CLOUD-BASED MONITORING OF PUMPING WELL PERFORMANCE

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Abstract

Data from fluid level, dynamometer, pressure, and motor power measurements were acquired by a standalone programmable monitoring system that uses internet and cellphone communication with the Cloud for remote monitoring of well performance. The system named Remote Asset Monitor or RAM is described in detail in this paper that presents results from the tests that lasted several weeks, beginning with well pump down, just after new pump installation and continuing during normal production operation. The performance of the well was monitored in detail and additional measurements were acquired as needed based on the real time performance of the pumping system.

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.

Description of the RAM System

The RAM system, shown schematically in Figure 1, has several objectives for improved analysis and optimization of flowing and artificial lift wells:

- 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 and download it to user's computer
- Manual Data Acquisition override
- Increase productivity and safety 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.

The RAM system consists of a portable electronic package that includes wireless data acquisition from distributed sensors, Wi-Fi communication electronics and network software, battery and battery charging capability. The user interfaces with the RAM via a laptop running the TAM program, for the purpose of acquiring data manually as needed and for programming the RAM for standalone acquisition and communication.

The RAM communicates with the cloud (hub) to provide remote access from any location with connection to the Internet. At the remote location, once the user has accessed the cloud and connected to the RAM, he/she can monitor the past performance of the well by reviewing the data that the RAM acquired based on the pre-programmed schedule, acquire more instantaneous data, analyze the data and allow the RAM to continue with the same schedule or edit the schedule to satisfy new requirements.

RAM Box Description

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.

For fluid level acquisition has the ability to control an external motor valve during liquid level test to isolate the casing annulus from production flowline while the acoustic data is being recorded and the casing pressure is being monitored.

The RAM's electronics are housed in an enclosure that withstands environmental conditions of temperature, wind, rain, etc.

Power management is one of the main considerations of the firmware that runs in the Single Board Computer and controls the status of the system, such as turning off the Wi-Fi after five minutes of inactivity, or putting the RAM in a low power mode when not communicating with the cloud.

Sensors and Hardware Installed with RAM

All the existing Echometer wireless sensors can be deployed with the RAM system. Unattended operation does require providing additional elements such as a motor valve, a nitrogen gas supply system and some type of external power source: AC power, batteries or solar panels for extended duration testing.

The standard Echometer WRFG is used but since multiple acoustic fluid level measurements will be acquired automatically without operator intervention it is necessary to provide, to the gun chamber, Nitrogen gas at a regulated pressure via a permanent high pressure hose connection to the gas supply bottle as shown in Figure 4.

Acquisition of acoustic records in the annulus of pumping wells (rod pump, PCP, or ESP) requires closing the flow of gas from the casing to the flowline. This action has several objectives:

- Reducing the acoustic background noise
- Preventing the reception of interfering echoes originated downstream in the flowline
- Maximizing the amplitude of the pulse traveling downhole
- Stopping the gas flow out of the casing
- Monitoring the change in casing pressure when the casing is shut-in

The motor valve illustrated in Figure 4 is a normally-open valve with a pneumatic actuator. The operating gas pressure is provided from the Nitrogen tank via a pressure reducer set at the recommended pressure for proper valve operation. The gas pressure is applied to the valve dome via an electrical solenoid valve that is normally closed. When the computer issues the command to “Close the Casing Valve” the solenoid valve is opened, the Nitrogen gas flows to the motor valve dome and the motor valve closes. The completion of this action can be verified in TAM by monitoring the reduction in background acoustic noise and the fact that the casing pressure generally will increase as a function of time.

RAM system deployed for a typical Rod Pump Application

The RAM and the sensors described in the previous section were installed at the well and programmed for standalone acquisition of fluid level, dynamometer and power data.

Figure 5 illustrates direct connection from TAM to RAM via Wi-Fi and wireless communication of the RAM box with the sensors installed on the well.

At the Well Stand Alone Acquisition

The laptop running the TAM application was connected wirelessly to the RAM hot spot. Fluid level and dynamometer data were acquired manually to verify that the system was operational and all sensors were communicating correctly with the RAM. Then the schedule of measurements to be performed automatically was designed and set up in the RAM. After double checking that everything was properly set up, execution of the schedule was started so that and the first records were acquired automatically. The first few records acquired by the programmed schedule were downloaded and analyzed to verify their accuracy. Everything was correct so TAM disconnected and the RAM box was left at the field to automatically continue acquisition in accordance with the schedule.

Cloud Based Acquisition

Logging into the Cloud will connect to the Server/Hub that operates as a secure pass-through to the RAM. Each RAM has an internal computer that listens for the Wakeup command that will come from the Server/Hub. Once the Wakeup command is received, the RAM computer will boot up and connection to the RAM will begin.

Upon connection the screen displays all RAMs that are currently active and are accessible by the user as shown in Figure 6 that includes:

- A list of RAMs the operator has access to is displayed.
- Each RAM displays an Active Status and the option to Wakeup or Login.
- No Active Well – The RAM is not being used for acquisition.
- Well Name displayed – The RAM is installed on a well and being used for acquisition.
- Internal RAM Battery % displayed.
- Offline – The RAM is not in use and in Low Power mode.
- Online – The RAM is active.

In order to connect and login to the RAM it needs to be in Operational Mode. Selecting the Wakeup button will request the RAM to transition from Low Power Mode to Operational Mode. If a RAM is currently in Low Power Mode this is indicated by the label “Offline” with an active “Wakeup” button.

The specific RAM that the user wants to control is selected by clicking on the “Connect” button.

As shown in Figure 7, TAM is now logged into RAM via the Cloud. It has an active Base Station and the available wireless sensors associated with the Base Station are shown at the left. The wireless RFG 614 is selected and its parameters are displayed on the right panel. The setup procedure is now complete and this window can be closed unless updates need to be applied. The status of individual sensors can be monitored and or adjusted using the TAM controls.

Remote acquisition of data can be initiated once connection to the RAM has been completed.

The standard TAM acquisition procedure is followed:

  - Select well and verify that well description is up to date
  - Select test module
  - Start acquisition

The user can either start by acquiring fluid level first or initiate dynamometer acquisition first and then proceed to liquid level.

Figure 8 displays a dynamometer record acquired manually via the cloud. Recording of dynamometer data, is displayed as load and acceleration vs. time for the first few strokes and then displayed as dynamometer cards in real time. Surface and pump cards are displayed live, as if the operator were observing the acquisition screen at the wellsite, until the user indicates that a sufficient number of strokes have been acquired and stops the recording.

After clicking on the acoustic button and selecting “New Test” the fluid level acquisition screen is displayed showing the background well noise. After closing the flowline valve the user should monitor the background noise level and notice the decrease in amplitude that gives an indication of the actual closing of the valve. Note: in wells with little or no flow of annular gas the change in amplitude may not be noticeable.

It is not necessary to stop dynamometer acquisition in order to acquire fluid level data as shown in Figure 9. Fluid level acquisition is in progress while dyno data continues to be recorded.

Concurrent acquisition of dynamometer and fluid level is implemented by opening the inset dyno display at the bottom left of the screen. This display is obtained by clicking on the (+) icon at the bottom left of the Dynamometer button.

Upon completion of the remote data acquisition session the connection to the RAM is closed by logging out. This is a two-step procedure: first logout from the RAM by clicking the Logout button and then the connection with the cloud is terminated.

All the data that has been acquired manually via the cloud, in addition to being stored in the RAM, is resident in the user’s laptop so one can proceed to analyze the records in detail and generate all the TAM reports as shown in Figure 10 since analysis tools provided by TAM are active during remote acquisition. Alternately, before disconnecting from the RAM, the user can set-up a schedule to continue acquiring data according to a programmed schedule as shown in the following section.

