REMOTE MONITORING OF PRESSURE TRANSIENT ACOUSTIC TESTS

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Abstract

Data from acoustic fluid level and surface pressure measurements were acquired by a standalone programmable monitoring system that uses internet and cellphone communication with the Cloud for remote monitoring of pressure transient well performance. The system named Remote Asset Monitor or RAM is described in detail in this paper that presents results from tests that lasted several weeks, beginning with well shut-in, continuing until pressure transient stabilization and afterwards during pump down until normal steady state production operation.

The progress of the buildup test was monitored remotely by downloading the acquired data and reviewing the pressure trend with additional measurements acquired manually as needed. After buildup stabilization the pumping system was activated and during pump-down the fluid level, dynamometer, pressure, and motor power measurements were acquired automatically based on a user defined schedule. The combined results of the analysis were used to estimate reservoir performance and well productivity.

In the past an operator was required to be at the wellsite to perform these tests. Once the portable RAM system was deployed at the well site and was programmed for standalone acquisition, the well performance trends were monitored wirelessly over extended periods of time without requiring an operator to return to the wellsite.

When connected via the cloud, the data acquisition schedule was adjusted remotely and the stored data was viewed and retrieved as needed. Additional measurements were performed and interpreted in real time so that the operator was able to troubleshoot and analyze the performance of the well from any location in the world.

Introduction

The present economic climate in the oil industry requires that maximum production efficiency be achieved with minimum engineering and technical manpower.

Flowing bottom hole pressure surveys, pressure buildup tests, pressure drawdown tests, and inflow performance analyses 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.

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. 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 first Automatic Acoustic Pressure Transient [4,5] system was based on the Echometer Well Analyzer configured for long term unattended operation and controlled by the TWM software specially developed for pressure transient data recording and analysis. The system has been available to industry since 1990. The equipment consists of an electronic package which includes a computer, analog to digital converter, amplifying and conditioning circuits. The electronic system is connected to the wellhead assembly with interconnecting cables. Once programmed and connected to external battery and Nitrogen gas source, the system, including the laptop computer, is left at the well site to automatically acquire fluid level records according to the preset schedule. To monitor the progress of the test the operator has to return to the well, open the laptop and review the data. When appropriate, the acquisition schedule is adjusted and power and gas supplies are replenished.

The new 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.

The RAM system [6], 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 also 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.

Pressure Transient Test Hardware Setup

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 of the TAM software.

The equipment setup for a pressure transient test at a pumping well is illustrated in Figure 2. It includes a Wireless Remote Fire Gas Gun, 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 dynamometer and a wireless pressure sensor. 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.

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 3, communicated with the sensors via a standard Echometer wireless base station and with a Cloud Server via a cellular network. 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 external laptop or with the cloud via internet connection. It utilizes existing wireless equipment for data acquisition and has the ability to run 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.

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 or in a location where internet connection is available. 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 with gas at a 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 (Figure 18) in the appendix 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. Initially the regulator should be set for 150 psi over normal operating casing pressure but since during the buildup test the well pressure will increase, the regulator 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 3, or solar panels or direct connection to AC power if available at the wellsite.

Software and RAM Schedule Setup for Pressure Transient

In addition to the description of the well and the completion system, the formation and fluid properties have to be entered in the program.

A special schedule for Advanced Analysis, shown in Figure 4, 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 presentation of pressure transient tests. The length of acquisition of the acoustic record and the duration of pressure monitoring are also specified.

Once the schedule has been activated the progress of the acquisition is monitored on a timeline where there is indication of the current 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 better to the expected future performance of the pressure and fluid level variation as a function of time.

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

Presentation of Results

At any time during and/or after the test it is possible to obtain graphical and tabular presentation of the data and the calculated results as shown in Figure 5 where data points for all the records acquired during 471 hours are plotted. This specific plot shows the variation of the Round-Trip Travel Time (RTTT) and the computed bottom hole pressure (BHP) as a function of time and is presented here as a means for illustration and is only one of several graphs. Below the graph the table presents the values that correspond to each record. The user can select which values are included in the table. The selected variables can also be exported to a spreadsheet in the CSV format.

The data to plot is selected from options in the data presentation menu. These include:

- Casinghead pressure vs. time
- Bottomhole pressure vs. time
- Liquid level vs. time
- Transducer temperature vs. time
- Acoustic round trip time (seconds) vs. time
- Acoustic Frequency (Jts/sec) vs. time
- MDH-BHP vs. Log(time)
- Horner
- Log-Log analysis
- Liquid after flow vs. time
- Gas after flow vs. time
- Smoothed velocity vs time
- Battery voltage vs time

These plots are the principal tools to determine the accuracy of the acquired data and the progress of the test. Random variations from the normal trends are indication of possible problems with the hardware or software. Detailed analysis of each record is required.

Acoustic Data Processing and Analysis

The first step is to ensure that fluid levels are determined correctly to be converted to accurate bottom hole pressure. The consistency of the 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 5. This plot should not exhibit random variations which are indications of erroneous analysis of the acoustic records. Random variations of fluid level 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. In order 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 5 is the final result obtained after careful analysis of each fluid level shot.

Acoustic Velocity Variation

During the well test (buildup or drawdown) the pressure, temperature and component distribution of the gas in the annulus will undergo significant changes. These in turn will cause variations in the acoustic velocity of the gas. At any given time, 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, as shown in Figure 6. When a sufficient number of records have not been acquired the data reduction program can interpolates between these points to calculate the depth to the gas/liquid interface from the measurement of the travel time of the liquid echo. If this variation were not taken into account and a single value for acoustic velocity were used in interpreting the travel time data 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 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 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 has to be taken in consideration in the BHP calculation. Experience indicates that a gaseous liquid column can extend for a significant period of time 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. 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 be depressed to a few joints above the pump 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.

FIELD EXAMPLE OF RAM PRESSURE BUILDUP TEST

Best Practices

Running a pressure buildup test involves a major commitment of time and manpower as well as temporary loss of income while the well is shut-in. Therefore, every effort should be made to guarantee that the final data is of sufficient good quality to yield an accurate representation of the formation permeability, skin and static reservoir pressure. The Appendix section of this paper presents recommended procedures and guidelines to help reach that objective. In particular it is important that everyone involved with the particular well knows that the test will be conducted. The well should be locked out and tagged out.

Inspect the well prior to start of Pressure Transient Test and make all necessary repairs. Verify that the stuffing box and casing wellhead will handle the additional pressure. Run Dynamometer and determine Liquid Level prior to Pressure Transient test. Verify that the production is stabilized.

The well for this test is a horizontal well that is being produced by rod pump in a reservoir that is near depletion. The pump is set near the top of the horizontal section as seen in Figure 7. The well was scheduled for a workover and the operator agreed to shut in the well to obtain an estimate of the reservoir static pressure and well productivity. Fluid level and dynamometer tests performed ahead of the shut-in test sowed that fluid level was just above the pump intake and that annular gas flow was about 5 Mscf/D. From previous experience, it was expected that after shutting down the pump the casing pressure would increase to about 100 psi from the operating pressure of 11 psi with some corresponding increase of liquid level.

Pressure Buildup Test Results

The test was setup as recommended and monitored periodically via cloud connection and all acquired data was progressively downloaded to the office computers.

Figure 8 shows a zoomed-in detail of the liquid level as a function of time. Note that in this particular well the liquid level initially increases but as the casing pressure increases due to the continued influx of gas, the liquid level is pushed back down until it drops below the pump intake and then stabilizes. Figure 9 shows a detail of the acoustic record (#66) acquired when the liquid level was above the pump intake. Note that the down-kick echo from the tubing anchor is used to determine a very accurate acoustic velocity. Figure 10 shows a detail of acoustic record #85 when the liquid level has been pushed back down past the end of the tubing string. This fact is verified by the presence of the up-kick echo that is observed before the liquid level echo. The physical reason for this acoustic response behavior is illustrated in Figure 11 that shows the probable distribution of the liquid in the undulating section of the horizontal wellbore. The wellbore oscillation leaves an open gas channel on the high side of the hole where the sound wave can travel until it reaches a low spot where the liquid occupies the full wellbore. The sound wave is totally reflected at this point creating the liquid level echo.

