Well Analyzer
and
TWM Software

Operating Manual
REV D

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WELL ANALYZER SYSTEM DATA SHEET

Shipping Date: ______________

WELL ANALYZER: SERIAL NUMBER _____________________
Pressure Transient Option Yes( ) No( )

COMPUTER MANUFACTURER: ___________________________________ **MODEL:** __________________________

COMPUTER SERIAL NUMBER: ____________________________________

REMOTELY FIRED GAS GUN: SERIAL NUMBER ____________

COMPACT GAS GUN: SERIAL NUMBER ____________________

HIGH PRESSURE GAS GUN: SERIAL NUMBER ______________ PRESSURE RATING _______________ psi

PRESSURE TRANSDUCER: SERIAL NUMBER ________________

COEFFICIENTS : C1 _______ C2 _______ C3 ________ C4 ________ C5 ________ C6 _______

PRESSURE TRANSDUCER: SERIAL NUMBER ________________

COEFFICIENTS: C1 _______ C2 _______ C3 ________ C4 ________ C5 ________ C6 _______

DYNAMOMETER TRANSDUCERS

SERIAL NUMBER: _____________

C1 _______ C2 _______ C3 ________ C4 _______ C5 _______ C6 ______

SERIAL NUMBER: _____________

C1 _______ C2 _______ C3 ________ C4 _______ C5 _______ C6 ______

POWER TRANSDUCER

SERIAL NUMBER: _____________________

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SAFETY

Please observe all safety rules in operating this equipment. The pressure ratings of the Echometer gas gun and all fittings, hoses, etc. should always exceed actual well pressure. Because the casing pressure normally increases during a build-up test, caution should be exercised that the well pressure does not exceed equipment pressure ratings.

Do not use worn or corroded parts. A used or corroded fitting may not withstand original pressure rating.

Not all safety precautions can be given herein. Please refer to all applicable safety manuals, bulletins, etc. Relating to pressure, metal characteristics, temperature effects, corrosion, wear, electrical properties, gas properties, etc. before operating this equipment.

The tests should not be undertaken if the operator, the test equipment and the well are not in conditions to operate safely. This equipment should not be used if the operator is tired, ill or under the influence of alcohol, drugs or medication.

LICENSE AND USE AGREEMENT FOR ECHOMETER TWM SOFTWARE AND EQUIPMENT

1. This Agreement, including the terms on the opening screen, is a legal contract between you and Echometer Company. This Agreement applies to the TWM software, including media, printed material and on-line documentation and to the Well Analyzer equipment.

2. The operator agrees to the terms on the opening screen and the terms in this Agreement by clicking on the Accept icon on the opening screen.

3. Following acceptance of this Agreement, the operator is entitled to use the software program designated as TWM.EXE to acquire and analyze data. However, this program and any related programs can be used only to acquire data by use of Echometer data acquisition systems. The analysis portion of these programs can be used on any computer to analyze data, but only data, which have been obtained using Echometer data acquisition systems.

4. THIS SOFTWARE AND DOCUMENTATION IS PROVIDED AS IS, AND ECHOMETER MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE OR THAT THE USE OF THE SOFTWARE, DOCUMENTATION OR EQUIPMENT WILL NOT INFRINGE ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADEMARKS OR OTHER RIGHTS.

5. Operator agrees that it is the responsibility of the operator to insure that the operator is working at a well pressure that is less than the rated operating pressure of the equipment involved. This includes the fittings on the well as well as valves and all Echometer equipment. The operator acknowledges that the safe operating pressure for equipment is less when the equipment is used, corroded or shows signs of abuse and wear, than when the equipment is new.

6. Operator agrees, on behalf of the operator, his/her heirs and related parties, to release and hold Echometer Company, including its employees, officers, agents and related parties, harmless from any and all liability to the operator and all related parties, for any and all loss or damage to property and injury or death to any person which results from or in any way relates to the use of Echometer software or Well Analyzer equipment.

7. The operator agrees that the terms on the opening screen and in this Agreement which are applicable to the operator are binding on the operator's company, employer, company employees and agents, provided, and to the extent, that the operator has authority to commit any one or more of these entities to these obligations.

HOW TO USE THIS MANUAL.

This is a COMPREHENSIVE MANUAL covering all the capabilities of the Well Analyzer and the TWM (Total Well Management) software. Since some users may be interested in only one aspect of the system the manual is divided into eight main sections which can be read independently.

1-Overview of the Well Analyzer System (Chapters 1, 2 and 3)
2-Acoustic Well Surveys (Chapters 4 and 5)
3-Pressure Transient Testing (Chapter 6)
4-Liquid Level Tracking (Chapter 7)
5-Dynamometer Surveys (Chapter 8)
6-Measurement of Motor Current and Power (Chapters 9 and 10)
7-Troubleshooting Well Analyzer and Utilities (Chapter 11)
8- General Data Acquisition (Chapter 12)
9-Related Technical Topics (Appendices)
10-Addendum Volume – Details of application of Well Analyzer system to **Gas Wells** and **Plunger Lift Wells**

If you are already familiar with the Well Analyzer system you may skip section 1 and proceed to the specific section of your interest.

If you are not familiar with the Well Analyzer System, please read Section 1 before proceeding. The publication "Total Well Management" that can be downloaded from the Echometer web page gives an overview of the system's capabilities as applied to optimizing pumping well performance.

ORGANIZATION OF TOPICS

Within each section the information is generally organized as follows:

- The Analyzer's hardware and software required for the specific application are described first.
- Detailed instructions for use of the software are given next.
- Field examples are given to illustrate typical applications.
- Troubleshooting guidelines are included when appropriate.
- Hardware operation and maintenance procedures are discussed.

1.0 - OBJECTIVES OF THE WELL ANALYZER SYSTEM

The principal objective of the Well Analyzer is to provide to the operator all the necessary data to analyze the performance of an oil or gas well. This objective is accomplished by using combinations of hardware and computer software which are specific to the particular measurement to be undertaken. The most general configuration of the Well Analyzer System is represented in the schematic block diagram shown in **Figure 1.**

Application and interpretation of the measurements that are made with the Well Analyzer can provide answers to numerous questions related to the production of pumping oil wells. The following are partial lists of typical questions that can be answered by proper use and interpretation of Analyzer measurements:

From Acoustic Surveys:

- Is there liquid above the pump? At what depth is the top of the liquid column?
- Is gas flowing up the annulus? If yes, at what rate?
- What is the casing-head pressure? Is it changing with time?
- What is the percent liquid in the annular fluid column?
- What is the pressure at the perforations?
- What is the percent of the maximum oil rate that is currently being produced?
- What is the maximum rate that could be produced from the well?
- What is the sound speed in the annular gas?
- What is the average gravity of the gas in the annulus?
- Are there any restrictions or anomalies in the annulus above the liquid level?

From Dynamometer measurements:

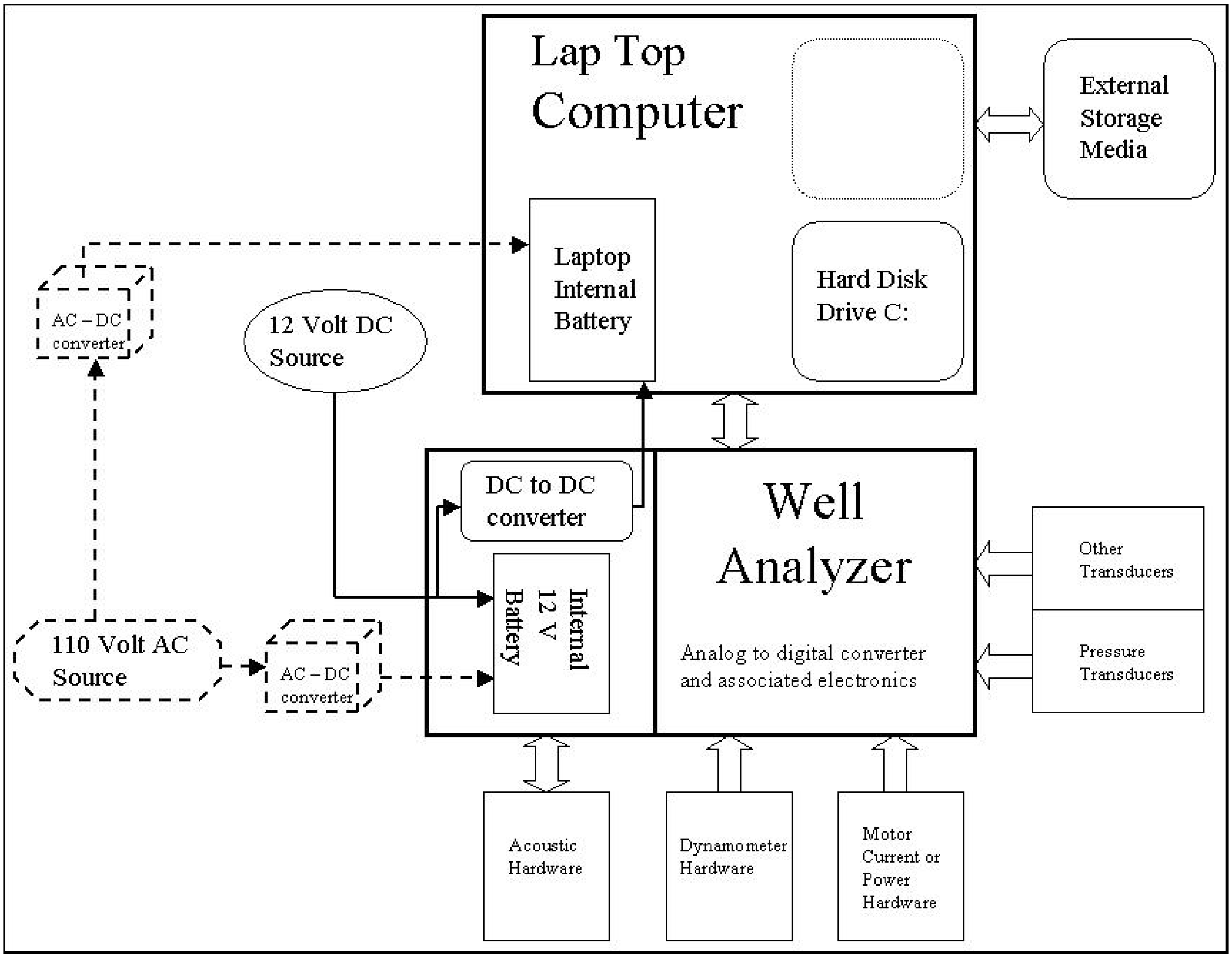
- Is the well pumped off?
- What is the percent pump fillage?
- Are the traveling and/or standing valves leaking?
- What is the pump displacement in barrels per day?
- What is the effective pump plunger travel?
- What is the current pumping speed?
- What is the fluid load on the pump?
- Are the maximum and minimum polished rod loads within the capacity of the pumping unit and the rods?
- What is the polished rod horsepower?
- Is the maximum torque less than the gearbox specification?
- Is the unit properly balanced?
- What movement of the counterweights is required in order to balance the unit?
- What is the weight of the rods in the fluid?
- Does the pumping system require a detailed analysis and/or redesign?

From Motor Current Survey:

- What is the motor current throughout the pumping cycle?
- Is the motor over/under sized for the unit and the load?
- Is the unit properly balanced?
- Does the motor performance require more detailed analysis ?

From Liquid Level Tracking Survey:

- What is the depth to the liquid level?
- Is the liquid level rising or falling?
- Is the liquid level within a pre-set depth interval?



Well Analyzer System Block Diagram

From Motor Power/Current Surveys

- What is the power use during a pump stroke?
- What is the apparent motor current?
- Is the motor generating electricity at some time during the stroke?
- What is the exact power consumption, KWH/day, $/month, $/BBL?
- Is the motor over/under sized for the unit and the load?
- What is the torque loading?
- Is the unit properly balanced?
- What movement of the counterweights is required in order to balance the unit?
- What is the recommended minimum sized motor?

From Transient Pressure Surveys:

- What is a good estimate of reservoir pressure?
- What is the flowing bottom-hole pressure?
- What is the pressure buildup rate?
- Is there annular afterflow of liquid/gas when the well is shut in?
- Is there any wellbore damage?
- Is the well fractured?
- Does the well require a detailed pressure transient analysis ?

From Plunger Lift Surveys

- Where is the plunger? Above the liquid?
- What are the velocities of the plunger?
- What is the depth to the top of the liquid?
- What is the producing BHP?
- Is liquid in the casing annulus above the tubing intake?
- What is the gas gravity?
- Are there any restrictions to plunger fall in the tubing?

From Custom Surveys:

- In gas lift wells, where is the fluid level in the annulus?
- How many gas lift valves are uncovered?
- In a shut-in gas well, where is the fluid level inside the tubing?
- In a shut-in well, what is the bottom-hole (reservoir) pressure?
- Status of a Subsurface Safety valve (open/closed)?
- In Plunger lift wells, what is the plunger fall speed and time to bottom?
- Position of liquid slugs in batch treatments ?
- Pressure buildup in flowing wells.?
- Calibration of downhole ESP pressure transducer.

The following sections of this manual explain in detail how the Well Analyzer may be used to solve the majority of problems faced when trying to optimize well performance and to minimize operating costs. It is strongly recommended that the operator become familiar with the material in the manual before attempting to operate the equipment.

2.0 - OVERVIEW OF WELL ANALYZER APPLICATIONS

The following is a discussion of the background technology that has resulted in the development of the Well Analyzer and a brief description of the measurements that can be undertaken.

2.1 - Acoustic Well Surveys

Acoustic echo-ranging techniques to generate well soundings have been in effect for over sixty years to aid in the analysis of pumping wells[1]. Early application was limited to determining the presence of liquid in the annulus above the pump. If liquid was found over the pump then the operator knew that additional production was available if a larger pump was installed; or, if the pump was not operating properly, that the pump should be pulled and repaired.

Soon after the development of these instruments, some operators realized that proper interpretation of the records could yield additional information. In particular bottom-hole pressure was calculated from the summation of the surface casing pressure plus the gas column hydrostatic and the liquid column hydrostatic pressures. This presumed some knowledge of the density and distribution of the oil and water in the liquid column especially in the case of shut-in wells where relatively high liquid columns were observed. Operators also observed that in those instances where gas was vented from the annulus, the calculated bottom-hole pressure was excessively high. This was attributed to the lowering of the effective liquid gradient by the presence of gas bubbles in the liquid column above the perforations. C. P. Walker[2] patented a method for determining the density of annular liquid columns which are aerated by gas bubbling upward through the liquid. Walker presented a technique whereby a back-pressure valve is used to control and increase the casing-head pressure causing the annular liquid level to fall a distance corresponding to the pressure increase. The gradient of the gaseous liquid is calculated by dividing the change in pressure at the top of the gaseous liquid column by the corresponding drop in liquid level. This gradient is then used to calculate the bottom-hole pressure. If the back-pressure valve setting is further increased until the top of the gaseous liquid column is stabilized in the vicinity of the pump intake, which generally is near the perforations, then the producing bottom-hole pressure can be estimated quite accurately since the contribution of the hydrostatic pressure from a short gaseous-liquid column is small in relation to the

[1]Walker, C. P., "Determination of Fluid Level in Oil Wells by the Pressure-wave Echo Method," AIME Transactions, 1937, pp. 32-43.

[2]Walker, C. P., "Method of Determining Fluid Density, Fluid Pressure, and the Production Capacity of Oil Wells, US. Patent No. 2,161,733 filed October 26, 1937.

casing-head pressure, and errors in the gradient estimate will not significantly affect the resulting total pressure. In the majority of producing wells in the United States, the liquid level is near the pump inlet and the casing-head pressure plus the gas hydrostatic will yield a very close estimate of the producing bottom-hole pressure. This method which was presented over 50 years ago is still one of the most useful methods for obtaining accurate producing bottom-hole pressure.

Recent studies by McCoy, et al.[3] have presented a technique of obtaining the casing annulus gas flow rate by measurement of the casing annulus gas pressure buildup rate. Utilizing the casing annulus gas pressure buildup rate and the void volume in the casing annulus, a reasonably accurate casing annulus gas flow rate can be obtained. If the casing annulus gas flow rate is known, an estimate of the liquid column gradient is made using a correlation developed from field data . This calculates a reasonably accurate producing bottom-hole pressure even when gaseous liquid columns exist above the pump. In addition to the casing annulus gas flow rate, the operator can determine the specific gravity of the gas if an acoustic well sounding is made since the acoustic velocity and the pressure are known and the temperature can be estimated. Determination of the annular gas specific gravity permits a more accurate calculation of the gas column pressure.

Use of digital lap-top computers permits an operator to automatically obtain acoustic liquid level data and surface pressure measurements from which bottom-hole pressures can be calculated. A long term pressure buildup and/or draw down test in pumping wells can thus be done inexpensively. Pressure buildup data, permits the operator to obtain reservoir properties such as permeability, skin damage, reservoir pressures and numerous other parameters at a relatively low cost.

Four important achievements are possible by utilization of a microcomputer. First, the computer can utilize digital processing of the acoustic data to obtain more accurate liquid level depths, automatically. Second, the determination of bottom-hole pressures from the acoustic liquid level measurement, the surface pressure, and properties of the produced fluids is automatically available. Third, the computer offers automatic operation of the equipment in that the computer can be programmed to perform well soundings and obtain casing pressure measurements on command, without operator attention. Fourth, well data can be stored and managed efficiently and accurately. This allows analysis of well performance, transient pressure and pumping performance in a timely way.

2.2 - Dynamometer Surveys

Rod pumping continues to be the most widely used method of artificial lift. Economic conditions dictate that maximum efficiency be maintained in these installations at all times. Methods for analysis of beam pump performance are principally based on Gilbert's[4] and Fagg's[5] development of the beam pump dynamometer where the load at the polished rod was recorded graphically as a function of its travel to generate a chart which represented the work undertaken at the surface unit for every pump stroke.

Modern developments have concentrated in refining the techniques for interpretation of the characteristics of this load-displacement curve so that a detailed analysis of the system can be undertaken which yields among others:

Load distribution in the rod string
Load and displacement at the pump
Pump valve operation and leakage
Surface torque and counterbalance efficiency
Fatigue loading and rod buckling
Motor performance

With the advent of high performance digital data acquisition systems, attention has been given to a more complete analysis of pumping unit performance. Simultaneous measurement of numerous dynamic parameters (Kilowatts input, power factor, motor torque, gear torque, polished rod position, velocity, acceleration and load, motor speed and unit's strokes per minute) are possible and cost effective.

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[3]McCoy, J. N., Podio, A. L. and K. L. Huddleston: "Acoustic Determination of Producing Bottomhole Pressure," SPE Formation Evaluation, September 1988, pp. 617-621.
[4]Gilbert, W.E., "An Oil Well Pumping Dynagraph," API Drilling and Production Practice, 1936, pp. 94-115
[5]Fagg, l. W., "Dynamometer Charts and Well Weighing," Petroleum Transactions, AIME, Vol. 189, 1950, pp. 165-174.

The Well Analyzer provides means to acquire data from load and acceleration transducers in order to undertake either simple or advanced dynamometer analysis. The operator can select this mode from the Analyzer's main menu by entering the appropriate choice and following up with the necessary information regarding the characteristics of the transducers that will be used.

The Analyzer provides means for acquiring and displaying the dynamometer data and to store the same information on diskette for further processing and analysis.

2.3 - Beam Pump Balancing and Torque Analysis

The importance of proper counterbalancing in beam pumping stems from its effect on operating and maintenance costs. Proper counterbalancing means a smoother operation of the pumping unit, reduction of variation in speed and load, reduction in variation of gearbox torque, reduction of stresses on the sucker rods and an increase in SPM.

Torque analysis is the primary means of counterbalance calculation. Calculation from dynamometer measurements requires measurement of the effect of the counterweight as transmitted to the polished rod. This is a function of the position of the counterweights on the cranks and the geometry of the beam pump. The counterbalance effect can be measured directly using the dynamometer. The unit geometry can be determined from physical measurement of dimensions of key elements, or in general is obtained from a data base of standard beam pumps. Balancing is then undertaken by measurement of the position of the counterweights on the cranks, identification of the cranks and calculation of the change in counterbalance moment corresponding to a change in the position of the counterweights.

The dynamometer data which consists of polished rod load as a function of position, is converted to net torque as a function of crank angle. The resulting torque function is then examined in terms of the torque exhibited during the upstroke and during the down stroke. Proper balancing is generally considered to be that which evens out the torque so that the peak torque on the upstroke is approximately equal to the peak torque on the down stroke. Once the actual torque curve has been calculated it is possible to calculate the effect of changing the position of the counterweights on the torque. Thus, the software provides a recommendation regarding how the unit would perform if it were properly balanced.

Since the majority of beam pumps are driven by electric motors, counterbalancing is often attempted by means of measurements of motor current. The basis for this is that there is a direct relation between electric motor current and motor torque but the relationship is not linear..

However, it must be pointed out that the commonly used electrical current probes do not differentiate between direction of current flow. In most beam pump installations, the cyclical loading imposed by the pump (rod load increases to rod-weight-in-fluid plus fluid load then decreases to rod-weight-in-fluid) is such that during certain portions of the stroke the motor is actually driven by the pumping unit. At these points the motor is acting as a generator and current is flowing back to the line. The current probe will indicate this generated current without regard to direction of flow. This can often mask the current peaks that correspond to the torque peaks and makes very difficult balancing of the unit using the standard current measurement.

The Echometer Motor Current Survey program, discussed in section 9.0 of this manual, provides a means of determining accurately the magnitude and direction of current flow in each of the lines of the 3-phase electrical supply.

The Echometer Power Survey program, discussed in Section 10 of this manual, provides a means of determining accurately the power use and current flow in the motor during a pump stroke. The power data is also interpreted in terms of gear reducer torque and the program gives information on how to adjust the counterweights in order to obtain a balanced condition. This does not require knowing the geometry of the unit nor identification of the cranks. The user only needs to input the weight of the counterweights that he wishes to move. The program calculates the distance that they need to be moved from their present location.

2.4 - Pressure Transient Testing

Flowing bottom-hole pressure surveys, pressure buildup tests and pressure draw down tests are the principal tools to determine reservoir pressure, formation permeability and skin factor. These techniques are widely used in flowing wells and in some gas lift wells, where the pressure information is easily obtained from wireline-conveyed bottom-hole pressure recorders. The presence of the sucker rods in beam pumped wells essentially precludes practical, routine, direct measurement of bottom-hole pressure, thus eliminating the single most important parameter for well performance analysis. Permanent installation of surface indicating bottom-hole pressure gauges have not become cost effective, nor have wireline measurements through the annular space.

The Automatic Acoustic Pressure Transient system is based on the Digital Well Analyzer configured for long term unattended operation. This is implemented by providing a long term source of power and gas, and switching to software specially developed for pressure transient data recording and analysis. The TWM program special module for Pressure Transient Data Acquisition and Analysis has the multiple functions of controlling the well testing sequence, acquiring, storing and analyzing the data and generating tabular and graphical outputs.

The bottom-hole pressure calculation is based on wellhead pressure measurement, determination of the depth of the gas/liquid interface and calculation of the annular fluid gradients. In order to achieve the maximum accuracy in calculating the BHP, the Well Analyzer software accounts for temperature variations, and acoustic velocity variations due to changes in composition of the annular fluid caused by the pressure variations during the transient test.

During the several days of the typical well test duration, the transducer sensing element may undergo temperature changes of over 60 degrees F. Even though the transducer is self temperature compensated such a temperature change can cause small errors in the measurement of casing head pressure which would be unacceptable for pressure transient analysis. Additional corrections are introduced by measuring the temperature with a thermistor and computing the corresponding pressure deviation from calibration curves obtained for each individual transducer and entered in the program.

During the well test (buildup or draw down) the pressure, temperature and composition 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 calculated from an automatic count of filtered collar reflections and the average joint length. A table of acoustic velocity as a function of time is generated for each testing sequence and is stored with the pressure data. The data reduction program 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 was not taken into account and a single value for acoustic velocity was used in interpreting the travel time data, a significant error in calculated BHP would be made.

Several papers have been presented on the correct methods for calculation of bottom-hole pressure from acoustic determination of annular liquid levels[6]. The BHP is the sum of the casing head 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 gradient of the annular fluid column is a function of the composition of the liquids, and the in-situ water/oil ratio and gas/liquid ratio. Pumping conditions and well geometry determine the fluid distributions. For example, at steady state pumping rate 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 afterflow period. These factors are taken into consideration by the program in calculation of the bottom-hole pressure. In-situ oil and water densities are calculated as a function of pressure and temperature using conventional correlations.

When the producing bottom-hole pressure is below the bubble point, free gas is produced from the reservoir and is generally produced from the annulus. This annular gas production reduces the liquid column gradient and thus has to be taken into 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[7] is used to account for this effect. However when a long gaseous liquid column is present, in order 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 casing head back pressure while maintaining a steady pumping rate. This is easily achieved by means of an adjustable back pressure regulator installed on the casing head valve. It is very important that the well has been stabilized before starting the pressure transient test.

[6]See reference papers in Appendix
[7]McCoy et al. 1988.

2.5 - Liquid Level Tracking

The position of the liquid level in the annulus is an important indicator of the well's pressure balance condition. This is especially important during workover operations when the Christmas tree is not in place and during well killing procedures when the well pressure status must be inferred. The Well Analyzer can be used in the continuous survey mode to automatically measure and track the position of the annular fluid level.

2.51 - Well Killing and Workover Operations

Whenever it is necessary to kill a well prior to undertaking certain workover operations, it is necessary to determine the minimum amount of kill fluid to be introduced into the well. Excessive overbalance will result in greater formation damage and excessive costs. Inadequate overbalance will result in a kicking well. By continuously monitoring the kill fluid level in the annulus it is possible to maintain close control of the back pressure on the formation. The module Liquid Tracking (LT) automatically fires acoustic pulses at preset intervals as frequent as 2 minutes, calculates the depth and displays the position of the liquid level as a function of time. An alarm is given if the fluid level rises above or falls below a predetermined depth interval. The program also can close a relay switch that may be connected to the rig's audible alarm system.

2.52 - Batch Treatment Monitoring

Periodic injection of chemicals into wellbores are commonly used as remedy to paraffin deposition, corrosion inhibition and perforation cleaning. The LT module provides a simple means for monitoring the position of the batch treatment once it has been injected into the well. The descent of the treatment fluid can be observed by monitoring the position of the gas/liquid interface as a function of time.

2.6 - Special Purpose Testing

Echometeric surveys have been developed primarily for application to beam pumping analysis and optimization. The recent advances in portable computing has made it possible to effectively use echometeric surveys for numerous other applications that involve determining the distribution of fluids and pressures in a wellbore.

2.6.1 - Gas Lift

The most common application involves the determination of the fluid level in the annulus in relation to the depth to the unloading valves. This allows monitoring the progress of the unloading operation and to determine if and when the operating valve has been uncovered and is injecting gas into the tubing. The casing fluid level measurements can also be interpreted in terms of flowing bottom hole pressure by the procedure presented by McCoy.[8] Fluid level measurements through tubing are similar to those undertaken in gas wells. See addendum for further information.

2.6.2 - Subsurface Safety Valve Testing

In offshore installations it is necessary to periodically test the operation of Surface Controlled Subsurface Safety Valves (SCSSV). This is generally undertaken by shutting-in the well at the Christmas tree, letting the pressure build up and stabilize, then shutting the SCSSV and then bleeding the pressure in the tubing above the valve. Often the valve will not fully close due to sand, debris or corrosion preventing its full motion. In general the gas-liquid interface in the tubing will stabilize below the SCSSV. Therefore an echometric survey will give a positive indication that the valve has operated properly and is closed prior to beginning the bleeding of the tubing pressure. This can save significant time since it is possible to actuate the valve several times until it operates properly. If this is not achieved then the decision to pull the valve can be made with minimum delay.

[8]McCoy: "Acoustic Determination of Bottomhole Pressure in Gas Lift Wells", Petroleum Engineer International, August 1976.

2.6.3 - Through Tubing BHP Surveys

Echometric surveys can be undertaken through tubing as well as through the annulus. The depth to the gas/liquid interface can be obtained by means of the various processing options provided by the Well Analyzer. When the tubing exhibits even minor internal cross sectional changes such as collar recesses, the automatic collar counting processing is easily undertaken. In those instances where the tubing is internally flush the other processing options: using depth to known landing nipples or cross-overs, using acoustic velocity, etc. provide the necessary information to make BHP calculations. A broad range of experience has been accumulated by Echometer Engineers in this type of unconventional testing in flowing and high pressure wells. Gas guns are available which have operating pressures up to 15000 psi. These guns use the gas in the well to generate an acoustic pulse.

2.6.4 - Liquid Displacement in Tubing

Echometeric surveys have been used successfully to determine the position of liquid slugs that have been introduced in a well as part of routine treatment with corrosion inhibitors, paraffin solvents or other batch treatments.

2.6.5 - Plunger Lift Applications

The Well Analyzer's Acoustic Fluid Level and Plunger Lift modules are used to determine the position of the plunger, the plunger fall speed and to analyze the performance of the well. These very powerful tools can be used to trouble shoot and optimized the operation of wells producing by plunger lift. See the manual addendum for further details.

Several articles have been published on the subject and reprints may be downloaded form www.echometer.com .

2.6.6 - Gas Well Applications

The Well Analyzer's Acoustic Fluid Level and Pressure Transient modules can be used to determine the fluid distribution in the tubing of flowing gas wells to evaluate liquid loading conditions. See the TWM manual addendum for further details.

3.0 - GENERAL CONSIDERATIONS ABOUT WELL ANALYZER SOFTWARE

The Well Analyzer is controlled by the laptop computer. The computer operates from a program, stored on the hard disk. Turn the computer on. A memory test will automatically start as displayed on the top line of the screen. Wait for the memory check to be completed. Then the Well Analyzer software program TWM will automatically load into memory. The following discussion assumes that you have a computer with a 486, or better, microprocessor, a hard drive and a CD or floppy drive as configured by Echometer Co. and running Windows 95, Windows 98, Windows 2000, ME, XP or NT.

3.1 - Programs

The Well Analyzer is used in conjunction with the TWM (Total Well Management) software although earlier models used DOS-based software programs DE, DYN, EBUP, POWER, LQTR. The DOS operation of the Well Analyzer is described in a separate operating manual. Please contact Echometer Company for more information.

<u>Data Acquisition and Analysis Programs:</u>

The Program TWM includes the following modules for data acquisition and analysis:

Acoustic
Dynamometer
Power/Current
Pressure Transient
Liquid Tracking
General Data Acquisition
Plunger Lift

<u>Beam Pump Design Program</u>

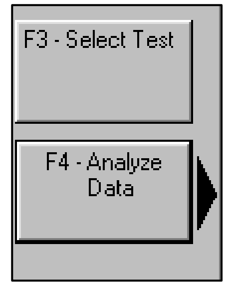
The Well Analyzer is supplied with Program **QRod 2.4** (Wave Equation Program for Beam Pump Design for Windows) to provide the user with the capability of designing and analyzing beam pump installations. The **QRod** program is a free program that can be downloaded from www.echometer.com and installed on numerous computers as needed.

3.1.1 - Use of Keyboard Keys and Mouse.

The TWM software has been designed to be as simple as possible to use. The graphical user interface follows all the Windows conventions. The majority of the modules are executed by following prompts which are presented on the screen and that either require entry of data or striking a function key or an Alt-key combination. Whenever possible function keys have been designated to produce similar results in the various applications. The user will often have to choose actions from a screen menu. The **tab, shift tab, enter, PageDown, PageUp, Arrow, function** and **escape** keys are commonly used to move within a screen or menu and to execute instructions. It is also possible to use an external mouse or built-in tracking pointer and click buttons to move within a screen and select actions to be completed. Additional menus and functions are accessed by **right-click** or **left-click** buttons on the mouse. Details are given in the corresponding sections of this manual.

NOTE

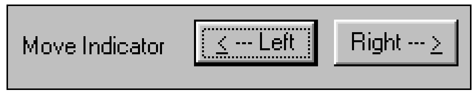
It is recommended that the **<u>user follow the instructions and menu choices that are displayed on a given screen</u>**. The programs were written for a fully Windows-compatible system, and the computer in use may not be fully compatible. The programs have been designed to be insensitive to accidental inputs from random keystroke, invalid data, etc. However there may be unusual combinations of keystrokes that will result in the programs not operating as expected. In these instances it is recommended that the computer be turned **OFF** and the program be re-initialized.



The **operator determines** the **flow** of the program by selecting and acting on the corresponding control button, function key or key combination. The standard Windows conventions are used for navigation within the form displayed on the screen:

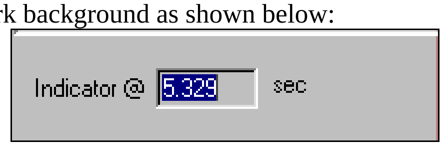
Function Keys: Pressing a function key is equivalent to clicking on the button labeled with the same F-number. For example pressing the F3 key is equivalent to clicking the Select Test button and initiates the same sequence of events.

Tab Key: Pressing the Tab key will traverse through the display and activate the various controls buttons or fields highlighting the one that is currently active:

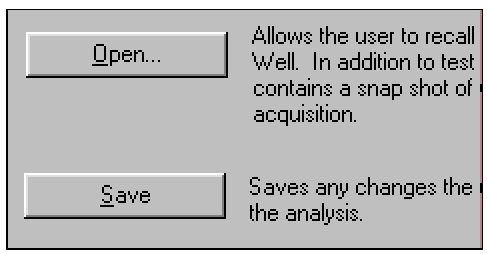


Once a button is highlighted it is activated by pressing the **Enter** key or the **Space Bar**.

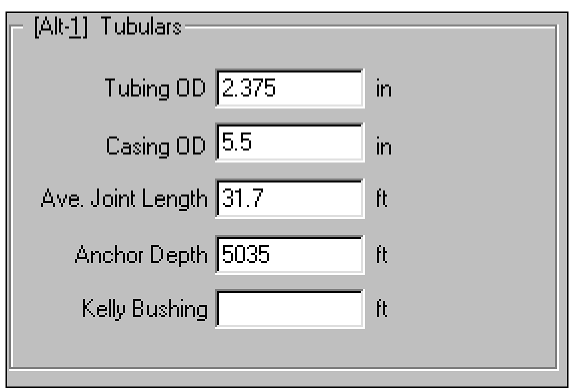
An active field is highlighted with a dark background as shown below:



Alt-Key: Pressing a key wich is displayed on a button with an <u>Underscore</u> while pressing the **Alt** key is equivalent to activating the corresponding control button or field. For example depressing **Alt-S** is equivalent to clicking on the **Save** button as shown below:



Pressing the **Alt-1** combination will activate the tab area for entry of tubular sizes as shown below:
Once the area has been made active the tab key allows to select the fields for entering data.



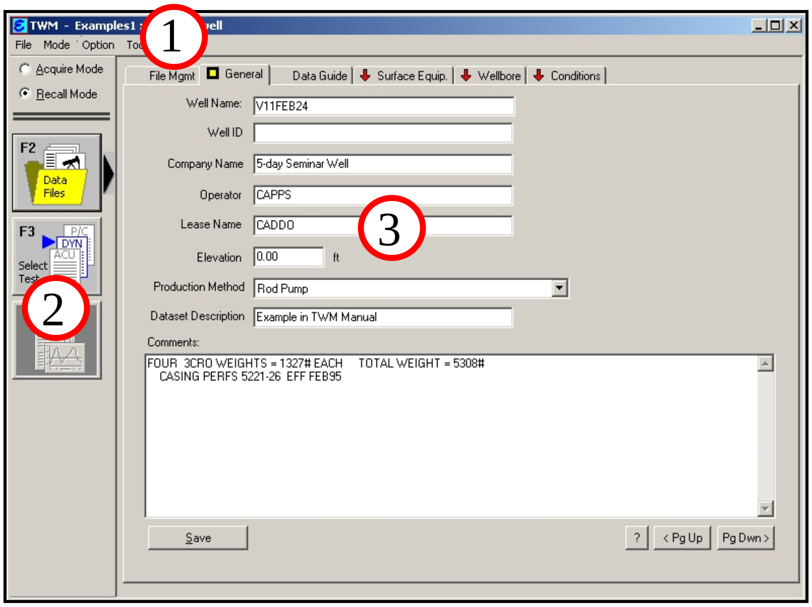
Generally fields with a **white background** are used for **typing-in** data or text, fields with a **grey background** are used to **display** stored data or calculated values

3.2 - Environment

The TWM Environment is divided into three regions:

1-The Menu Bar
2-The Dialog Bar
3-The Tab Area

As shown in the following figure

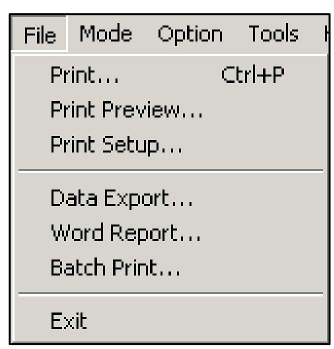


3.2.1 - The Menu Bar

The menu bar at the top of the window allows you to select various commands in TWM.

While TWM's submenus may change based on your location in the program, the six main menus will not change.

3.2.2 - The File Menu:



Print
Outputs a report to the printer. The type of report printed is determined by the current location within the environment.
Print Preview
Creates a window displaying the report to be printed.
Print Setup
Allows you to choose a default printer, paper size, and orientation.
Data Export
Creates a spreadsheet that contains selected values from tests
Word Report
Creates a standard report through an MS Word macro.
Batch Print
Allows printing test reports for multiple wells
Exit
Quits TWM.

3.2.3 - The Mode Menu:

The Mode Menu has the same function as the upper portion of the Dialog Bar. It allows you to switch between the two modes of the program.

Acquire Mode

Configures TWM to capture new test data.

Recall Mode

Configures TWM to display and analyze tests previously captured.

3.2.4 - The Options Menu:

The Options Menu has the same function as the lower portion of the Dialog Bar. It allows you select which option is available in the Tab Area.

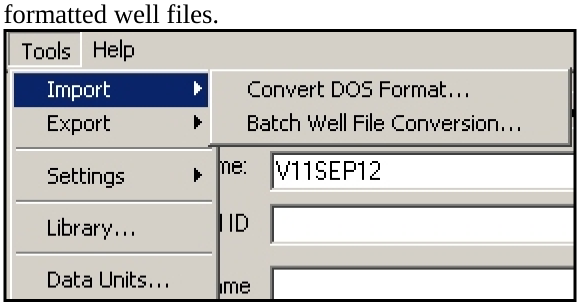
Note: This menu changes depending on which mode is selected.

3.2.5 - The Tools Menu

3.2.5.1 - Import

Convert DOS Format: Allows data and well files from the DOS version of Well Analyzer to be used with TWM.

Batch Well File Conversion: Allows conversion of several DOS version Well Files to the TWM formatted well files.

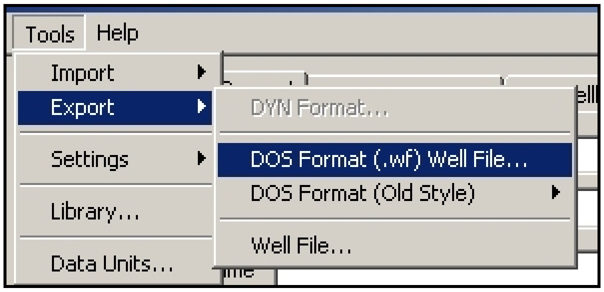


3.2.5.2 - Export

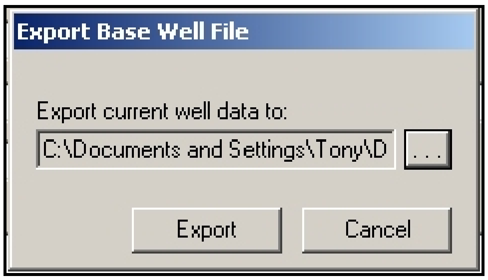
DOS Format (.wf) Well File: Creates a **Well File** (*.wf) that can be used with the DOS version of Well Analyzer.

DOS Format (Old Style): Creates DOS formatted **data files** from TWM data

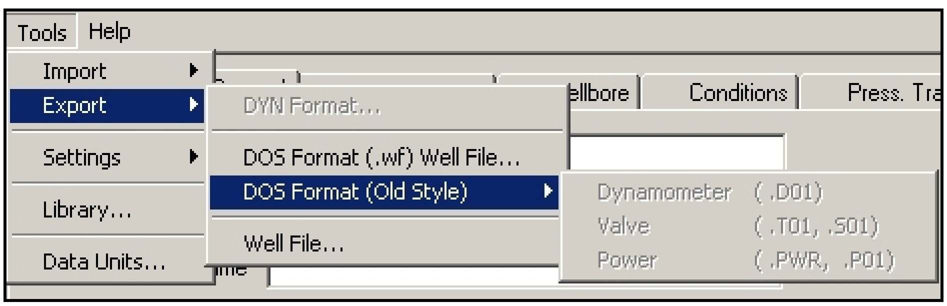
DYN Format: Creates a surface dynamometer text file in the standard DYN format.



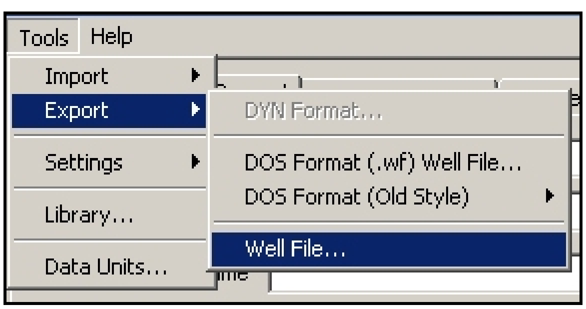
The program then asks for the location where to export the file:



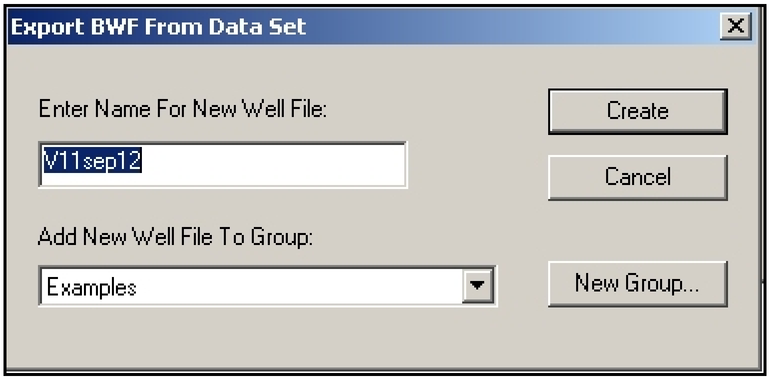
Old format DOS data files may be exported from TWM data:



TWM formatted Base Well Files may be exported or stored in different groups:

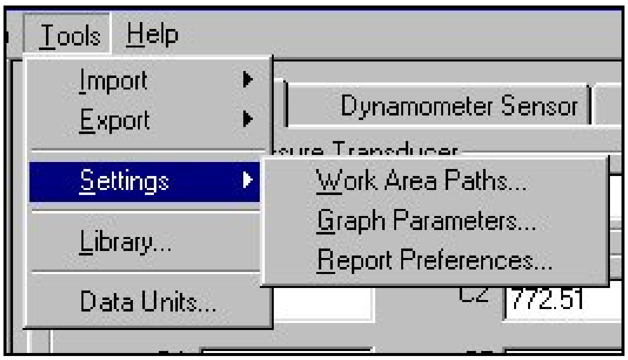


Destination of the copied base file is selected by the user in the next screen:

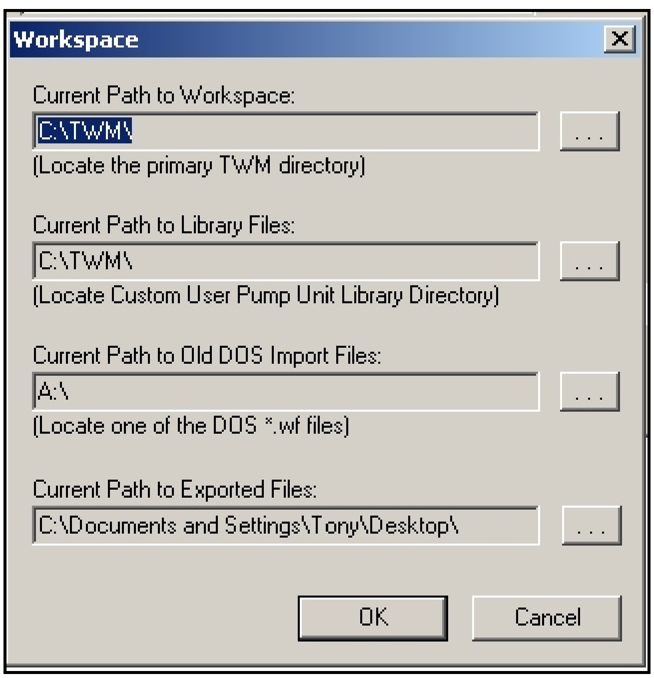


3.2.5.3 - Settings

Allows modifying the user's preferences regarding files, graphs and reports.

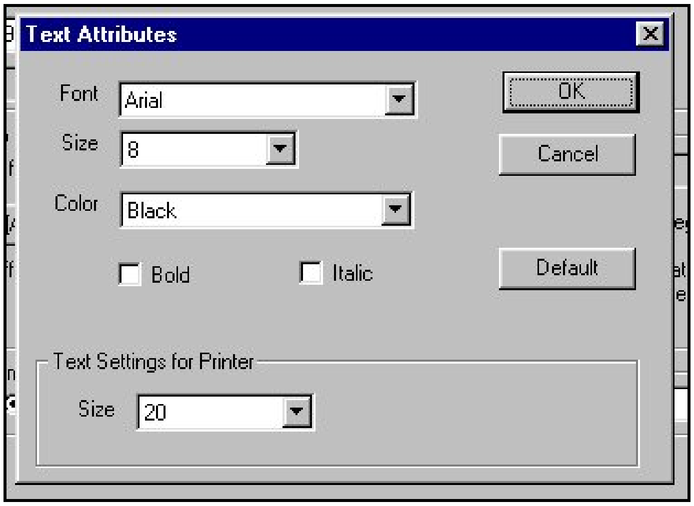


Work Area Paths: Sets the default paths used by TWM.

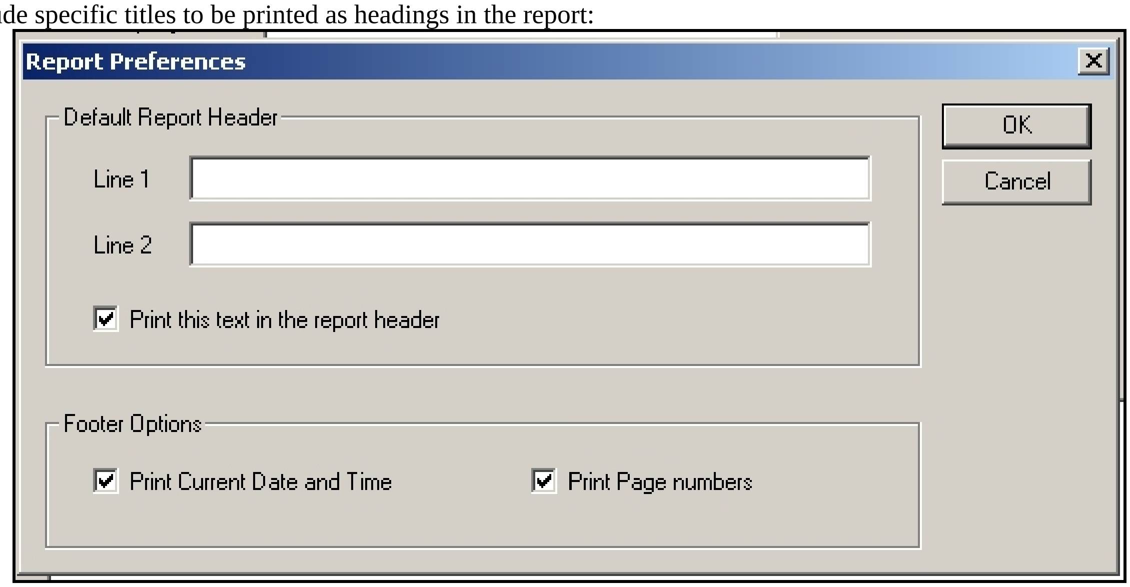


The path could be directed to TWM files on a remote server if the computer has access to a network.

Graph Parameters: Sets the parameters used by TWM to draw graphs.

