WIRELESS SIMULTANEOUS ACQUISITION OF DYNAMOMETER AND FLUID LEVEL DATA FACILITATES ROD PUMPED WELL OPTIMIZATION

J.N. McCoy, Dieter Becker, and O. L. Rowlan
Echometer Company
Kay Capps, Capsher Technology,
A. L. Podio, University of Texas - Austin

ABSTRACT

Real time analysis and visualization of the performance of a rod pumped well are achieved using multiple small and compact wireless sensors that simultaneously transmit acquired data to a digital laptop manager that integrates the measurements, displays performance graphs and provides advanced tools for analysis and troubleshooting of the pumping system.

Battery powered wireless sensors for fluid level, pressure and dynamometer data acquisition are easily deployed and quickly installed on the well. The laptop manager automatically recognizes and commissions the sensors. The user sets up and controls the acquisition of data which may include multiple sensors that synchronously monitor variables such as tubing and casing pressures, fluid level and polished rod acceleration/position and load as a function of time. Elimination of cables and connectors improves the reliability of the hardware and data while speeding up the set-up-tear-down process. The user interface presents a smart instrument rather than a complex application.
Among the many innovations provided by these well performance analysis tools stand out the real time visualization of the operation and fluid distribution in the down-hole pump, the simultaneous display of quantitative surface and pump dynamometer graphs in conjunction with fluid level and wellbore pressures. Acquired data, wellbore description and pumping system characteristics are saved as a historical data base creating a continuum of the well's information and performance for direct comparison and detailed analysis.

The paper describes the hardware and user interface, the procedures for installation and acquisition and several examples of field data and well performance analyses for a variety of rod pumping installations.

INTRODUCTION

Monitoring of rod pumped well performance from surface measurements of fluid level and dynamometer loads has been in use since the early 1930s when the original objective was only to observe whether fluid was present in the annulus above the pump and whether the pump was filled with liquid at the time of the test. The tedious task of manually converting the echo travel time to the distance to the liquid level and the load and position of the polished rod to a pump dynamometer diagram was greatly improved and facilitated by the introduction of portable laptop computers in the early 1990s that could be operated at the well site [1,2]. These programs for well performance data acquisition and analysis, although greatly improved, generally present quantitative results to the user in terms of numeric and graphical values. However, accurate determination of the well's performance still requires a significant degree of data interpretation on the part of the user who in many instances does not have the time or the necessary background to efficiently perform this analysis.

The new generation of software and hardware discussed in this paper, takes advantage of the tremendous increase in laptop processing speed, memory size and screen resolution to generate in real time a quantitative visualization of the downhole rod pump operation, plunger motion, valve action and fluid flow. This animation is presented simultaneously with the corresponding fluid distribution in the wellbore, obtained from the acoustic fluid level survey, to let the user see the complete performance of the well and lift system without having to interpret the conventional dynamometer card or fluid level record for the majority of wells that he monitors. The new system also takes advantage of the development of reliable, miniaturized wireless instrumentation that increase measurement flexibility, eliminate inaccuracies caused by defective cables and connectors and greatly speeds up installation and tear-down.

HARDWARE

The preferred configuration of the system includes a wireless Base Station connected to the USB port of a laptop computer that communicates with multiple wireless sensors and manages data transfer and communications. Figure 1 shows the base station located on the dashboard of the user's field vehicle.

Wireless Sensors

The sensors discussed in this paper include only those typically used in conjunction with rod pumped wells to monitor the annular fluid level, the dynamometer and tubing pressure. Sensors are powered by long lasting rechargeable batteries.

Wellbore Monitor

This sensor provides wireless acquisition of fluid level and pressure data. It includes a remotely fired gas gun (WRFG)and an integral pressure sensor that is generally connected to the casing valve but can also be installed on the tubing head for special monitoring.

Pump Monitor

Two sensors are available for acquisition of polished rod load and acceleration: a wireless Polished Rod Transducer (WPRT) for easy installation on the polished rod below the carrier bar and a wireless Horse Shoe Transducer rated at 30,000 Lbs (WHT) for installation between the carrier bar and the polished rod clamp.

Pressure Monitor

Wireless acquisition of tubing pressure is achieved simultaneously with dynamometer acquisition using a wireless pressure sensor rated in accordance with the pressure observed at the stuffing box. One objective described in this paper is to monitor pressure variations during normal pumping and to perform tubing integrity and pump pressure testing.

Wired Well Analyzer

The existing Echometer Well Analyzer electronics can also be used as a front end for the new asset monitoring software to perform fluid level and dynamometer acquisition using the conventional wired sensors (remote-fired gas gun, PRT and HT). The software also has the flexibility of performing data acquisition using a mix of wireless and wired sensors. For example, using a wireless PRT with a wired remotely fired gas gun and pressure sensor allows performing simultaneous dynamometer and fluid level measurements to aid in optimizing timer or POC settings.

SOFTWARE AND USER INTERFACE

The software, based on the Echometer Total Well Management program[3], includes totally redesigned software to provide real time pump dynamometer calculation and visualization of plunger motion and fluid flow in the pump. Easy access to previously recorded fluid level and dynamometer tests facilitates analysis of present well performance by overlaying and comparing the previous data to the current records. Graphical tools have been significantly updated and improved to assist in the analysis of complex records.

