Dynamometer Analysis Features in TAM

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I. Dynamometer Analysis Windows

For analysis and review of dynamometer records, TAM provides eight different analysis windows: the traditional field view, details view, chamber view, power torque view, power analysis view, plots view, valve test view and raw data view.

Analysis View Selector

Along the top of the analysis screen is a series of buttons that correspond to the available analysis views. The buttons available are determined by several factors including data available, event type and what mode TAM is in (Acquisition, Static or Replay). Clicking a button will switch the screen to the corresponding analysis view. The views are described in detail below.

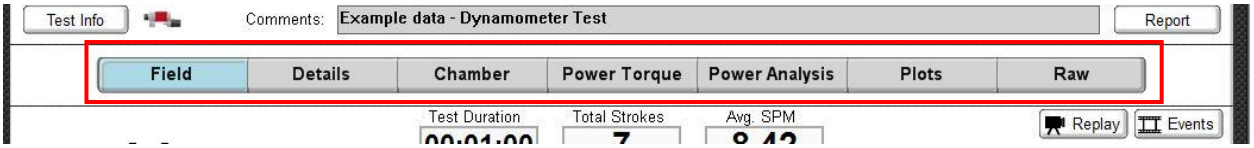

Figure 1: Analysis View Selector

Field View

The default view for the ***Dynamometer*** Analysis module is the traditional two card view (Figure 2). In addition to it showing both the surface and pump cards, this screen also displays a pump animation computed from the recorded data, tubing pressure gauge (when pressure was acquired), power bar showing power computed from the dynamometer card, and digitals showing values like fillage and pump displacement. On this screen, the user can also manually adjust the effective plunger stroke by clicking and dragging the ***EPT*** dashed cursor displayed on the pump card.

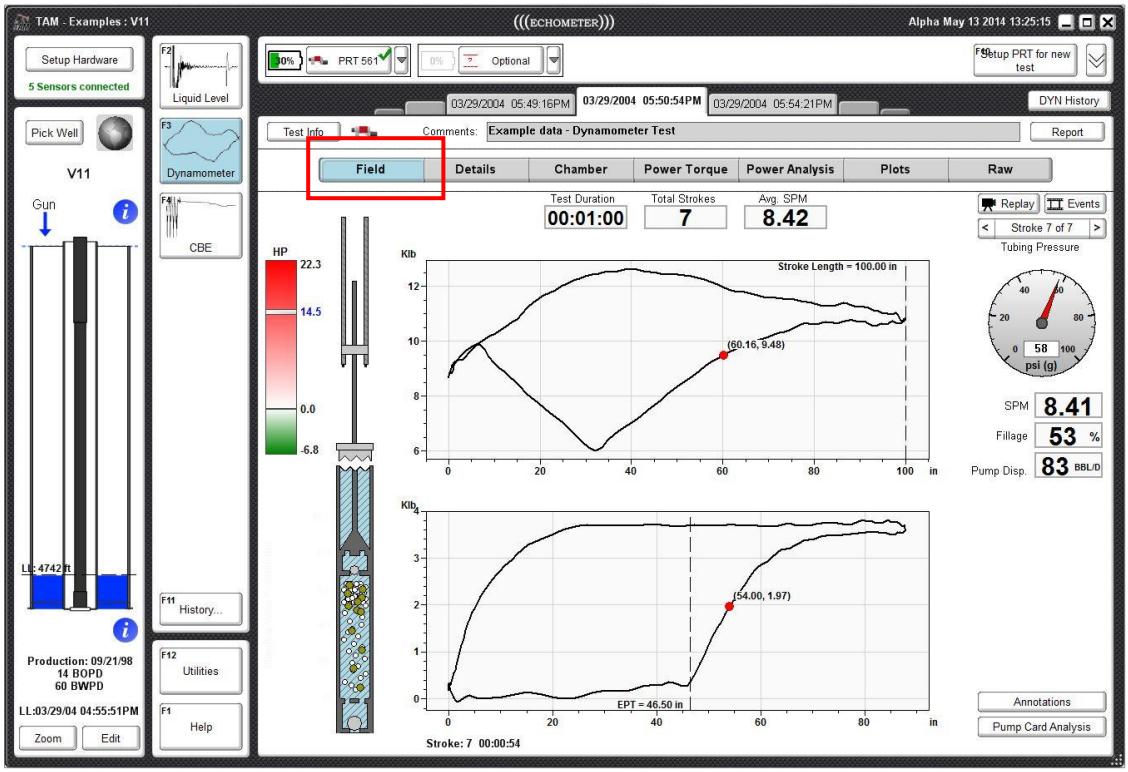

Figure 2: DYN Field View

Details View

From the details view the user can view many details about the pump and well. The user can view the following quantities:

- Polished rod peak load, min load and power.
- Pump peak load, min load and power.
- Pump Displacement
- Calculated Fluid Load Max
- Surface Efficiency
- Pumping Speed
- Motor to Pump Efficiency
- Damp Up and Down
- Fillage
- Effective Plunger Stroke
- Tubing Pressure
- Anchored Kt
- Kr

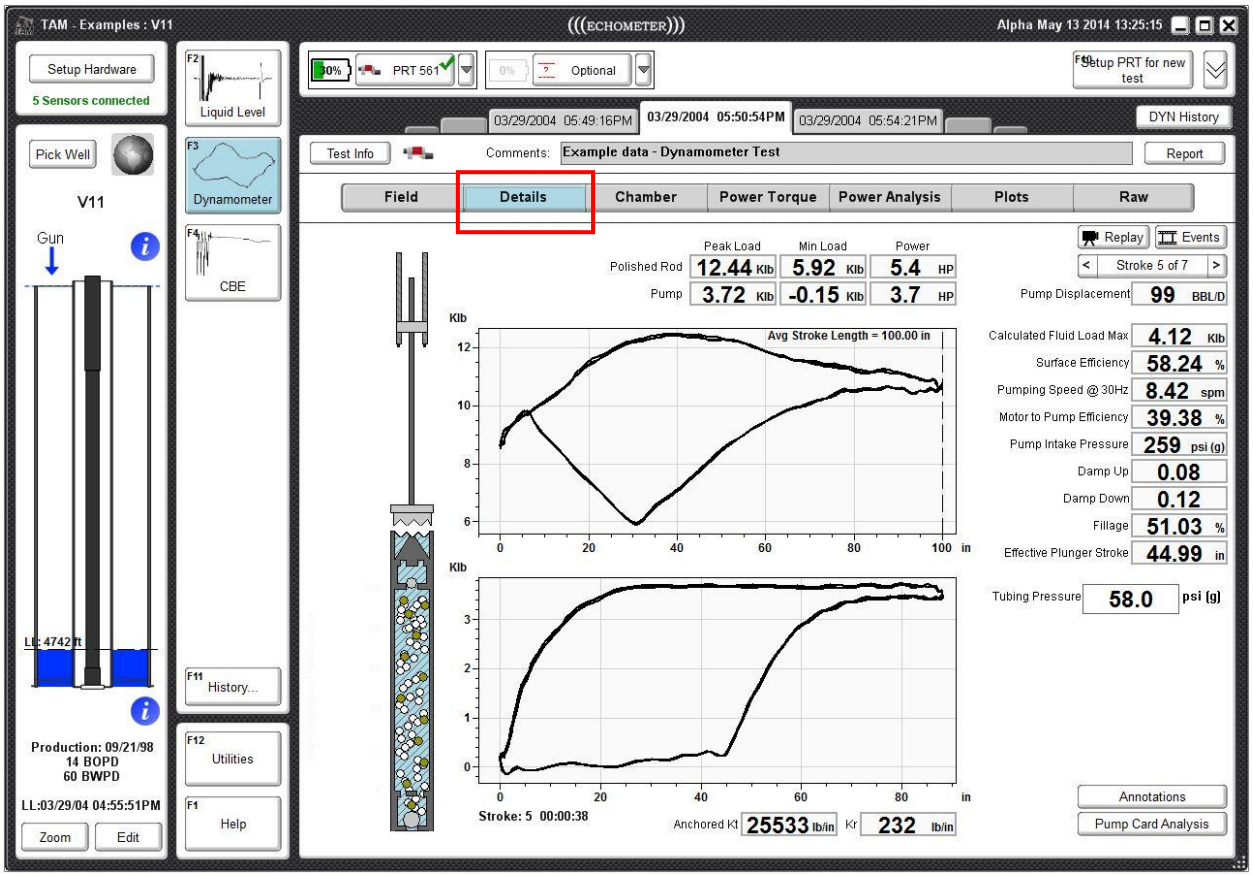

Figure 3: Details View

Chamber View

This view shows the load of the pump card, the plunger position and the variation of chamber pressure during the stroke. The pump animation is expanded to show plunger and tubing movement relative to the position of the standing valve at the bottom of the stroke

Additional annotations like pump discharge pressure or pump intake pressure are also presented on this screen and can be turned on and off using the Annotations dialog (Section IV).

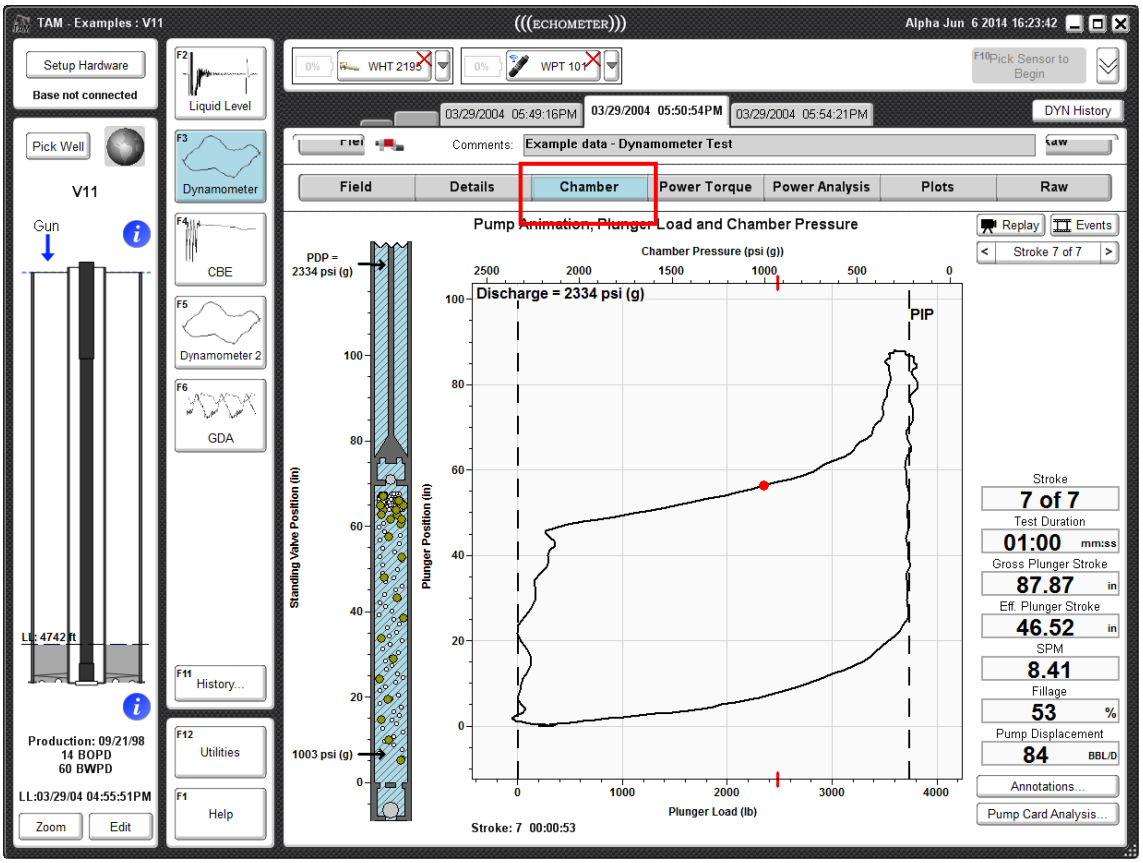

Figure 4: Chamber View

Power Torque View

This view shows the Balanced and Measured Torque plotted over time for a single stroke. The peak torque values are also displayed along with instructions to achieve balance.

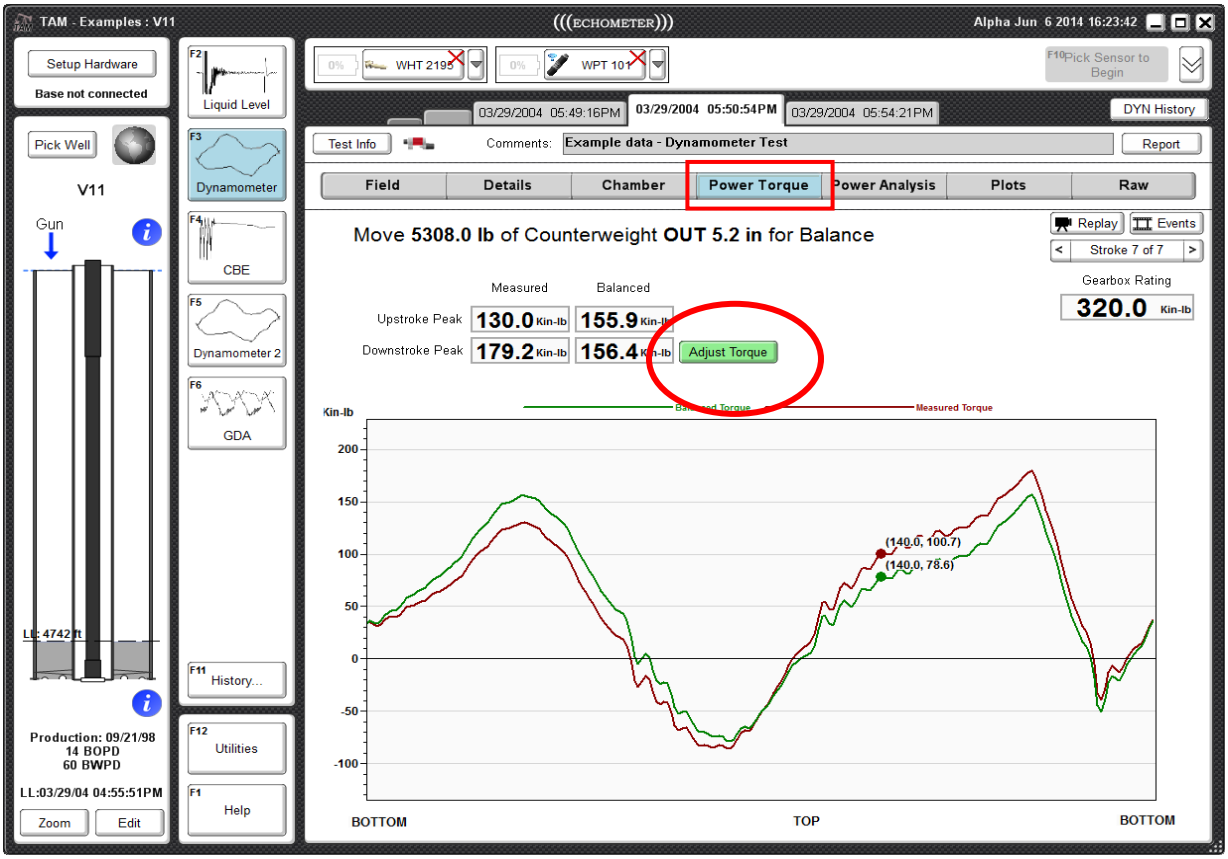

Figure 5: Power Torque View

From this view the torque can be adjusted by clicking on the “Adjust Torque” button which will bring up a dialog that allows the variables and torque plot to be changed.