Defining and starting a Schedule for Remote Unattended Acquisition

The RAM system is designed to be programmed to acquire records according to a specified sequence without user intervention.

Objectives

- Unattended data acquisition according to a preset schedule
- Remote monitoring of schedule progress
- Remote updating of acquisition schedule
- Downloading acquired data remotely
- Terminating scheduled acquisition

The “Schedule” function is accessed by clicking on the “Scheduler” mode button that displays the screen in Figure 11, that allows setting up the sequencing of liquid level and dynamometer acquisition.

The user selects which set of records he wants to schedule for acquisition:

- Liquid Level
- Dynamometer

By clicking on the corresponding button. The schedules are independent and can be set up with different time intervals and durations. Figure 12 is an example of how a schedule for acquisition of liquid level records may be organized by choosing the test parameters:

Specifying LL Schedule Parameters

- Starting time and ending time and the frequency of fluid level acquisition.
- Acquisition parameters and options

Specifying DYN Schedule Parameters

- Starting time and ending time and the frequency of dynamometer acquisition.
- Duration of dynamometer record.
- Select Sensors

Once the setup of the schedule is complete the user may have the schedule begin immediately or may program the start of acquisition at a later time.

By default the schedule is displayed as a time-line graph with selectable time periods of hours, days or weeks as shown in Figure 13. The display is in real time which is shown on the screen as the current time of the RAM clock. The vertical blue bar is located at the current time of 17:58 corresponding to the hourly time scale displayed at the top of the strip. Each programmed test is indicated by a circle that may be empty or filled as noted in the figure's legend. Circles are located approximately at the times specified by the user when the time scale is appropriate. Records that will be acquired are represented by dotted line large circles in red (fluid level) or blue (dynamometer).

Once the records have been acquired, small circles filled with their corresponding color are displayed inside the dotted circles. Solid small red circles indicate that liquid level acquisition and analysis are completed. Solid blue small circle indicates that acquisition of dynamometer records has been completed

At any time during the execution of scheduled acquisition the user can review the status of the acquisition, verify which tests have been completed and determine which records will be acquired in the future. At the bottom of the schedule time line the slider allows scrolling through the time scale to the region of interest. The timing and parameters of the schedule can be modified by pausing and then entering the new parameters.

All data that has been acquired by the schedule or remotely by the user can be downloaded to the computer that is connected to the RAM either locally or via the Cloud.

Downloading and Analyzing Data Acquired During Unattended Acquisition

Remote or local connection to the RAM also allows downloading all the data that has been acquired to that point in time. The downloading process is illustrated in Figure 14 where the large filled circles represent records that have been downloaded to the user's computer. As each record is transferred the display shows the progress. The time required for the transfer depends on the number of records and the speed of the internet connection but typically is of the order of tens of minutes for several hundred records.

Once transfer has been completed the data acquired by a schedule can be analyzed in TAM using all the tools and following the same procedures as analyzing data acquired conventionally with a wireless or wired Echometer system.

The only difference is that the data is managed and presented using a special set of tables and graphs as shown in Figures 15 and 16.

The table presents a row for each record that was acquired and lists the most relevant parameters in columns. Double clicking on a row brings up a panel with the corresponding record, such as the acoustic record displayed in Figure 15. Note that all the usual analysis tools are active so the user can perform a detailed analysis.

The graph in Figure 16 is one of various plots of important variables that can be selected to monitor the performance of the rod pump by viewing the pump fillage as a function of time. Each dot represents the liquid fillage averaged over the number of strokes acquired for that particular record. In this example the dynamometer records were acquired once an hour for a duration of 64 strokes.

At the beginning of the schedule the pump is filled with liquid then the fillage decreases and stabilizes at about 86% during sixteen hours. After this time the fillage begins to vary over a wide range of values indicating possibly that there may be a problem with the pump or variable gas interference.

The graph in Figure 17 displays variation of fluid level in a different well during several days. Points that are off the general trend corresponds to acoustic records where the liquid level echo was not detected or analyzed automatically. These records must be reviewed and analyzed by the user.

The general trend of FAP shows three distinct sections. At the beginning of the period (day 10 and 11) the well is still pumping down but almost stabilized then fluid accumulates and builds up above the pump. This corresponds to the occurrence of a rod failure that requires a workover lasting almost 2 days. At the start of day 13 the pump is again operating and the fluid pumps down but there is a discontinuity on the 14^{th} caused by interruption of electrical power that is restored in a matter of a few hours.

These figures illustrate some of the potential benefits of the RAM system. Additional filed examples will be included in the paper's presentation.

RAM Applications to Monitoring Well Performance

Although the examples presented in this paper refer to application to rod pumped wells, the RAM system is applicable to all types of production operations as outlined below

Rod Pump Wells

- First Delivery Monitoring
- Well Pump Down Tracking
- POC/Timer Set-Up and Evaluation
- Power Analysis
- Pressure Transient Tests (Buildup/Drawdown)
- Fluid Level Depression Tests

Gas Lift Wells

- Start Up Sequence
- Intermittent Monitoring
- Pressure Transient Buildup Tests

ESP Wells

- First Delivery Monitoring
- Pump Down Tracking
- Fluid Level Trends
- Pressure Transient Tests