INSTALLATION AND MONITORING PROCEDURES

The wireless hardware and software are fully initialized and commissioned prior to shipping to the user. Well data entry is streamlined using templates for the most common wellbore combinations. Uploading well information and data records from existing TWM well files is automated and requires minimum user intervention.

Initialization of Monitoring Session

Prior to initiating a monitoring session the recommended procedure is to verify that all sensor batteries are fully charged. Well information, such as recent well test flow rates or changes in wellbore configurations, is updated in the well database after loading the software. The base station is then plugged into the USB port and the system is ready for deployment.

Sensor Installation

The small size of the sensors makes for easy and quick installation as shown in Figure 2 that illustrates installation of the wireless PRT load cell.

A typical monitoring session at the well begins when the user drives up. The software automatically selects the particular well's information and displays the last data records that were acquired and analyzed previously. A list of available sensors is displayed and the user decides which sensors to use, then installs them on the well and initiates data acquisition. Sensors remain active during the session so that continuous recording of dynamometer data and repeated fluid level measurements can be undertaken. Upon completion, the sensors are uninstalled and the user proceeds to the next location.

Acquisition Management

Data acquisition management and sequencing can be performed by the user either from the installed sensors by actuating the control buttons and observing the LEDs that are on the sensor body (see Figure 2) or using the controls on the corresponding screens displayed on the laptop. Therefore it is not required that the user stay at the laptop location, generally located inside the vehicle as shown in Figure 3, to drive the acquisition sequence but the operator is free to move about the location and perform additional tasks while acquisition of records continues automatically.

Simultaneous acquisition of dynamometer and fluid level data is illustrated in Figure 4 that shows an acoustic fluid level record being acquired as dynamometer data is recorded as shown by the small inset displayed in real time of the position of the polished rod, pump plunger and pump fillage.

Figure 5 shows a detail of the dynamometer acquisition screen that shows how the load and position data that is being acquired during the current stroke is plotted (in red) over the surface and pump dynamometer graphs that correspond to the previous stroke. At the same time the pump viewer (at left) shows the quantitative visualization of the pump's liquid and gas fillage, the motion of the plunger and the opening and closing of the valves.

When the user chooses to install a wireless pressure sensor at the tubing head tee, then this pressure is displayed on the screen as shown by the pressure gage in Figure 6 and a continuous record of the pressure is obtained as shown in Figure 7 where the polished rod load (top trace) and tubing head pressure (bottom trace) are displayed as a function of real time showing how the tubing pressure increases after the flow line valve is closed when performing a tubing integrity test and pump operation continues. A steady pressure value after the pump is stopped indicates a holding standing valve and no tubing leaks.

A typical monitoring session may include a continuous record of dynamometer data lasting several minutes (15 to 20 minutes) from the time the sensor is installed until the pump is finally stopped at the end of the session. Depending on the pumping speed the record will include a sufficient number of pumps strokes to establish the predominant fillage and performance of the pump. During this time, several fluid level measurements can be performed to monitor the variation of the fluid level and correlate pump submergence with pump fillage.

When desired, the user can perform valve tests without interrupting the dynamometer acquisition record. The software automatically detects that a TV or SV test is performed and presents the corresponding analysis plot. After the test is completed, acquisition of additional pump strokes is continued.

DETAILED ANALYSIS AND REPORTING TOOLS

Whenever the user finds it necessary to undertake a more detailed analysis of the data, such as identifying unusual problems that may exist in the pump or distinguishing the liquid level echo from a multitude of echoes generated by several perforated intervals, the software provides very powerful tools for visualization and processing of the records. Following are some examples of a few of these features.

Overlay of Previous Records

Figure 8 shows the stroke viewer tool that allows superimposing dynamometer graphs for selected multiple strokes. The example shows an overlay of the first and last pump strokes from a sequence of 150 total strokes that displays the change in pump fillage that has taken place during this operating time.

Figure 9 shows that by having access to all the test history for this well, using the test history viewer at the left of the screen, it is very easy to overlay acoustic traces to visualize the change in fluid level position over time or to compare the quality of the records.

Replay of Pump Operation and Dynamometer Records

Upon completion of the acquisition session, the complete record of pump strokes can be replayed in real time or at faster speeds so as to recreate the exact performance and operation of the pump. This is especially useful when showing and explaining the presence of unusual conditions to fellow operators or supervisors that were not present at the well site.

Multiple Analysis Methods

Fluid level and pressure distribution in the wellbore is undertaken automatically using the time and field tested automatic liquid level detection and collar count methods developed for the Well Analyzer [2, 3].

In those instances when the acoustic record shows multiple echoes caused by known diameter changes in the wellbore, or the record includes multiple echoes that obscure the liquid level echoes, the user can access very powerful special processing tools as shown in Figure 10.

This example shows a record taken inside a tapered tubing string in a pumping well with a suspected tubing leak or a severe valve leakage. The liquid level in the tubing is observed below the depth of the crossover from 3-1/2 to 2-7/8 inch.

Special Purpose Analysis

The software also provides several analysis tools used to diagnose performance problems such as valve or tubing leakage. Figure 11 illustrates the pressure record obtained during a tubing integrity test obtained during the record shown earlier in Figure 7.

