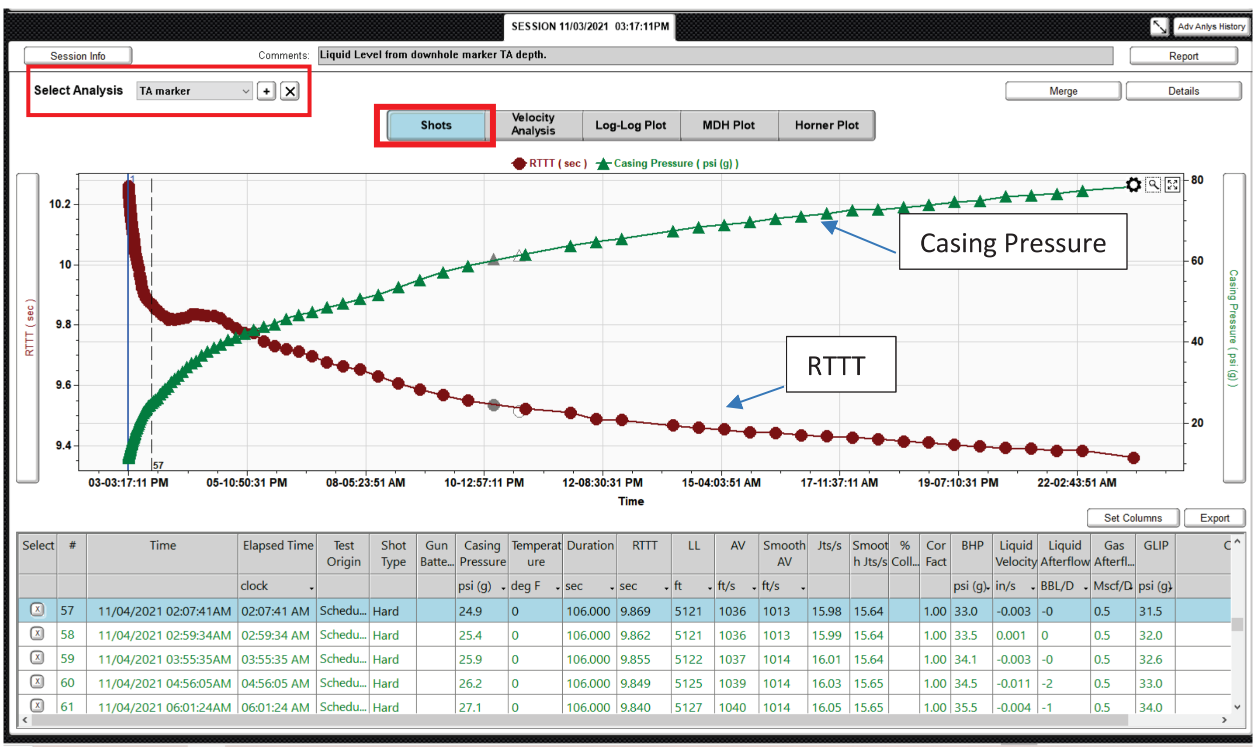


Figure 14: – Advanced Analysis Tab – records acquired during 471 hours – plotting RTTT and Casing pressure vs. time.

NOTE: After downloading from the RAM, the acoustic records are initially analyzed by default using TAM's **automatic <u>collar</u>** analysis.

The computed values displayed in Figure 14 are the results from the user's subsequent analysis. In this case the user, instead of the automatic collar method, selected the <u>downhole marker method</u> to determine the acoustic velocity and compute the distance to the liquid level. This is indicated by leaving blank the % Collars column in the table.

Plotting Variable Options

The plot in Figure 14 shows the variation of the Round-Trip Travel Time (RTTT) and the measured casing head pressure as a function of time and is presented here as a means for illustration and is only one of several possible graphs. The table below the graph, presents the data values that correspond to each record. The user can select which values are included in the table. The variables in the table can also be exported to a spreadsheet in the CSV format.

The variables to plot in the dual axis graph are selected from options in the data presentation menu that is pulled down by **clicking on the label button of each vertical axis**. These include:

Vertical Axis Variable Plotting Options

- Liquid Level vs. time
- Casinghead pressure vs. time
- RTTT vs. time
- LL interface Velocity vs. time
- % Liquid Correction Factor vs. time
- BHP Bottomhole pressure vs. time
- Acoustic Velocity vs. time
- Smoothed Acoustic Velocity vs. time
- % Collars counted, vs. time
- Transducer temperature vs. time
- Sensor Battery % vs. time
- Liquid After flow vs. time
- Gas after flow vs. time
- GLIP Gas/Liquid interface pressure vs. time
- Duration of record acquisition vs. time

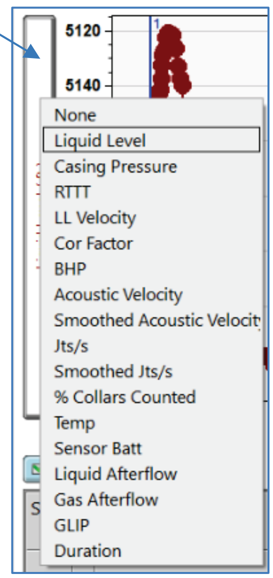


Figure 15: Vertical Axis Plotting Options

These plots are the principal tools used to determine the accuracy of the acquired data and the progress of the test. Random variations from the normal trend of a given variable are indication of possible problems with the hardware or software. The user should perform a detailed analysis of each record that deviates from the expected values.

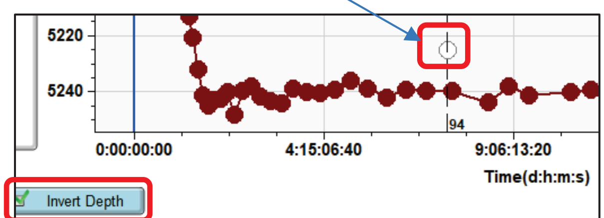
Session Table Columns Selection

The first four columns are always displayed and include:

Select	#	Time	Elapsed Time
			d:h:m:s
X	1	11/03/2021 03:17:11PM	0:00:00:00
X	2	11/03/2021 03:19:12PM	0:00:02:01
X	3	11/03/2021 03:21:12PM	0:00:04:01
X	4	11/03/2021 03:23:12PM	0:00:06:01

Figure 16: Session Table fixed columns

The Select column includes the **"X"** button that determines whether that record is to be excluded from the analysis. By default, all records are automatically analyzed and are included in the report. By double clicking the "X" button that record is excluded from the analysis, the button changes to **"+"** and the corresponding dot in the graph shows an **open circle**. (Record 94 did not detect the shot being fired so there is no acoustic record in the data. It is labeled as a **Soft** shot type)



Select	#	Time	Elapsed Time	Test Origin	Shot Type
			d:h:m:s		
X	91	11/09/2021 05:38:14PM	6:03:21:03	Scheduled	Hard
X	92	11/10/2021 05:23:31AM	6:15:06:20	Scheduled	Hard
X	93	11/10/2021 05:23:31PM	7:03:06:20	Scheduled	Hard
+	94	11/11/2021 05:23:31AM	7:15:06:20	Scheduled	Soft

Figure 17: Record Unselected by using the Select Column (X) Button

Clicking on the (+) button reinstates the record in the analysis.

The **# column** displays the sequential record number.

The **Time column** displays the date and time when the record was acquired.

NOTE: the time displayed corresponds to the time zone of the computer that is being used to analyze the data and does not necessarily display the local time for the location where the record was acquired.

The **Elapsed Time column** displays the time elapsed since the first record was acquired.

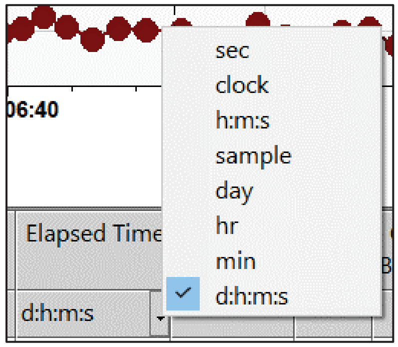


Figure 18: Time Units Pull Down Menu

The units of the elapsed time are selected by the pull-down menu.

NOTE: The unit of time selected in this menu is also used for the X-axis of the graphs.

The variables to be displayed in the remaining columns of the session table are selected by clicking on the **Set Columns** button:

The user can select which variables are included in the session table by clicking on the **Set Columns** button.

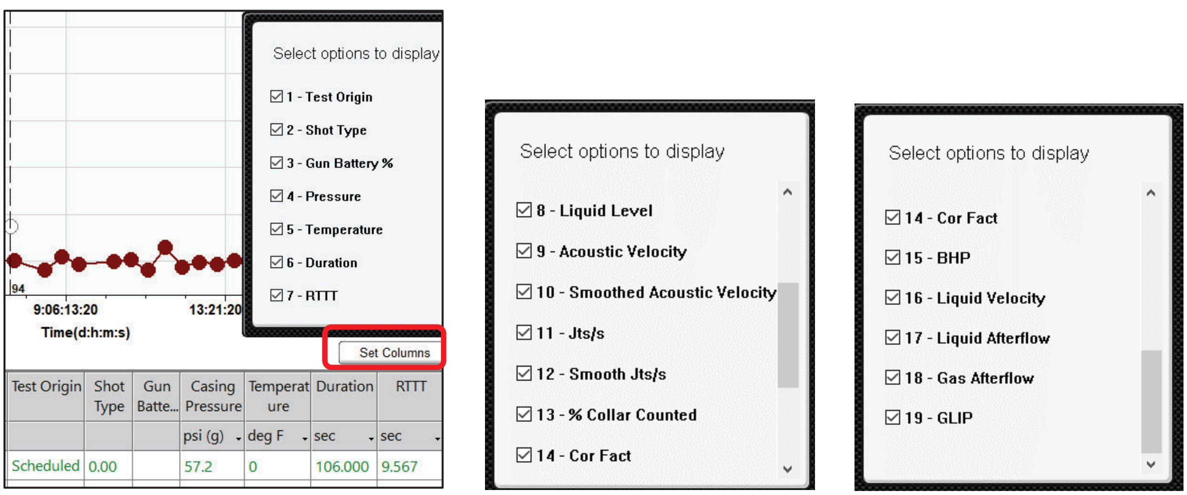


Figure 19: Selection of the Columns of the Session Table

When the Liquid Level Depth is plotted (Figure 17), an **Invert Depth** button is displayed for the user to select the direction of the depth axis of the graph. When clicked, the depth axis values increase from the top down.

Analysis of Pressure Transient Acoustic Records

The first step is to ensure that fluid levels are determined correctly so they can be converted to accurate bottom hole pressure. The consistency of the acoustic data can be easily visualized by plotting the RTTT value as the test progresses so that a smooth variation can be observed as shown in Figure 14. These plots should not exhibit random variations which generally are indications of erroneous analysis of the acoustic records. Random variations of RTTT and/or casing pressure will result in variations in computed BHP that are not representative of the reservoir behavior.

Bottomhole pressure (BHP) determination is based on wellhead pressure measurement, determination of the gas/liquid interface pressure and calculation of the annular fluid gradients. To achieve the maximum accuracy in BHP it is necessary to account for temperature variations, acoustic velocity variations, and changes in composition of the annular fluid. The plot of BHP in Figure 26 is the final result obtained after completing a careful analysis of each fluid level shot.

Acoustic Velocity Variation

During the well test (buildup or drawdown) the pressure, temperature and the gas component distribution in the annulus may undergo significant changes. These in turn will cause variations in the acoustic velocity of the gas. By default, the average acoustic velocity is obtained from an automatic count of filtered collar reflections, when available, and the average joint length. For wells where the acoustic record does not show collar reflections, the variation of acoustic velocity is computed from the known gas gravity the average temperature and the measured pressure.

Experience indicates that pressure-dependent velocity variations occur gradually and continuously and follow the trend of pressure variation, as shown in Figure (20).

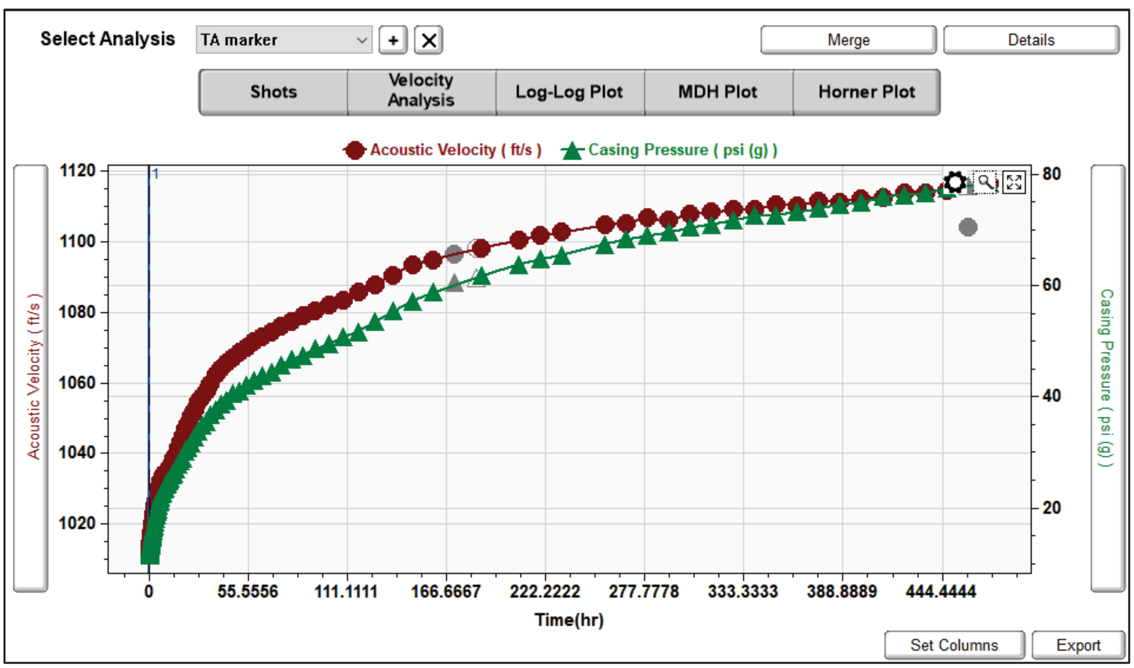


Figure 20: Variation of Acoustic Velocity during the Test

When enough consecutive records have not been acquired or there is excessive random variation of velocity the **Velocity Analysis** tab (See page 29) is used to interpolate between available points to smooth the velocity values and calculate the depth to the gas/liquid interface from the measurement of the travel time of the liquid echo. If this variation were not considered and a single value of acoustic velocity were used in interpreting the travel time of all the records, a significant error in calculated BHP would be made.

BHP Calculation

Several papers have been presented on the correct methods for calculation of bottomhole pressure from acoustic determination of annular liquid levels [2,3]. The BHP is the sum of the casinghead pressure and the hydrostatic column pressures due to the annular gas and liquid. The gas column gradient is calculated as a function of pressure, temperature, and gas gravity. The liquid column pressure is a function of the composition of the liquids, and the in-situ water/oil ratio and gas/liquid ratio. Flowing conditions and well geometry determine the fluid distributions. For example, for steady state pumping conditions the liquid above the pump intake is mainly oil due to gravity segregation occurring in the annulus. When the well is shut in for a buildup, the water cut remains essentially constant during the after-flow period and a moving oil/water interface develops during the test. These factors are taken into consideration by the program in the calculation of the bottomhole pressure. In-situ oil and water densities are calculated as a function of pressure and temperature using conventional correlations.

When the producing bottomhole pressure is below the bubble point, free gas is produced from the reservoir and is generally vented from the annulus. This annular gas production reduces the liquid column gradient and thus must be taken in consideration in the BHP calculation. Experience indicates that a gaseous liquid column can extend for a significant period after the well is shut in. A correlation derived from a multitude of field measurements of gaseous liquid column gradients[3] is used to account for this effect.

Recommendation: When a long annular gaseous liquid column is present in a pumping well, to obtain the most accurate results, it is recommended that before the initiation of the buildup test the liquid level should be depressed to a few joints above the pump intake by increasing the casinghead back pressure while maintaining a steady pumping rate. This is easily achieved by means of an adjustable back pressure regulator installed on the casinghead valve that will maintain the casing pressure constant during the process of liquid level depression until stabilization. The result will be that at the end of the after-flow period the height of the liquid column will be minimized and a major portion of the BHP will be provided by the surface casing pressure (that is measured very accurately) and the gas column pressure.

Description of Tools and Buttons in the Session Screen

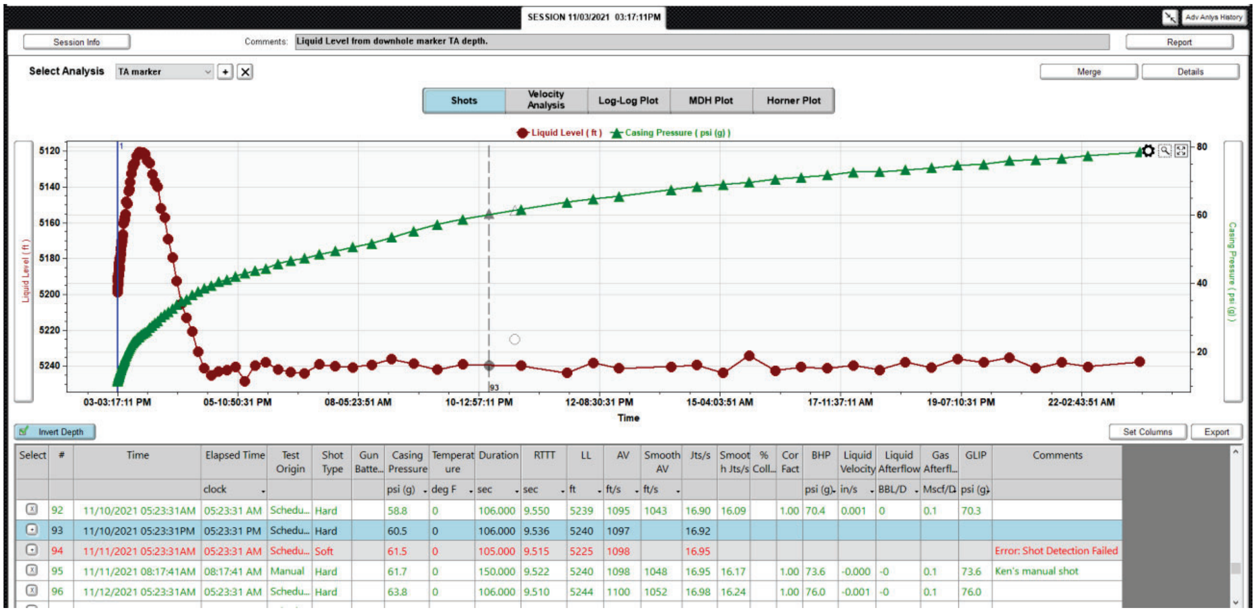


Figure 21: – Pressure Transient Session Graphs and Table of Records.

Session Info

Information about the software and hardware used for acquisition of the advanced analysis records are displayed in the Session Info tab.