The combination of increased casing pressure and variation of liquid level yield a computed bottom hole pressure that continually increases as the reservoir pressure builds up as seen in Figure 8. The bottom hole pressure is still increasing, but at a lower rate, at the end of the test after 480 hours. The question is whether sufficient data has been acquired to be able to interpret the results, in terms of the formation properties and static reservoir pressure, so that the buildup test can be terminated. For this purpose, a series of advanced analysis graphs, such as the Log-Log plot for all type of wells and the MDH and Horner plots for vertical wells, are available to perform a preliminary evaluation of the test. Eventually the BHP vs. time results are exported for final detailed analysis using specialized pressure transient software applications.

In horizontal wells the behavior of the change in pressure vs. incremental time and the corresponding derivative are complex functions that depend on many variables as shown in the generalized response for a closed outer boundary well in Figure 12.

In the advanced transient plots, tools are made available to aid in the interpretation. These include least square line fits of selectable portions of the data, unit slope and half slope trend line, zooming to portions of the data and calculation of time derivatives. Figure 13, shows the Log-Log plot for the data acquired in the test well. Comparing its pressure and derivative trends with those in Figure 12 one may conclude that the buildup response has reached the end of the Early Linear Flow region.

Pump Down Performance

Once a buildup test has been completed, the RAM system provides the additional benefit of monitoring the performance of the well and the pumping system during the time when the well is pumping down and stabilizes back at the normal operating condition. The recommended procedure for this test is as follows.

- Bleed Casing Pressure to normal operating pressure.
- Acquire periodically fluid level records until casing pressure stabilizes.
- Install Wireless Polished Rod sensor for dynamometer measurements.
- Start pump and acquire manual dynamometer record.
- Setup schedule to acquire fluid level and dynamometer records as the well pumps down.
- Remotely monitor progress of pump down by downloading accumulated data.
- Stop schedule once production has stabilized.

After termination of the acquisition of the Pressure Buildup session and downloading all the acquired session data, The RAM system in this well was setup for the Pump-Down test. This included installing a wireless dynamometer sensor and a wireless pressure sensor to record the tubing head pressure during dynamometer acquisition. The fluid level sensor was already installed for the buildup test.

Before restarting the pump operation, it was necessary to reduce the casing pressure to the normal operation range. The process was performed in several steps during about 2 hours and 20 minutes.

Figure 14 shows the increase in fluid level due to evolution and expansion of the gas in the annular fluid from an initial depth of 5260 ft to a stabilized depth of 4970 feet bringing the fluid level above the pump intake.

Before starting the pump, the RAM system was set up with two schedules: one for acoustic record acquisition and one for dynamometer and pumping tee pressure acquisition. The schedules are shown in Figure 15. They are synchronized for logarithmic frequency of 30 measurements per log cycle. (The resulting BHP pressure data could be exported and used for drawdown analysis).

Figure 16 shows a composite of the liquid level vs. time with samples of the dynamometer pump cards that show how at the start of the pump-down the pump liquid fillage was 100%, which was expected since the liquid level was above the pump intake, and then decreased to a pumped-off condition after about two hours of pumping. Fluid level then stabilized at about 5200 feet when pump off control was implemented.

A simple productivity analysis can be undertaken using the producing bottom hole pressure of 49 psi at stabilized conditions and the stabilized production rate of 11 BPD in conjunction with the estimated static bottom hole pressure of 91.5 psi from the pressure buildup test. This yields a PI of about 0.26 BPD per psi of drawdown as shown in Figure 16. Exporting the drawdown data to a specialized application could result in a more precise analysis.

Summary

The progress of a pressure buildup test was monitored remotely during 24 days via cloud connection to the Remote Asset Monitor (RAM) system by downloading and analyzing the acoustic data that was acquired automatically by a user defined schedule. Data was downloaded via Internet at various times during progress of the buildup and fluid level records were processed to compute the bottom hole pressure. BHP data vs. elapsed time was exported for detailed analysis with specialty pressure transient software. During the duration of the test the operator visited the wellsite a few times just to check the Nitrogen supply.

After buildup pressure stabilization the pumping system was activated and during pump-down the fluid level, dynamometer, pressure, and motor power measurements were acquired automatically based on a user defined schedule. The combined results of the buildup estimated static reservoir pressure and the stabilized producing pressure were used to estimate reservoir performance and well productivity.

References

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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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4. Podio, A. L., McCoy, J. N. and Huddleston, K.L.: “Automatic Pressure Buildup Data Acquisition and Interpretation Using a Microcomputer-based Acoustic Liquid Level Instrument”, SPE 16228 Presented at the SPE Production Operations Symposium, Oklahoma City, OK, March8-10,1987.