Gas Wells

- Liquid Loading Trends
- Monitor Batch Treatments
- Pressure Buildup Tests

Plunger Lift Wells

- Liquid Level Monitoring
- Plunger Cycle Monitoring
- Pressure Transient Tests

Flowing Wells

- Flowing Pressure Trends
- Pressure Transient Tests

Injection Wells

- Injection Pressure Trend
- Injectivity Test
- Fall-Off Test

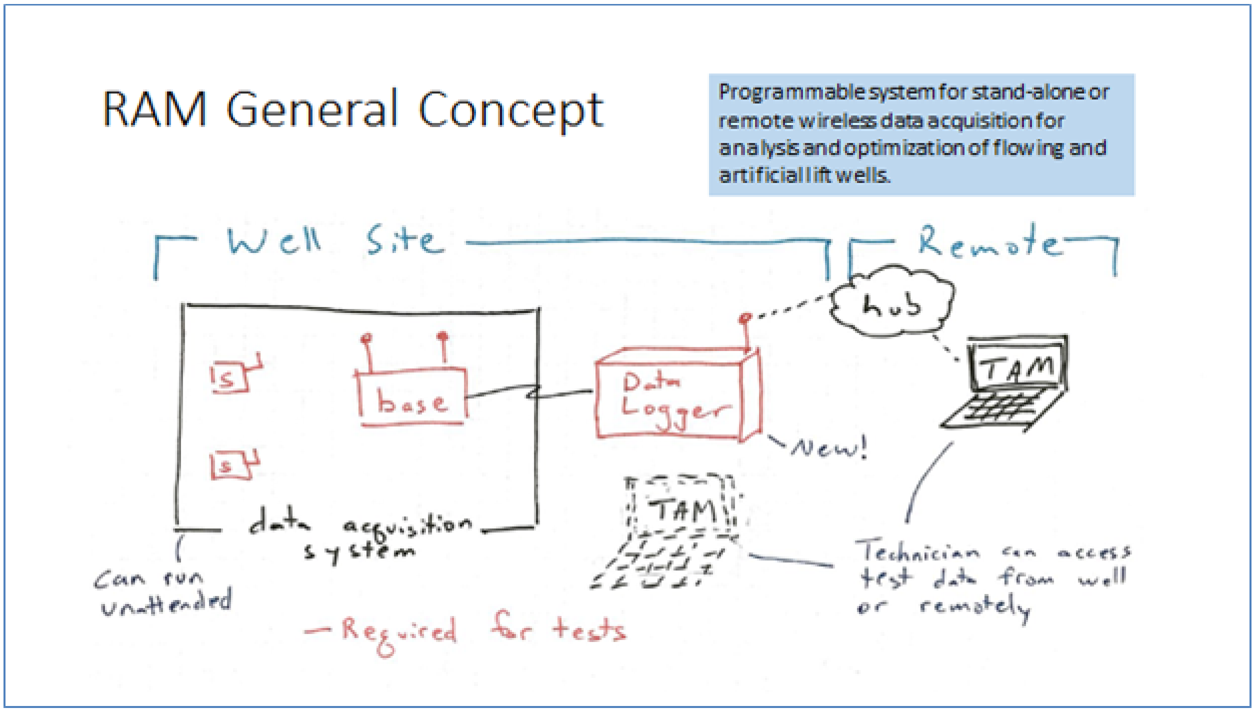

Figure 1 – General concept of the RAM system

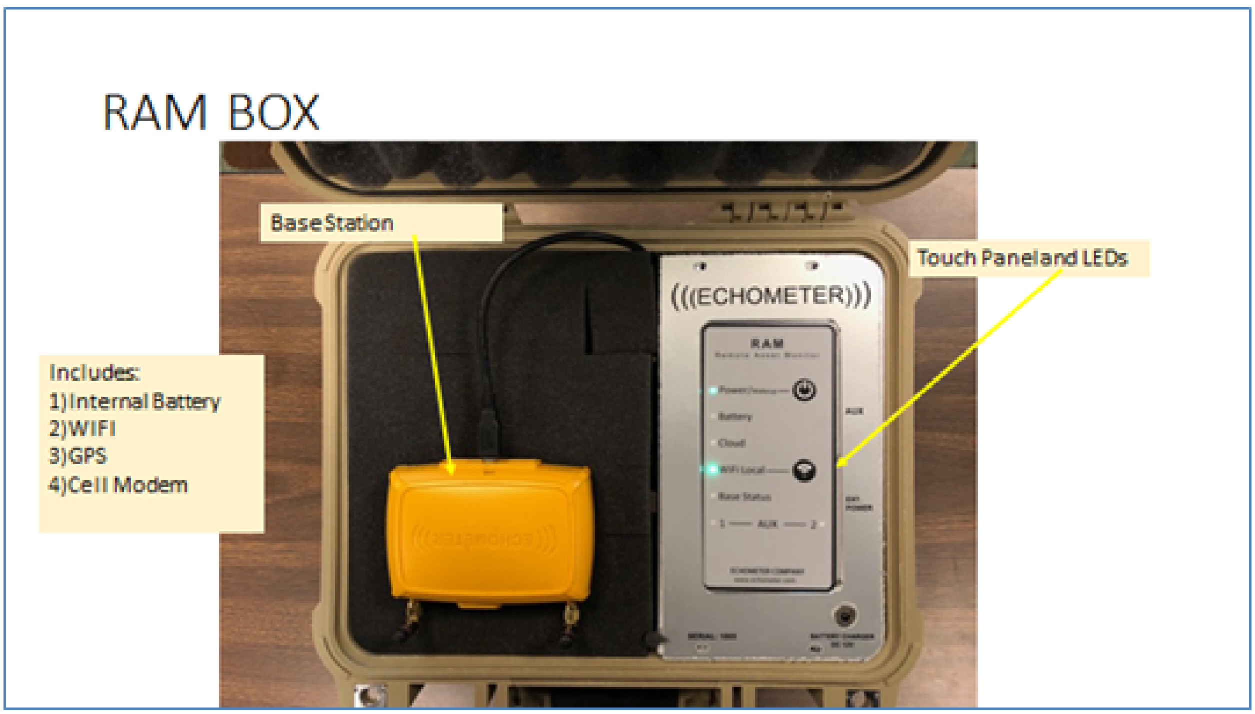

Figure 2 – The RAM Box

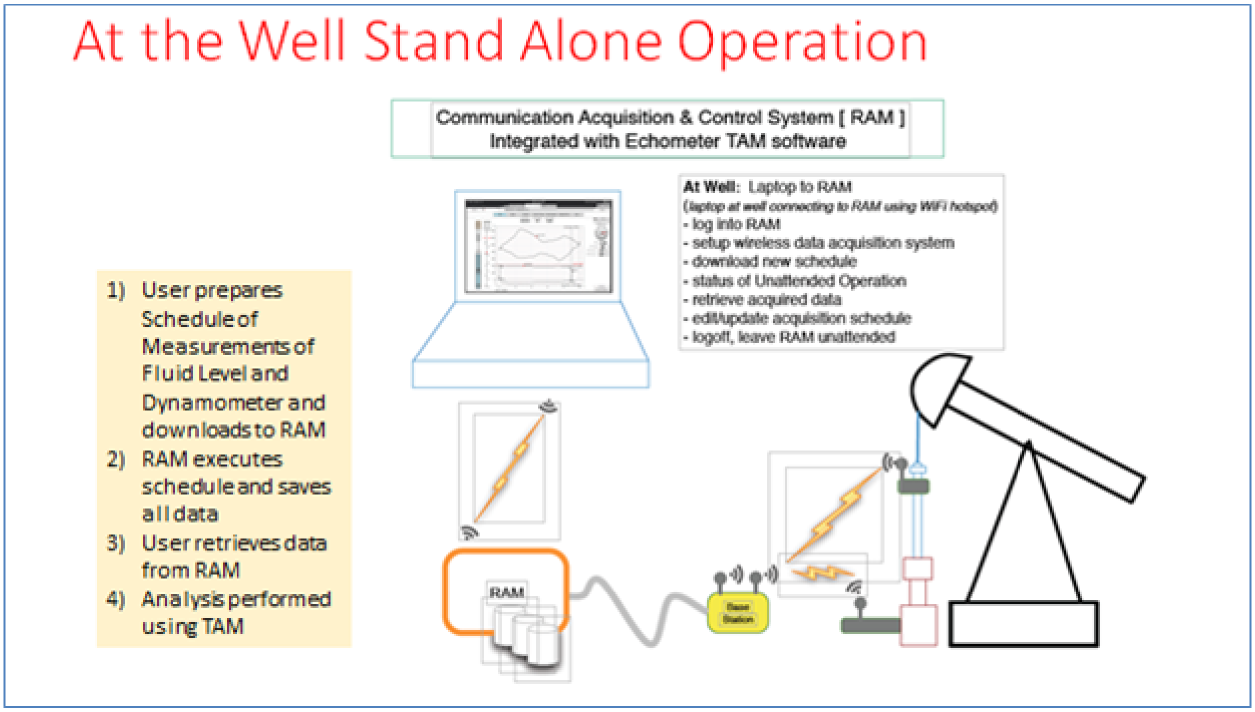

Figure 3 – Stand Alone Operation

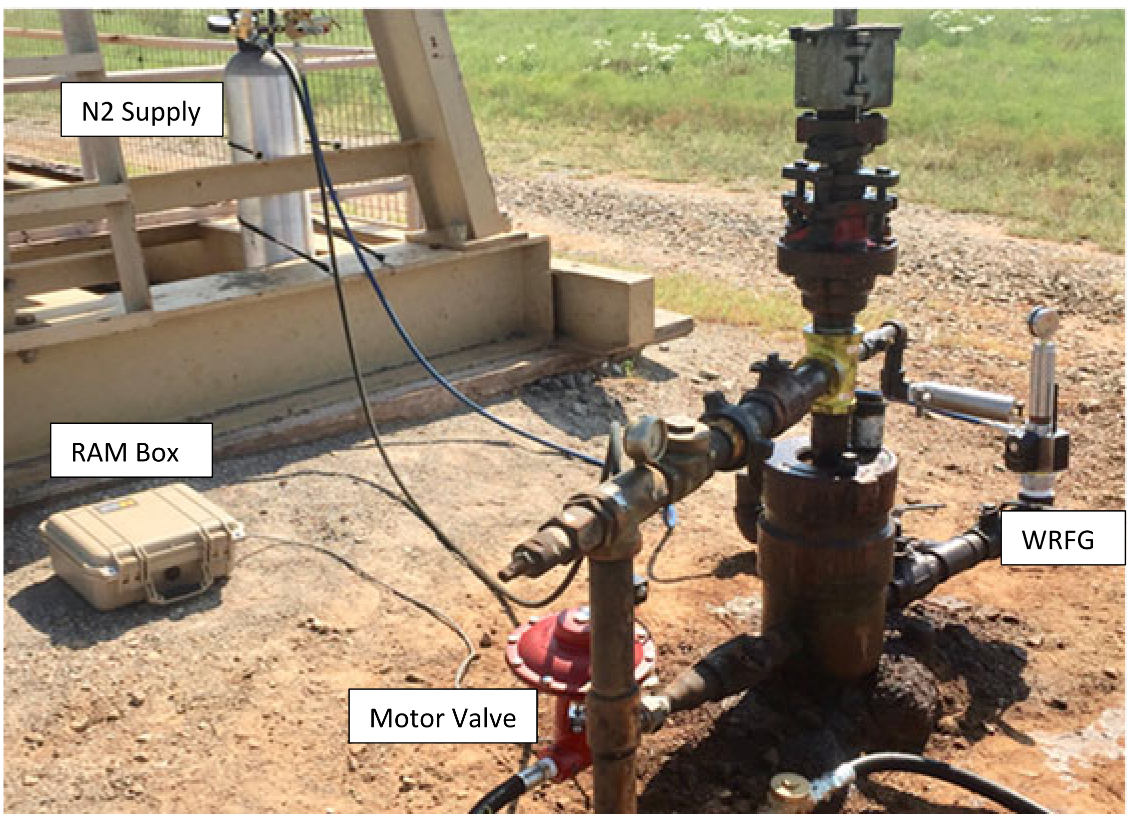

Figure 4 –At the Pumping Well