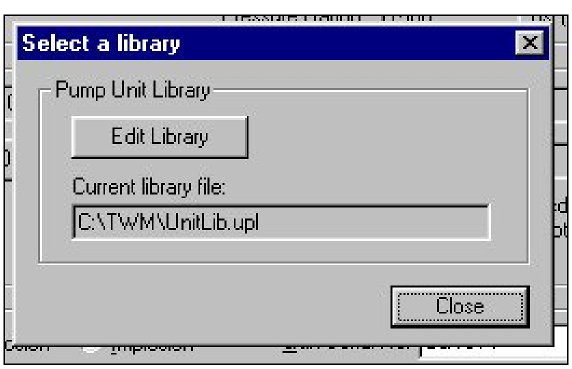


Report Preferences: Reports are printed from the **File Menu**. The following screen is used to define report format and to include specific titles to be printed as headings in the report:

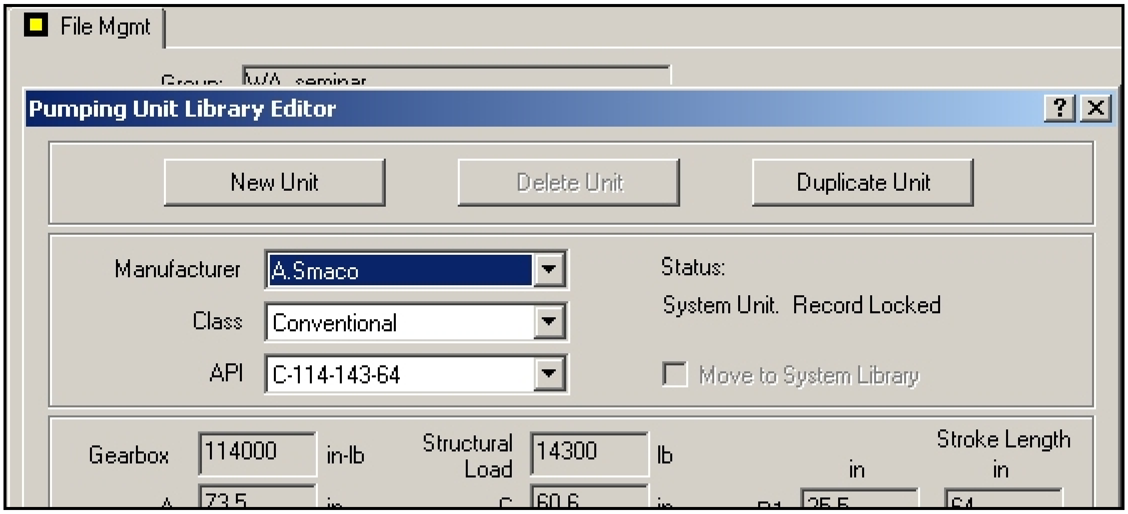


3.2.5.4 - Library

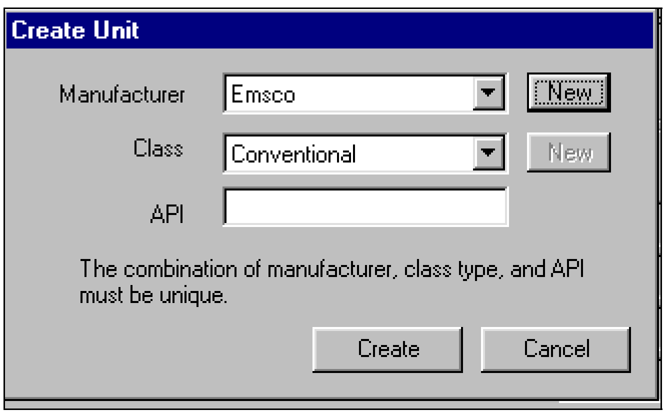
Allows the user to view and maintain the **Pump Unit Library** information.



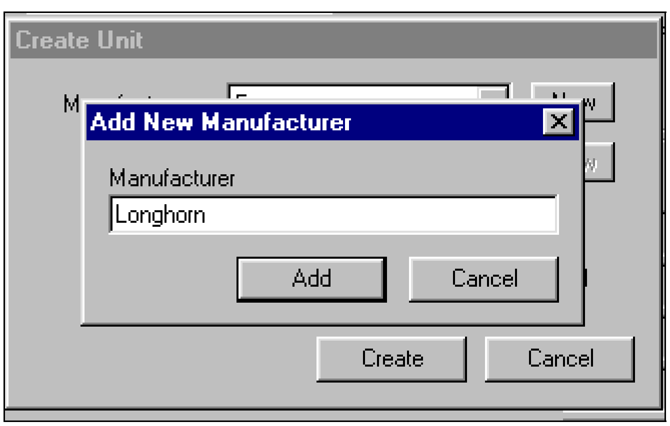
The **Edit Library** option allows modifying the parameters of a unit which is already part of the library. It can also be used to enter parameters for a new unit.



When an existing unit does not match a unit already included in the library the **Create Unit** option will present the following input form:
Adding a **new unit** for an existing manufacturer:

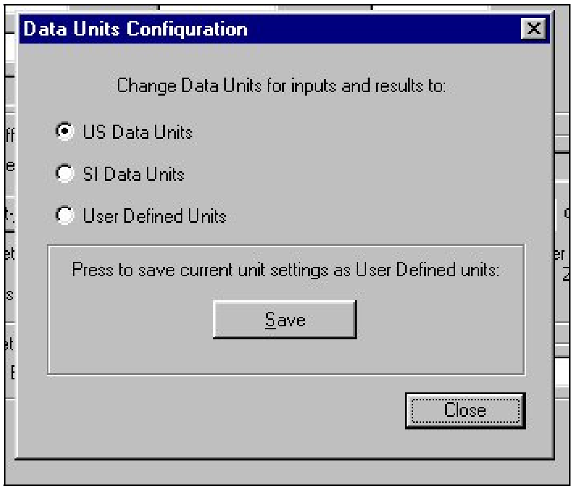


Adding a new pumping unit **Manufacturer** to the library so as to add the corresponding beam pumps:



3.2.5.5 - Data Units

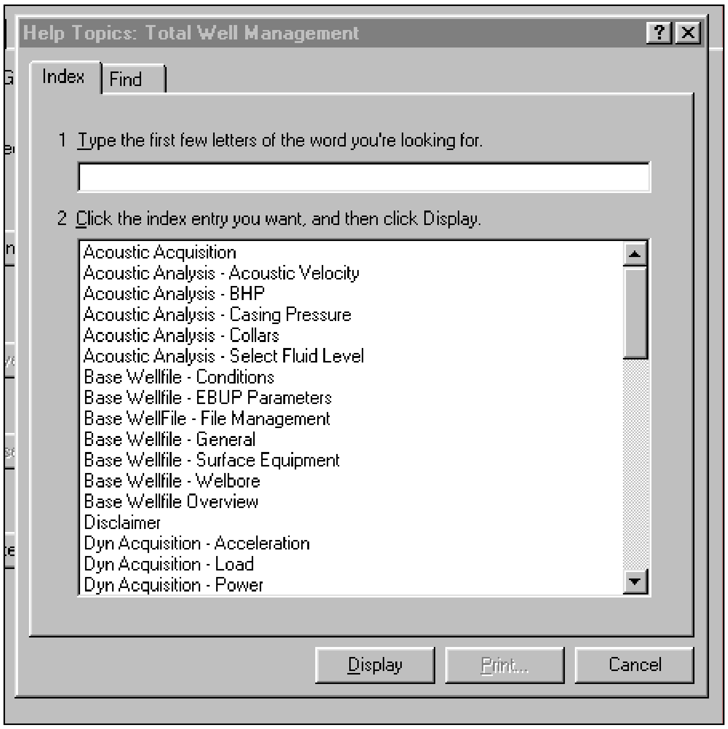
Sets the default system of **units of measurement** to be used throughout TWM.



3.2.6 - Help Menu

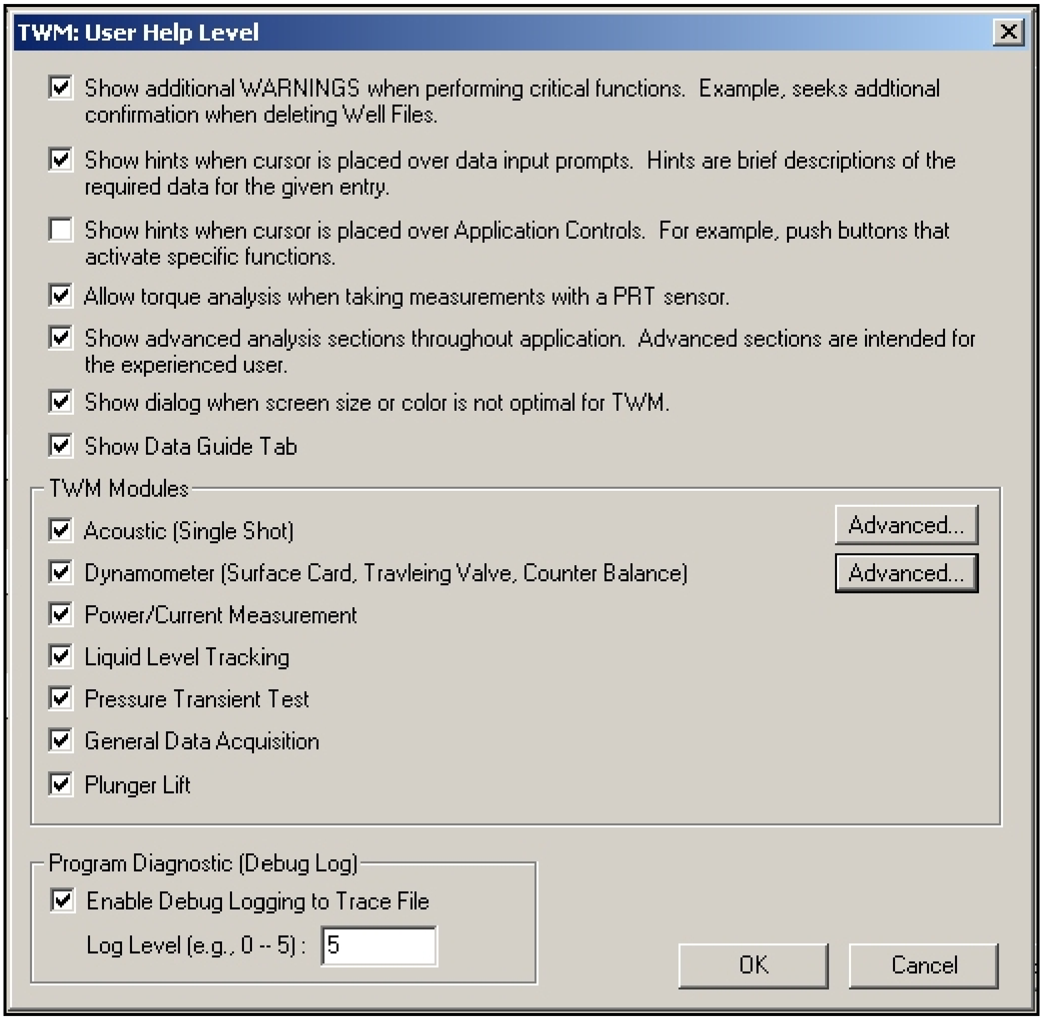
3.2.6.1 - Contents

Displays the Help file **Index**. The user selects the specific topic and clicks on **Display** to view a brief description of the topic.

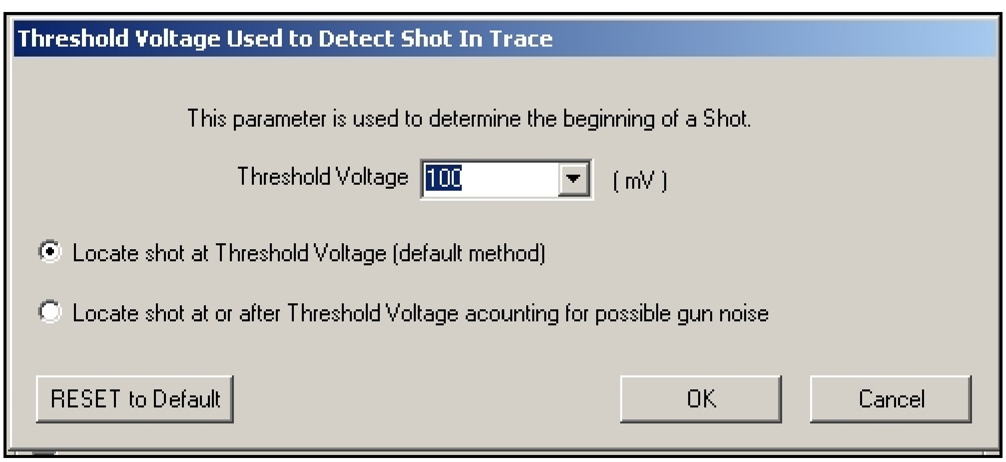


3.2.6.2 - User Help Level

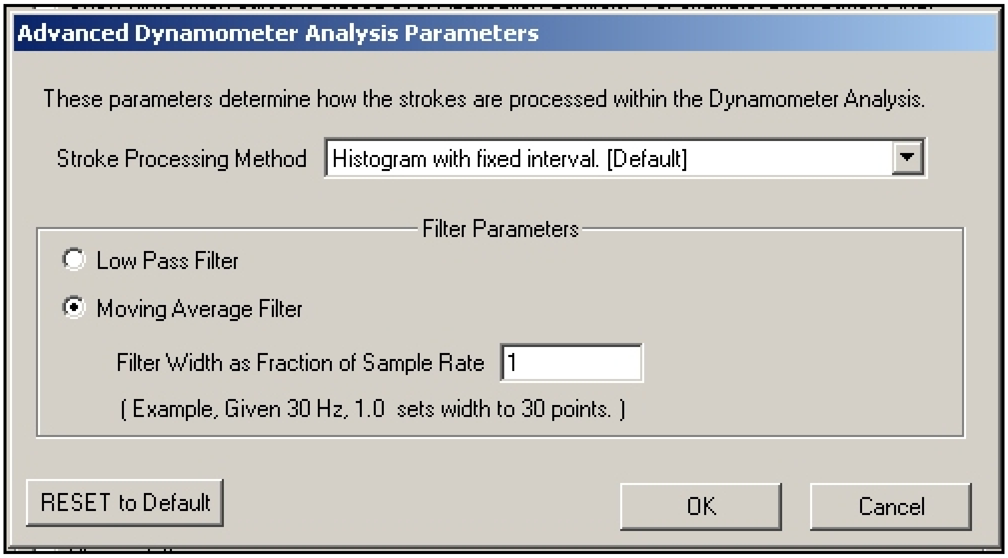
Allows you to set the level of user feedback desired, select the TWM modules to be active, set-up diagnostic log capture, set the acoustic signal threshold level for detecting the shot and select the method for processing acceleration data by the dynamometer analysis module.



Clicking on the top **Advanced** button displays the following input menu:



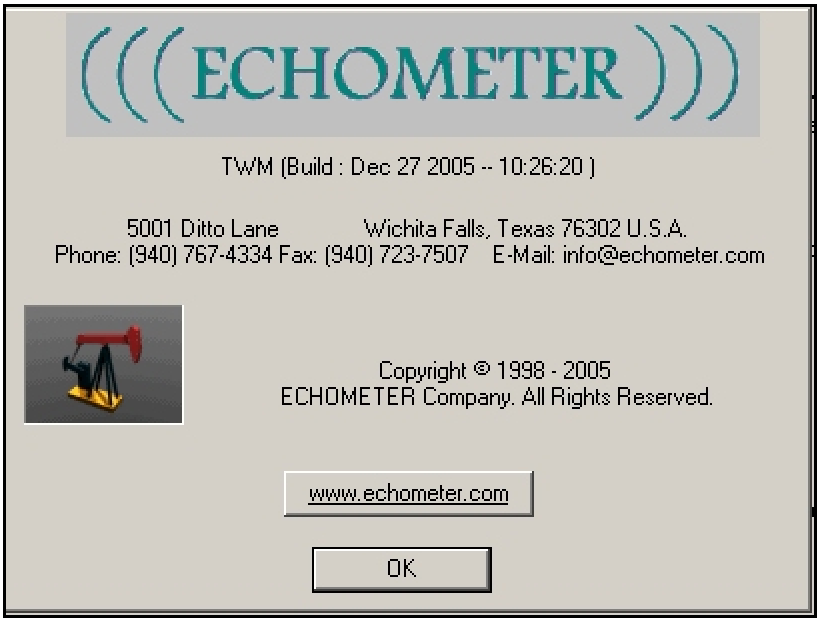
The voltage level should be set at the **Threshold Voltage** unless the software has problems detecting the start of the shot. Clicking on the bottom **Advanced** button displays the following input menu to select dynamometer stroke processing method:



The figure above shows the **Default** selection. This is the preferred mode for the processing of the acceleration data to determine the top and bottom of the polished rod stroke. When the acceleration signal is very noisy or the pumping speed is below 1-2 strokes per minute, the software may have difficulty in processing the acceleration data to yield a reliable and consistent polished rod stroke. In these cases the user may want to try to change the filter width to a value between 0.5 and 5.0 to observe if the program is able to process the dynamometer data more accurately.

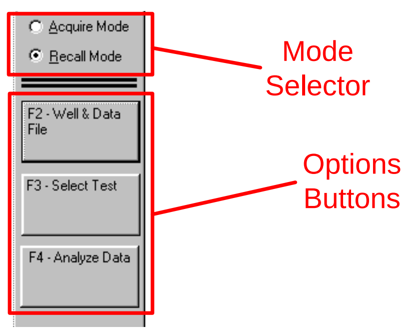
3.2.6.3 - About TWM

Displays copyright information for TWM. The date of the current version of the program is also shown. Program updates can be downloaded, free of charge, from the Echometer WWW page as they become available.

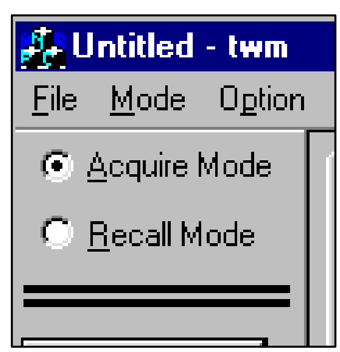


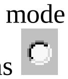
3.2.7 - The Dialog Bar

The Dialog Bar is located along the left side of the TWM window. It is divided into two sections, the mode selector and the options buttons. These perform the same function as the Mode Menu and Options Menu.



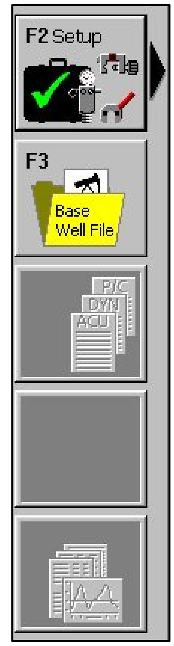
3.2.7.1 - Mode Selector



TWM operates under two different modes. **Acquire Mode** is designed to capture well information from your Well Analyzer. **Recall Mode** is used to analyze tests previously captured. You can switch between these two modes by using the mode selector. You can determine which mode is active by looking at the circular buttons  next to each mode name. The active mode's circle will be filled. 

3.2.7.2 - Options Buttons

The options buttons represent the steps in which TWM operates. The buttons are arranged so that you can start with the top button (the first step) and work your way down. You will not be able to move on to the next step until you have completed the current step. To show that the next step is not yet available the lower buttons will be deactivated (the button's text will be transparent and the buttons can not be clicked).



As you click on each button, the tabs in the Tab Area change accordingly. You can also use your keyboards function keys to select an option. The appropriate function key is listed in front of the button's title (i.e. F2 – Setup).

3.2.8 - The Tab Area

The tab area is where you can view your data and enter information. Because of the large amounts of data TWM must display, tab pages are used. These are like dividers in a notebook. Each divider has a small piece that sticks up above the rest of this page. This piece allows you to jump directly to that page. To select one of the tab pages, you can click the tab's title. The tab titles are located at the top of the tab area. You can also step through the tabs in order by clicking the page up/page down buttons at the bottom of the tab area or by using your keyboard's page up/page down keys. You may also jump to a specific page by holding the Ctrl key plus the page number (page 1 is on the far left). The active page will always have a square in front of the page title.

It may be helpful to think of the TWM environment as a set of two filing cabinets. You choose between the two filing cabinets by selecting the appropriate mode. Choosing a specific drawer of the filing cabinet is like selecting one of the options available. And finally, you can choose which file to view by selecting one of the available tabs.

3.3 - The File System

All information obtained with the Well Analyzer is organized as files within directories on the internal hard disk. On the hard drive, a directory named **TWM** is created at install where all the Echometer Well Analyzer software is loaded. All programs and associated files are stored in this directory.

BACKUPS
As a precaution against loss of important data, all well files and data files should be copied frequently to back-up disks.

The **WELL NAME** is used in the creation of file names by the program. Data may consist of well information, acquired data or results from calculations or graphic data corresponding to information presented on the computer screen.

3.3.1- The Workspace

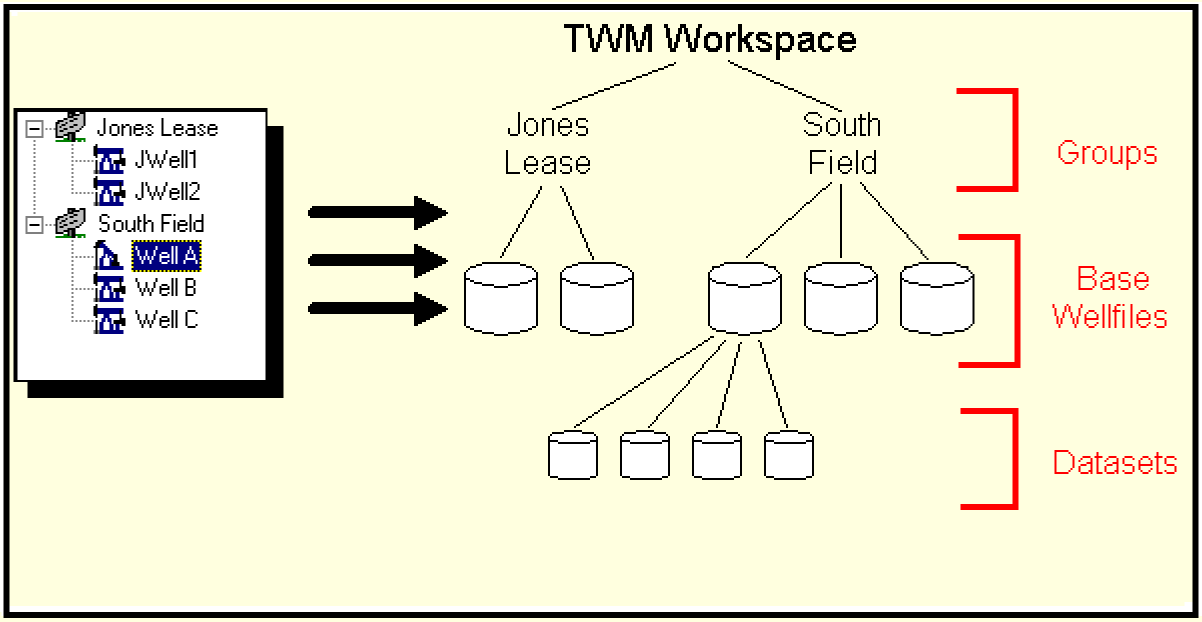
All files associated with TWM are stored in the **TWM workspace** (by default created at install as C:\TWM\ or redefined by the user with the **Tools/Settings/Work Area Path** menu). This includes groups, well information, library files, device drivers and help files.

3.3.2 - TWM Groups

TWM allows you to organize well and test information into categories or groupings that make sense to you. To be able to access the TWM data each well file and data must be stored within a group, and each well name must be unique within that group. You can use groups to separate wells by location, owner, or any other criteria.

3.3.3 - Base Wellfiles and Datasets

TWM stores completion, production and equipment information about each well in a **base wellfile** (extension .bwf) To acquire new data (dynamometer, acoustic, etc.) you must first choose a well (and thereby a wellfile) to be associated with this data. Once the measurement data is acquired, it is saved in a **dataset file**. The dataset file holds all the information about the tests performed as well as a **copy of the base well file's** information. By storing a snapshot of the current wellfile configuration in the dataset, the base wellfile can be updated , as well equipment or completion change in time, without changing past datasets associated with the wellfile specific to that dataset.

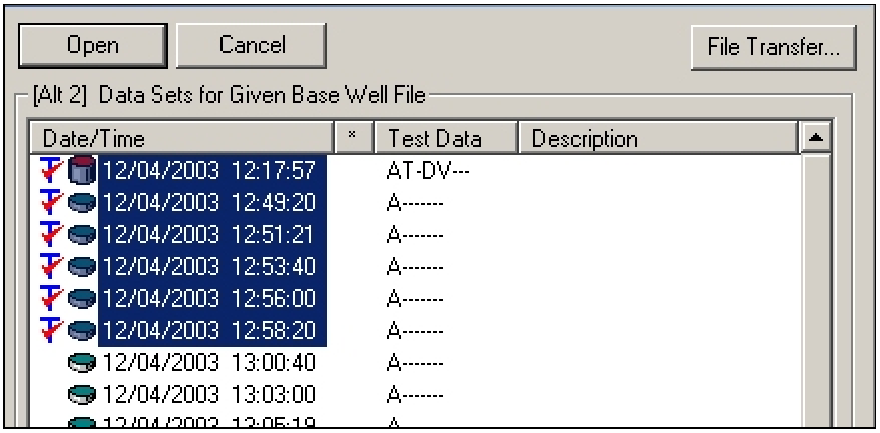


The TWM program uses the following file extensions to differentiate between the various files that it manipulates:

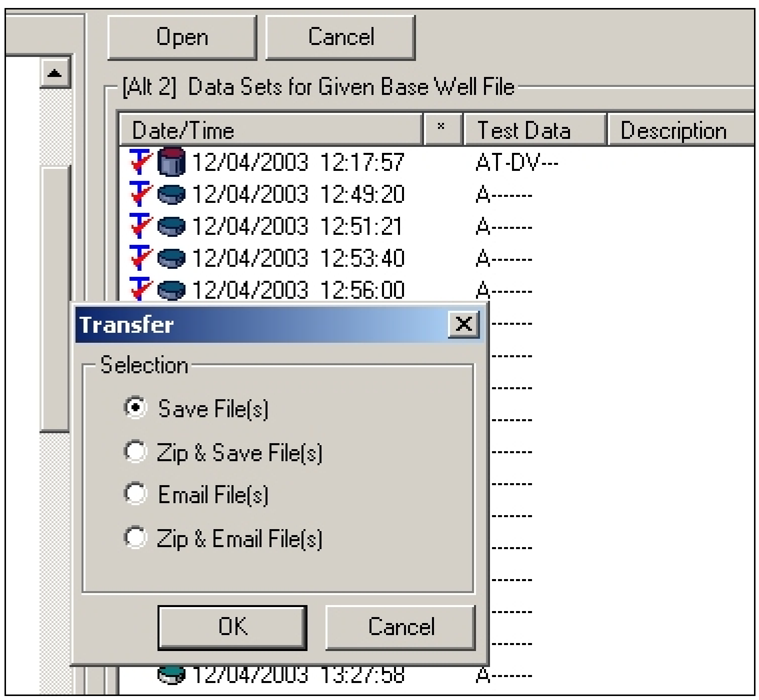
- **.bwf** – Base well file
- **.001** – Sequential number TWM data acquisition file
- **.hlp** – Help file
- **.cfg** – Well Analyzer configuration file with transducer coefficients
- **.log** – TWM log file
- **.exe** - Executable files that are used in the Well Analyzer

3.3.4 - Data Files and Base Well File Transfer to Other Computers

The **Data Set** file transfer option can be used for transferring specific data set files especially when the laptop is connected to a network. The Data Set files to be transferred are selected by **Right Clicking** on the file name (use Ctrl-Right Click for multiple selections) to mark the files for transfer:

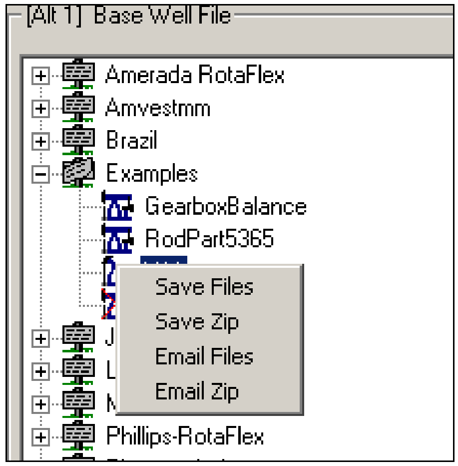


Then clicking the **File Transfer** button opens the following menu:

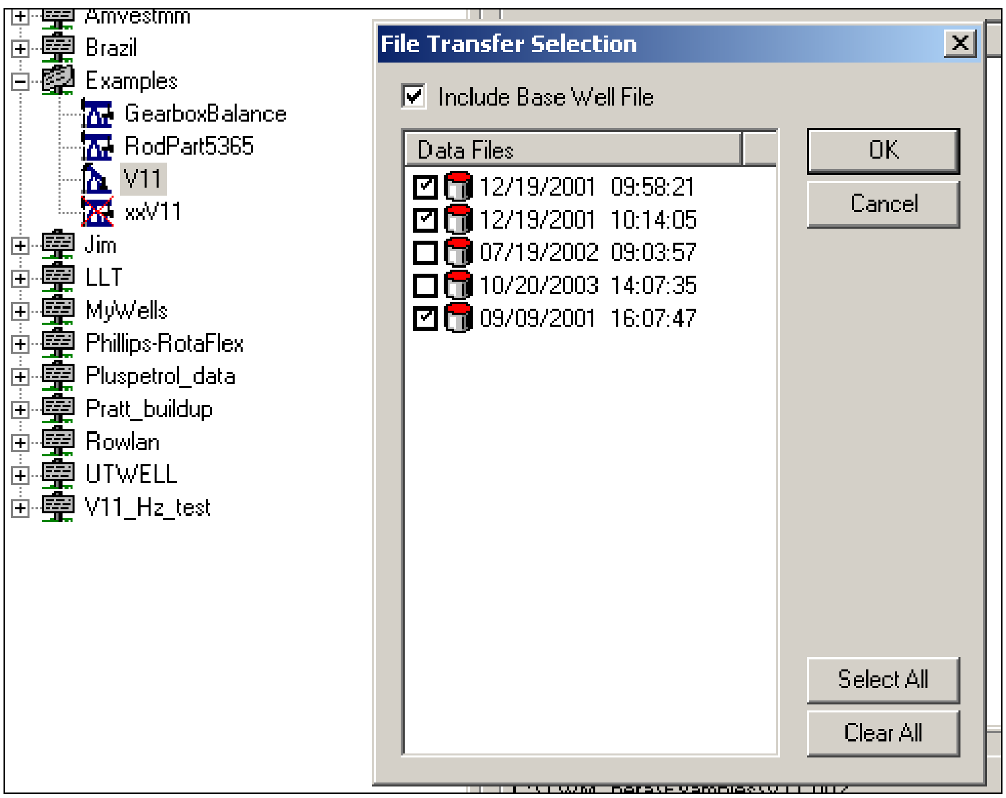


This allows saving the data sets files to another disk (for example a USB memory stick) or another computer when connected to a network, or e-mail them using the default e-mail application.

If the **base well files** or **multiple data sets** are to be included in the transfer to other computers then **Right Clicking** on the well file name, as shown below, displays a menu of choices for the transfer:



After selecting the transfer option a listing of the available files is displayed. The user then checks the boxes of the data sets to be transferred and include the base well file:



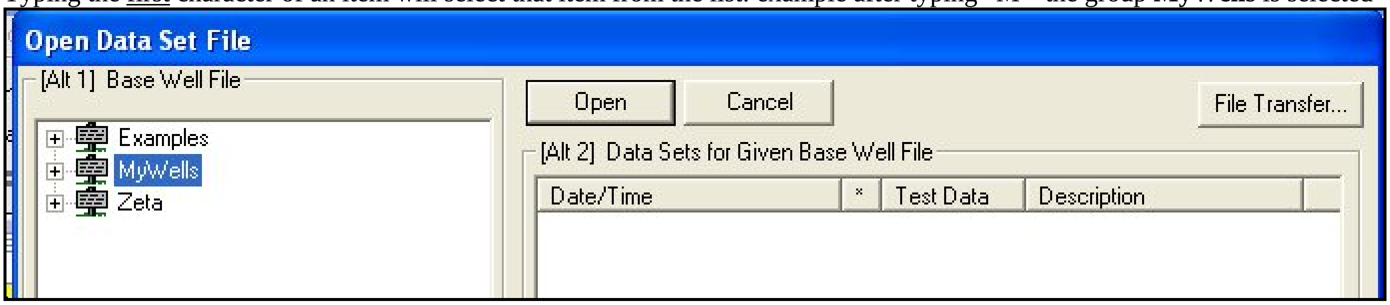
3.3.5 Keyboard Navigation of Well Files

Selecting groups of wells, well files and data sets can be accomplished using the keyboard instead of the pointer by using the following keys: Page Up, Page Down, Home, End, Left/Right arrows, Up/Down Arrows and single characters, as is illustrated in following figures:

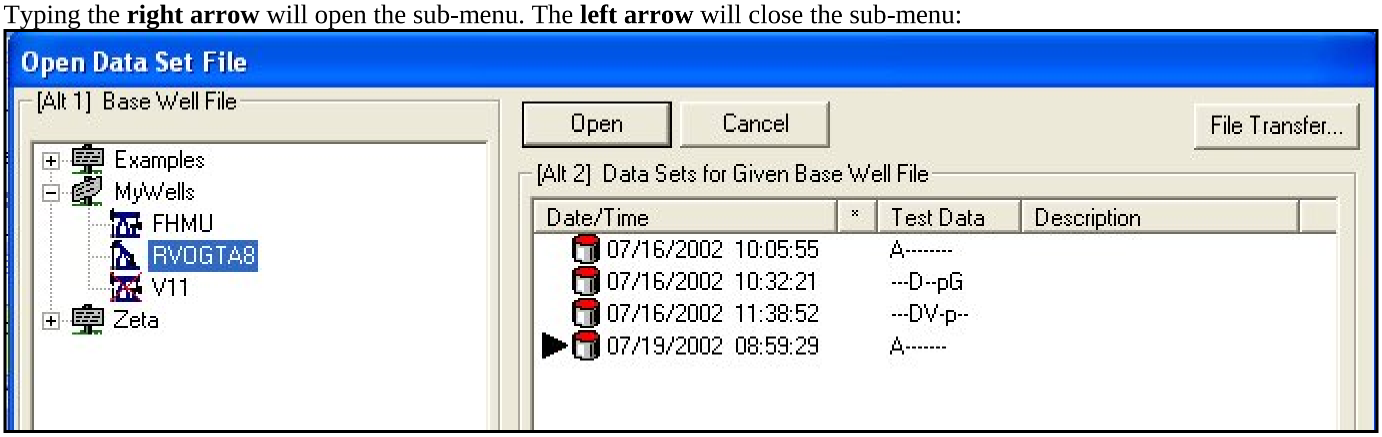
Typing the Page Down and/or End , keys will select the bottom of the displayed list:

Page Up and **Home** select the top item on the list

Typing the first character of an item will select that item from the list: example after typing "M" the group **MyWells** is selected



Typing the **right arrow** will open the sub-menu. The **left arrow** will close the sub-menu:



The **Up** and **Down** arrows will scroll selection one item at a time.

These keystrokes are most useful when the user has to manage large numbers of groups, well files and data sets.

3.4 - Types of Computers

The Well Analyzer is designed to operate with the PC laptop that is provided by Echometer Co. It has been found from experience that not all similar "PC-compatible" computers function properly with the Well Analyzer software. The user is advised that he may experience problems when using computers purchased from other suppliers. Some vendors' software programs interfere with the computer operation and can cause bad data and analysis. Contact Echometer Company before using a non-standard computer or replacing a laptop supplied by Echometer Co. with another laptop.

3.5 - Overview of Computer Systems

This is a section on basics of Windows. The user should refer to the Windows Manual provided with the Well Analyzer for detailed information.

3.5.1 - Formatting disks

The FORMAT command is used to prepare disks to record data and other files. If information is already present on the disk it WILL BE ERASED when the disk is formatted. Most disks and diskettes are already formatted, but **if you need** to format a diskette and you have access to a diskette drive (internal/external diskette drives are optional for the Well Analyzer, the standard system is currently being shipped with a USB memory stick) you can format the disk by opening a **Command Prompt** window (Programs/accessories/command prompt) and selecting C: as the current drive by typing: CD\ (followed by Enter.)

When the current drive is C:, then to format a disk in drive A: the following command should be typed:

format a: (followed by Enter)

the system will tell you to insert the diskette to be formatted into the drive. After completion it will ask if you want to format additional diskettes. It is convenient to format a batch of disks at a time. The recommended procedure is to use disks already formatted.

WARNING

DO NOT
DO NOT
DO NOT
format C:

since **this will erase all the programs and data** on the hard drive.

3.5.2 - File Names

A Windows or DOS file name looks like this:

filename.EXT

The file name has two parts, the *filename* and an extension (EXT). The period separates the *filename* from the extension. A *filename* can be from 1 to 24 characters long. The optional extension is 1 to 3 characters long and usually indicates the type of file.
(Do not use extensions when entering the name of a well. The appropriate extension will be added by the software)
You can enter *filename* in either upper or lower case letters. DOS translates file names into uppercase.

RESERVED CHARACTERS: The following characters are reserved and cannot be used in naming files:

Usually you will use letters and numbers for your file names and extensions.
You cannot use any of the following symbols in your file names:

| \ , . < > ? / : ; " [ ] * + =

3.5.3 - File Types

File types are designated by the file extension, a code following the file name and preceded by a period:

- **.bwf –** Base well file
- **.001** – Sequential number TWM data acquisition file
- **.hlp** – Help file
- **.cfg –** Well Analyzer configuration file with transducer coefficients
- **.log** – TWM log file
- **.exe** - Executable files which can be any size. Executable file which are used in the Well Analyzer

TWM.EXE	Main program for using the Well Analyzer

3.5.4 - File Management

Normal use of the software will require managing a large set of data files. The user should refer to the corresponding section in the Windows manual for detailed suggestions and instructions dealing with operations involving files.

3.5.5 - Directories

Directories are to a hard disk what rooms, shelves and bins are to a warehouse. When you organize your files and data into directories you are grouping the information into common categories or types. The ROOT DIRECTORY corresponds to the warehouse. It holds DIRECTORIES which correspond to the rooms. The shelves are other DIRECTORIES of lower level than the "room" directories. The bins are generally files that contain data or programs. This structure can become quite complicated so it is convenient to organize the information in a logical manner. The recommended procedure is to store all Well Analyzer software in a directory called TWM along with the Group files, Base Well files and Data Sets. This is the default directory used by the **Setup.exe** procedure for installing and updating the software.

3.6 - Care of A/D and Computer

The Well Analyzer is a precision electronic instrument. Although it is rugged and has been tested in various harsh environments (from the Kuwaiti desert to northern Alberta, Canada) there is no reason for the user to be careless and not use the equipment with common sense. Whenever possible the equipment should be kept in its case and protected from wet or dusty conditions. The keyboard cover should be kept in place. Diskettes and CDs should be kept clean and free of dust. A plastic case is recommended for storage of disks. Do not write data to the disks during dusty or dirty conditions. Wait until you are inside a car or in the office.

All connectors and cables must be cleaned after every use and kept in a dry clean place. Connector covers should be re-attached after every use.

Turn **off** the **master power switch** on the electronics at the end of the day.

The computer and A/D batteries should be kept at full charge and in good conditions.

3.7 - Computer Troubleshooting

Computer will not power up

Make sure that the battery is charged. When using the AC charger make sure that the power cord is fully plugged into the charger. In some models it is possible that a poor contact prevents the charger from operating properly. Refer to computer manual for troubleshooting suggestions.

Well analyzer programs have been deleted from the TWM directory.

Use the **install disk** provided by Echometer Company to load or update all programs onto the hard drive.
Alternately you may download the latest TWM software from Echometer's web page: www.echometer.com following the link to: **Software**
Follow the instructions that appear on the screen when the install program is executed.

Analyzer programs do not run or hang up

Check that the computer is operating correctly. Turn **ON** the Well Analyzer Power switch and wait for a **GREEN LED** on the well analyzer panel **BEFORE** loading the TWM acquisition program. Follow the troubleshooting procedures as detailed in Chapter 11 of this manual.

Installing other applications on the well analyzer computer can cause serious problems when acquiring data. Often this results in erroneous data and/or erratic operation of the Well Analyzer. These problems are caused by modification of some system files by the installation of the extraneous programs. If these problems are noted it is recommended that you contact Echometer Company.

3.8 - Charging Batteries

Use the correct AC charger for the Well Analyzer and the computer. The well analyzer charger connects to the top connector on the aluminum cover of the instrumentation box. The computer charger connects to the back of the computer. Connecting the **external charger** to the Well Analyzer **will not charge the computer battery** The system is provided with a cable for connecting to a 12 volt automobile battery via the cigarette lighter. This cable can be used for recharging **both** the **computer** and the **Well Analyzer** battery for powering the system in the field during long term testing. In this case the internal charger for the computer battery must be connected to the computer using the corresponding cable and connector found at the back of the computer.

NOTE: if the laptop provided with the Well Analyzer **is substituted with a different laptop** the DC to DC charger internal to the Well Analyzer may not be compatible with the new laptop and **will have to be replaced**.

When not in use, the computer and Well Analyzer batteries should be recharged fully using the corresponding AC chargers at least once a weak.

3.8.1 - Fuses

The internal electronics are protected with internal **Automatic Reset Fuses** from power surges and the accidental use of battery chargers which are not properly rated for the Well Analyzer. The automobile power cord has an integral 7 amp fuse that may have to be replaced occasionally.

3.8.2 - Important Instructions for Rechargeable Lead-Acid Batteries

1. **Charge before using**. Read your equipment manual for charging instructions. Use only the charger that comes with your equipment.
2. Do not short circuit battery terminals, this may cause severe damage to the battery.
3. Keep batteries away from fire and do not incinerate... they may explode.
4. Under no circumstance should you attempt to open the battery case.
5. Do not expose the battery to moisture or rain.
6. Do not drop, hit or abuse battery. it may break and release electrolyte, which is corrosive.
7. The AC charger supplied by Echometer can be connected indefinitely to the lead-acid battery because the charge mode changes to a trickle-charge state as the battery becomes fully charged.
8. **If the Well Analyzer is not being used for an extended period of time the AC charger should be left connected to achieve maximum battery life.**

3.8.3 - Notes on Battery Use

1. The battery will become warm during charging and discharging.
2. The life of the battery under normal conditions may be as long as 1,000 charge-discharge cycles.
3. New batteries may require four or five charge-discharge cycles before they achieve their design capacity.
4. **It is normal for a battery to "self-discharge" during storage. Always fully charge the battery before you use it after it has been stored for over one week.**
5. For the battery used in the computer, follow the procedure recommended by the computer manufacturer.

4.0 - ACOUSTIC WELL SURVEY PROCEDURE AND EQUIPMENT

The principal objectives for making acoustic well surveys are: measurement of the depth to the liquid level, determination of bottom hole pressure, annular pressure distribution and estimation of the inflow performance of the well. The Well Analyzer gives detailed results about these four elements.

4.1 - Summary of Operating Instructions

The following summary may be downloaded as a 2 page guide from www.echometer.com/support/quickrefs/idex.html

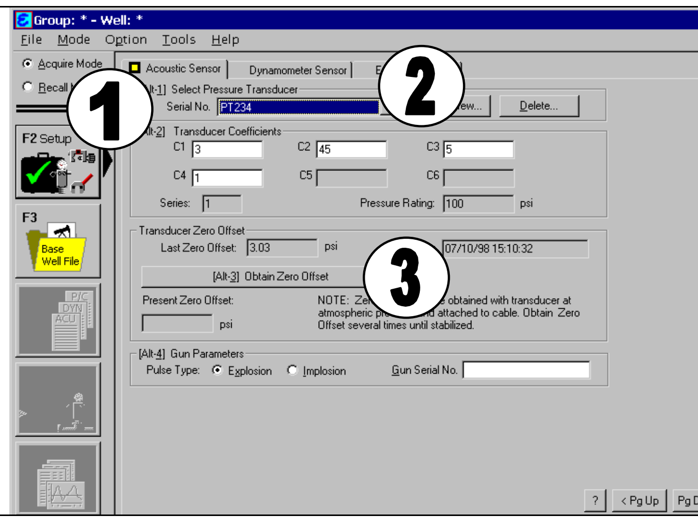
THIS SUMMARY IS TO BE USED FOR QUICK REFERENCE AND AS A CHECK LIST ONCE YOU HAVE READ THE MANUAL AND UNDERSTOOD THE SYSTEM AND FOLLOWED THE SETUP INSTRUCTIONS GIVEN IN THE NEXT SECTION

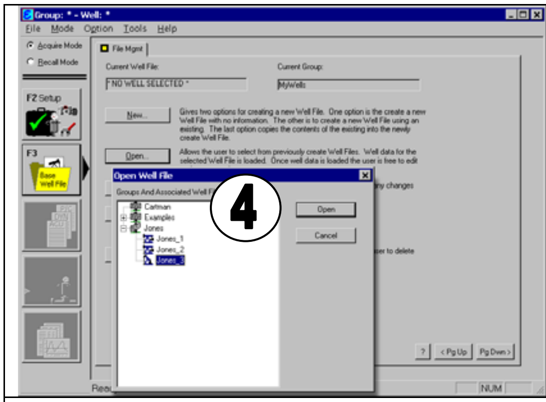
1. Attach the Echometer gas gun to the well. Check the threads on the wellhead valve for corrosion and obtain at least 4 1/2 turns when attaching the Echometer gun. Leave the valve to the wellhead closed.
2. Connect the pressure transducer, if present, to the gas gun.
3. Connect the cables to the gas gun and to the Well Analyzer as shown below.

4. Turn on Well Analyzer and wait for **GREEN LED**. Turn on the computer and start the **TWM** program.

1-Start **TWM**. Select **Acquire Mode**.
2-Select the serial number of the pressure transducer. Use **Create New…** if your serial number is not found in the list. Make sure all coefficients are entered as typed on transducer label. Also enter **Gun Parameters** at bottom.

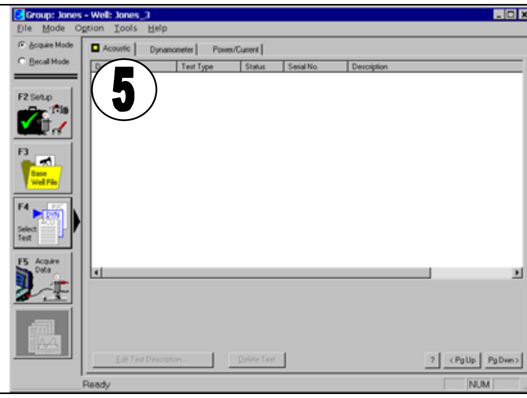
3-Start process of zeroing transducer by selecting **Obtain Zero Offset** button (**Alt-3**). Once the reading displayed in **Present Zero Offset** has stabilized press **Update Zero Offset with Present Reading** button to record this value.

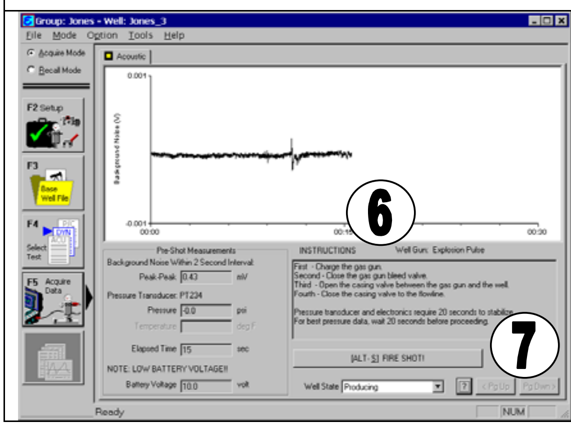




4. Open Base Well File for the well where data is to be acquired. Use **New…** to create a Base Well File if one does not exist. Be sure to enter at least pump and formation depths.

5. From the “F4” Select Test screen pick the **Acoustic** Tab to indicate that acoustic test data is to be acquired.





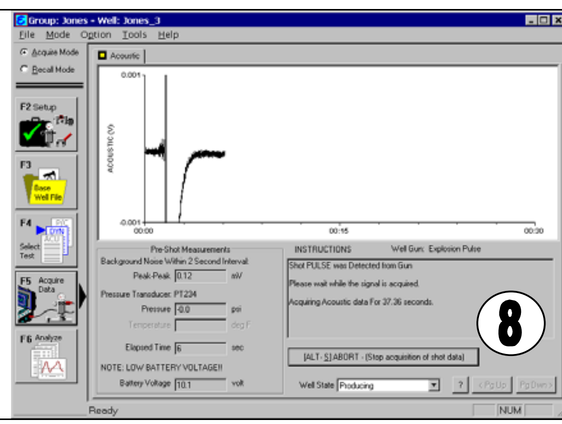
6. Prepare to acquire shot “F5” by following steps detailed on **INSTRUCTIONS** panel**.**

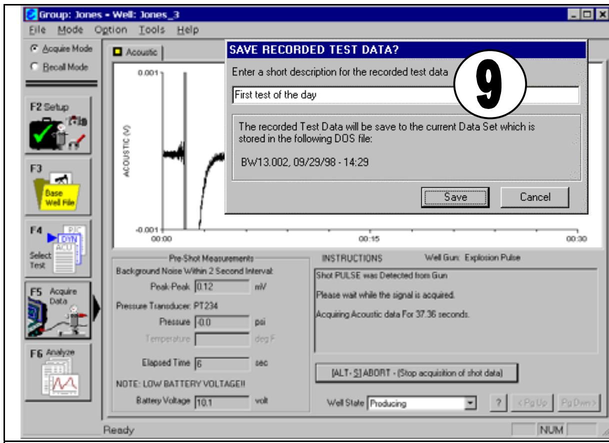
At this point the graph is displaying background noise.

7. Acquire shot by pressing **FIRE SHOT** button (Alt-S). If using a Compact Gas Gun, prepare to pull pin when TWM displays the message “**Automatic Gun has Been Fired, If present**.” along with a BEEP sound.

8. The message “Shot PULSE was Detected from Gun” is displayed once the gun is fired. Then shot data is acquired for a predetermined numbers of seconds based on the given formation depth.