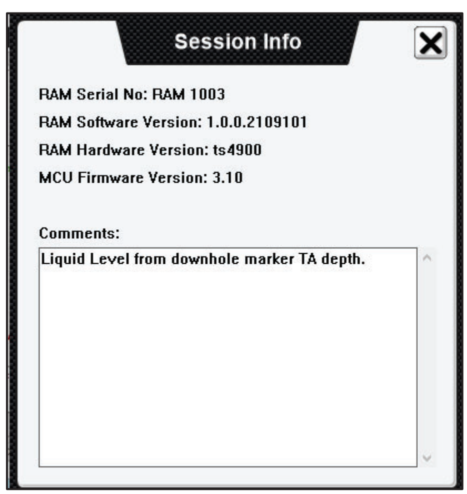


Figure 22: Session Information Tab

Comments entered by the user in the Comments field are also displayed in this tab.

Comments

This field should be used to describe how the data is being interpreted and analyzed as well as any special procedures followed during acquisition.

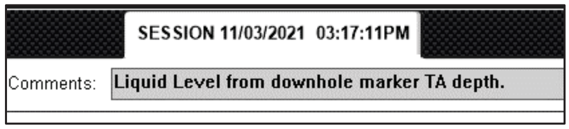


Figure 23: Comments Input Field

Clicking in the comments field opens the **Session Info** tab, described earlier, to edit or input additional test information.

Reports

Once the data is processed and analyzed a summary report can be generated to be printed or saved and or e-mailed as a pdf file.

Figure 24: Session Report Button

Clicking on the **Report** button opens the Reports tab for the user to select which summary information is presented.

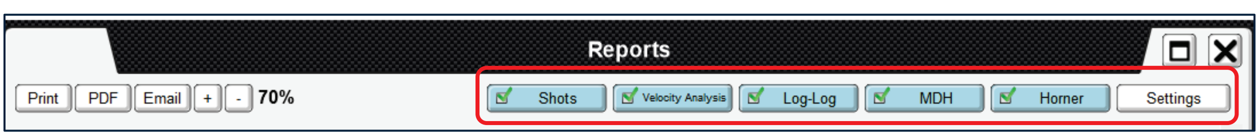


Figure 25: Buttons for Selection of Report Pages

The pages the user wants to include in the report are selected by clicking on the corresponding buttons/check boxes at the top right of the Reports tab.

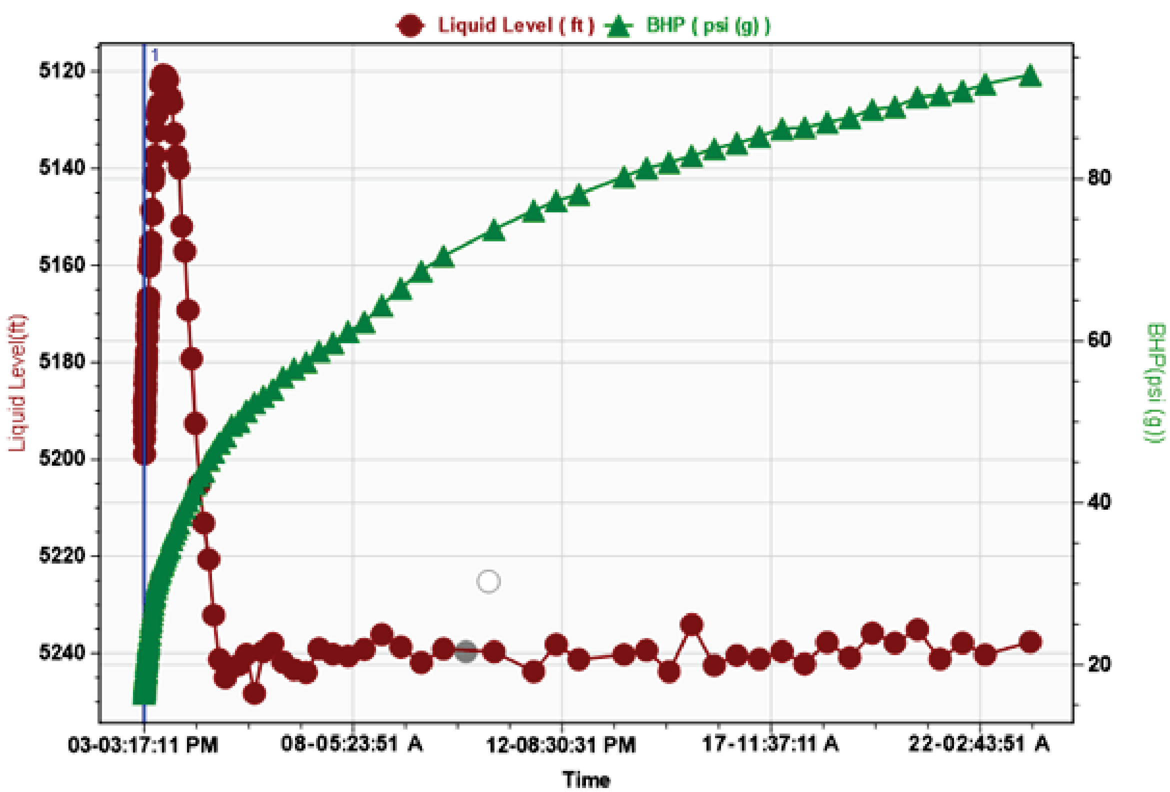
Buttons at the top left side give options to print, save a pdf or forward the report information via Email.

The following figure is an example of the first page of the Advanced Analysis Report.

(((ECHOMETER))) Roddy Lease 1H 11/03/2021 03:17:11PM Click here to select image...

Pressure Transient : TA marker

Shots



Number Of Tests in Analysis	114
Number of Tests Omitted	2
Duration	471.11 hr

Values

First Liquid Level	5188 ft	First BHP	16.5 psi (g)
Last Liquid Level	5238 ft	Last BHP	92.8 psi (g)
Avg Liquid Level	5194 ft	Avg BHP	42.4 psi (g)

BHP Depth	5240 ft MD	4823 ft TVD

COMMENTS

Liquid Level from downhole marker TA depth.

Echometer Company
5001 Ditto Lane
Wichita Falls, TX 76302
(940) 767-4334
info@echometer.com

Figure 26: First page of the Advanced Analysis Report

Adv Analysis History

A table that lists all the records acquired during the Advanced Analysis session is displayed by clicking the button at the top right of the session screen. The “Adv Anlys History” button.

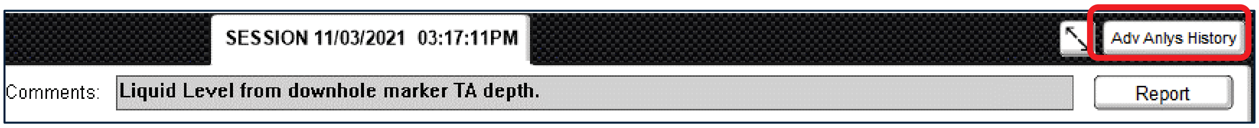


Figure 27: Advanced Analysis History Button

The “Test History” tab presents a table that lists the acquired records and sessions.

Test History Tab

Displays information about each of the Advanced Analysis sessions that have been completed.

Clicking on the square labeled Start Date/End Date, displays a thumbnail of each record for that session (last record at top row), the data and time when it was acquired, whether it was acquired manually or automatically via the schedule and any relevant comment.

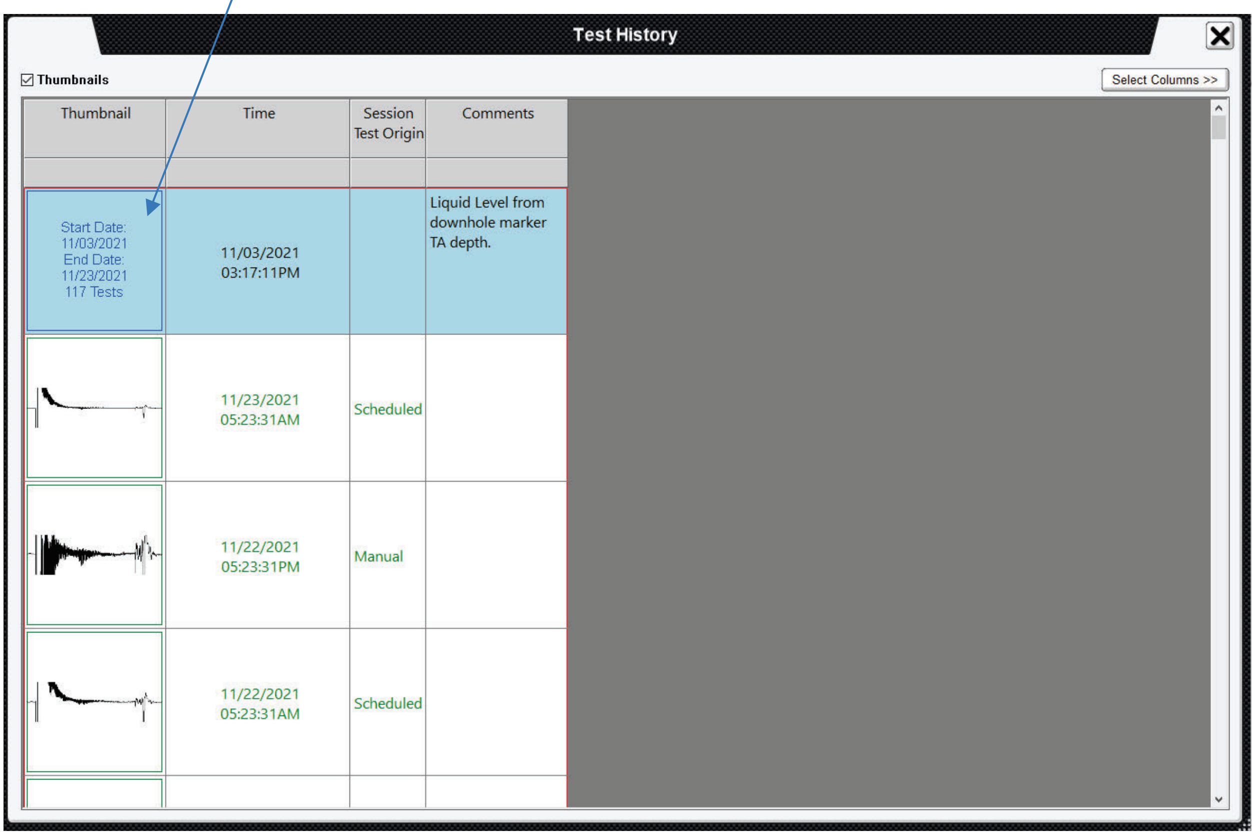


Figure 28: Test History Tab

Clicking a row in the table will select that same record in the session table and plot. Clicking a dot in the graph will select the corresponding row in the table.

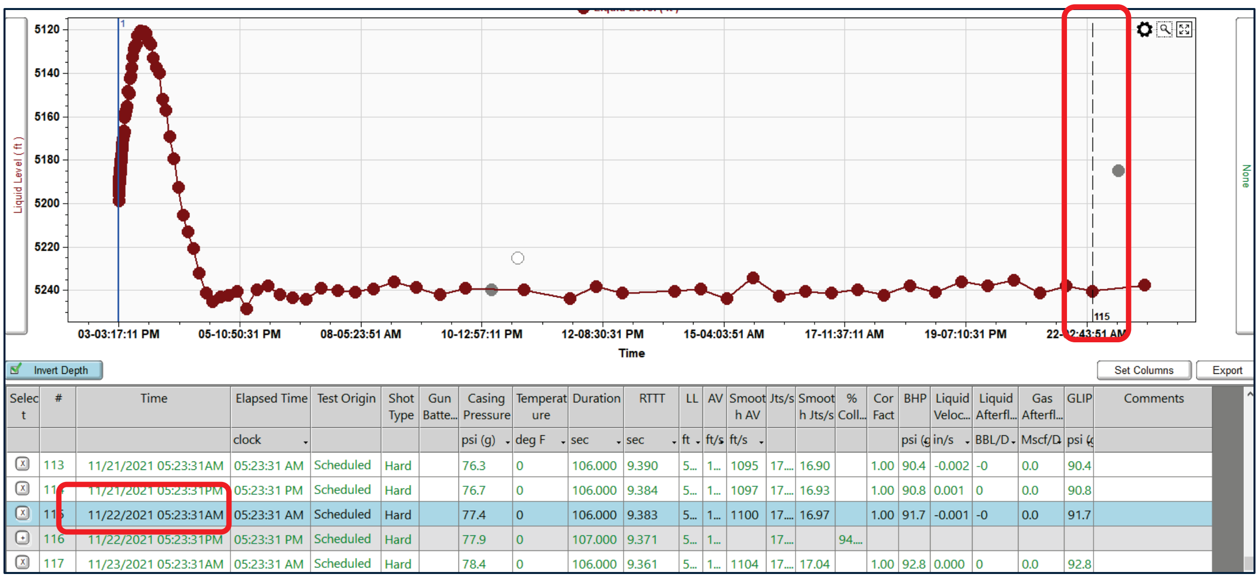


Figure 29: Record Selected by clicking on the Thumbnail in the History Tab (Fig. 27)

The acoustic record can be viewed, in a pop-up window, by double clicking on the specific row in the table or the dot in the graph.

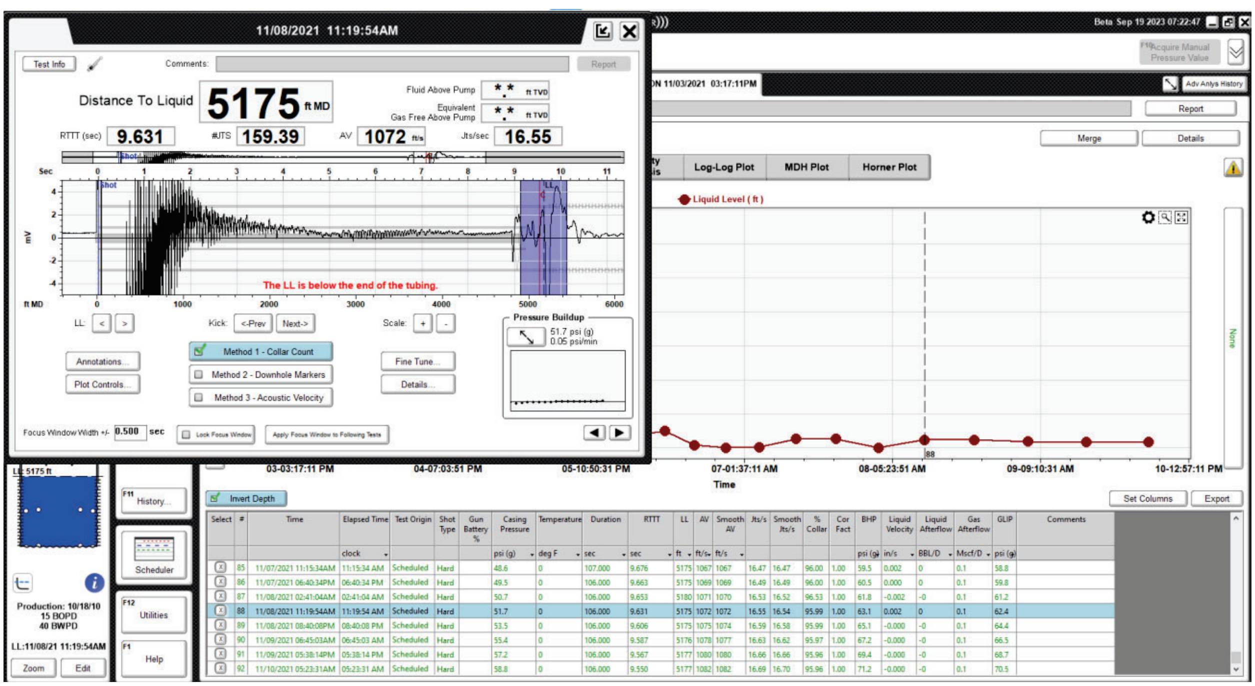


Figure 30: Record displayed by double clicking the row or the dot.

Select Analysis Menu

When the user processes the acoustic records with different settings or options then each analysis may be stored under different names. TAM's automatic analysis is labeled Default. The user, after reprocessing the records, can store the new analysis by clicking on the (+) button.

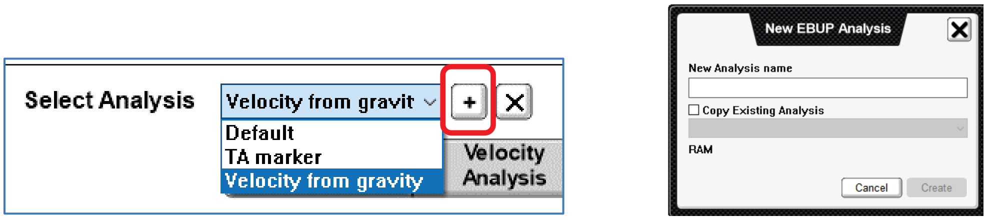


Figure 31: Saving Current Analysis under a New EBUP Name

The "New EBUP Analysis" dialog is opened to enter a name for the current reprocessed records.

All existing analyses are listed in the pull-down menu. Selecting an analysis and clicking the (X) button will delete that analysis.

Merge Tab

In some cases, after initiating a pressure buildup test, it may be necessary to stop the acquisition of records for a certain time. Generally, this is caused by failure of the sensor, loss of power or loss of gas supply. The session may be stopped and the data is downloaded and stored on the user's computer. When the repairs are performed then a new Advanced Analysis session is initiated to continue acquiring records for the transient test.

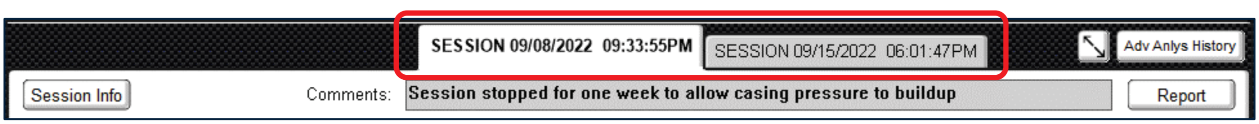


Figure 32: Two Sessions to be Merged

When the transient test is completed and the well is put back in production, there will be two separate sessions in the user's computer as shown in the previous figure.

It is possible to combine the records from the two sessions using the **Merge** function that opens a tab that lists all the sessions that were acquired for this well.

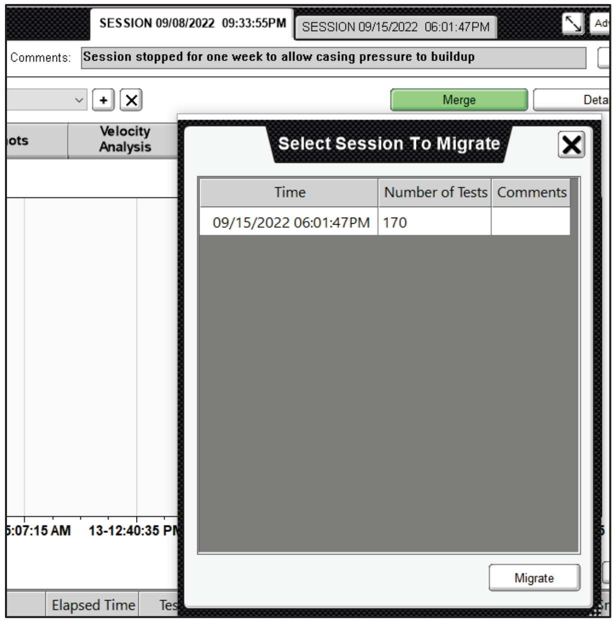


Figure 33: Select Session to Migrate Tab

More information about merging Advanced Analysis sessions is presented at Page 54 of this document.