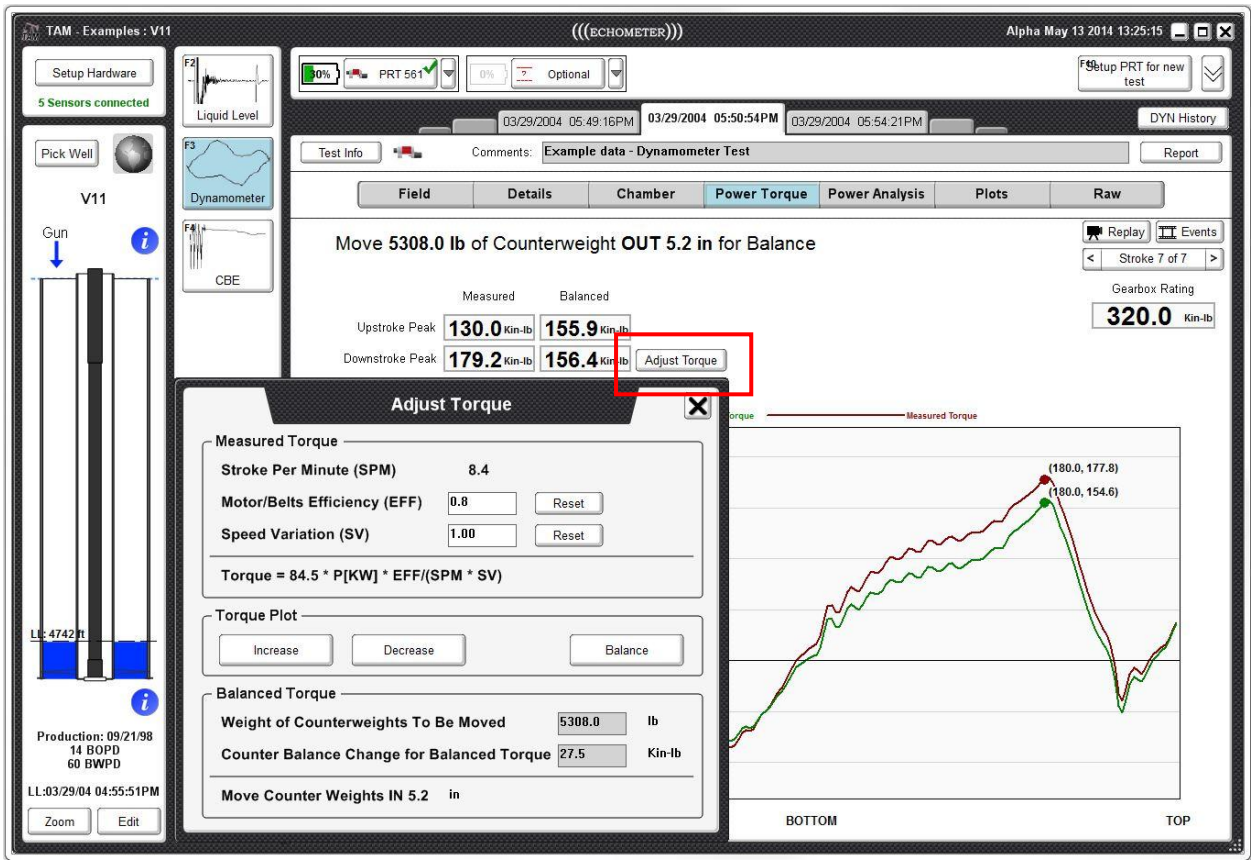

Figure 6: Adjust Torque

Power Analysis

This view shows the Power and Current plotted over time. Values of system efficiency, run time, 30 day cost to run, thermal amps, recommended minimum NEMA D motor, rated current and motor rating can also be viewed in this screen.

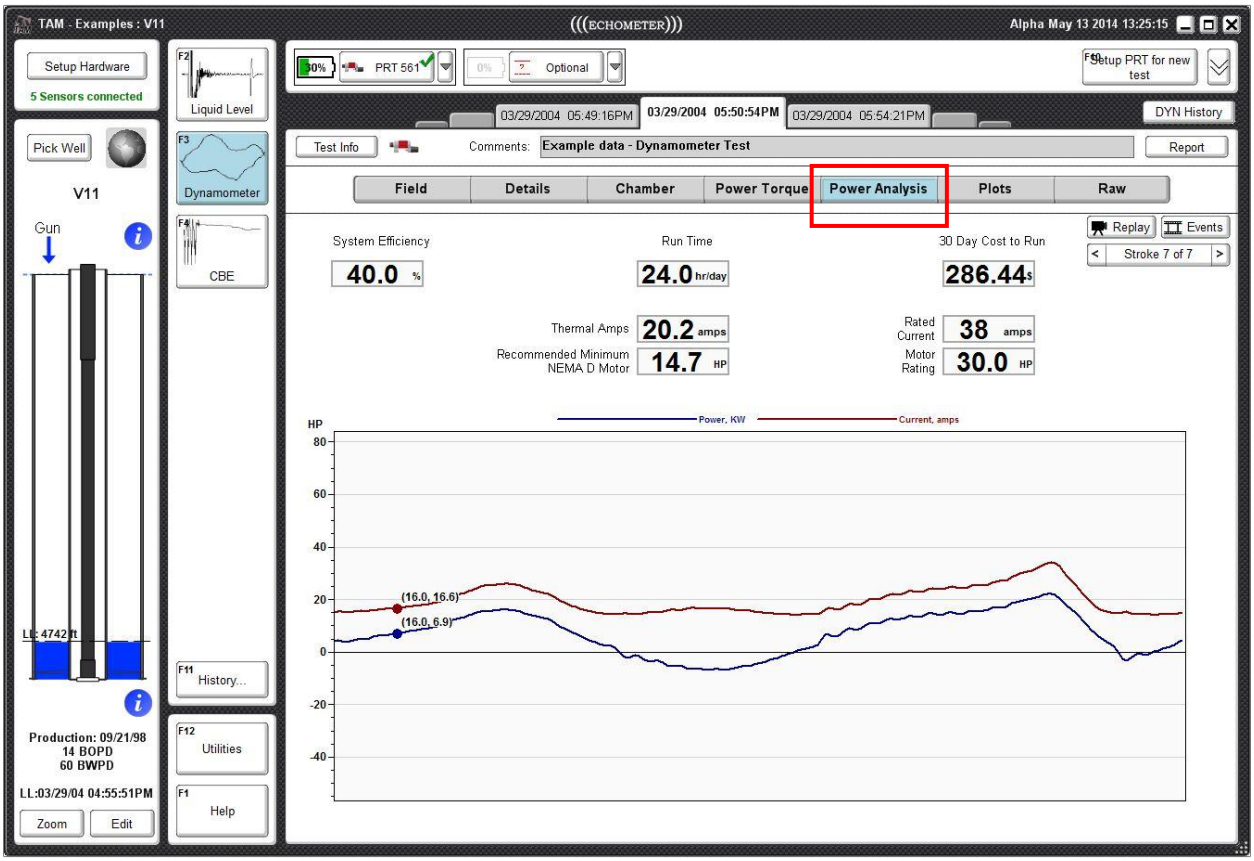

Figure 7: Power Analysis View

Plots View

This view displays two customizable plots for making comparisons. For each of the plots there are two vertical axes and one horizontal axis that can be assigned different variables. Clicking the expand button on the bottom right of the view will expand the plot to the size of the entire view. Clicking the collapse button on the bottom right of the view will collapse a full view plot back into a half view plot.

There are three buttons on the lower right corner of the screen that will zoom in on either the whole, surface or pump section of the well respectively.

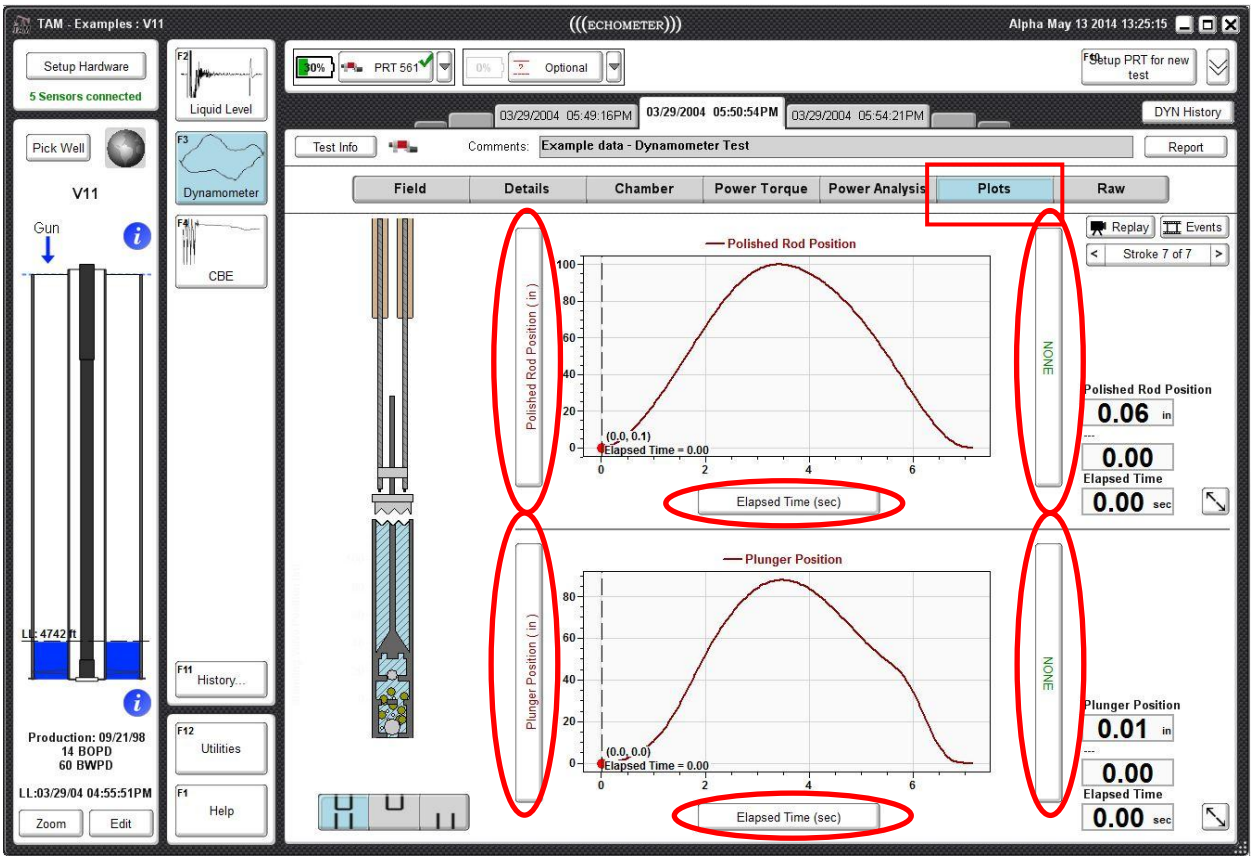

Figure 8: Plots View

Raw Data View

Both during acquisition and when reviewing the data the user can see the ***raw data*** as a function of time as it was acquired from the sensors.

On the raw data screen, load and acceleration are displayed by default. The display can be customized with options to view pressure (when acquired), position, velocity, power and current. Filters can also be used to apply smoothing to the displayed curves. Engineering units versus raw units (mV/V) can be toggled using the ***Eng Units*** button in the top-left corner of the analysis screen.

Figure 9: Raw Data View

Valve Test View

One of the novel features of TAM is the ability for to automatically detect that the operator is performing a valve tests during the normal acquisition of a Dynamometer test; generally it is not necessary to interact with the software when a valve test is going to be performed. TAM monitors the acceleration signal and determines when the polished rod is stopped and exits the dynamometer card screens to display the load vs. time record until the normal pumping operation of the unit is continued for at least two strokes. (This feature can be disabled when the sucker rod is driven by linear motion pumping units, such as Hydraulic or Rotaflex, where the acceleration signal is nearly constant at 1G during most of the up and down strokes). If the user performed a valve test while acquiring dynamometer data, then he may review the valve test screen by clicking on the corresponding tab. The valve test screen shows a plot containing the load values acquired over time (Figure 10). Candidate intervals for valve test analysis are highlighted by gray bands. When the ***Enable TV/SV Analysis*** buttons are clicked, the program automatically selects the most appropriate interval to be analyzed and displays the corresponding vertical markers (Figure 11). If not satisfied with the software's analysis, the user can change the size and position of the ***yellow TV region***, by clicking and dragging it to a new leakage interval. The traveling valve leakage calculations are controlled by the width of the yellow marker bars which is defaulted to 5 seconds but can be adjusted using the corresponding handles. Also the ***SV cursor*** can be moved to the position where its corresponding load should be measured.