NOTE: If shot pulse was not detected after the gun was fired press **Abort (Stop acquisition of shot data)** button, recharge at a higher pressure, go to step 6.

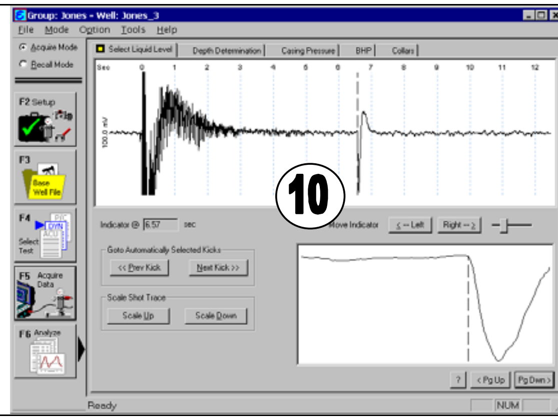


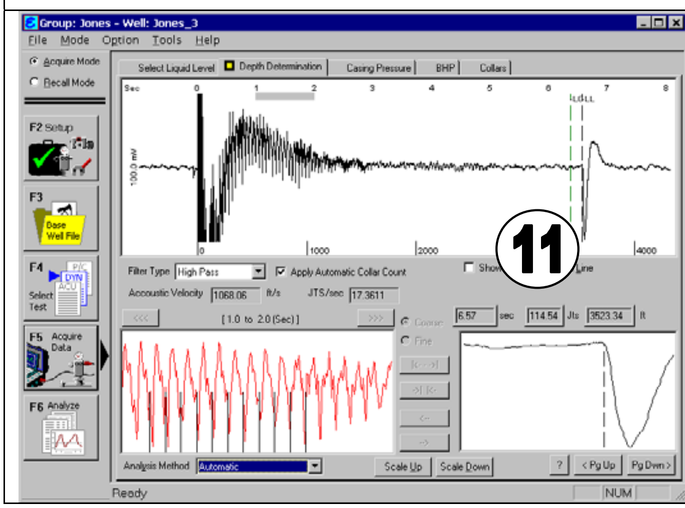


9. Once the shot has been acquired a Dialog appears. At this point the data can be saved or discarded so another shot can be taken. A brief comment can be entered into the description field. Otherwise, just Enter (press OK) to save the data set.

Note once the shot is saved TWM continues to acquire casing pressure every 15 seconds for a maximum of 15 minutes or until manually stopped.

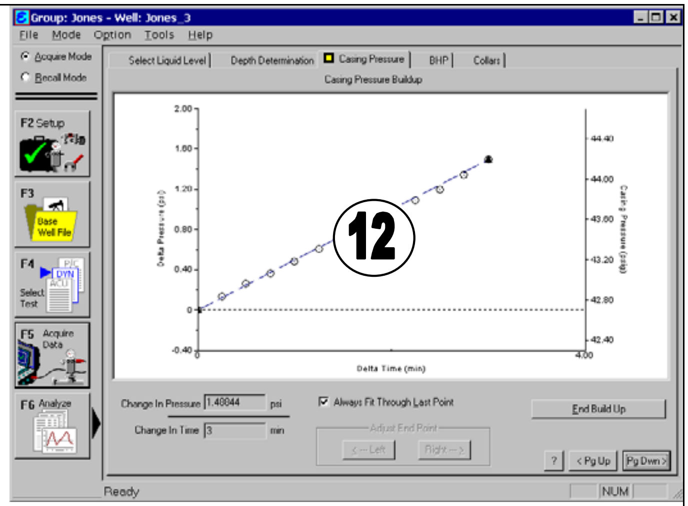
10. When the data is saved TWM automatically goes to the **Select Liquid Level** Tab in the Analyze Section. Note, TWM has calculated and selected a candidate for the best kick. Use the **← Left** and **Right →** buttons to fine tune the selected kick. The graph in the lower right shows a close-up of the kick.

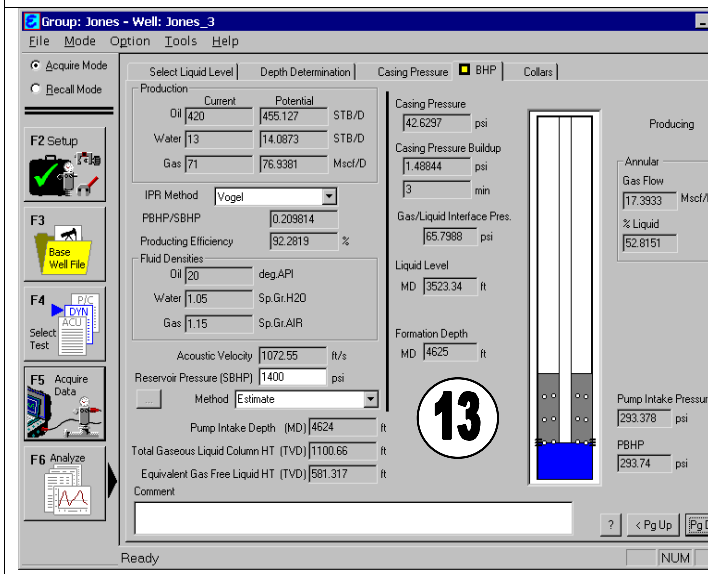




11. Now go to the **Depth Determination** Tab. Here TWM displays the calculated depth to the previously selected kick. The depth is calculated using an acoustic velocity determined by the automatic spreader analysis, shown in the graph on lower left.

12. The **Casing Pressure** Tab displays pressure data TWM has been acquiring every 15 seconds. Press **End**





13. Finally, go to the **BHP** Tab. Here TWM displays results based on the determined liquid level, acquired casing pressure, and well file data. Please, refer to the **TWM** Manual for a more detailed discussion of the analysis and calculated results.

4.2 - Measurement System Configuration

Acoustic measurements can be undertaken either with a remotely fired gas gun or with a manually fired gas gun. The recommended practice is to use a remotely fired gas gun since this provides the maximum flexibility and safety since the operator can locate at some distance from the well when the gas pulse is discharged.

4.2.1 - Electronics

The following section describes the components used when making acoustic measurements with the Well Analyzer.

4.2.1.1 - Computer

The Well Analyzer is controlled by the notebook computer. The computer's internal battery should be charged with the appropriate charger.

4.2.1.2 - Well Analyzer

The Well Analyzer is a compact electronic unit. This unit acquires and digitizes the signals from the microphone and pressure transducer. These data are then sent to the computer for processing. The Well Analyzer contains an internal 12-volt battery pack. The battery is a 2.5 Amp-Hour battery. Current drain is less than 1 amp when the amplifier is on. When not in use, the Well Analyzer can be left plugged into the appropriate charger if desired. The battery cannot be overcharged when using the AC charger supplied with the system. The battery **Voltage** and **Remaining On Time** is checked with the TWM program in Acquire Mode using the Equipment Check tab.

For the **E1** and **E2** models: when the **MASTER POWER SWITCH** is turned **ON** a **YELLOW** indicator will light indicating that the A/D circuit has been powered. The indicator will change to **GREEN** when the A/D processor has booted and is ready to communicate with the laptop computer. This indicator light will change to **RED** whenever data is being acquired. The red light indicates when the amplifier is **ON**.
For the **E3** model: when the **Power Switch is momentarily turned to ON**, the electronics are powered and the internal computer performs a system and a battery check and the **Batt. OK** indicator is lighted.

The computer turns the amplifiers **ON** and **OFF** as needed to acquire data as shown by the corresponding indicator lights. Always make sure that the amplifier is OFF before closing the case and storing the unit. Turn OFF the MASTER POWER SWITCH at the end of each day.

4.2.1.3 - Cables

The well analyzer is connected to the sensors and acoustic guns using appropriate cables. The user has the choice of specifying weather proof connectors as well as requesting custom length cables.

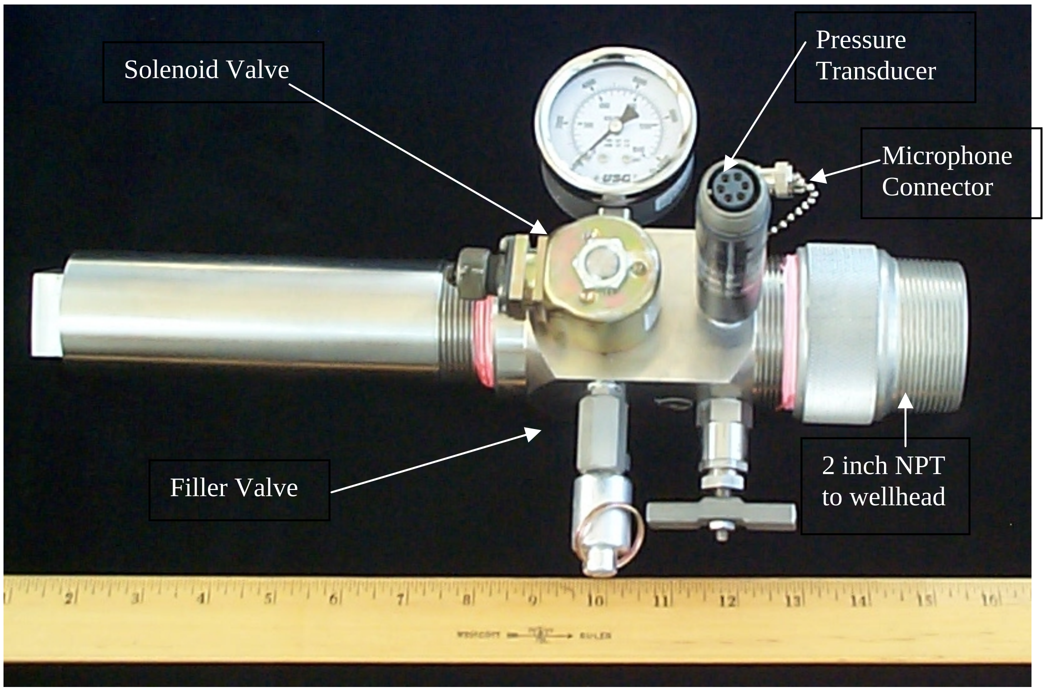
4.2.2 - Description and Use of the Remotely Fired Gas Gun (WG)

The remotely fired gas gun (WG) generates an acoustic pulse and detects the downhole reflections. The gas gun includes a volume chamber which is filled with compressed gas to deliver the acoustic pulse to the well. A microphone housed in the gas gun detects the shot, collar and other wellbore reflections, and liquid level. The serial number of this type of gun consists of the letters WG (on newer units) followed by three digits. For example: WG123.
The standard unit is manufactured entirely with 316 stainless steel and has a working pressure of 1500 PSI, but the design can be modified to operate up to 3000 PSI. A remote fired gun assembly (brand new and never used in the field) has been successfully pressure tested with water to a maximum pressure of 7500 psi. Contact Echometer Co. for further details.

4.2.2.1 - Gas Valve and Solenoid

The solenoid serves as a trigger mechanism to initiate the acoustic pulse. When energized, the solenoid lifts a small plunger and allows gas pressure to bleed off the top of the gas valve. Gas pressure below the valve, then forces the gas valve back and open, causing an acoustic pulse to be delivered to the well as the gas flows from the volume chamber into the well, (see the remotely fired gun assembly diagram in the appendix)..

The gas valve, by itself, does not hold pressure from the well. Therefore, the gas gun volume chamber should be pressurized above well pressure before opening the casing valve otherwise well fluids will flow backwards through the gun and the gas valve into the volume chamber. The flow of fluids from the well may carry solid particles (sand, scale, corrosion) that will eventually cause the gun to malfunction and require more frequent maintenance To minimize this potential problem it is advisable to charge the volume chamber with clean gas as soon as the data from the previous shot has been displayed on the screen. This will prevent the well fluids from entering the valve mechanism.



4.2.2.2 - WG Pressure Gage

The pressure gauge measures the pressure in the gas gun volume chamber. It should be used to determine if the chamber pressure is sufficiently larger than well pressure (explosion mode) to generate a good quality acoustic pulse.

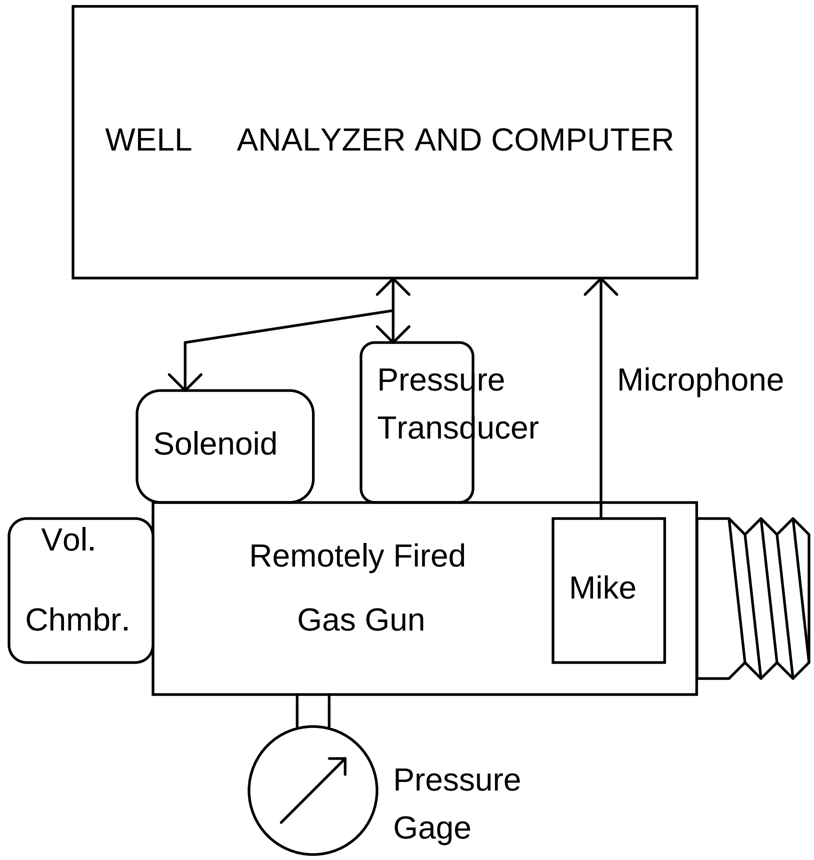
4.2.2.3 - Pressure Transducer

Casing pressure measurements are made with a strain-gauge type transducer. The standard pressure transducer has a working pressure range of 0 to 1500 PSI. The burst pressure is 3000 PSI. Engraved on the pressure transducer's label are a serial number and 6 coefficients. These coefficients are used to calculate pressure from the transducer's output signal. These numbers must be entered correctly into the software setup screen before starting a test. (See ACOUSTIC SOFTWARE SECTION). Transducers pressure readings are compensated for the effects of temperature change over the range from 0 to 140 degrees F.. A corroded transducer will have a lower burst resistance

4.2.2.4 - 2 inch Male to Female Adaptor

The 2 " male to female collar attached to the bottom of the body of the remotely fired gas gun (and the Compact Gas Gun discussed in the next section) is manufactured with 4140 carbon steel that is Cadmium plated. It is not heat treated. It is not suitable for H2S service. The purpose of this adaptor is to protect the threads on the gun from excessive wear. By special order, an adaptor attachment made from 316 SS is available for H2S service and other corrosive applications, but the user should be aware that it has a tendency to gall.

The following schematic shows the hardware connections when using the REMOTELY FIRED GAS GUN:



4.2.2.5 - Charging the Gas Volume Chamber

To charge the volume chamber, first connect the filler adapter to a CO2 bottle. Then, press the adapter against the filler fitting on the gun. When these two fittings are pressed together, a valve core in the bottle is depressed and gas will flow from the bottle into the volume chamber. Charge the chamber to at least 100 PSI above casing pressure. The volume chamber pressure can be read on the gun-mounted gauge. A 5 LB, CO2 bottle and hose with connector is the standard gas container supplied with the Well Analyzer.

4.2.2.6 - Attaching the Remote Fired Gas Gun to the Well

The following figure shows the recommended installation of the gun onto the wellhead, assuming the acoustic measurement will be undertaken through the casing valve.

The optimum results will be obtained when the gas gun is connected to a 2-inch, fully opening, valve with the shortest possible distance (less that 5 feet) between the gun and the casing. Adaptors and pipe size reducers may be used if necessary but they will result in reduced signal amplitude.

4.2.3 - Description and Use of the Compact Gas Gun (CGG)

The Compact Gas Gun (see section 4-32) consists of a microphone and a ten cubic inch volume chamber with a 1/4" outlet valve. The gun should be attached to the casing in a similar manner as the remote fired gas gun (as described in section 4.225) and connected to the Well Analyzer using only the microphone cable unless the optional pressure transducer was purchased with the system. In this case the transducer should be attached to the gun and then to the well analyzer using the cable provided. The gun's outlet valve will open rapidly when the trigger is pulled. This generates a pressure pulse. A differential pressure must exist between the volume chamber and the casing annulus for a pressure pulse to be generated. The operator has the choice of using an explosion or implosion pulse. If the pressure is greater in the volume chamber than in the casing annulus, a compression pulse is generated. If the pressure is greater in the casing annulus than the volume chamber, a rarefaction pulse is created.

4.2.3.1 - Explosion Pulse

Explosion utilizes an external gas supply to generate an acoustic pulse in the well. In the explosion mode, the volume chamber is charged from an external gas supply to a pressure in excess of the well pressure.

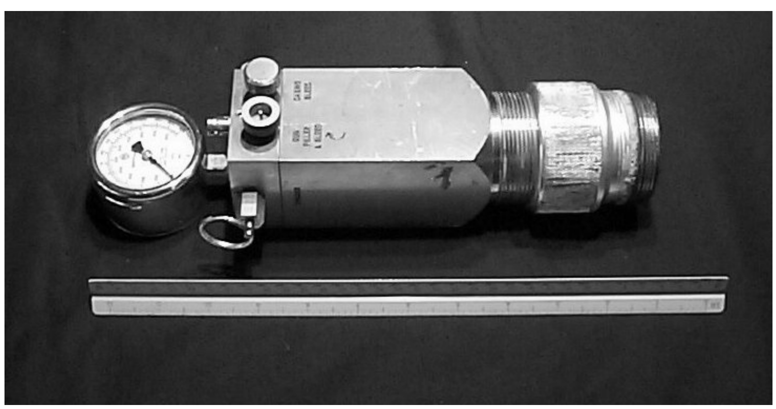
4.2.3.2 - Implosion Pulse

If the well's casing pressure is greater than 100 PSI, implosion can be used. This method uses the well's pressure to generate a pulse. Use the manual gas gun filler/bleed valve to release gas from the volume chamber. An external gas supply is not necessary to operate in the implosion mode.

NOTE: The WG model of remotely fired gun can be provided with an optional attachment chamber that allows manual generation of implosion pulses. Contact Echometer Co. for details.

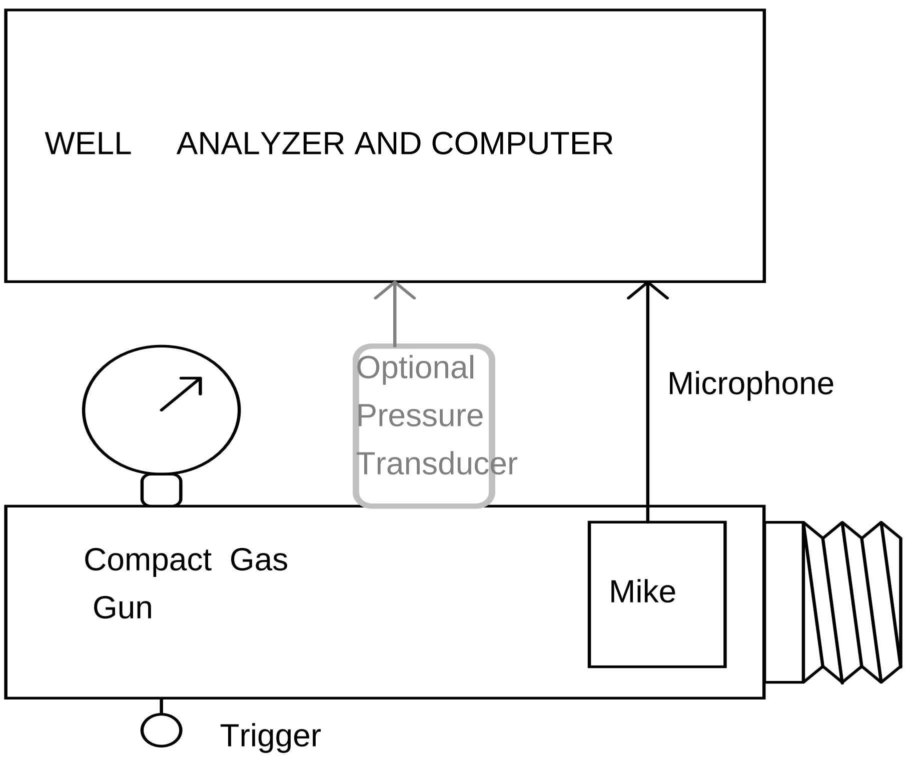
The compact gas gun consists of a microphone and a ten cubic inch volume chamber with a 1/4" outlet valve. The outlet valve will open rapidly when the trigger is pulled. This generates a pressure pulse. If the pressure is greater in the volume chamber than in the casing annulus a compression pulse (explosion) is generated. If the pressure is greater in the casing annulus than in the volume chamber, a rarefaction pulse (implosion) is created. A differential pressure must exist between the volume chamber and the casing annulus for a pressure pulse to be generated. The type of pulse must be specified in the set-up screen for proper liquid level selection.

General view of the Compact Gas Gun:



Detail view showing microphone connection and filler/bleed valves

The following schematic shows the system configuration when using the compact gas gun.



4.2.3.3 - Pressure Gauge

The pressure gauge indicates the pressure in the gas gun volume chamber. If the gas gun valve is open - and the casing annulus valve is open - the gauge will register casing pressure.

4.2.3.4 - Casing Pressure Quick Connector

A casing pressure quick connector is located on the side of the gun. A separate pressure gauge with a mating adapter can be used to read the casing pressure through this fitting or, an optional pressure transducer can be located in this outlet to obtain pressure automatically.

4.2.3.5 - 2 inch Male to Female Adaptor

The 2 " male to female collar attached to the bottom of the body of the remotely fired gas gun (and the Compact Gas Gun discussed in the next section) is manufactured with 4140 carbon steel that is Cadmium plated. It is not heat treated. It is not suitable for H2S service. The purpose of this adaptor is to protect the threads on the gun from excessive wear. By special order, an adaptor attachment made from 316 SS is available for H2S service and other corrosive applications, but the user should be aware that it has a tendency to gall.

4.2.3.6 - Cocking Arm

The cocking arm is lifted to depress and close the gas valve. When frequently used at pressures above 500 psi, the recommended practice to cock the compact gas gun is to aid or supplement the standard Cocking Arm with an optional Cocking Device that applies leverage to the standard cocking arm. For occasional use at pressures above 500 psi a screwdriver can be inserted through the hole in the cocking arm to provide a mechanical aid to grip the cocking arm. A crescent wrench can also be used to add more leverage to the end of the cocking arm, but the cocking arm can be bent or damaged if the crescent wrench slips or too much force is applied to the end of the cocking arm.

Using The Compact Gas Gun at Pressures from 500 to 1500 psi

The Compact Gas Gun (CGG) is being used more frequently on higher pressure wells in the 500 to 1500 psi range especially in gas and gas lift wells .The CGG is difficult to cock when the well pressure exceeds 500 psi and is extremely difficult to cock at 1500 psi.

Optional Cocking Device (Part Number GG2085)

A simple and practical cocking device is available to help the operator cock the gun at higher pressures. The following figure shows the device as it is used with the CGG.

.The round rod of the CGG Cocking Device is inserted into the hole in the cocking arm on the CGG. The handle on the Cocking Device is raised only until the CGG trigger pawl drops into the gas valve closed position. Do not raise the Cocking Device further as the cocking arm on the CGG can be damaged. The operator should watch the trigger pawl when raising the Cocking Device and stop raising the Cocking Device as soon as the trigger pawl drops into position that keeps the gas valve depressed.

Trigger Pawl

At high pressures, the pull ring attached to the trigger pawl on the CGG should be rotated as it is pulled to reduce the force necessary to retract the trigger pawl. Use the Cocking Device to pull on the trigger pawl pull ring. The Cocking Device has a slot to slip the trigger pawl ring into.

Socket Screws Tightening

When re-assembling the CCG after maintenance operations, the four cap-retaining socket head screws (5/16 x 18) should be tightened to a torque of 50 in-lbs. Additional tightening of the four socket head cap screws will cause excessive tension in the screws before well pressure is applied, and could result in failure of the four screws when the well pressure and the jarring of the gas valve against the cap causes an excessive shock load on the screws that exceed the screws strength.

4.2.3.7 - Casing Pressure Bleed Valve

The casing pressure bleed valve is a needle valve used to bleed the casing pressure off the gas gun. To open the valve, turn the knob counterclockwise.

4.2.3.8 - Filler-Bleed Chamber Valve

The filler-bleed chamber valve is used to pressurize the gas gun volume chamber or to remove gas from the chamber. Gas is added to the volume chamber through the filler-bleed valve by insertion of a mating connector which is attached to a pressurized gas source. Gas is bled from the chamber by rotating the knob clockwise. This depresses a valve core which permits gas to escape from the volume chamber. The gas valve must be closed by lifting the cocking arm before filling or bleeding gas from the volume chamber.

4.2.3.9 - Trigger Pawl

The trigger pawl is pulled to release the gas valve. If sufficient pressure exists in the volume chamber or on the end of the gas valve, the gas valve will open. At high pressures, the pull ring attached to the trigger pawl on the CGG should be rotated as it is pulled to reduce the force necessary to retract the trigger pawl.

4.2.3.10 - Microphone

The microphone is a twin-disc pressure sensitive device that is vibration canceling. Do not remove the microphone unless the gun is being repaired. Periodically clean the cavity where the microphone is located using kerosene or other solvents that will not harm Mylar.

High Temperature Service

The Mylar microphone covering melts at 302 degrees F. To protect the Mylar from higher temperatures it is covered with a thin stainless steel sheet. In laboratory tests the stainless steel protected the microphones for 1 hour at 400 degrees F. If the gun/microphone is operated for an extended time above 400 degrees then “o” rings and Mylar will melt. One technique used successfully in California steam wells is to cool the gun in a bucket of ice water prior to installing it on the well and cooling it down as soon as it is removed from the well.

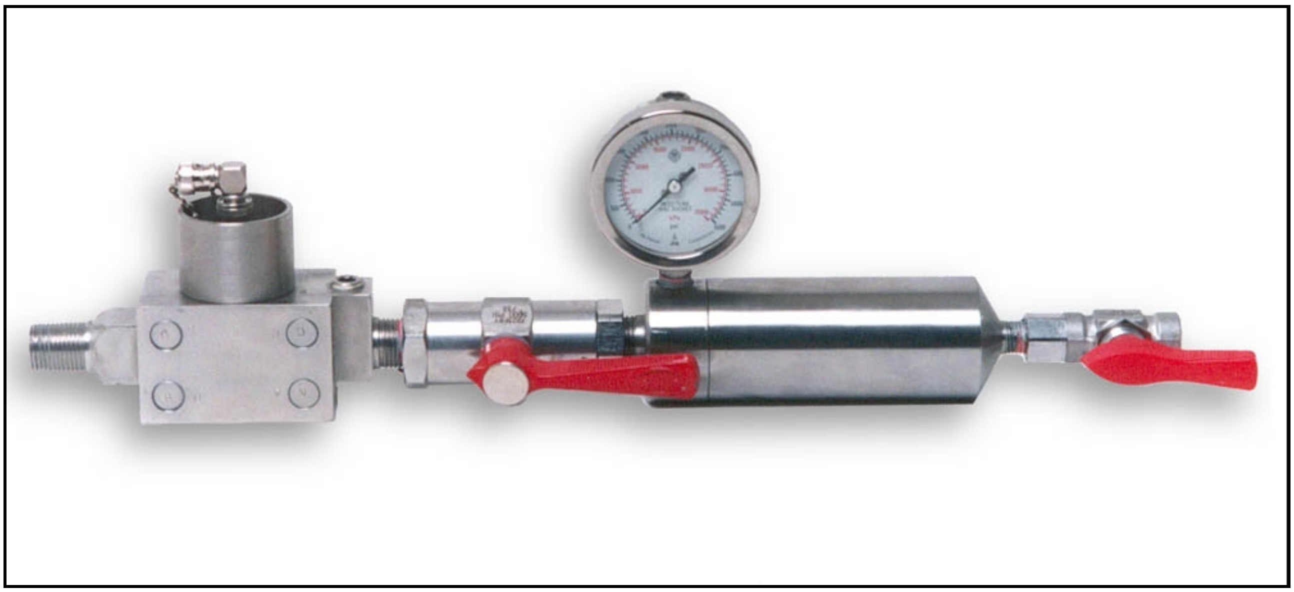
4.2.4 - Description and Use of the High Pressure Gas Guns

For high pressure applications, up to 15000 psi, the high pressure gas guns can be used in conjunction with the Well Analyzer to measure wellhead pressure and fluid level and to calculate the bottom hole pressure. Typical applications involve measurements inside the tubing in gas wells, injection wells, flowing high pressure oil and condensate wells.

The acoustic pulse is generated manually by implosion using the well pressure as the source of energy. Two designs are currently being manufactured: one for operation up to 5000 PSIG and one rated at 15,000 PSIG.

4.2.4.1 - High Pressure 5000 psi Gas Gun

The 5000 psi gun consists of a microphone assembly and a volume chamber separated by a ball valve. When the valve is open the well pressure is transmitted to the volume chamber. This gun is generally used in the **implosion mode** but can also be used in the explosion mode by charging the chamber with CO2 or nitrogen gas. In the implosion mode, closing the isolation valve allows decreasing the pressure in the chamber through the bleed valve, to a pressure lower than the well pressure. Rapid actuation of the isolation valve (**a full 180 degree rotation of the valve**) discharges the well pressure into the volume chamber creating a rarefaction wave which propagates down the well. Additional details are given in the Appendix II.



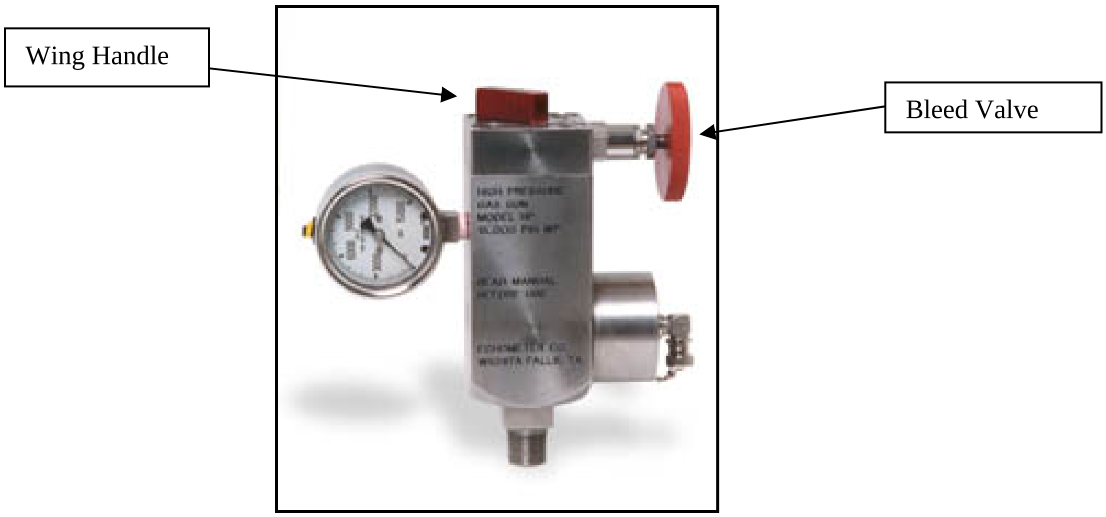
Picture of Standard 5000 psi Gas Gun

4.2.4.2 - High Pressure 15000 psi Gas Gun

The mechanism of the **15,000 psi model** is similar to the Compact Gas gun. A **poppet valve** is displaced downwards by rotating the **wing handle** clockwise to the closed position. This closes the passage between the volume chamber and the connection to the well which is sealed by the "O" ring at the tip of the poppet valve. Continued rotation of the wing handle to the FREE position, lets the poppet valve move upwards under the action of a pressure differential from the well to the volume chamber.

WARNING

The MAXIMUM DIFFERENTIAL THAT CAN BE SUSTAINED BY THE POPPET VALVE IS 1000 PSID. HIGHER DIFFERENTIALS WILL FAIL THE "O" RING, THUS THE VALVE MUST BE IN THE FREE POSITION BEFORE EXPOSING THE GAS GUN TO WELL PRESSURE



The correct sequence of steps for arming and firing the high pressure gas gun are as follows:

1. Connect the High Pressure gun to the well. Typically connection is made at the tree's pressure gage shut-off valve (1/2 inch NPT connection).

2. Turn the **wing handle** to the **FREE** position.

3. Open the valve on the tree to admit well pressure into the high pressure gas gun. The well pressure is indicated on the gun's pressure gage since the poppet valve is open.

4. Rotate the **wing handle** to the **SHUT** position

5. Slowly open the **bleed valve** and allow the **volume chamber** pressure to decrease by the amount desired (**MAXIMUM 1000 PSI** less than the well pressure). The gage now reads the volume chamber pressure since the poppet valve is closed.

6. As soon as the Well Analyzer program displays the message " Gun Has Been Fired" **rotate** the **wing handle** to the **FREE** position. This releases the poppet valve and allows the well's gas to implode into the volume chamber.

An optional high pressure transducer allows recording of the well pressure by the Well Analyzer. This permits recording wellhead pressure changes during transient pressure tests.

If the differential pressure limit is exceeded and the poppet valve leaks, the "O" ring can easily be replaced by removing the four Allen-head bolts in the cover and lifting the poppet valve out of the volume chamber. Always lubricate the "O" ring prior to installing it. When reassembling the cover make sure that the cover "O" ring is in place and is not pinched when tightening the bolts. DO NOT OVER TORQUE the bolts.

4.3 - Standard Gas Guns Operation and Maintenance

4.3.1 - Mechanical And Electrical Connections

All connections and connectors should be clean, dry and in good condition. Most electronic problems occur in the cables and connections.

Generally the gas gun should be attached to the casing annulus valve (except for tests through tubing as discussed in the **Gas Well and Plunger Lift Applications** manual). Preferably, the distance between the gas valve-microphone assembly and the casing annulus should be 3 feet or less. Also, all the piping connections should be 2 inch. diameter and without elbows, tees, reducers, etc. One inch connections interfere with collar reflections and often result in low quality acoustic traces from collar reflections.

4.3.2 - Refilling The 7.5 Oz. CO2 Container

NOTE: Since 2004 Echometer Co. does not supply the 7.5 Oz CO2 containers. The 5.0 Lb CO2 gas bottle will be supplied unless a different size is ordered.

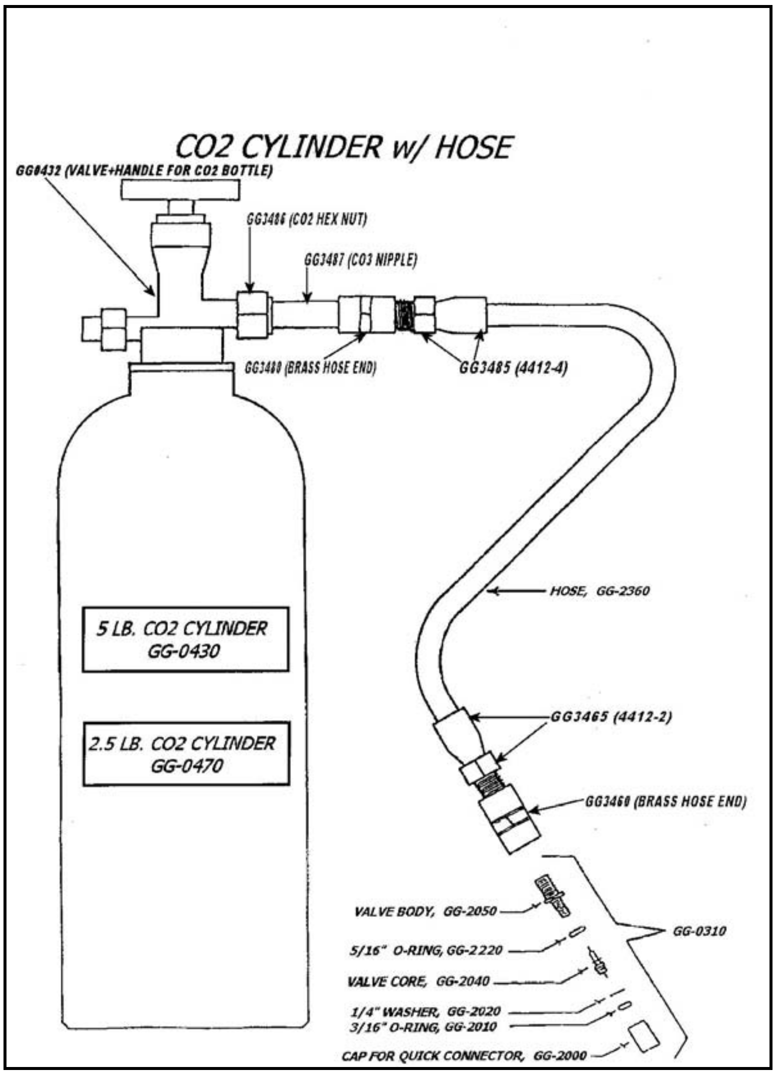
1. Do not attempt to refill the container if it is damaged, the threads are defective, or any signs of container deterioration is evident. **Container should be discarded after two years**. Use only CO2 gas.
2. Remove Filler Connector part # GG042 and empty container.
3. Weigh the empty container.
4. Lubricate the o-ring on Filler Connector part #GG044 and attach it to the 7.5 oz. container on one end and a large siphon type CO2 bottle on the other end.
5. Open the valve on the large CO2 bottle for 30 seconds. Close the valve.
6. Disconnect the 7.5 oz. container.
7. Weigh the filled container. If the filled weight is more than 7.5 oz. greater than the empty weight, discharge some gas with discharge tool #GG045 until 7.5 oz. of CO2 are in the container.

NOTE: It may be necessary to cool the container to obtain a complete 7.5 oz. fill up. This can be accomplished by rapidly discharging pressure from the container. The chilled container can then be filled with a larger amount of CO2 gas.

4.3.3 - Refilling The 2.5 Lb or 5.0 Lb CO2 Bottle

Either a 2.5 lb. (GG0470) or a 5 lb. (GG0430) cylinder is supplied with Echometer gas guns for use in the explosion mode. For either cylinder the service pressure = 1800psi, the test pressure = 3000psi, and the safety disc ruptures at 3000psi. Safety precautions are in red letters on the side of the cylinder.

A refill adaptor (GG3050) is required for transferring the liquid CO2 from a large supply cylinder to the smaller containers. The supply cylinder must either have a siphon or must be inverted to get the liquid CO2 to transfer to the small bottle. The Echometer cylinder must be cooler than the supply cylinder to be able to transfer a good amount of CO2.



Following is the recommended procedure for filling the CO2 bottles:

1. Make sure cylinder is empty, if not, open to atmosphere and discharge all the remaining CO2. (this will also cool the cylinder)
2. Measure and record the weight of the empty cylinder.
3. Connect the cylinder to the supply cylinder using the refill adaptor.
4. Fill with 2.5 lbs of liquid CO2 for the GG0470 or 5 lbs for the GG0430.
5. Weigh the cylinder afterwards and check the new weight with the recorded empty weight to assure it has not been overfilled.
6. If it was overfilled, vent a sufficient amount of CO2 to obtain the correct fillage.

4.3.4 - Gas Gun Maintenance Videos

Detailed instructions on proper maintenance of the gas guns and other components are presented as video files that may be downloaded from the www.echometer.com page or obtained in CD format by contacting Echometer Company. The videos are also loaded on the laptop computer and are accessed via the Help Center under the heading: Support.

5.0 - TWM SOFTWARE SET UP AND WELL DATA INPUT

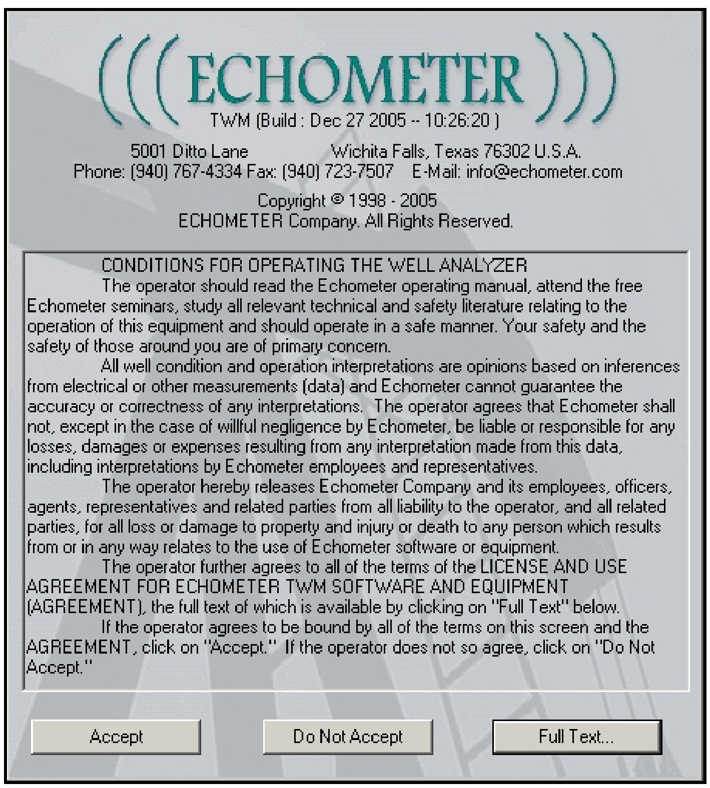
The Well Analyzer's TWM software consists of a series of routines for acquisition, analysis and presentation of the data. Whenever appropriate, the user is prompted by the program to undertake a specific action or to select one of several options which are presented in menus on the screen. Choices are usually made by means of the keyboard keys or using the built-in tracking device.

5.1 - TWM Program Operation

Numerous combinations are available for operating the computer, the software, the hard disk directories and the floppy disks. The recommended procedure described herein assumes that a master TWM directory is installed on the hard drive. This directory contains all necessary Well Analyzer software and all well and measured data.

5.1.1 - Start-up and Disclaimer

The first time the Echometer well analyzer software is executed (by double-clicking the TWM icon on the desktop) in a given day, the following disclaimer text will be displayed on the screen. If the user does not agree with the statement and indicates so by entering any character other than **Alt-A** (Accept) or clicking the Accept button, then the program will stop executing and return to the Windows operating system.

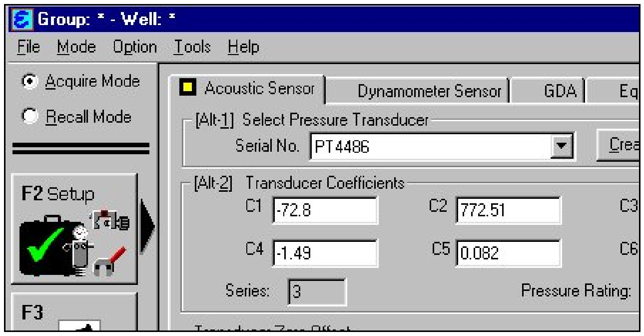


Once the user has accepted the disclaimer, the program will display one of the **Start Up** screens depending on what operation was being undertaken the last time the program was used.

The Well Analyzer master power switch should be **ON** and the **POWER-ON** indicator light should be **green** before loading the TWM software. A memory test will automatically start when the computer is turned on, then the Windows operating system will be loaded and the desktop will be displayed. The TWM software is executed by double-clicking the TWM icon in the START menu or the TWM shortcut on the desk top. The software may be used either to **Acquire** new data or to **Recall** and process data that had been acquired previously.

5.1.2 - The Start Up Screens

After accepting the disclaimer the following **Set Up** screen is displayed when the **Acquire** mode is active:



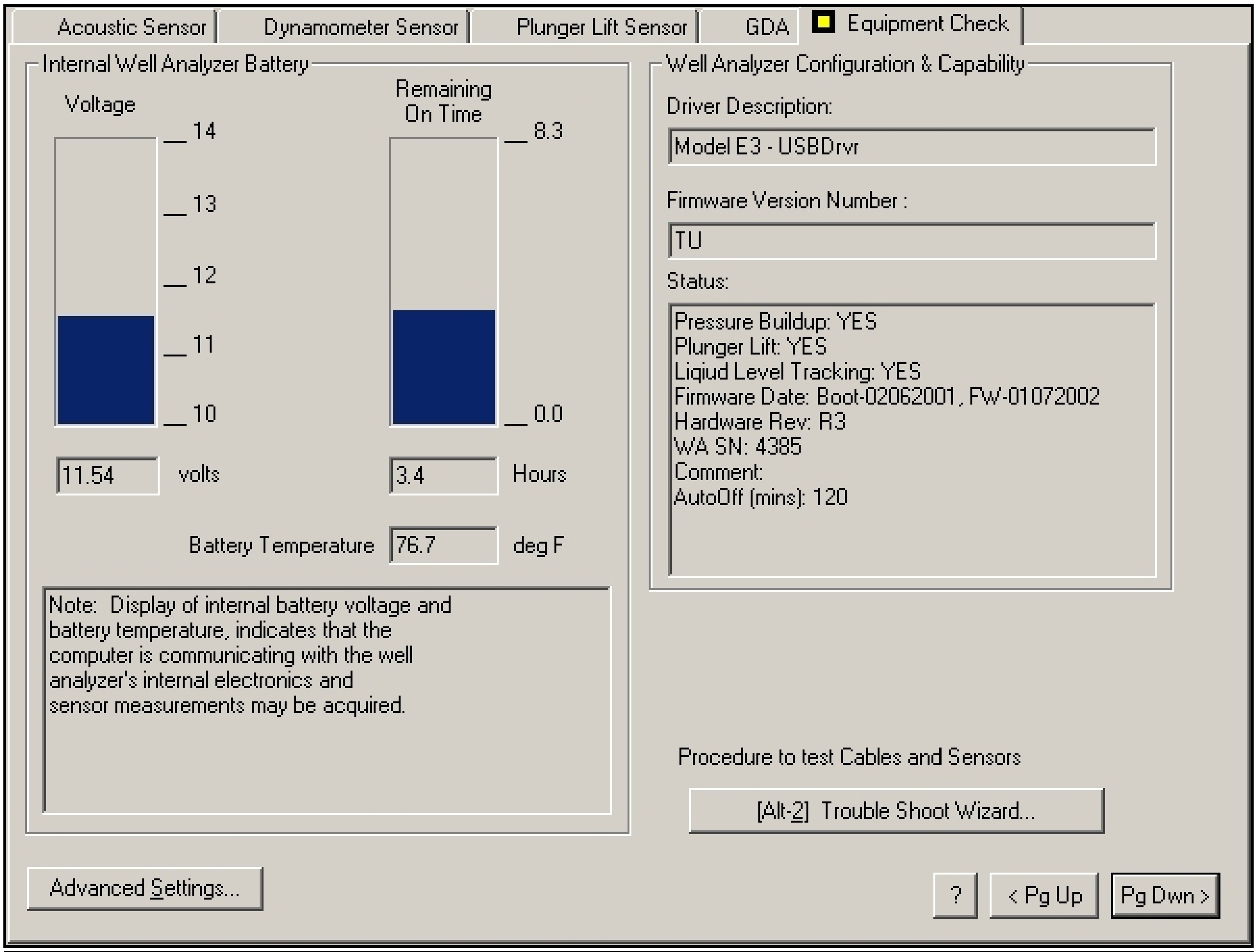
If the **Recall** mode is active the following **File Management** screen will be displayed:

The first time the system is used on a given day, or whenever changes of transducers or other hardware are made, it is necessary to undertake system set-up procedure by selecting the **Acquire** mode and the corresponding **equipment set-up tabs**.

5.1.3 - Equipment Check Tab

The Equipment Check Tab has the following functions:

1. Check proper communication between the computer and the A/D.
2. The user is shown the **A/D battery voltage** and remaining **battery life**.
3. Access is provided to a Wizard to troubleshoot communication problems (E1 or E2)
4. Access is provided to a Wizard to test the cables and A/D electronics.
5. Access is provided to Advanced Settings
6. Configuration and capability of the WA are displayed



The battery voltage and life that are displayed are those of the **battery of the A/D** converter and **not the computer** battery.