Details Tab

This tab is opened by clicking on the Details button at the top right of the Session screen. The user is required to select the calculation options that are appropriate for the analysis of the records.

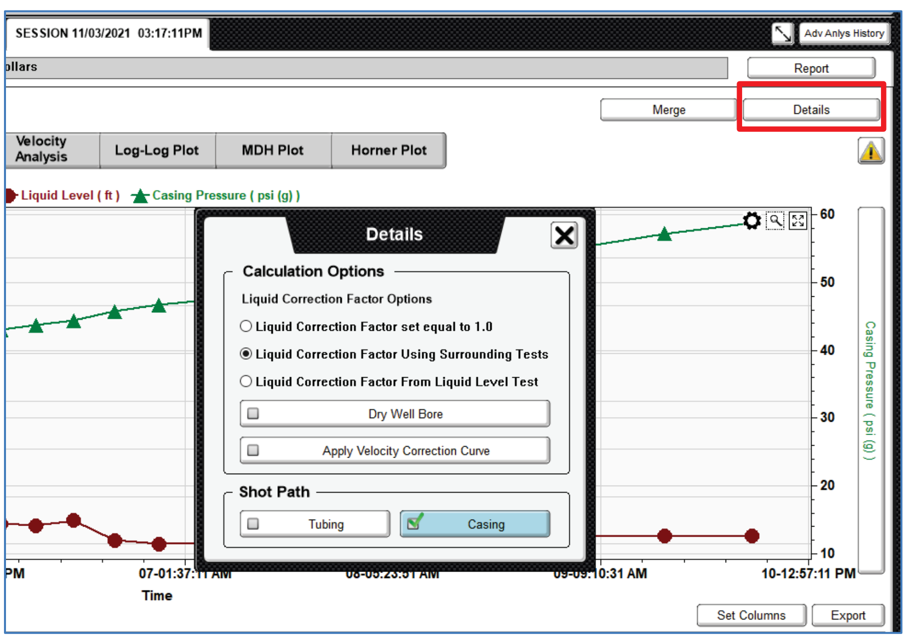


Figure 34: Test and Analysis Details Menu

Calculation Options

No Liquid Correction Factor Used: this really means that the liquid correction factor is set to 1.0 for all records.

Liquid Correction Factor Using Surrounding Tests: the liquid correction factor is computed based on the difference in measured surface pressure between the current record and the previous and next record.

Liquid Correction Factor from Liquid Level Test: the liquid correction factor is computed from the change of pressure during the acquisition of the current record. This yields the dp/dt value used in the Echometer "S" curve to determine the % liquid in the gaseous column for the BHP calculation at that time.

Dry Wellbore Button

Clicking this button forces TAM to consider that there is only dry gas in the wellbore when computing the BHP.

Apply Velocity Correction Curve

Calculation of the liquid level depth will use the acoustic velocity interpolated from the points selected by the user in the **Velocity Analysis** plot.

Shot Path

The user must indicate whether the records are acquired in the tubing or in the casing.

Shots Tab

This is the default TAB for viewing Advanced Analysis records. It opens to display, at the top, a plot of the data points vs. time (Liquid level) based on TAM's automatic fluid level processing.

The following paragraphs describe in detail each feature of this TAB.

Invert Depth

This button is displayed only when Liquid Level depth is plotted. When it is clicked, the vertical depth axis is inverted so that depth increases from the top down.

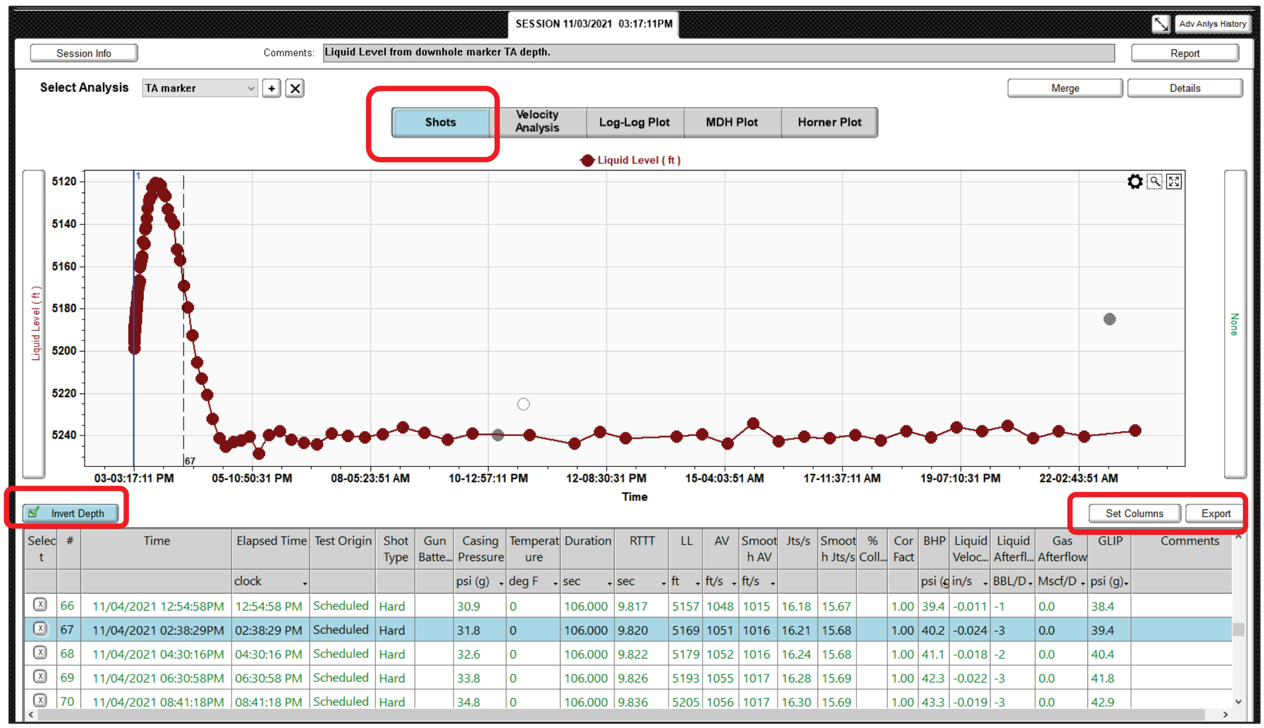


Figure 35: Shots View with Inverted Depth for Advanced Analysis Window

Below the graph, a table is displayed with rows corresponding to each acoustic record acquired.

The columns that are displayed in the table are user-selectable by clicking the **Set Columns** button.

Set Columns

Clicking this button opens the menu for selecting which columns are displayed in the Session Table.

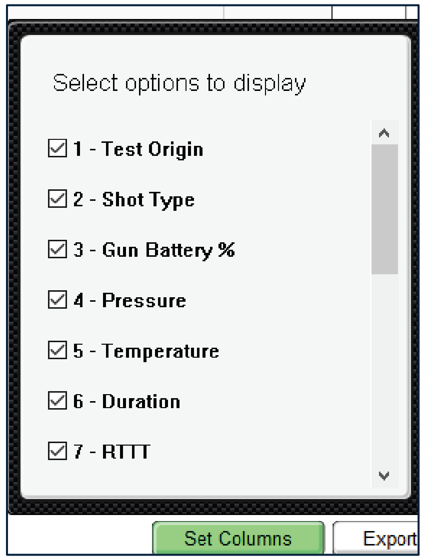


Figure 36: Session Table Columns Selection Menu

Export

Clicking the **Export** button opens the menu for selecting the format to be used when the Advanced Analysis results are exported to an external file.

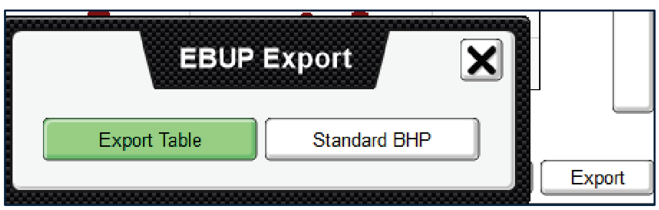


Figure 37: EBUP Export Options Tab

Please see an example of exported files at page 52.

Velocity Analysis

Clicking this button opens the tab where the acoustic velocity corresponding to each record is plotted vs. time. The purpose of this tab is to select the values that best represent the variation of the acoustic velocity during the transient test and generate a "smooth" interpolating function. The user selects which points (indicated by the red dots) are to be used for interpolation.

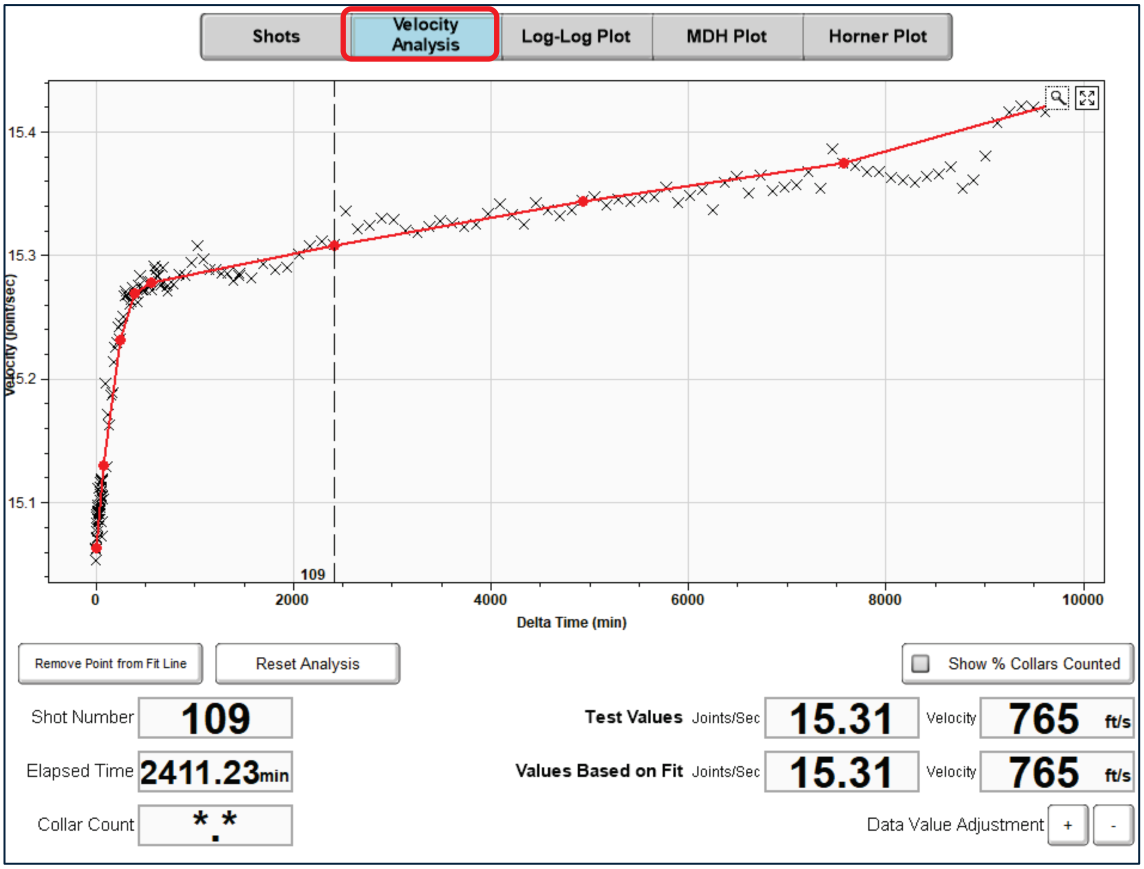


Figure 38: Velocity Analysis Smoothing Curve Selection of Data Points

The smoothing function eliminates the effect of acoustic velocity variations that are considered random in nature. The user can select whether TAM should use the velocity that TAM determined for each record or use the smoothed interpolated values (represented by the red linear segments) to compute the distance to the liquid level. The points to be added to or removed from the curve fit are selected by pointing and clicking with the mouse or by dragging the marker line.

Log-Log Plot

The purpose of this graph is for quality control of the data, by viewing all the computed BHP pressure values presented as the difference in BHP as a function of elapsed time. The user can determine, from the characteristics of the graph, whether the pressure transient test has run a sufficient time and will provide adequate data for detailed analysis of the reservoir properties.

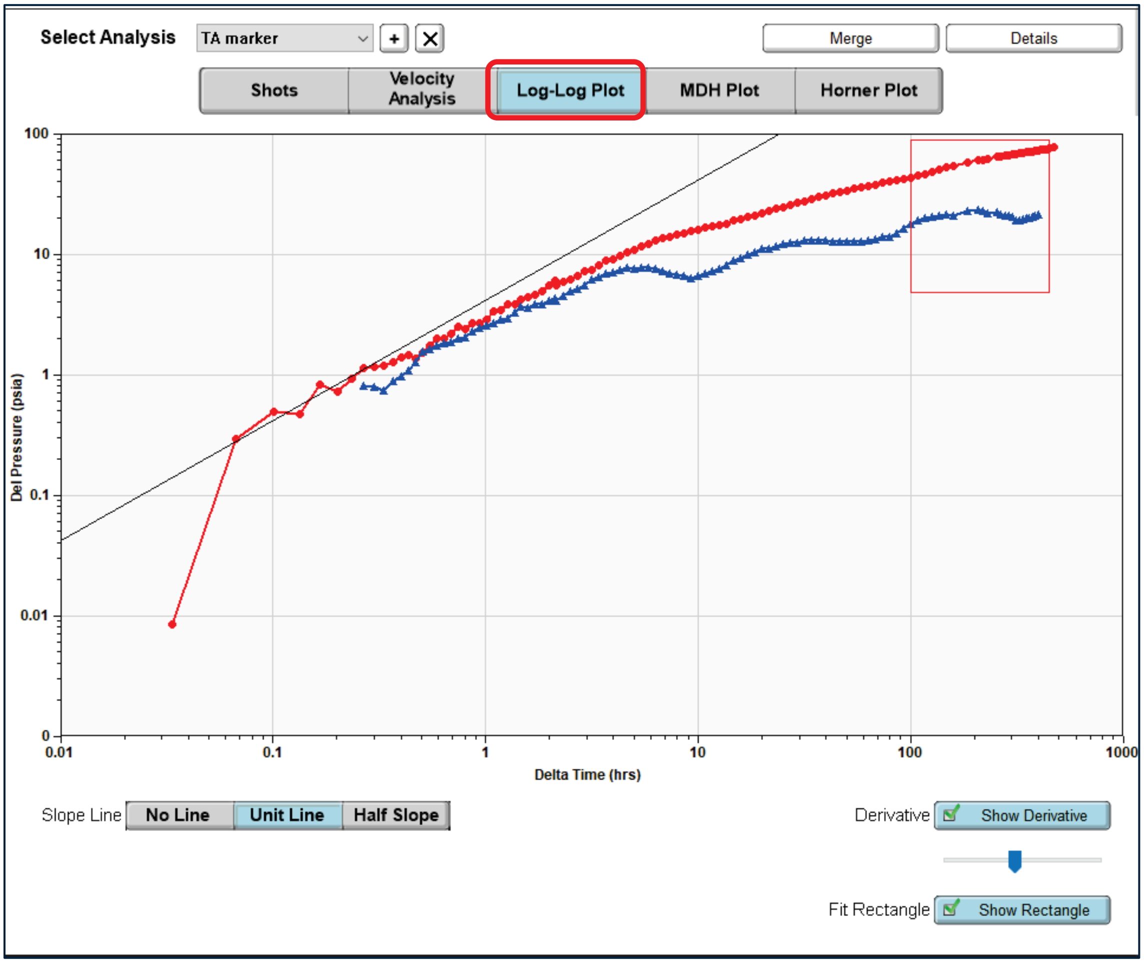


Figure 39: Log-Log Pressure Buildup Plot

Reference slope lines can be displayed by clicking on the Slope Line buttons and adjusted manually by dragging with the mouse pointer.

The derivative function (t dp/dt) can be displayed and its level of smoothing is adjusted with the slider tool.

Sections of the data, to be used in subsequent plots, can be indicated by clicking the “Show Rectangle” button and adjusted by dragging the boundaries of the rectangle.

MDH Plot

The purpose of this plot is to estimate some producing formation properties by selecting the data points in the region that corresponds to a transient behavior characteristic of radial flow.

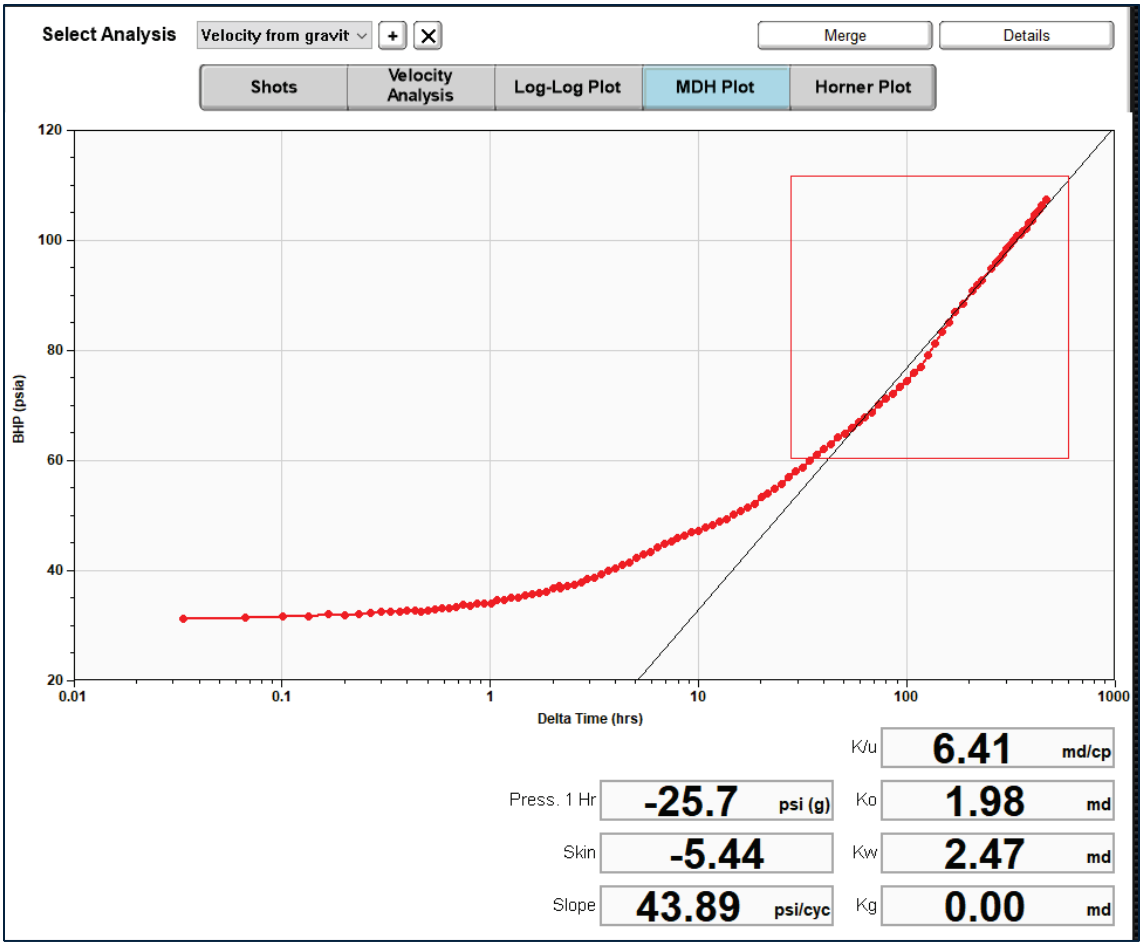


Figure 40: MDH Pressure Buildup Plot

NOTE: the values displayed in the boxes, can be computed only when the Reservoir and Fluid Properties have been entered in the Producing Interval tab (see Figure 41). Otherwise, the asterisk (*) symbol will be displayed.