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

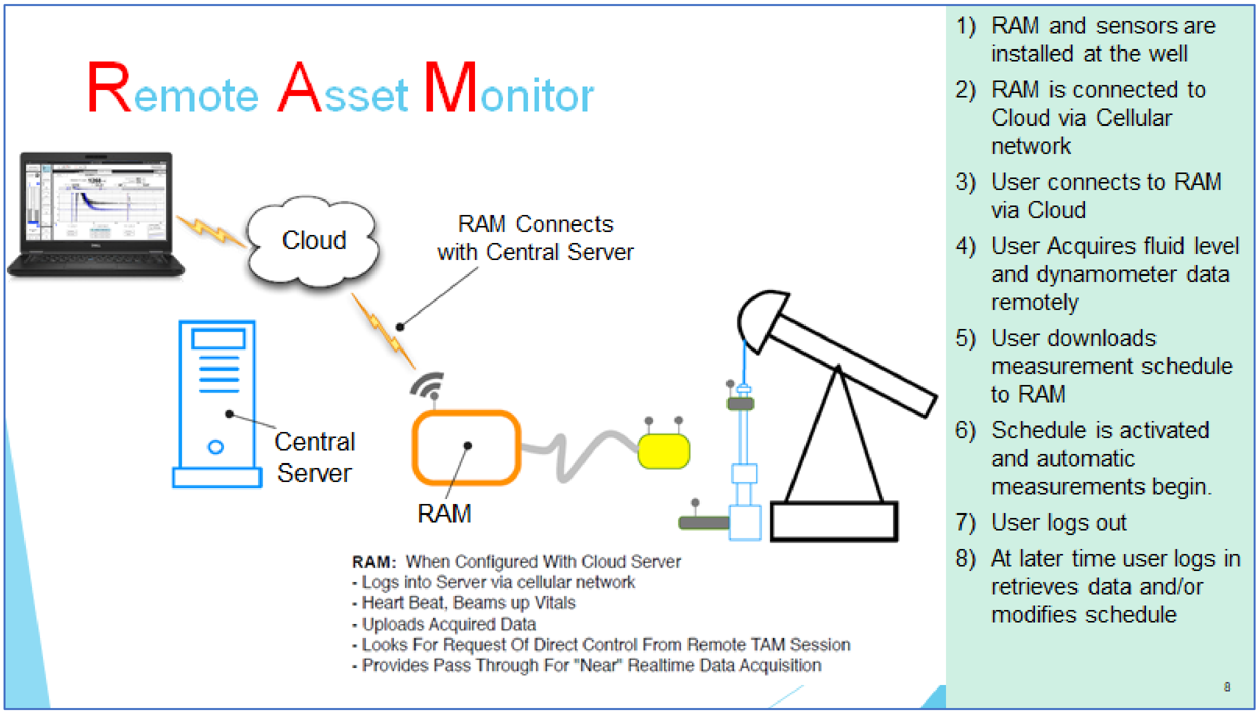


Figure 1 – The RAM System

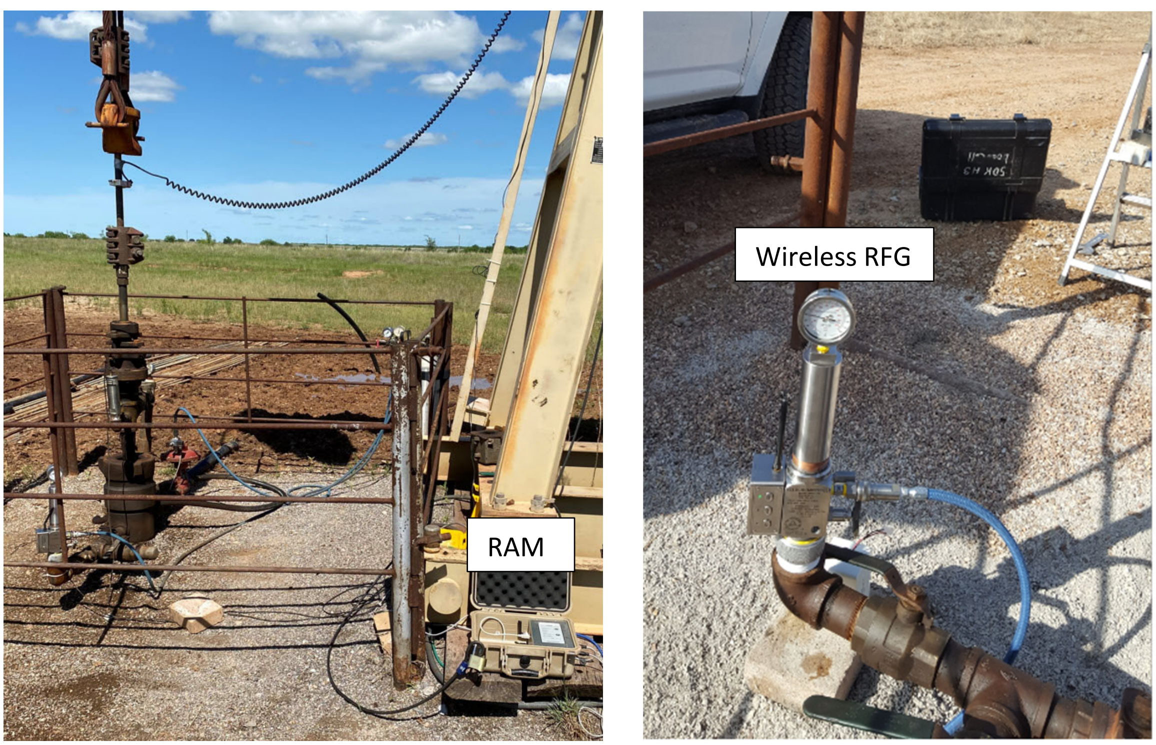


Figure 2 – RAM setup for Pressure Buildup Test

Figure 3 – RAM connected to external battery and Nitrogen supply for long term operation.

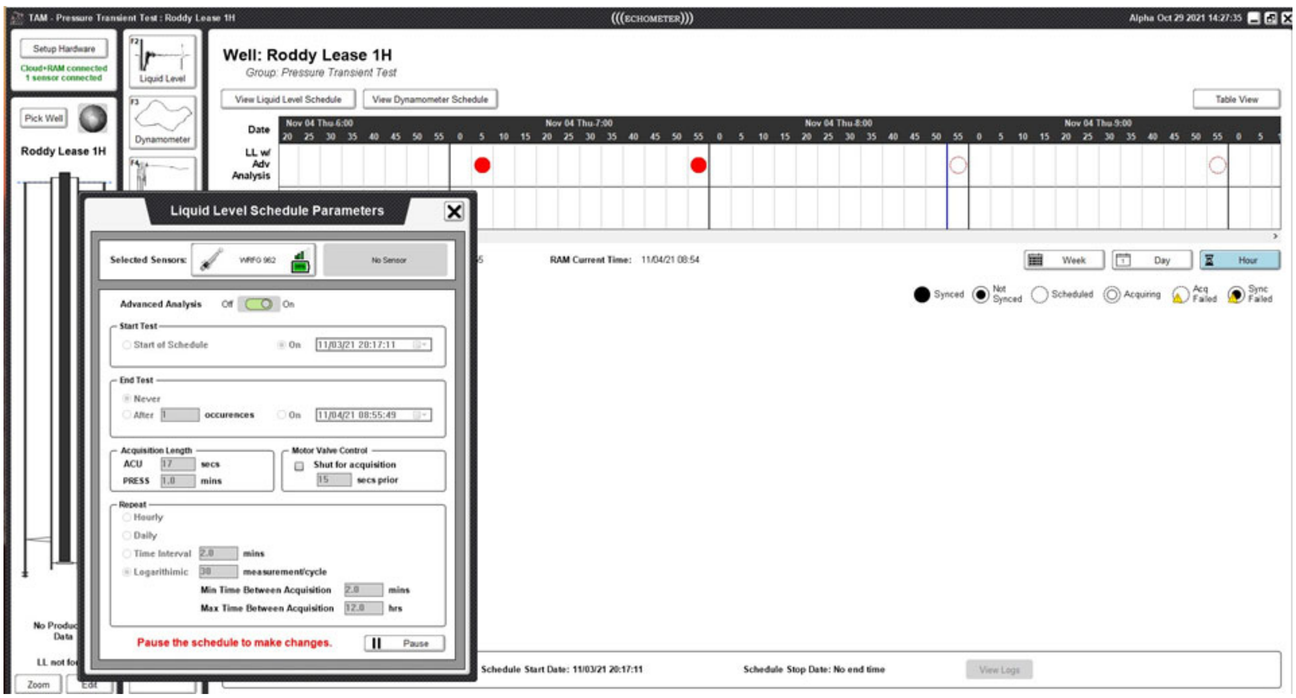


Figure 4 – Liquid Level Record Acquisition Schedule for Advanced Analysis Pressure Transient.

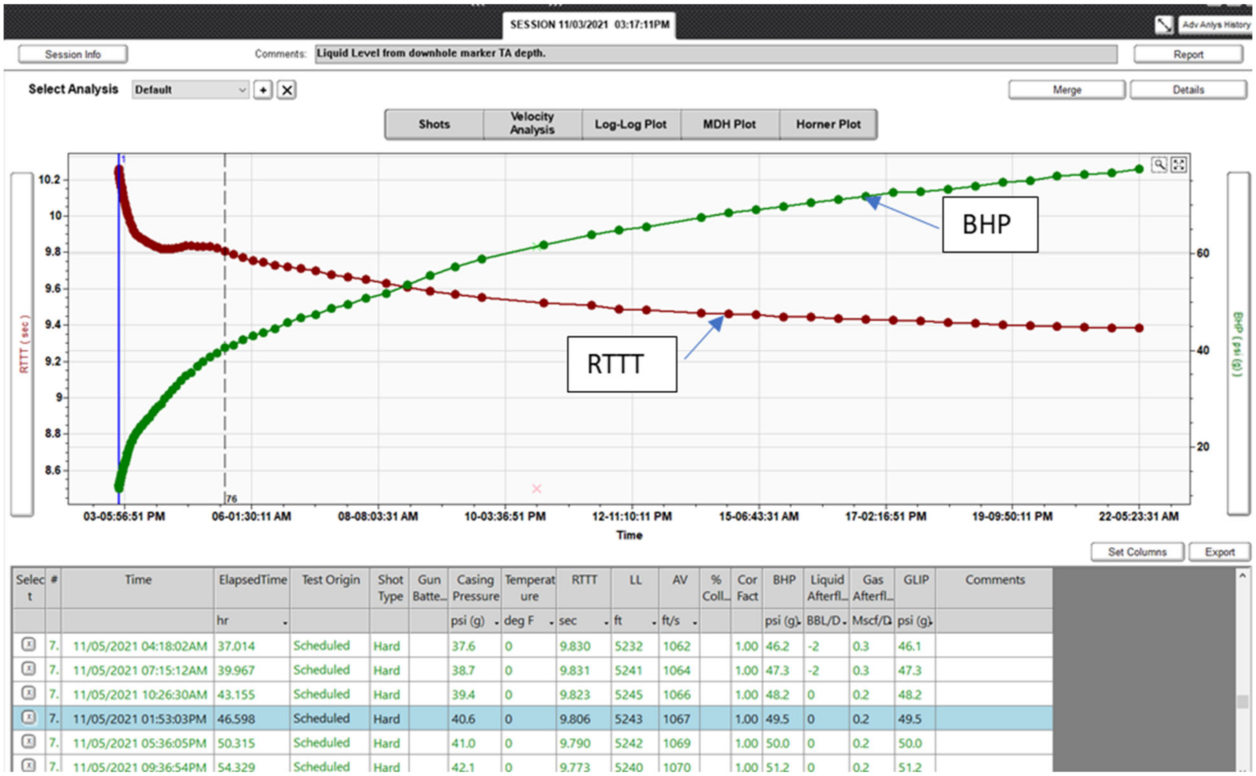


Figure 5 – Pressure Buildup test – data acquisition during 471 hours – RTTT and Casing pressure.