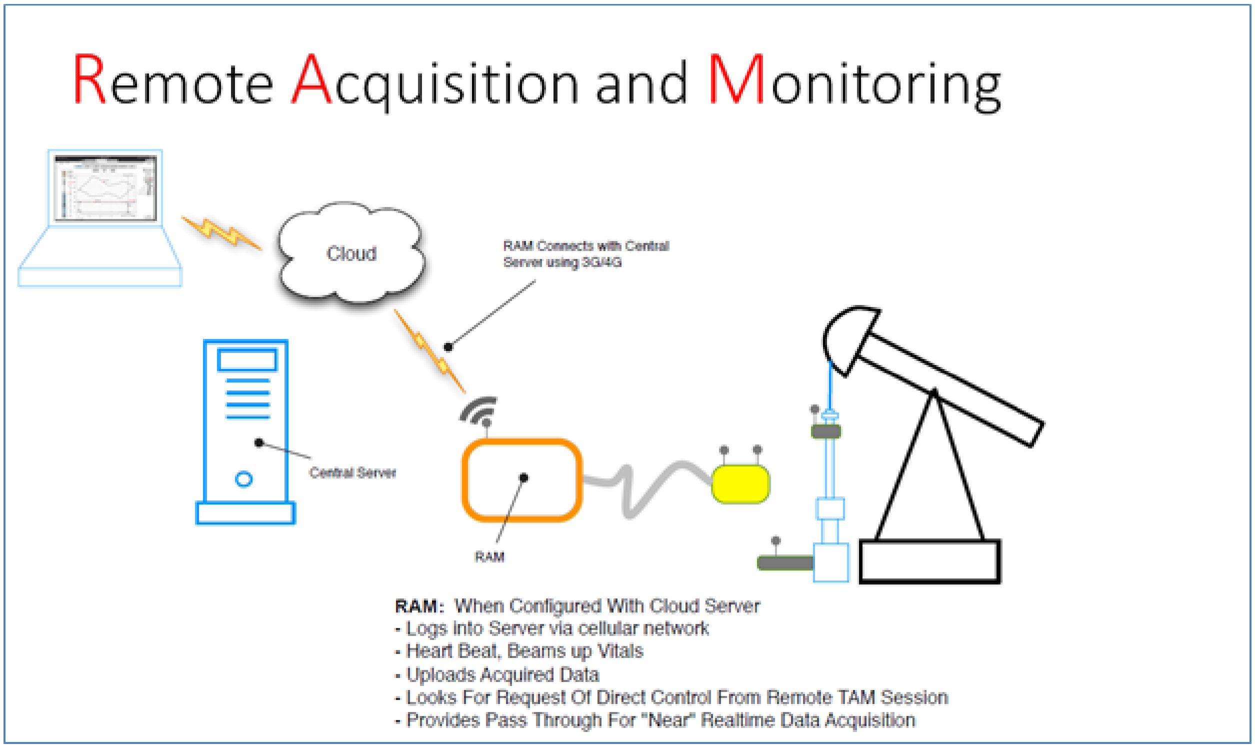

Figure 5 – Cloud Based Operation

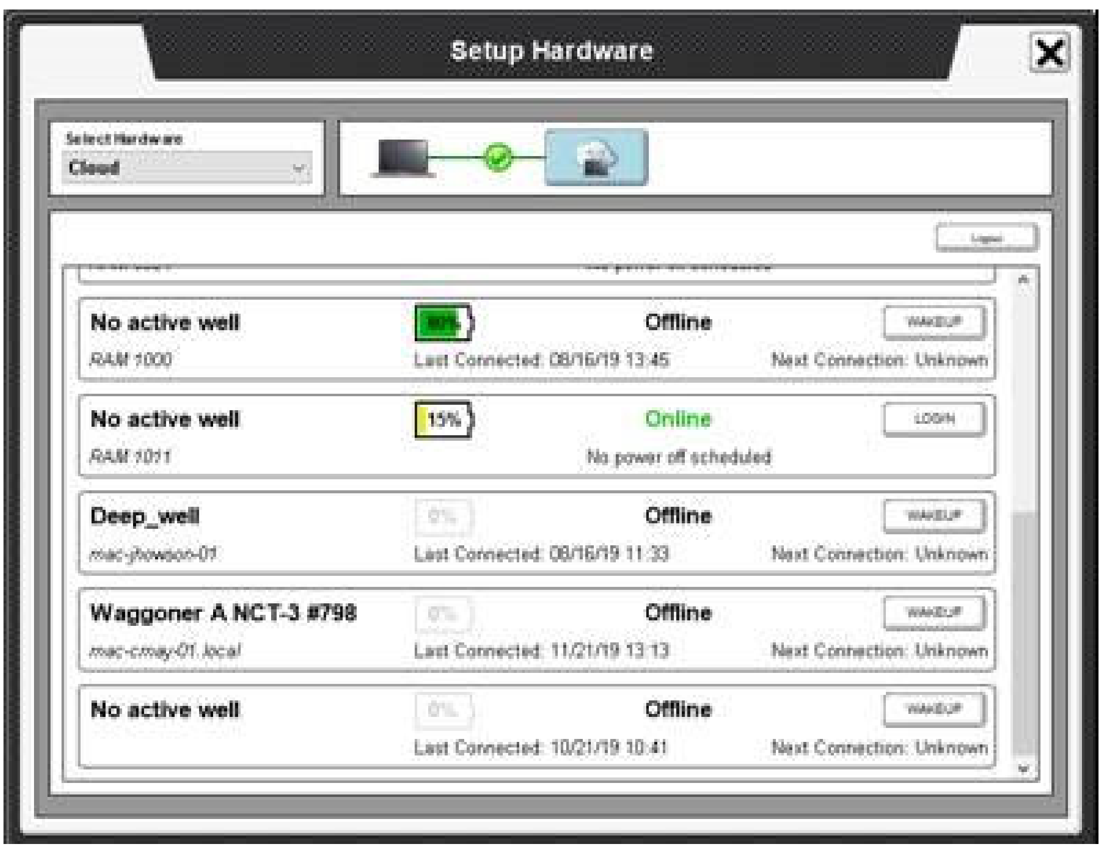

Figure 6 – Cloud Connection display of active RAMs

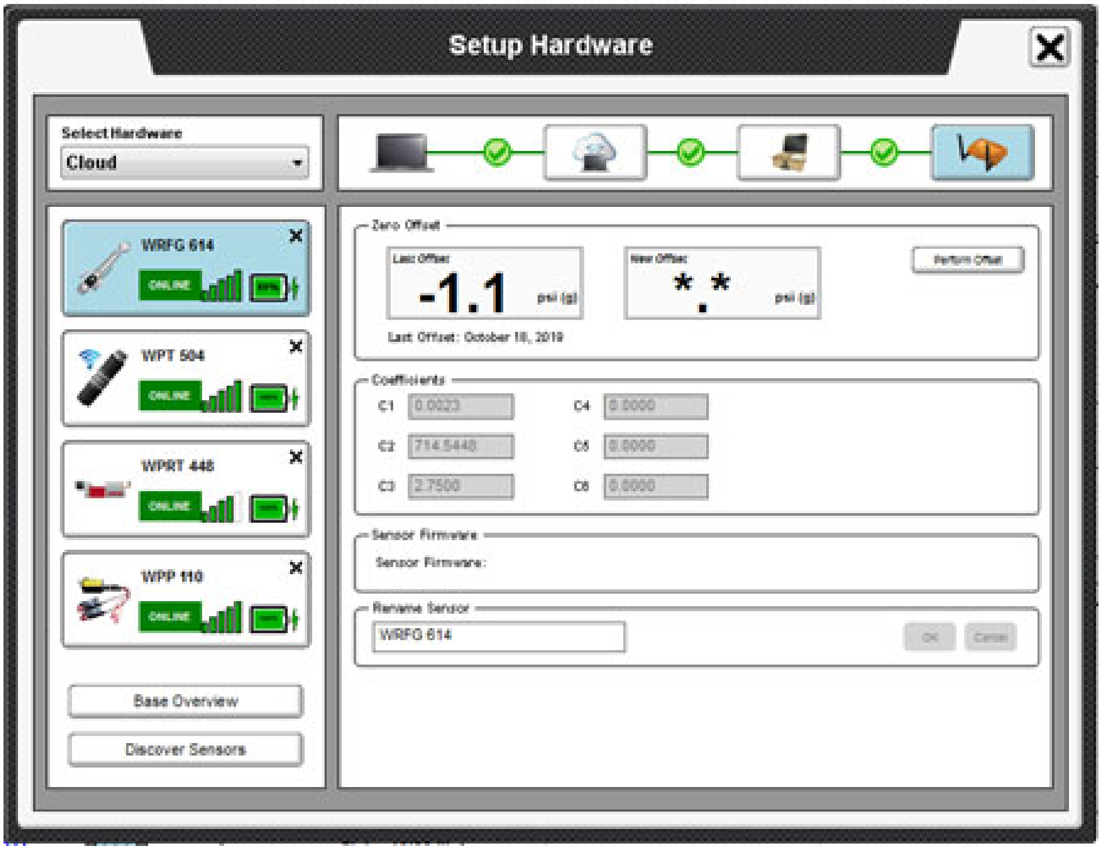

Figure 7 – Connected to the RAM via Cloud and Display of sensors on the Well

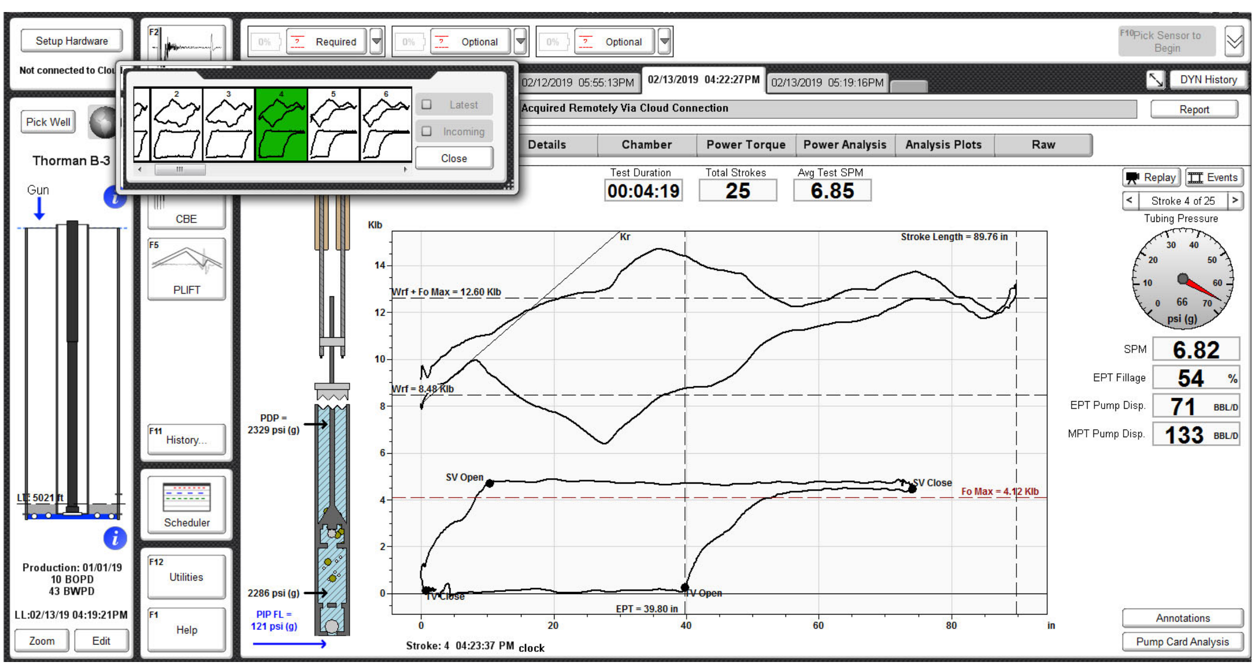