5.1.4 - Acoustic Sensor Tab (Acoustic BHP Measurements)

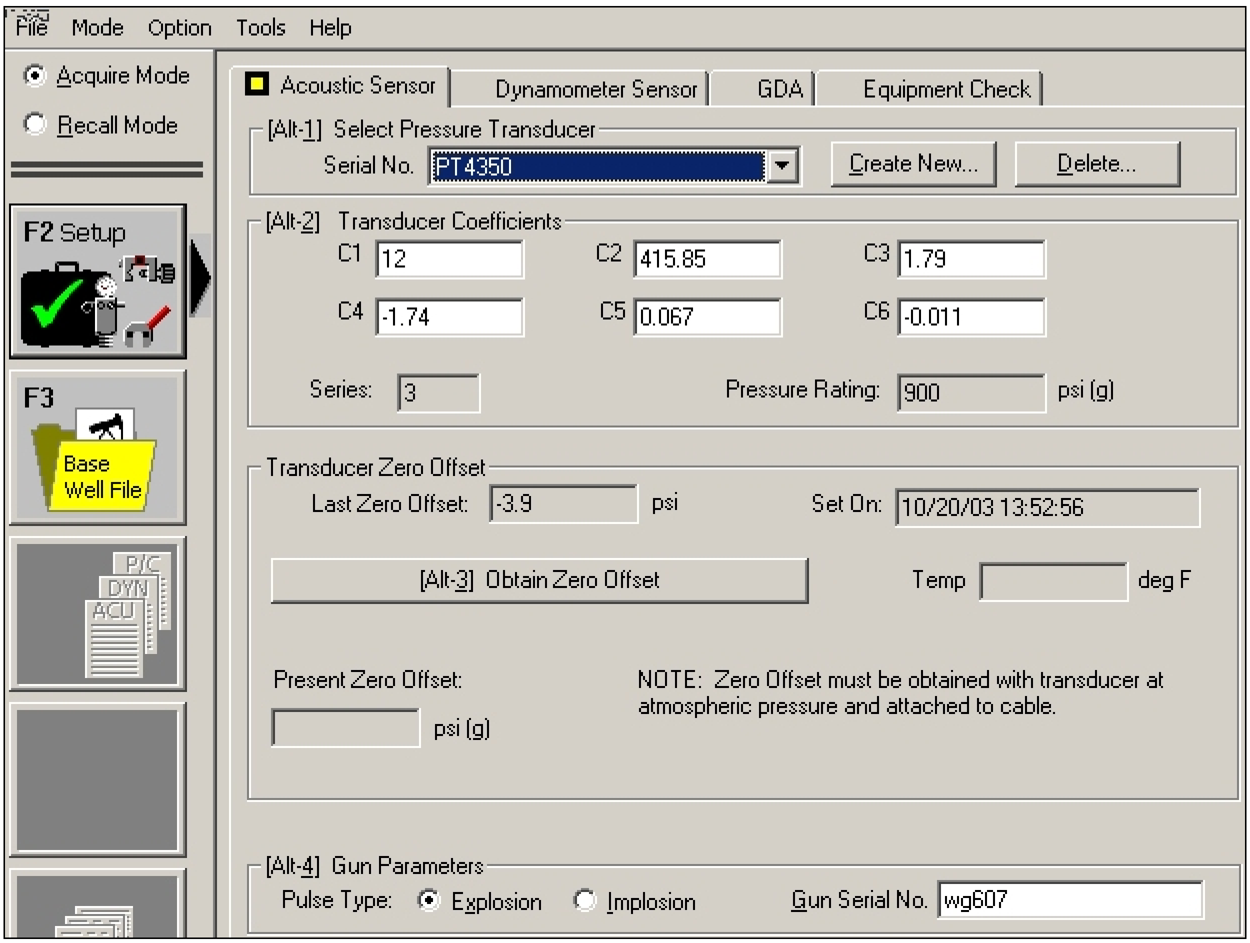
The Acoustic Sensor Tab has the following functions:

1. If a pressure transducer is present, its **coefficients** and **serial number** must be entered or selected from the pull-down menu. The coefficients are used to calculate pressures from the transducer's voltage output.
2. Obtain **Zero Offset** of the pressure transducer. The pressure transducer should be zeroed at the first well each day. (It may be desirable to re-zero the pressure transducer if there are large temperature fluctuations throughout the day.) Close the casing valve to the gun and open the "T" handle valve to expose the transducer to atmospheric pressure. Press **Alt-3**. Continue to press the **Alt-3** key monitoring the "zero" readings until they stabilize. This procedure usually requires two or three readings.
3. Select the **shot type**, **explosion or implosion**. This allows the software to correctly process the returning signals. Enter the gun **Serial Number** such as WG134 (remote fired), CG134 (compact), IG134 (5000psi), HG134 (15000psi)

IMPORTANT NOTE - PRESSURE TRANSDUCER

When the gas gun is installed on the wellhead be sure the casing valve is **closed** and the bleed valve is **open** to the atmosphere while zeroing the transducer. If the zero reading is large, over +/- 100 PSI, the transducer may be defective. Check the transducer against a conventional gauge. The transducer's maximum operating pressure in PSI units, is approximately 2 times the coefficient C2. Over-pressuring the transducer will result in transducer damage. If the transducer is not accurate it may be corroded and dangerous to use. Send to Echometer Co. for recalibration and testing.

The following Figure shows the SET-UP Screen:



IMPORTANT NOTE - SERIAL NUMBER

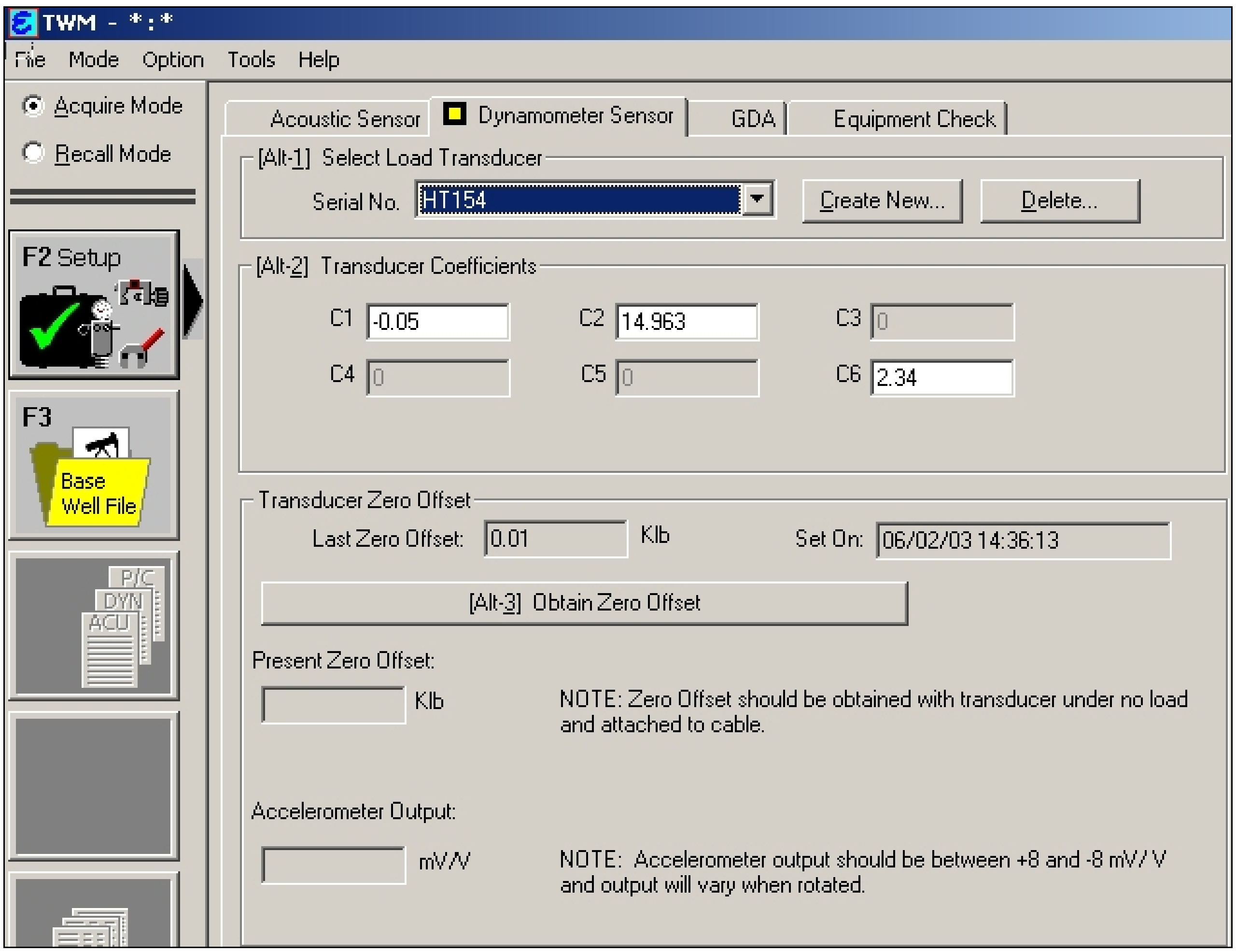
It is also very important that the correct **serial numbers** and **coefficients** be entered for each transducer used since the program uses this information to decide on the correct sequence for calibration and data acquisition.

5.1.5 - Dynamometer Sensor Tab (Dynamometer Measurements)

The **Dynamometer Sensor Tab** has the following functions:

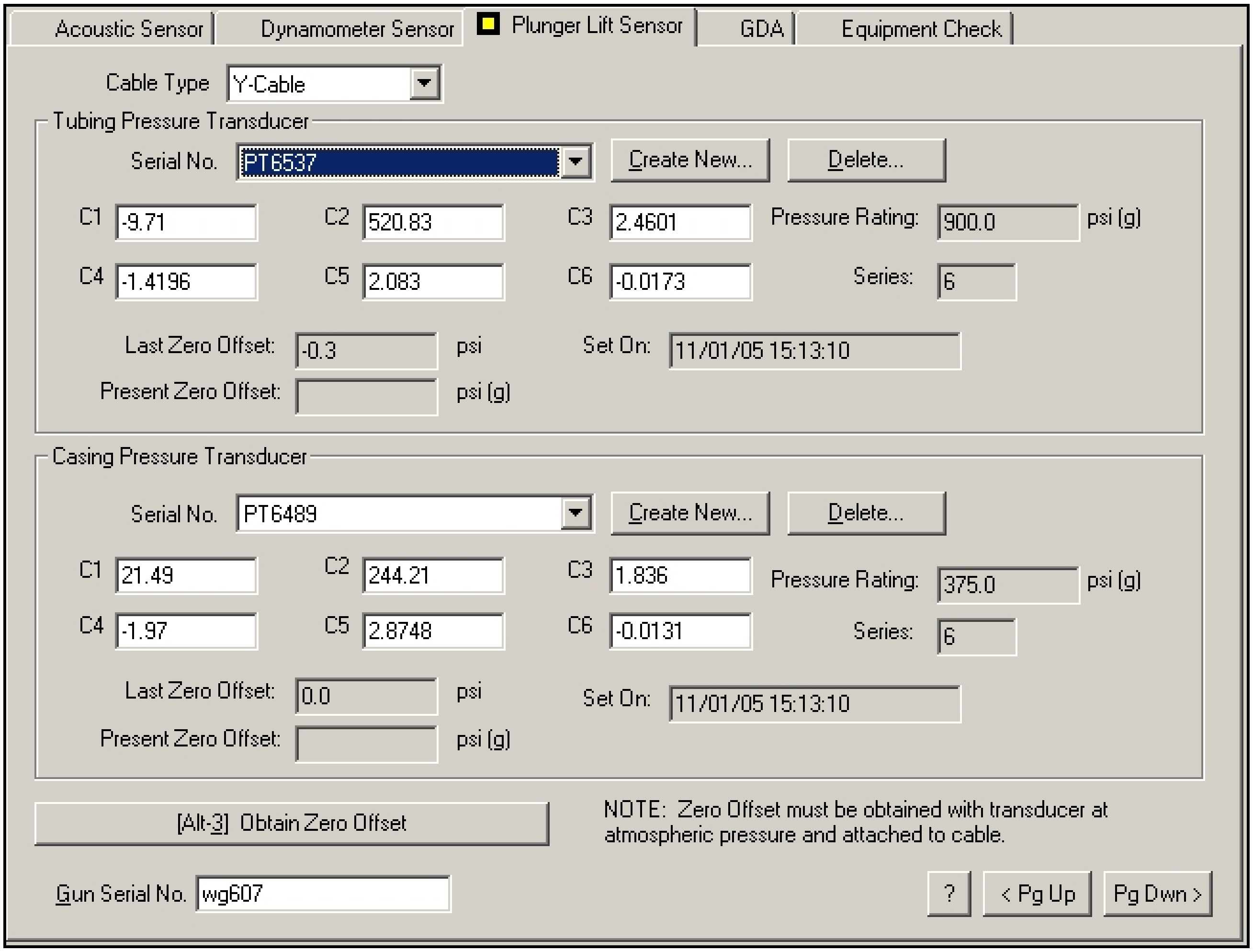
1. The dynamometer load cell **coefficients** and **serial number** must be entered or selected from the pull-down menu. The coefficients are used to calculate load from the transducer's voltage output.
2. Obtain **Zero Offset** for the Horse-Shoe type transducer. The transducer should be zeroed at the first well each day. (It may be desirable to re-zero the transducer if there are large temperature fluctuations throughout the day). Make sure that the load cell is not loaded when checking the zero offset.
3. Entering the serial number and coefficients for additional transducers.
4. Checking the value of the **accelerometer** output.

For dynamometer data acquisition the load transducer information and coefficients must be entered. Coefficients 1and 2 are used to calculate the load from the transducer voltage output. Coefficient 6 is used to calculate position from the accelerometer output. C6 is the sensitivity coefficient having units of mV/v/g. Coefficient C6 is used in calculating the stroke length.



5.1.6 - Plunger Lift Tab (Plunger Well Monitoring)

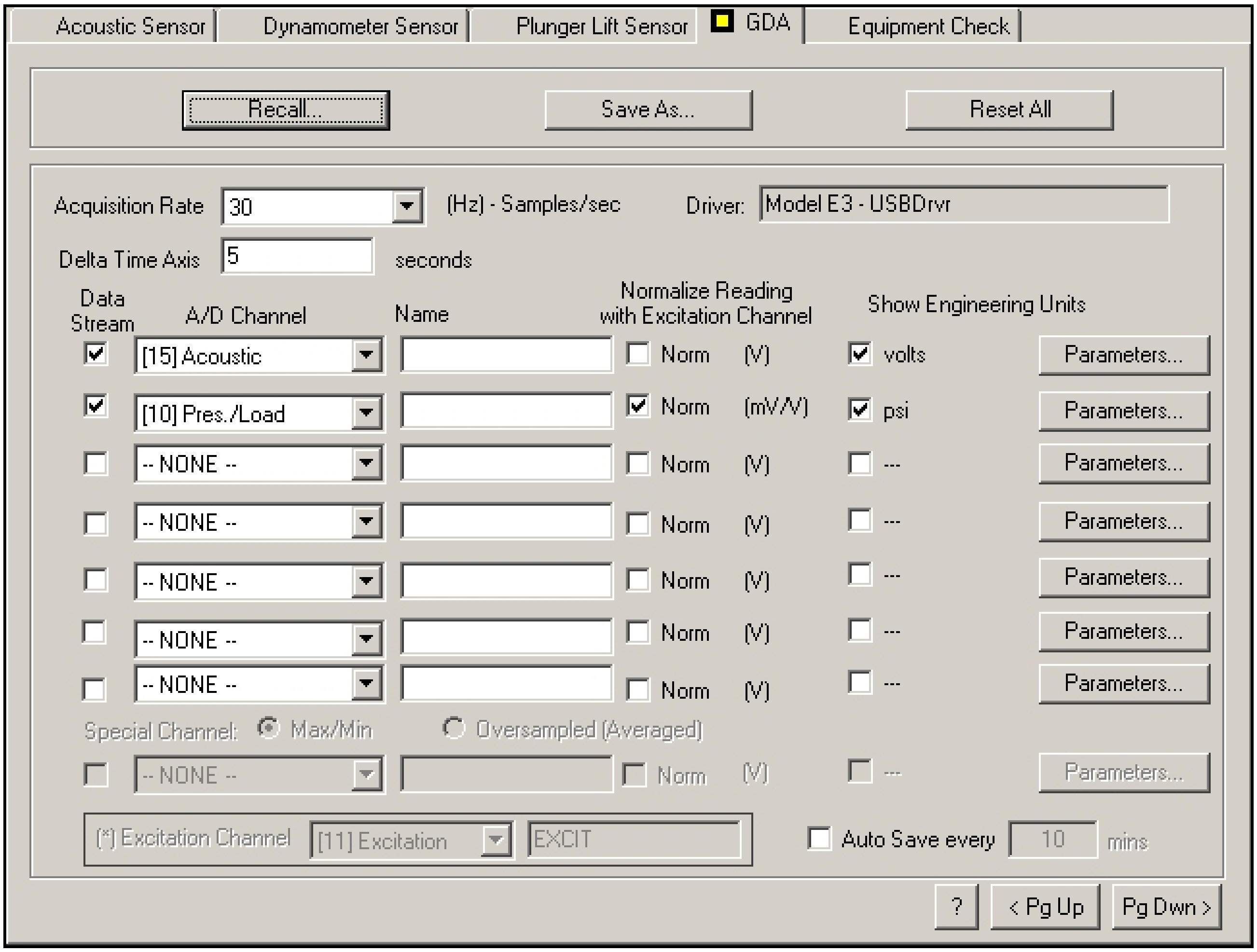
Acoustic measurements in plunger lift wells are generally made using two pressure sensors. The following set up screen is used for this application:



Details regarding plunger lift applications of the Well Analyzer are discussed in the separate manual addendum.

5.1.7 - General Data Acquisition (GDA) Tab

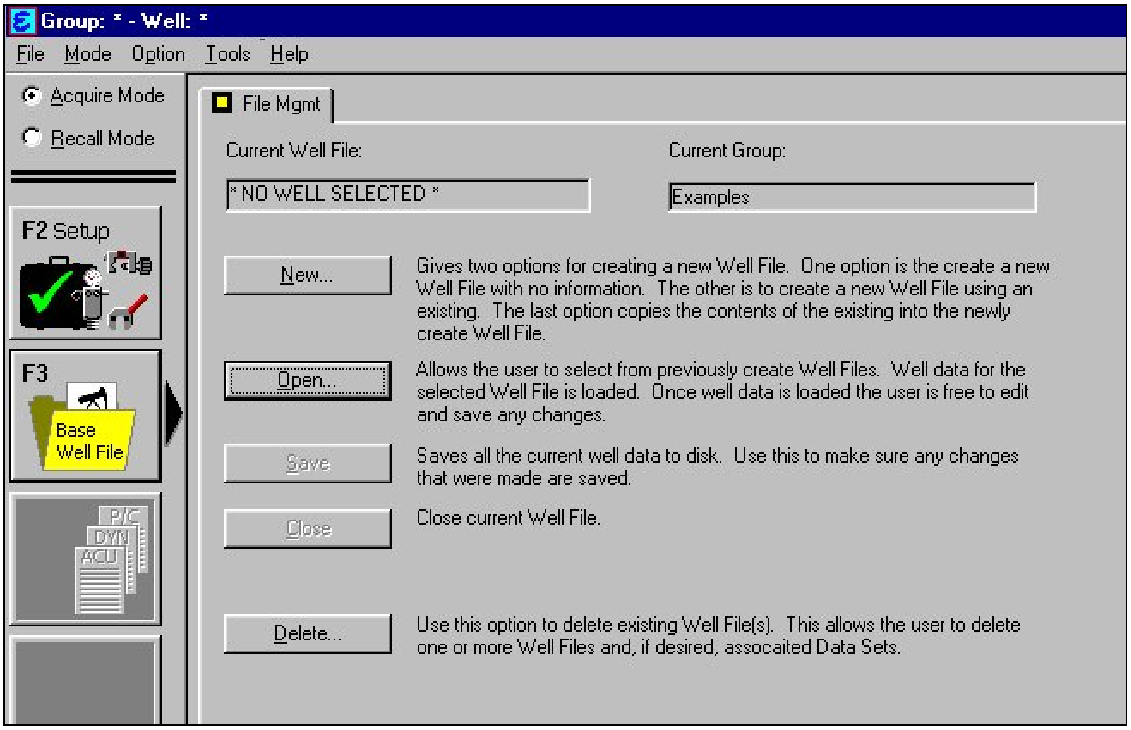
The GDA tab is used to select the channels to be sampled and the sampling rate when using the Well Analyzer as a general data acquisition instrument to log the signals from various transducers.



The rate of data acquisition, the graphics settings and the data streams to be monitored are selected by the user. Details are described in **Chapter 12** of this manual.

5.2 - Base Well File Information

In order to use the TWM program it is necessary to **enter or recall** information about the well that is stored in the **Base Well File**. Regardless of what type of measurements are to be undertaken it is recommended that the data in the base well file be as complete and as accurate as possible. Data may be entered directly in the TWM program by filling the corresponding forms or it may be imported if the user has already created well files using the DOS version of the Well Analyzer programs. The Base Well File is accessed by selecting **F3** when in the **Acquire** mode. This will display the following screen:



Select the **New** (Alt-N) option when entering data for a new well. Select **Open** (Alt-O) when data for an existing well has been previously entered in the program. The **Delete** (Alt-D) option allows deleting a well and its associated data sets from the computer.

Well data is divided into four separate groups under the following tabs:

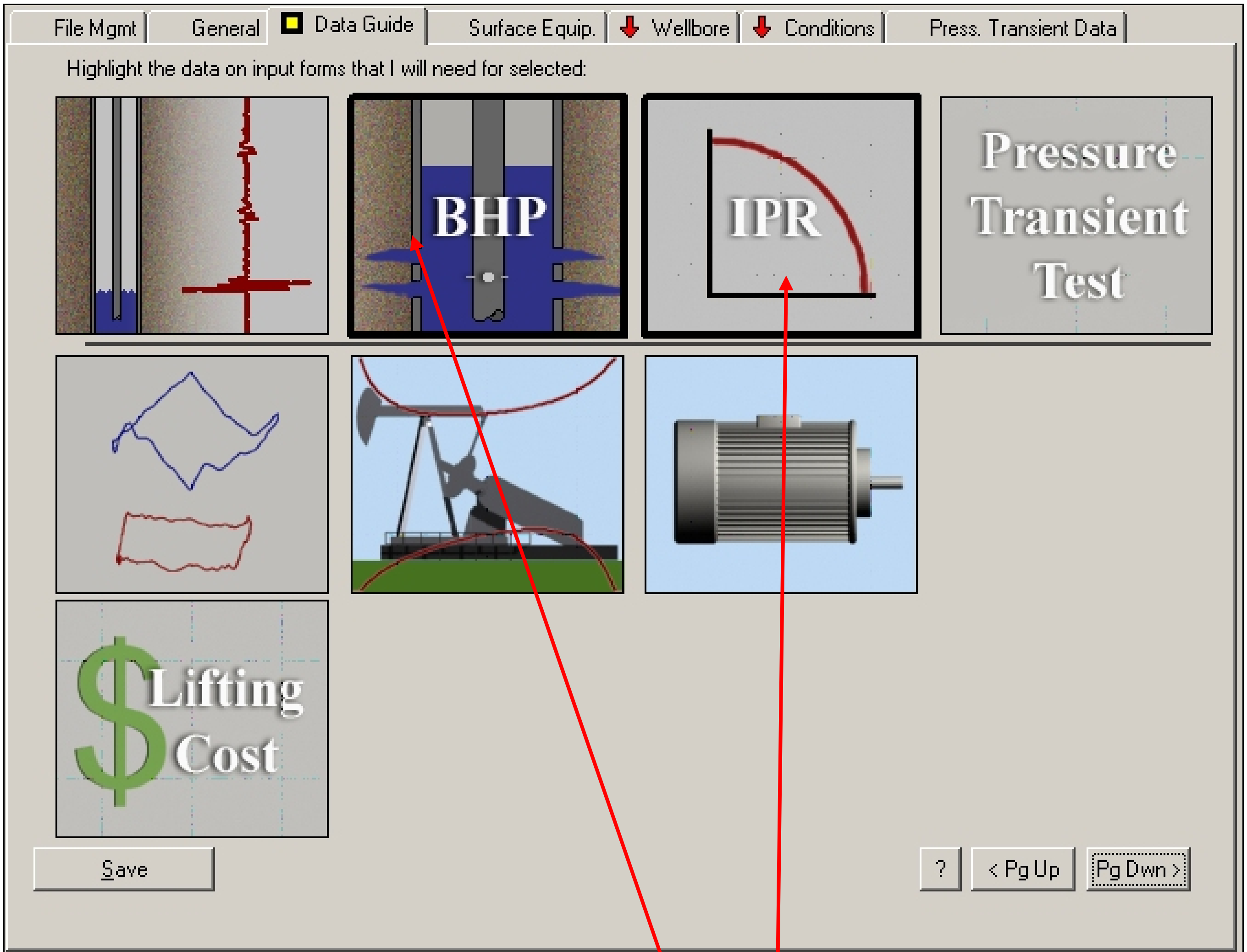
- **General**: identifies the well the operator and the type of well
- **Surface Equipment**: describes the surface equipment in use with the well
- **Wellbore**: describes the equipment installed in the wellbore
- **Conditions**: describes the performance parameters of the well and the reservoir

If "Display the Data Guide Tab" is selected in the User Help Menu, the **Data Guide** Tab will be displayed.

If Pressure Transient is selected as an active module in the User Help Level screen, then a fifth Tab for **Press. Transient Data** will be displayed.

5.2.1 - Data Guide Tab

The purpose of this tab is to assist the new user in determining the **minimum number** of well data items that **are required** to be able to analyze correctly the acquired data, depending on the specific purpose of the measurements.



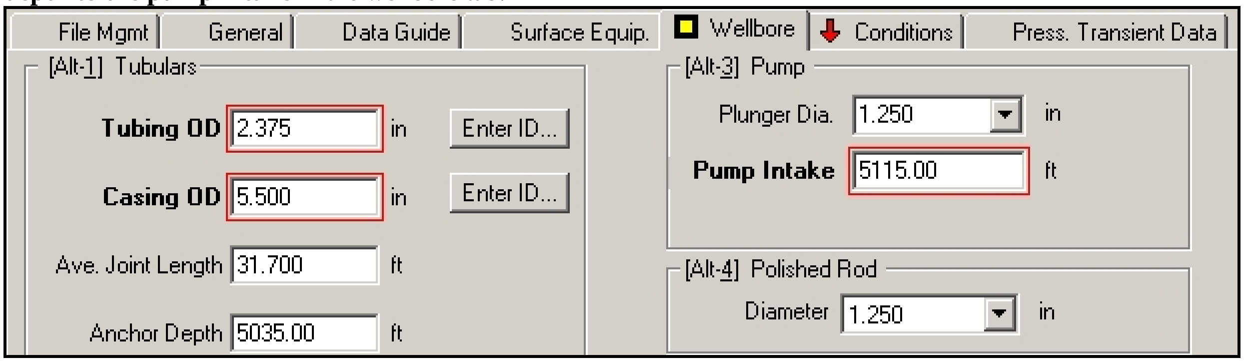
This optional tab may be used to highlight the input data fields that are **required by the software** to perform a specific analysis (for example calculate BHP and IPR) by selecting the appropriate buttons.

In response to the user's selection, the pertinent data input tabs are flagged with a downward red arrow:

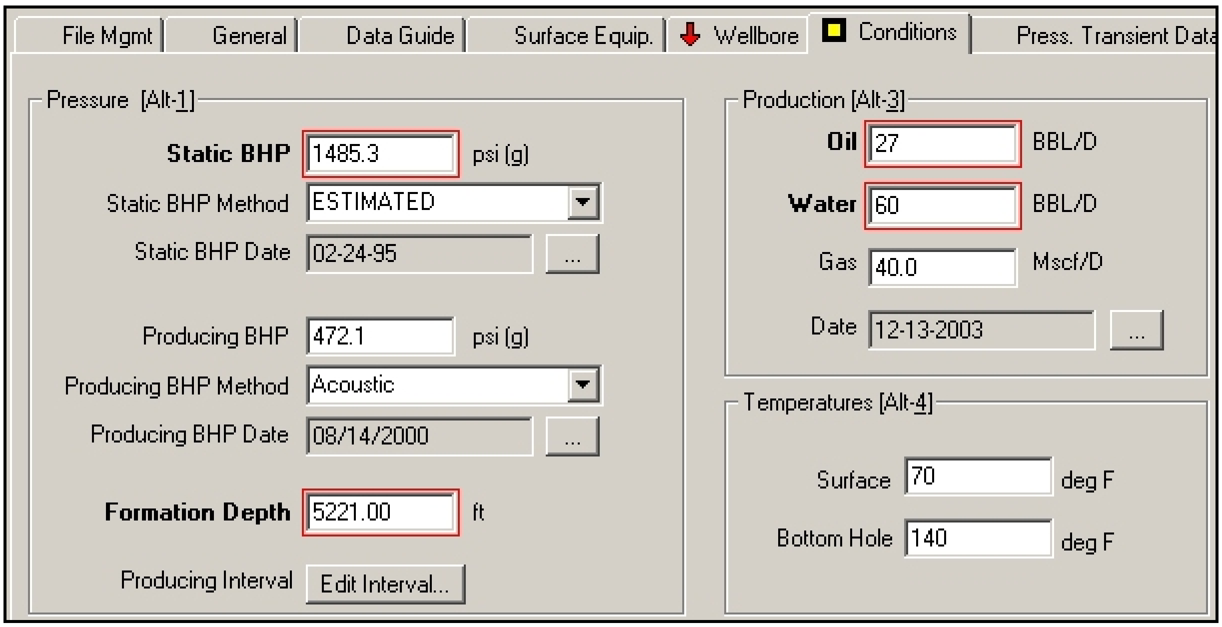
and in each data input tab the required data fields are outlined in red and the data label is bolded :

The user is required to enter the correct data in these fields in order to insure that the analysis is performed correctly using the data that corresponds to the specific well.

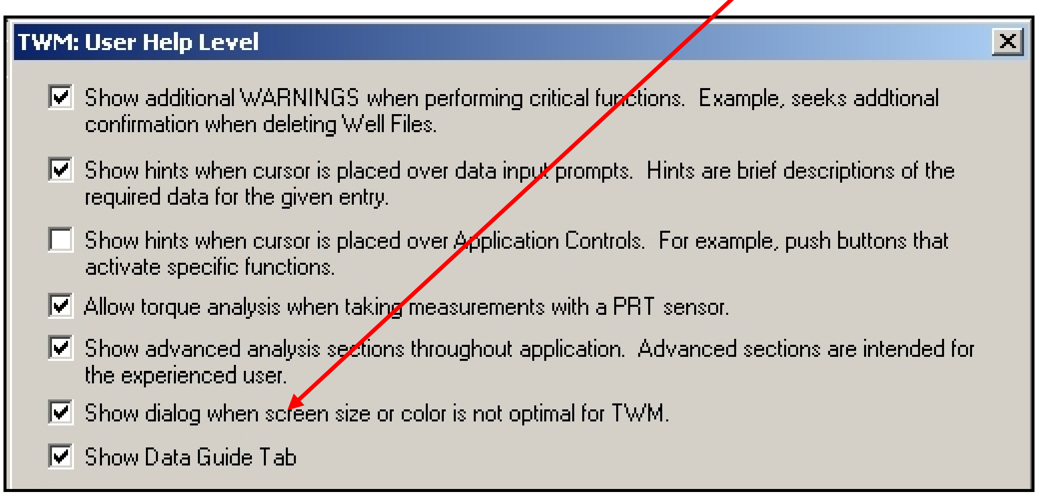
Calculating the **BHP** from the acoustic measurements requires knowledge of the **casing and tubing diameters** and the **depth to the pump intake** in the wellbore tab:



Calculation of the **IPR** of the well, in addition requires the **Static BHP**, the well test **oil and water rates** and the **formation depth**:



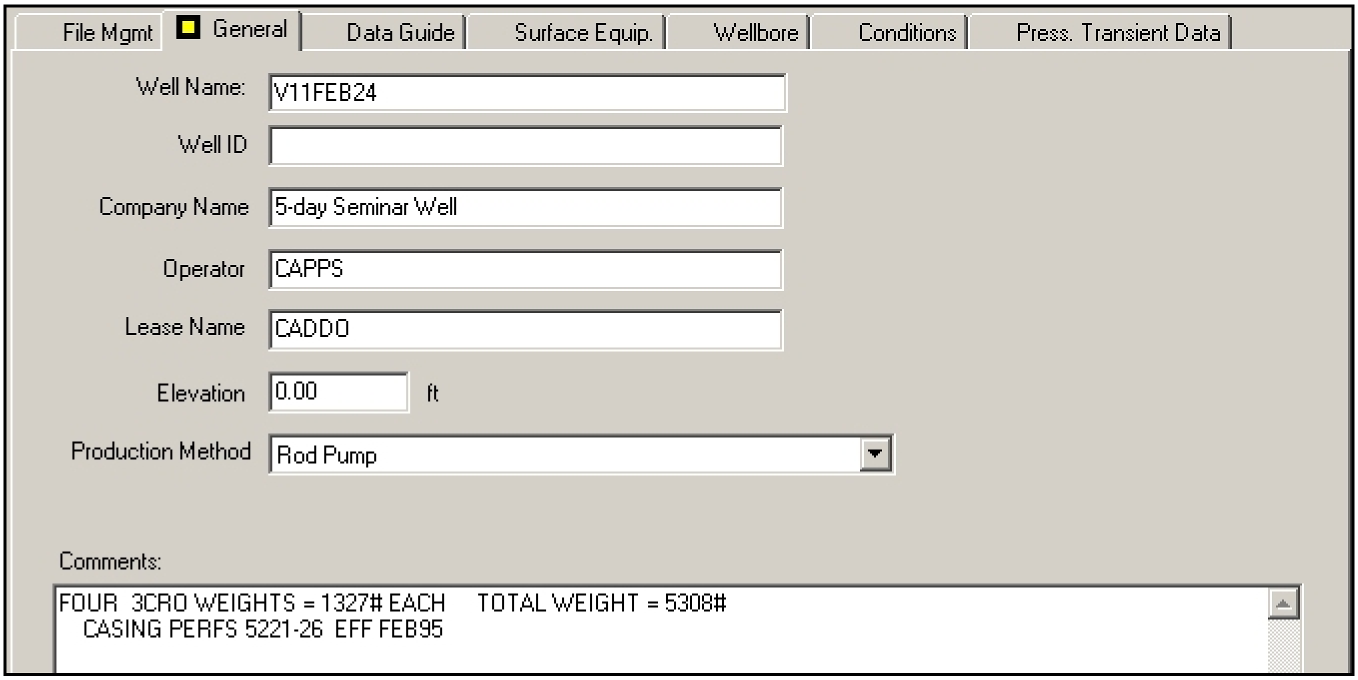
Once the user has become familiar with the TWM data requirements, the Data Guide Tab may **be hidden** by deselecting the corresponding check box in the User Help Level menu.



5.2.2 - Rod Pump Well - Definition of Data Fields in Tabs

Data for the sample well V11Feb24 will be used to illustrate the various tabs corresponding to the well data. The following figure shows the **General** data:

5.2.2.1 - General Tab Rod Pump Well



- **WELL NAME** Enter the well name here. Do not use more than 24 letters in the well name and do not use an extension, the software will add an appropriate extension. The name entered will be shown on data files and analysis screens.

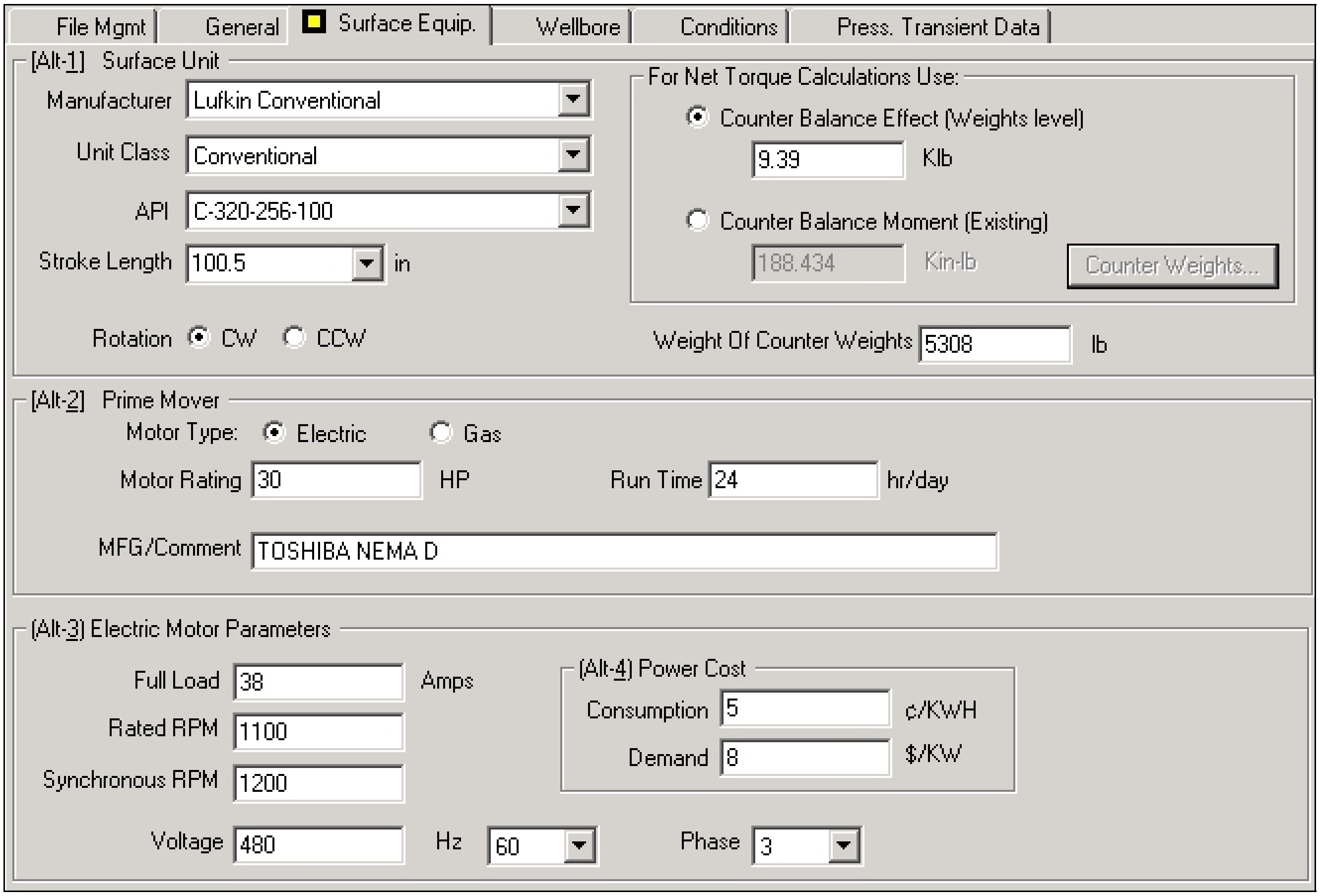
DO NOT USE THE FOLLOWING CHARACTERS:

| \ , . ? / : ; " [ ] * + =

- **WELL ID** Enter other well identification.
- **COMPANY** Enter the company name.
- **OPERATOR** Enter the name of the person conducting the test.
- **LEASE NAME** Enter the lease name.
- **ELEVATION** Enter the elevation of casing head relative to Mean Sea Level.
- **ARTIFICIAL LIFT TYPE** Select the type from the **pull-down menu** (controls type of data to be entered)
- **COMMENTS** This field is used to enter important information regarding the equipment or the well completion.
- **DATASET DESCRIPTION (In Recall Mode)** Enter a description of the series of tests to be performed.

5.222 - Surface Equipment Tab – Rod Pump Well

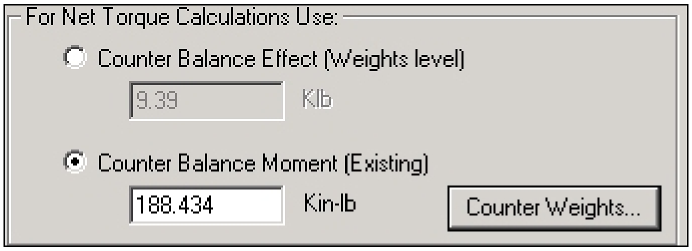
The following figure shows the **Surface Equipment** tab:



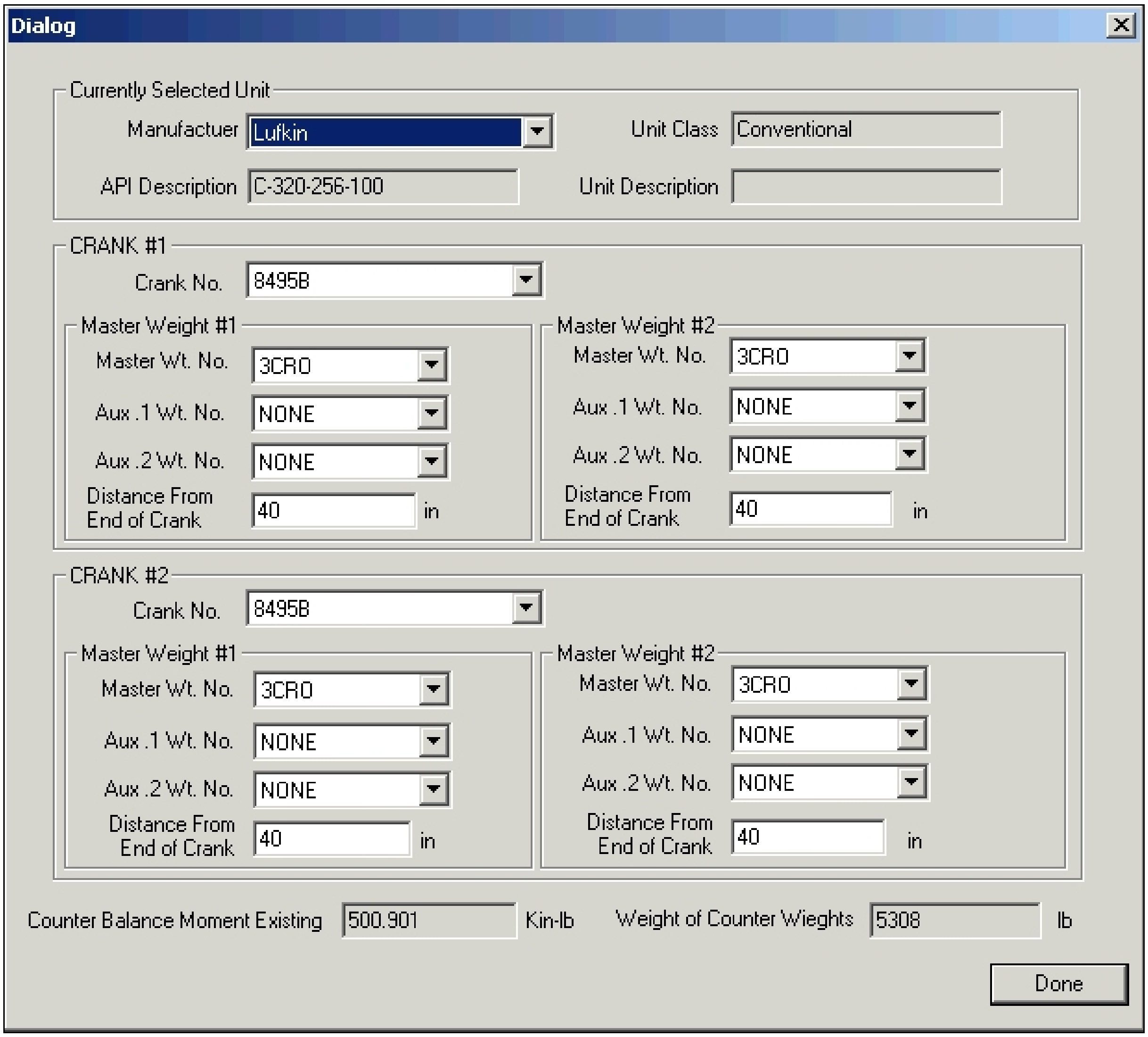
Surface Unit Data:

- **MANUFACTURER MODEL** Select the pumping unit manufacturer model from the pull-down menu The model number is written on a metal plate on the Samson post generally.
- **UNIT CLASS** The class corresponds to the API geometry designation.
- **API** Select the unit's size from the pull-down menu.
- **STROKE LENGTH** Select the polished rod stroke length in inches. The acceleration data is matched to the entered stroke length at the option of the operator. The operator should measure this length with the accuracy desired.
- **ROTATION** Select CW for clockwise rotation of gear box cranks. Enter CCW for counterclockwise rotation of cranks. The polished rod is to the operator's right when viewing the gear box.
- **COUNTER BALANCE EFFECT (Weights Level)** This load is exerted by the weights, cranks, etc. on the polished rod when the cranks are level and the polished rod is stopped on the upstroke and the brake is released. This number is determined by field measurement. The operator can enter this number or the operator can position an indicator on the counterbalance plot and hit enter to place this value in the well file. The counter balance effect (**CBE**) is used in torque analysis.
- **WEIGHT OF COUNTERWEIGHTS** Enter the total weight of the counterweights installed on the unit or use the **COUNTERBALANCE MOMENT** calculator to select crank and counterweights from library by clicking on the **Counter Weights** button and entering the position of the counterweights on the crank.

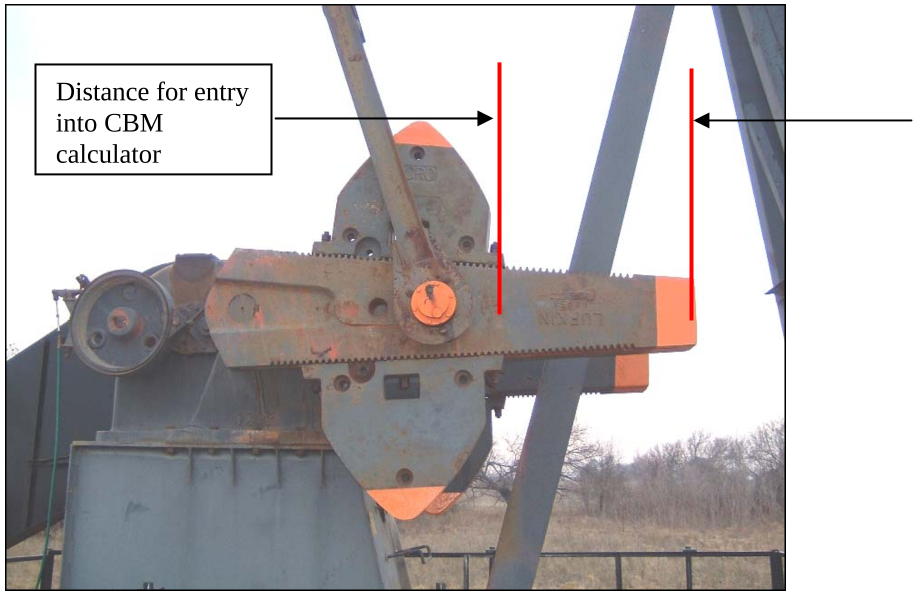
Counterbalance Moment (CBM) Calculation
Select the counterbalance moment radio button:



Click on the **Counter Weights** button to bring up the counter weight selection screen and select the corresponding cranks and counterweights fro the pull down menus:



The software calculates the existing counterbalance moment based on the selected weights and the measured **Distance from End of the Crank** to the outer edge of the counterweight.



The weights of the counterweights can be obtained from the TWM **Counterweight List** that is installed with the TWM program.

Prime Mover Data

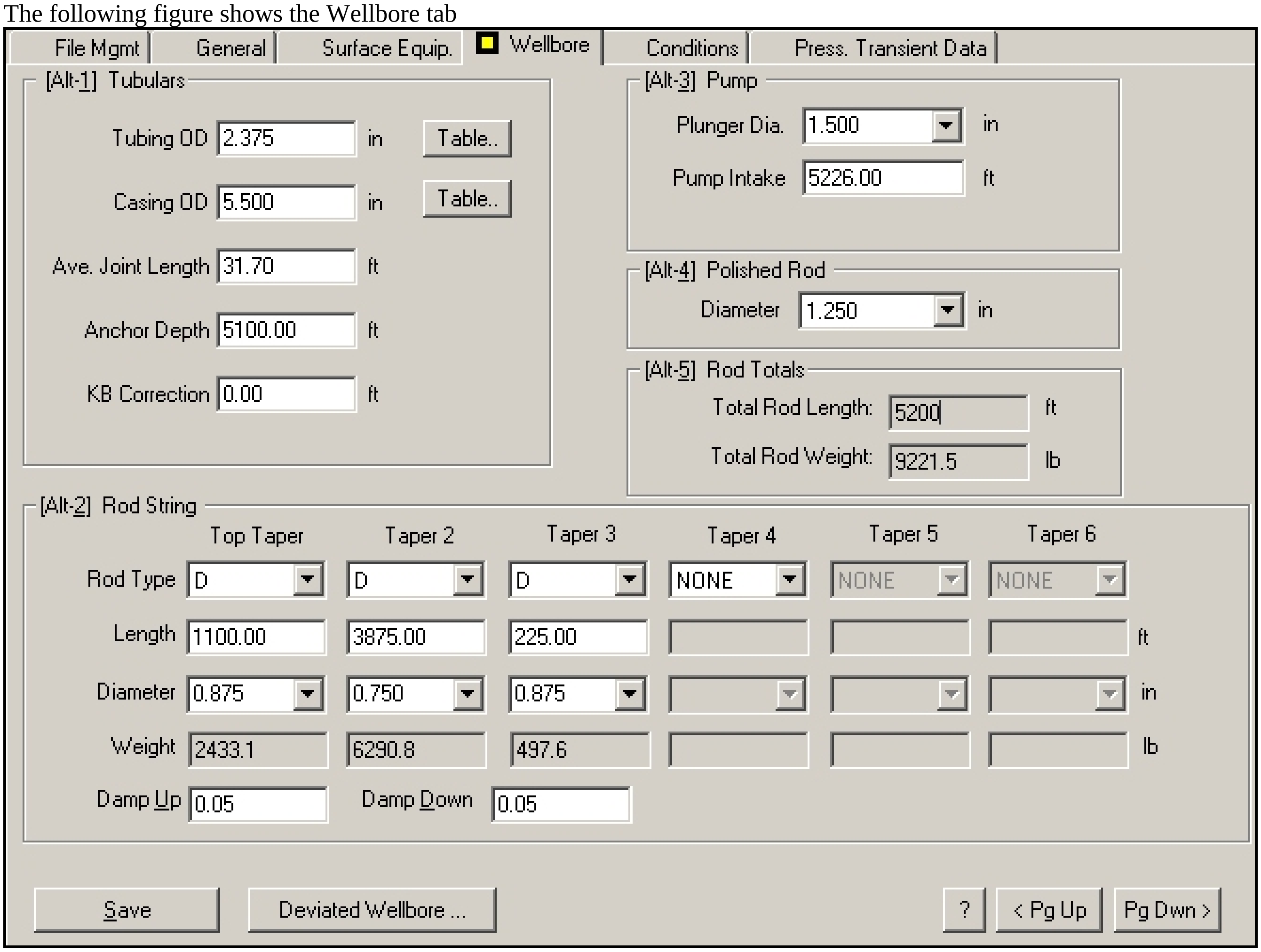
- **MOTOR TYPE** Select Electric or Gas engine
- **MOTOR RATING** For electric motors enter the value for **rated Horsepower** listed on the motor's nameplate that corresponds to the wiring that is being used.. For gas engines enter the **rated Horsepower at the average RPM**. See APPENDIX IV for typical gas engine performance curves.
- **RUN TIME** For units operating **on timers,** enter the hours per day that the unit operates.
- **MFG/Comment** Enter a description of the motor/engine type and model.
- **FULL LOAD AMPS** Enter the value corresponding to the wiring that is being used, as read from the motor's nameplate.
- **RATED RPM** Enter the motor speed at rated power and torque
- **VOLTAGE** Enter the line voltage at the switch box
- **Hz** Select the frequency of the line voltage
- **PHASE** Select the number of phases for the line voltage.