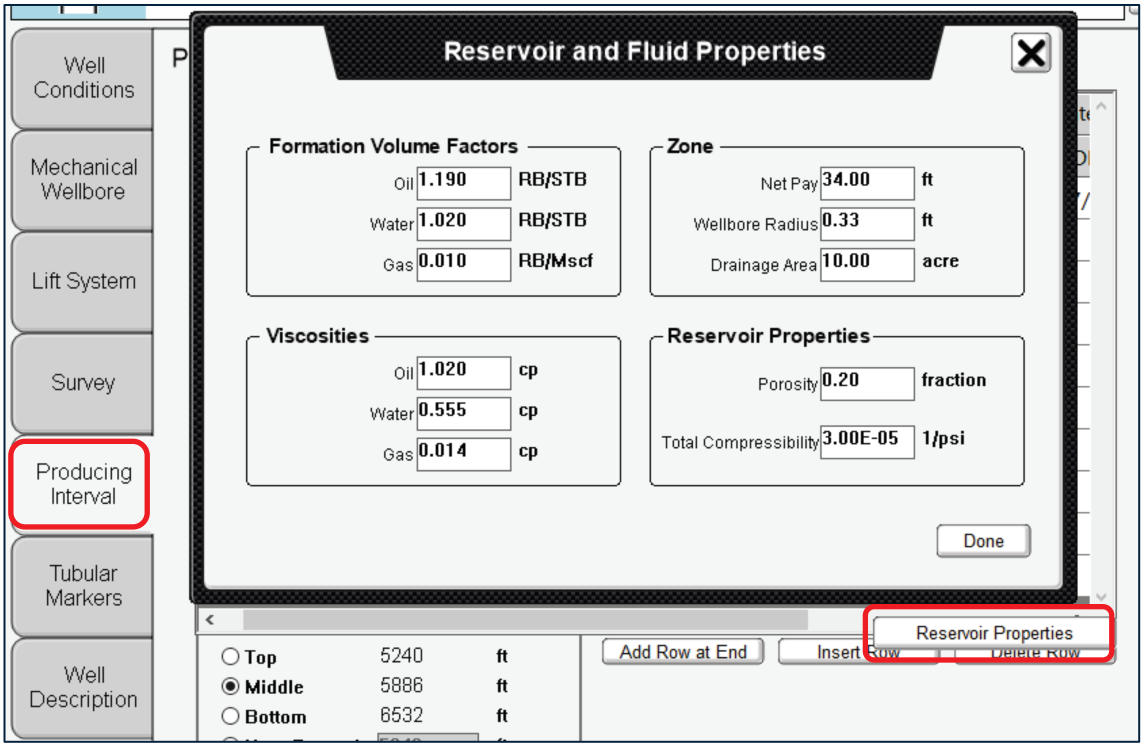


Figure 41: Reservoir Properties Input Tab

The dialog for inputting the values is opened by clicking the “Reservoir Properties” button.

Horner Plot

The purpose of this plot is to estimate the Average Reservoir Pressure from the Horner Extrapolated Pressure (P*) in addition to the reservoir skin and permeability values.

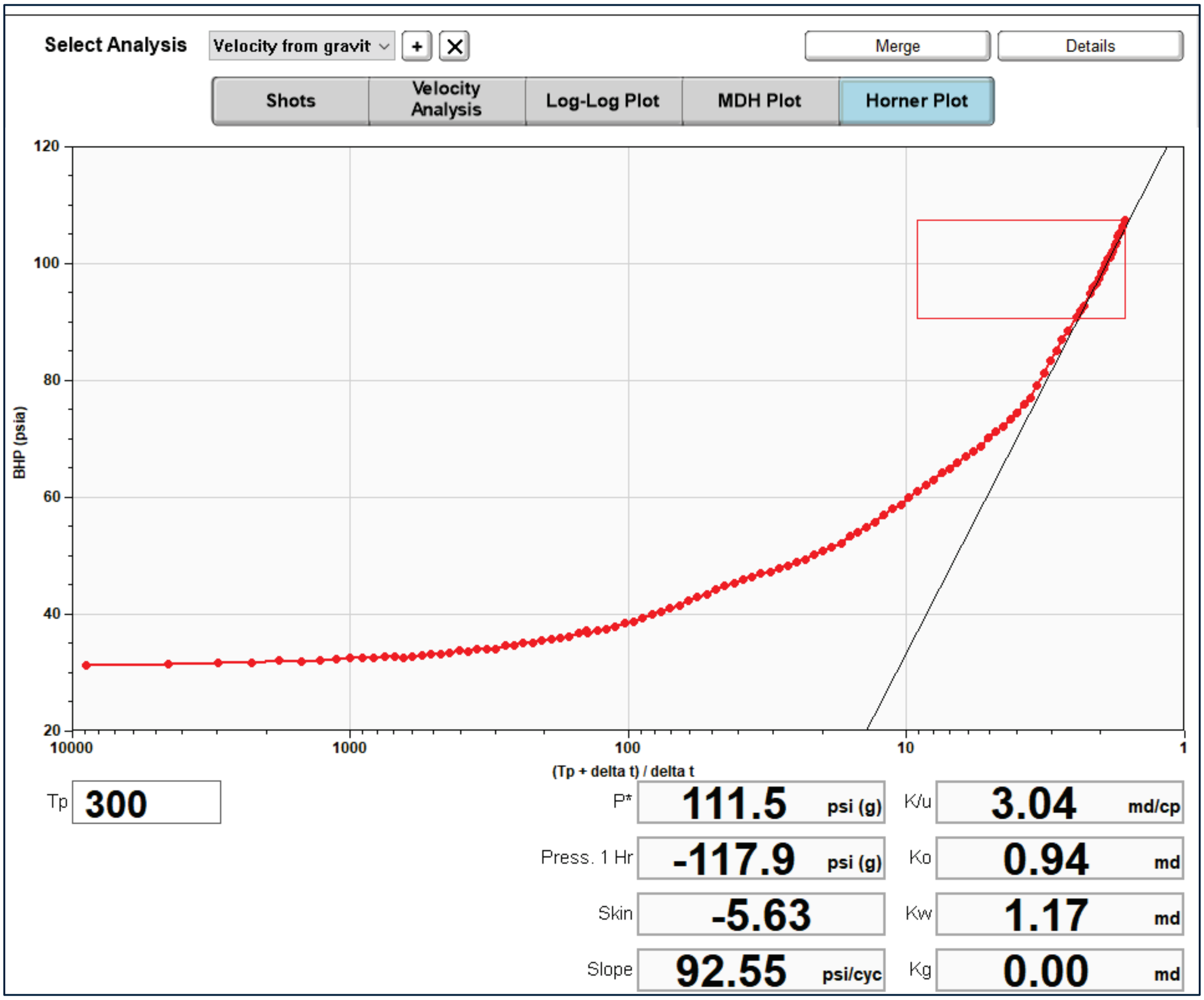


Figure 42: HORNER Pressure Transient Plot

The Horner Producing Time **Tp** must be input by the user. It represents the time (hours) during which the well has been producing at a steady flow rate.

NOTE: The value of 300 hours is a TAM default.

Adjusting Views and Scales

Record 57 in the Session View is displayed to discuss in detail the numerous buttons and other tools that are available to the user for analysis of the acoustic records.

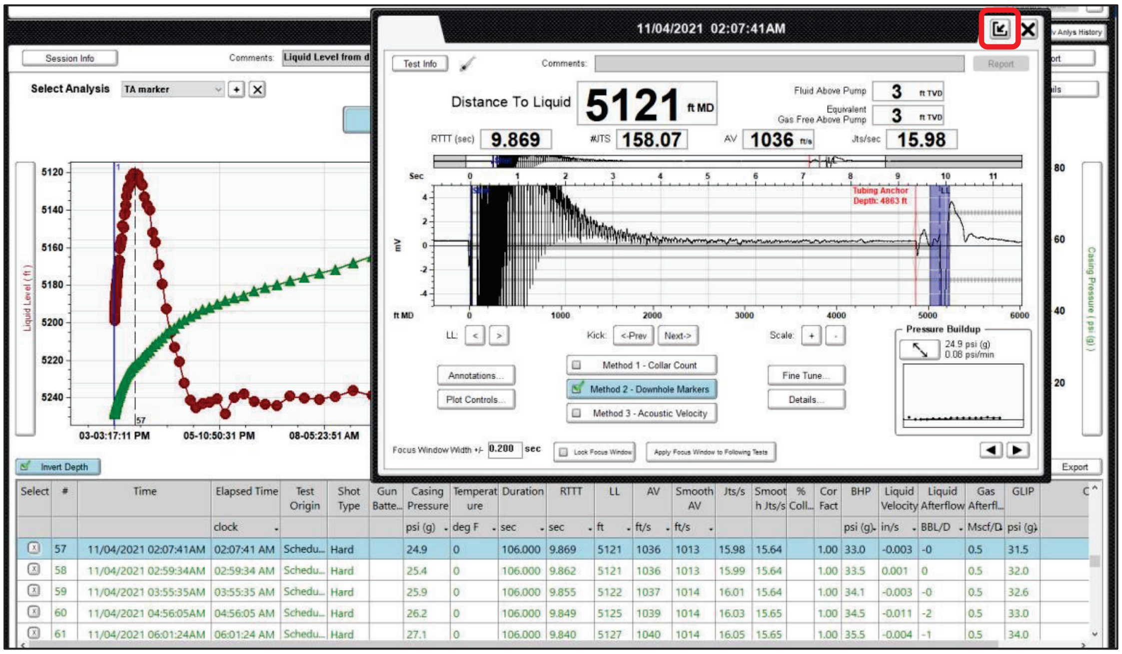


Figure 43: Acoustic Record for Shot 57

Clicking on the  button expands the acoustic record to the full screen for detailed analysis.

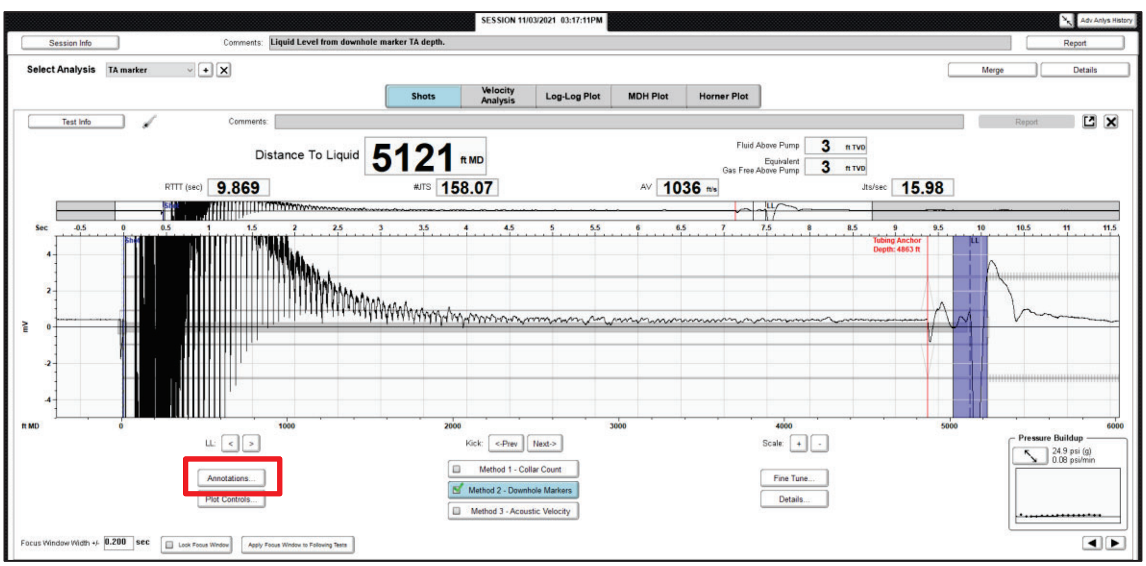


Figure 44: Expanded View of Shot 57 Acoustic Record

The section of the record highlighted with a purple band defines the "**Focus Window**" that corresponds to the time slot where TAM is automatically selecting the echo from the Liquid level. By default, the window is 1-second wide but in this figure, it has been edited to 0.4 seconds. This is discussed in more detail later.

Focus Window

Whenever the acoustic record exhibits several echoes that could be interpreted by TAM automatically as representing the liquid level, such as down-kicks from a liner or from a tubing anchor or any other annular restriction, it is necessary to indicate to the program which of the echoes to select. This is accomplished by defining the time slot where the program should search for the liquid level echo signal and highlighting the region in the record display. Similar echoes outside the window are ignored by the program.

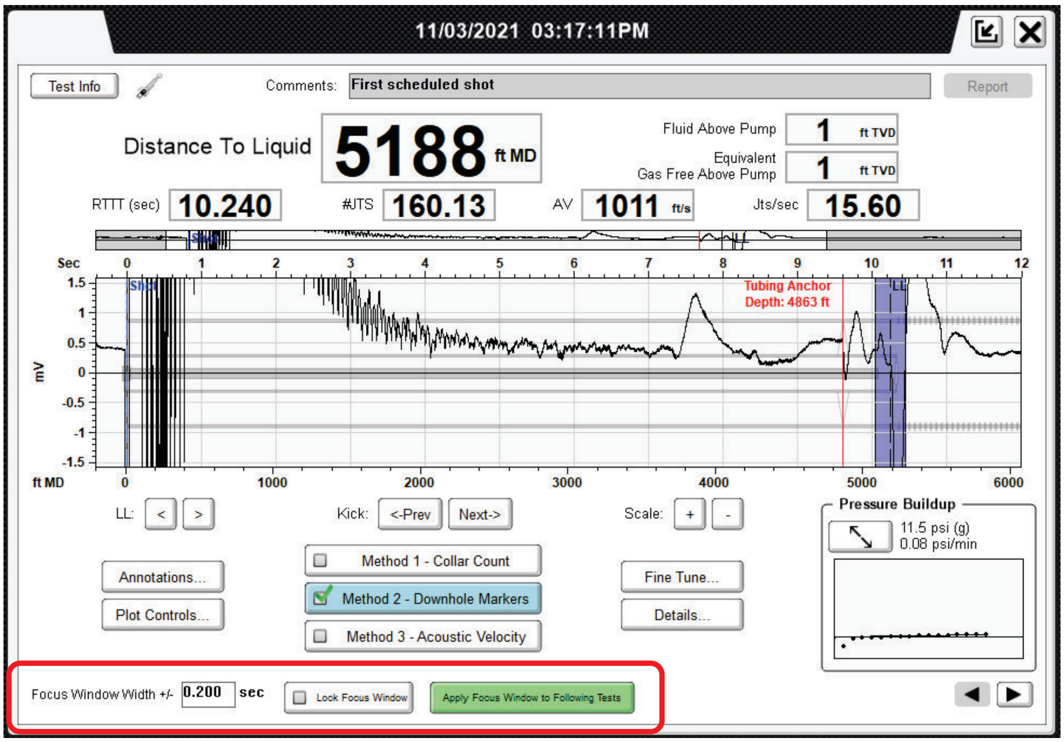


Figure 45: Focus Window Controls

Focus Window Width

By default, the window width is set at +/- 0.5 seconds. Setting the width to zero seconds removes the window from the graph.

Lock Focus Window

The position in time of the focus window is set constant for every shot analysis.

Normally, the position in time of the focus window is centered at the time of the Liquid Level Echo. As the position of the liquid level echo changes during the transient test, the focus window follows the position of the Liquid Level echo.

Annotations

Annotations can be added to the shot plot by clicking the ***Annotations*** button in the bottom left-hand corner (Figure 44). User can add up to five overlays of previous shot traces, display a depth reference line, overlay a trace folded about the LL marker and an overlay of the wellbore schematic. The "Opacity" slider can be used to modify the opacity of the wellbore overlay, when it is enabled.

Overlay of Previous Shots

Clicking on ***Previous Shot*** opens an additional dialog that allows selecting up to five records from existing acoustic tests, for the specific well, and plotting them simultaneously with the shot trace being analyzed as shown in Figure 46, where the **black** trace is the trace being analyzed and the **blue** trace corresponds to the overlay trace. 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 next to their ***LL*** cursors. The user also has the option of lining up overlays based on ***Depth*** (default) or based on ***Time***.

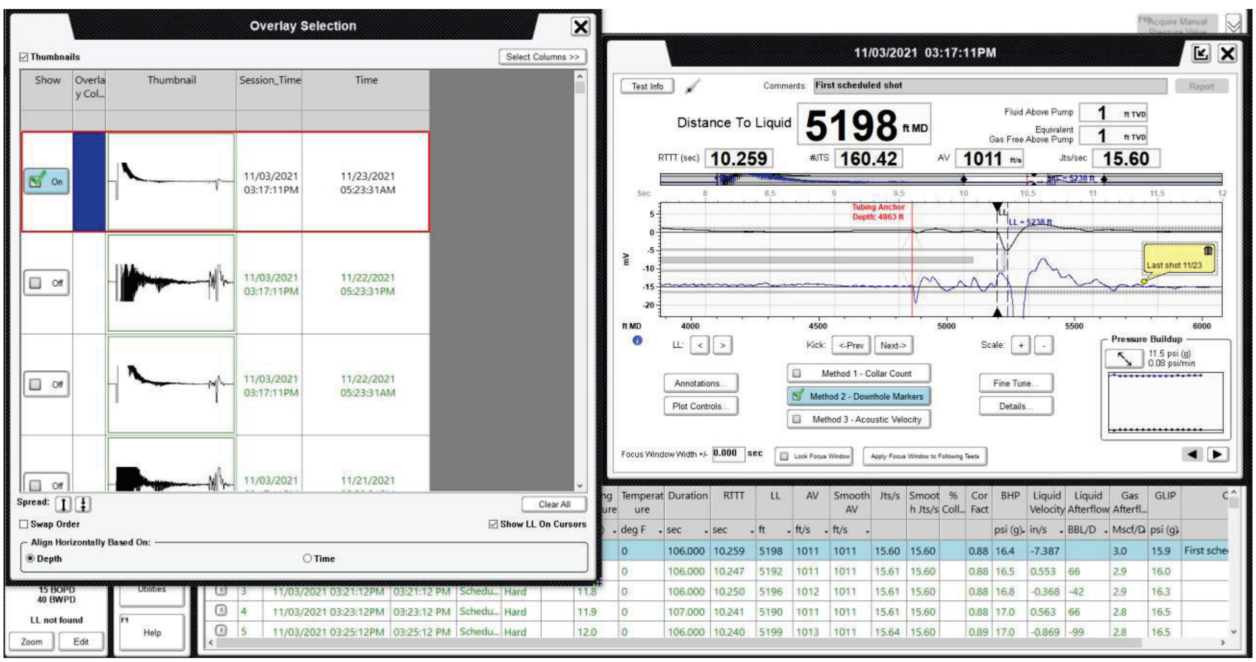


Figure 46: Example of Overlay of Acoustic Traces

Zoomed-in view of overlay of the first and the last acoustic records acquired during the test.