Figure 8 – Remotely acquired Dynamometer Record via Cloud Connection

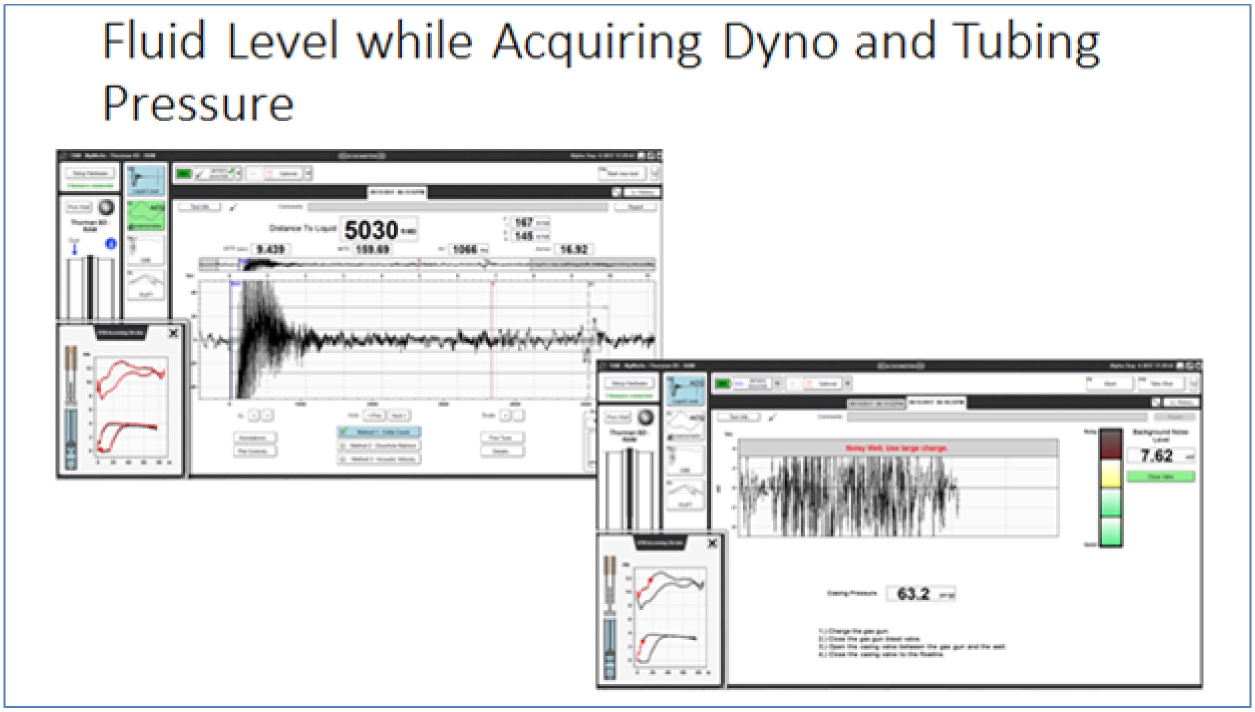

Figure 9 – Simultaneous fluid level and dynamometer remote acquisition

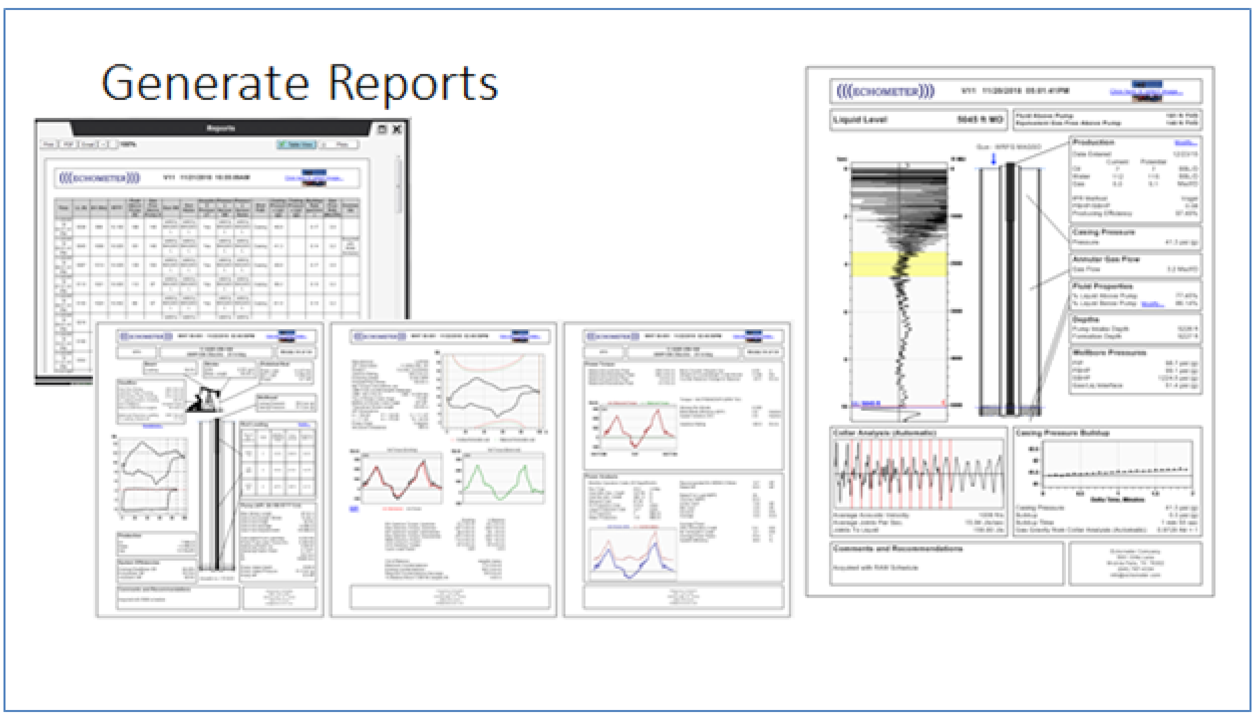

Figure 10 – Generation of reports from Manual Remotely Acquisition

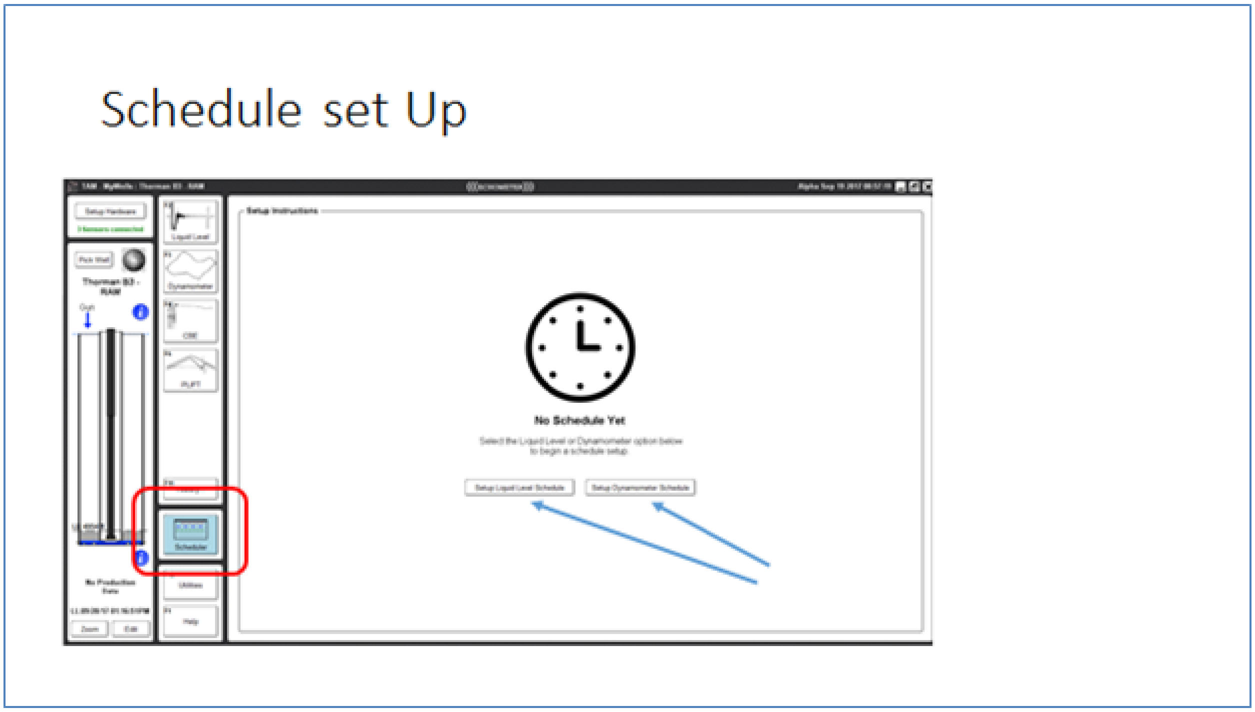