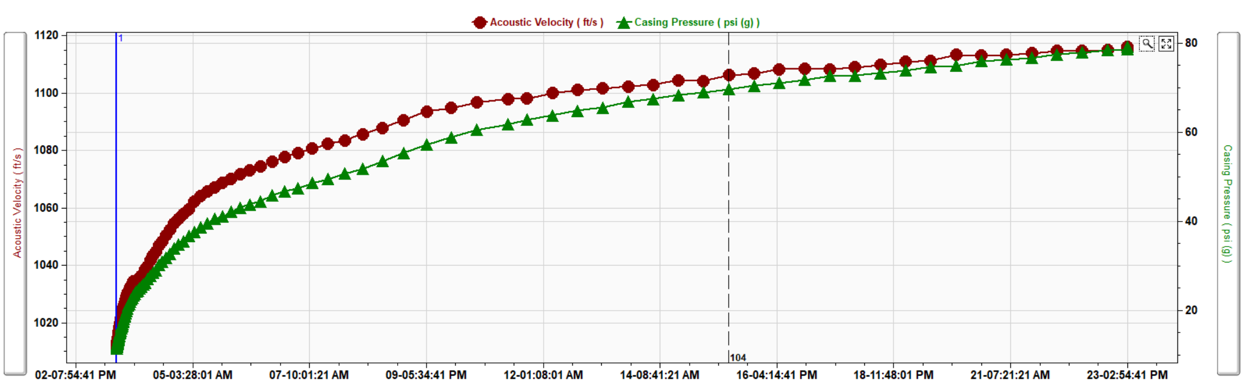
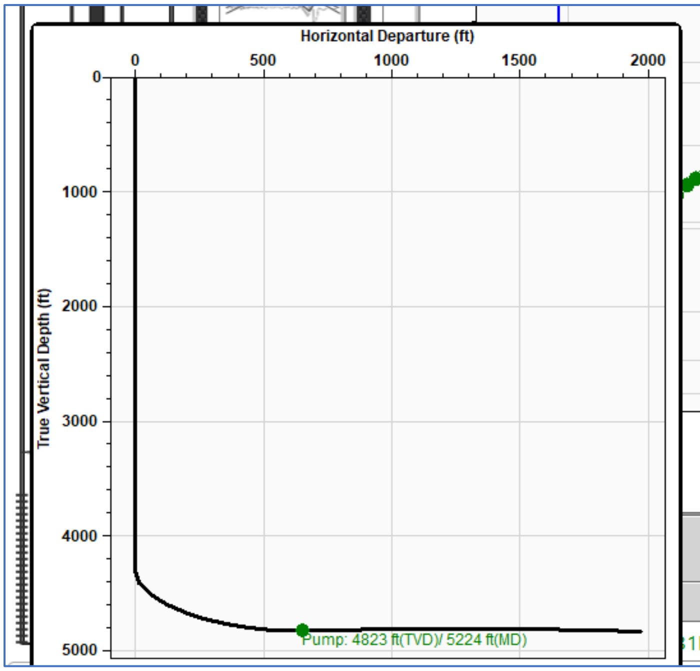


Figure 6 – Acoustic Velocity and Casing Head Pressure vs. Time



During Buildup test as the casing pressure increases due to gas after-flow the liquid in the annulus may be depressed past the end of the tubing.

Figure 7– Wellbore geometry of test well.

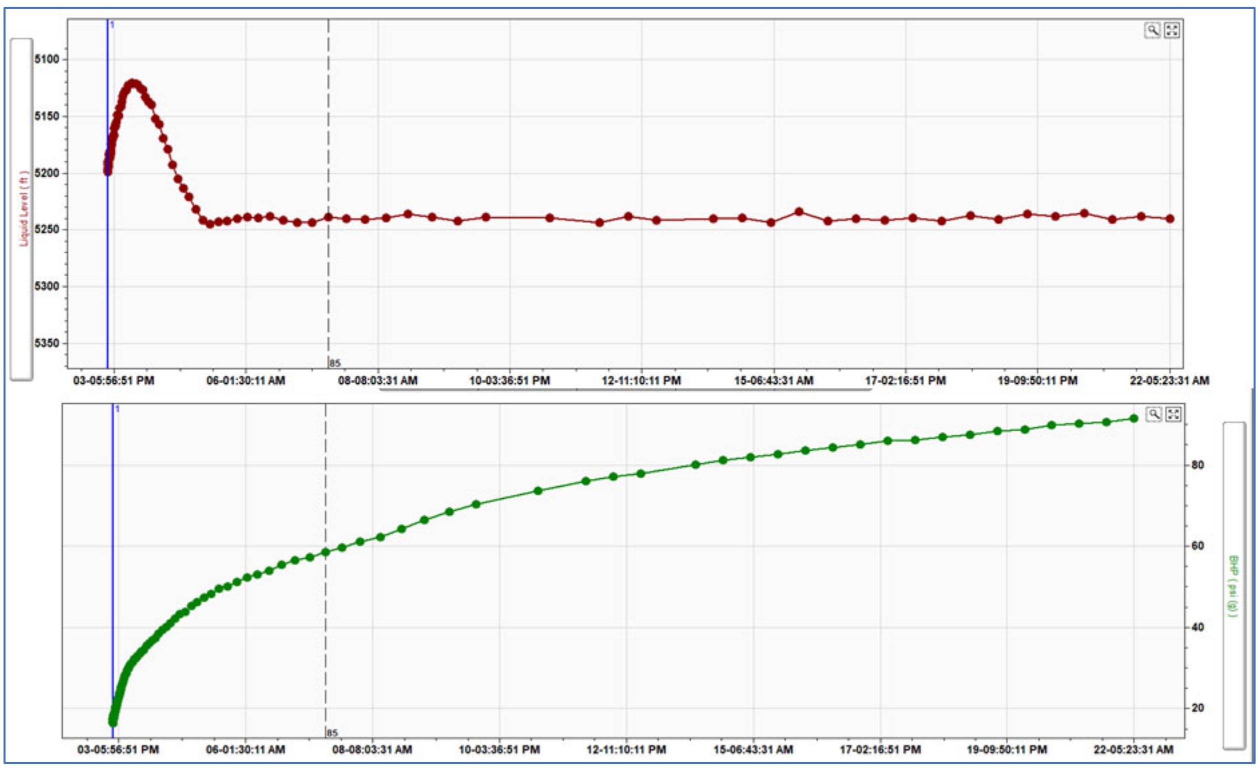
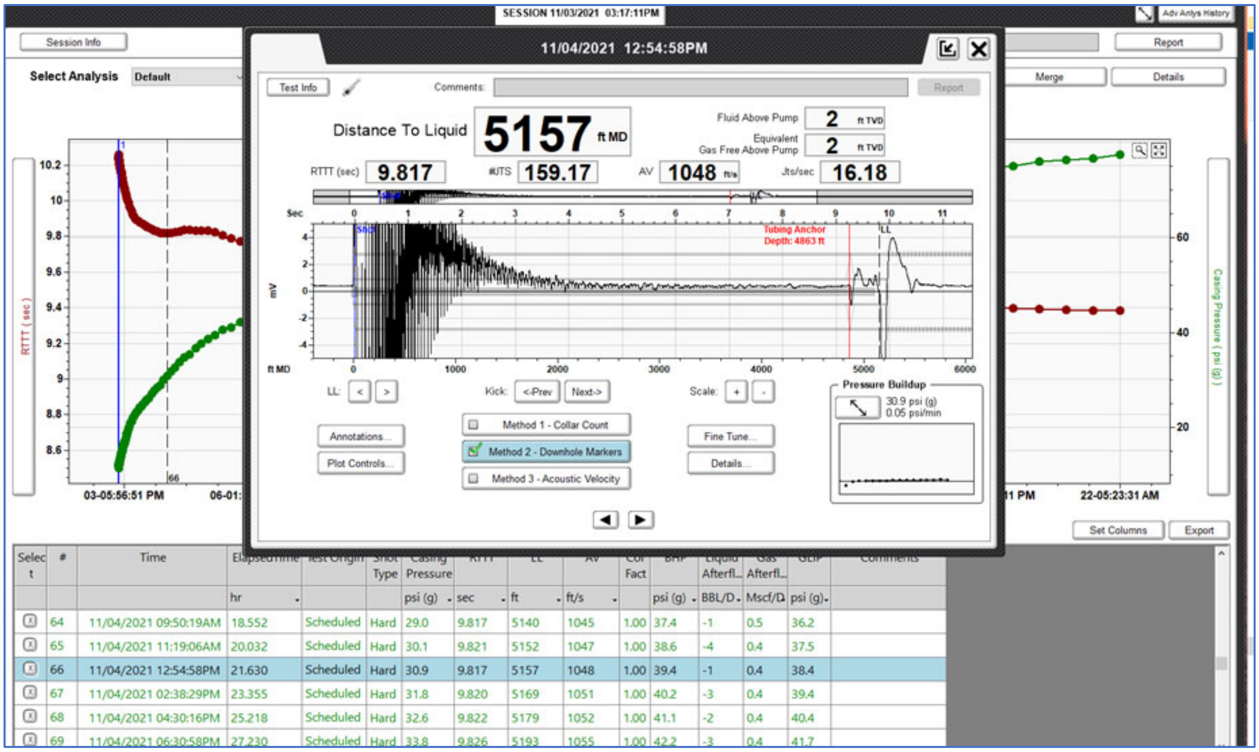