Power Cost Data

- **CONSUMPTION** Enter the cost of electricity such as 8 for 8 cents/KWH.
- **DEMAND** Enter the demand charge such as 12 for 12 $/kW

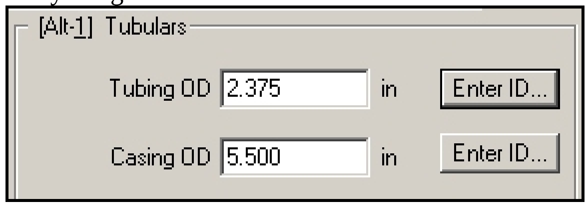
5.2.2.3 - Wellbore Tab – Rod Pumped Well

The following figure shows the Wellbore tab

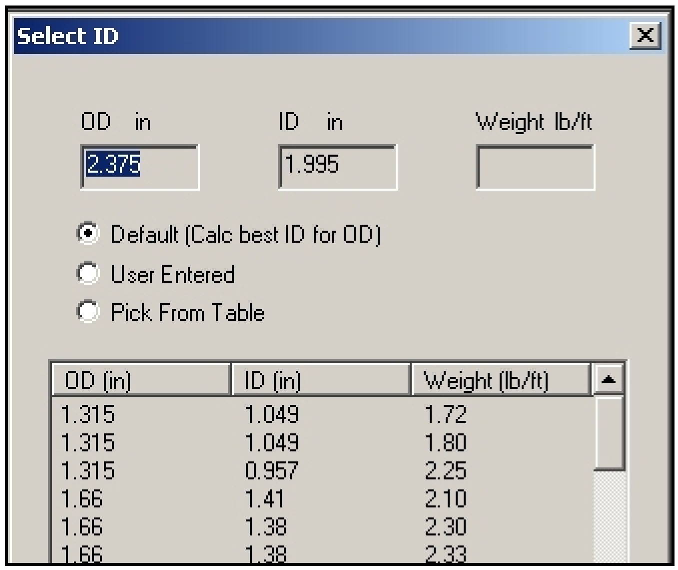


Tubulars Data:

- **TUBING OD**
- **CASING OD (IN)** These two entries are selected from the **pull-down menus** and are used to calculate annular area and afterflow rates of the liquid and gas. For example, entering 5.5 inch casing and 2.375 inch tubing as shown below, the software automatically assigns values to the internal diameter based on the most commonly used tubular



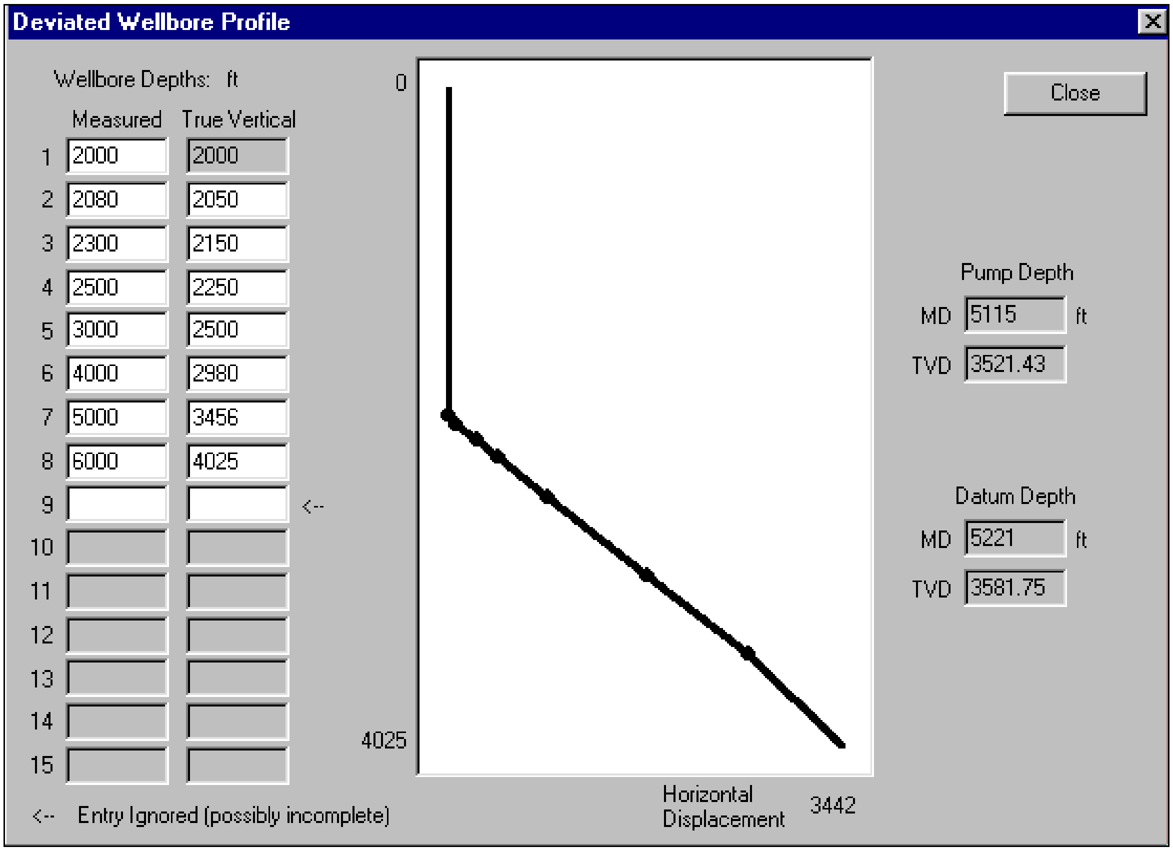
The user may override these default values by clicking on the **Enter ID** button. This opens the following ID selection menu:



The user may then **Pick from Table** a specific tubular size and weight from the table, or type a custom **User Entered** ID for the specific tubular.

- **AVERAGE JOINT LENGTH (FT**) is needed to determine the depth to the liquid level. Obtain from a current tubing tally. Do not count subs in the determination of average joint length. This number should be calculated to the hundredth of a foot for maximum accuracy. Example: 31.27 ft.
- **ANCHOR DEPTH (FT)** The entry of the tubing anchor can be used to aid the operator in selecting the liquid level kick and also can be used as a distance reference when processing the acoustic data using one of the special processing techniques discussed later. Enter as **Measured Depth.**
- **KB CORRECTION** Enter the distance between wellhead and kelly bushing, ft.
- **PLUNGER DIAMETER** Enter the diameter of the pump plunger in inches; for example 1.25 inches.
- **PUMP INTAKE (FT)** This entry (measured depth) corresponds to the depth of the **Standing Valve** in a rod pump or the depth to the pump intake for **ESPs**. If water is produced with the oil, the software assumes all liquid below the pump to be water and all liquid above the pump is oil. For efficient pump operation a long tail pipe should not be used.
- **TAPER** Enter the **type**, **length** and **diameter** of each section of rods. For example: footage, 1200 feet; diameter, 0.875 inches. Also, select rod type such as C, D, K, H for steel, SB for sinker bars or FG for fiberglass.
- **DAMP UP/DOWN** The damping factor used by the wave equation model of the rod string. Use the default value unless the shape of the pump card indicates that it should be modified. Adjust number to correct the shape of the downhole card to known pump conditions. A smaller number tends to fatten the card and increase the difference between maximum and minimum loads at mid-stroke.
- **ROD TOTALS** The total rod string **length and weight** based on the values entered in tapers.

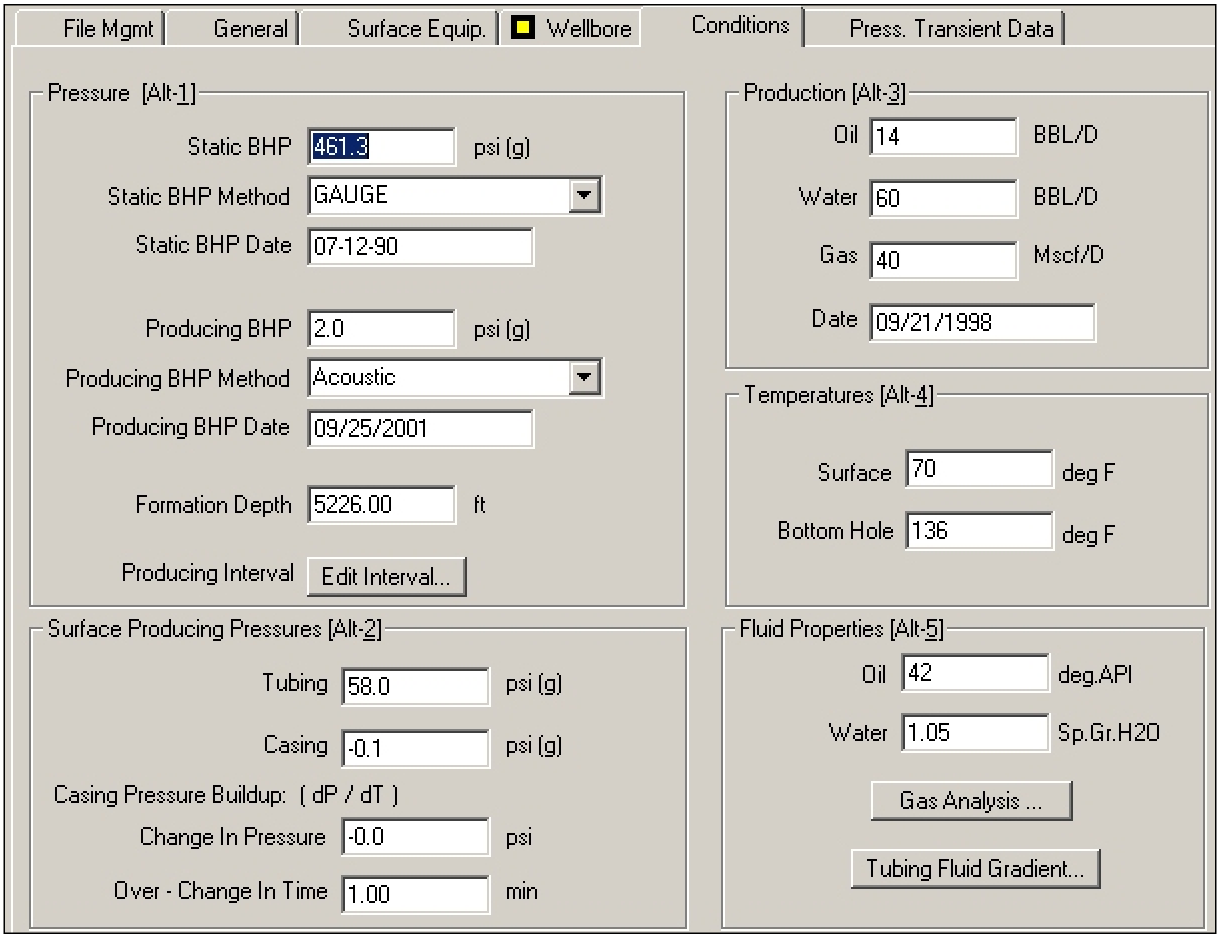
- **DEVIATED WELLBORE** Select this option to enter the wellbore directional survey for deviated wells. The following form is displayed for entry of the corresponding pairs of **Measured and True Vertical Depths**.



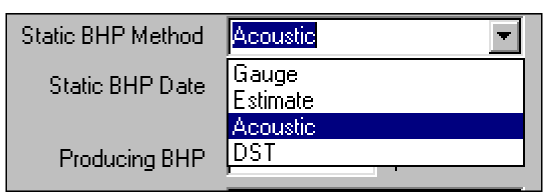
The software uses these data to compute the pump intake and the datum pressures based on their actual True Vertical Depths. The form displays the computed values.

5.2.2.4 - Conditions Tab – Pumping Wells

This form includes the data that describes the characteristics of the well, the well completion, the formation and the produced fluids:

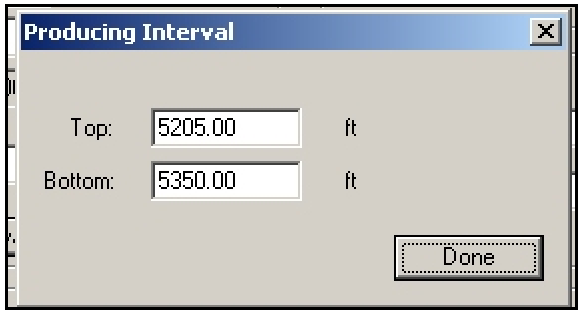


- **STATIC SBHP** Enter the static reservoir pressure (SBHP). This value is compared to the producing bottomhole pressure to determine the producing rate efficiency and maximum available flow rates.
- **STATIC BHP METHOD** Denotes the method used to obtain the static reservoir pressure such as gauge, estimated, etc. selected from the pulldown menu:



- **STATIC BHP DATE** The date when SBHP was obtained.
- **PRODUCING BHP** This is the pressure computed at the datum depth (generally the formation depth).
- **PRODUCING BHP METHOD** Denotes the method used to obtain the pressure at the datum depth.
- **PRODUCING BHP DATE** The date when the PBHP was obtained.
- **FORMATION DEPTH (DATUM) (FT)** is the depth in feet to the pressure datum. The **BOTTOM** of the producing interval should be entered unless the operator desires otherwise. The PBHP is calculated at this depth and the location of the pump can be compared to the lowermost producing zone as a way of detecting potential gas interference problems.

- **PRODUCING INTERVAL** Enter top and bottom depth of producing zone(s) in the following form that is displayed after clicking on "**Edit Interval..**" button:



Production Data:

- **OIL BOPD** Oil production from the most recent well test in stock tank barrels/day. This number is used for calculating the maximum available oil production.
- **WATER BWPD** Water production from the well test in barrels/day. It is used to calculate liquid gradients and maximum water production rates.
- **GAS MCFD** Enter the total gas flow rate from the well test.
- **DATE** Enter the date of the well test information

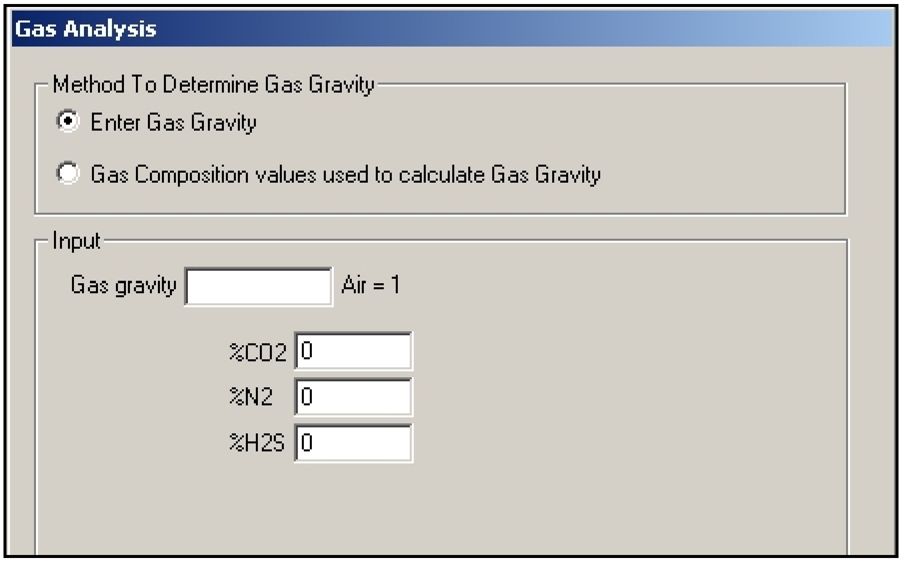
Temperature Data:

- **SURFACE TEMPERATURE (F)** The surface temperature of the wellhead gas is used to calculate gas gradients. Typically this value is between 60-70 ^{O}F. NOTE: this is not the thermistor or air temperature; it is the ground temperature a few feet below the surface.
- **BOTTOMHOLE TEMPERATURE (F)** Used in conjunction with the surface temperature to correct fluid gradients for downhole conditions. Obtained from well logs or calculated from local geothermal gradient (average 15 ^{O}F/1000 feet).

Fluid Properties:

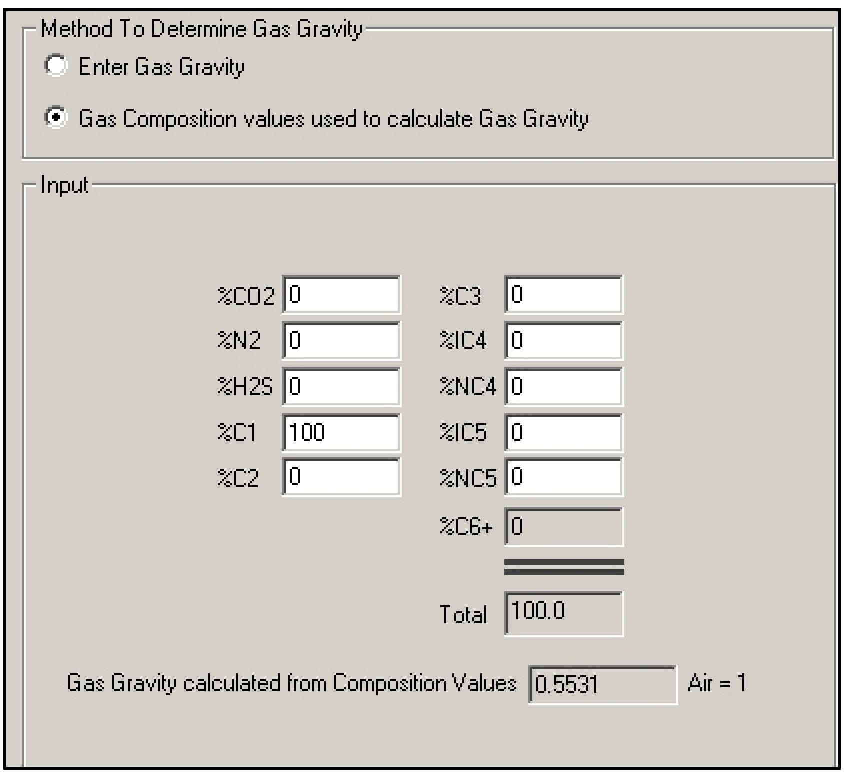
- **OIL GRAVITY (API)** The API gravity of the produced oil is needed for liquid gradient calculations.
- **WATER GRAVITY (SG)** The water gravity should be entered as a specific gravity. Enter 1.05 if unknown.
- **GAS GRAVITY (SG)** The gas gravity relative to air
- **GAS ANALYSIS** This button opens a form for input of the gas gravity or the composition of the gas in the wellbore. Generally this composition is different from the composition of the gas sampled at the sale line or at the separator.

The user may enter a valuye of the gas gravity if it is known or the composition of the gas using the following form.



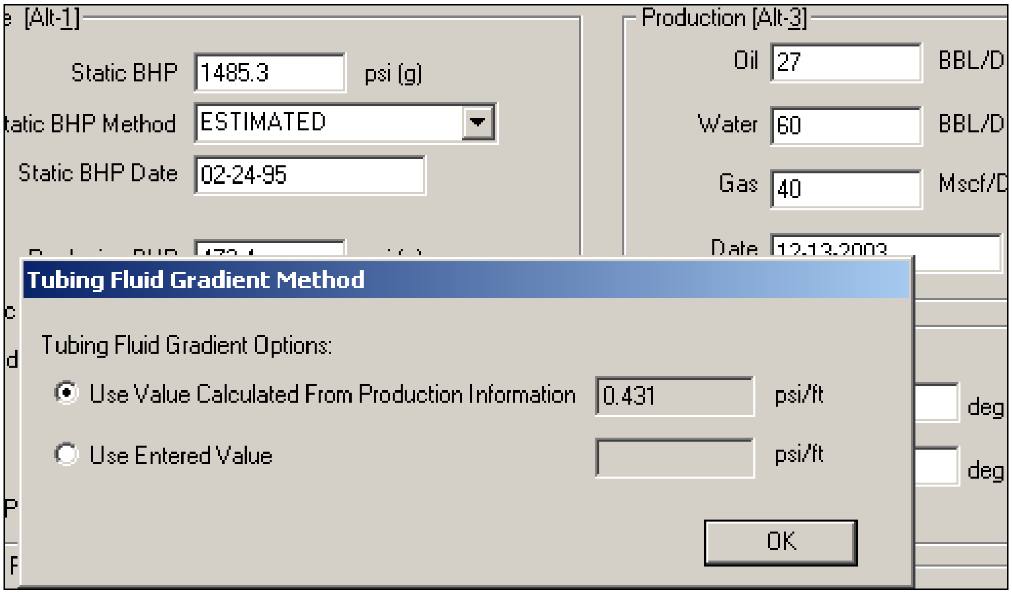
NOTE: If the gas gravity input is left BLANK then the program will compute the gas gravity from the gas acoustic velocity determined from the last acoustic fluid level measurement

If the Gas Composition option is selected then the follwing form is displayed:



The form includes a default value of 100% C1 that results in a gas gravity of 0.5531

- **TUBING FLUID GRADIENT** This input screen allows defining the gradient of the fluid in the tubing based on either the oil and water production test data and fluid densities or entering a user-defined value:



Surface Producing Pressures:

- **TUBING PRESSURE (PSIG)** The average tubing pressure while pumping.
- **CASINGHEAD PRESSURE (PSIG**) If a pressure transducer is not available, the casing pressure may be read manually and entered here.

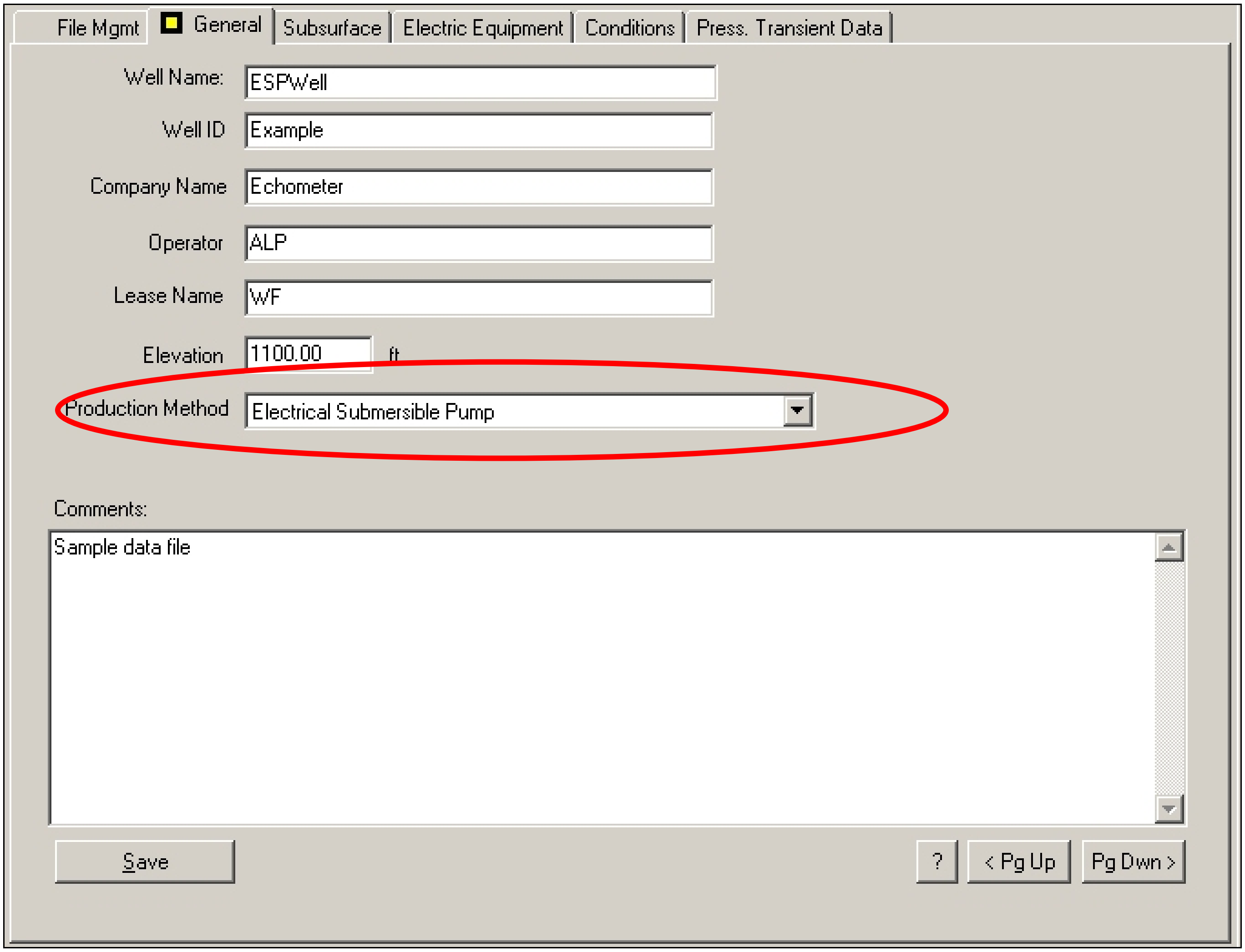
Casing Pressure Buildup:

- **CHANGE IN CASING PRESSURE (PSI/MIN)** If a pressure transducer is not used, the operator must enter the change in casing pressure and the time over which the change took place.
- **NOTE**: IF dp AND dt ARE MEASURED MANUALLY WITH A PRESSURE GAUGE RATHER THAN A PRESSURE TRANSDUCER, RECORD PRESSURE DATA FOR EITHER TEN MINUTES OR UNTIL A TEN PSI CHANGE HAS OCCURRED.
- **OVER CHANGE IN TIME** Enter the time interval over which the casing pressure change was observed.

5.2.3 - Electrical Submersible Pump Well - Definition of Data Fields in Tabs

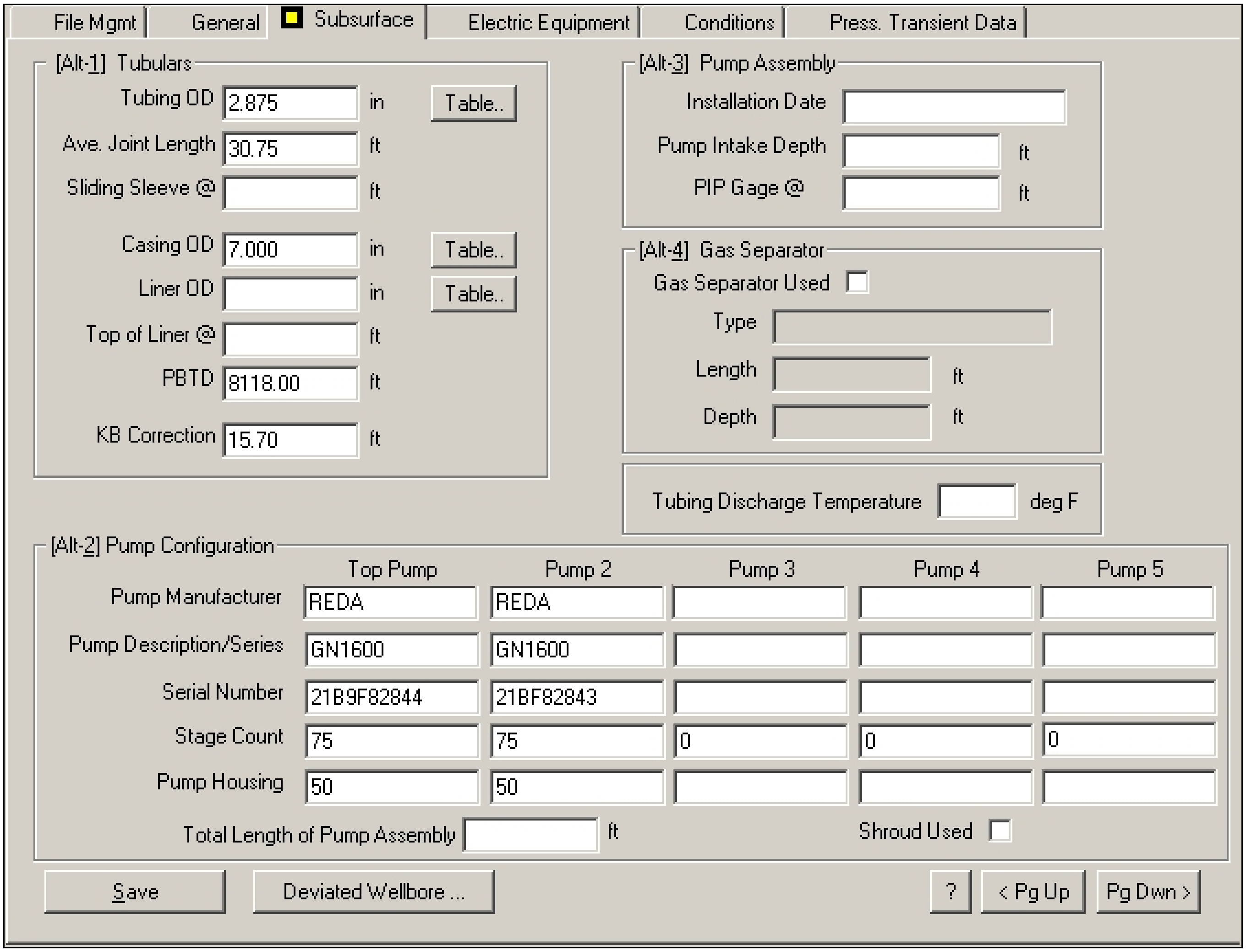
The following screens shows the tabs for a well where the Artificial Lift Type has been set to Electrical Submersible pump.

5.2.3.1 - General Tab – ESP Well



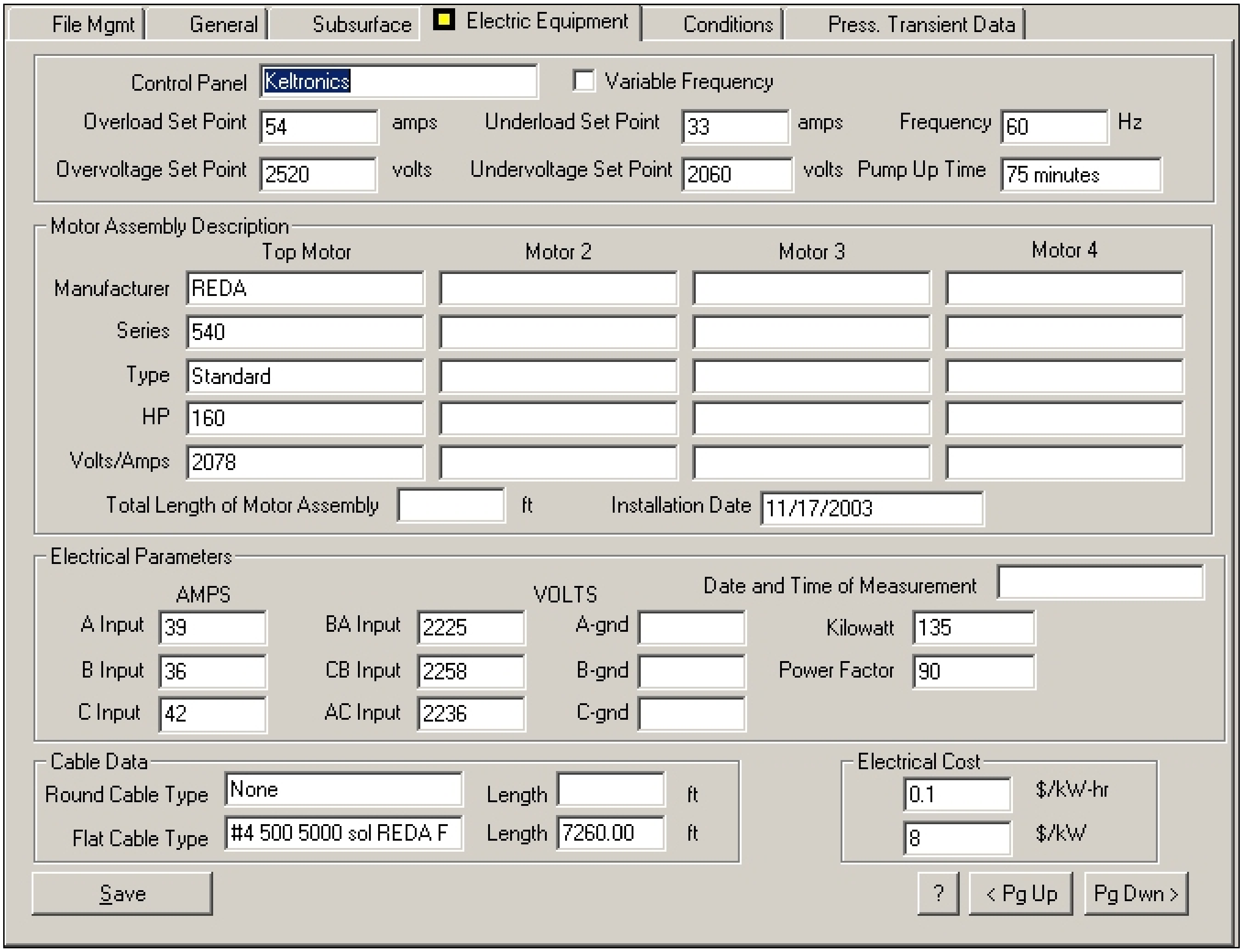
5.2.3.2 - Subsurface Equipment Tab – ESP Well

The subsurface equipment data is entered in the following screen



5.2.3.3 - Electrical Equipment Tab – ESP Well

The description of the electrical system is entered in the following screen

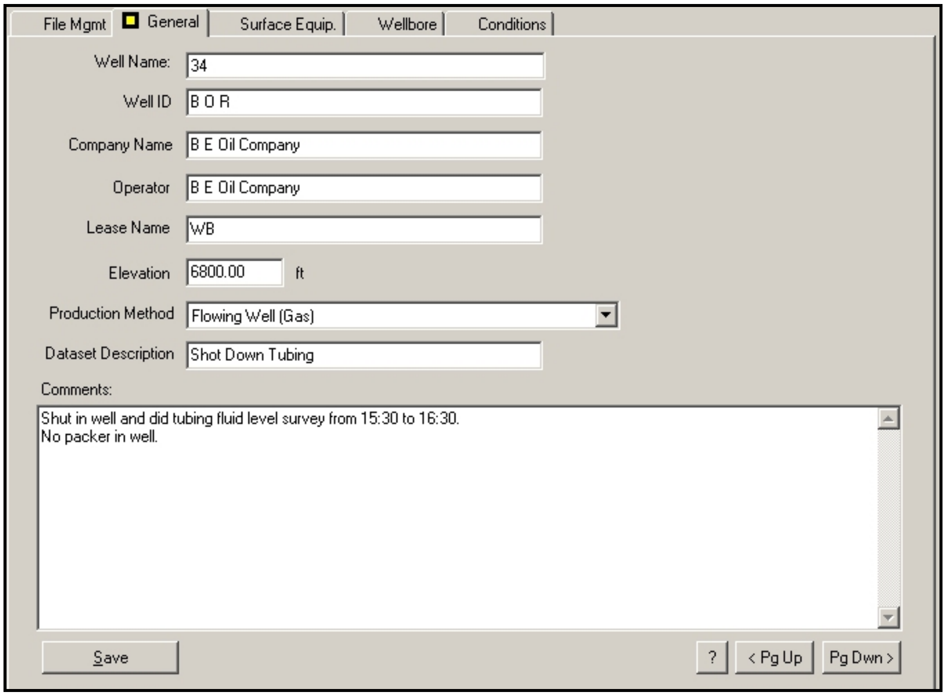


5.2.4 - Flowing Gas Well - Definition of Data Fields in Tabs

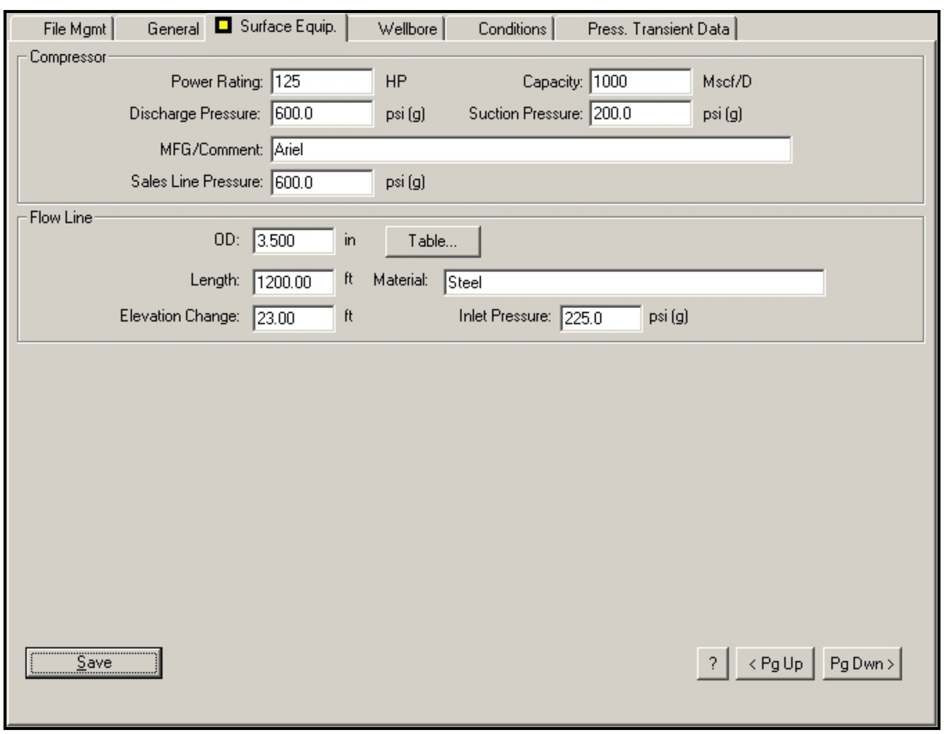
Detailed description of the fields in the following gas well tabs is found in the separate TWM manual addendum "Gas well and Plunger Lift Applications".

5.2.4.1 - General Tab – Flowing Gas Well

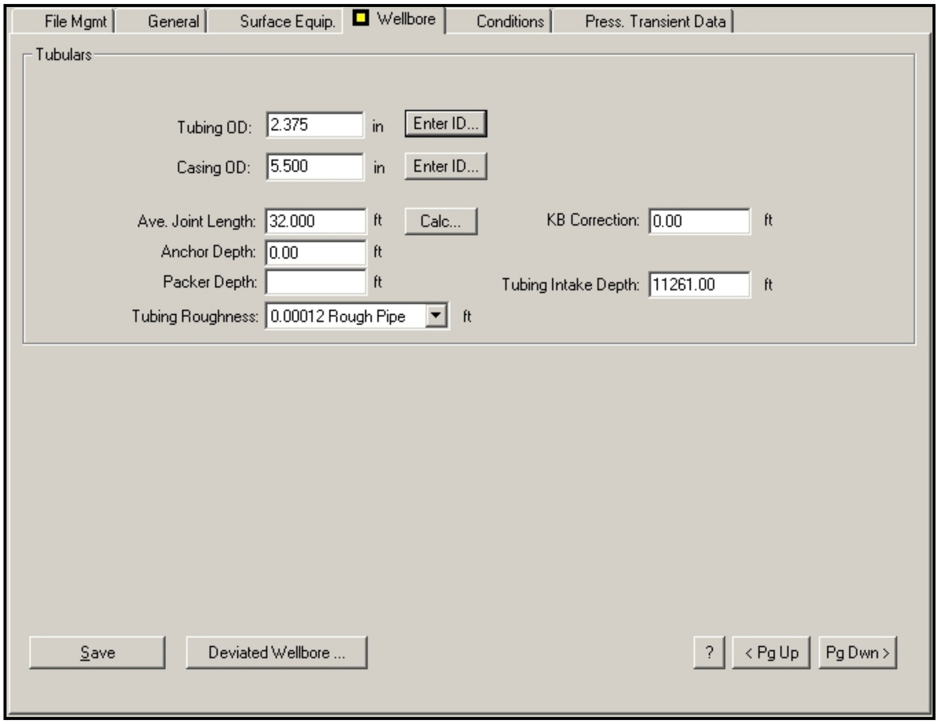
The following figure shows the **General** tab when the Flowing Well (Gas) option has been selected:



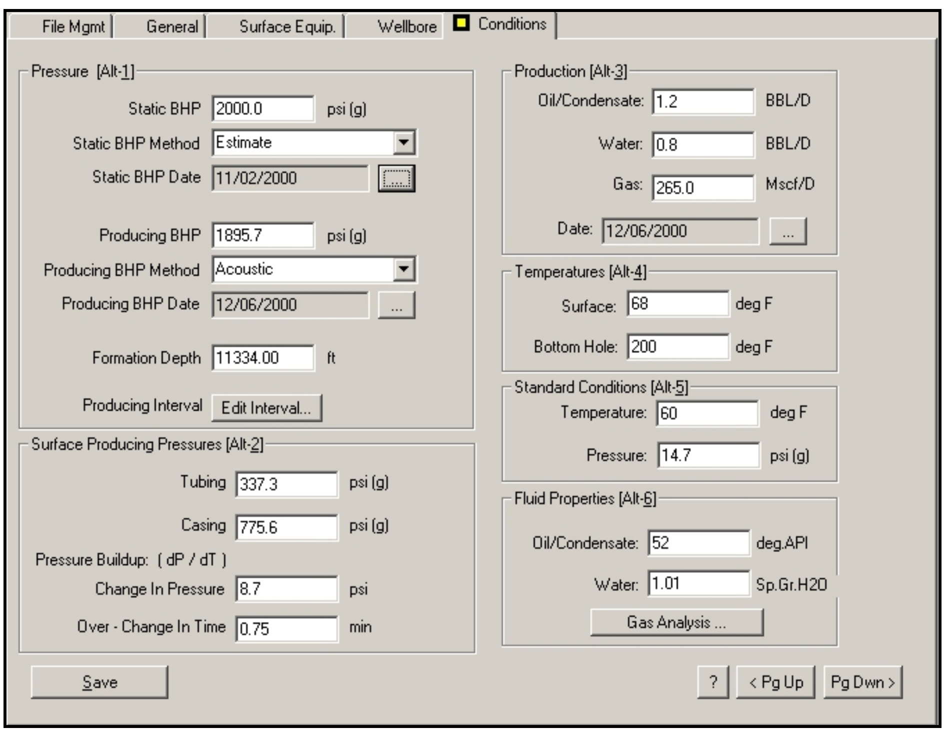
5.2.4.2 - Surface Equipment Tab – Flowing Gas Well



5.2.4.3 - Wellbore Tab – Flowing Gas Well



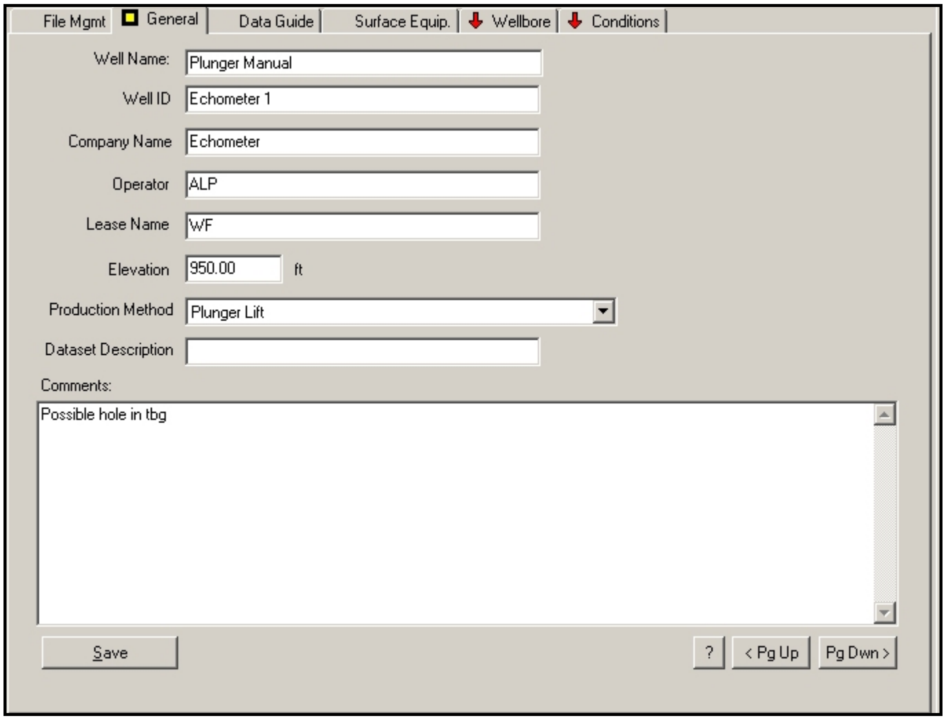
5.2.4.4 - Conditions Tab – Flowing Gas Well



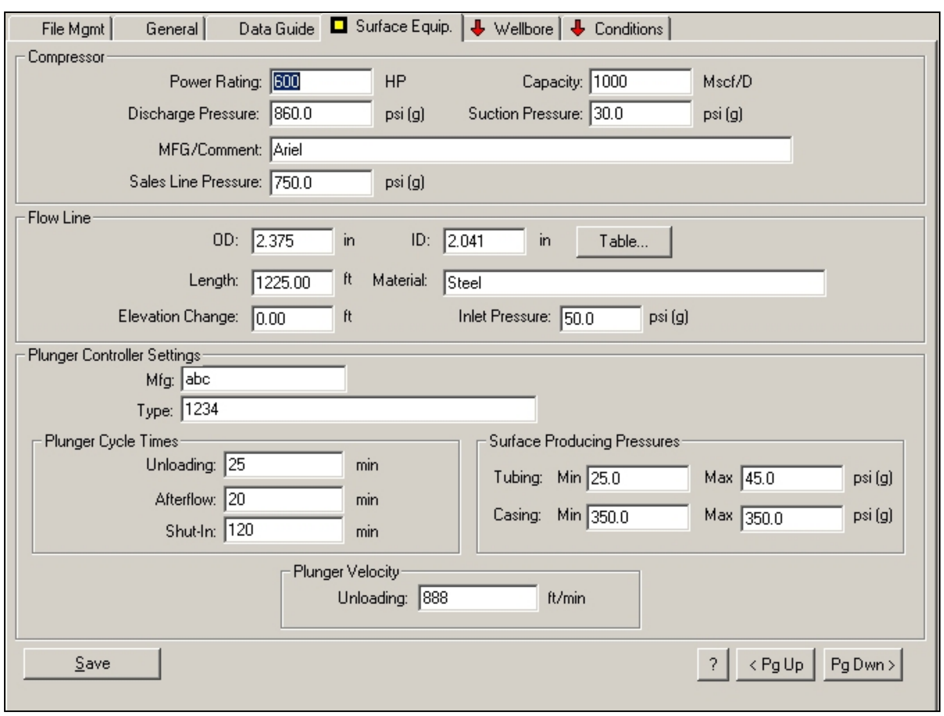
5.2.5 - Plunger Lift Well - Definition of Data Fields in Tabs

Detailed description of the fields in this and the following plunger lift well tabs is found in the separate TWM manual addendum "Gas well and Plunger Lift Applications".