Tubing pressure is recorded vs. time while the flow is moving normally to the flow line (time 0 to 50 seconds) then as the flow line valve is partially closed (time 50 to 120 seconds) and after the flow line valve is completely shut. Then the tubing head pressure increases from about 50psi to 115 psi during a total of 14 pump strokes, after which the pump is stopped. This increase is an indication that the pump is operating normally and can pressure up the tubing. The additional increase in tubing pressure after the pump is stopped, from 250 to 700 seconds, is an indication that the fluid in the tubing is a mixture of gas and liquid and that gas slugs are percolating to the surface without possibility of gas expansion in the tubing since the flow line valve is closed and the standing valve is holding pressure.

Reports of Monitoring Session

The results from the monitoring session can be presented in summary format as shown in Figures 12 and 13. These reports can be customized by the user to satisfy his needs and then they can be printed or saved as pdf files or e-mailed to interested parties.

SUMMARY

This paper presents a brief discussion of new wireless hardware and software that greatly improves and facilitates data acquisition of fluid level and dynamometer data for analysis of well performance. By providing the user a real time visualization of what is occurring in the well and in the pump it is possible to observe directly the performance of the system instead of having to interpret numerical and graphical displays. This should lead to more efficient and improved rod pump performance optimization.

REFERENCES

1 - McCoy, J. N. and Podio, A. L.:"Well Performance Visualization and Analysis", SPE Permian Basin Oil and Gas Recovery Conference, 8-9 March 1990, Midland, Texas

2 - Podio, A. L., McCoy J. N. and D. Becker: "Integrated Well Performance and Analysis", SPE Computer Applications, Volume 4, No 2, June 1992.

3 – Podio, A. L., McCoy J. N., D. Becker, O. Lynn Rowlan and Bill Drake: "Total Well Management II ,SPE 67273, Production and Operations Symposium, Oklahoma City, Oklahoma, U.S.A., 24–27 March 2001.

Figure 1- Wireless Base Station

Figure 2 – Wireless Polished Rod Transducer (WPRT) Installation

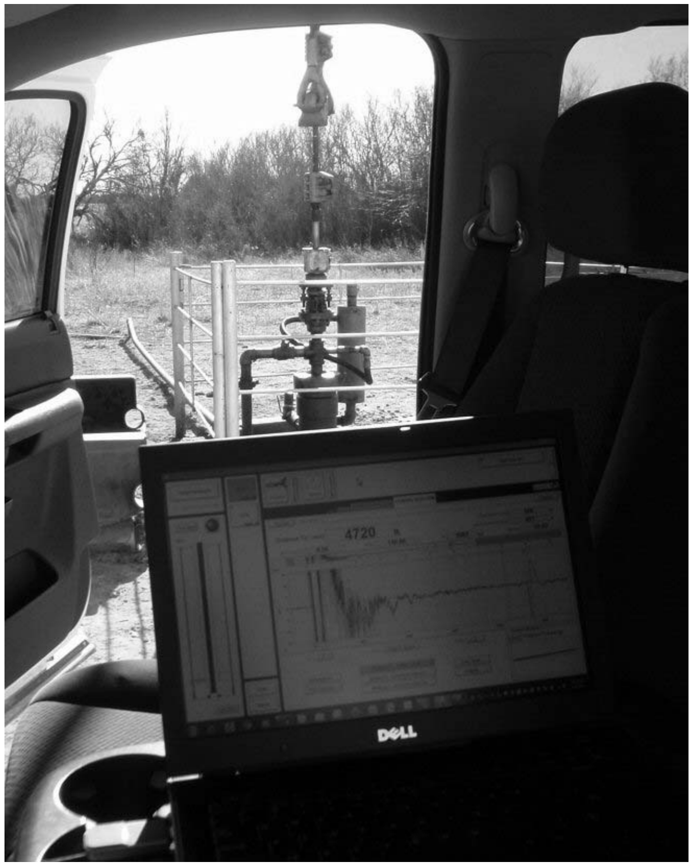

Figure 3 – Wireless Acoustic Fluid Level Acquisition Display.

Figure 4 - Simultaneous Real-time Monitoring of Dynamometer and Acoustic Fluid Level Acquisition.