Figure 8 – Liquid level and BHP during buildup test



Select	#	Time	Elapsed time	Test Origin	Shot Type	Casing Pressure	RTTT	LL	AV	Cor Fact	BHP	Liquid Afterfl...	Gas Afterfl...	GLIP
			hr			psi (g)	sec	ft	ft/s		psi (g)	BBL/D	Mscf/D	psi (g)
	64	11/04/2021 09:50:19AM	18.552	Scheduled	Hard	29.0	9.817	5140	1045	1.00	37.4	-1	0.5	36.2
	65	11/04/2021 11:19:06AM	20.032	Scheduled	Hard	30.1	9.821	5152	1047	1.00	38.6	-4	0.4	37.5
	66	11/04/2021 12:54:58PM	21.630	Scheduled	Hard	30.9	9.817	5157	1048	1.00	39.4	-1	0.4	38.4
	67	11/04/2021 02:38:29PM	23.355	Scheduled	Hard	31.8	9.820	5169	1051	1.00	40.2	-3	0.4	39.4
	68	11/04/2021 04:30:16PM	25.218	Scheduled	Hard	32.6	9.822	5179	1052	1.00	41.1	-2	0.4	40.4
	69	11/04/2021 06:30:58PM	27.230	Scheduled	Hard	33.8	9.826	5193	1055	1.00	42.2	-3	0.4	41.7

Figure 9 – Acoustic record at start of buildup test with liquid level above pump intake

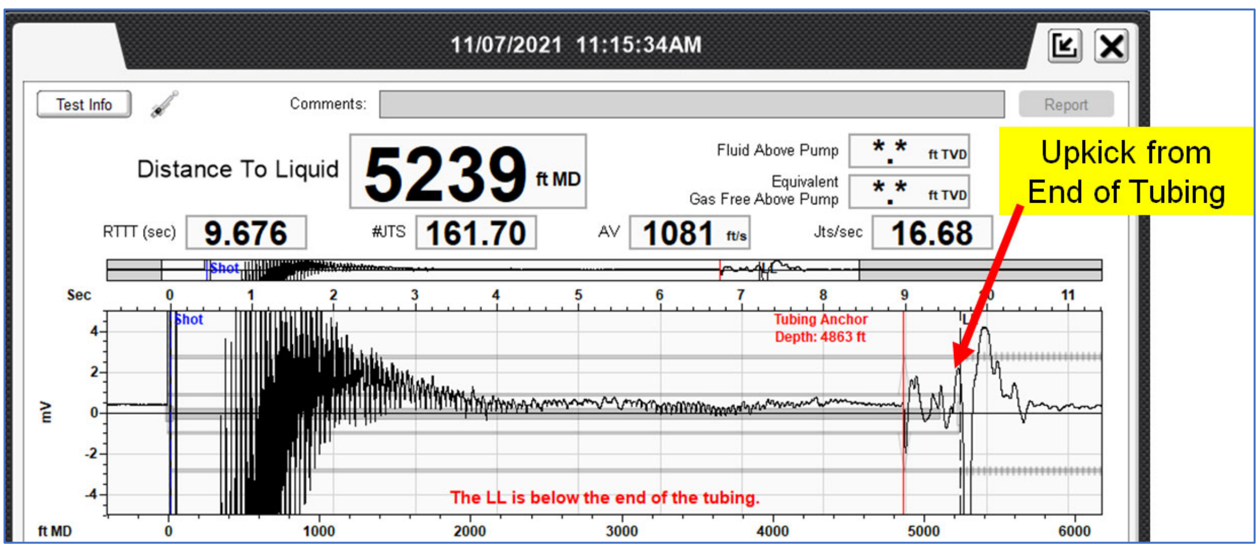


Figure 10 – Acoustic record #85 showing Liquid Level past the end of the tubing.