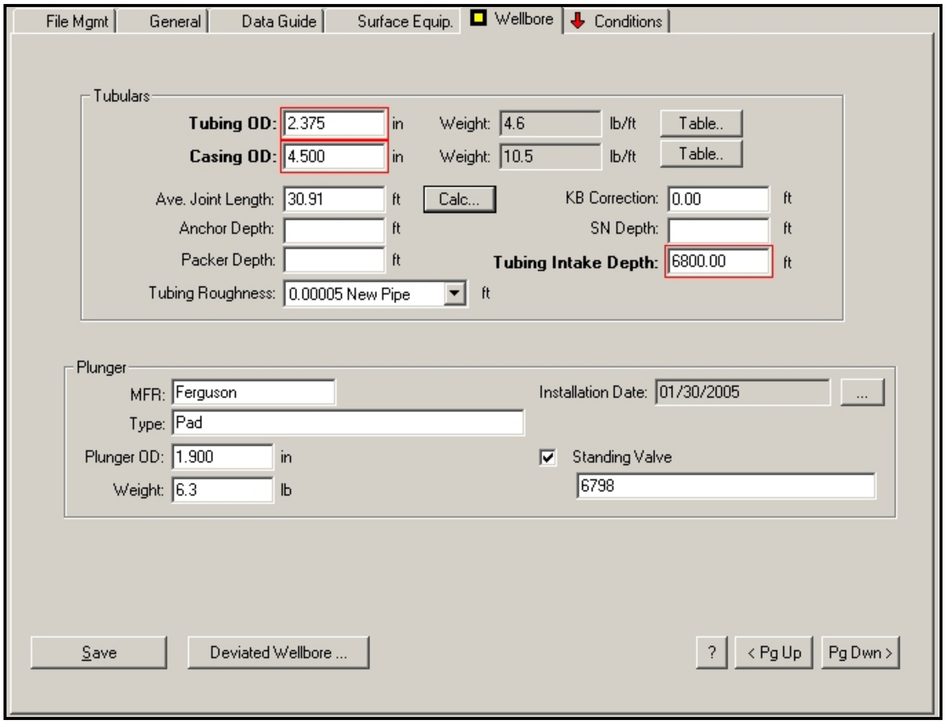
5.2.5.1 - General Tab – Plunger Lift Well



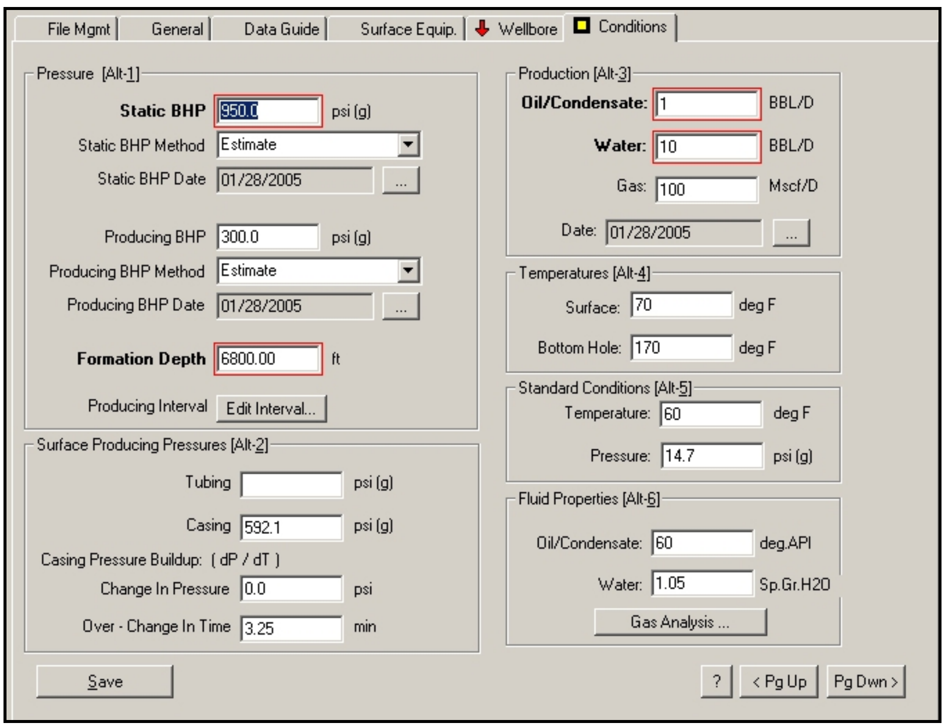
5.2.5.2 - Surface Equipment Tab – Plunger Lift Well



5.2.5.3 - Wellbore Tab – Plunger Lift Well



5.2.5.4 - Conditions Tab – Plunger Lift Well



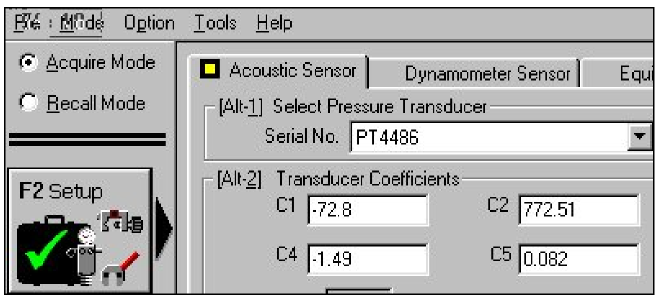
6.0 - ACOUSTIC FLUID LEVEL TEST SOFTWARE

This allows firing an acoustic pulse, digitizing the echoes from the well and storing the data in the computer's memory for further processing. In addition the casinghead pressure (if a pressure transducer is connected to the Well Analyzer) is recorded at 15 seconds intervals in order to determine the rate at which free gas is flowing with the liquid into the well and the gradient of the annular fluid.

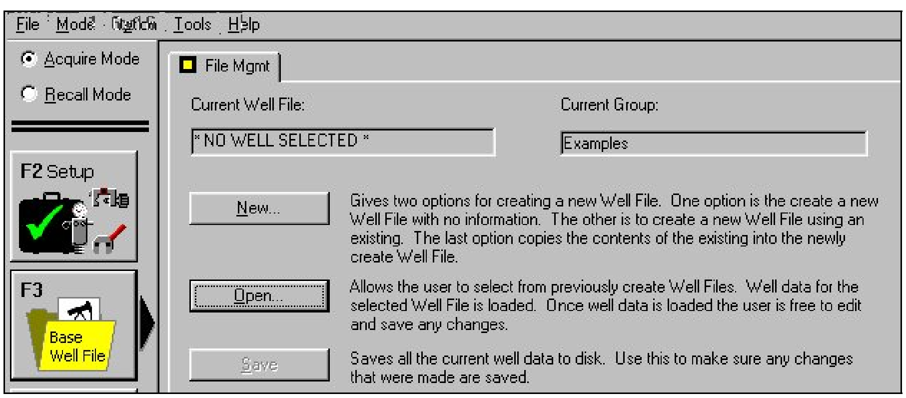
6.1 - Acquisition of Acoustic Data and Quality Control

The following discussion assumes that the master cable has been connected from the Well Analyzer to the Remote Fire gas gun with a casing pressure transducer and that the gun is installed on the casinghead.

The TWM program is executed and the Setup, sensor selection and zeroing sequence is completed:



To acquire an acoustic record and obtain a bottom-hole pressure, a base well data file must first be created or recalled from the disk.

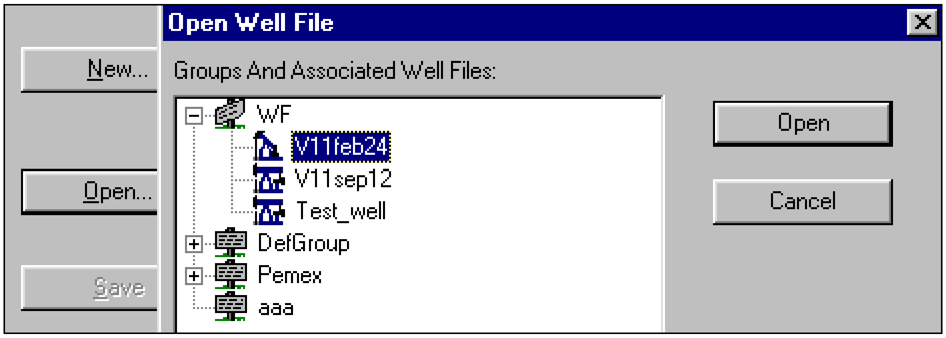


A minimum amount of data must be entered before the operator can proceed. Refer to description of well file entry described in the previous sections.

- The following data **MUST** be entered to **ACQUIRE DATA** from acoustic tests:

  - Well Name
  - Pressure Datum
  - Pump Depth
  - Average Joint Length (Program will default to 31.7 ft.)

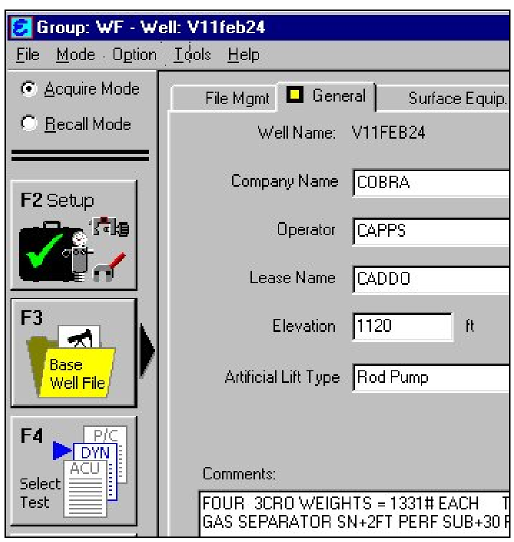
It is recommended that the well data be entered in the file as **completely as possible BEFORE going** to the well site to undertake the tests. This will allow the operator to analyze the data at the well site and to insure that the results are of good quality.



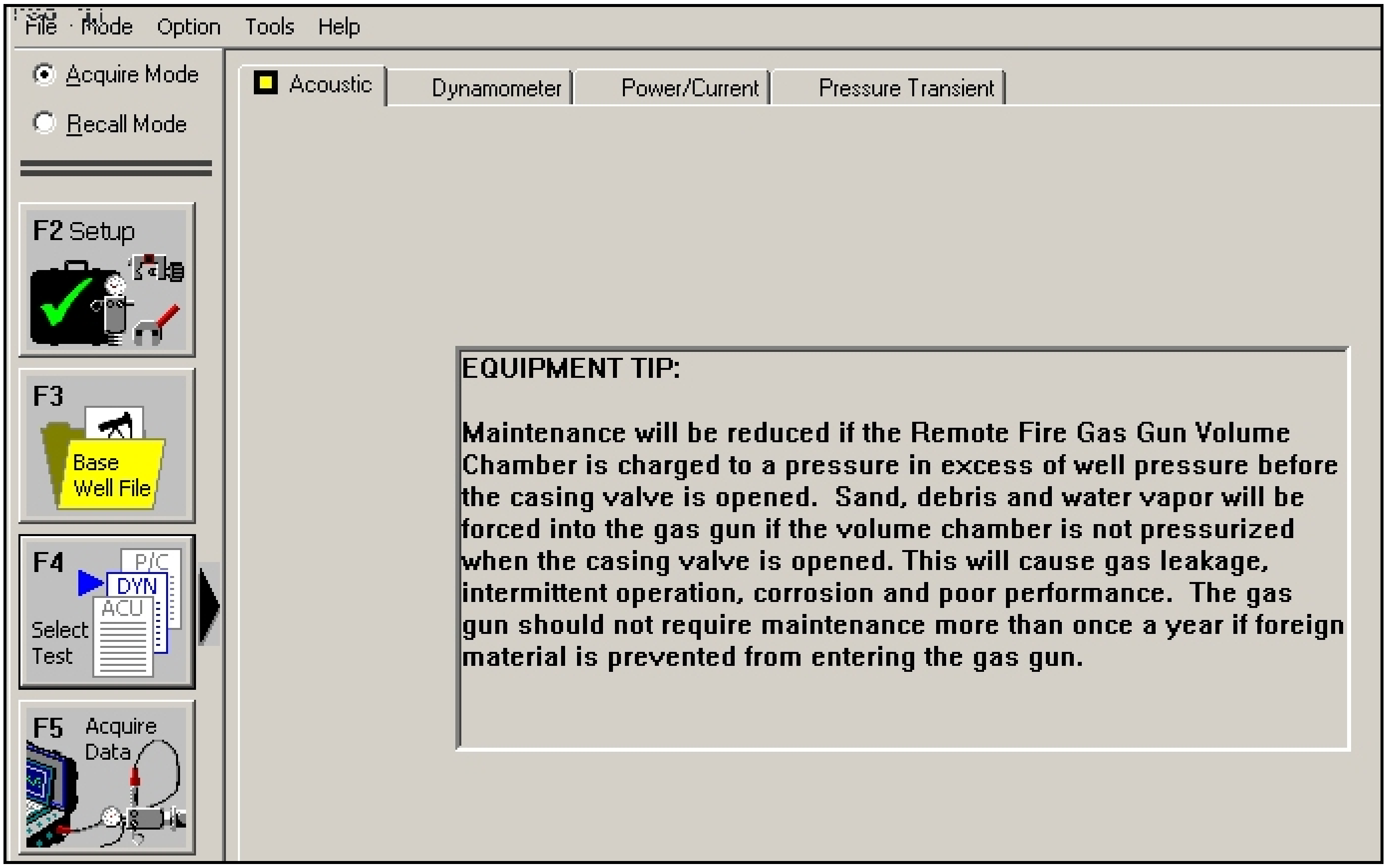
- The following data **MUST** be entered in the well data file to run a **COMPLETE BHP ANALYSIS:**

> - Well Name
> - Pressure Datum
> - Pump Depth
> - Casing OD
> - Tubing OD
> - BOPD
> - BWPD
> - Surface Temperature
> - Downhole Temperature
> - Oil Gravity
> - Water Specific Gravity
> - Casing Pressure (Entered or Acquired)
> - Casing Pressure Buildup Rate (Entered or Acquired)
> - SBHP

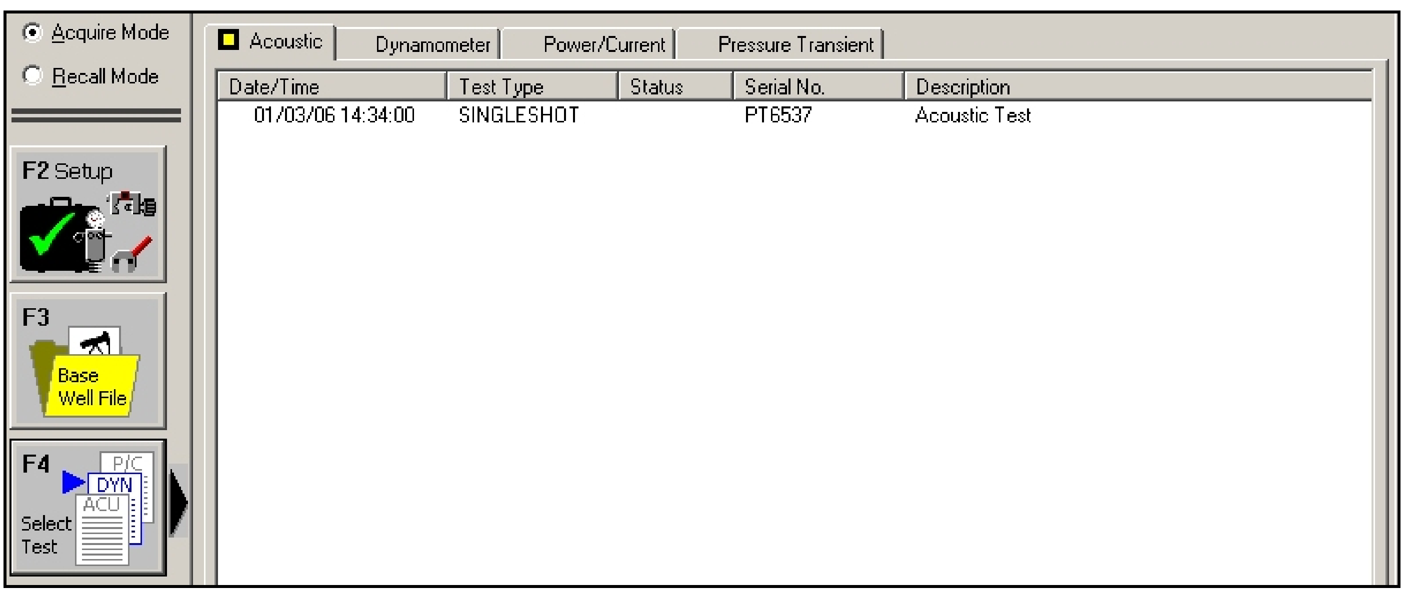
When recalling an existing well data file it is recommended that the operator check it to make certain that it represents accurately the present conditions in the well. In particular the well test information should be updated to the values of the most recent well test.



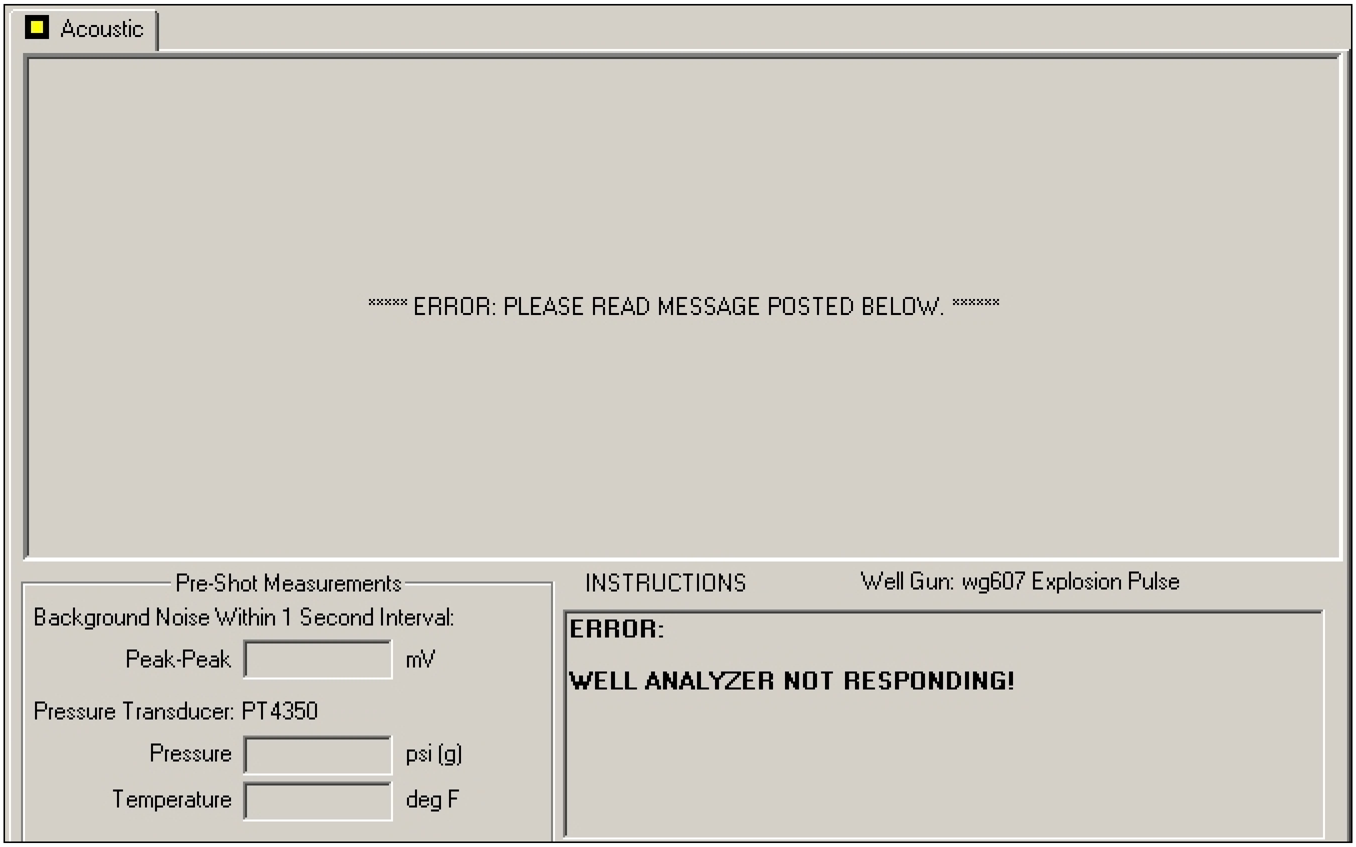
After the well data has been entered or recalled from an existing file the user may proceed to acquire a new data set by selecting the **F4 Select Test** function to specify the type of test to be undertaken:



The default Acoustic Tab with an **Equipment Tip** is displayed as shown above. As data is acquired the software will enter, in place of the tip, the corresponding test information in each tab to keep a record of tests completed during the current session, as shown below:

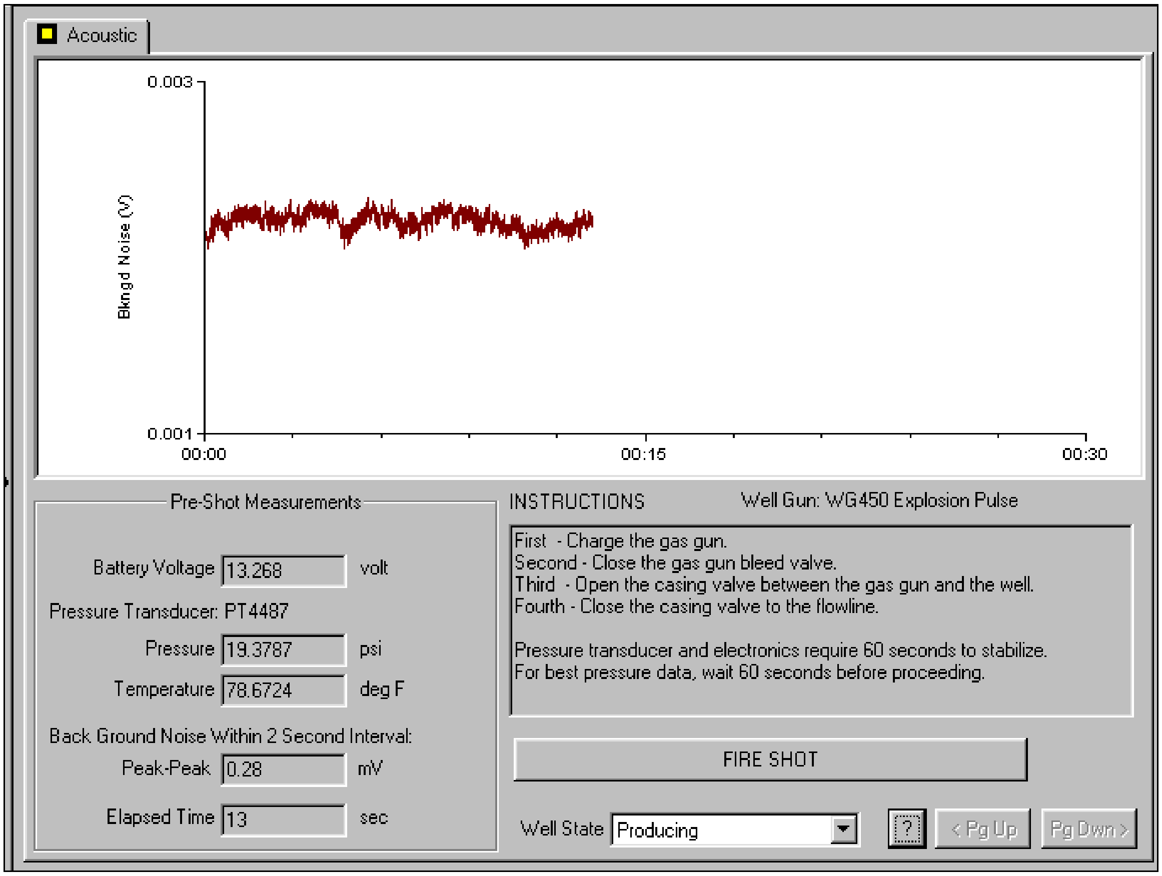


Acquisition of the data is initiated by selecting the **F5 – Acquire Data** function. If the computer cannot communicate with the A/D electronics (the Master Switch was turned OFF or the well analyzer battery voltage is low) the following message is displayed:



If the problem persists go to the **F2 Setup** option, **Equipment Check tab** and follow the instructions in the trouble shooting section of this manual.

Otherwise the following **Data Acquisition** form is displayed which shows the background well noise and the values of pressure, transducer temperature and battery voltage:



This display can be used to verify that the system is indeed recording data. If any large individual spikes are present consistently, they may indicate problems with the electronics. Verify that cable connections are clean and secure. Generally, a peak to peak noise amplitude above 5 mV indicates considerable downhole noise possibly caused by the presence of **a gaseous liquid column**. The operator is alerted when well noise exceeds 5 mV and the recommendation is made to use a greater pressure in the volume chamber. Normally the pumping unit should be running during acoustic and pressure data acquisition. If excessive noise exists, close the casing valve between the well and the gas gun to determine if the noise is coming from downhole or from the surface. If the noise is coming from surface vibrations, stop the pumping unit. If the noise is coming from downhole, the signal to noise ratio can be improved by allowing the casing pressure to increase. Valves connecting the casing to downstream flow lines should always be closed if possible. Wait at least 20 seconds for the amplifier and pressure transducer to stabilize.

Before opening the casing valve, the gas gun volume chamber should be charged with gas pressure in excess of well pressure so that the internal gas valve and the volume chamber will not be exposed to debris, which might be present in the casing valve. This will reduce gas gun maintenance.

NOTE: The default mode for **Well State** is "Producing" since the majority of the acoustic tests will be taken in producing wells. If the well is shut-in and the purpose of the test is to determine the **Static BHP** the well state should be changed to ": Static" as discussed in section 5.361 of this manual

One of the following procedures is used to acquire acoustic data:

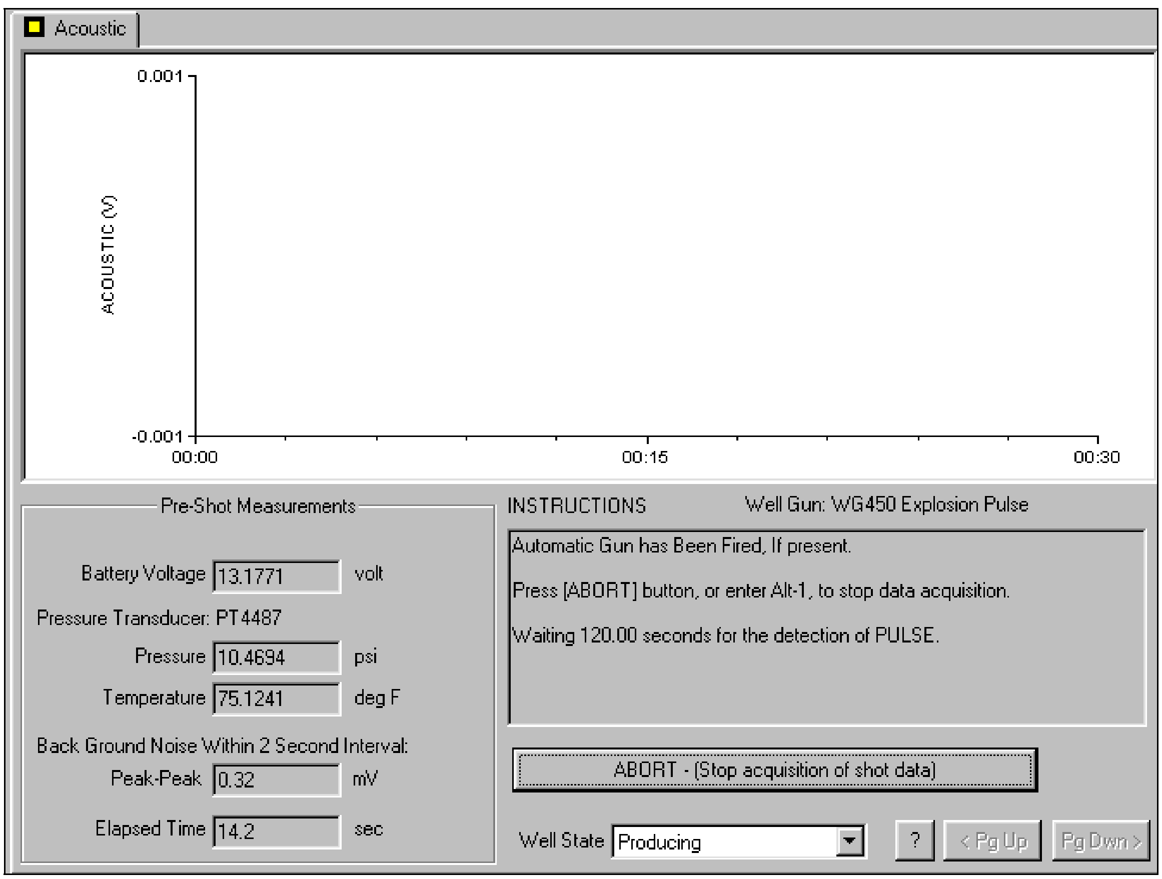
- Using **REMOTELY FIRED GAS GUN**:

  Select the **Fire Shot** option to fire the remote gun.

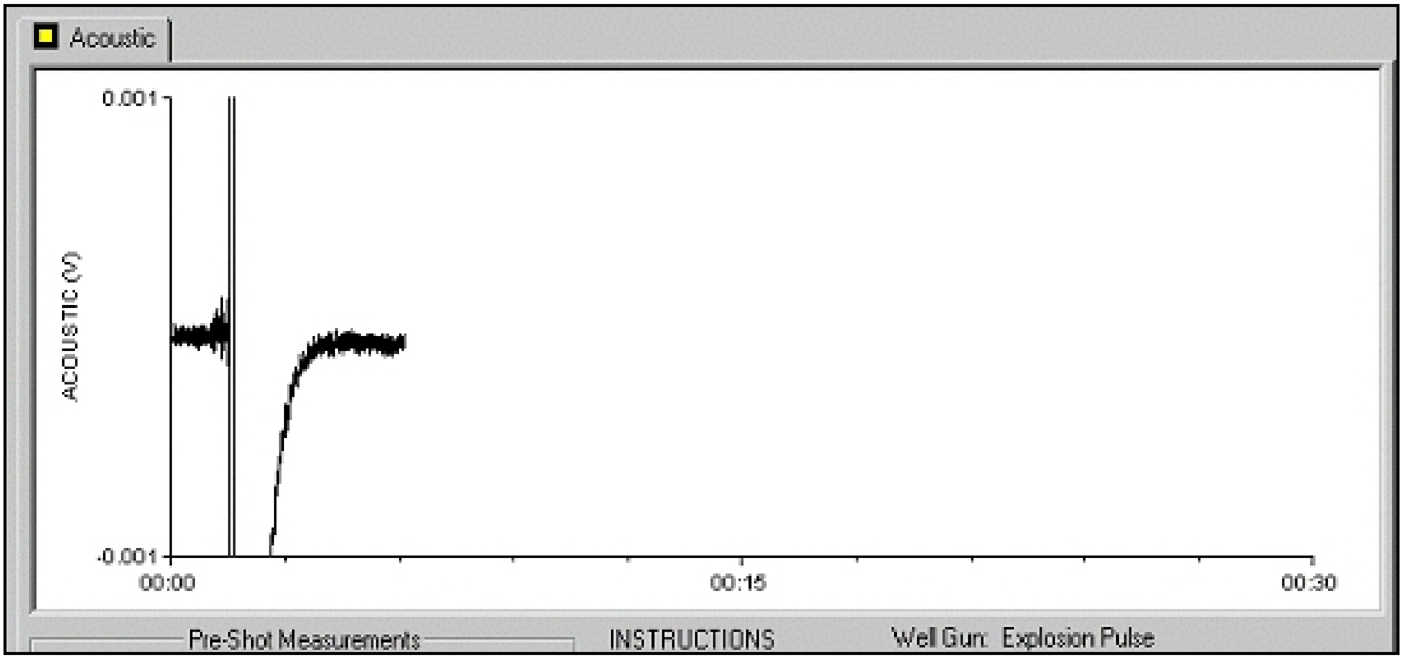
- Using **COMPACT GAS GUN or HIGH PRESSURE GAS GUN:**

1. Select the **Fire Shot** option and wait for the message that the **remotely fired gun has been fired if present**, then,
2. **Manually fire** the gas gun.

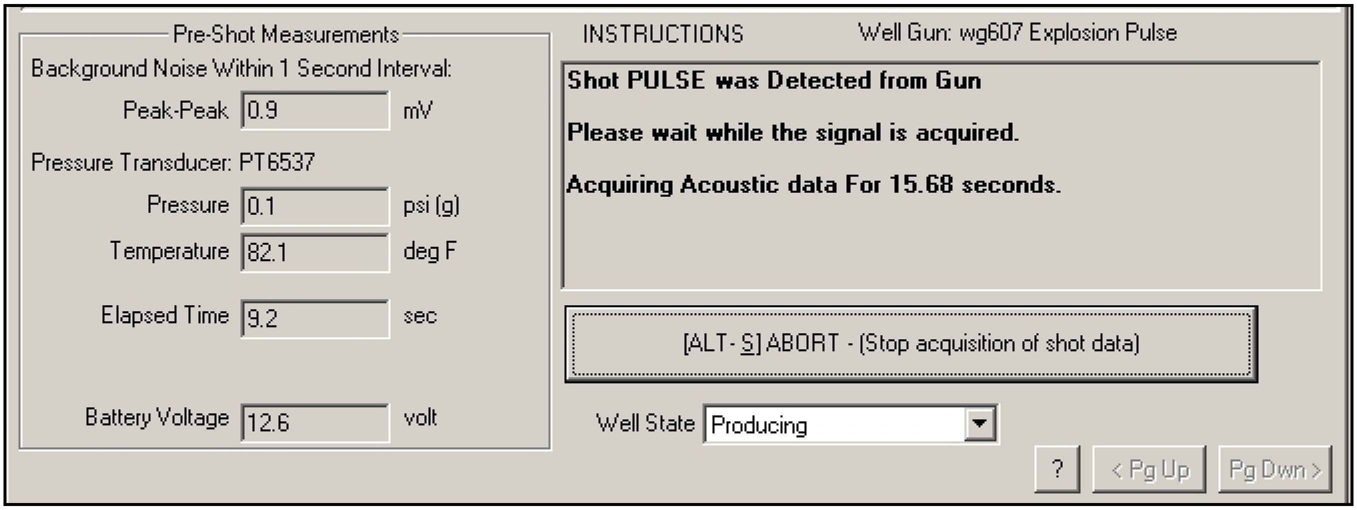
The well analyzer will acquire data for the time period calculated from the previously entered pressure datum or pump depth. **NOTE: IF neither value has been entered acquisition time defaults to 30 seconds**. If an incorrect pressure datum depth is entered, acquisition of the acoustic data may terminate prematurely. This may not allow sufficient time to receive the liquid level echo. After the data has been acquired you will be presented with a choice of options described later. The acoustic signal will be displayed as it is received.



As soon as the shot is detected, the software begins to acquire and display the acoustic data for the length of time corresponding to the well's depth. The software will try to adjust the scale of the plot so that the signal can be observed clearly. It is possible, however that the amplitude be such that the signal may go off-scale, as shown below. The data is being recorded correctly and the user will be able to adjust the scale once acquisition is complete.

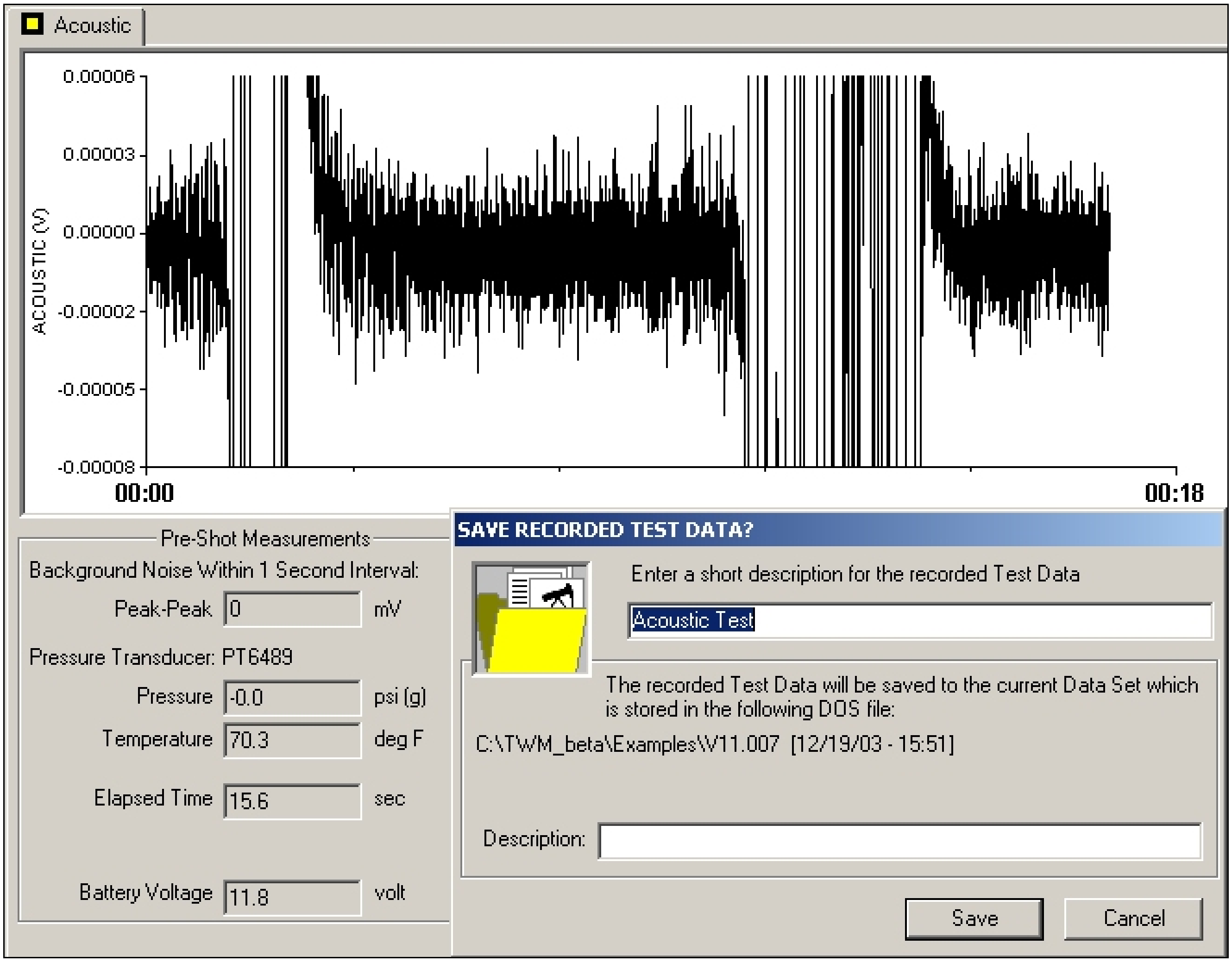


At the bottom of the screen are displayed messages that describe the steps that are being followed and the options available to the operator.



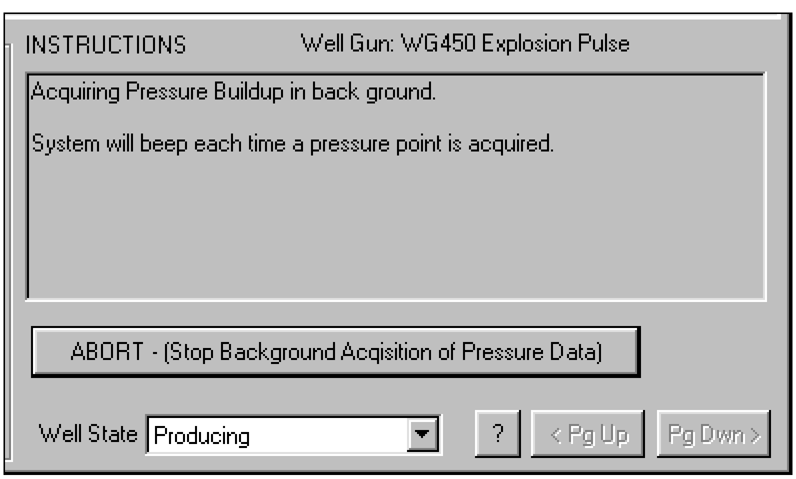
Reflected acoustic signals are digitized and stored in the computer.

When acquisition is complete the following form is displayed for optional entry of test description and acceptance of the data:

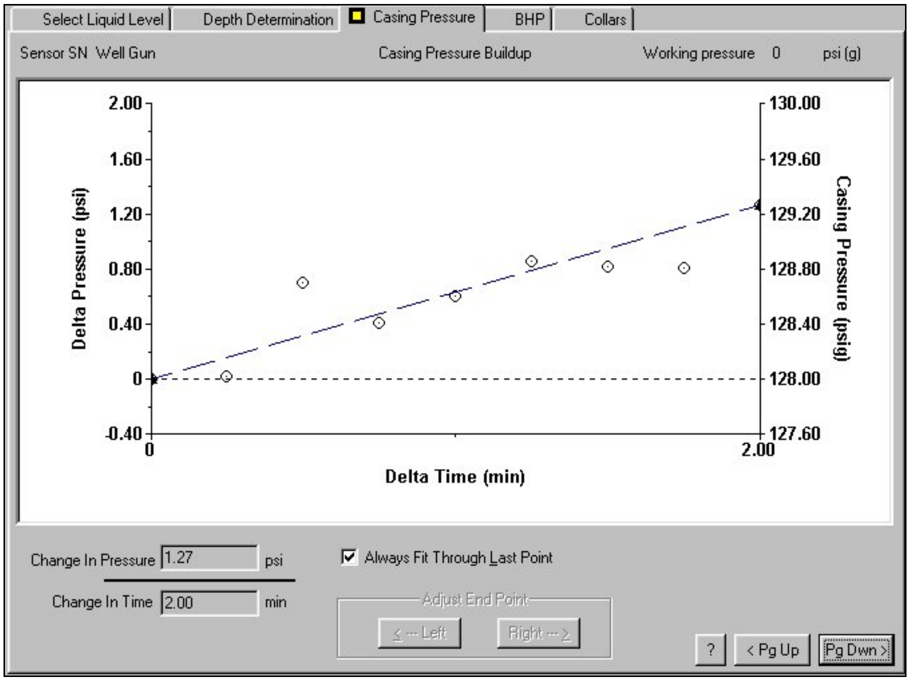


After the raw data has been acquired, and **saved**, the operator is presented with a display of the data and the liquid level selection made by the computer.

While acoustic data is being acquired and saved, the program continually monitors and records the casing pressure at 15 seconds intervals as indicated by the following legend:

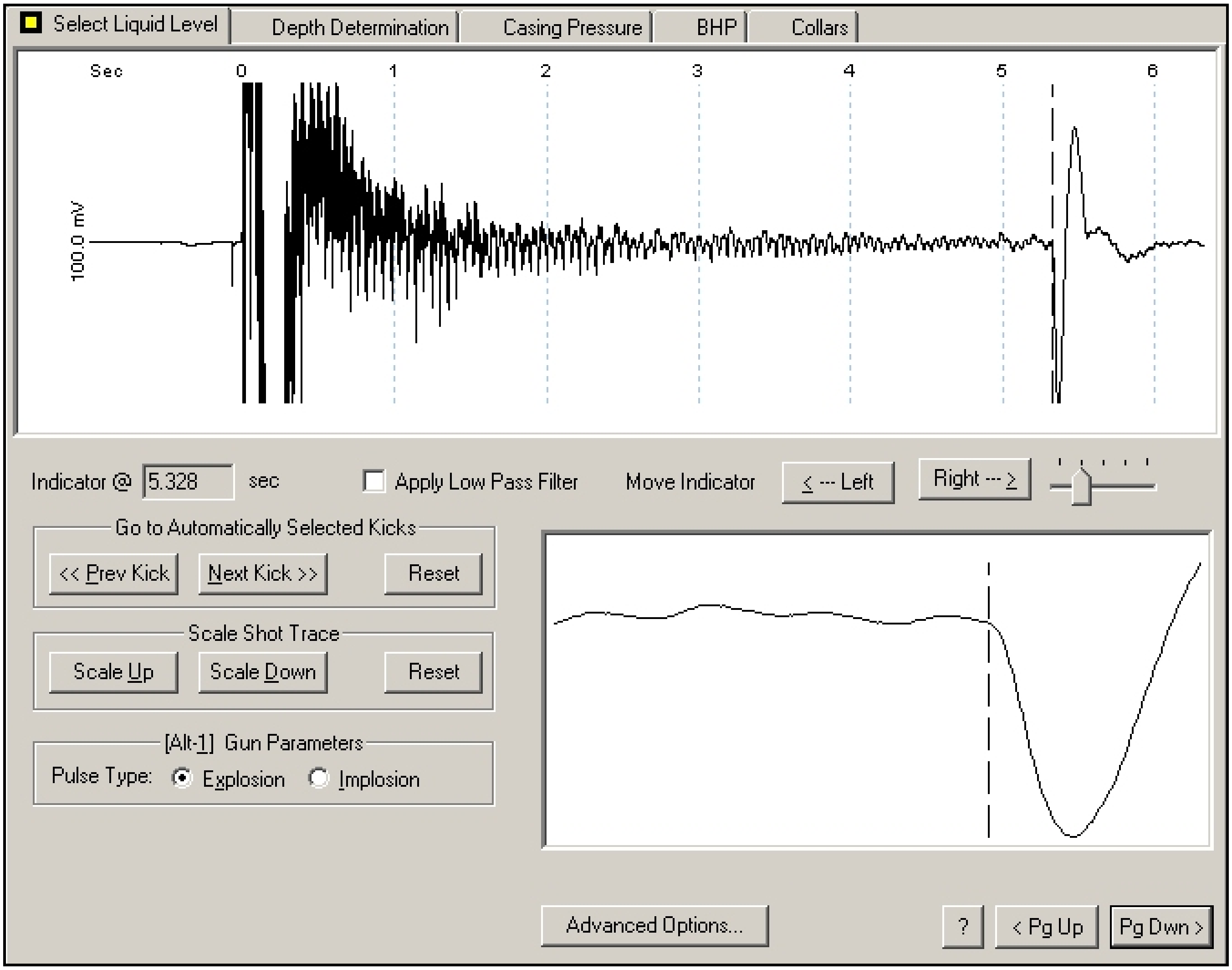


Generally this process is allowed to continue **for at least 2 minutes** to obtain a representative value of the casing pressure buildup rate. The casing pressure may be viewed with the **Casing pressure Tab** in the **Analysis** form:



After the acoustic data has been saved the acoustic signal is analyzed to determine the depth to the liquid level by selecting the **Analyze Data** option.

A dashed vertical line marks the most probable liquid level signal (down kick) and its corresponding position in time is displayed in the **Indicator @** box. An amplified image of the signal in the vicinity of the liquid level is displayed in the box at the lower right of the following figure. the Indicator @ 5.328 seconds is the round trip travel time, RTTT, to the liquid level.



Occasionally, the techniques used to automatically select the liquid level will fail due to unusual well conditions such as the presence of signals from tubing anchors, liners, restrictions, etc. so that the program will flag a signal which is not the fluid level. If this occurs, the operator can adjust the liquid level indicator in two fashions:

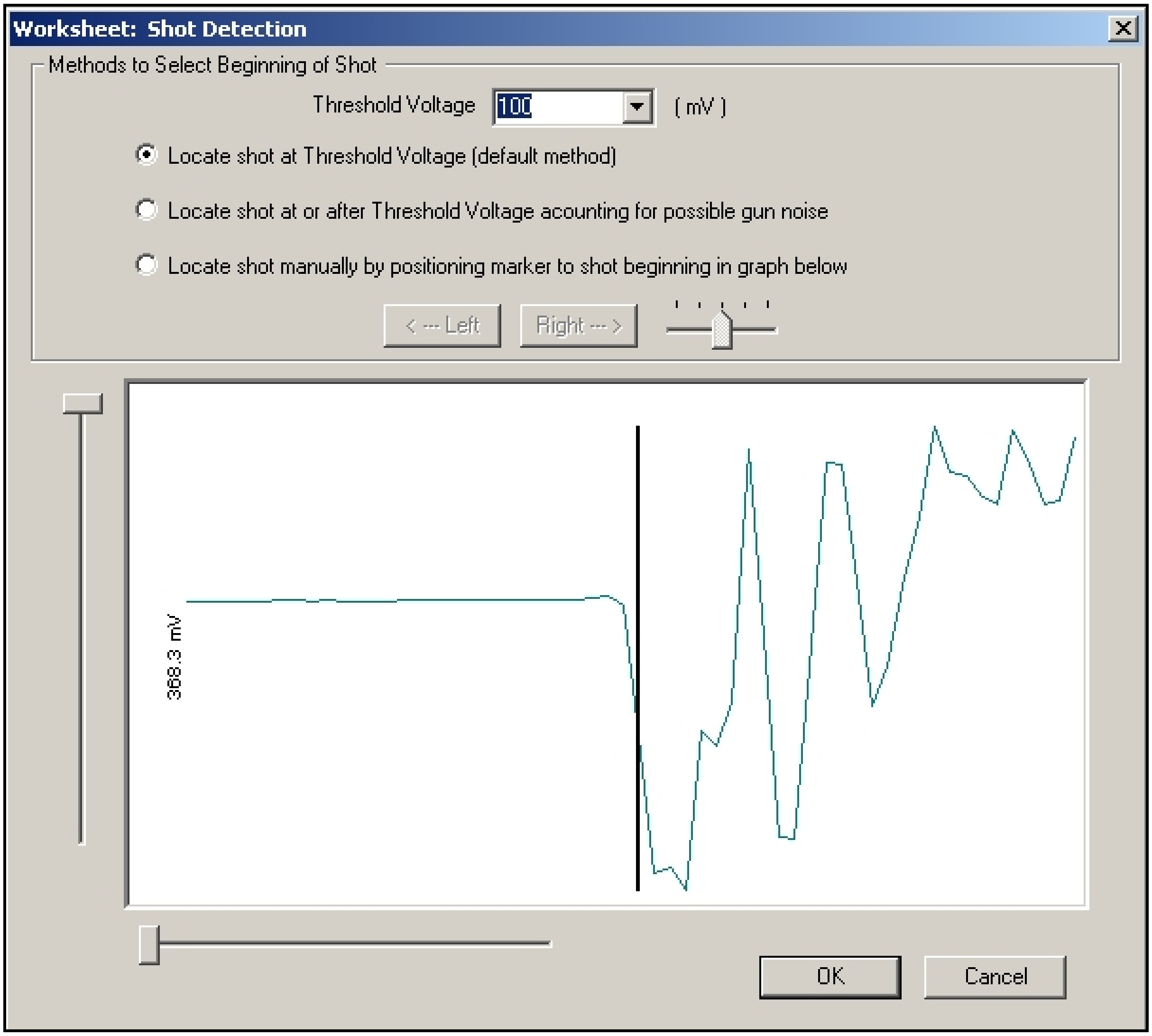
- One method is to use the **Prev Kick/ Next Kick** controls to toggle the indicator between any other "automatically flagged" points that might indicate a liquid level.