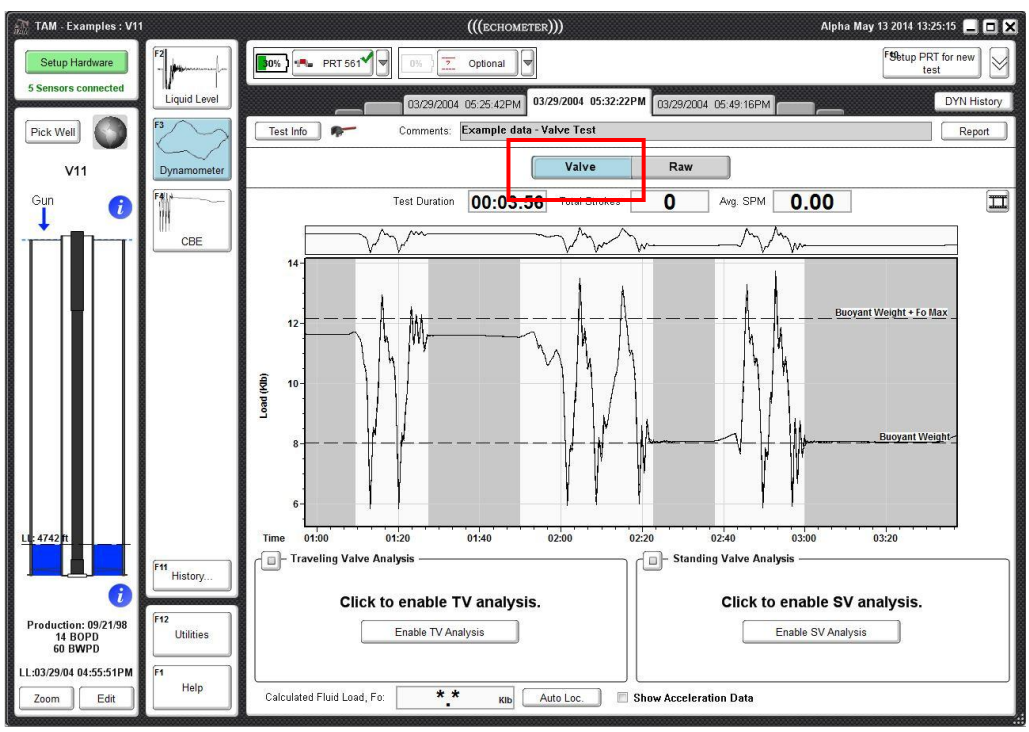

Figure 10: Valve Test View

Results are shown in the digitals below the plot. Clicking the **Auto Locate** button positions all markers to the automatic analysis. When the valve test is performed using a PRT, that was not properly stabilized and the data exhibits significant drift, it may be necessary to adjust the SV load to match the computed ***Buoyant Rod Weight*** by clicking the corresponding button.

Figure 11: Valve Test Analysis View

II. Selecting Dynamometer Events

Specific strokes are selected from the dynamometer record via the stroke viewer control, accessed through the button Events at the top right of the analysis screen (Figure 12). This control displays thumbnails of all the events in the current test. By default it highlights and displays the last stroke. To switch to a different event, click the corresponding numbered thumbnail.

You can also overlay multiple strokes by holding ***Ctrl*** while you are clicking thumbnails of various strokes (Figure 13). If you click while holding ***Shift,*** you can select a range of events. Right clicking on a stroke will give you the option to **"Lock"** or **"Unlock**" a stroke. When a stroke is locked, it will always be selected as an overlay as you click through other strokes. Finally, you can select all events by hitting ***Ctrl+A*** on the keyboard, or by right-clicking an event and selecting ***"Select All".***

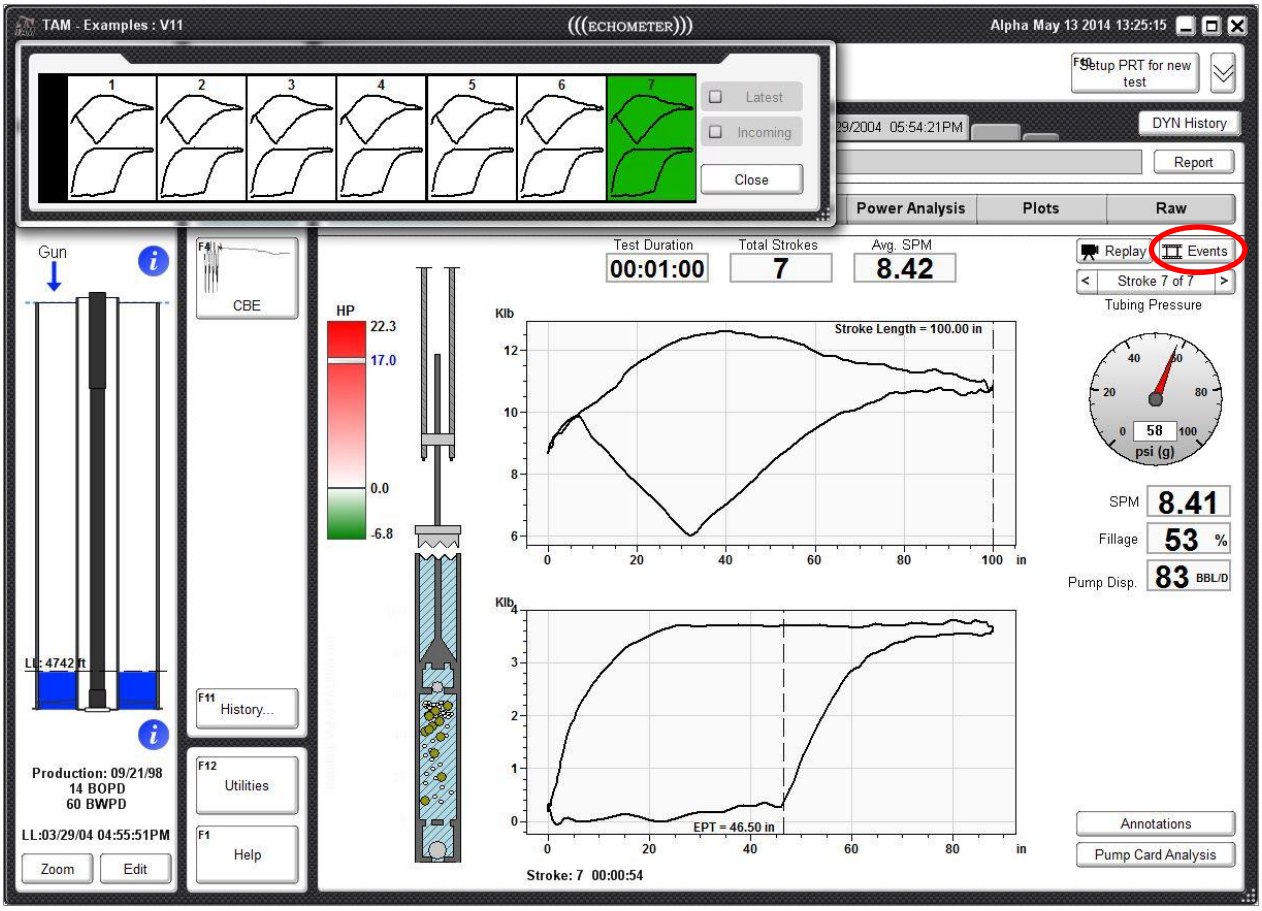

Figure 12:Event Viewer Control

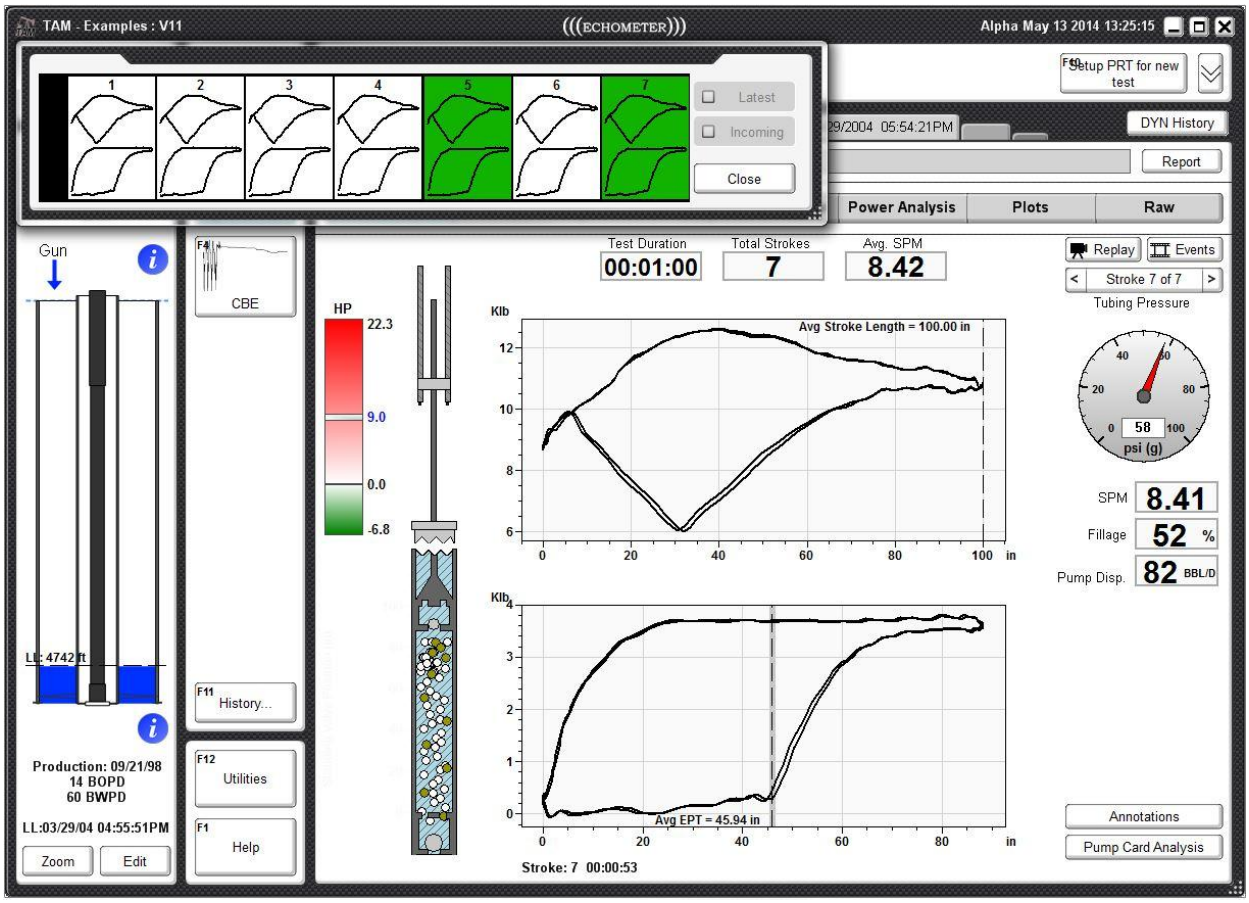

Figure 13: Stroke Overlay Example

III. Dynamometer Replay

Clicking on the ***"Replay"*** button on the Dynamometer Analysis window will display the replay controls for viewing in real time the recorded pump strokes as they were acquired originally.

Controls

Figure 14 shows at the top left the replay controls dialog. Some of the basic controls include play, stop, pause, and rewind. There is also a loop button (circular arrow) that allows the replay to continue indefinitely until the user decides to stop replay. Below these buttons are plus and minus buttons that can be used to control the playback speed. Playback speed include: 0.25x speed, 0.5x speed, 1x speed (**real time**), 2x speed, 4x speed, and 8x speed. The user can also specify a stroke range to use for replay by entering the stroke number into the provided textboxes and clicking ***"Update***". The moving red line on the event viewer indicates the current replay position.

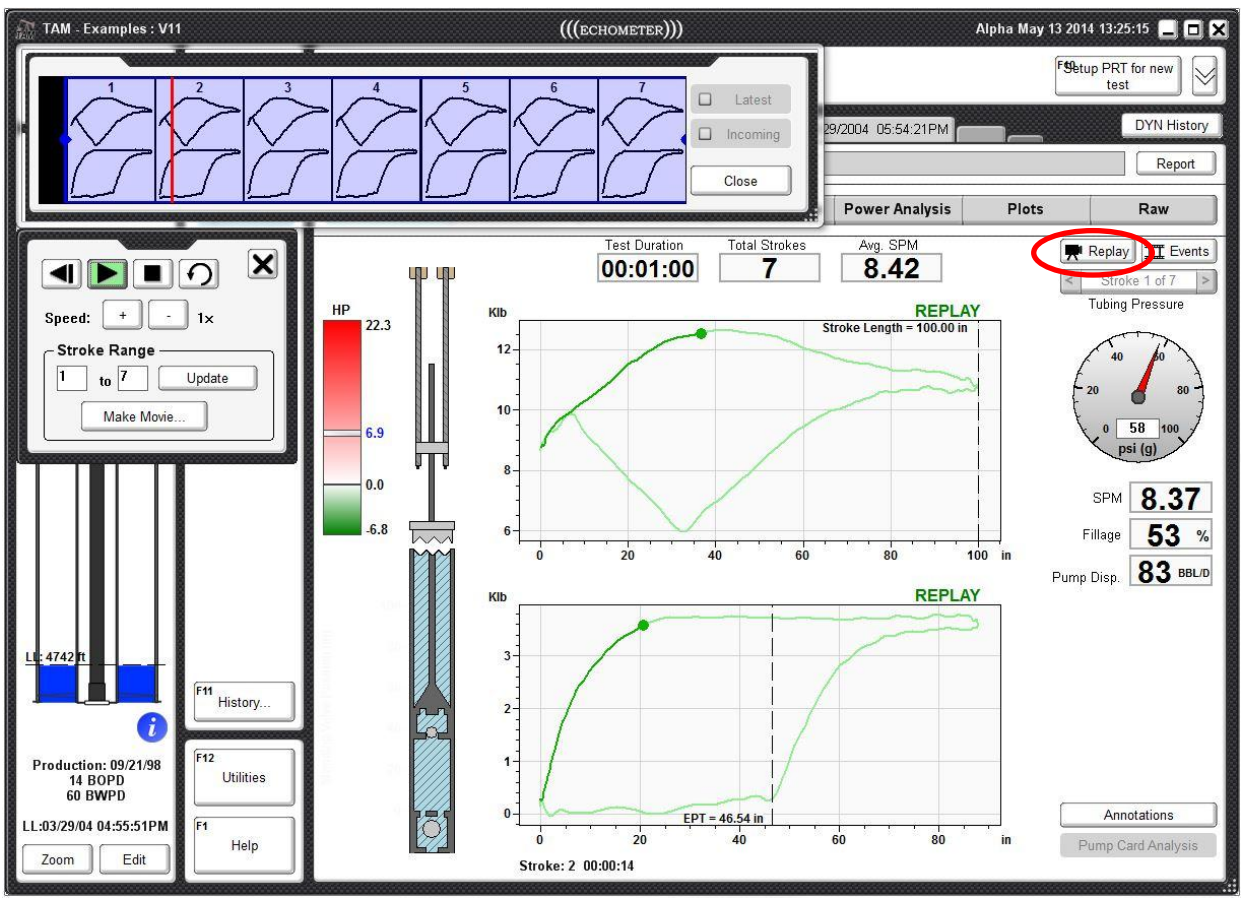

Figure 14: Dynamometer Replay Controls

Selecting a Stroke Range

In addition to manually entering a range in the textboxes of the replay dialog, the user can also specify a range in the event viewer above the replay dialog, as seen in Figure 15. On the event viewer, a transparent blue area will appear indicating the selected stroke range. The ends of this box can be clicked and dragged to specify a new range.