Figure 11 – Scheduler setup

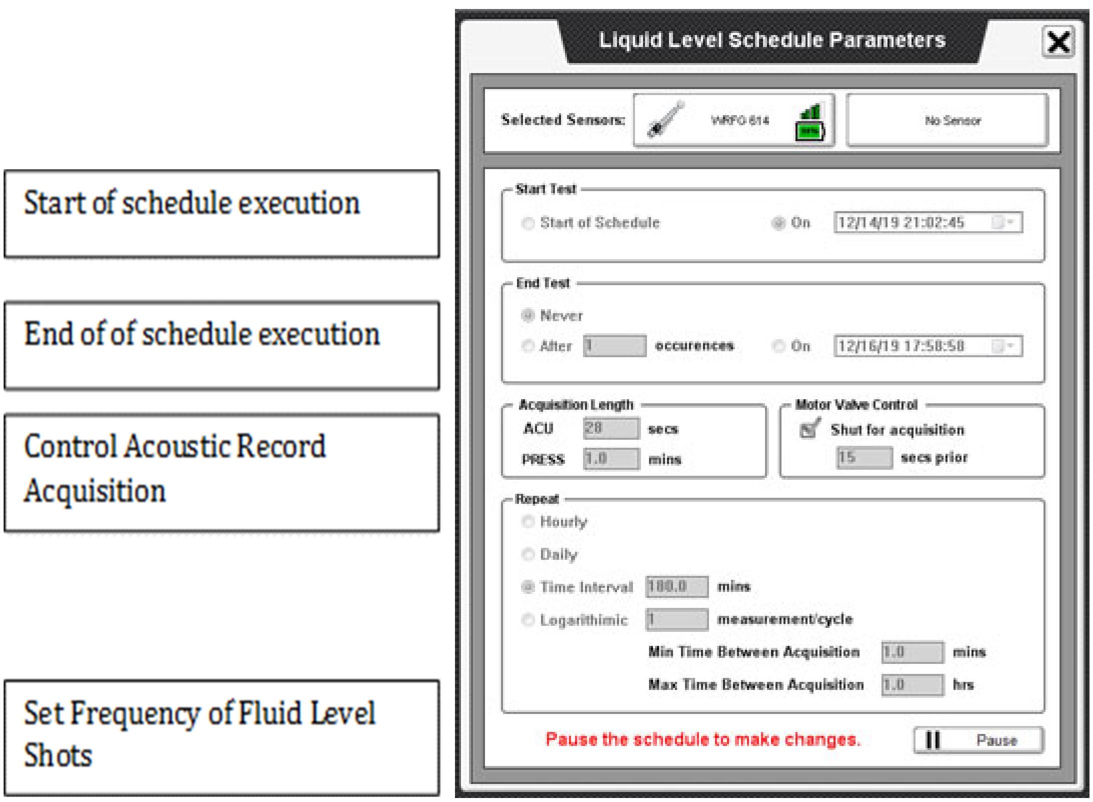

Figure 12 – Typical inputs for Scheduling Acquisition

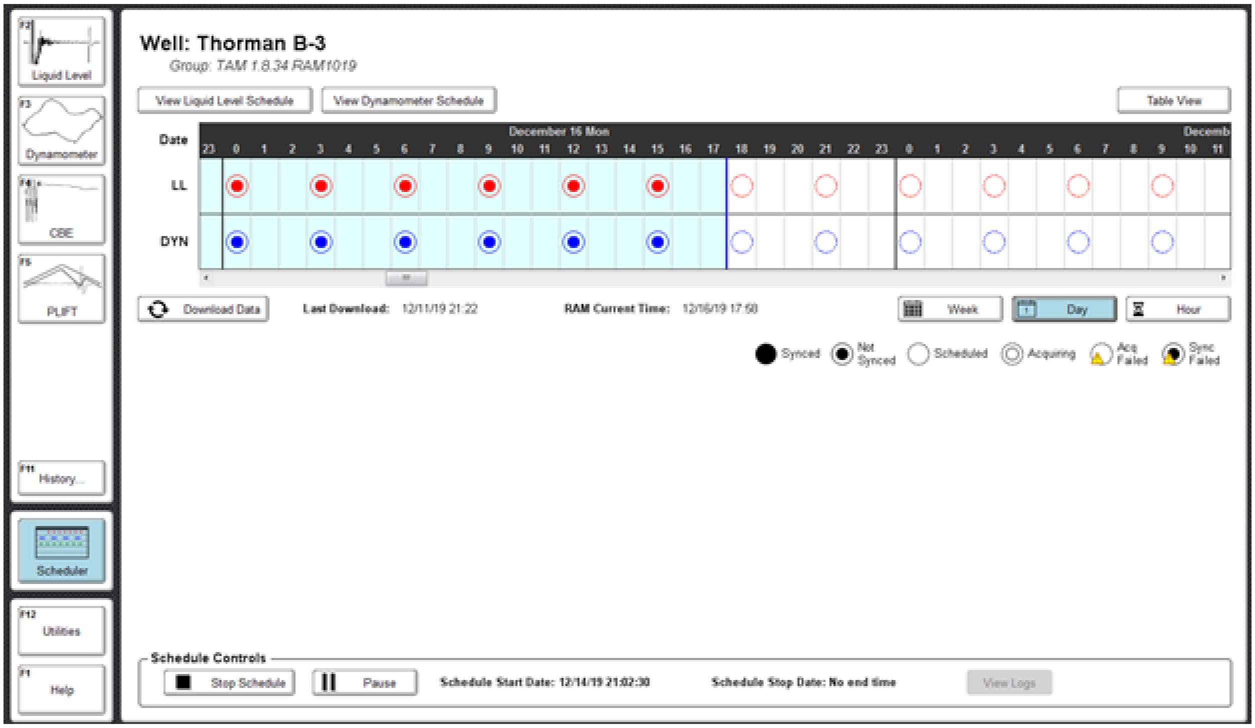

Figure 13 – Viewing Schedule Progress and Retrieving Data

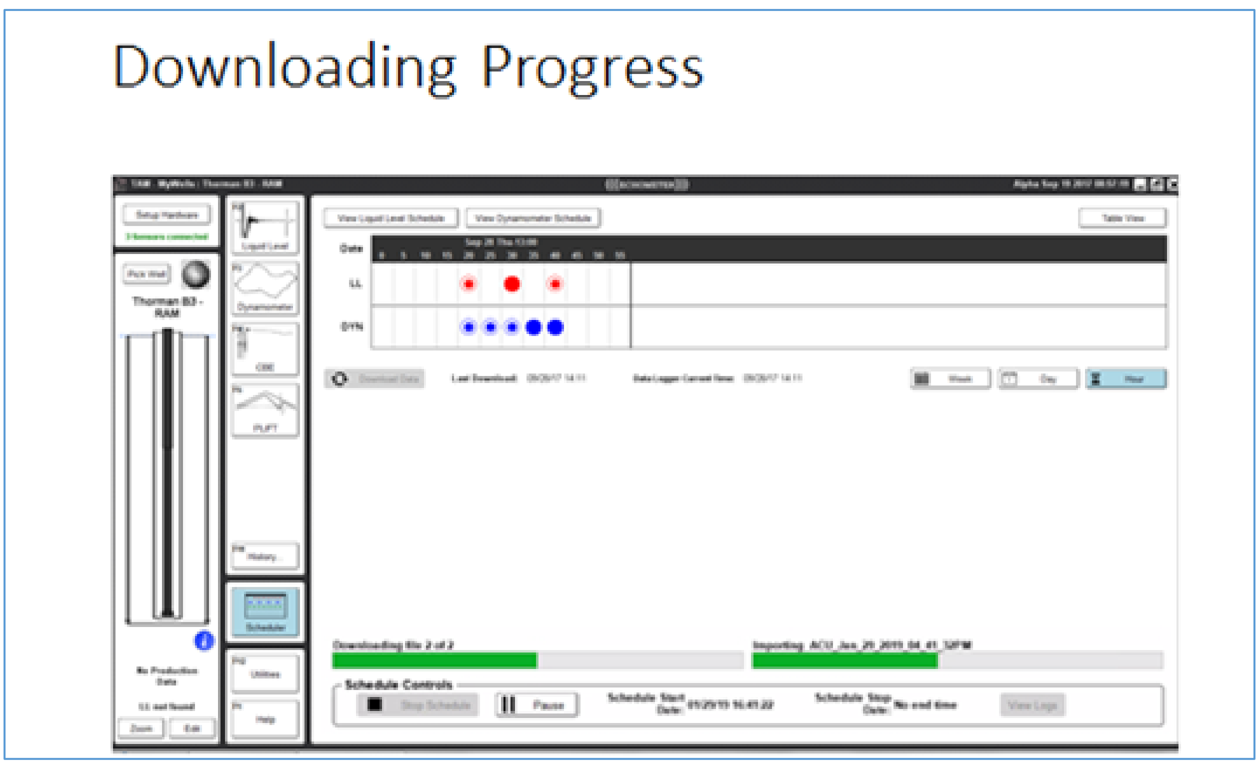

Figure 14 – Downloading Acquired Scheduled