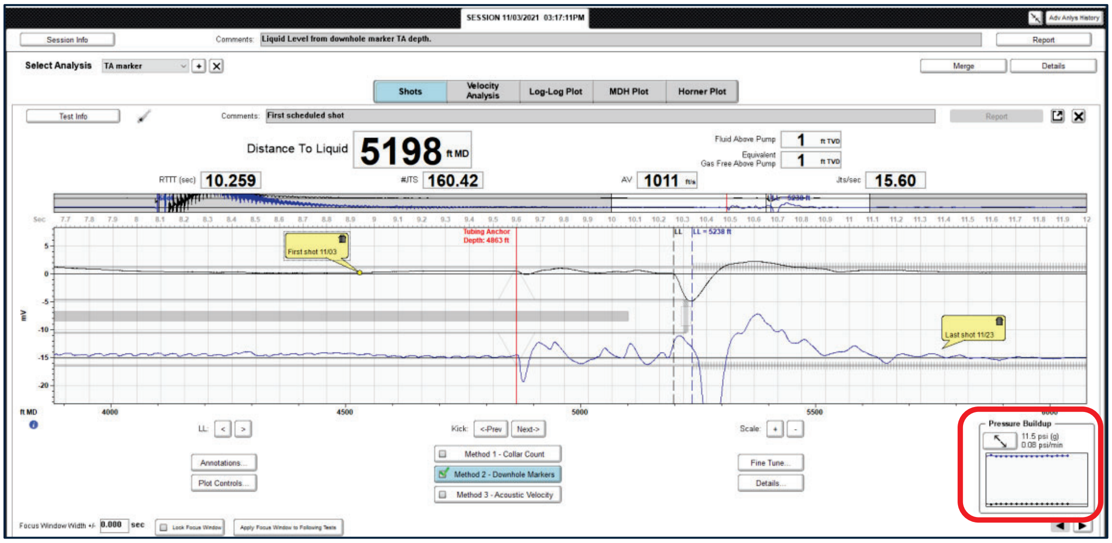


Figure 47: Example of Zoomed-in Overlay of Acoustic Traces

The figure shows that during the transient test the liquid level moved deeper and the casing pressure increased

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

Depth Reference Line Marker

Clicking the ***Depth Reference Line*** button, places on the graph a moveable, dashed red, cursor that displays the time and depth of its current location near the end of the tubing that was entered in the mechanical wellbore table at 5224 ft. This is a good tool to check of the validity of the input data and the acoustic velocity.

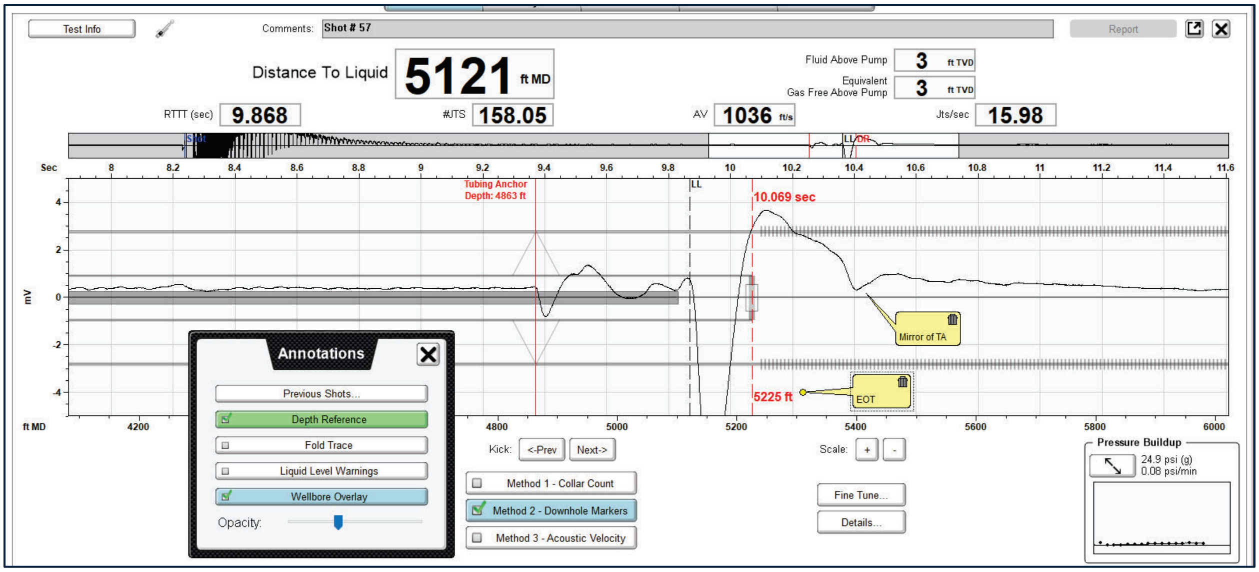


Figure 48: Example of Overlay Depth Reference marker set at the EOT

The Depth Reference marker, that displays its position and time, can be dragged to any depth in the record.

Trace Folding

The ***Fold Trace*** option under ***Annotations*** allows the user to overlay a reflection of the shot trace folded around the selected liquid level echo. When enabled, the folded firing shot trace appears in red. A "shadow" of the reflected part of the original shot trace remains in a lighter gray color (see Figure 49).

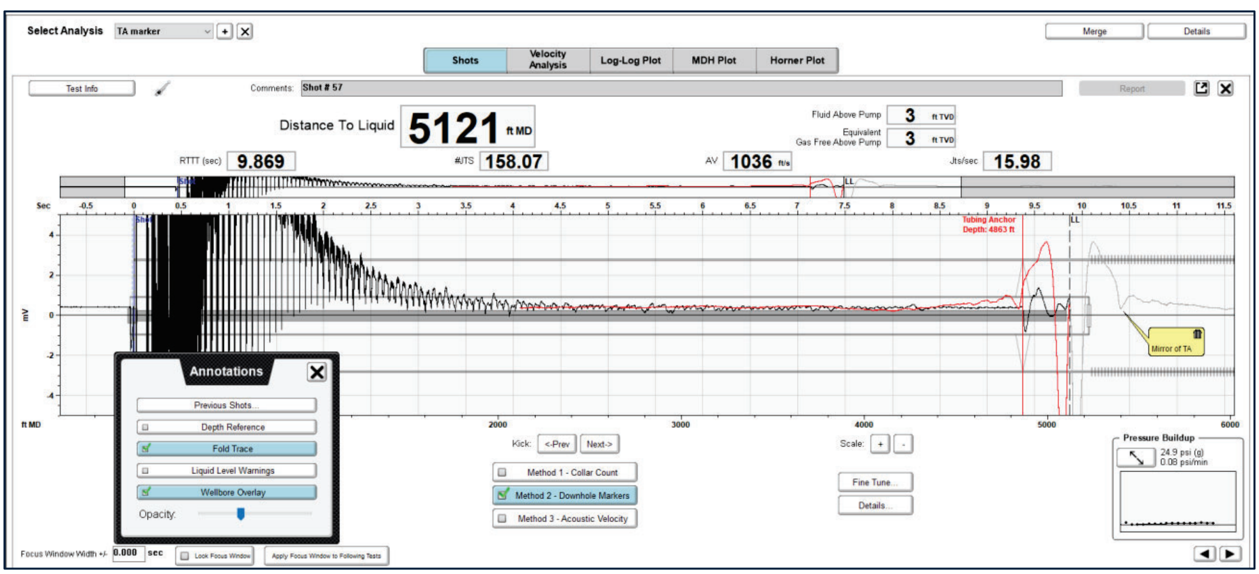


Figure 49: Example of Acoustic Trace Folding about the Liquid Level Echo

After folding, the red repeat of the Tubing Anchor echo (relative to the LL echo) is aligned with the **black** Tubing Anchor echo **just before the liquid level echo. This indicates that the liquid level echo has been correctly identified** and the acoustic velocity has been estimated correctly.

This is an important tool when there are questions about the identification of the liquid level echo.

Liquid Level Warning and Wellbore Overlay

By default, the Wellbore schematic is displayed in detail on the acoustic trace. The opacity of this overlay can be adjusted using the ***Opacity*** slider at the bottom of the ***Annotations*** menu.

The Liquid Level Warning is displayed, by default, on the trace whenever the Liquid Level marker is located at a depth greater than the depth of the end of the tubing as entered in the well description table.

Both these features can be deselected by unchecking their boxes.

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. The options currently available include: ***Echo Zoom, Zoom All, Select, Pan,*** and ***Undo***.

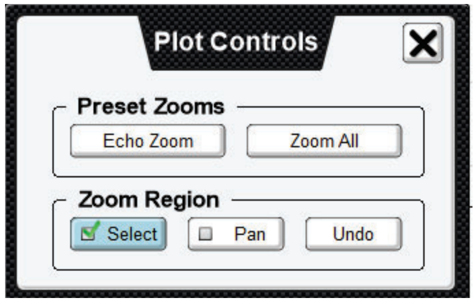


Figure 50: Plot Controls Buttons

- 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 firing 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 recorded shot traces are visible. After clicking the button, the vertical scales need to be readjusted to an appropriate level by the user.

- 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 allows the user to draw a red box (see Figure 51) over the trace enclosing the section of interest (from 9 to 10.2 seconds) to display the record with an expanded timescale as shown in Figure 52.

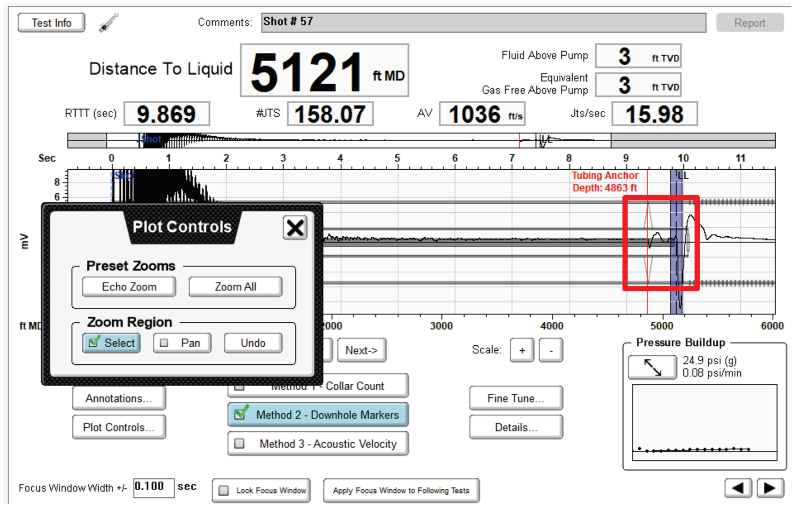


Figure 51: Select Zoom Region Plot Control Button

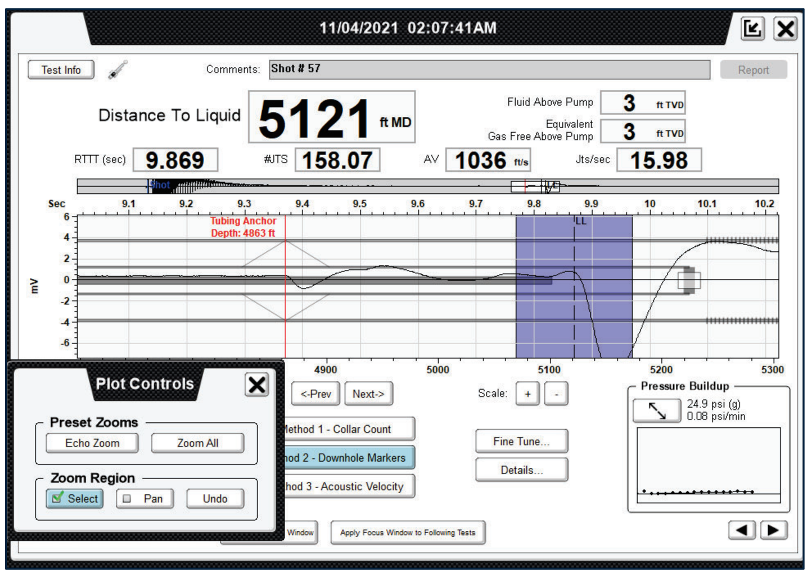


Figure 52: Zoomed-in region from 9 to 10.2 seconds.

The **Select** tool can be used multiple times.

- The ***Pan*** tool converts 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.*

Shot Fine Tune

The TAM program automatically processes the acoustic record and selects the most probable echo from the liquid level. In some wells there may be excessive acoustic noise that could mask the liquid level echo or generate signals that are misinterpreted as the liquid level echo. These problems can be addressed using the Fine Tune option

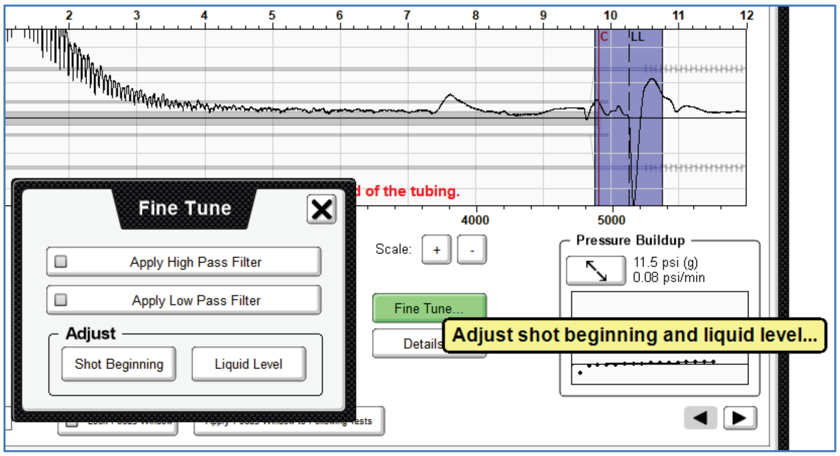


Figure 53: Fine Tune Buttons and Tab

Filtering the Acoustic Record

It is possible to modify the acoustic record by enhancing either the high frequency or the low frequency components by selecting one of the buttons with check boxes in the Fine Tune tab.

Unfiltered signal

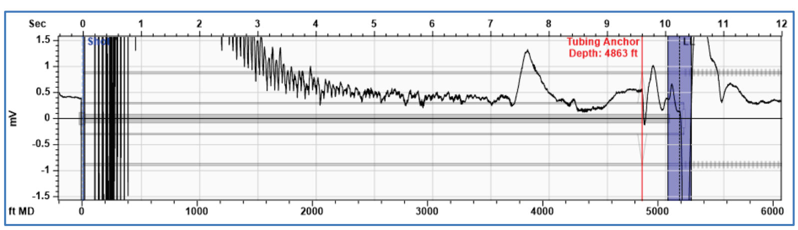


Figure 54

By default, the raw data is presented as recorded

Apply Low Pass Filter

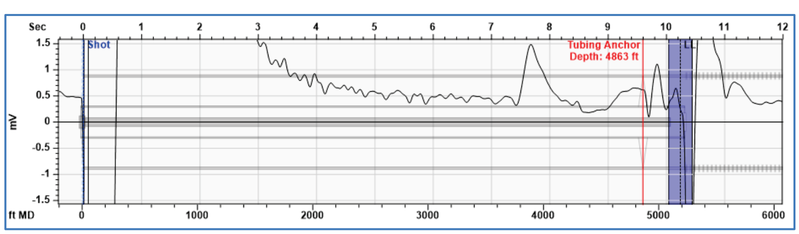
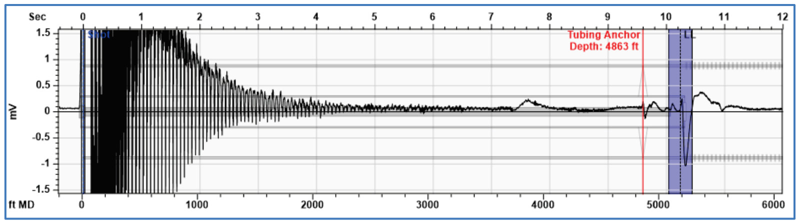


Figure 55

Applying this filter attenuates the high frequency components

Apply High Pass Filter  Figure 56

Applying this filter attenuates the low frequency components

Adjust Shot Beginning and liquid Level Echo

As seen in Figure 53, 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 firing shot trace data. The results of this filter will be present not only on the fine tune dialogs, but also on the plot of the main ***LL*** screen.

Shot Beginning

The shot beginning dialog displays a zoomed-in plot of the trace screen (Figure 57). Like the main trace plot, the shot beginning dialog plot has a sub-plot that can be used to adjust the zooming of 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.

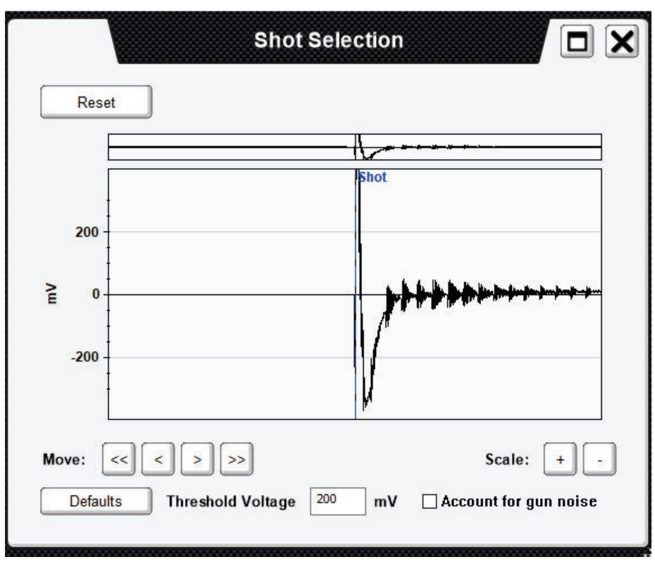


Figure 57 - Shot beginning dialog

In very noisy wells, where the automatic shot detection may fail to locate the start of the pulse correctly, rather than moving the shot beginning cursor manually the user can increase 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 to their normal values.

Liquid Level Cursor Adjustment

Although the liquid level cursor can be moved on the main ***LL*** analysis screen, the 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 firing trace liquid level indicator (Figure 58). 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.

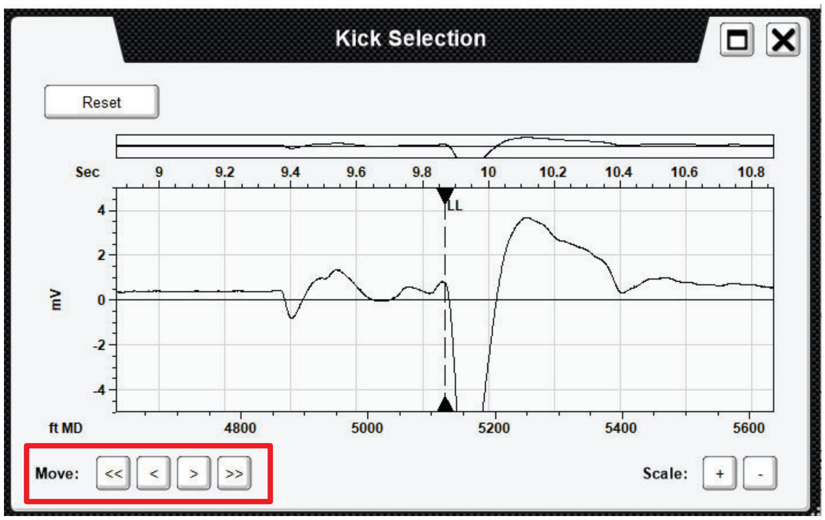


Figure 58 - Refining the liquid level marker position

Shot Details

The details for records are specific to the record that is being acquired. This information should be entered before the corresponding set of records are acquired.