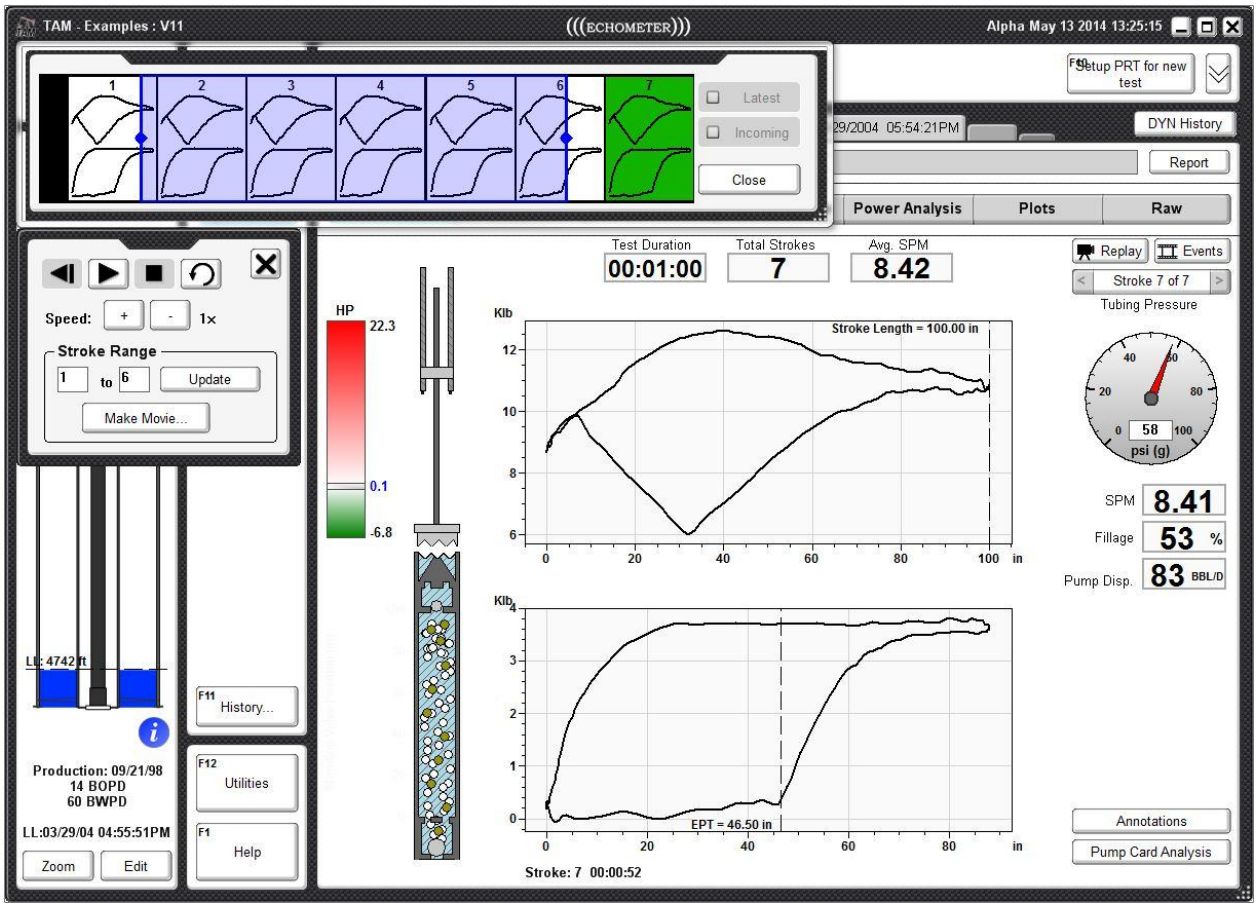

Figure 15: Selecting Range in the event viewer alongside replay.

Making a Movie

Another tool provided by the replay control is the ability to save a movie file of stroke playback. Simply click ***"Make Movie"*** and a save dialog will appear, allowing the user to specify a save location of the movie file (Figure 16). The movie will be generated using the stroke range and speed settings specified in the replay dialog. Movie generation occurs in the background of the application, so the user can still work in TAM while a movie file is being created.

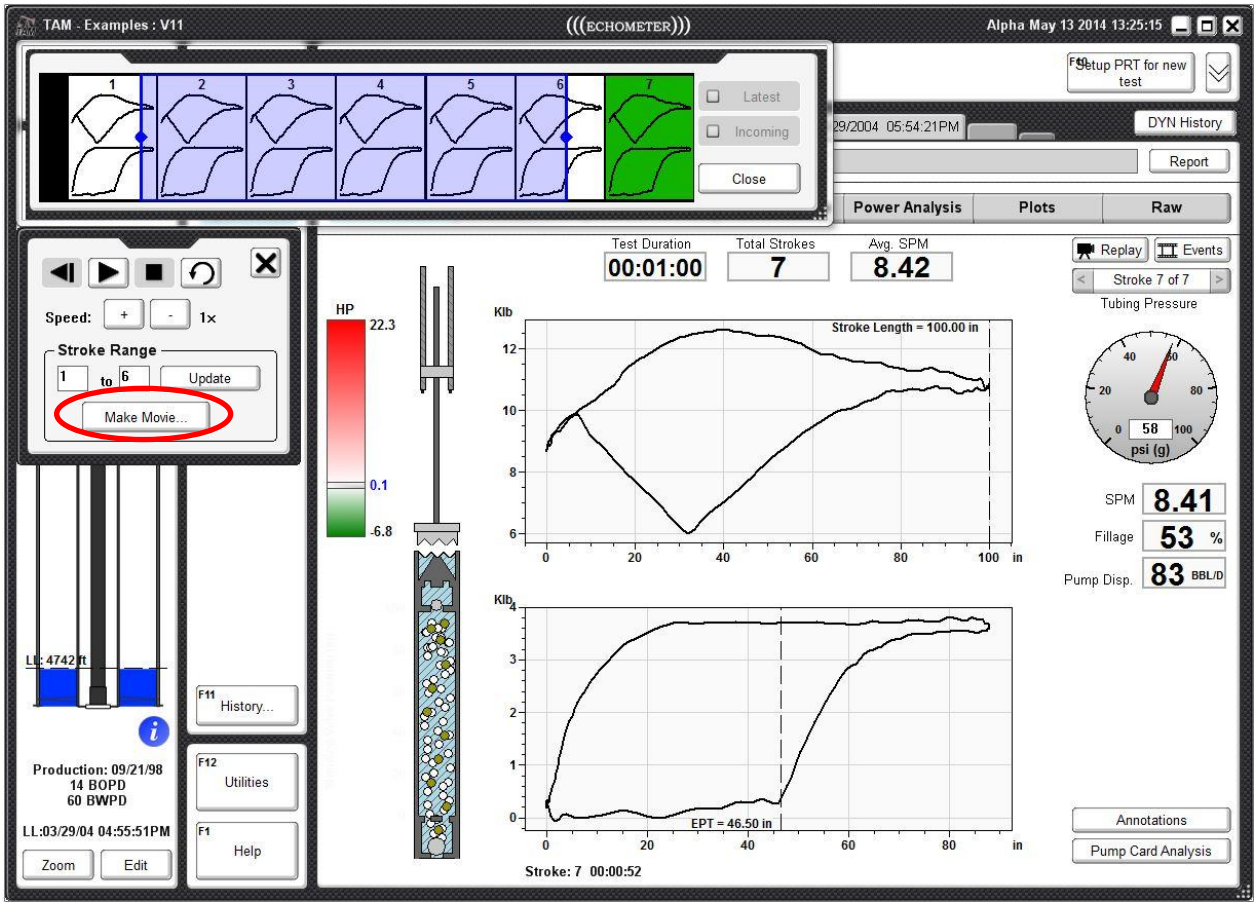

Figure 16: Make Movie Tool

After the user selects the destination of the movie file (Figure 17) the progress of movie generation is displayed on the screen as a sequence of information screens as shown in Figure 18 through Figure 20. Once the movie has been generated the file can be located (***Show Movie in Folder***) or attached to an E-mail message (***E-Mail***) or the movie can be replayed (***Play Movie***).