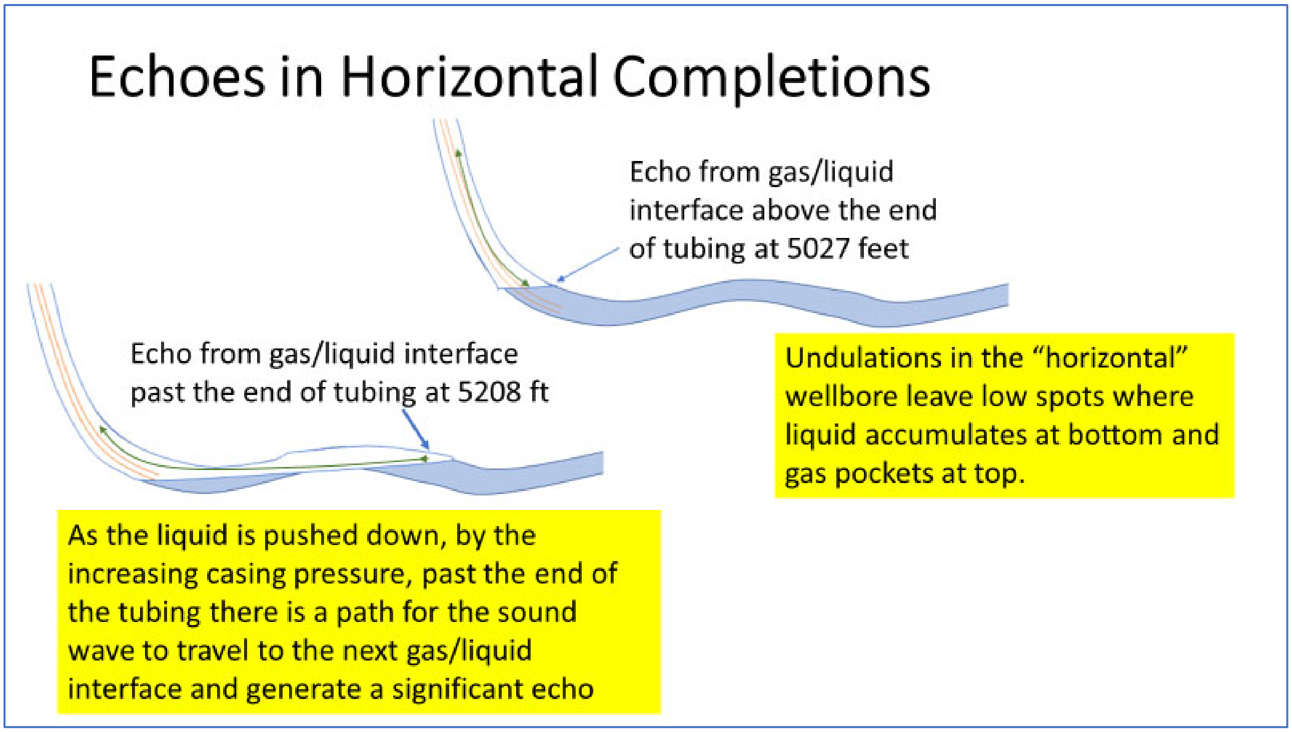


Figure 11 – Acoustic echoes in a horizontal wellbore.

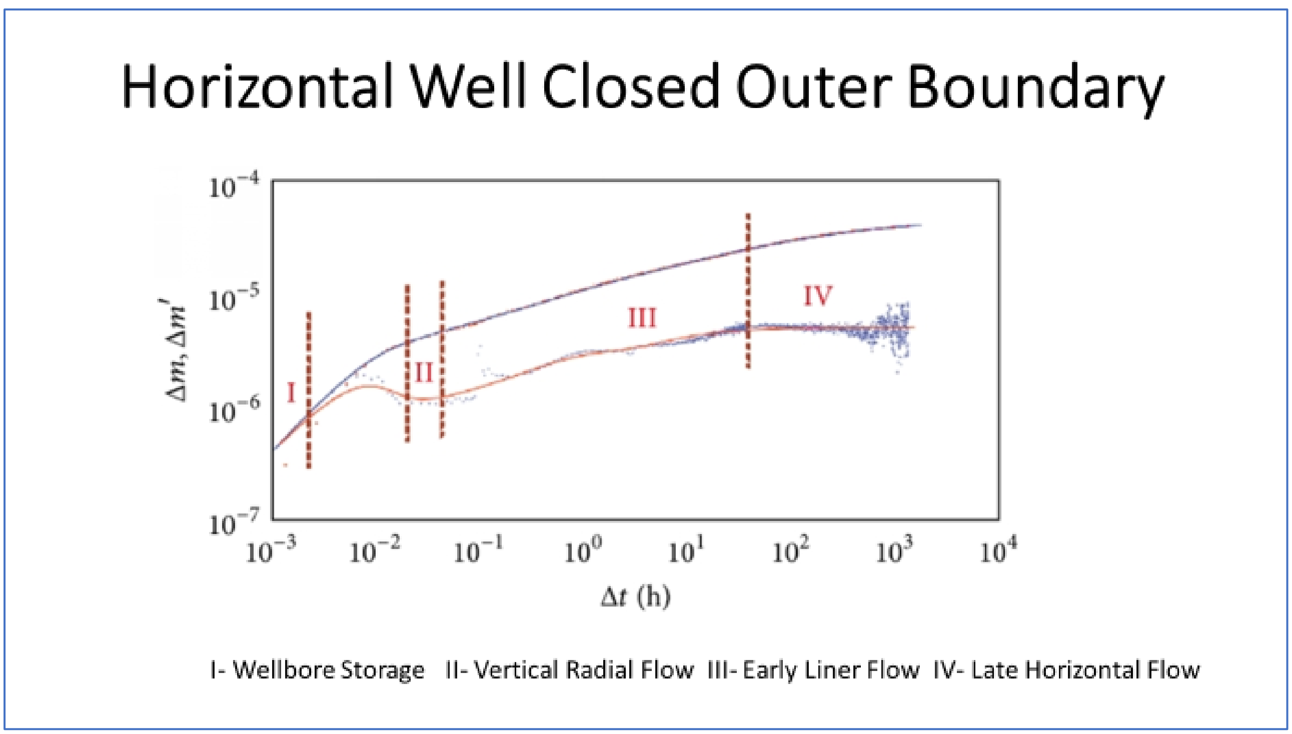


Figure 12 – Typical Pressure Buildup Response of Horizontal Gas Well.