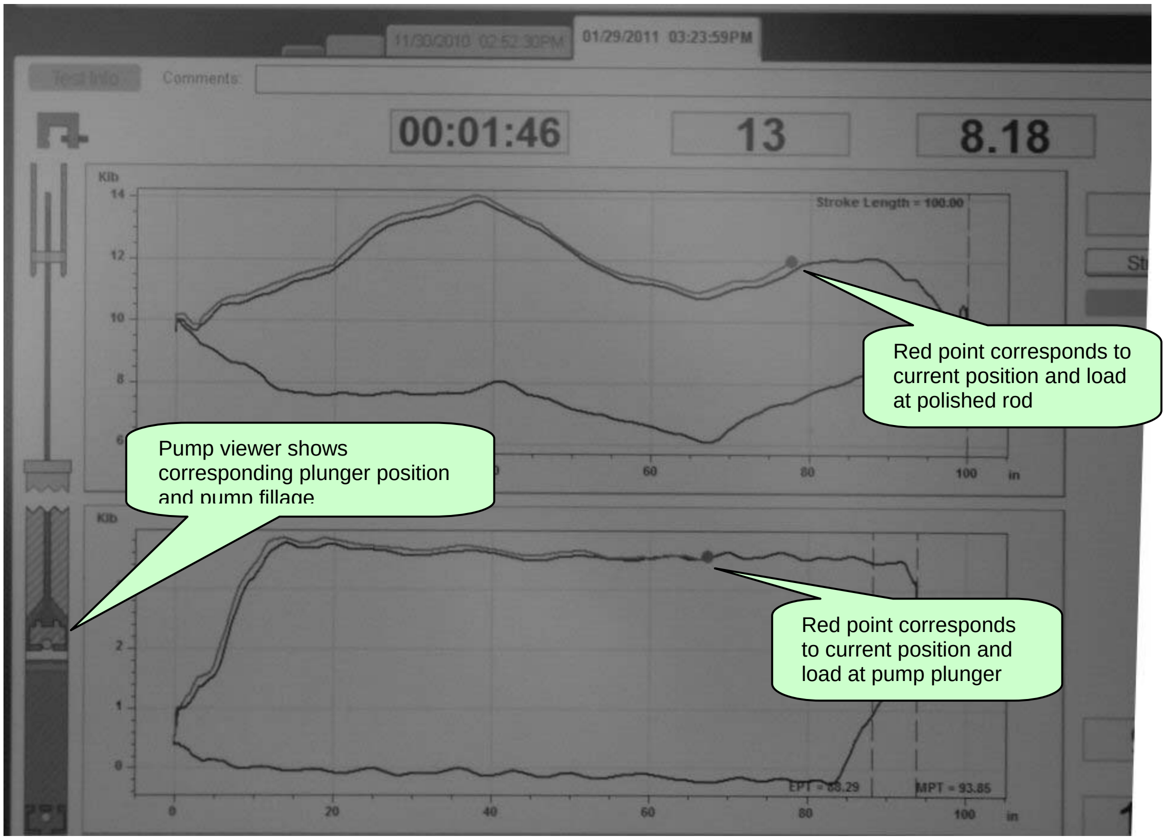

Figure 5 – Real Time Visualization of Pump Fillage and Dynamometers for stroke 13 (red dot and line). Black lines show dynamometer record for the preceding stroke number 12.

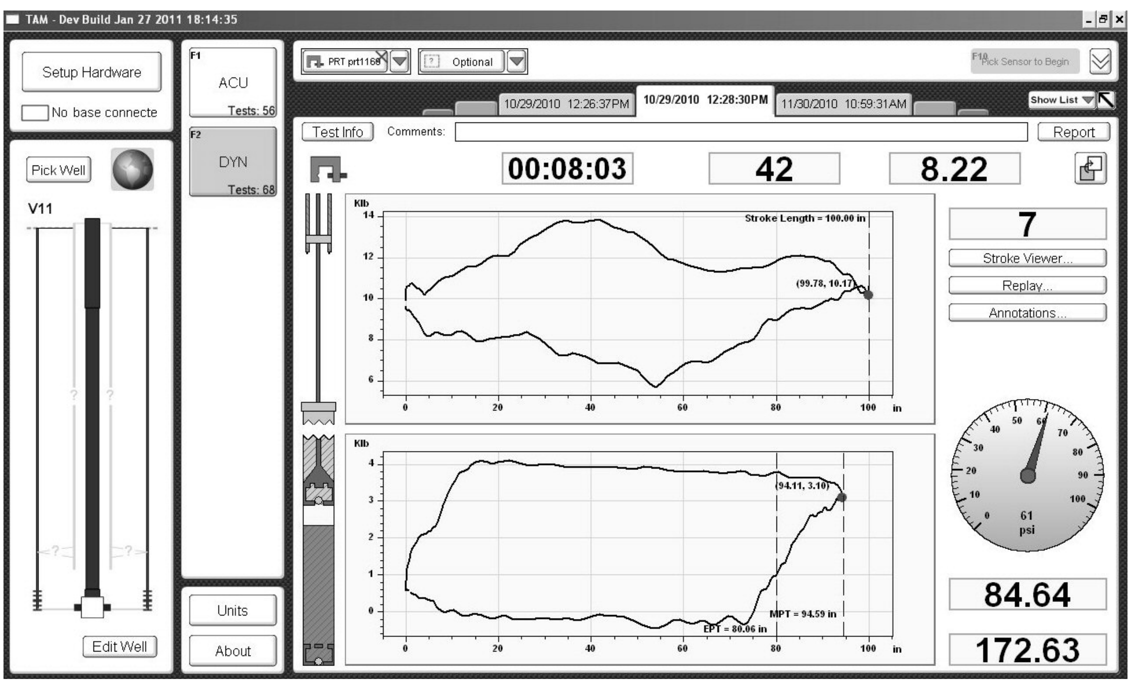

Figure 6 - Tubing Head Pressure and Dynamometer Acquisition Screen.