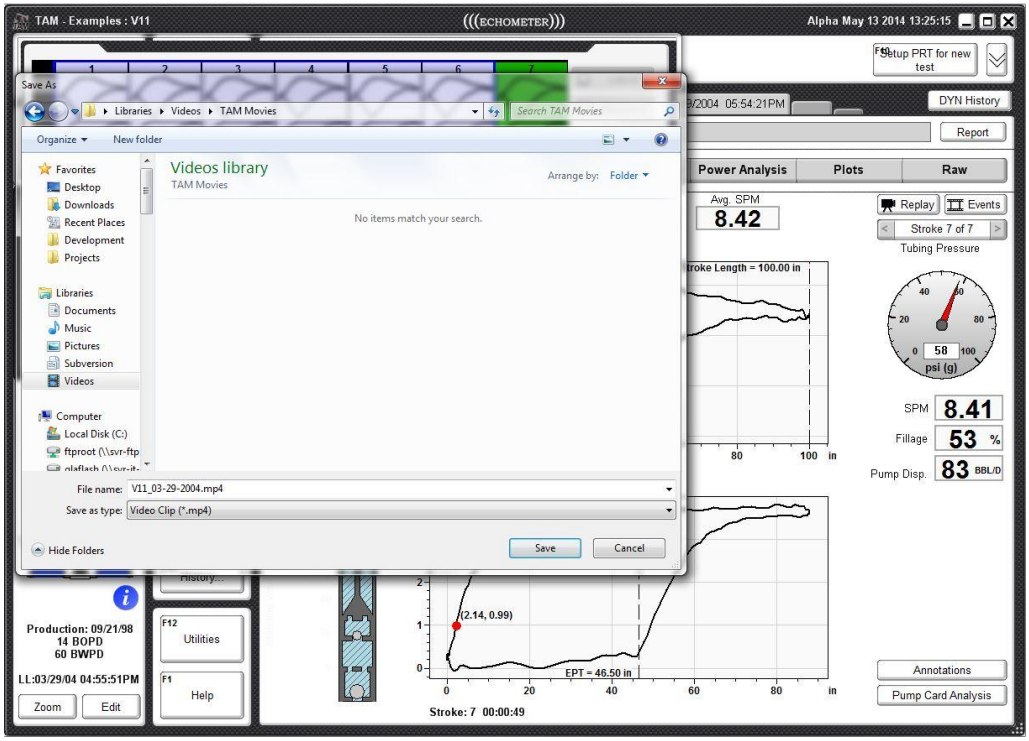

Figure 17: Save Movie Dialog

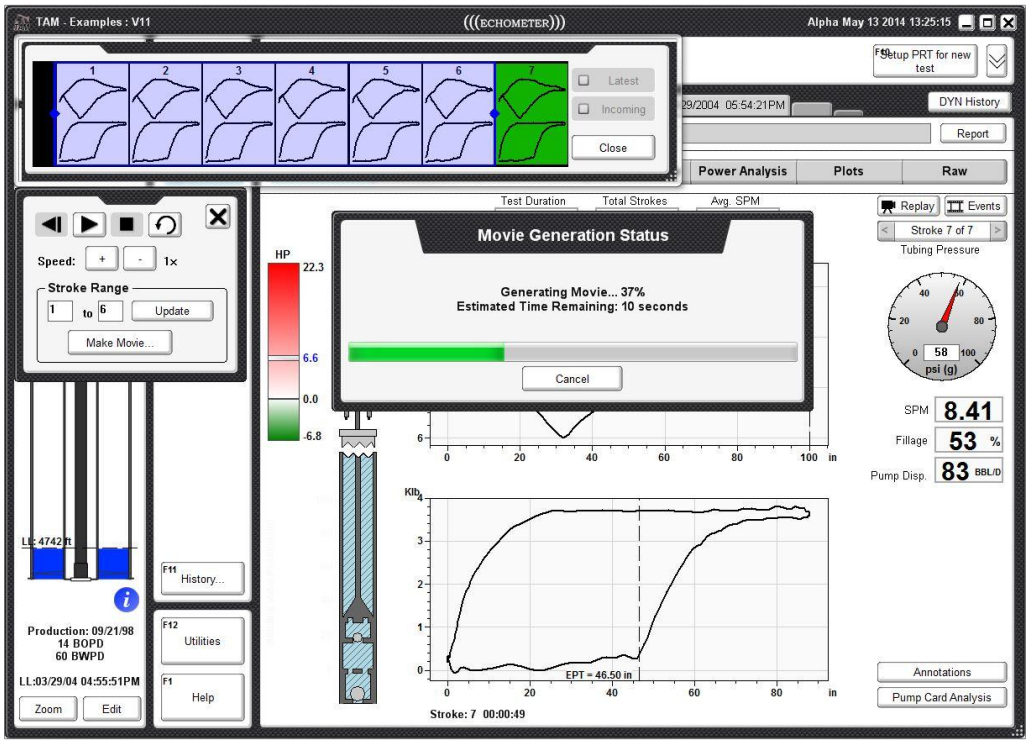

Figure 18: Movie Generation Progress

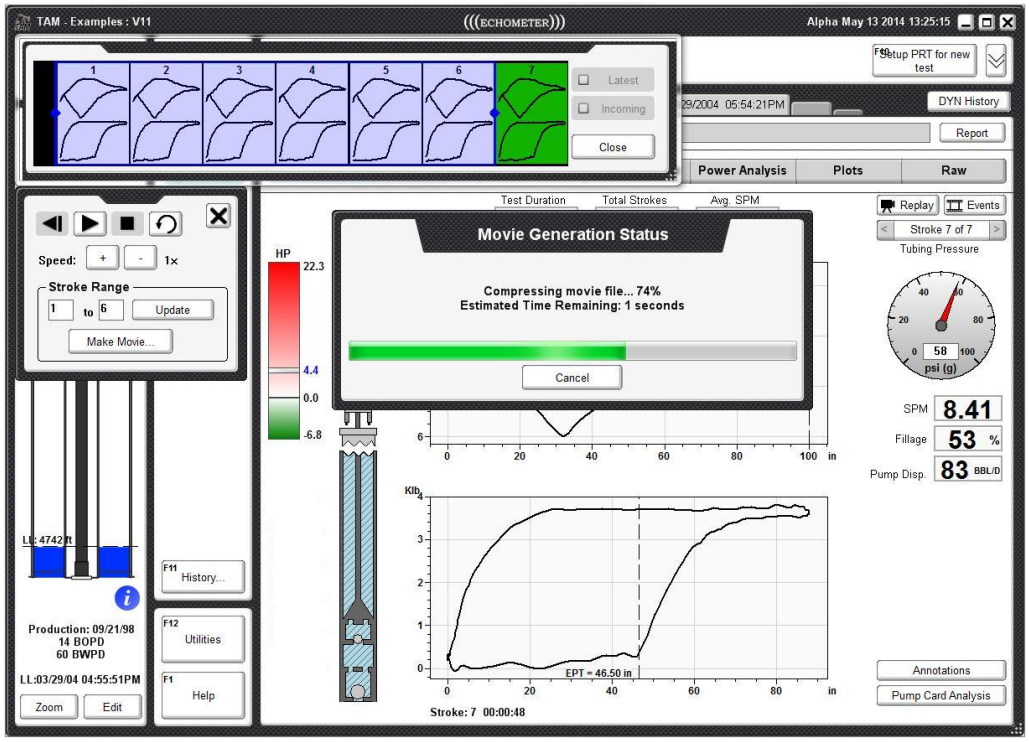

Figure 19: Movie File Compression

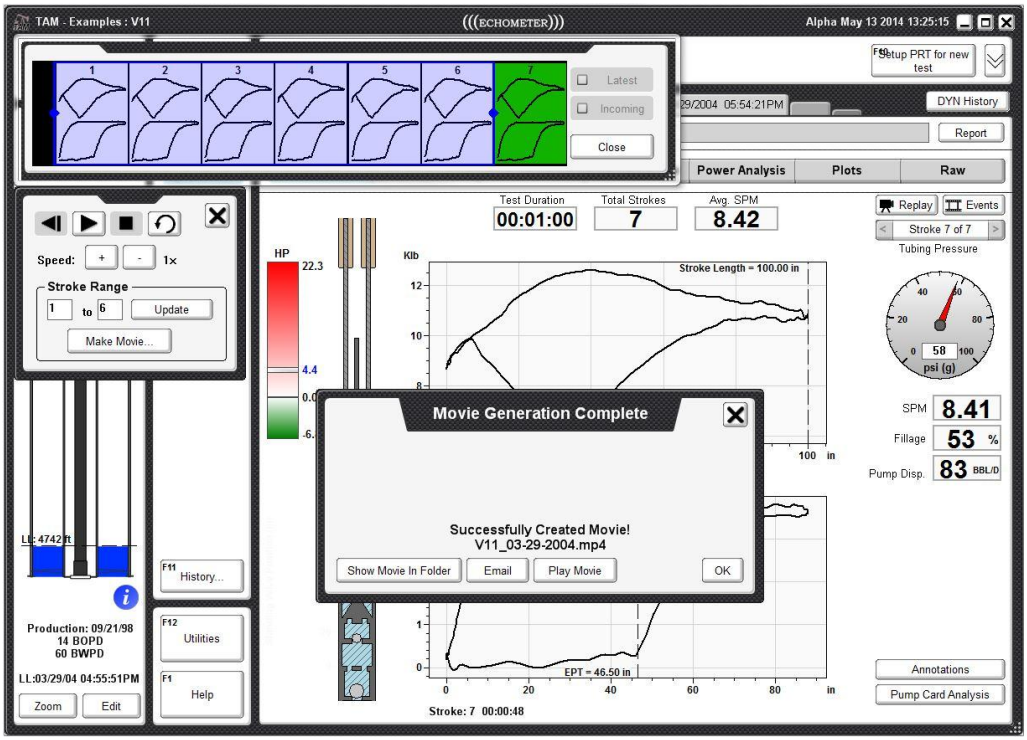

Figure 20: Completion Dialog and Options

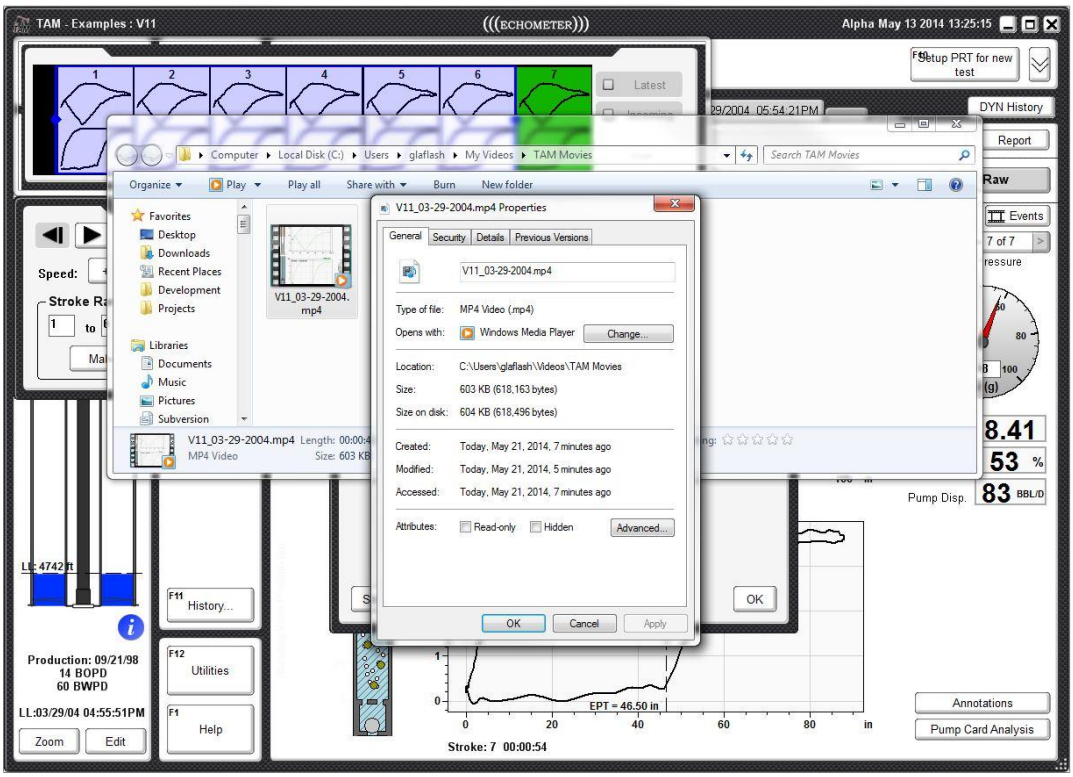

Figure 21: Movie File Properties and Location

IV. Dynamometer Annotations

The Dynamometer Analysis screen provides a set of annotations that can be turned on and off depending on the level of detail the user is interested in seeing. Most of these annotations appear as cursors or reference lines on the plots of particular views. To turn annotations on or off, simply click the ***"Annotations"*** button on the card or pump analysis view (Figure 22). Table I shows a brief overview of what each option in the annotations dialog does, as well as the Dynamometer views that are affected by it.

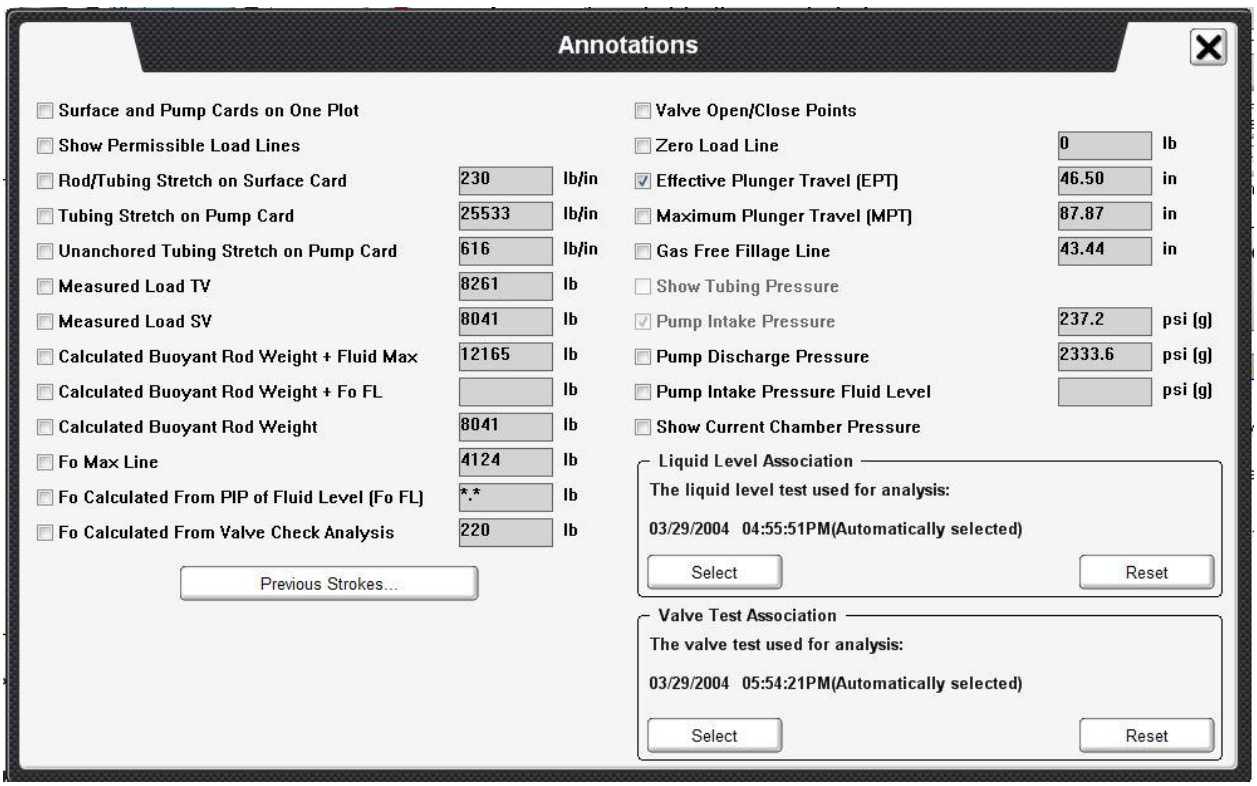

Figure 22: Annotations Dialog

Label	View(s) Affected	Description
Surface and Pump Cards on One Plot	Card	Displays card on a single, continuous plot instead of two
Show Permissible Load Lines	Card	Displays the Permissible Load Lines if they were able to be calculated.
Rod/Tubing Stretch on Surface Card	Card	Displays the Kr line on the surface card plot

Tubing Stretch on Pump Card	Card, Pump	Displays the Kt line on the pump card plot
Measured Load TV	Card	Displays the measured TV load on the surface card plot (if valve test performed)
Measured Load SV	Card	Displays the measured SV load on the surface card plot (if valve test performed)
Calculated Buoyant Rod Weight + Fluid Max	Card	Displays the Wrf + FoMax load value on the surface card plot
Calculated Buoyant Rod Weight + Fo FL	Card	Displays the Wrf + Fo FL load value on the surface card plot
Calculated Buoyant Rod Weight	Card	Displays the Wrf load value on the surface card plot
Fo Max Line	Card	Displays the FoMax load value on the pump card
Fo Calculated From PIP of Fluid Level Analysis	Card	Fo computed from pump intake pressure found during a recent fluid level test
Fo Calculated From Valve Check Analysis	Card	Fo computed from the difference in measured TV and SV loads (if valve test performed)
Valve Open/Close Points	Card, Pump Analysis	Displays the TV and SV opening and closing points used for the pump animation
Zero Load Line	Card	Displays a solid line at zero load of the pump card
Effective Plunger (Pump Fillage) Travel	Card	Displays the EPT cursor at fillage position on the pump card
Maximum Plunger Travel	Card	Displays the MPT cursor at the max position of the pump card
Gas Free Fillage Line	Card	Displays the Equivalent Gas Free Fillage cursor at the gas free fillage position on the pump card
Show Tubing Pressure	Card	Displays acquired pressure vs. position overlay on the surface card
Pump Intake Pressure	Pump Analysis	Displays the PIP cursor on the pump card plot and PIP value shown at the bottom of the pump animation
Pump Discharge Pressure	Pump Analysis	Displays the discharge pressure cursor on the pump card and DP value shown at the top of the pump animation
Pump Intake Pressure Fluid Level	Pump Analysis	Displays the PIP FL cursor on the pump card plot and PIP FL value shown at the bottom of the pump animation
Show Current Chamber Pressure	Card, Pump Analysis	Displays the chamber pressure value next to the pump animation at a given point on the pump card

Table 1: List of annotations

Overlaying Strokes from Previous Tests

The user can click on the ***"Previous Strokes"*** button (Figure 23) to overlay on the dynamometer stroke that is currently being analyzed, one or more strokes from different dynamometer tests. This is similar to overlaying multiple strokes on top of another using the stroke viewer. A user can choose to overlay the strokes from up to five different tests by clicking the checkbox next to each test they wish to overlay (see Figure 24).

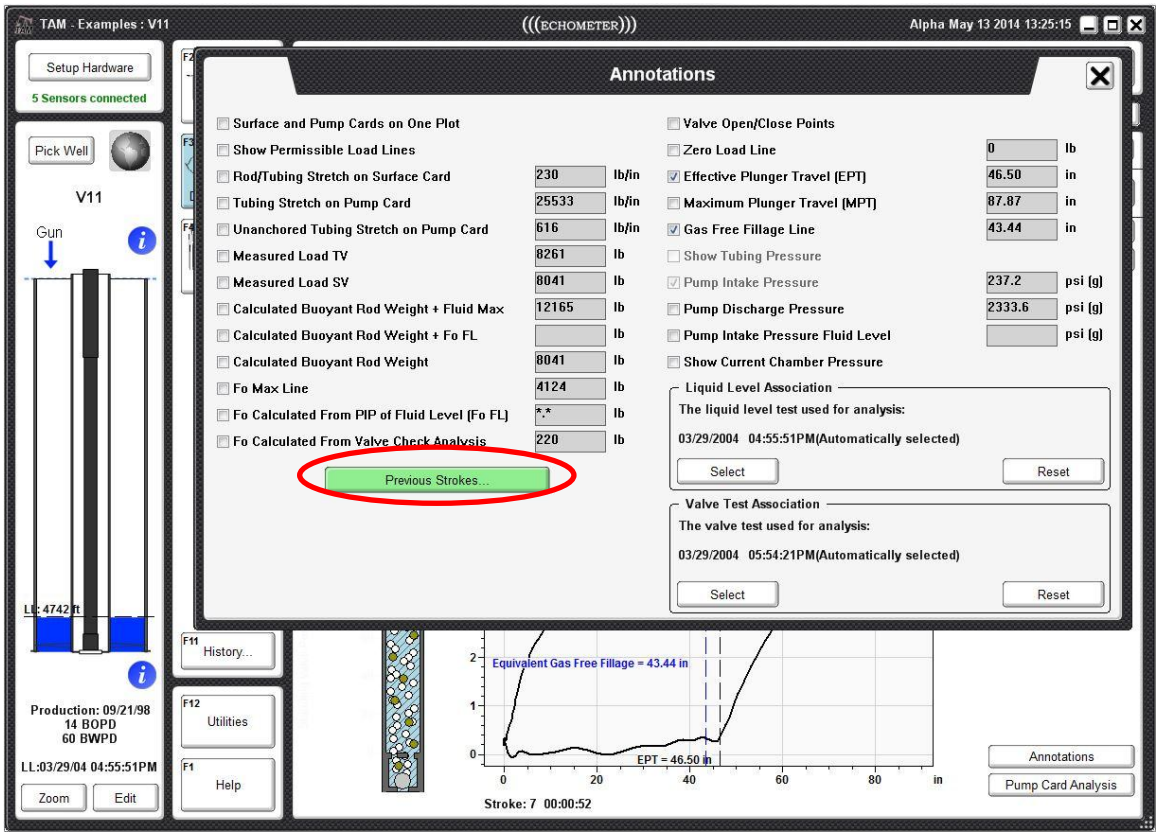

Figure 23: Control Button for Overlay of Strokes from Different Records

Note that the black dynamometer card corresponds to the stroke being analyzed and the blue card is the overlay card. The overlay card corresponds to the particular stroke in that record <u>that was last analyzed</u> by the user as shown in Figure 24. After selecting the strokes the selection window can be closed as shown in Figure 25.