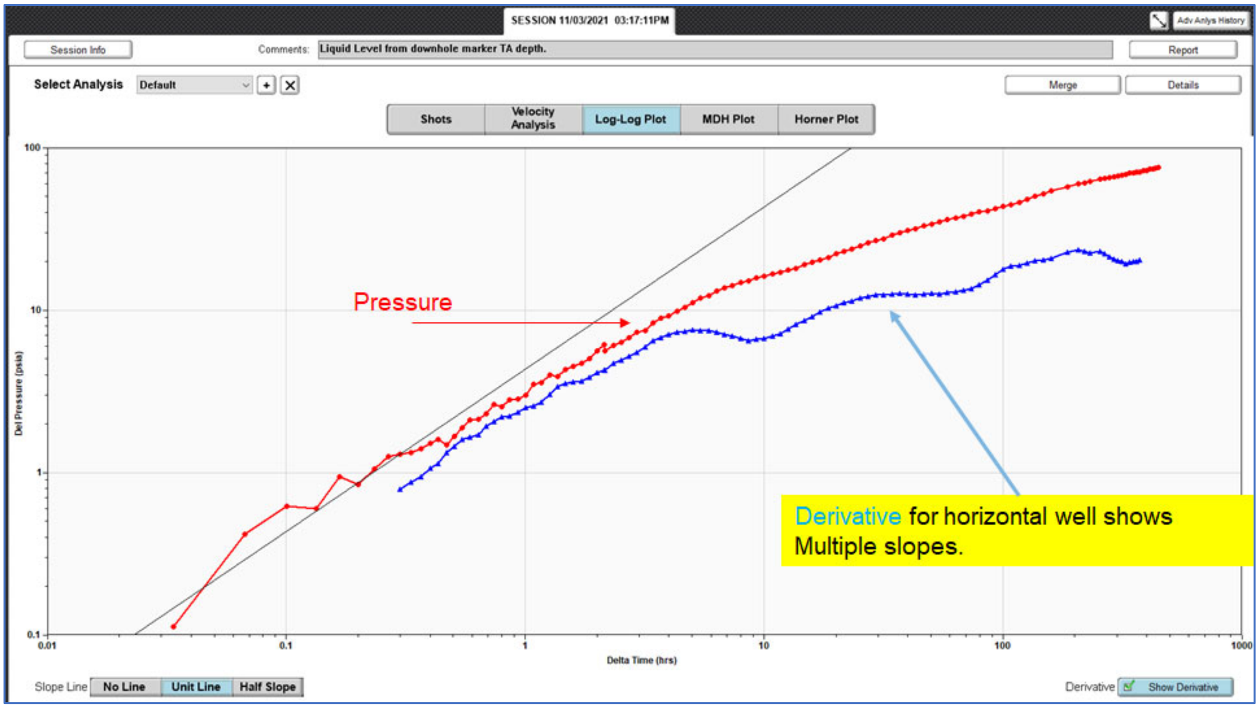


Figure 13 – Buildup Analysis plot of Log P vs. Log dt

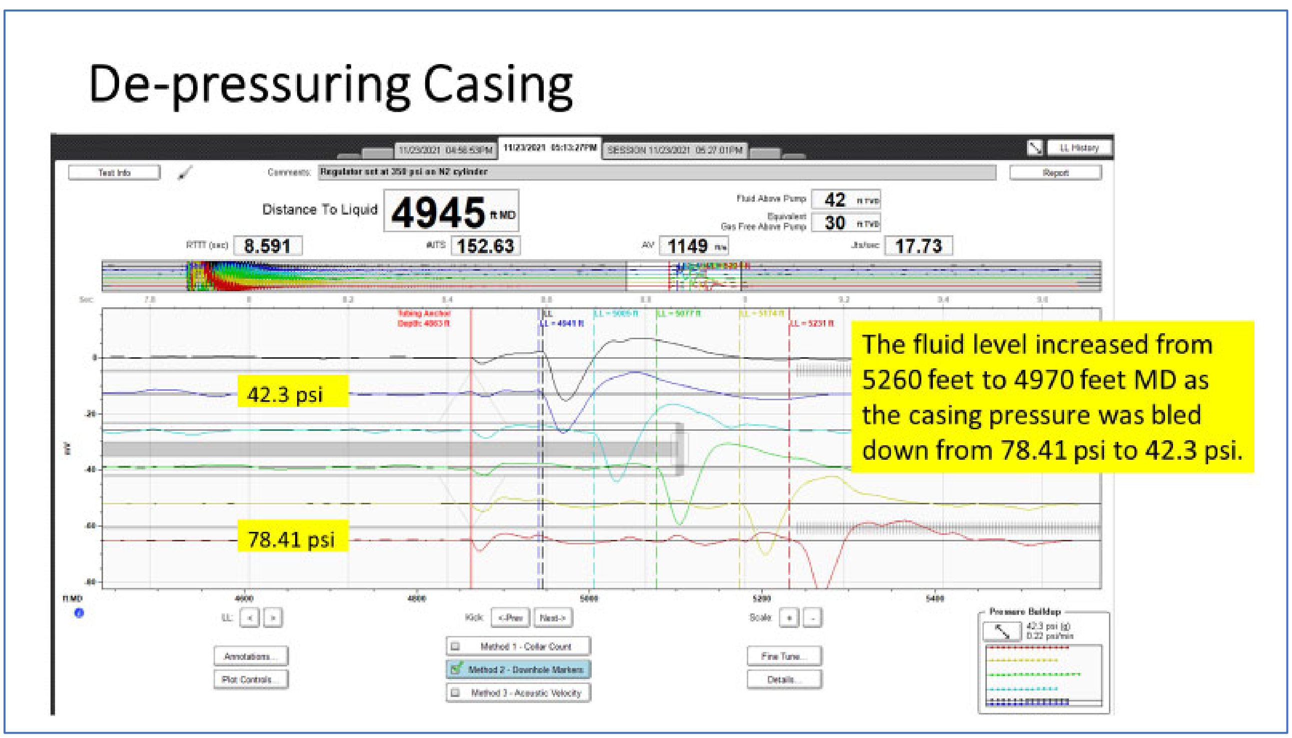


Figure 14 – Liquid level variation while de-pressurizing the casing annulus.

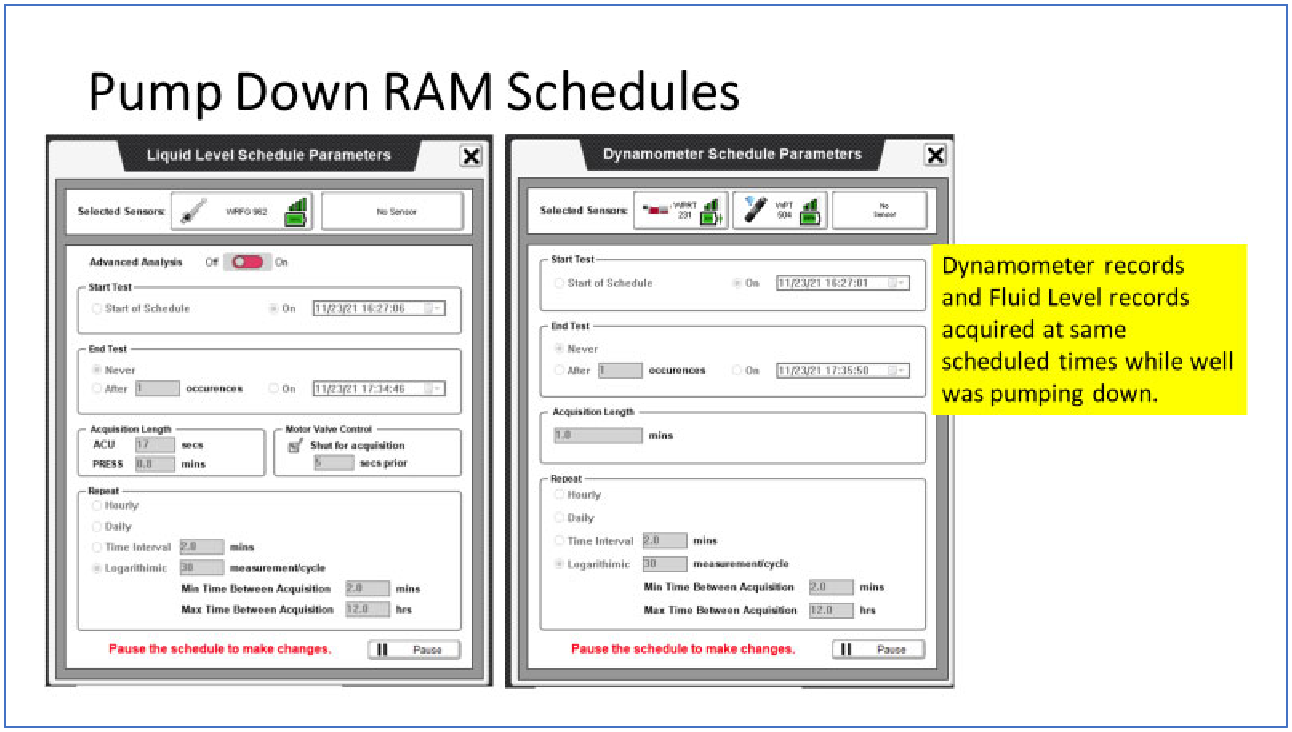


Figure 15 – Schedules for Dynamometer and Fluid Level Acquisition during Pump Down