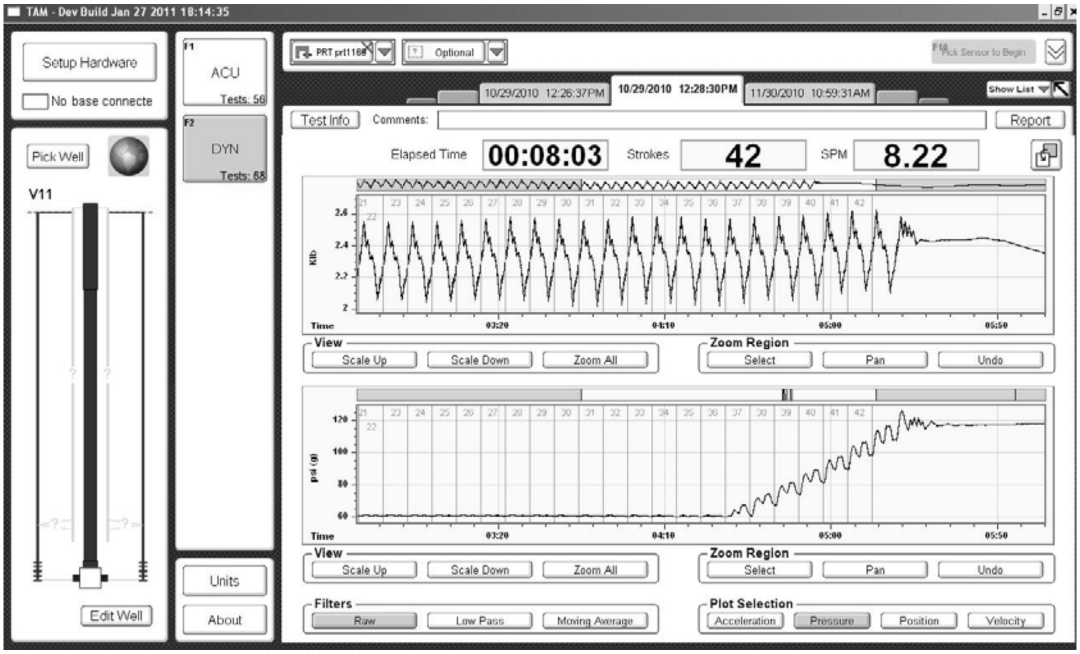

Figure 7 - Tubing Head Pressure and Polished Rod load Before and During Tubing Integrity Test

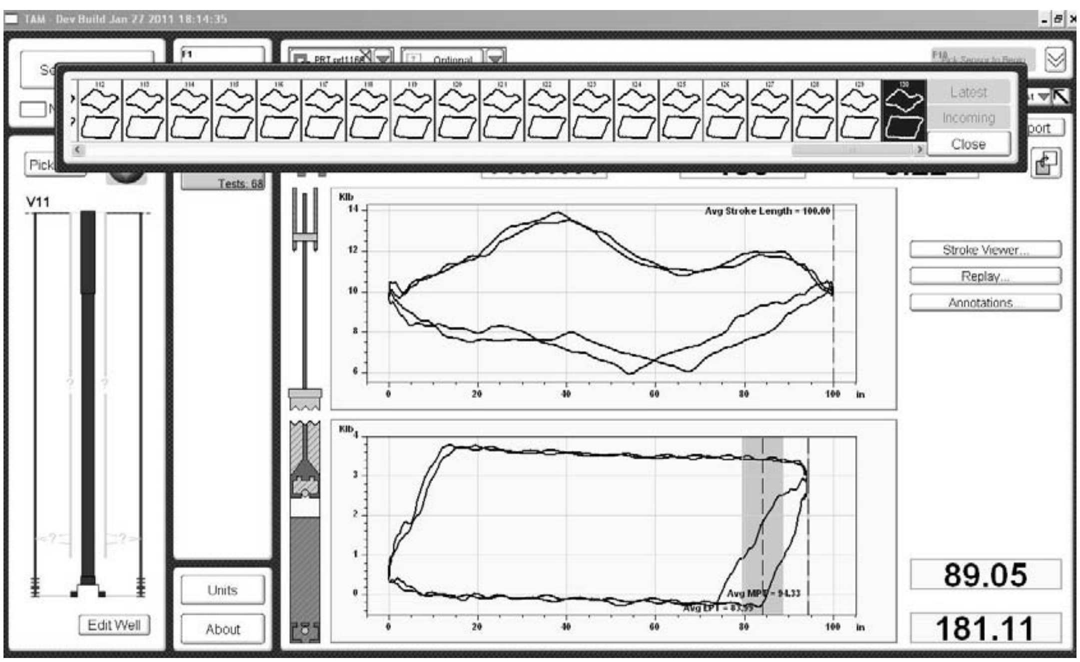

Figure 8 – Dynamometer Replay and Stroke Overlay.