The ***Details*** button on the main LL screen will bring up a dialog that allows the user to indicate the pulse type used (generally explosion).

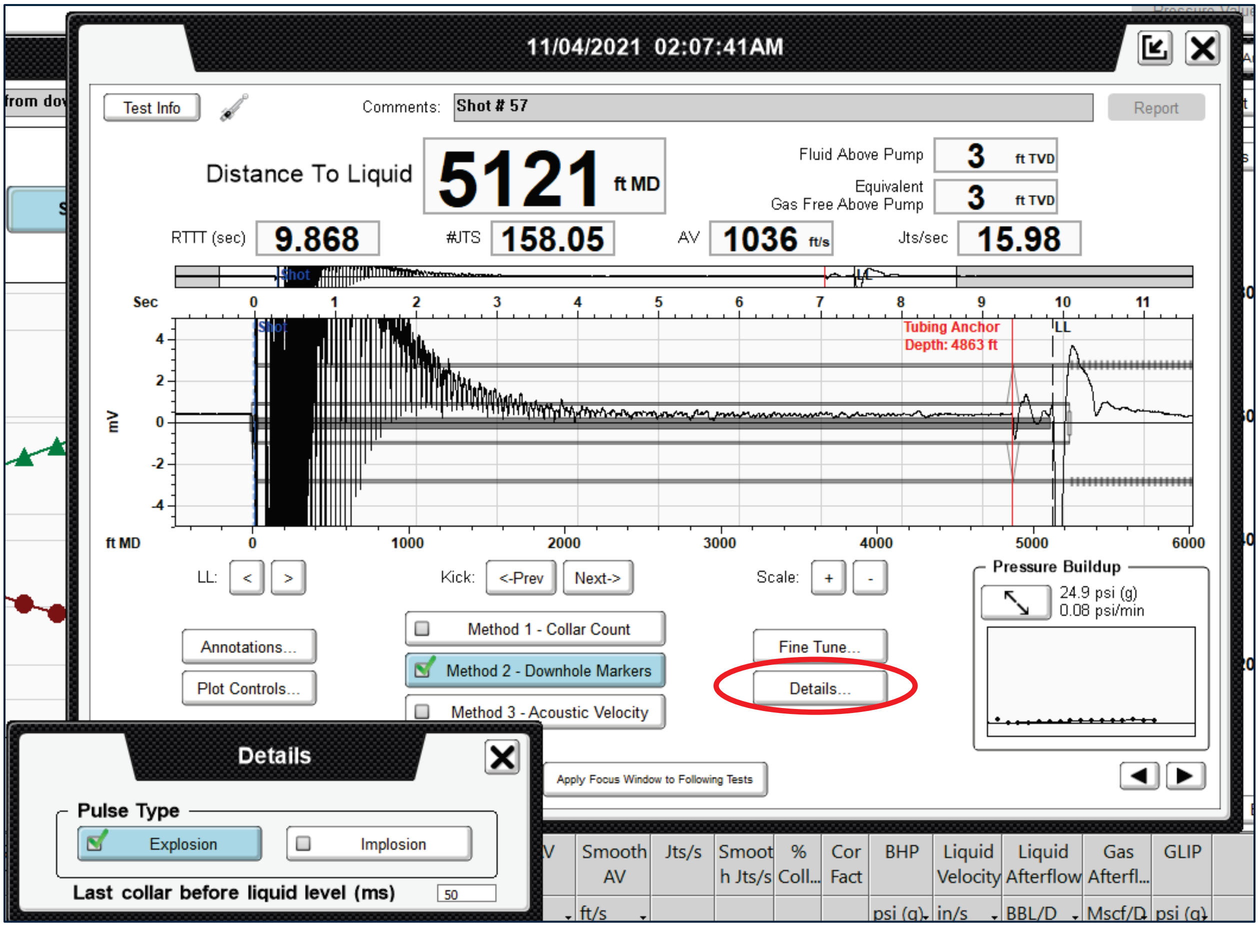


Figure 59 – Shot Record Details dialog

When collar echoes can be identified down to the liquid level echo, the automatic collar count algorithm is set to locate the last identifiable collar echo at a minimum distance of 50 ms. before the LL marker.

Liquid Level Analysis Methods

TAM currently provides three different methods for determining acoustic velocity and consequently calculating 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 60. 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*

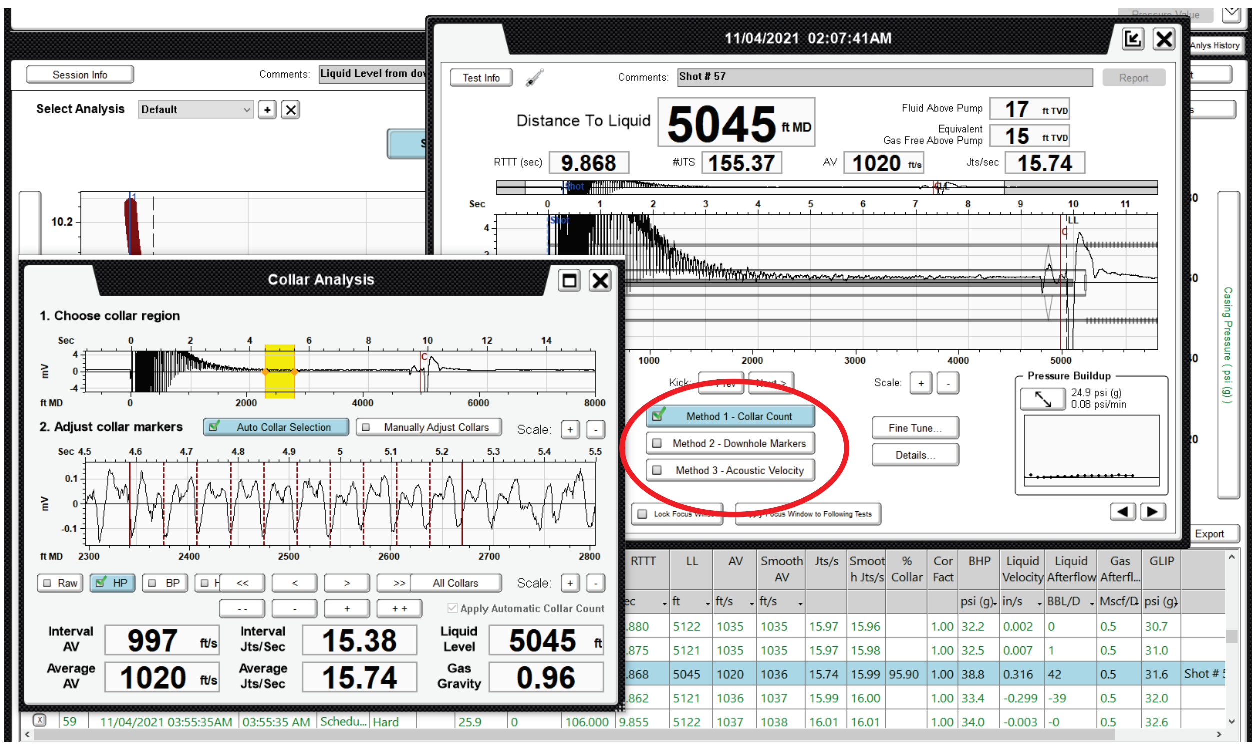


Figure 60 – Collar Analysis Method selected by default

Collar Count Method

No action by the user is normally required since the TAM program follows a very efficient algorithm 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 earlier than 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 60) 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 collar 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 echo counted.

Downhole Marker Method

Wellbores that include downhole features that cause acoustic reflections, such as gas-lift mandrels, allow a more precise estimate of acoustic velocity and the distance to the liquid level.

Clicking the ***Method 2 – Downhole Markers*** button will display the dialog shown in Figure 61. At the top of this screen is a list of possible markers, based on the wellbore 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 at 4863 feet) 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 window showing the zoomed-in area around the selected marker. Here the marker position can be further refined as needed.

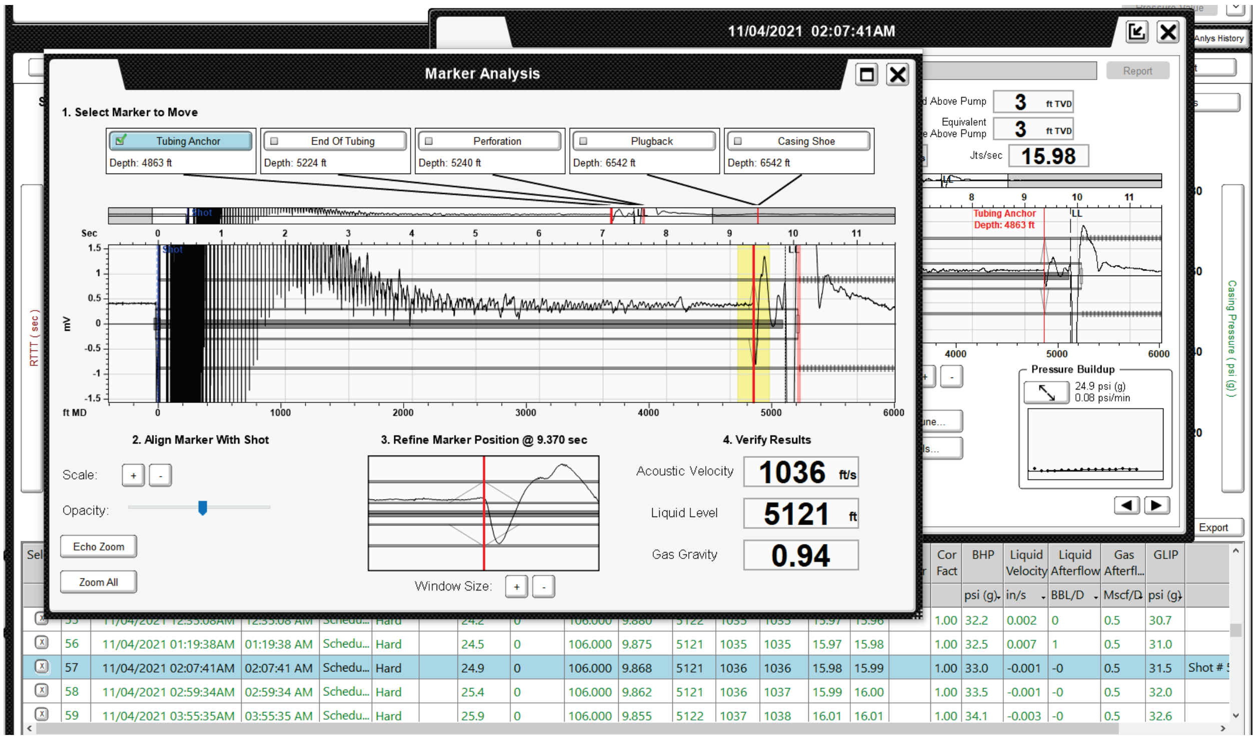


Figure 61 – Downhole Marker Analysis dialog

The result of the **marker analysis** is shown in Figure 59 with the annotation Tubing Anchor Depth: 4863 displayed on the record to indicate which marker was used for the calculations.

The acoustic velocity determined by this method, 1036 ft/sec, corresponds to the average acoustic velocity in the gas present in the annulus from the casing head to the gas/liquid interface. This value is used to compute the depth to the liquid level.

Acoustic Velocity Method

This method is used whenever the acoustic record does not show echoes from tubing collars or downhole markers such as for acoustic measurements inside internally flush tubing or cased holes without interior tubing string.

Clicking on Method ***3 – Acoustic Velocity*** allows the user to manually enter a known acoustic velocity (Figure 62) or have the program calculate a velocity by manually entering a value for gas gravity or a detailed gas composition.

Acoustic Velocity Input

The user enters a value of acoustic velocity based on previous experience or determined in similar wells producing from the same reservoir at similar casing pressure.

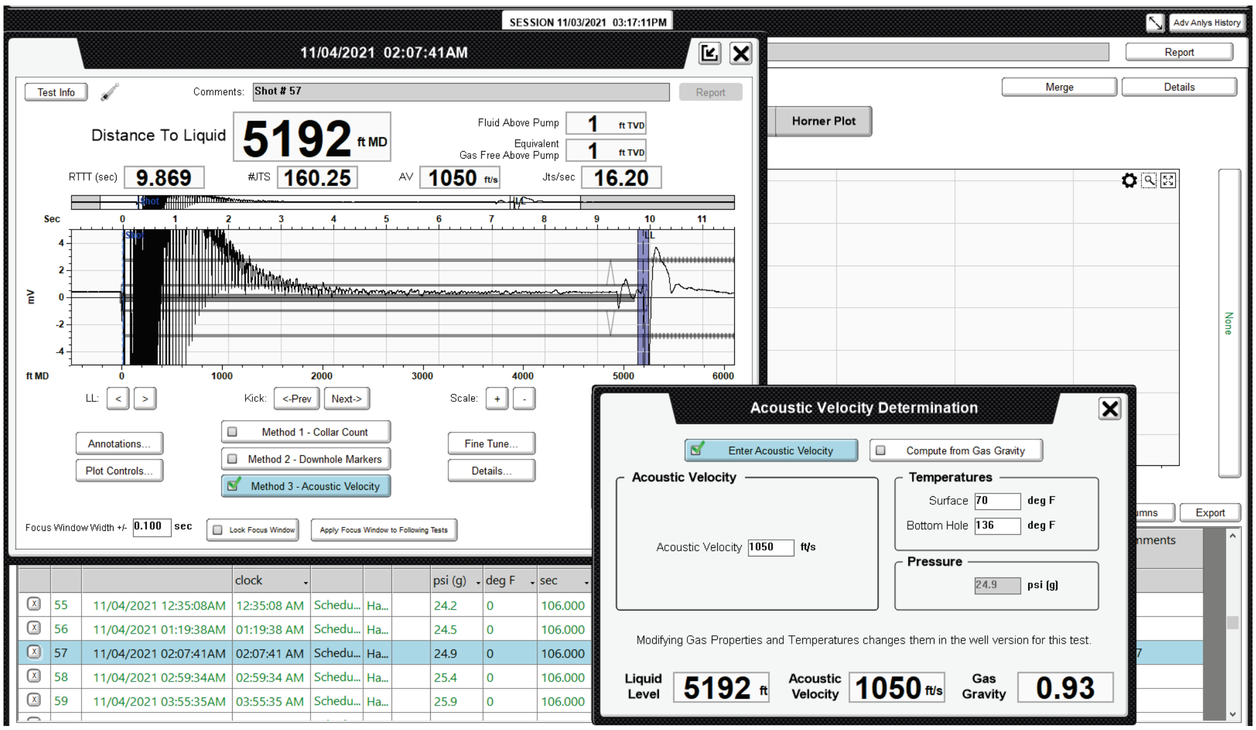


Figure 62– Acoustic Velocity dialog to enter know value

The fluid level analysis based on <u>Acoustic Velocity input of 1050 ft/sec</u> is shown in Figure 63

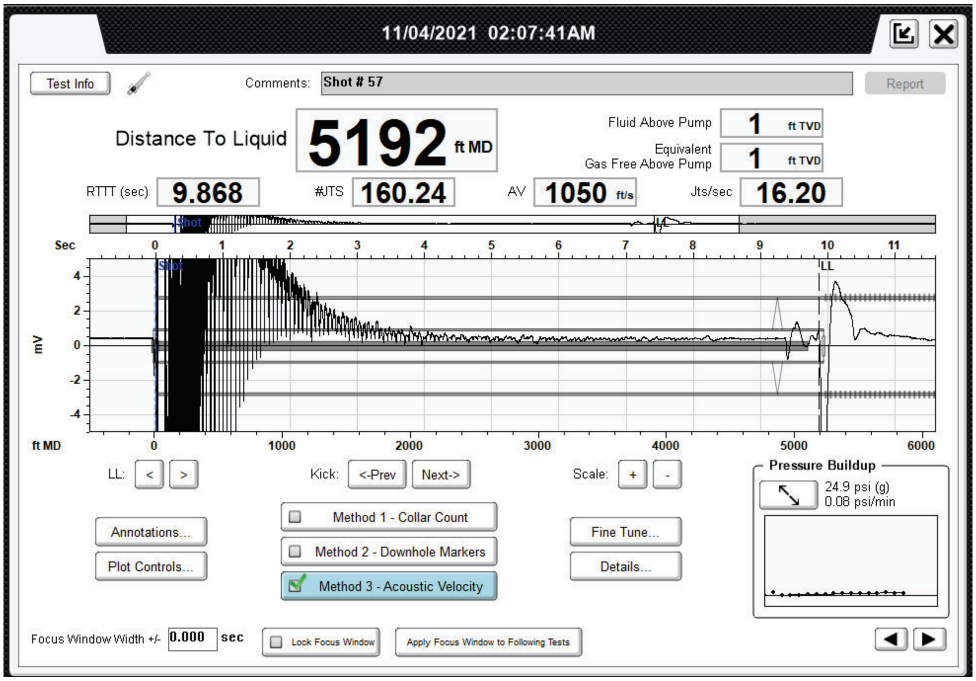


Figure 63 – Acoustic velocity result

Acoustic velocity from Gas Properties

Select the Compute ***from Gas Gravity*** button to derive an acoustic velocity based on entered gas gravity (Figure 64) or computed from gas composition (Figure 65).