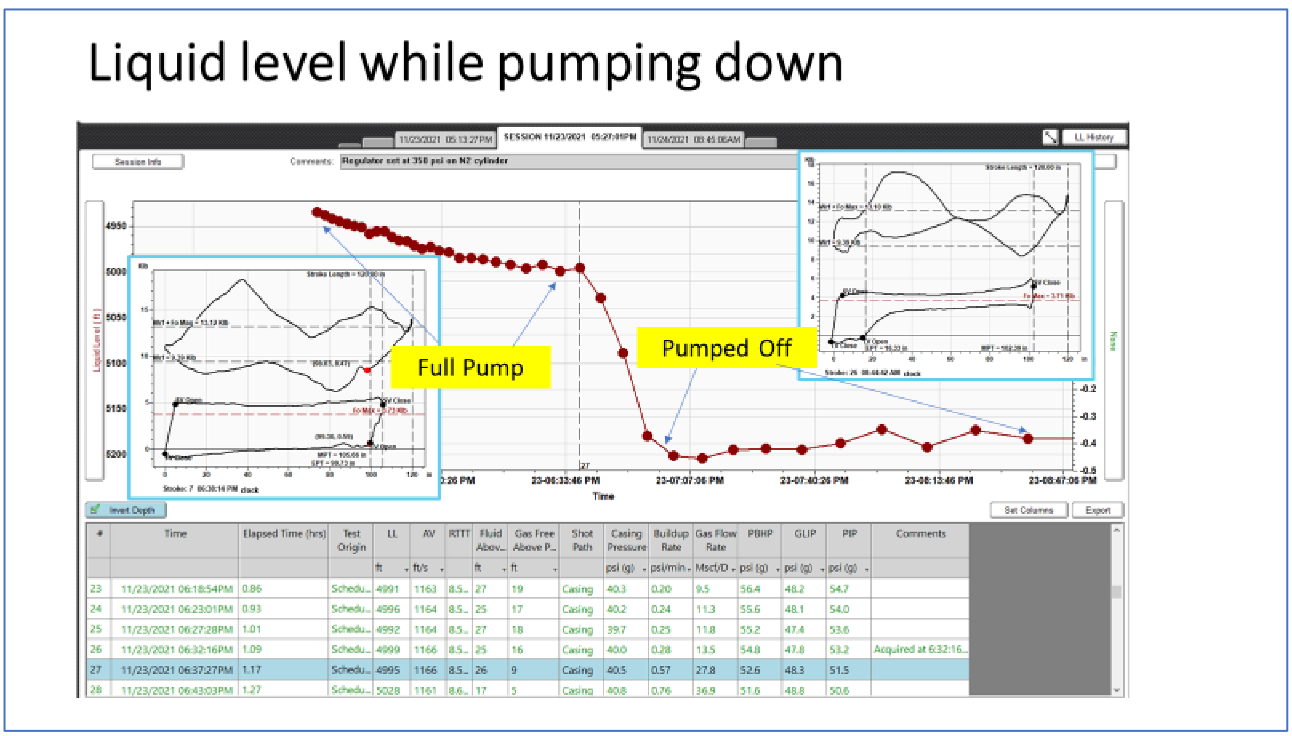


Figure 16 – Fluid Level and Pump Performance during Pump Down

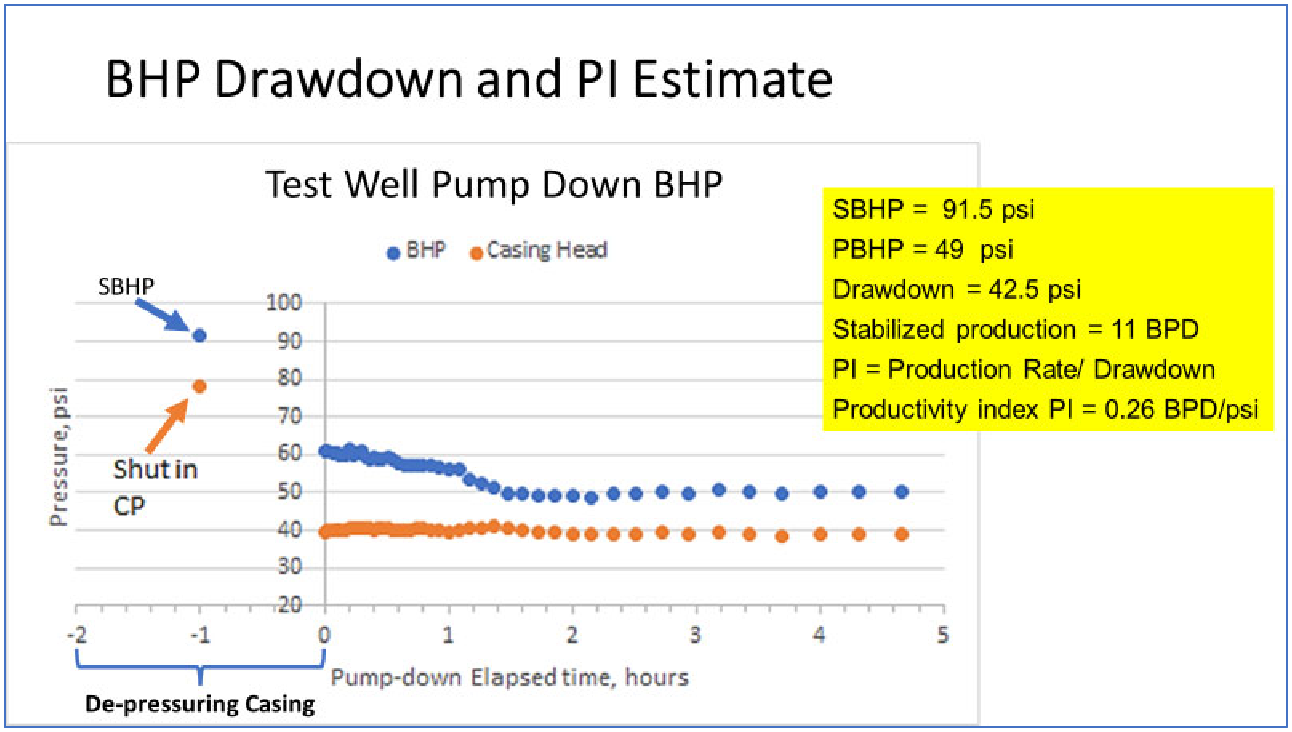


Figure 17 – Producing Bottom Hole Pressure at Stabilized Conditions.

APPENDIX

Recommended Practices for RAM-based Acoustic Pressure Buildup Tests.

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 (1-hour) 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 SV 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.

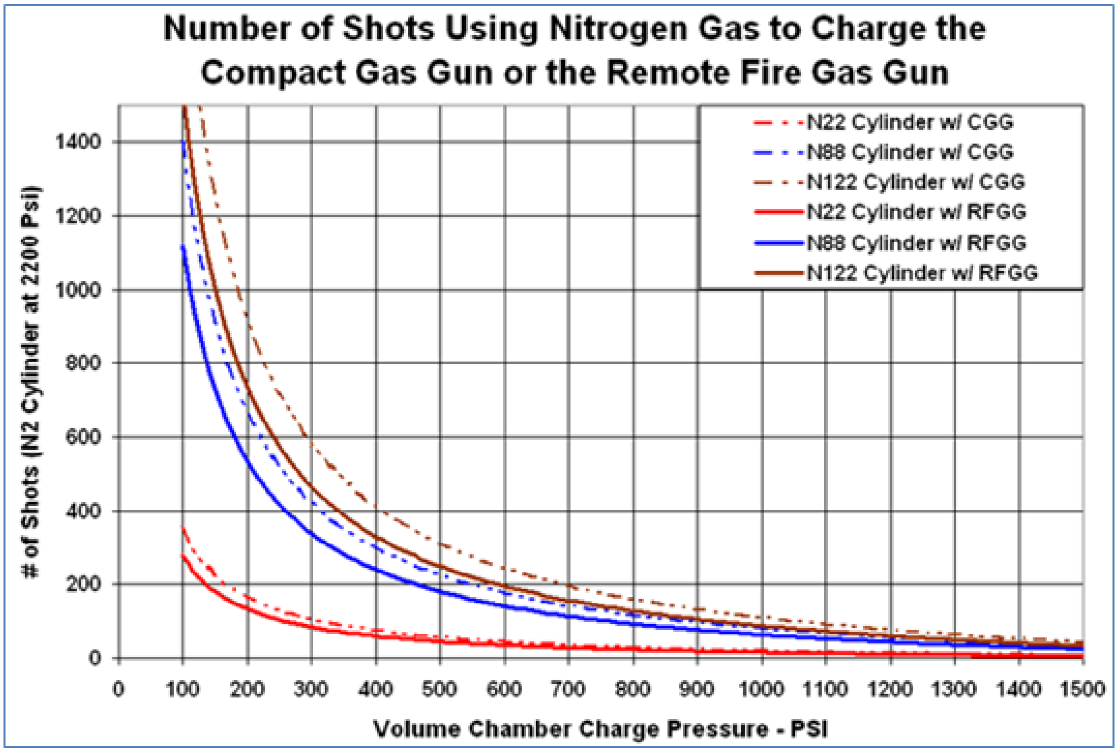


Figure 18 – Number of Fluid Level Shots for various Nitrogen Cylinders

<u>Dynamometer Sensors for Pump-down test.</u>

All Echometer wireless dynamometer sensors can be used in conjunction with the RAM. Due to its inherent stability and accuracy the horseshoe dynamometers 30K and 50K are preferred for long term scheduled acquisition.

Wireless 50 K Dynamometer

Wireless PRT

Figure 19 – Wireless Dynamometer Sensors

All the sensors are moisture resistant but should be protected from heavy rain using plastic enclosures. The wireless antenna should be oriented for line-of-sight communication with the RAM box. Power cables or external batteries that are also moisture resistance should be connected to each sensor when long term measurements are to be performed.