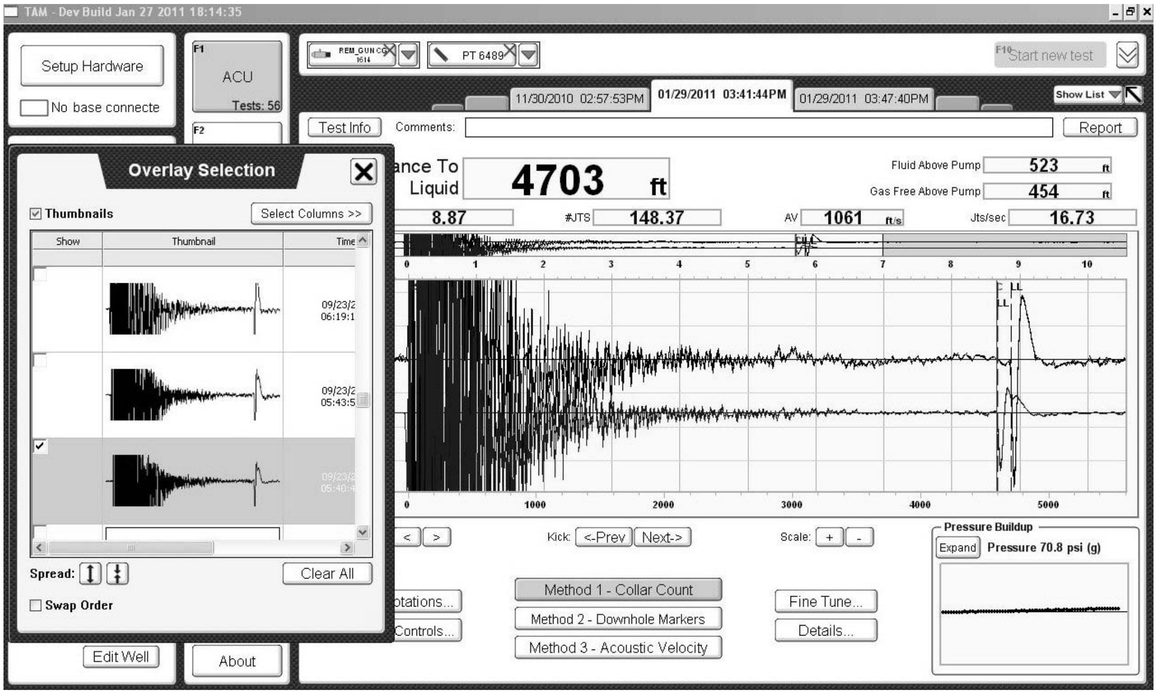

Figure 9 - Overlay of Previous Fluid Level Record for Comparative Analysis.

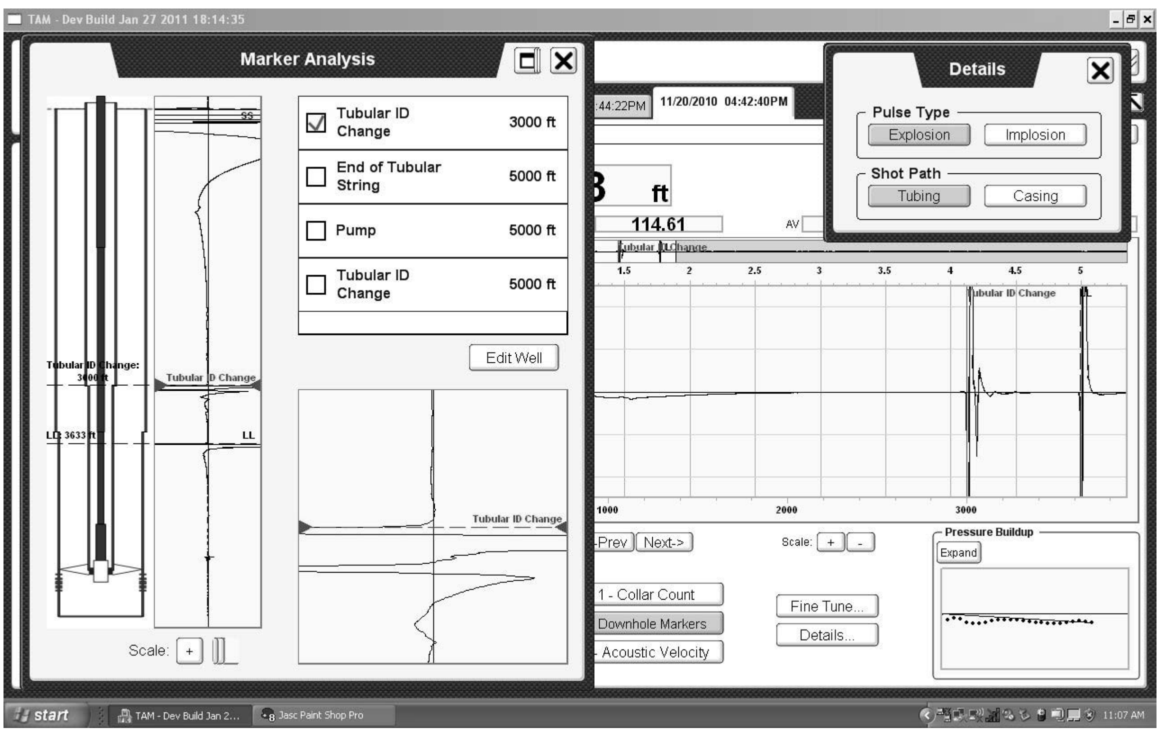

Figure 10 - Special Acoustic Fluid Level Analysis Using Down Hole Markers and Corresponding Wellbore Fluid Distribution.