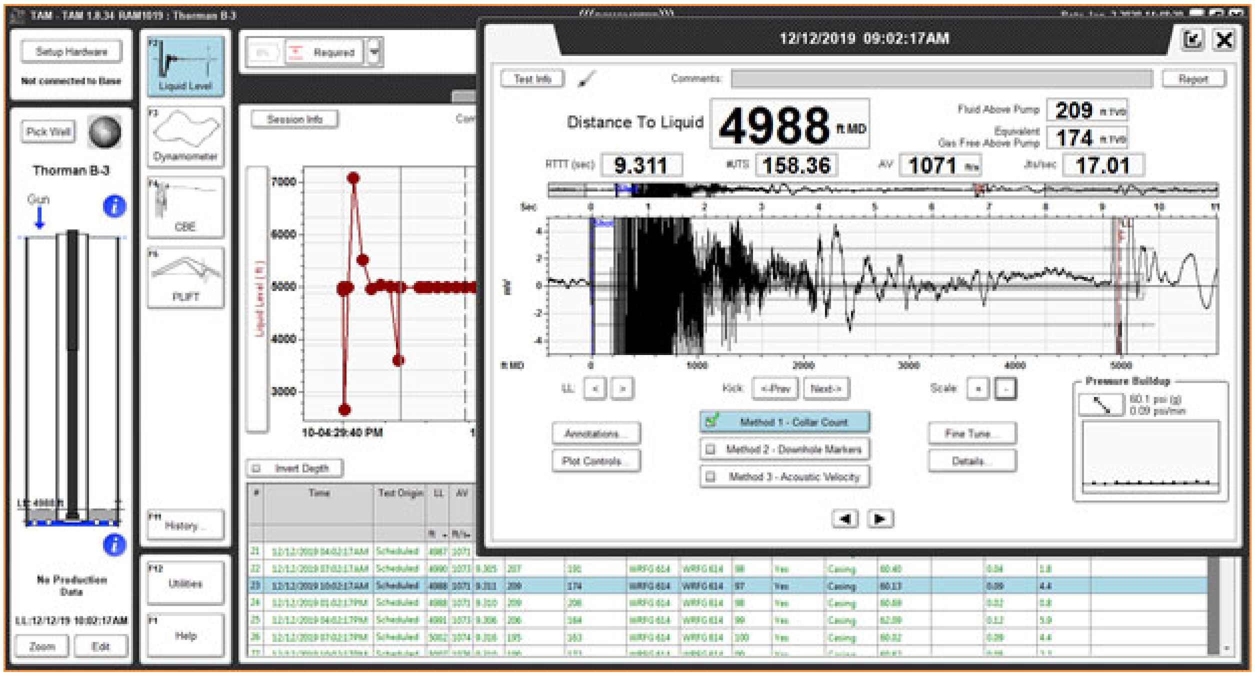

Figure 15 –Example Acoustic Record Displayed within Retrieved Scheduled Data

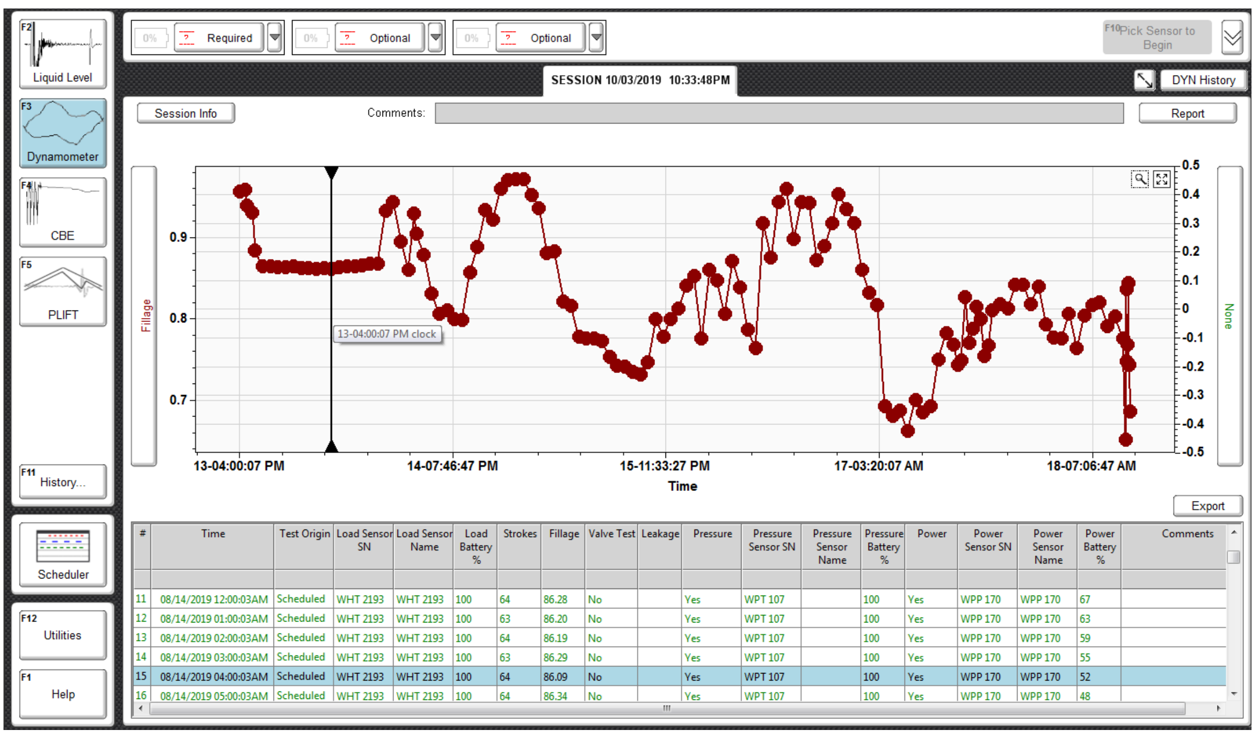

Figure 16 – Dynamometer Scheduled Acquisition during 5 Days showing Hourly Variable Pump Fillage

Figure 17 – Fluid Above Pump vs. Time Acquired automatically with RAM Schedule