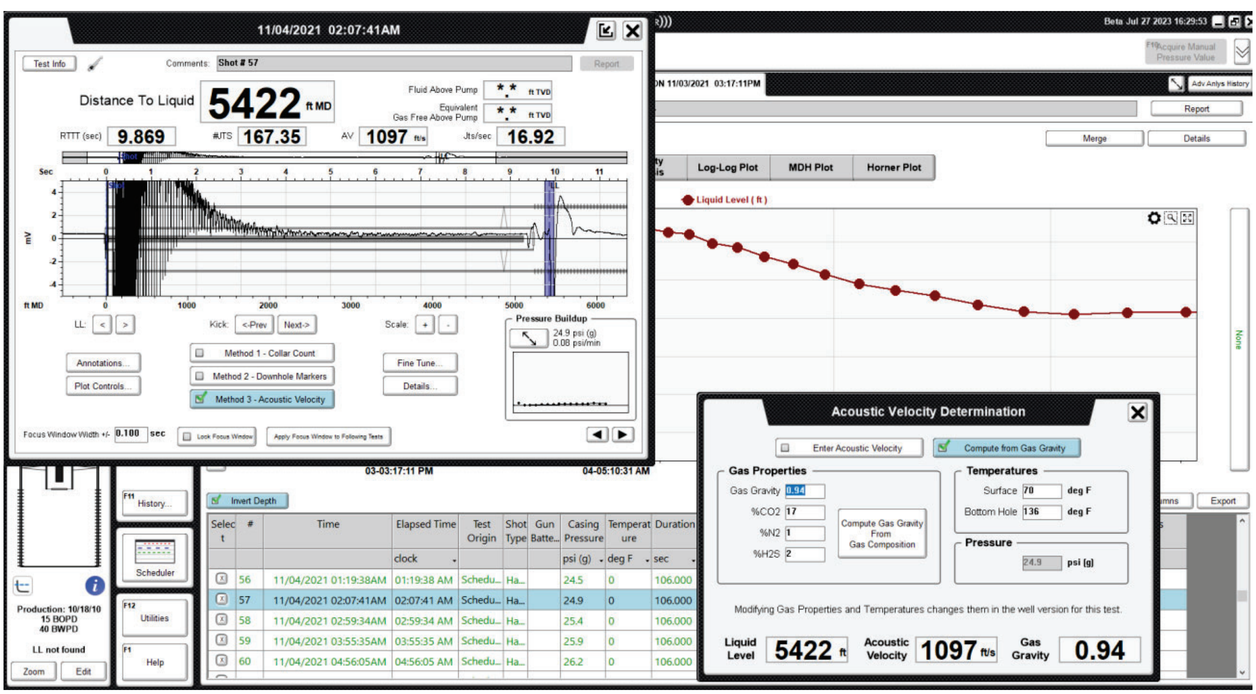


Figure 64 – Velocity computed from input of Gas Gravity

When a gas sample, taken at the casing head, is analyzed into its component gases the percentage values for each constituent are entered in the **Gas Composition** tab, as shown below:

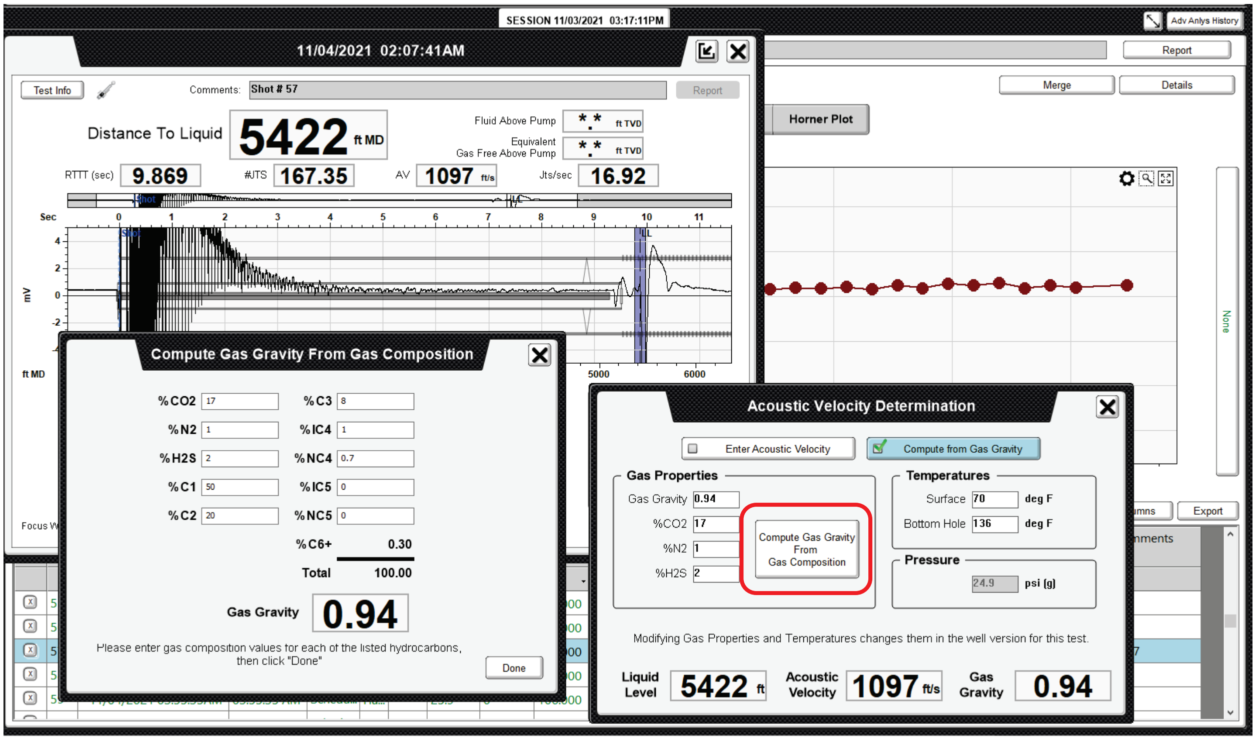


Figure 65 – Velocity from input of Gas Composition

Note also that the velocity values computed from gas gravity and gas composition are dependent of Pressure and Temperature. The pressure is the value measured by the sensor in the gun when the record is acquired. The temperature is the average of the surface and Bottom hole temperatures entered in the tab by the user.

Exporting Pressure Transient Test Results to a File

Once all the records have been analyzed to yield an accurate liquid level as a function of time and the BHP has been correctly estimated, the pressure transient data can be exported as text files. These files may be used to input into specialized Pressure Transient analysis software to obtain a complete characterization of the reservoir pressure and formation properties.

Clicking the Export button opens the following dialog that is used to select the format of the exported file.

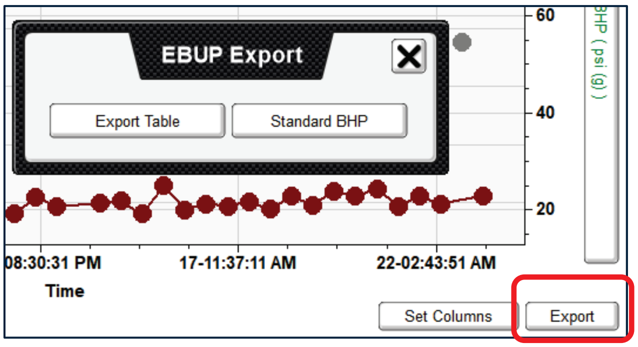


Figure 66 – Export EBUP Results Tab

The user can export the complete session table or just the computed BHP pressure vs. time

Export Table Option

This option generates a spreadsheet, in CSV format, identified by the name of the well and date of the Pressure Transient session.

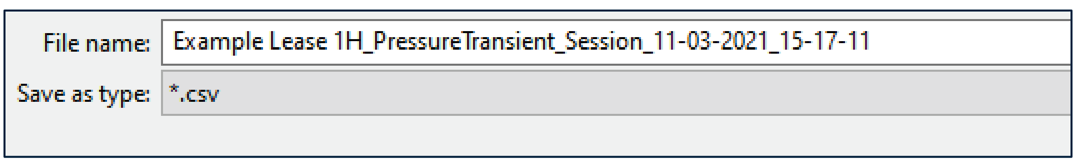


Figure 67 – Export Session Table File Name

The spreadsheet columns correspond to the session table columns that the user selected for display.

	A	B	C	D	E	F	G	H	I	J	K	L
1	#	Time	Elapsed Time	Test Origin	Shot Type	Gun Battery %	Casing Pressure	Temperature	Duration	RTTT	LL	AV
2			clock				psi (g)	deg F	sec	sec	ft	ft/s
3	1	11/03/2021 03:17:	3:17:11 PM	Scheduled	Hard		11.5	0	106	10.24	5188	1011
4	2	11/03/2021 03:19:	3:19:12 PM	Scheduled	Hard		11.5	0	106	10.247	5192	1011
5	3	11/03/2021 03:21:	3:21:12 PM	Scheduled	Hard		11.8	0	106	10.25	5196	1012
6	4	11/03/2021 03:23:	3:23:12 PM	Scheduled	Hard		11.9	0	107	10.241	5190	1011
7	5	11/03/2021 03:25:	3:25:12 PM	Scheduled	Hard		12	0	106	10.24	5199	1013
8	6	11/03/2021 03:27:	3:27:12 PM	Scheduled	Hard		12.2	0	107	10.236	5192	1012
9	7	11/03/2021 03:29:	3:29:12 PM	Scheduled	Hard		12.2	0	106	10.233	5194	1013
10	8	11/03/2021 03:31:	3:31:12 PM	Scheduled	Hard		12.3	0	106	10.232	5191	1012
11	9	11/03/2021 03:33:	3:33:12 PM	Scheduled	Hard		12.5	0	106	10.227	5189	1013
12	10	11/03/2021 03:35:	3:35:12 PM	Scheduled	Hard		12.5	0	106	10.224	5189	1013

	M	N	O	P	Q	R	S	T	U	V	W	X
1	Smooth AV	Jts/s	Smooth Jts/s	% Collar	Cor Fact	BHP	Liquid Velocity	Liquid Afterflow	Gas Afterflow	GLIP	Comments	
2	ft/s					psi (g)	in/s	BBL/D	Mscf/D	psi (g)		
3	1011	15.6	15.6		1	16.6	-0.408		0	16	First scheduled shot	
4	1011	15.61	15.6		1	16.5	-0.408	-54	0	16		
5	1011	15.61	15.6		1	16.8	-0.368	-49	0	16.3		
6	1011	15.61	15.6		1	17	0.563	74	0	16.5		
7	1011	15.64	15.6		1	17	-0.869	-115	0	16.6		
8	1011	15.62	15.6		1	17.4	0.69	91	0	16.8		
9	1011	15.63	15.6		1	17.3	-0.227	-30	0	16.8		
10	1011	15.62	15.6		1	17.5	0.375	49	0	16.9		
11	1011	15.63	15.6		1	17.7	0.145	19	0	17.1		
12	1011	15.63	15.61		1	17.7	-0.01	-1	0	17.1		

Figure 68 – Example Spreadsheet created by Export Table

Standard BHP Option

This option generates a spreadsheet in CSV format identified by the name of the well and date of the session.

The Standard BHP format consists of two columns: Elapsed Time in hours and Bottom Hole Pressure in psia.

File name:	Example Lease 1H_StandardBHP_Session_11-03-2021_15-17-11
Save as type:	*.csv

Figure 69 – Export Standard BHP file name

Following figure shows the Standard BHP spreadsheet format.

	A	B	C	D	E
1	Elapsed Time	BHP			
2	hrs	psi-a			
3	0	31.2518			
4	0.034	31.2434			
5	0.067	31.543			
6	0.1	31.7484			
7	0.134	31.718			
8	0.167	32.0728			
9	0.2	31.9706			
10	0.234	32.184			
11	0.267	32.3842			
12	0.3	32.4204			
13	0.334	32.4481			
14	0.367	32.5309			
15	0.4	32.6287			
16	0.434	32.7135			
17	0.468	32.5988			
18	0.505	32.7834			
19	0.546	33.003			

Figure 70 – Example Spreadsheet created by Export Standard BHP

Merge Sessions

This function allows combining two or more Pressure Transient data sets that were acquired separately, in the same well, over sequential time intervals.

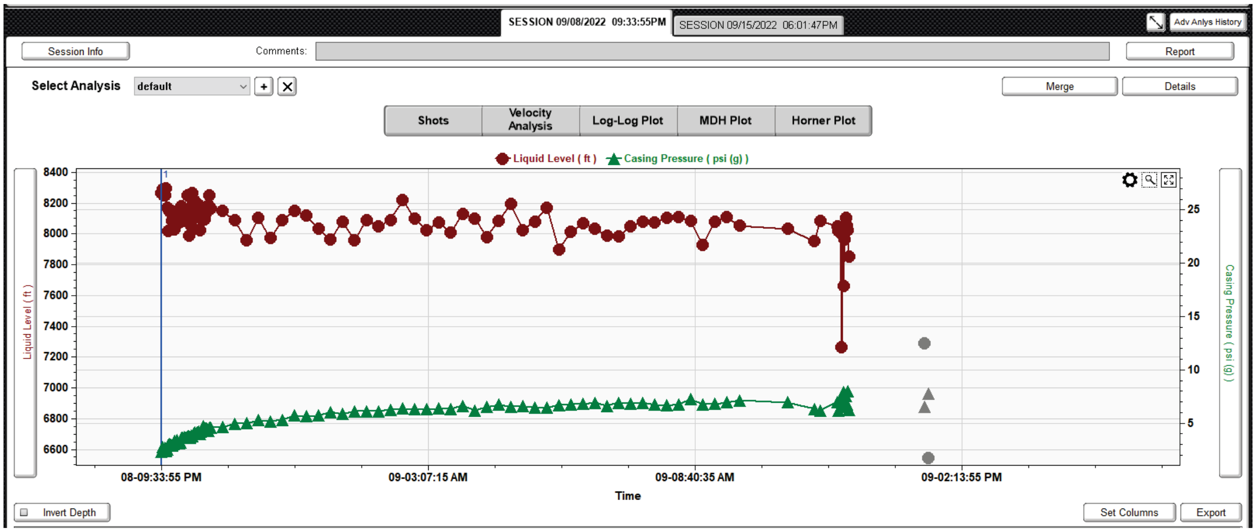


Figure 71 – First Scheduled Advanced Analysis Session

First session was stopped (probably due to hardware battery problems) and the acquired data was downloaded from the RAM as seen in Figure 71.

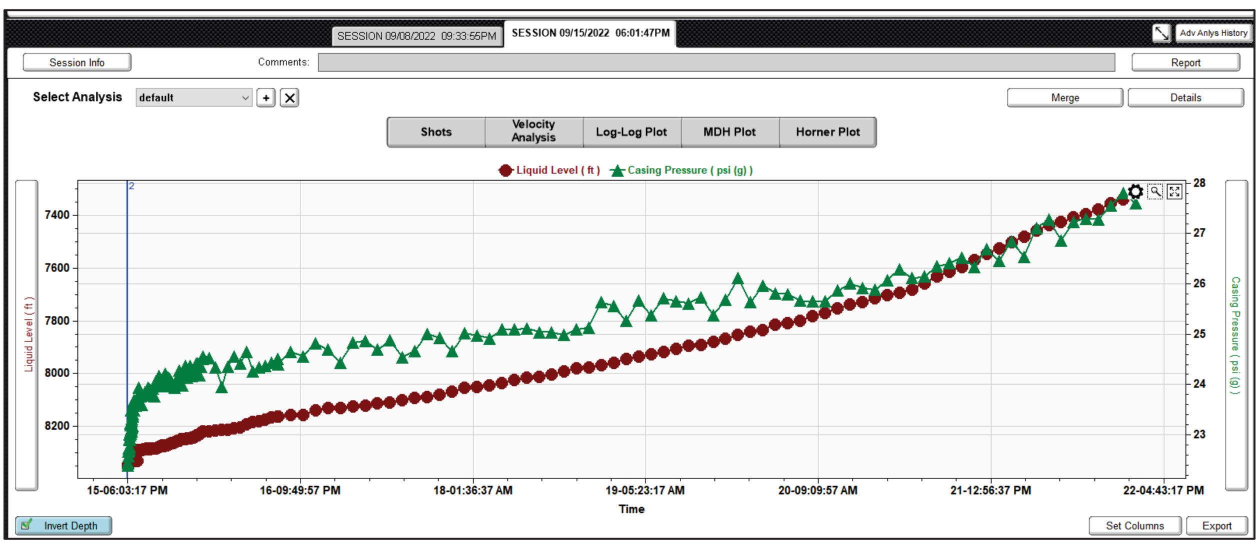


Figure 72 – Second Scheduled Advanced Analysis Session

At end of second session the additional records seen in Figure 72, were downloaded to the same computer.

After opening TAM with the first session the Merge function is activated by clicking the Merge button.

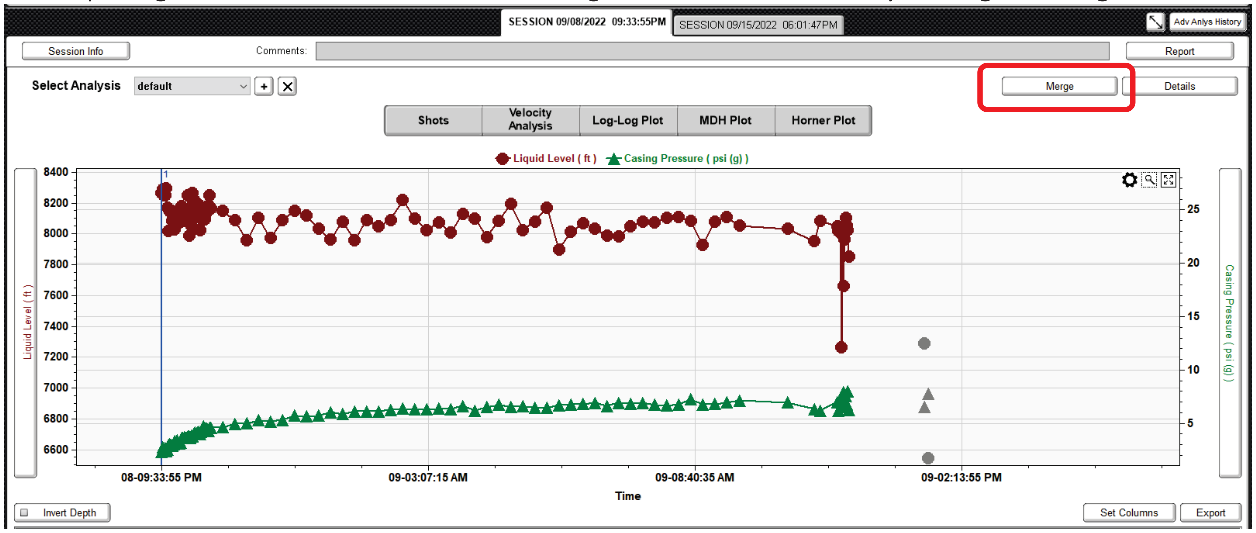


Figure 73 – First Scheduled Advanced Analysis Session 9/08/2022

Clicking the Merge button opens the following dialog:

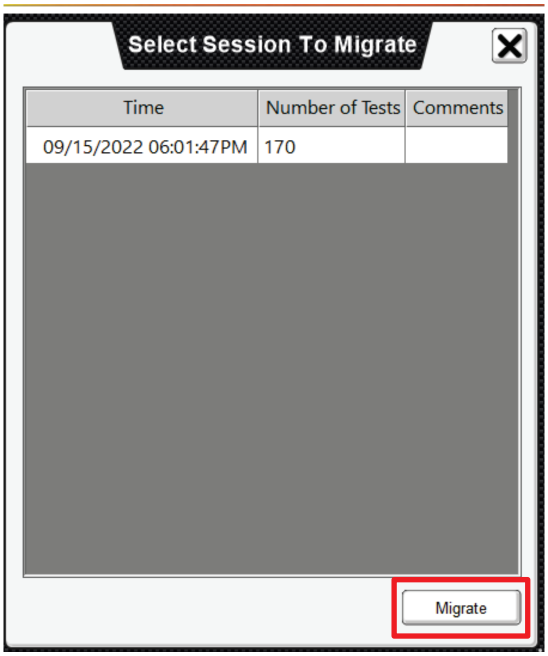


Figure 74 – Select Session to Migrate Tab

Sessions that were acquired after the currently open session are listed in this dialog. The second session for this well, started on 9/15/2022 is listed in the table. Clicking the **Migrate** button allows combining the later session records to the present session records.