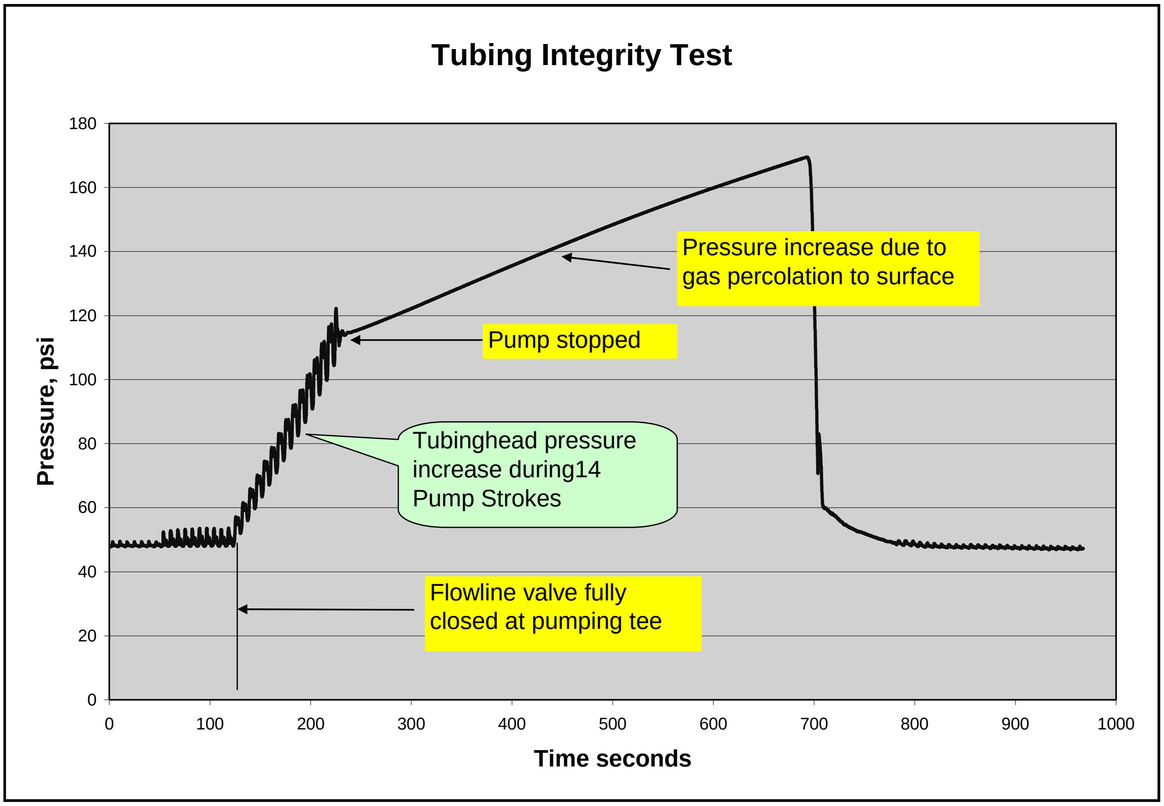

Figure 11 - Detail of Tubing Integrity Test Showing Tubing Head Pressure vs. Time.