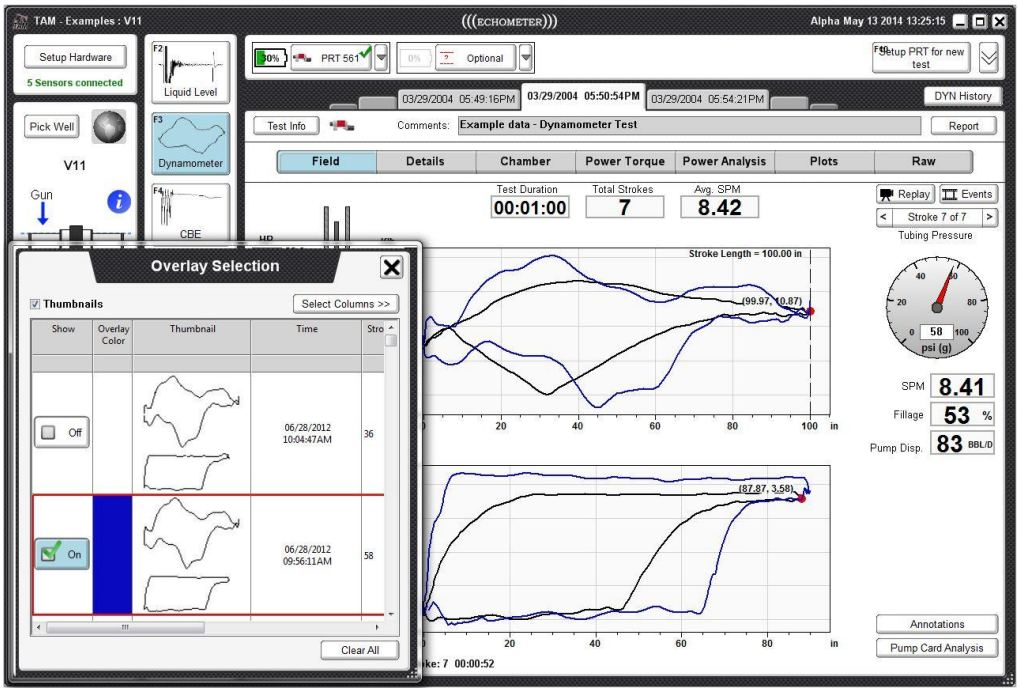

Figure 24: Selection of Stroke for Overlay

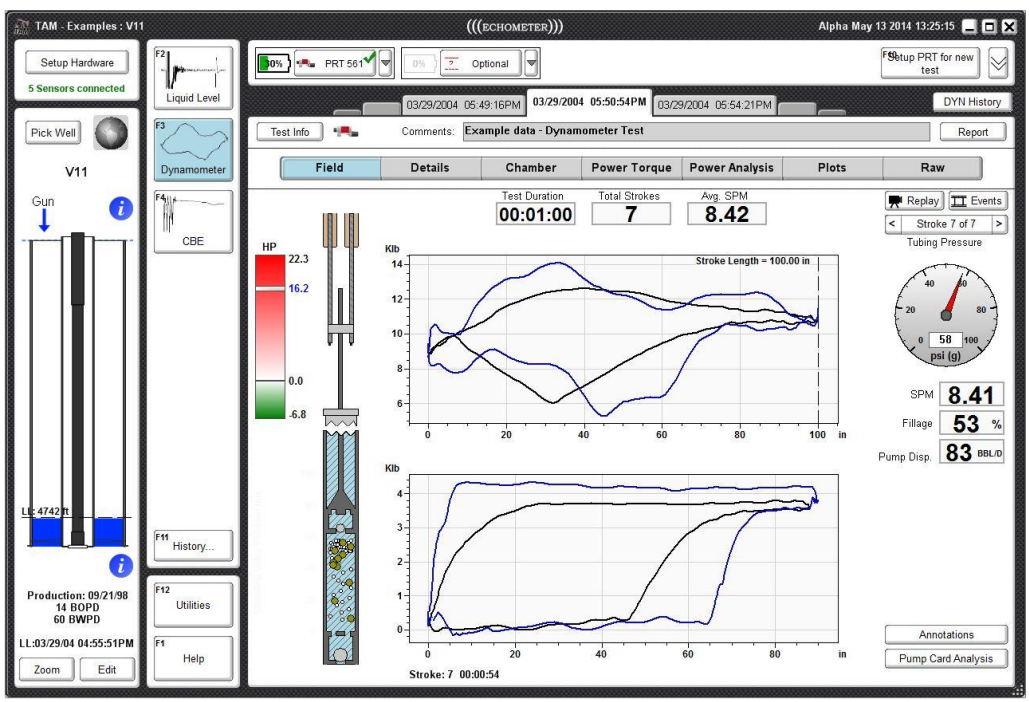

Figure 25: Overlaying strokes from other tests

V. Pump Card Analysis

The Pump Card Analysis dialog can be accessed through the ***Pump Card Analysis*** button on the card or chamber analysis view (Figure 26). The five tabs allow the user to modify the damping

factor used for card calculation, choose to de-ramp the cards, edit the tubing gradient, modify the up stroke and down stroke pump load and change the factors to take into account when calculating pump displacement.

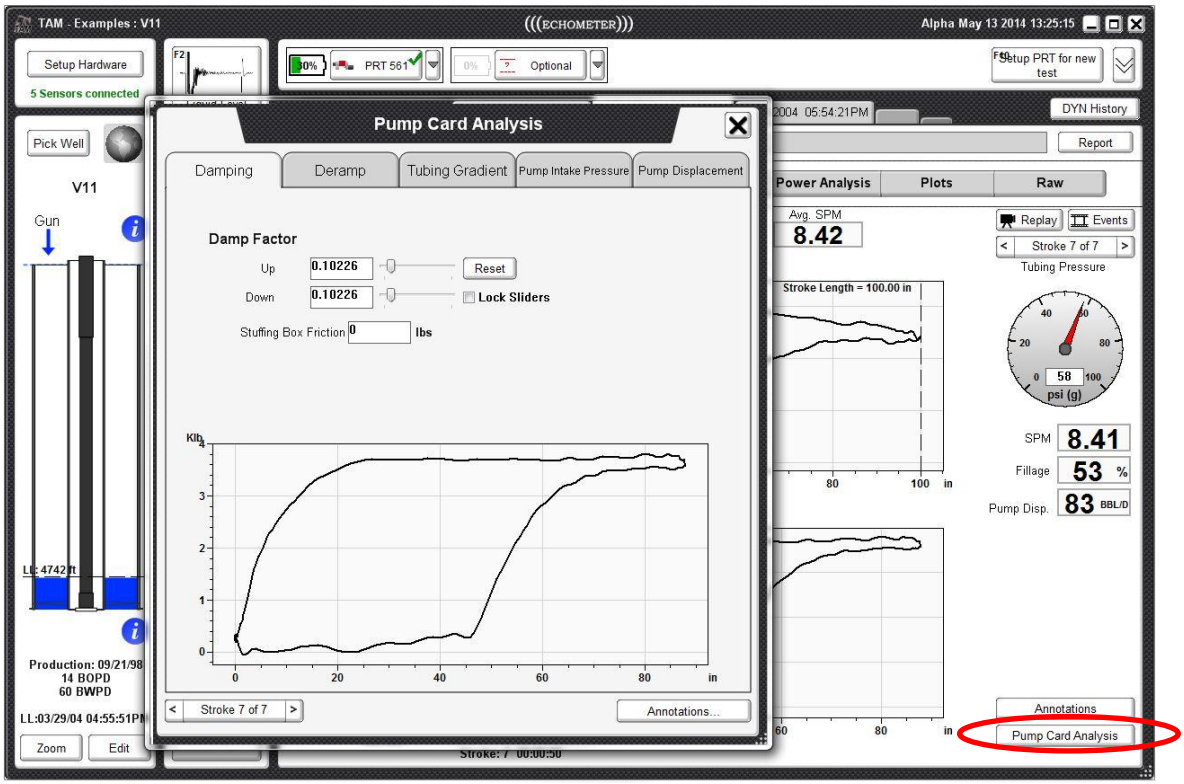

Figure 26: Dynamometer Pump Card Analysis dialog

Damping

The user can change the damping factor used in modeling the rod string dynamics in the save equation calculation. Doing so updates the calculation of the pump card. A new value can be entered or the slider control can be used to quickly view the change in the pump card characteristics as the damping factor is adjusted.

De-ramping

This tool is used to adjust the tilt of a pump dynamometer card acquired with a PRT on a well where the polished rod is bending due to misalignment of the pumping unit and the wellhead. The user can choose to de-ramp the pump card by clicking on the on button from the **Deramp** tab. The software eliminates the tilt and redraws the card so that the load on the upstroke is mostly horizontal as shown in Figure 28.

Figure 27: Pump card before deramping

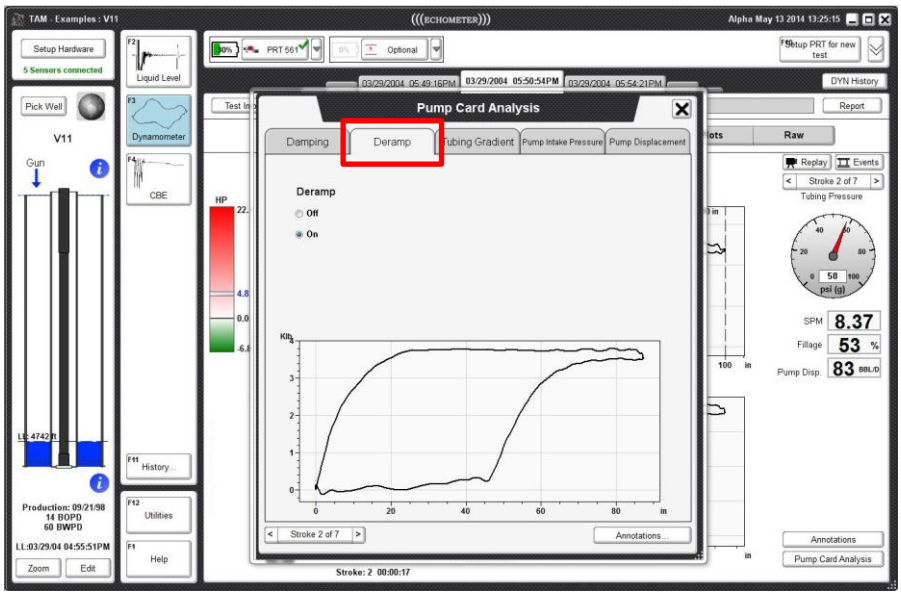

Figure 28: Pump card after deramping

Tubing Gradient

From the tubing gradient tab the user can select to use the gas free gradient computed from production Water/Oil Ratio history, the gradient computed from measured weight of rods in

fluid from a SV test, or estimated from multiphase flow correlations or a user entered gradient. The user can also choose to include tubing back pressure from Polish Rod Piston Force.

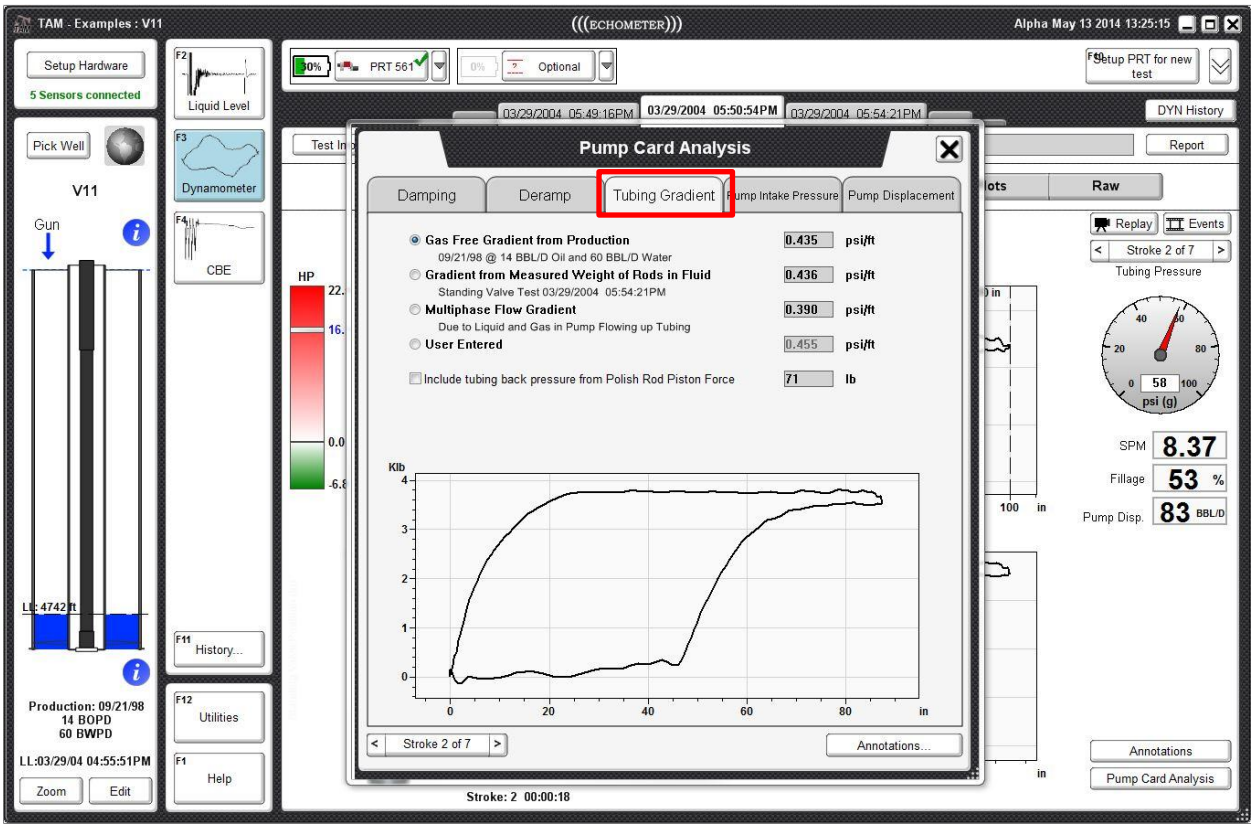

Figure 29: Tubing Gradient Tab

Pump Intake Pressure

From the Pump Intake Pressure tab the user can select the up and down stroke pump loads that will be used for the PIP calculations or enter a custom value.