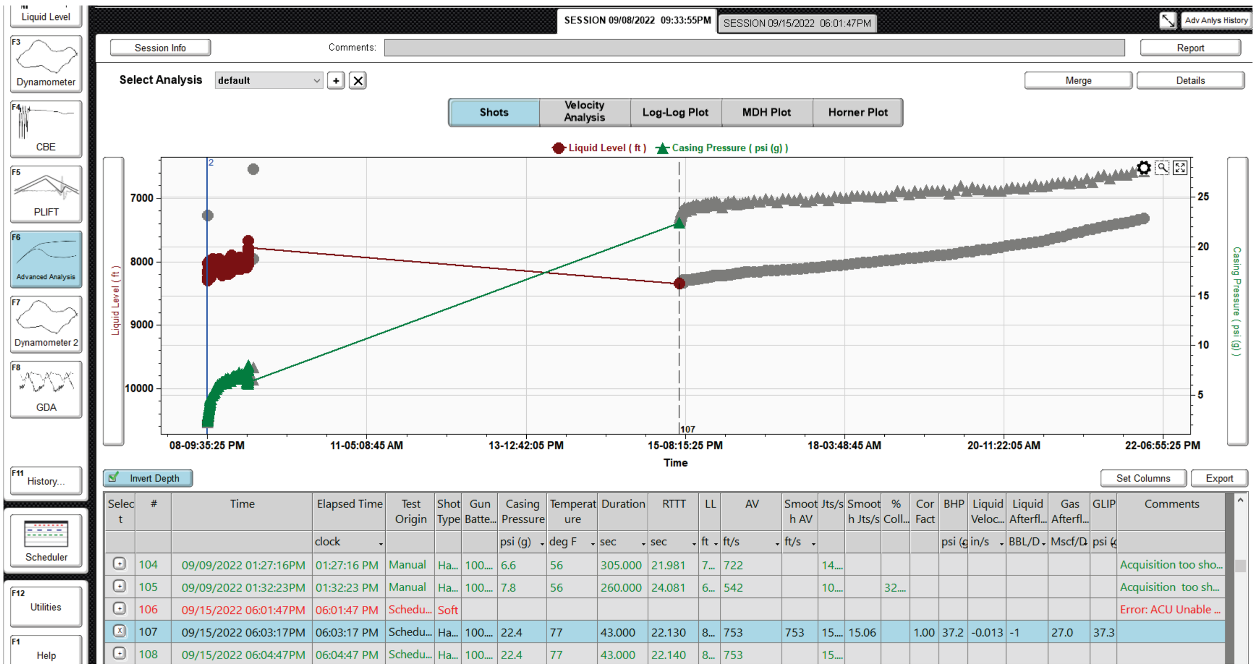


Figure 75 – First session with added Second session records

After clicking the Migrate button the data files are combined with the later data added to the first session records as seen in Figure 75.

The added data points are grayed out indicating that they are not yet included in the advanced analysis of the combined session.

NOTE: During the time when records were not acquired the well continued to be shut-in and the BHP pressure continued increasing.

Procedure to Include the Grayed-out Merged records

First, the user must analyze each record of the merged session:

1) Open the record on the screen, record 158 shown below:

Select	#	Time	Elapsed Time	Test Origin	Shot Type	Gun Battery	Casing Pressure	Temperature	Duration	RTTT	LL	AV	Smooth AV	Jts/s	Smooth Jts/s	% Coll	Cor Fact	BHP	Liquid Veloc	Liquid Afterfl	Gas Afterfl	GLIP	Comme
			clock				psi (g)	deg F	sec	sec	ft	ft/s	ft/s					psi (g)	in/s	BBL/D	Mscf/D	psi (g)	
	156	09/15/2022 09:04:36PM	09:04:36 PM	Scheduled	Hard	100.00	23.9	63	58.000	21.747	8285	761	818	15.21	16.35		0.60	44.4	0.016	1	13.6	39.1	
	157	09/15/2022 09:19:36PM	09:19:36 PM	Scheduled	Hard	100.00	23.9	62	58.000	21.732	8285	761	818	15.23	16.35		0.62	44.6	-0.003	0	12.5	39.2	
	158	09/15/2022 09:34:36PM	09:34:36 PM	Scheduled	Hard	100.00	23.9	62	58.000	21.728	8285	761		15.23									
	159	09/15/2022 09:49:36PM	09:49:36 PM	Scheduled	Hard	100.00	23.8	61	58.000	21.704	8283	762		15.24									
	160	09/15/2022 10:04:36PM	10:04:36 PM	Scheduled	Hard	100.00	23.9	60	58.000	21.718	8283	762		15.23									

Figure 76 – Including new Records in the Merged Data

2) Adjust the vertical scale
3) Verify that the liquid level echo is identified correctly
4) Verify that the acoustic velocity is determined correctly
5) Click the Select "+" button
6) Select the next record by clicking on the ">" button.
7) Repeat from step 2.

That is the procedure that was used to include record 158 and all the remaining records until the end of the buildup.

After including all the merged points, the data is displayed in the following figure with all records being included in the analysis:

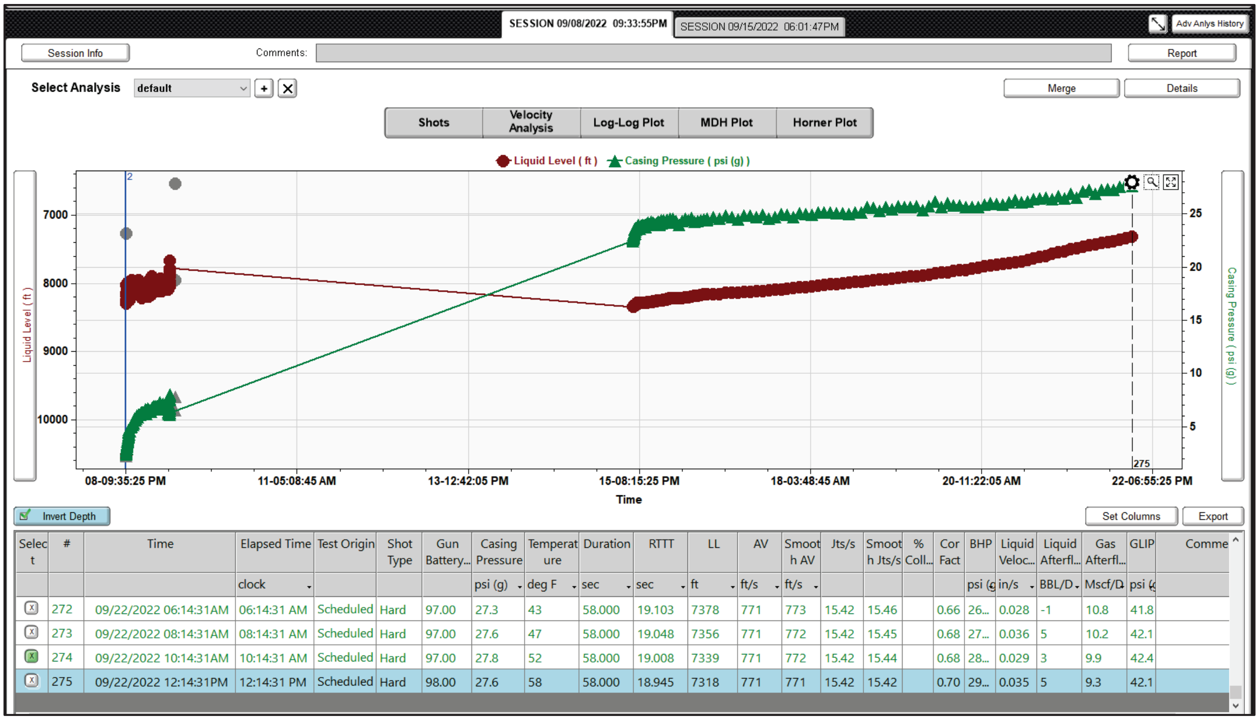


Figure 77 – Merged session with included Second session records

The two buildup sessions can now be analyzed as a single extended buildup session.
Optionally the second session can also be analyzed as the main buildup sequence since after merging the two sessions the second session remains unchanged as seen in the following figure.

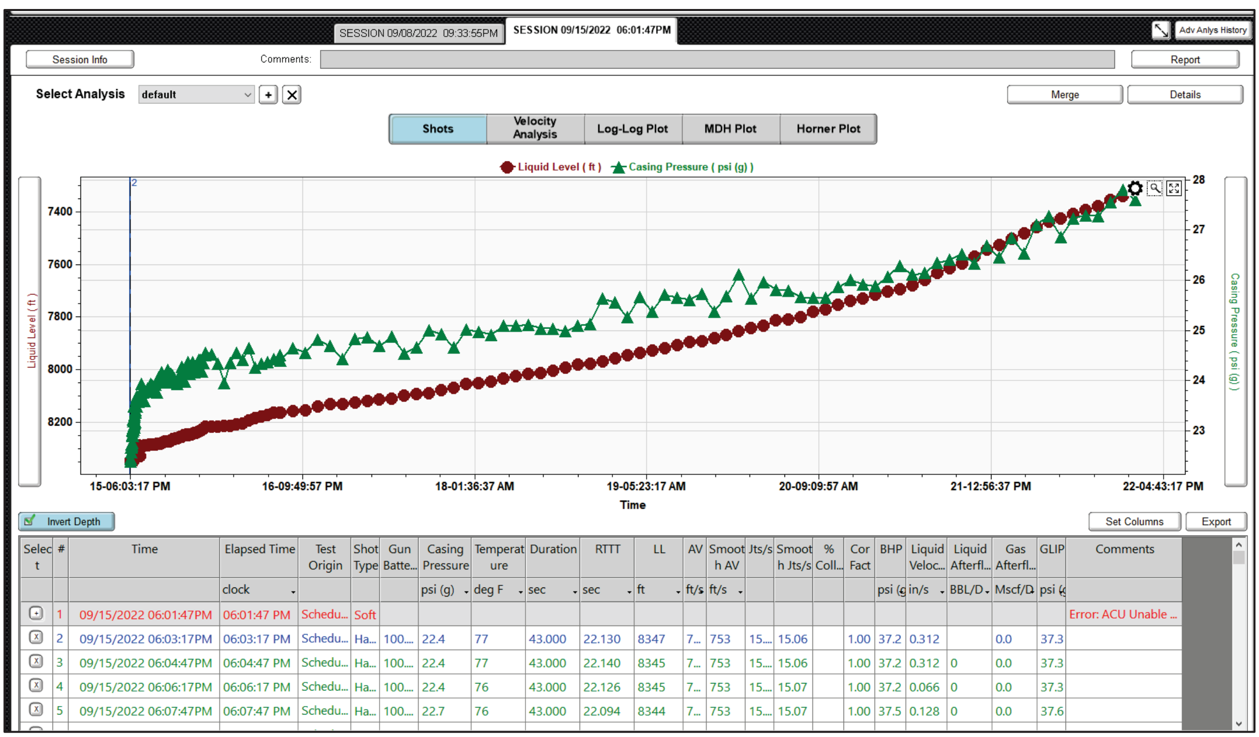


Figure 78 – Second Session Records

Recommended Practices for RAM-based Acoustic Pressure Buildup Tests.

The following recommendations have been generated based on field experience of several operators.

Beam Pumped Wells

1- Obtain all necessary data for acquisition and pressure transient analysis. Review and update well completion, fluid properties and reservoir description data. Obtain or draw a wellbore diagram to identify all changes in annular cross section that could be used as downhole markers or that could interfere with automatic liquid level selection (liners, tubing cross-overs, etc.)

2- Prior to date of well test, perform acoustic measurements to determine normal producing conditions, acoustic velocity, casing pressure and existence of a gaseous liquid column. Perform dynamometer test to determine normal pump fillage and effective pump displacement.

3- If height of gaseous liquid column is significant, perform a short duration (1hour) liquid level depression test (by closing the casing to flowline valve) to estimate the time required to depress the liquid level to the pump intake.

4- Inspect all well connections to flowlines, casinghead, tubing head, stuffing box, condition of valves, leaks etc. and report any problems to the operator so that they may be fixed before date of well test. It is important that the Standing Valve in the pump is holding otherwise there will be excessive back flow of liquid from the tubing, during the early stages of the buildup and this will show up as additional after-flow.

5- Shortly before (24-48 hours) date of test put the well on a production test in order to determine the average 24-hour production rate, water cut and GOR.

6- Review and update all well data and prepare test procedure and check list.

7- If gaseous liquid column depression is to be performed, install back pressure regulator on casing to flowline outlet (if possible) and start increasing casinghead pressure while monitoring liquid level. (Use the RAM to monitor depression test). This may take several hours or days as estimated in step 3. This should continue until the fluid level is indicated to be about 60 feet above the pump intake. When this is reached the casing pressure should be stabilized to a constant value (+/- 5% of the measured value)

8- Make sure all wireless sensor batteries are fully charged before starting the test. On the day of the test after setting up the equipment take a fluid level to verify that all is normal. Take a dynamometer record and verify that the pump fillage and operation is the same as was established in step 2 and pump displacement agrees with the well test information. If the difference is more than 10% continue monitoring the dynamometer during 30 minutes to detect any abnormalities. If the pump operation is erratic, then postpone the test until the problem is fixed since it would be impossible to determine an accurate well flow rate that will be needed for pressure buildup interpretation.

9- Verify that all connections between the gas bottle and the wireless remote fire gun do not have any leaks. Check connection to external power supplies: batteries or solar panel.

10- Start the TAM program and go through the Set-Up procedure to get the zero offset of the pressure transducer and complete the test set up procedure. Take a manual shot and verify that the program is picking the fluid level correctly and that the acoustic velocity and fluid level depth are computed correctly as established earlier (steps 7 and 8).

11- Select the **Advanced Analysis** module of the Scheduler and set up the fluid level acquisition schedule by selecting the frequency of shots and the opter options. Use Logarithmic schedule unless there is a reason for selecting otherwise. Close the casing to flowline valve. Start the buildup acquisition (START SCHEDULE) while the well is still pumping (first pressure value corresponds to PBHP). As soon as the program completes the acquisition of the first shot, STOP the pump. Set brake and lock out the motor switch. Close tubing flow valve to prevent the well to flow as the pressure builds up during the test.

12- Monitor the progress of the schedule at least for 30 minutes. Download the records and check that the fluid level is picked correctly and all the data is consistent (fluid level may rise or fall depending on well conditions) especially the casing pressure should show a consistent trend. Make any adjustments to obtain accurate RTTT time to liquid level echo as described in the TAM manual.

13- Determine the rate of casing pressure increase (psi/hour) to estimate the likely casing pressure for the time when you will return to the well to check the condition of the equipment and test progress. Set the regulator pressure to 200 psi above the estimated future casing pressure to ensure that fluid level shots will be acquired correctly at that time.

14- Check all connections before leaving the well. Take a manual shot and wait until it is added to the schedule time line before leaving the site.

15- Monitor the progress of the test via cloud connection. Check the Scheduler screen and verify when the last shot was taken, when the next shot is due, the presence of missed shots. Take a MANUAL shot and observe the pick of the liquid level echo and depth calculation. Download the schedule data. Check a time plot of Casing Pressure vs. time and observe if there are any anomalies (step changes of pressure or abrupt changes of slope) that may indicate the presence of leaks at the wellhead or transducer problems.

16- Check a plot of RTTT to notice values that seem outside of the normal trend. Review all records and make necessary adjustments to obtain accurate fluid level and depth values.

17- Determine casing pressure increase rate and determine if the regulator pressure needs to be adjusted. If so, then schedule a technician to go to the well site and also check the pressure in Nitrogen bottle and external power sources and replace as necessary.

18- Review analysis plots (log-log, MDH, Horner, etc.) to determine whether pressure stabilization has been established and whether the buildup test could be terminated.

19- If the test is to be continued go back to step 14.

20- If the test is to be terminated, take a MANUAL shot and when the computer finishes processing the data select Pause the Schedule and exit the Advanced Analysis Module.

21- Select the Acoustic Test module, select “shut-in” to indicate the well status and take an acoustic record to establish the present value of Static Bottom Hole Pressure to be entered later in the well file.

ESP Wells

At the end of the buildup in ESP wells it is very important to reduce the casing pressure very slowly since gas will dissolve in the downhole cable’s insulation as the pressure in the annulus generally increases during the test. A rapid reduction of casing pressure will cause the insulation to swell and possibly damage the cable. A slow decrease in casing pressure allows the dissolved gas to evolve gradually without causing swelling of the insulation.

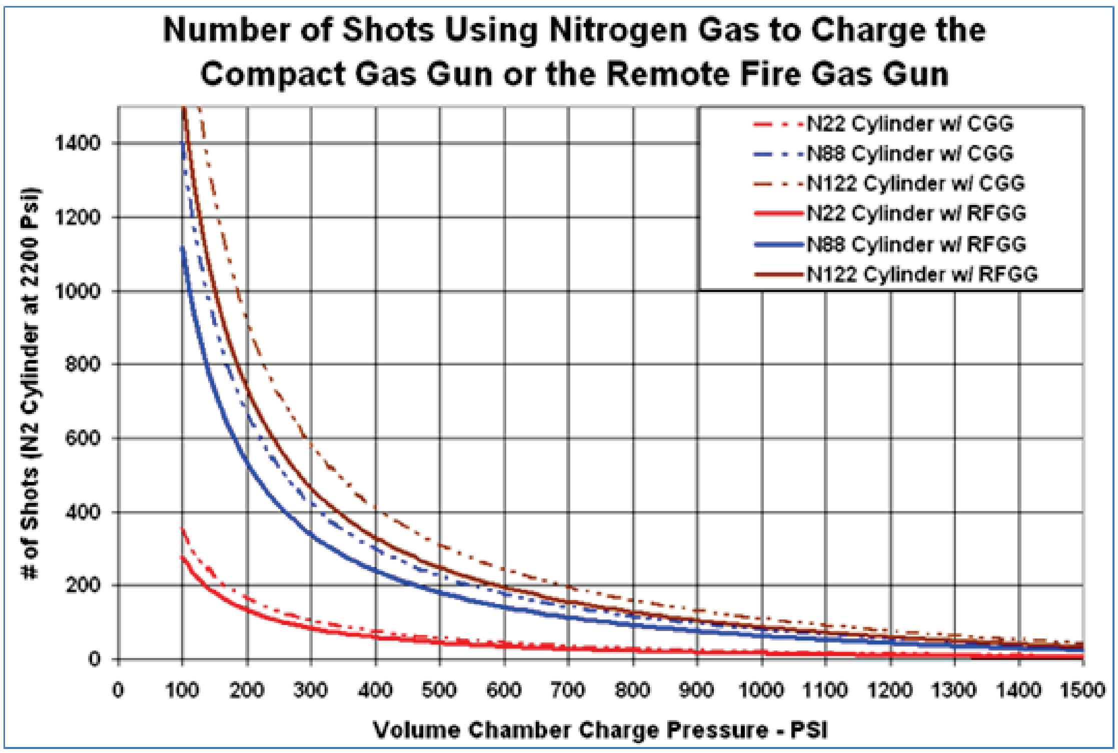


Figure 79 – Number of Fluid Level Shots for various Nitrogen Cylinders

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2. Mc Coy, J. N., Podio, A. L., Huddleston, K. L., and B. Drake:” Acoustic Static Bottomhole Pressures,” SPE 13810, Production Operations Symposium, Oklahoma City, OK, March 10-12, 1985.

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5. Becker, D., McCoy, J.N. and A. L. Podio: “Best Practices for Pressure Transient Tests Using Surface Based Measurements”, SWPSC, Lubbock, TX, 2007

6. Becker, D., G. Fernandez, K. Skinner, J. Bates: “Cloud-based Monitoring of Pumping Well Performance,” SWPSC Lubbock, TX, 2022.