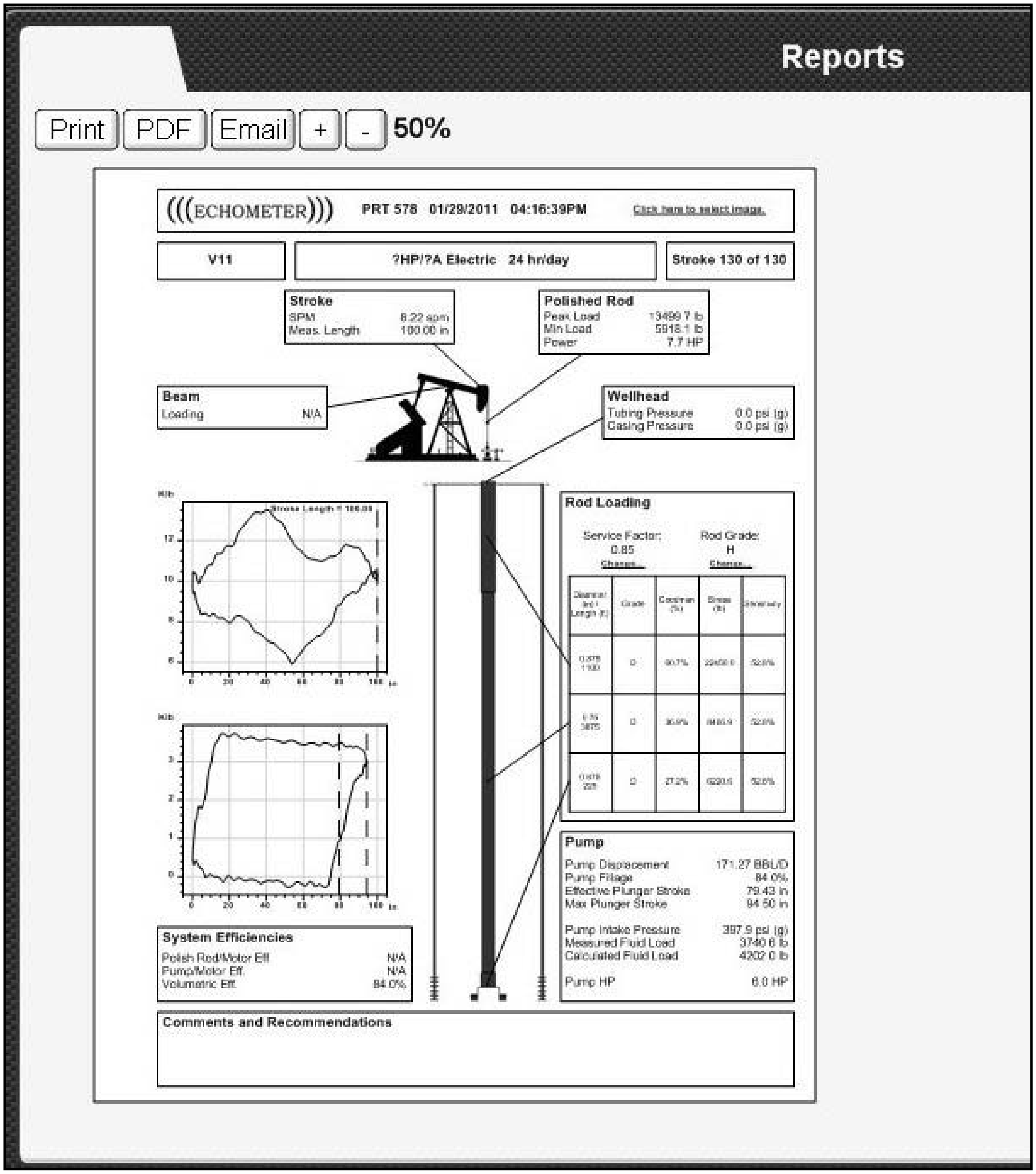

Figure 12 – Dynamometer Report in Executive Summary Format. (As viewed on the screen)

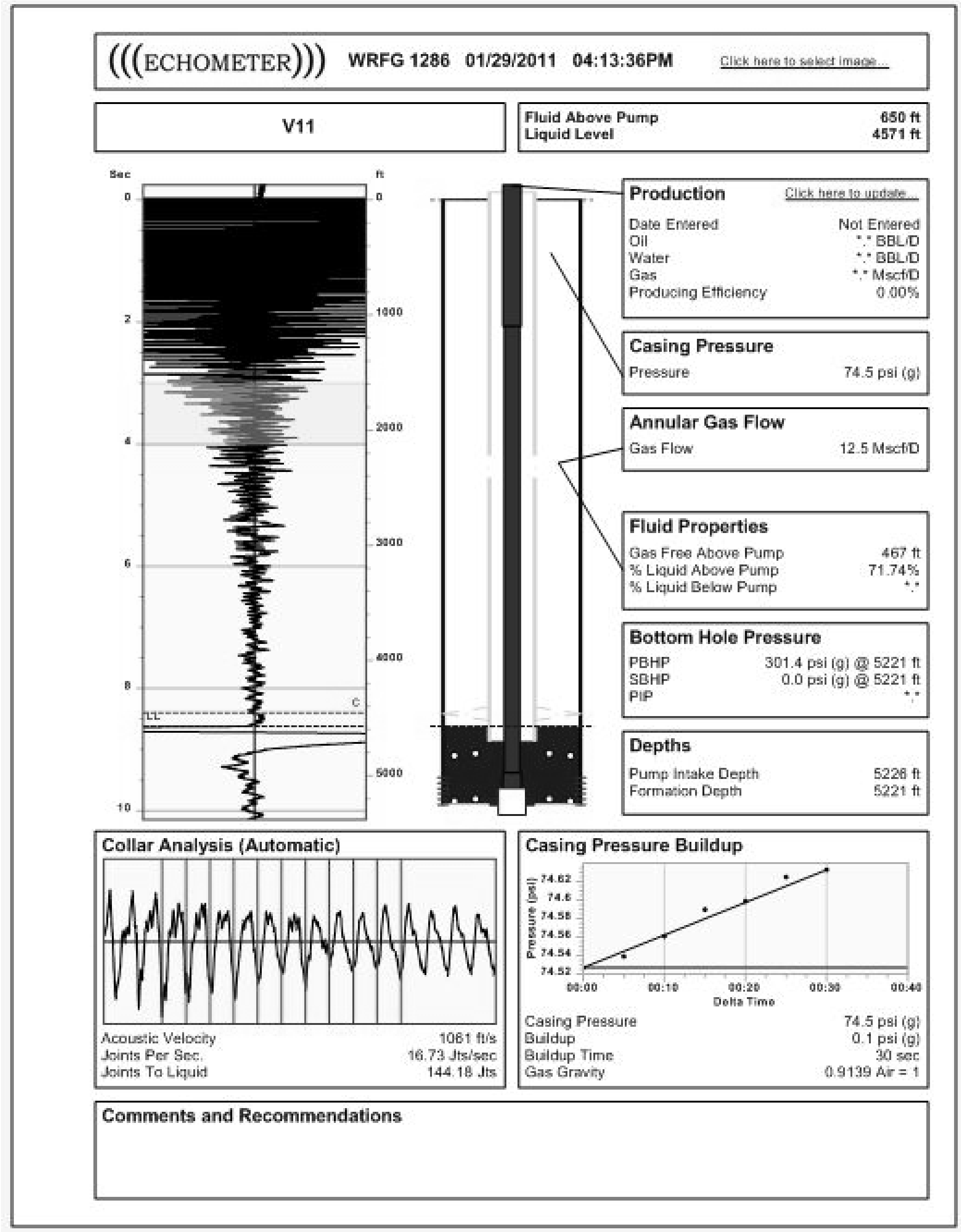

Figure 13 - Acoustic Fluid Level Report in Executive Summary Format.(Imported from pdf file).