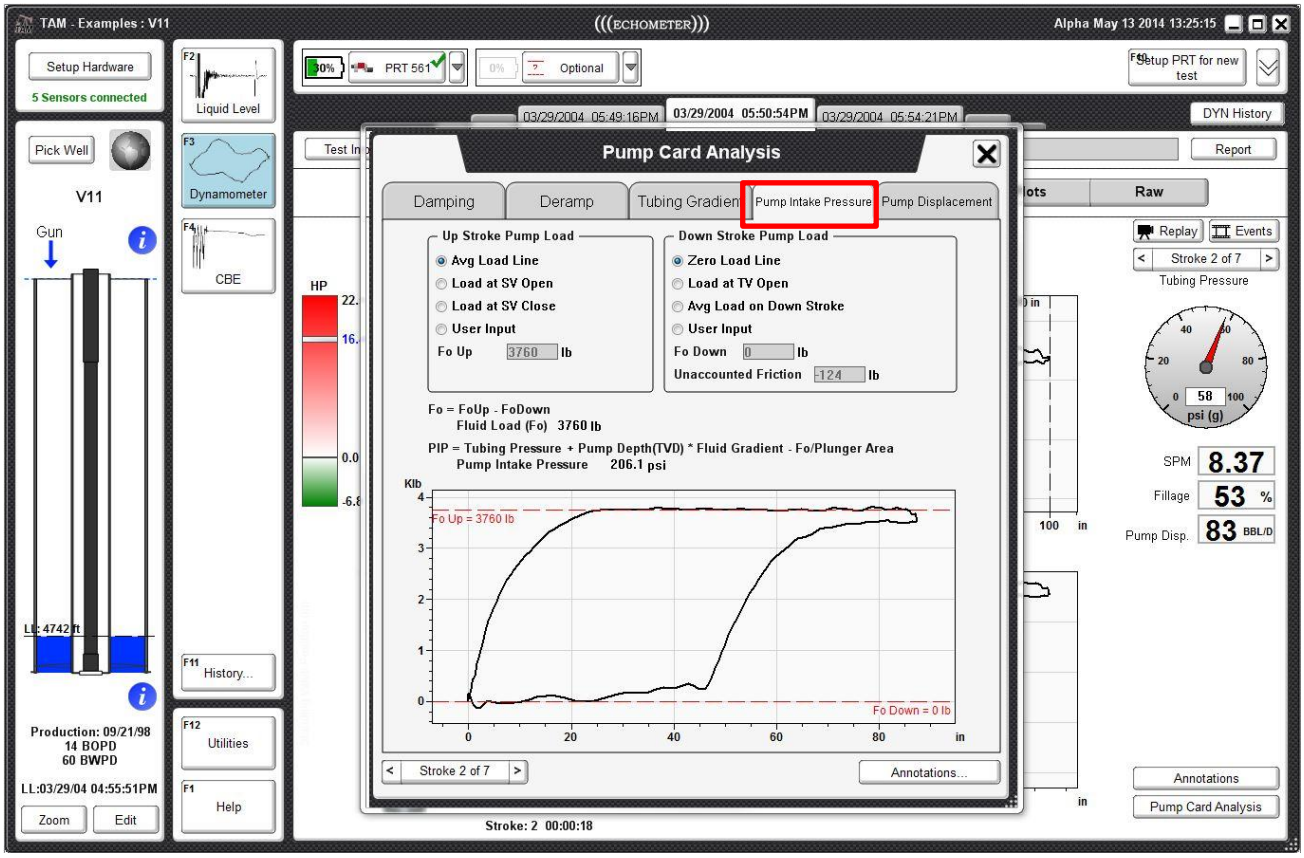

Figure 30: Pump Intake Pressure Tab

Pump Displacement

From the Pump Displacement Tab the user can select which factors are taken into consideration when computing pump displacement. When a factor is selected, with a checkmark in the list at right, it will appear black in the table on the left. When a factor is not selected it will appear grayed out.

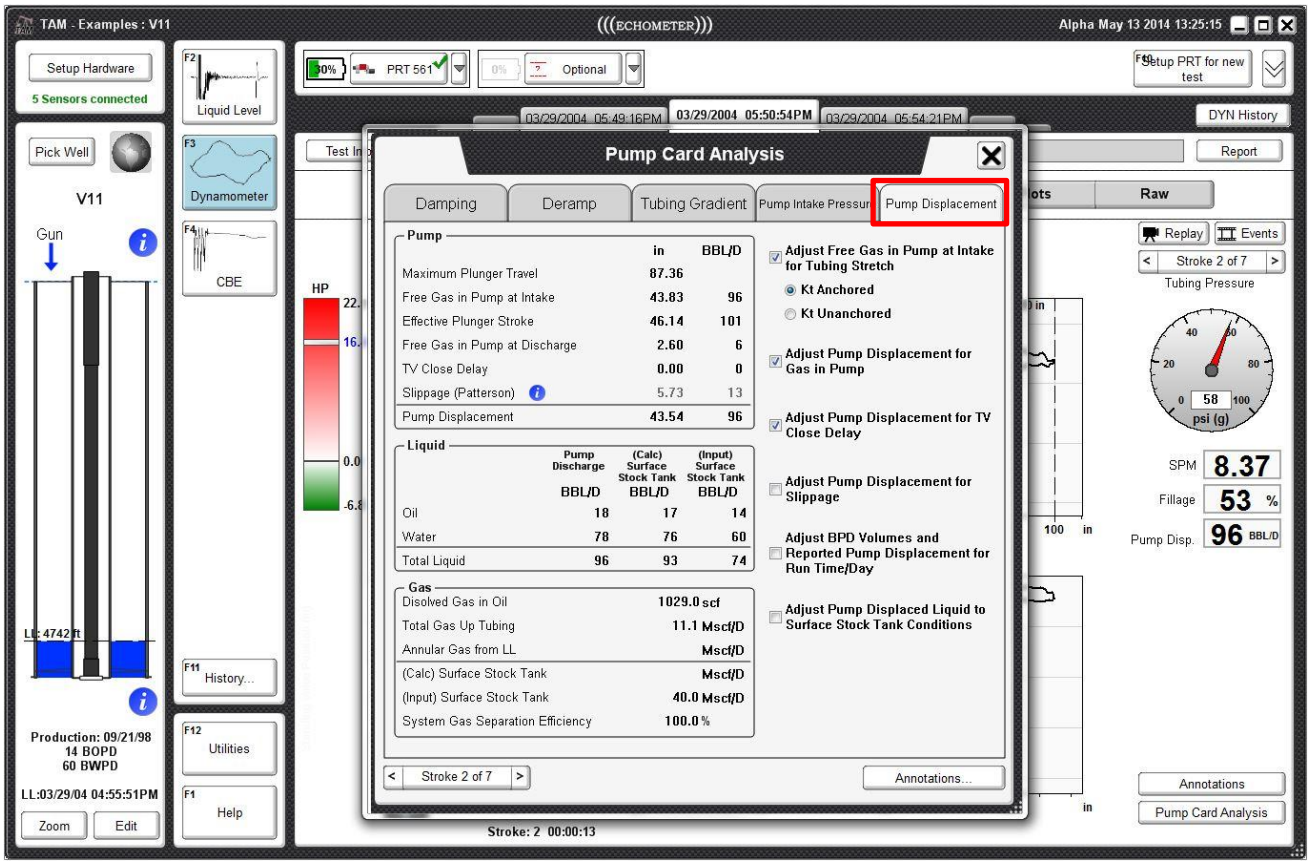

Figure 31: Pump Displacement Tab

VI. Dynamometer Plot Interaction

There are several useful tools for interaction with the data on the card view and pump analysis dynamometer screens.

Follow Dot

A red dot will follow the user's mouse cursor around as the curves of the card plots are traced (Figure 32). The cursor will display the current position and load value next to the red dot and will also update the pump animation and tubing pressure gauge (when tubing pressure is measured with the wireless pressure transducer). Right-clicking the dot and selecting the ***"Lock"*** option locks the dot in place and no longer follow the mouse cursor. Repeating the process and choosing ***"Unlock"*** will re-enable the dot's motion. At any point, the left and right arrow keys on the keyboard can be used to control the motion of the dot.

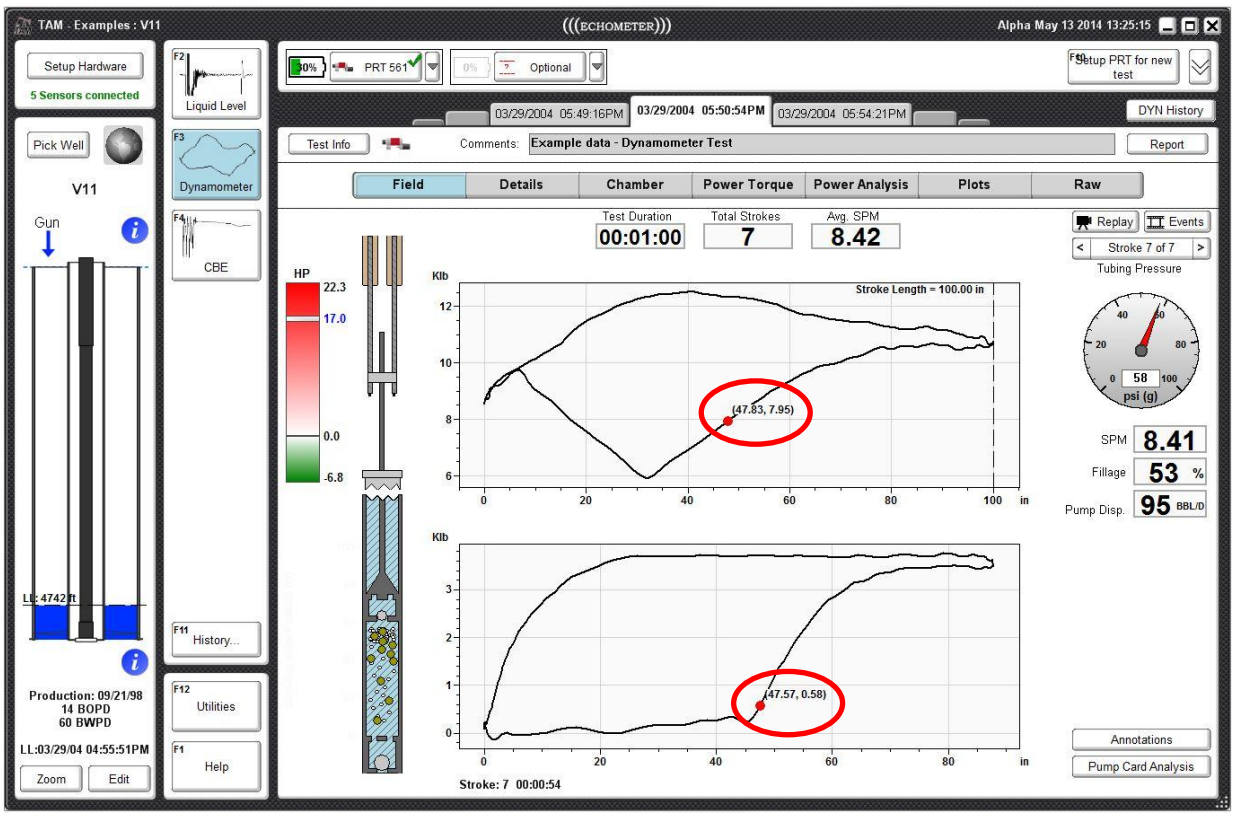

Figure 32: Follow cursor on Dynamometer card plots

VII. Right Click Menu

Additional plot options can be accessed by right-clicking inside the plot area. This brings up the popup menu seen in Figure 33 with the following options:

- *Print Image*: sends an image of the plot to the printer
- *Copy Image to Clipboard*: copies the plot image to the system clipboard
- *Copy Data to Clipboard*: copies the position, load, and pressure (if acquired) values of the selected strokes to the system clipboard
- *Export Data to File*: saves the position, load, and pressure values of the selected strokes to a text file (which can be loaded into spreadsheet programs like Excel)
- *Export Stroke to DYN*: saves the stroke load data, CBE information, valve loads, calculated stroke information, and information about the well and sensors used to record the data to an industry standard .DYN file.
- *Add Note*: add a note/annotation to the plot (see ***"Plot Notes"*** section in ***"TAM Features"*** document)