- The second method is to use the **Left** and **Right** buttons. These controls move the liquid level indicator forward and backward in increments from 0.1 to 0.001seconds, as controlled by the slider at the right of the buttons.

The operator should use one of the above mentioned techniques to relocate the indicator in the vicinity of the most appropriate liquid level signal and then when the liquid level selection appears valid, the Depth Determination Tab is selected to proceed with further data processing.

It is also important to check that the start of the shot is detected correctly by the software. This may be verified and adjusted if necessary by opening the shot detection screen using the **Advanced Options** button and making the necessary adjustments in the following Worksheet.

6.1.1 - Shot Detection Worksheet

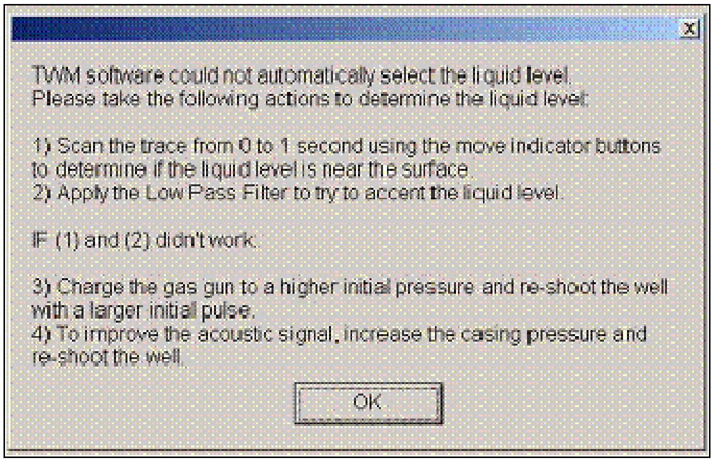


The marker should be aligned with the start of the shot. Use the arrow buttons to locate it manually if the Threshold Voltage options are not effective due to excessive noise.

NOTE: See Section 7.44 for further discussion of the shot detection and fluid level quality control

6.1.2 Liquid Level NOT detected

Occasionally the software is not able to identify any signals that have the characteristics of an echo from any obstructions in the wellbore nor from the liquid level. In such instances the program will display the following message:



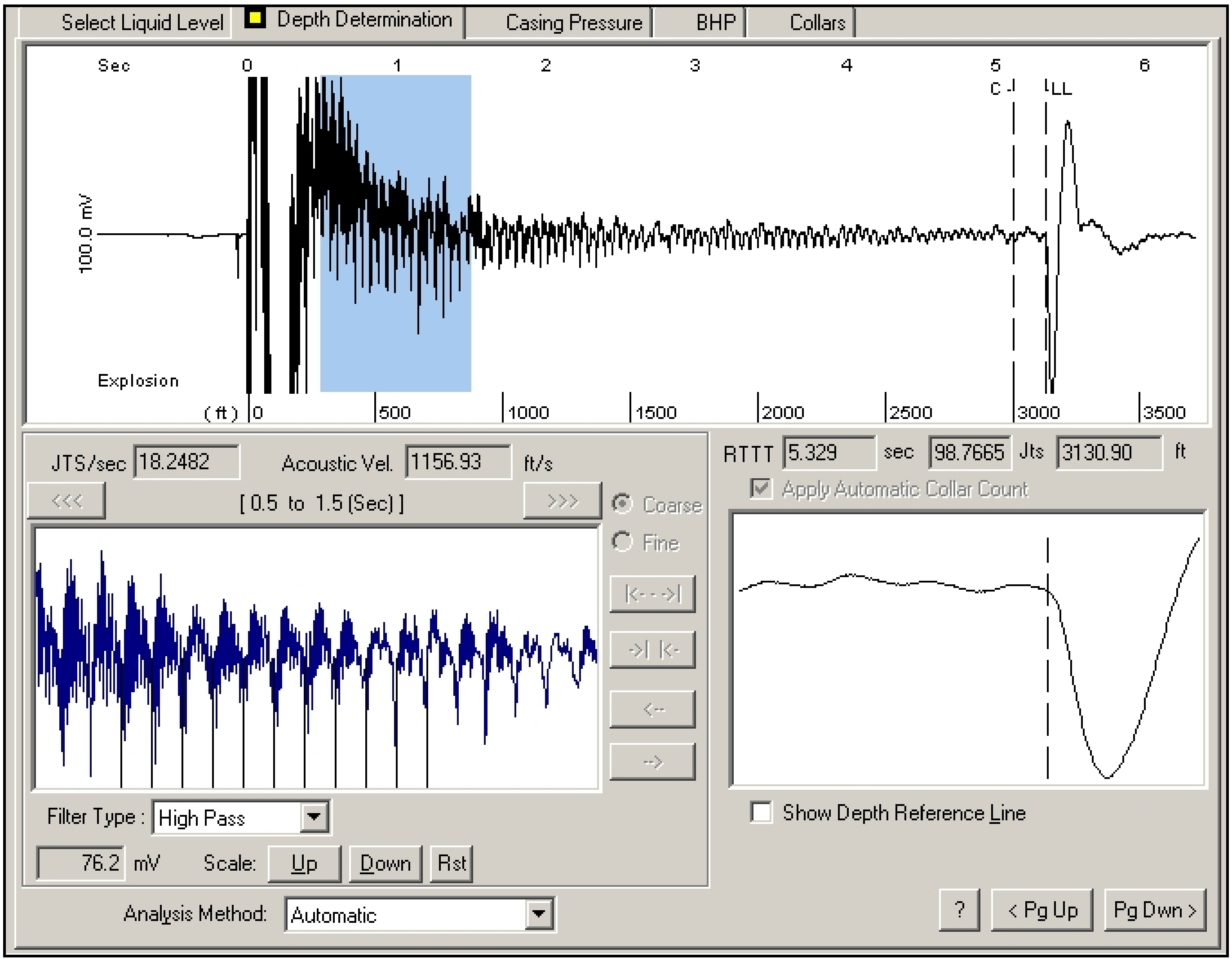
Generally the problem is caused by forgetting to open the casing valve between the gun and the well which results in high frequency echoes, or by a very high fluid level less than 30 feet from surface. It could also be caused by a defective microphone or cable connection.

6.2 - Analysis of Acoustic Fluid Level Records

After acquisition and quality control has been completed the data is analyzed by sequentially proceeding through the Depth Determination, Casing Pressure buildup, BHP and Collars tabs as described below. Analysis of the data is generally done automatically by the software but occasionally the user may have to make manual corrections as explained in the following sections.

6.2.1 - DEPTH DETERMINATION TAB

The Depth Determination tab is selected after a liquid level has been correctly identified. Three windows are displayed on this screen; their functions are described below.



The upper window displays a record of the raw, unfiltered acoustic signal. The duration of the record corresponds to the time between the shot and slightly past the position of the liquid level as selected in the previous tab.

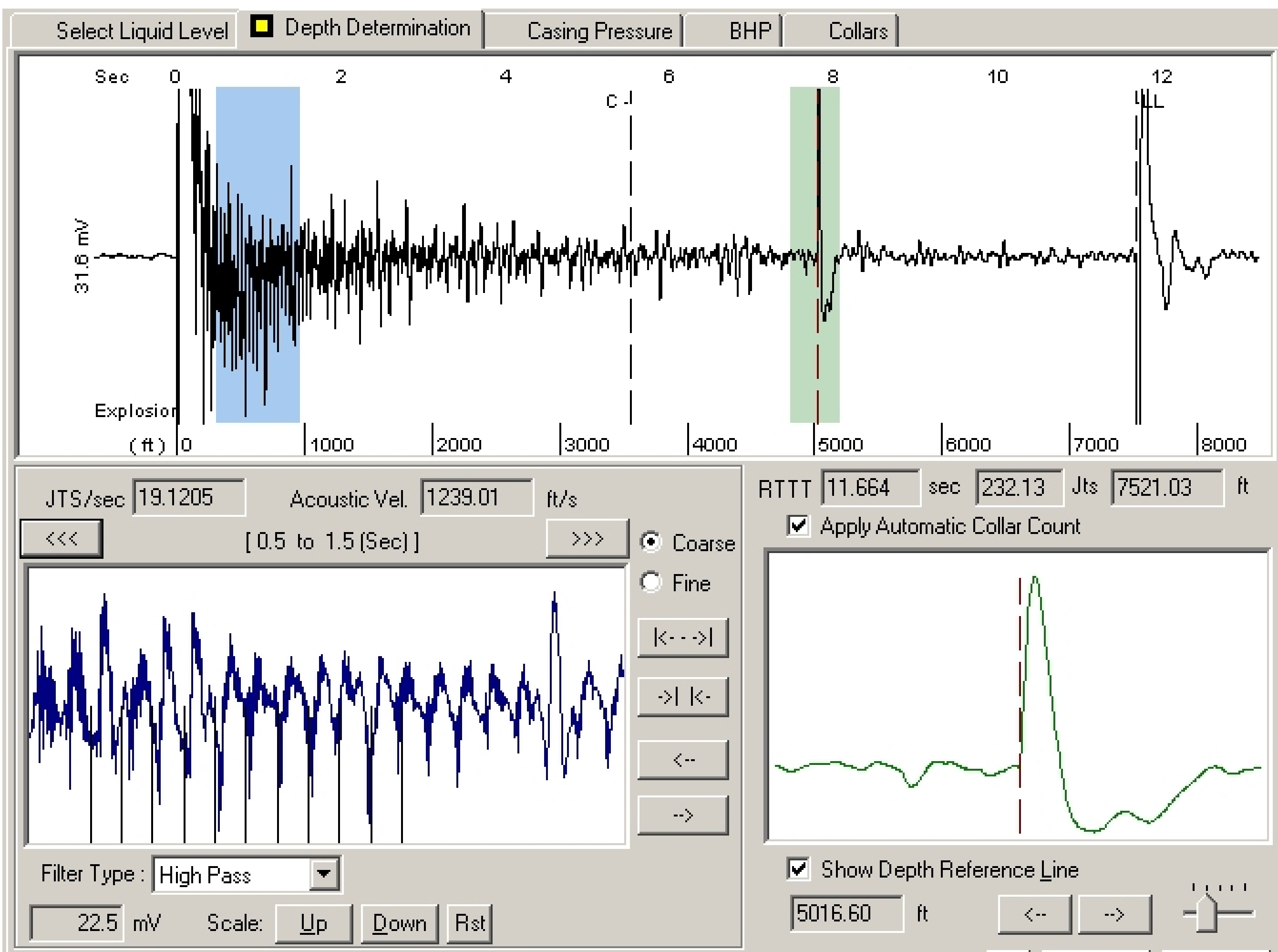
A detail of the liquid level selection is displayed at the lower right corner of the screen. A dashed vertical line is drawn through the liquid level signal. The liquid level selection may be fine-tuned by returning to the **Select Liquid Level Tab**. The thick colored band segment (one second in width) on the top trace marks the portion of the signal that is analyzed to calculate the collar frequency. This portion of the signal is displayed in **High Pass** filtered form, in the window at the lower left of the screen. The vertical scale of this window can be adjusted using the Scale **Up/Dwn/Rst** buttons. The maximum peak to peak amplitude it this segment is also displayed in mV.

The depth scale and the calculated liquid level depth shown on this screen are very close estimates obtained with **Automatic Collar Count** of the data which is the default option as indicated by the check box in the following figure:

The collar frequency (+2Hz/-2Hz) determined from the one second data segment is used to design the band pass filter applied to the signal to identify and count the collar reflections from the shot to the liquid level echo. The collar count terminates when the signal to noise ratio becomes unfavorable. At this point a dashed vertical marker (labeled **C** for end of Collar count) is plotted on the acoustic trace. Ideally this point should be as close to the liquid level as possible or at least **past 80%** of the distance to the liquid level. If this were not the case the shot should be repeated with an increased chamber pressure in order to improve the signal to noise ratio.

6.2.1.1 - Depth Reference Line

Checking this box displays a movable reference line that can be used to identify the depth of known features in the wellbore such as a liner top, as shown below, or other changes in cross sectional area that may be used as markers for verification that the depth scale has been computed correctly. The marked signal and its corresponding depth are displayed in the lower right.

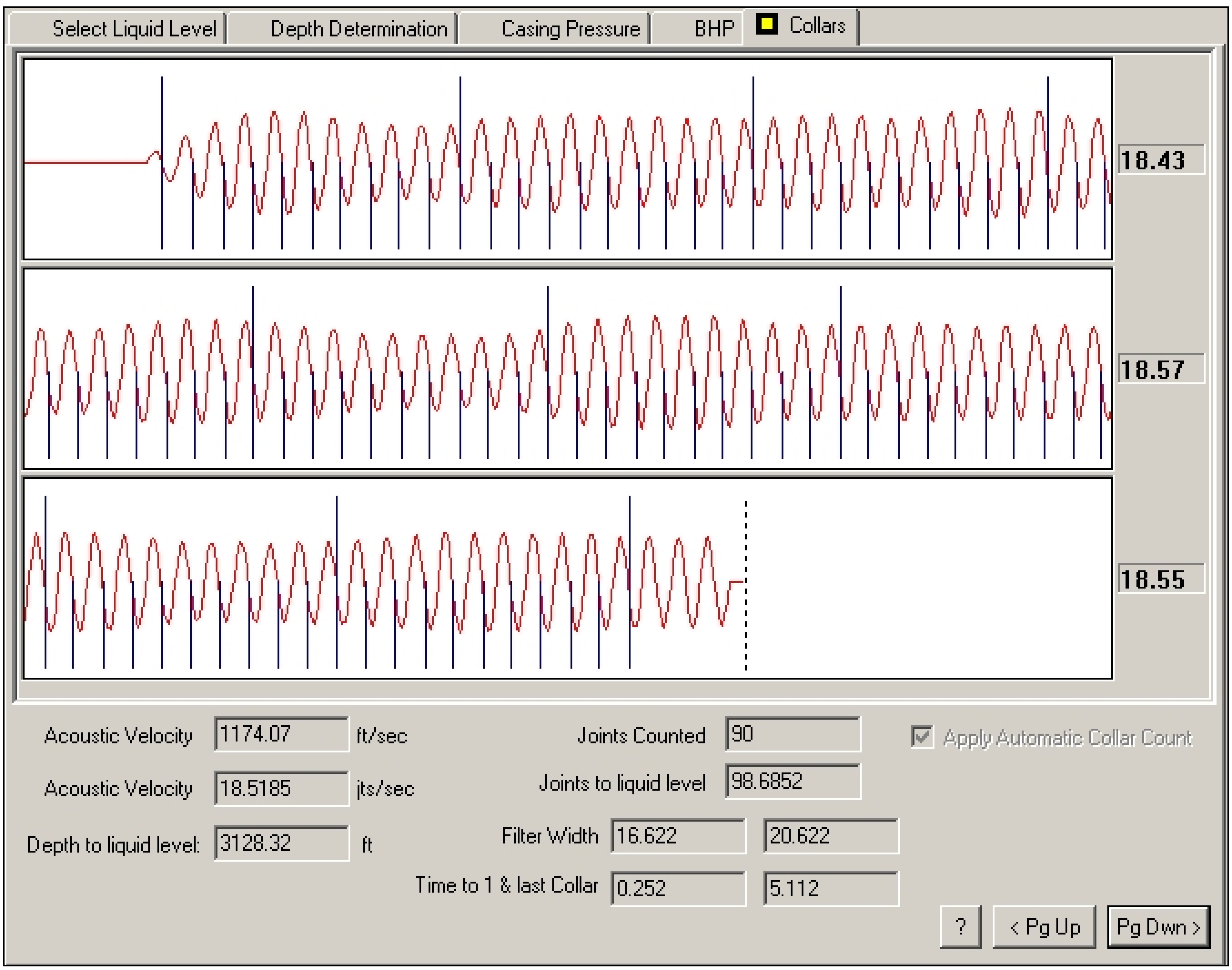


The example above corresponds to the signal (shooting down the tubing) created by a ½ inch diameter hole in the tubing in a plunger lift well operating with a tubing pressure of 490 psi .

In some wells, the collar frequency will change throughout the wellbore due to variations in acoustic velocity with depth; this is why it is necessary to process the data more rigorously and actually count each individual reflection to obtain an exact collar count. This count, which is one of the many patented features of the Well Analyzer, is done automatically and may be displayed by selecting the **Collars Tab** as shown below:

6.2.2 - COLLARS TAB

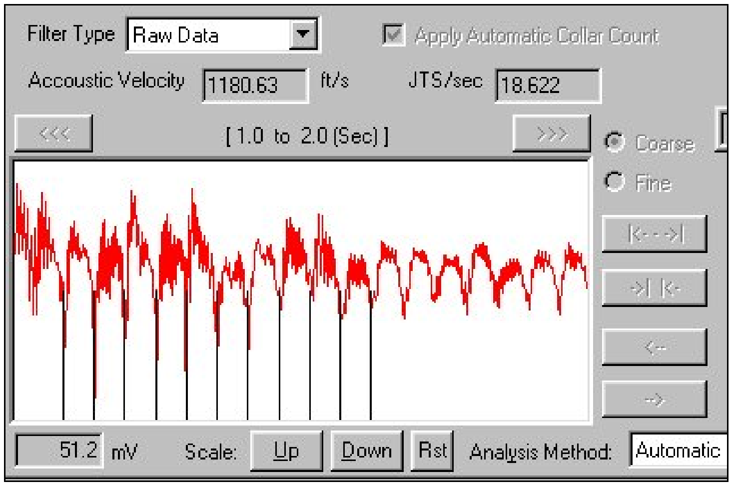
This allows the user to inspect the entire acoustic trace after it has been processed to accent collar response. The software displays the filtered signal and counts the joints to the liquid level. Vertical tick marks are drawn to each individual collar reflection as they are counted. The collar display on this chart is obtained by digitally filtering the acoustic data at the precise collar frequency previously determined and shown on the depth determination tab in the lower left hand corner. The collar count is continued until the signal to noise ratio decreases below a preset limit. The **average collar frequency (jts/sec)** is multiplied by twice the **average joint length (ft/joint)**, entered in wellbore tab of the well file, to calculate the **acoustic velocity** in feet/sec.



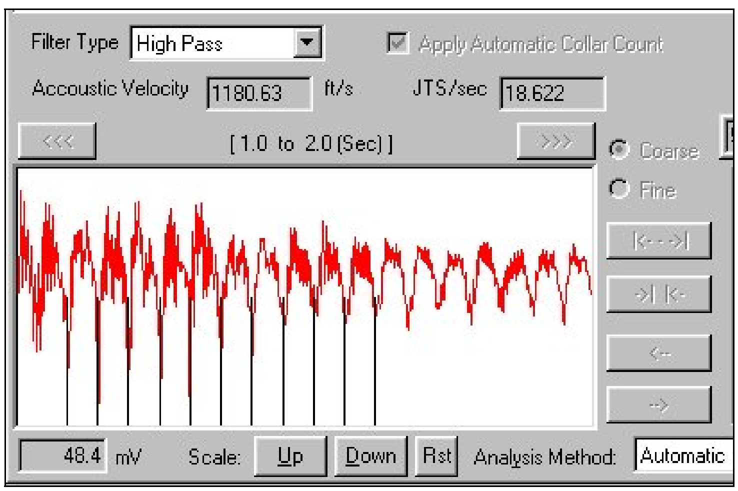
The operator should strive to obtain the best possible collar count to insure an accurate fluid level and bottom hole pressure calculation. If possible the collar count should include 80-90% of the total number of collars in the well. A low percentage of collars counted is an indication that the signal level may be too low and close to the noise level or an inaccurate collar frequency is used. The operator should repeat the shot with greater pressure in the chamber in order to improve the signal to noise ratio. (NOTE: the above figure corresponds to the “advanced analysis” presentation.)

6.2.3 - FILTERING OPTIONS

Estimation of the correct collar frequency may be enhanced by applying a band pass filter to the raw data (shown below). This may be done in **Manual Analysis** mode. Examples of **raw data,** high **pass** and **band pass** filtered data are shown below:

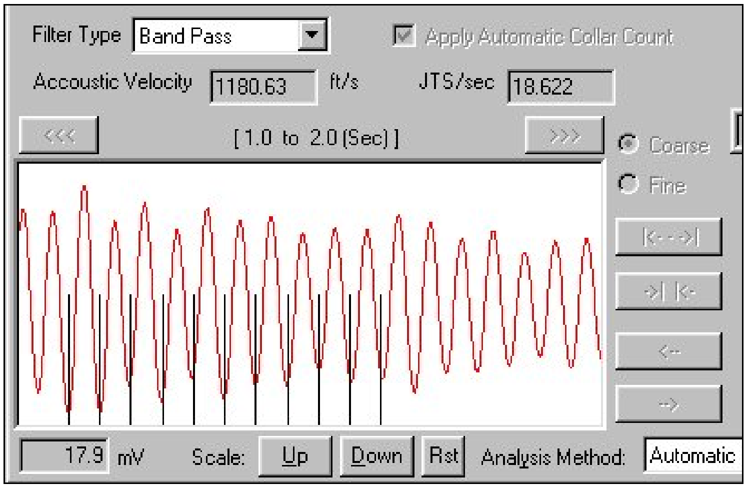


Selecting the **High Pass** filter eliminates the low frequency components:



The data may also be filtered with a Band Pass filter that is centered at the collar frequency and has a width of +/- 1 Hz.

The following figure shows the result of applying the **band pass** filter

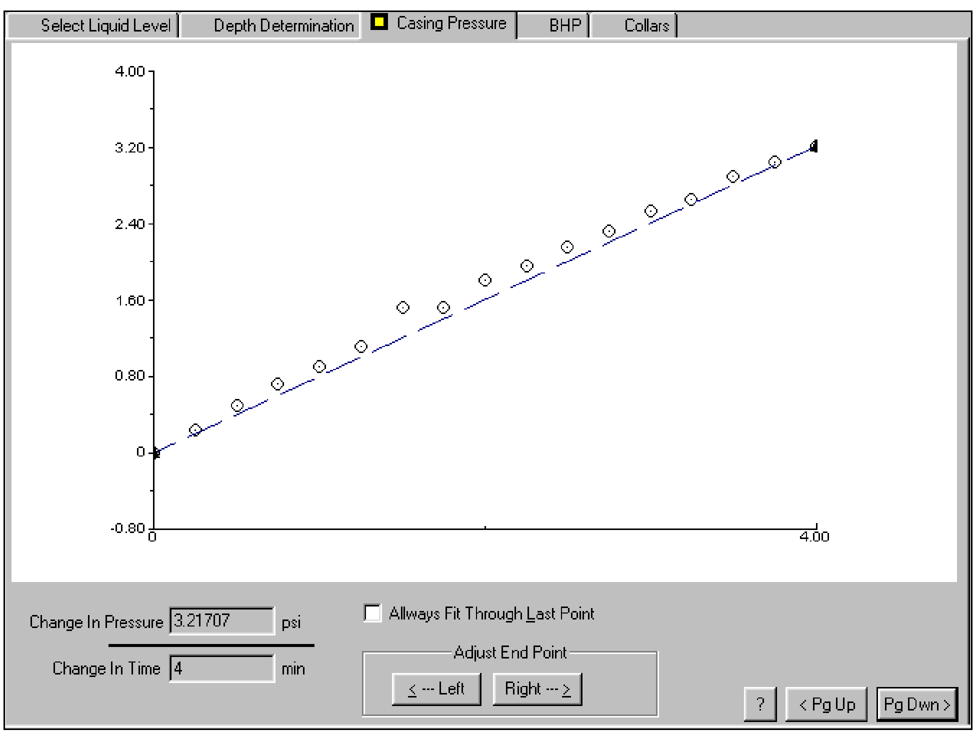


6.2.4 - CASING PRESSURE TAB

This form displays a plot of the **casing pressure**, and the **change in casing** pressure versus **time** during the period the casing valves are closed. This data is used to calculate the **annular gas flow** rate and estimate the amount of gas present in the annular fluid column.

An audible tone will sound every 15 seconds as the casing pressure is measured. The casing pressure data will be collected for a maximum of 15 minutes and then acquisition will be automatically terminated. The operator has the option to end the data collection at any point that is deemed suitable. Generally, **two minutes** are sufficient time for measuring an accurate casing pressure buildup rate. The casing pressure buildup should be terminated by pressing the **Abort** button in the acquisition screen, which also turns off the amplifier and conserves the Well Analyzer's battery energy.

As the casing pressure data is being collected a line will be displayed to allow the operator to verify the consistency of the data.

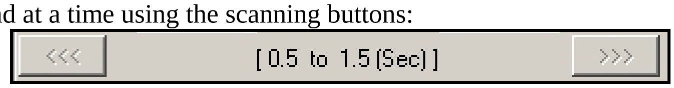


The line is drawn from the first point to the last and all the other points should lie on or next to that line. This plot will normally indicate a consistent buildup rate. A consistent buildup rate is an indication that the well is performing in a predictable steady state manner and that the data is satisfactory for analysis. If serious deviations from the straight line exist, the well may not be completely stabilized.

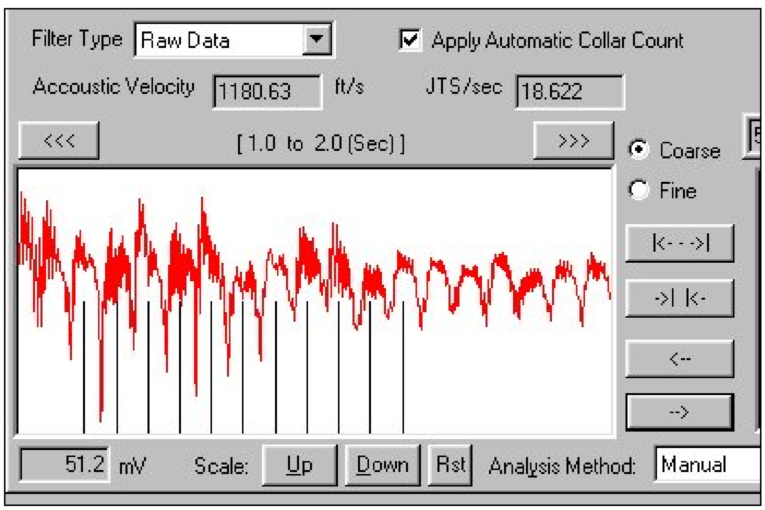
At the bottom of the form are buttons to adjust the fitting of the line to the data. **Adjust** end point: **Left-Right** are used to override the automatic fitting (**Fit Through Last Point**) in case extraneous data points are recorded.

6.2.5 - MANUAL ANALYSIS

Manual Analysis is used for detailed examination of the acoustic data and for those cases when the software is not able to complete the Automatic Analysis such as in the presence of a very high liquid level. The display of the raw or filtered data is used to view the signal one second at a time using the scanning buttons:

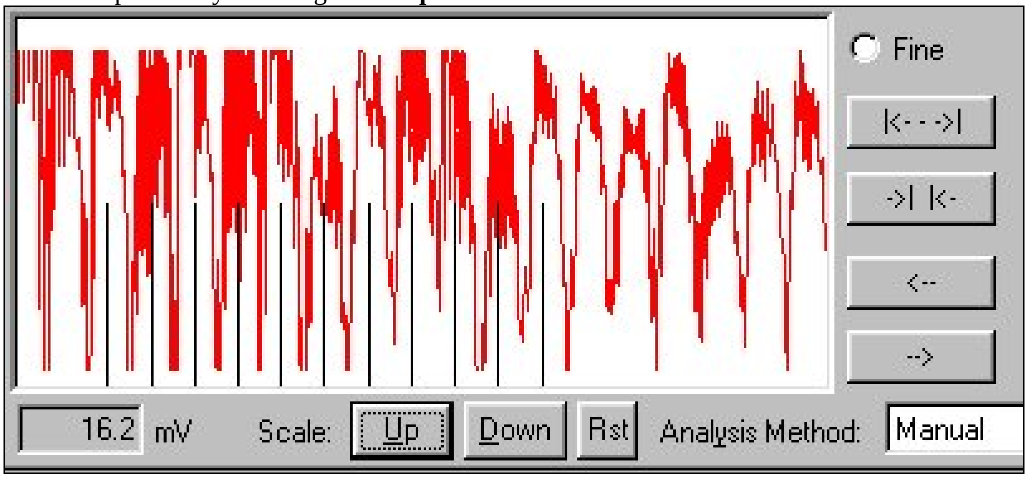


to move through the signal and select any one-second interval.

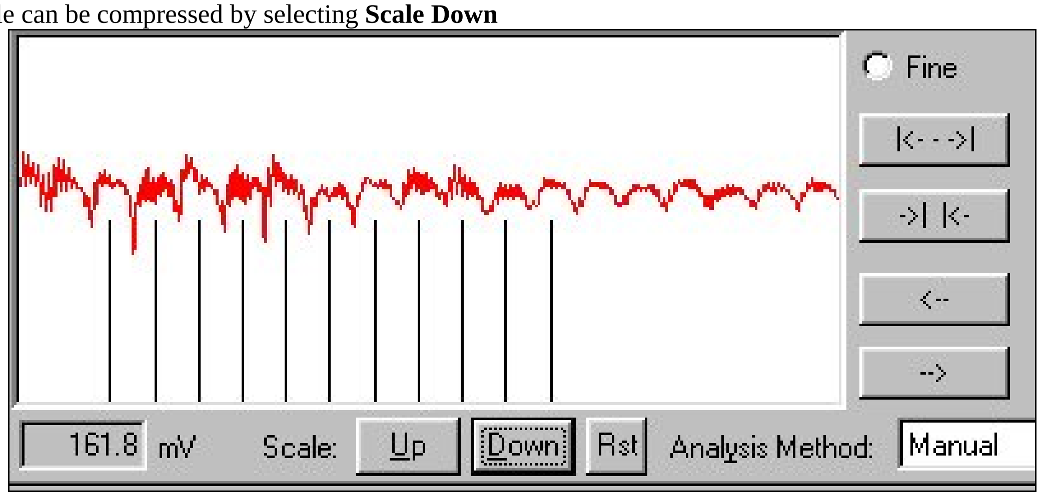


Using these controls it is possible to inspect the signal in great detail to identify the collar reflections as well as signals generated by changes in cross sectional area such as liners, mandrels, seating nipples, anchors, perforations, etc. At each position it is possible to apply the filtering options to enhance the appearance of the signal.

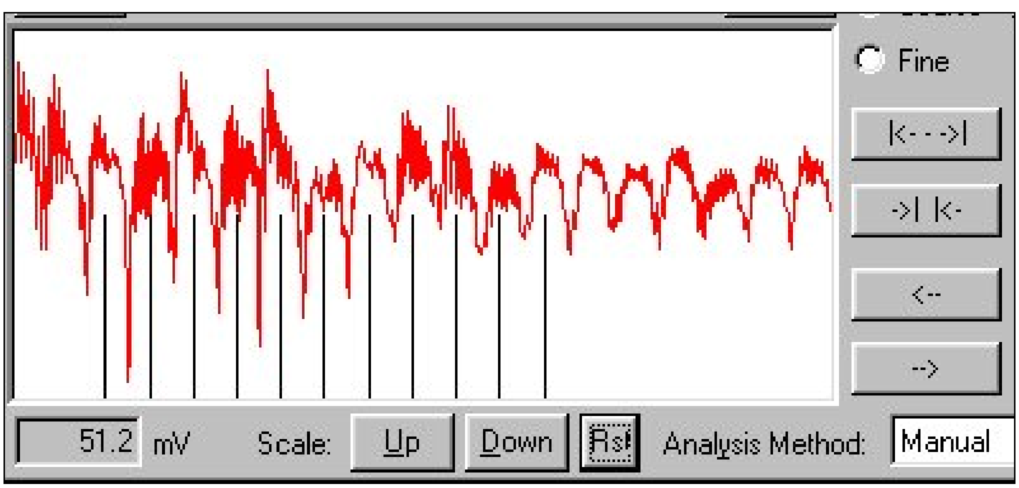
The vertical scale can be expanded by selecting **Scale Up**:



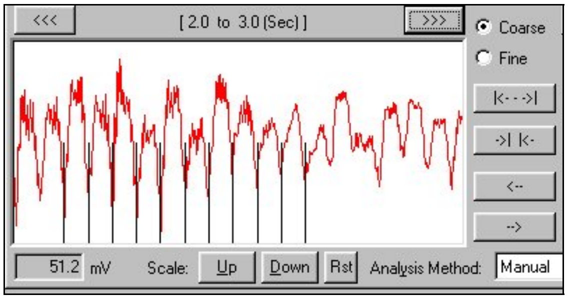
The vertical scale can be compressed by selecting **Scale Down**



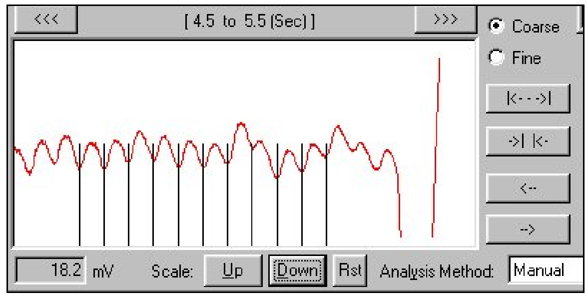
Selecting **Reset** returns the vertical scale to the original default value:



The following figures show various portions of the example well acoustic signal viewed in the **Raw Data** presentation.



Signal from 2 to 3 seconds

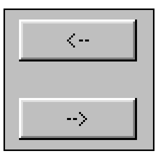


Signal near Fluid Level

The **Manual** function can be used in two ways:

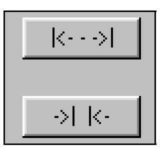
1- to examine in detail the acoustic signal after collar processing has been completed,
2- to process the collars using the frequency contained in a selected portion of the trace.

In each window are displayed vertical markers (11 point dividers) which can be positioned in alignment with the first identifiable collar signal using the arrow control buttons:



These controls move the dividers left or right.

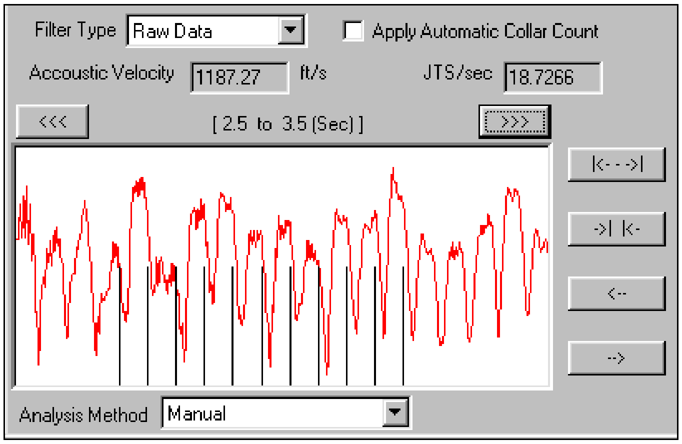
The spacing between vertical markers is adjustable by using the spacing controls:



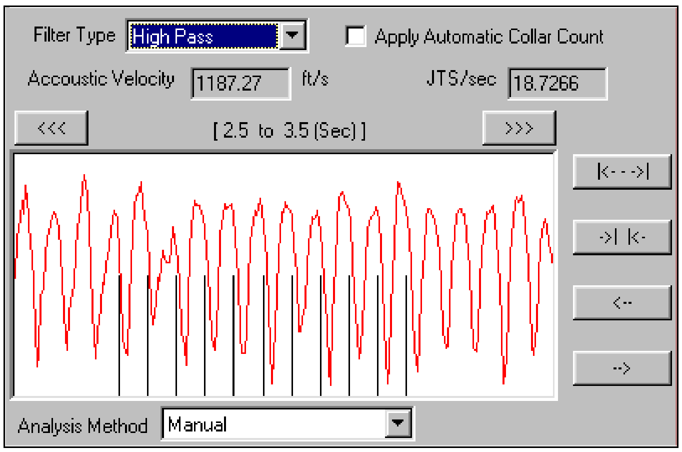
These controls adjust the spacing of the dividers

The operator has the option of processing any 1-second interval of raw data shown in the upper trace to determine the liquid level depth. Occasionally, due to a poor gas-gun connection to the well, excessive noise, a liner, paraffin or other anomaly a signal of poor quality may be present in the portion of the acoustic trace that the computer selected to determine the collar frequency. An incorrect collar rate could thus be determined resulting in an incorrect liquid level depth. If this is the case, an alternate signal segment may be selected by the operator where the collar raw signal is more clearly present with less noise or interference. The following section describes the procedure for manual analysis of the collar count.

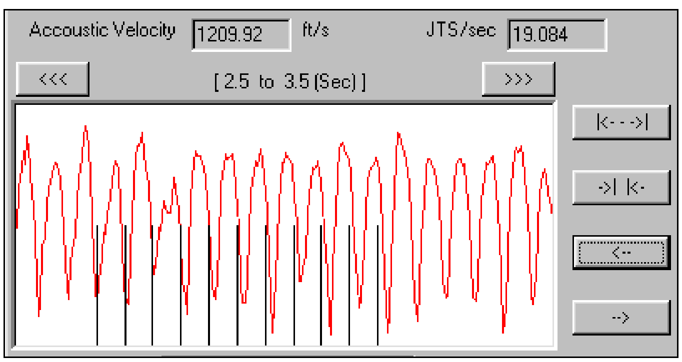
In the **Manual Analysis** mode and with **Apply Automatic Collar Count** <u>unchecked</u>, toggle through the acoustic data and select an interval, between the shot and liquid level, which contains distinct collars and no anomalies, as shown in the following sequence of figures:



1-Select the signal interval to be used.



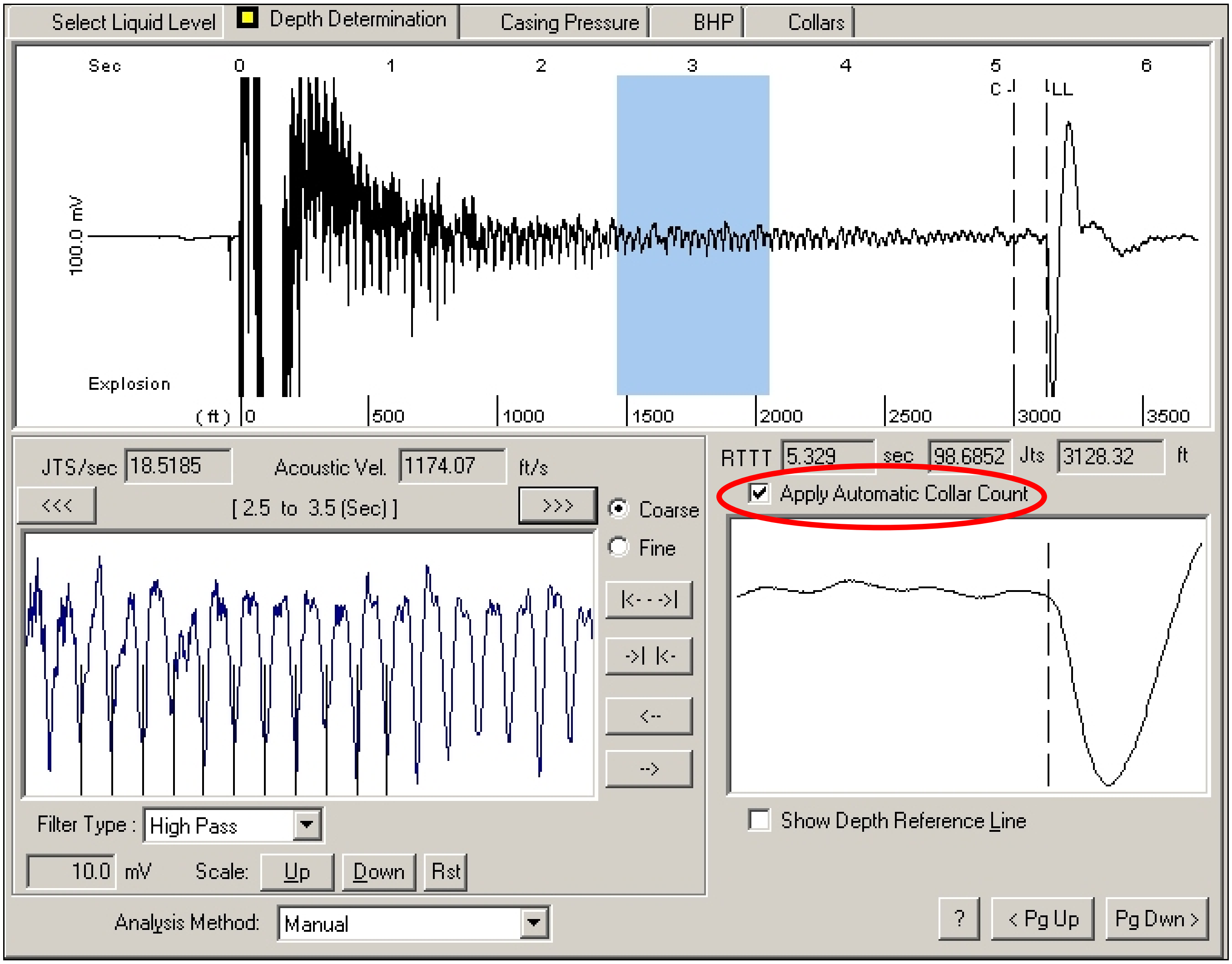
2-Filter signal as needed



3-Align first marker with collar signal

4-Adjust marker spacing to match collar frequency

From step 3 to step 4 notice the change in collar frequency (and acoustic velocity) from 19.08 jts/sec to the more representative 18.38 jts/sec in the final frame. If desired, all of the complete trace can be filtered with a narrow band-pass filter centered at the frequency of this collar rate and a new collar count undertaken by reselecting **Apply Automatic Collar Count** as shown below:



When you align the vertical black lines (11 point dividers) you are determining the Acoustic velocity. The closer the spacing of the vertical lines then the faster acoustic velocity is determined by TWM. If you check the “Apply Automatic Collar Count” box, then TWM automatically counts collars over the acoustic trace and displays the collar count on the Collars tab. The acoustic velocity determined on the Depth Determination tab is used to help in filtering the signal to process the automatic collar count on the Collars tab. The acoustic velocity from the Collars tab is displayed in the BHP tab, if you check the “Apply Automatic Collar Count” box. If you uncheck the Apply Automatic Collar Count” box, then TWM uses the Acoustic Velocity determined for the 1 second interval selected on the Depth Determination and displays this acoustic velocity on the BHP tab.

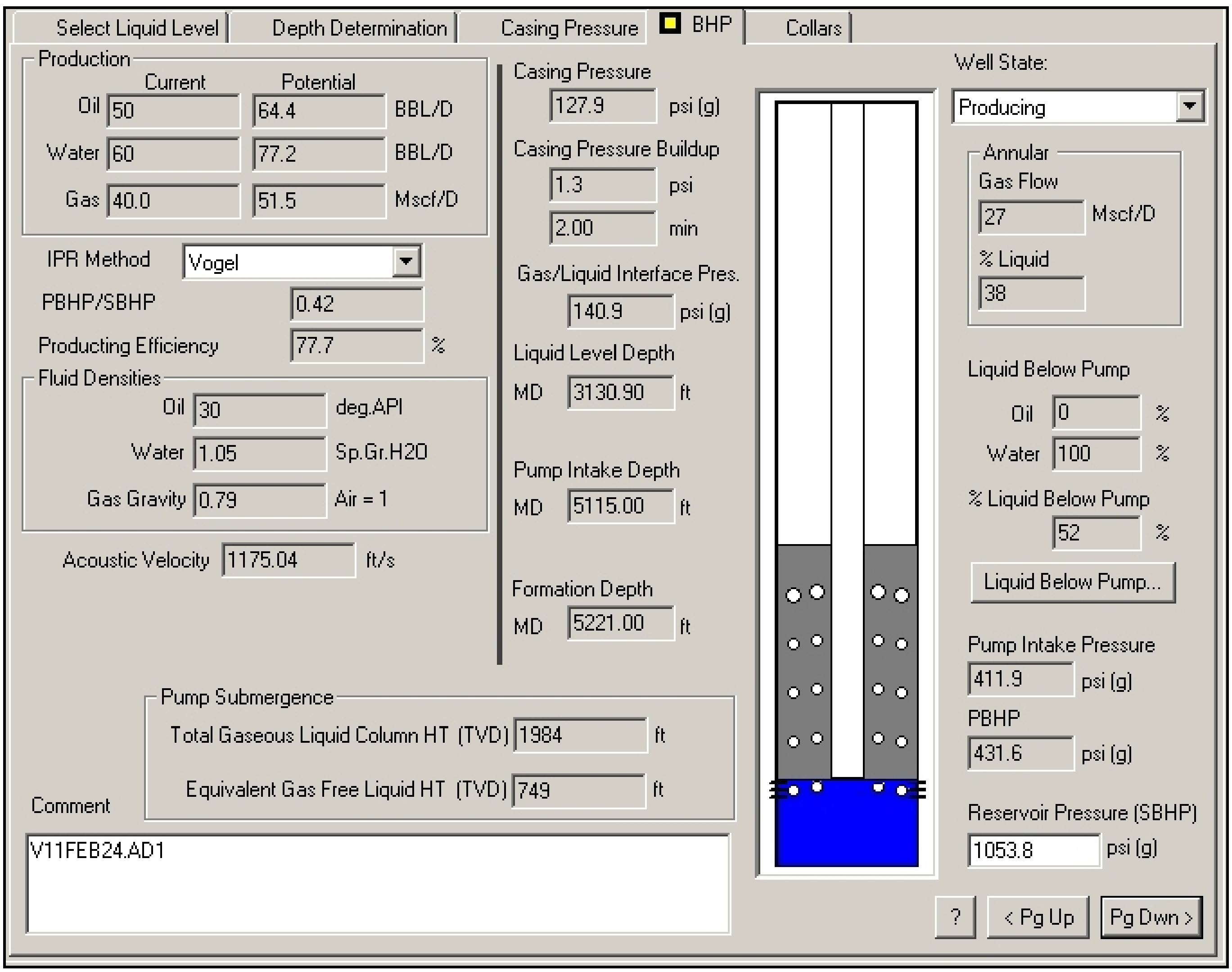
6.2.6 - BHP TAB

This Tab computes the BHP based on the measured acoustic fluid level and casing pressure data in conjunction with the well and fluid data in the well file. The objective of this display is to provide a complete analysis of the well conditions at the time of the measurement. The display is divided in two sections:

- On the right is a schematic diagram of the wellbore indicating whether the well is **Producing** or **Static** and whether the well is **Vertical** or **Deviated** and the results of flow and pressure calculations.
- On the left are several blocks containing data about the well's performance, fluid data and reservoir parameters.

Once the producing bottom-hole pressure is calculated, the value is compared to the static bottom-hole pressure and **Vogel's IPR** relationship is used to determine the well's inflow performance efficiency and the maximum obtainable flow rates. The user may select **Productivity Index** as an alternate relation to determine the well potential.

In the BHP screen, the wellbore schematic (on the right half of the display) shows the position of the annular liquid level as well as the position of the pump intake in relation to the formation depth.



The following parameters are displayed on the BHP diagram and are labeled as follows:

- **Casing Pressure**: This is the casing head pressure, either measured automatically by the Well Analyzer or entered manually in the well data screen.
- **Casing Pressure Buildup**: This is the rate of change in casing head pressure as a function of time when the casing head valve is closed, expressed in PSI per minute. It is either calculated from the slope of the line of the casing pressure vs. time screen or entered manually.
- **Annular Gas Flow** It is the flow rate of gas bubbling through the annular liquid and normally being vented through the casing head valve, Mscf/D. It is calculated from the casing pressure buildup rate and the annular volume.
- **% Liquid** This is the calculated percentage of liquid present in the annular gaseous liquid column. It is calculated from the annular gas flow using a correlation based upon field data.(see Acoustic Determination of Producing BHP paper)
- **Gas/Liquid Interface Pressure (PSIG)**: This is the calculated pressure at the depth of the gas/liquid interface. It is calculated from the casing head pressure by adding the weight of the gas column.
- **Liquid Level**: This is the depth (in feet) to the gas/liquid interface as determined from the Echometer survey. It corresponds to the depth calculated and displayed in the BHP Tab. The distance to the liquid level is equal to the acoustic velocity x the RTTT/2.
- **Formation Depth**: This is the **datum depth** (in feet), as entered in the well data screen, at which the program will calculate the pressure.
- **Pump Intake Pressure** this is the **pressure in the annulus** calculated at the depth of the pump intake (depth to SV)
- **PBHP**: This is the calculated producing bottom-hole pressure at the **datum depth**.
- **Reservoir Pressure (SBHP)**: This is the shut-in BHP as entered in the well data file.