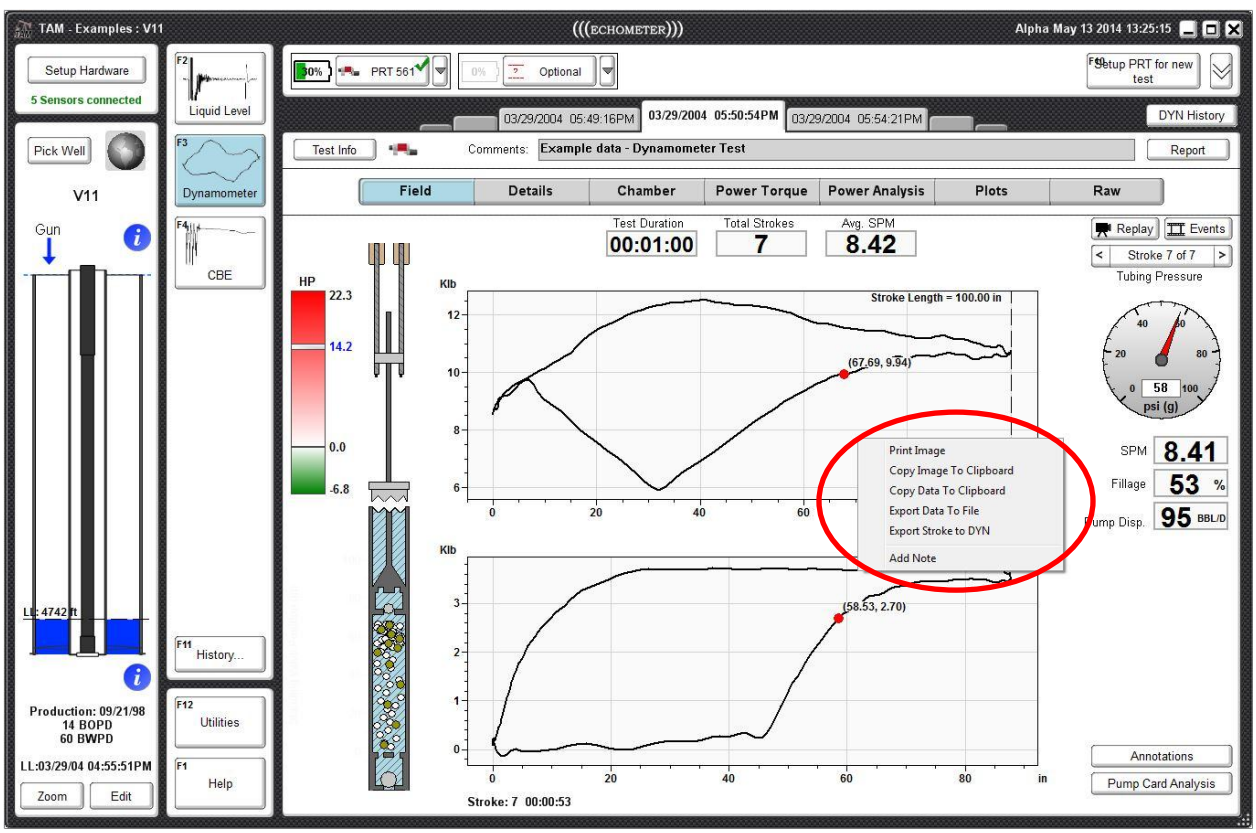

Figure 33: Dynamometer plots right click menu

VIII. Manual Valve Test Analysis

This option is useful when Automatic Valve Test Detection interrupts the real time display of surface and pump cards and the display reverts to showing load and acceleration vs. time as if a valve test were in progress although the pumping unit is stroking the polished rod. Typically this may happen when the pumping system is operating at pumping speeds slower than 2 strokes per minute. In order to take advantage of this feature, Automatic Valve Detection must be turned off on the Lift System tab of the Edit Well Dialog (Figure 34).

When this mode is implemented the valve test is performed stopping the polished rod at the usual position but the program does not display the valve test analysis screen. After acquisition of the dynamometer data is completed, the user selects the portion of the record that corresponds to the valve test section and directs the program to perform the Custom Valve analysis as shown in the next section.

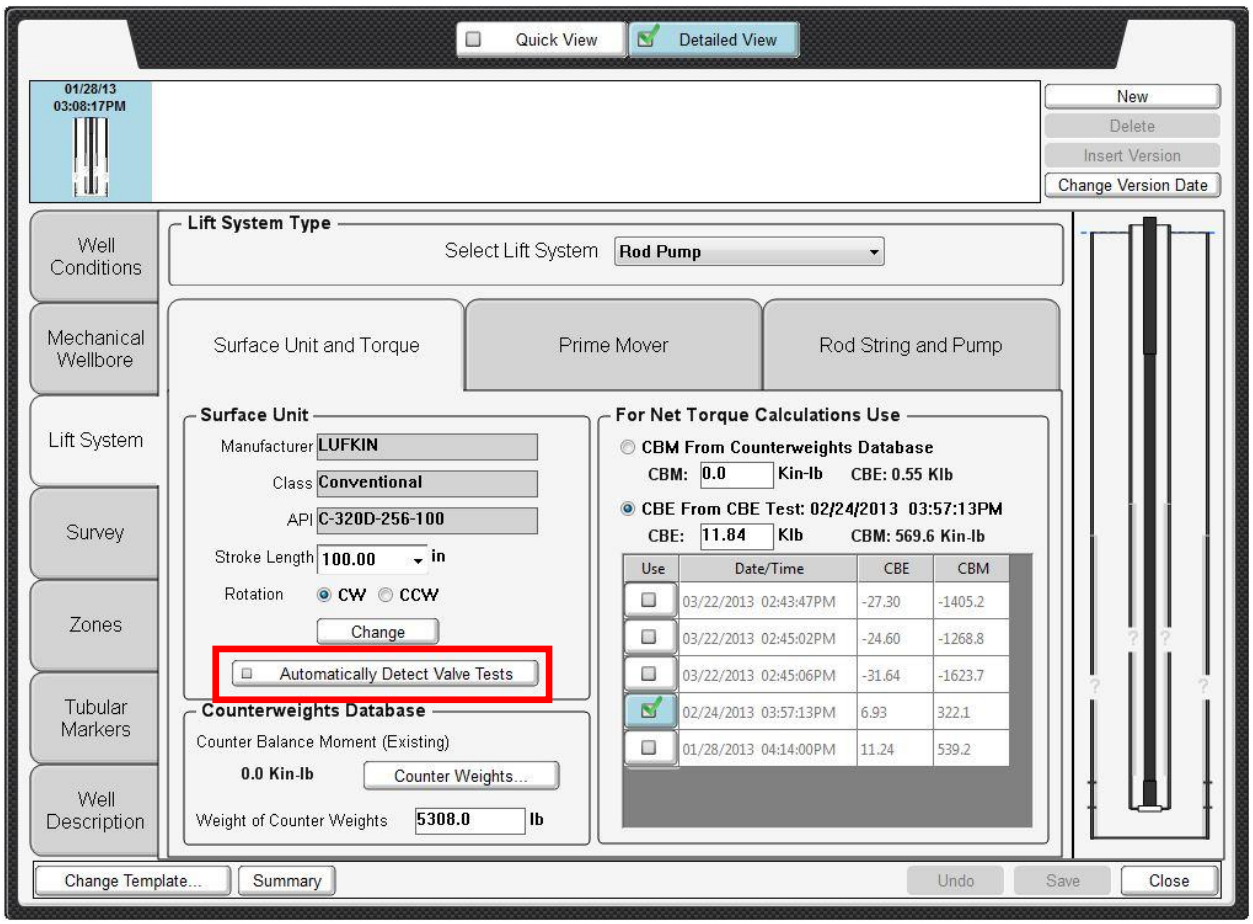

Figure 34: Automatic Valve Test Detection Option

Custom Valve Test Analysis Cursor

The Custom Valve Test Analysis Cursor is used to define and edit a Custom Valve Test Analysis. The cursor can be accessed on the Raw Data view and on the Stroke Selection Strip.

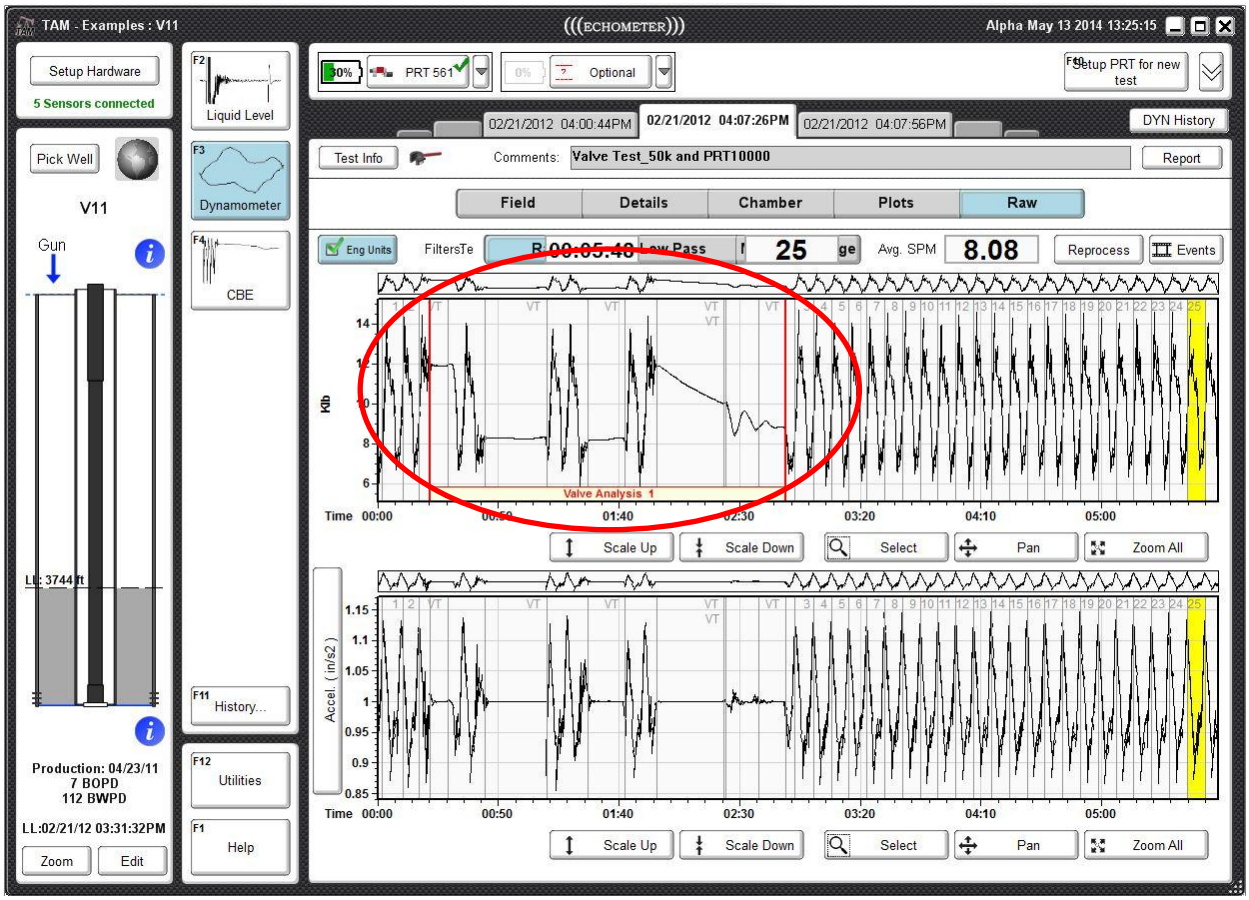

Figure 35: Automatic Valve Test Analysis Cursor on the Raw Data View

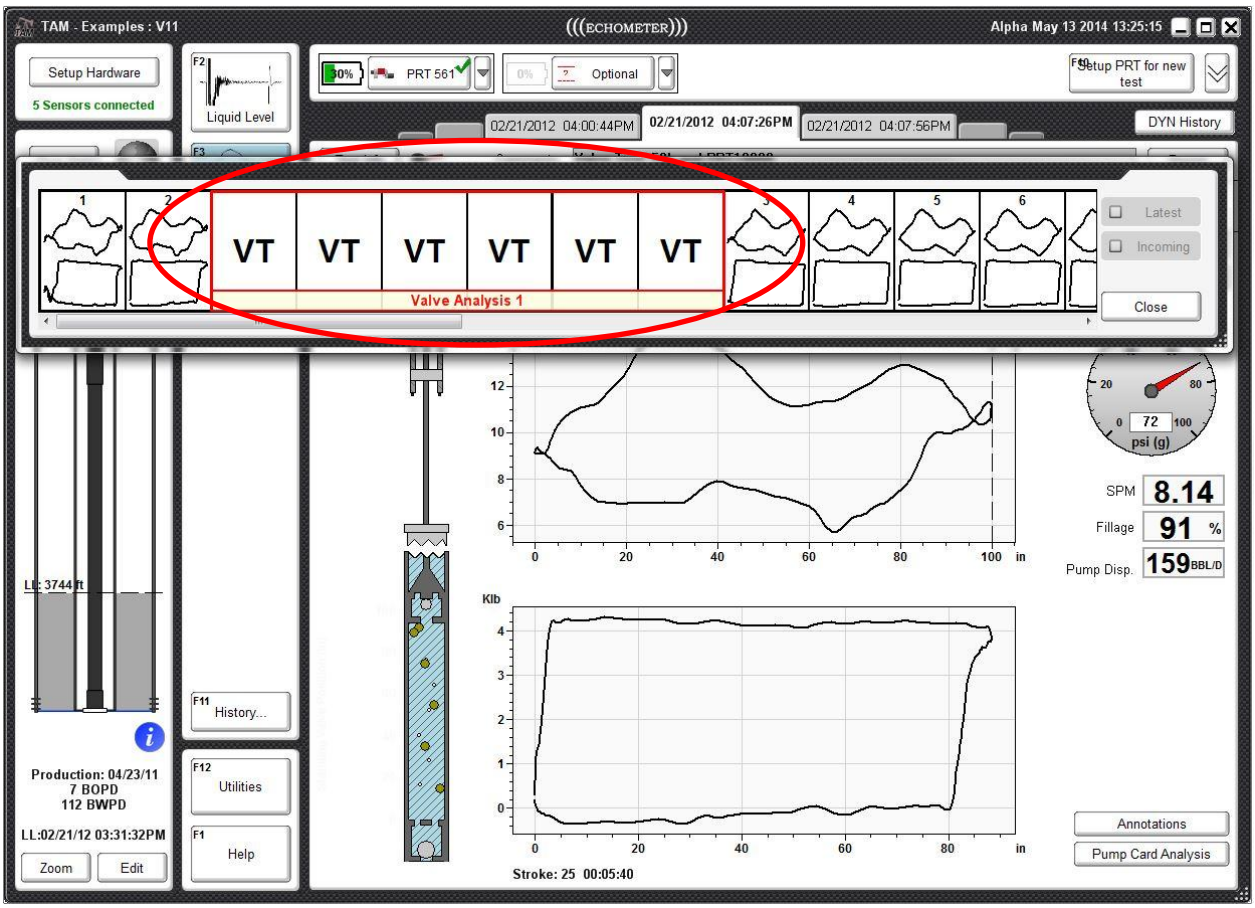

Figure 36: Automatic Valve Test Analysis Cursor on the Event Manager

The Cursors can be created by right-clicking on either the top graph of the Raw Data view or on a stroke or selection of strokes from the Stroke Selection Strip and selecting “Add Valve Analysis.” Both cursors can be adjusted by clicking and dragging on the left and right edges of the cursor. The Raw Data view cursor can be dragged by clicking on the yellow tinted label of the cursor and dragging. Both cursors can be deleted by right clicking on the cursor and selecting the “Delete Valve Analysis” option. The Custom Valve Analysis can be examined in more detail by double clicking on the label of either cursor (Figure 35 and 36).