The information on this schematic diagram is a complete representation of the well's operating conditions at the time of the survey. The left-hand side of the display shows the following information:

Production

-The current **oil, water** and **gas** flow rate data from the most recent production test as entered in the well data file. This information is used in subsequent calculations of well performance and should be as recent and as accurate as possible.

-The potential **maximum production** rate if the producing pressure (PBHP) were reduced to zero, based on the selected IPR Method.

- **IPR Method –** The selected method for representing the well’s performance: (**Productivity Index or Vogel IPR**)
- **PBHP/SBHP-**This is the ratio of the current producing bottom-hole pressure to the shut-in bottom-hole pressure. A value of 1.0 corresponds to a shut-in well. A value of zero corresponds to a well producing at open flow or maximum production rate.
- **Production Rate Efficiency %**: Expresses the current well test flow rate as a percentage of the calculated maximum flow rate.

Fluid Densities:

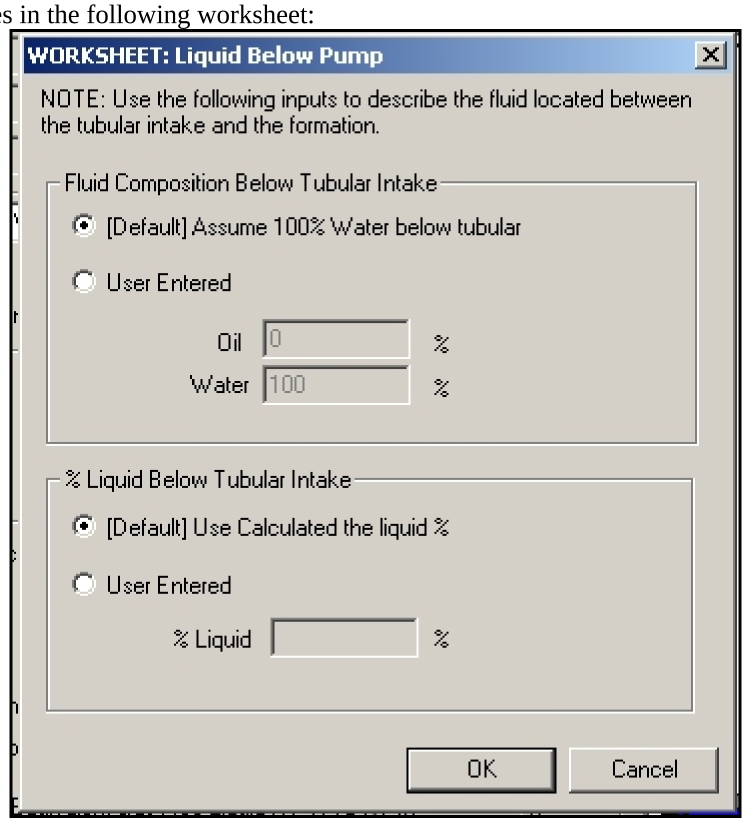
- **API Oil -** The stock tank oil gravity.

- **Water SG -** The specific gravity of the produced brine (water = 1.00).

- **Gas SG -** The specific gravity of the gas in the annulus (air = 1.0). The specific gravity is **calculated from the measured acoustic velocity**. The gravity of the gas in the annulus is probably different than the specific gravity of the separator gas since these have different compositions.

Liquid Below Pump

By default the program computes the % liquid and considers that the liquid below the pump is primarily produced water, regardless of the produced WOR. The user has the option of changing these values by clicking on the **Liquid Below Pump** button and entering his choices in the following worksheet:



Additional Parameters

- **Acoustic Velocity**: This is the speed of sound (ft/sec) of the annular gas calculated as follows:

Method	Option	Tab where displayed	Velocity Value
Automatic		Collar	Average velocity
Downhole Marker	Feet or joints to marker	Depth Determination	Average velocity
Manual	Collar Count No collar count	Collar Depth Determination	Average velocity Constant velocity
Acoustic Velocity	Entered Gas Gravity Gas Composition	Depth Determination	Constant velocity

- **Reservoir Pressure (SBHP) -** This is a best estimate of the stabilized shut-in formation pressure.

- **Method -** Annotation giving information as to how the reservoir pressure was determined. The best method is to let the reservoir pressure increase by shutting-in the well while automatically recording an extended pressure transient build-up test (See section 6.0). Alternately the shut-in bottom-hole pressure is determined from an echometric survey after a few days of well shut-in status, when the fluid level and casing pressure have approximately stabilized.

- **Pump Intake Depth** is the depth of the pump's **Standing Valve (SV)**.

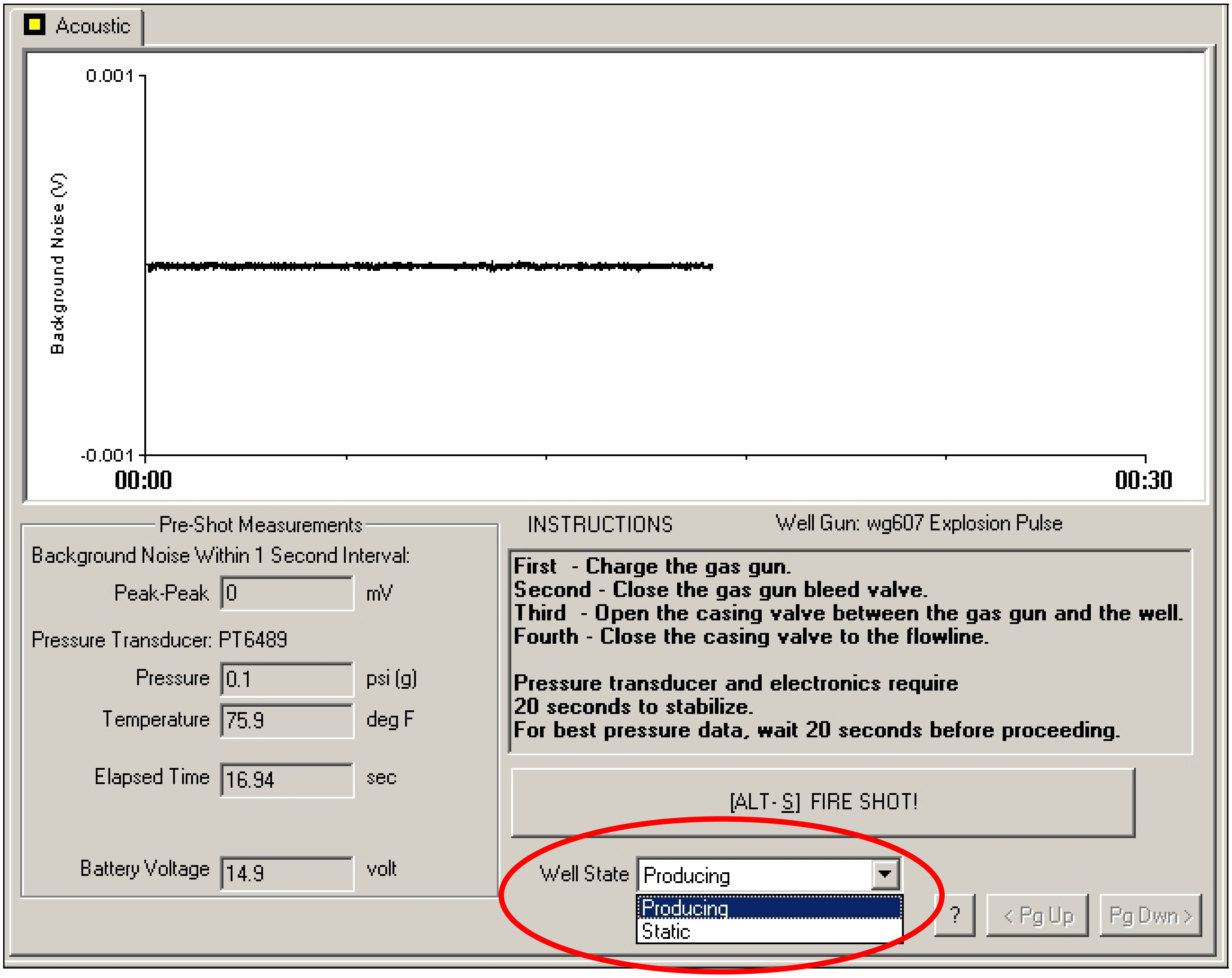
- **Total Gaseous Column HT** is the vertical height of the fluid column above the pump intake including the total volume of the mixture of free gas bubbles and liquid.

- **Equivalent Gas-Free Liquid HT** expresses the height above the pump to which the liquid present in the annulus would exist if all the free gas were removed. This quantity is calculated from the annular geometry and the % Liquid value calculated from the casing pressure buildup rate.

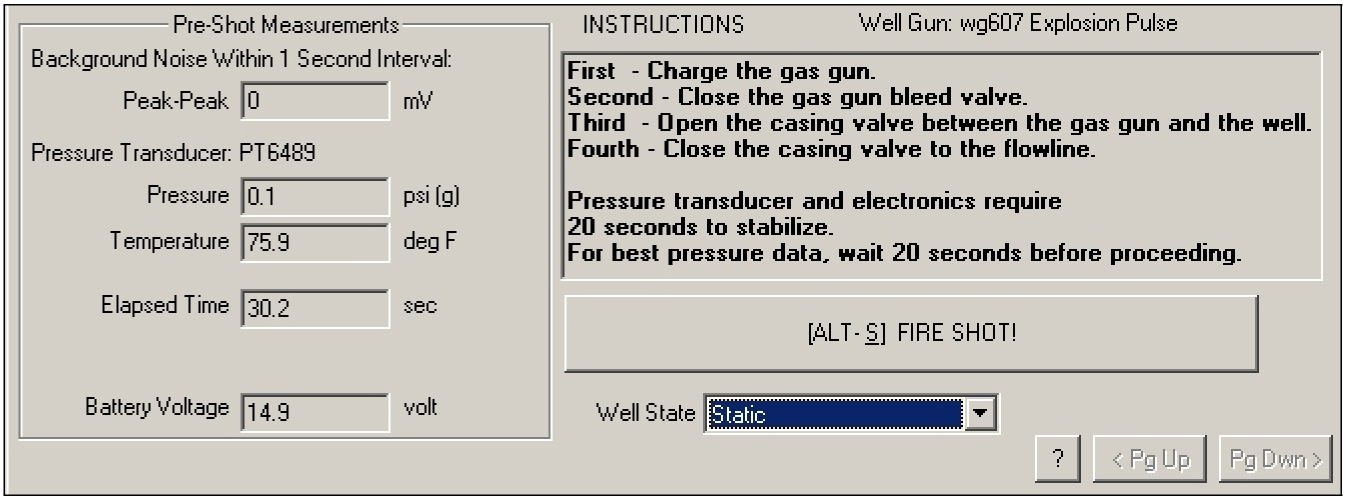
It is very important that the well data be accurate. All these values are used by the program in the calculations of bottom hole pressure and the performance analysis.

6.2.6.1 - Static Bottom Hole Pressure

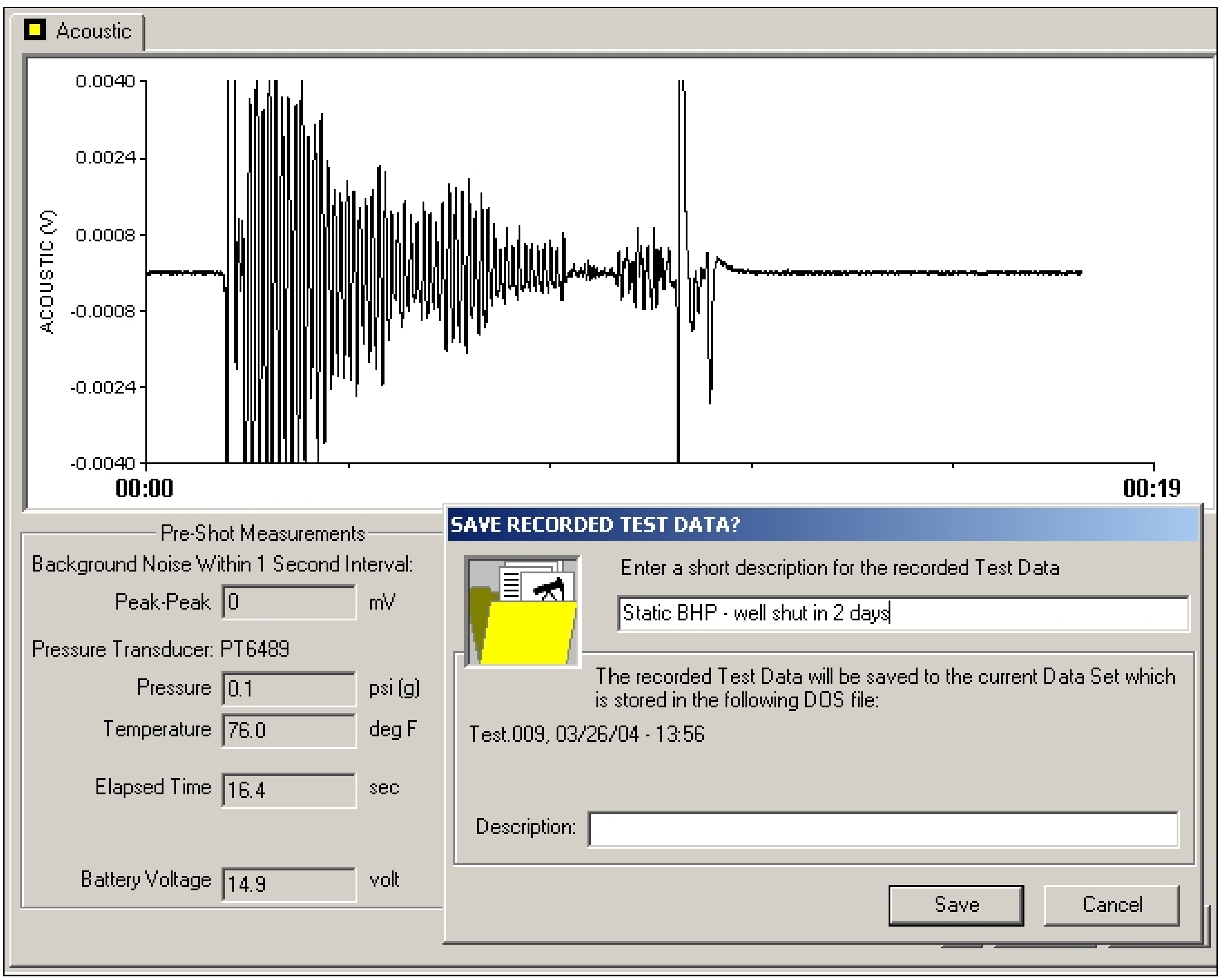
When an acoustic test is taken in a well that has been shut-in for a period of time (intentionally or because of mechanical problems) and the objective is the determination of the Static Bottom Hole Pressure (SBHP) this should be indicated to the software at the time of acquisition of the data by selecting the **Well State** pull-down menu as shown in the following figure:



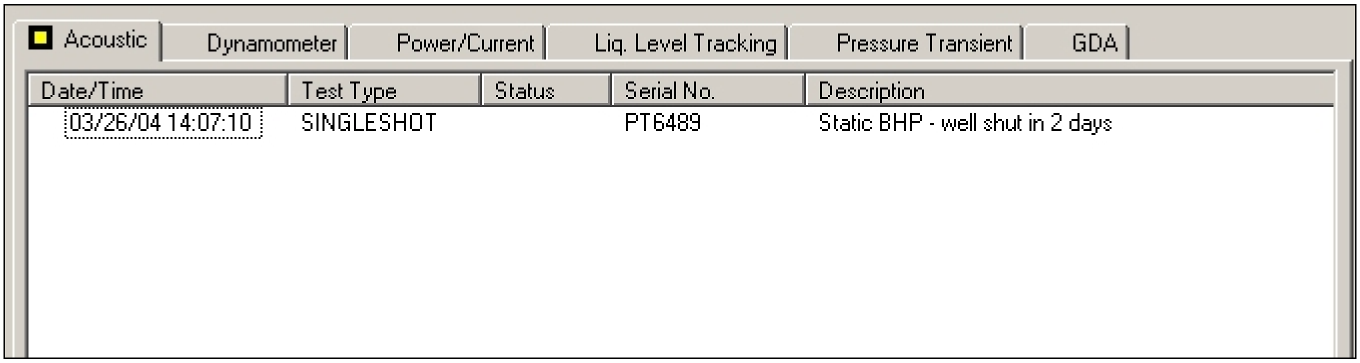
and selecting "**Static**"



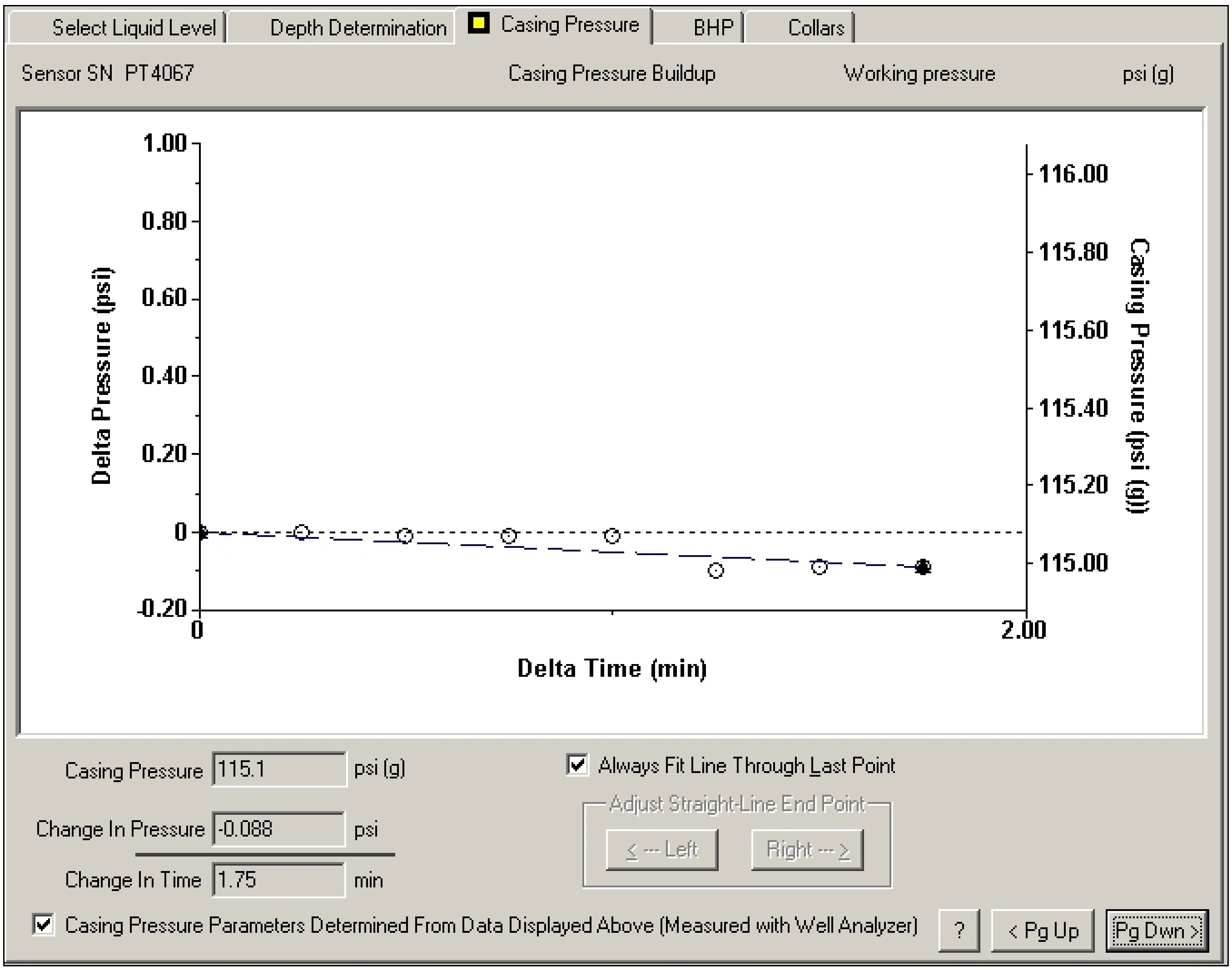
The data acquisition procedure remains unchanged from the usual steps but it is recommended that a comment be included once the data is acquired that also notes the length of time that the well was shut-in:



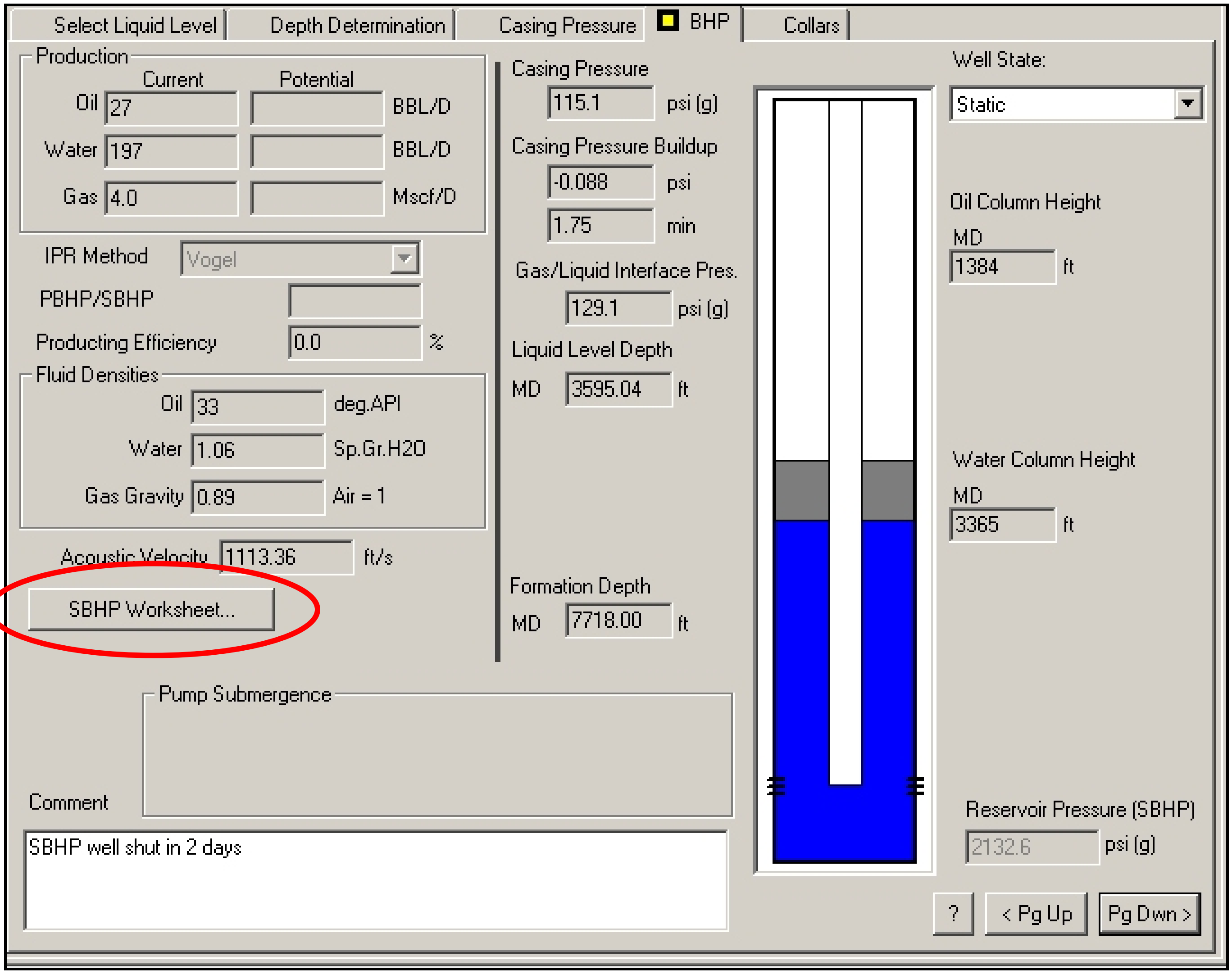
The comment will appear in the description of the test:



In a static well that has reached a good level of stabilization, the casing pressure generally will remain constant or slightly decrease during the 2 minute test as shown below:

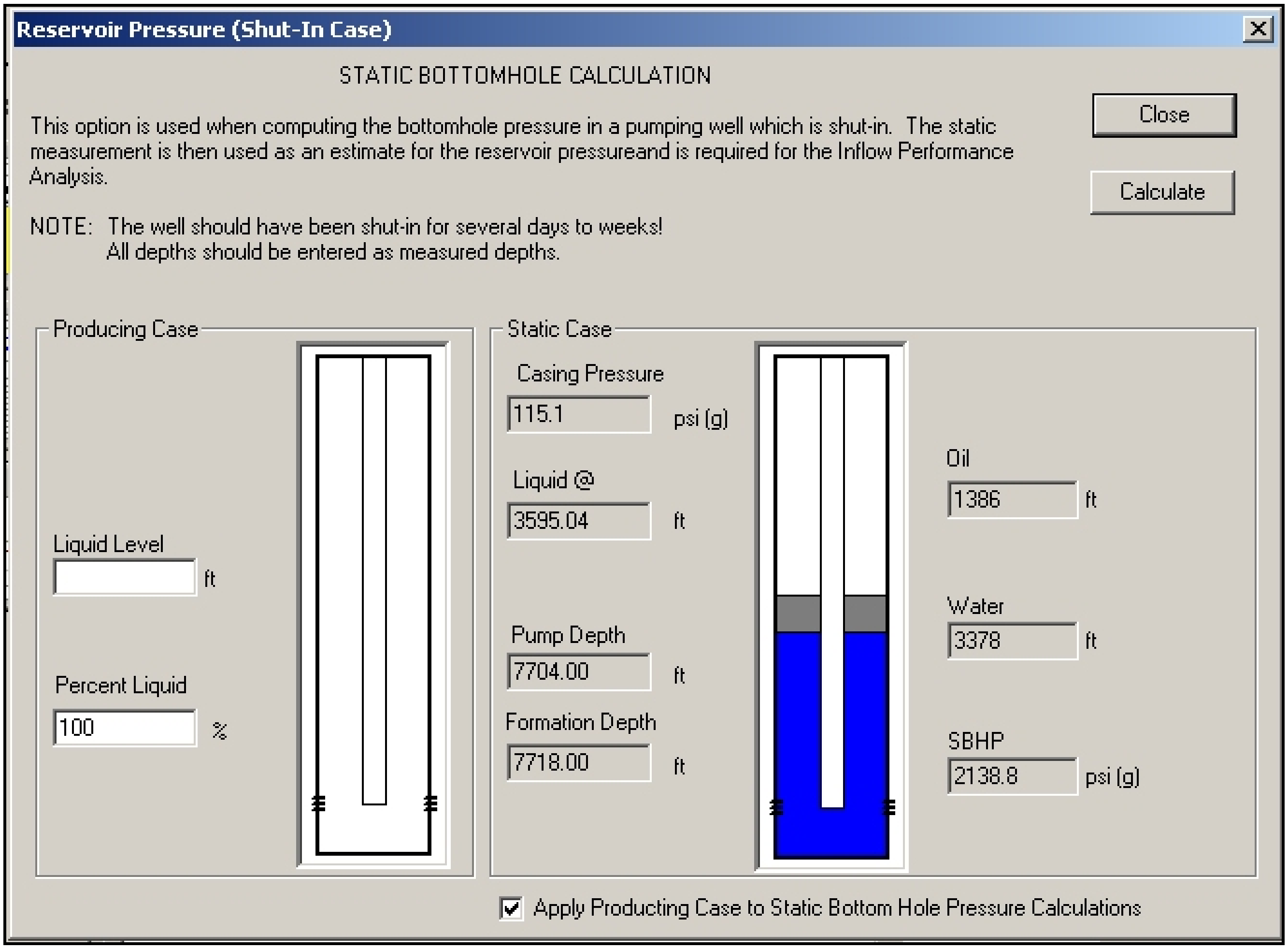


This is an indication that the annular fluid consists of a column of 100% liquid (oil and water). In order to obtain an accurate calculation of SBHP it is necessary to account for the liquid that was present in the wellbore BEFORE the well was shut-in and calculate the % of oil and water in the annulus taking into account an afterflow Water/Oil ratio equal to the producing Water/Oil ratio

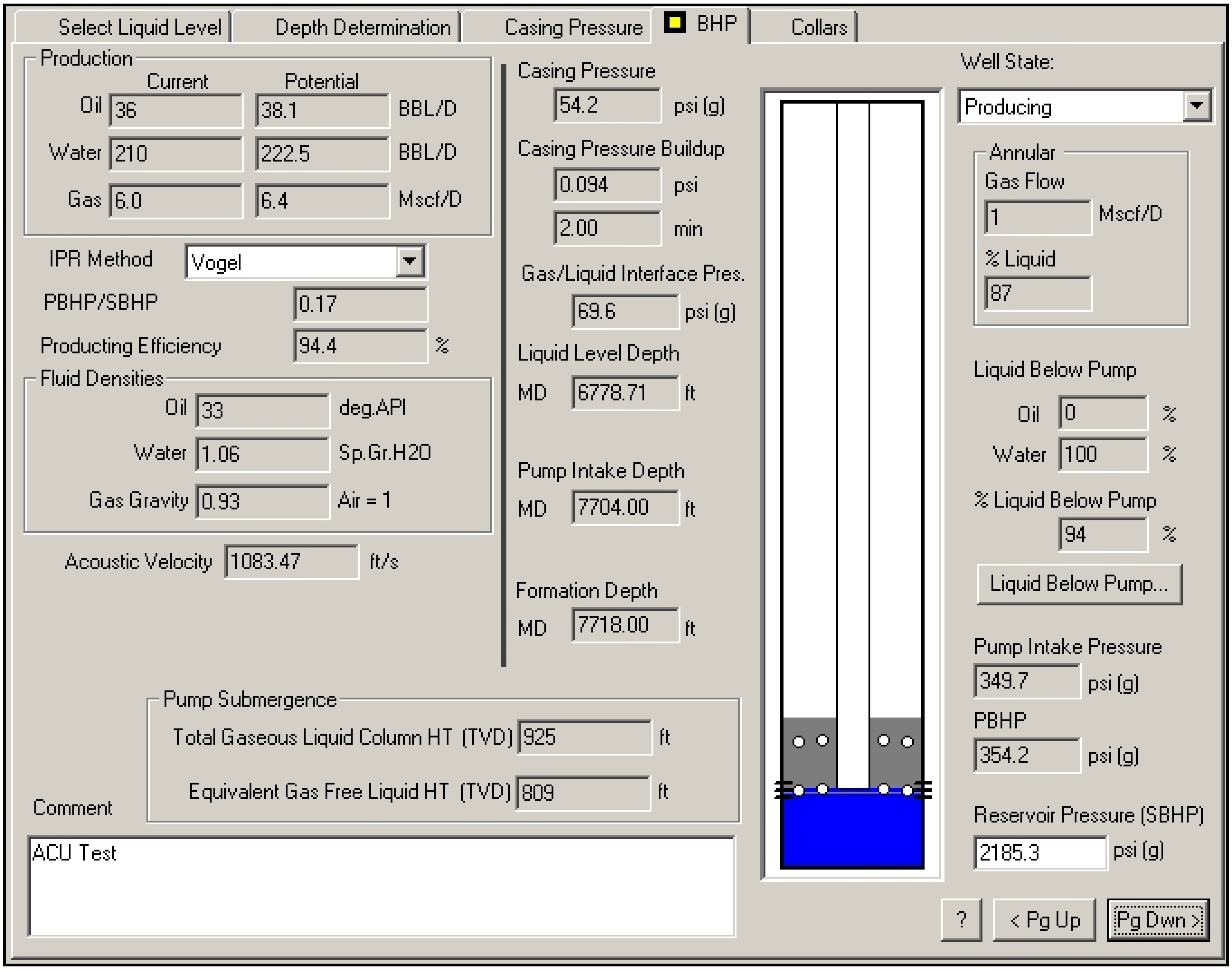


At this point the indicated **SBHP (2132.6) is not correct** since the annular gradient calculation does not include the fluid that was present in the well prior to shut-in. The correct calculation is done by clicking **SBHP Worksheet** button.

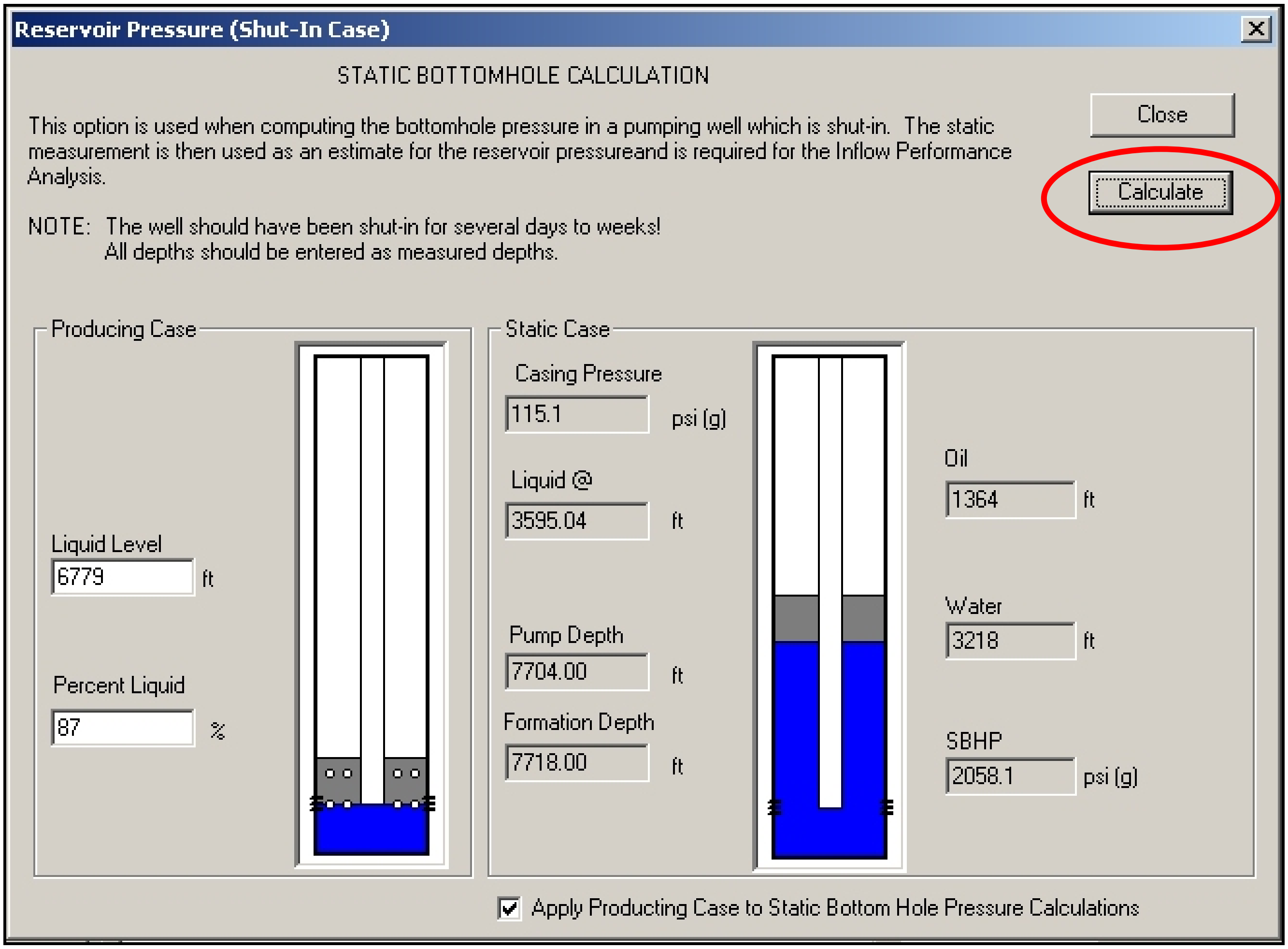
This displays the following data input form:



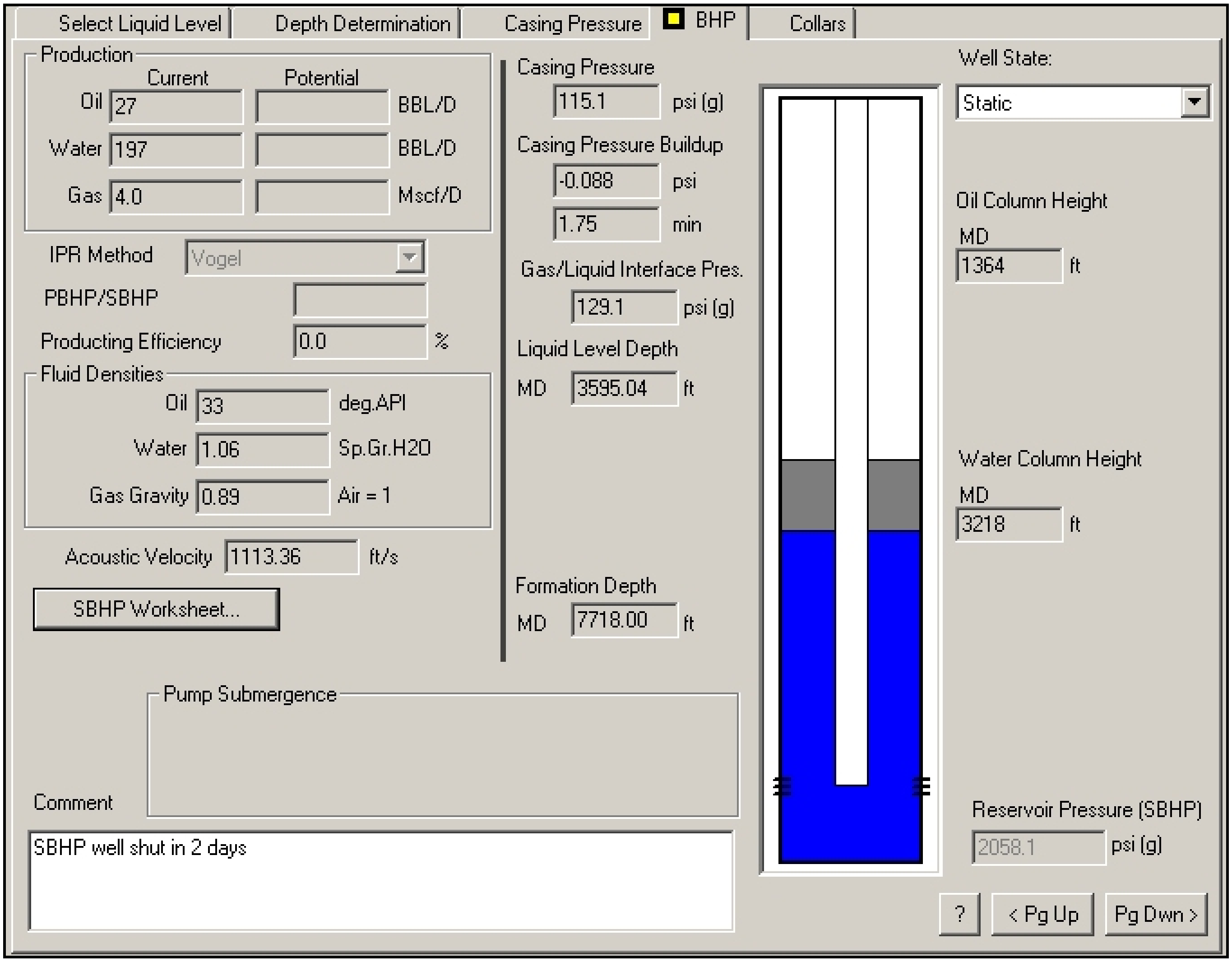
The Producing Liquid Level and % of Liquid that were recorded for the last acoustic fluid level measurement that was recorded prior to shut-in are reviewed in the following figure:



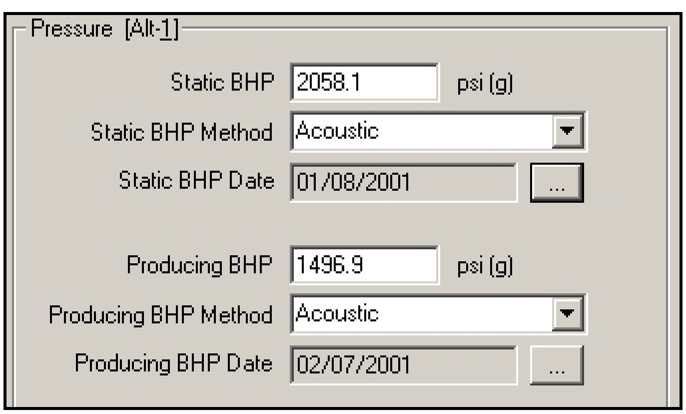
The values of liquid level depth (6779) and % Liquid (87%) that were present in the wellbore, before the well was shut in, are entered in the corresponding fields at the left of the form as seen in the following figure:



Clicking the **Calculate** button performs the correction and records the correct SBHP **(2058.1 psig)** in the well file and in the BHP tab:



The newly determined SBHP of 2058.1 psi is also updated in the well file in the Conditions tab.



6.2.6.2 Static BHP upon Recalling Data

If the BHP correction is not done at the time of acquiring the test data, it can be done later upon recalling the test data, going to the BHP tab, selecting “static” as the well state and entering the producing data using the SBHP worksheet as shown above.

6.3 - Special Processing of Acoustic Data

The Well Analyzer is intended to be used successfully in all possible applications throughout the world. As such it is designed to provide the capability to process data from wells where unusual conditions exist such as very shallow liquid levels, annular partial obstructions, flush pipe without collars, short tubing joints, etc. The following section describes the special data processing procedures.

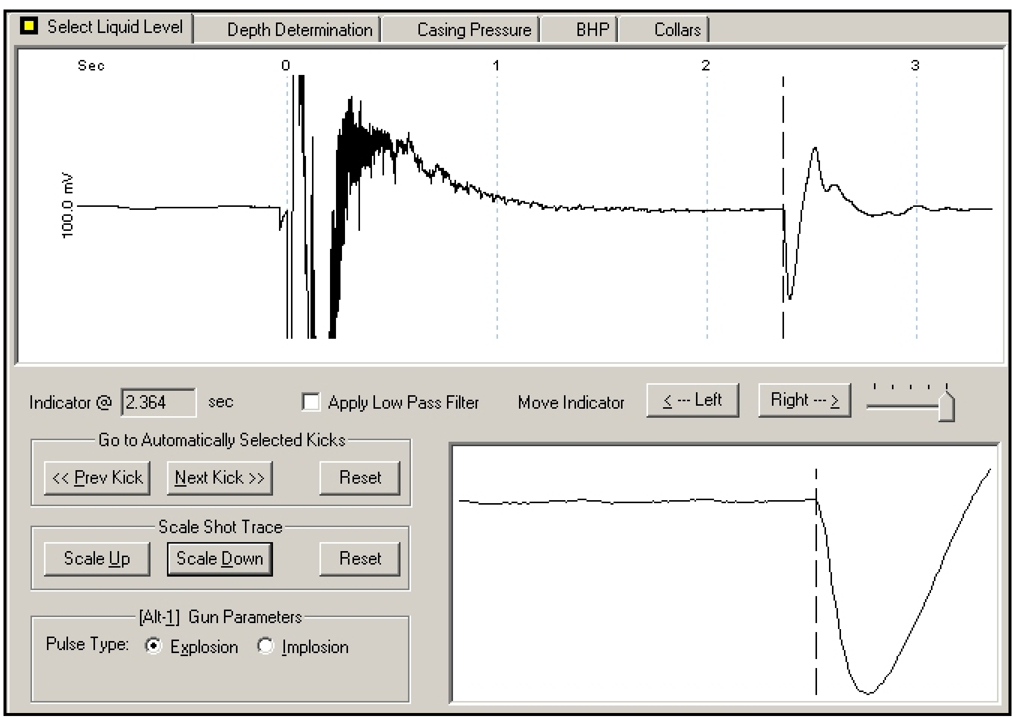
Some of the wells will have liners, upper perforations, paraffin, odd length of joints, poor surface connections and other conditions which result in an acoustic chart that may be very difficult to interpret. Normally, the computer and software locate the liquid level and then process collar reflections in order to obtain a collar frequency (jts/sec). The acoustic data is filtered by a narrow band-pass filter centered at this frequency and the program will automatically attempt to count all of the collars from the initial blast to the liquid level. The automatic analysis will correctly determine the liquid level depth for 95% of the wells. However, some wells will have conditions or anomalies such that these procedures will not function as desired.

If the time to the liquid level echo is less than 1.0 seconds, the operator should consider using one of the special processing options. However the special processing techniques are available whenever the automatic collar count is not satisfactory.

Special processing assumes that the position in time of the liquid level has already been determined by the operator by positioning the movable indicator line on the liquid level signal.

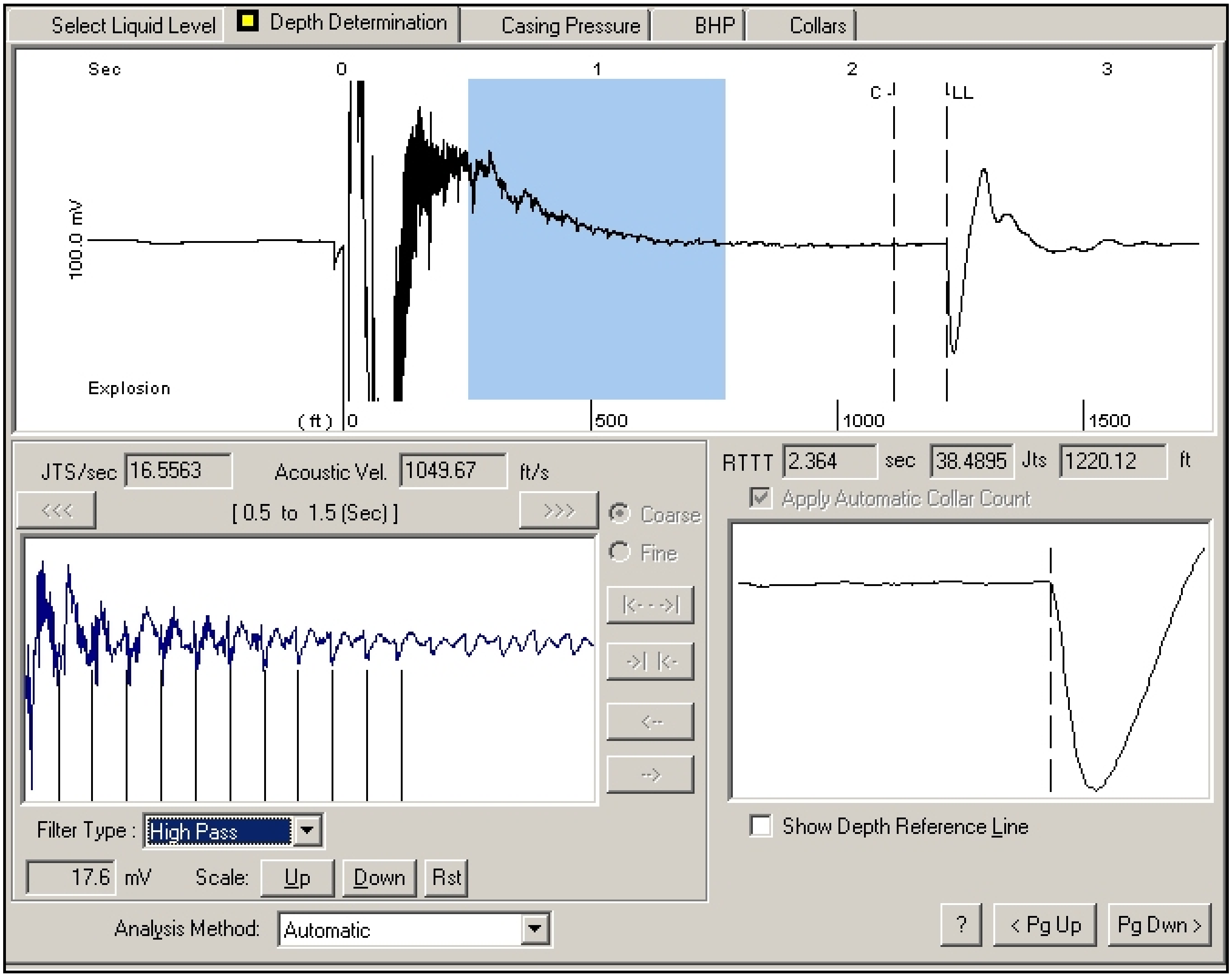
6.3.1 - Shallow Liquid Level

If the round-trip travel time between the surface and the liquid is less than 1.0 seconds, it is difficult to pick the liquid level automatically in shallow wells and the operator may be required to move the liquid level indicator manually. A sample shallow well data file is shown below.



The indicator may be moved left to right by using the **Left** and **Right** controls. These keys move the indicator in increments and will allow the operator to position the indicator close to the liquid level.

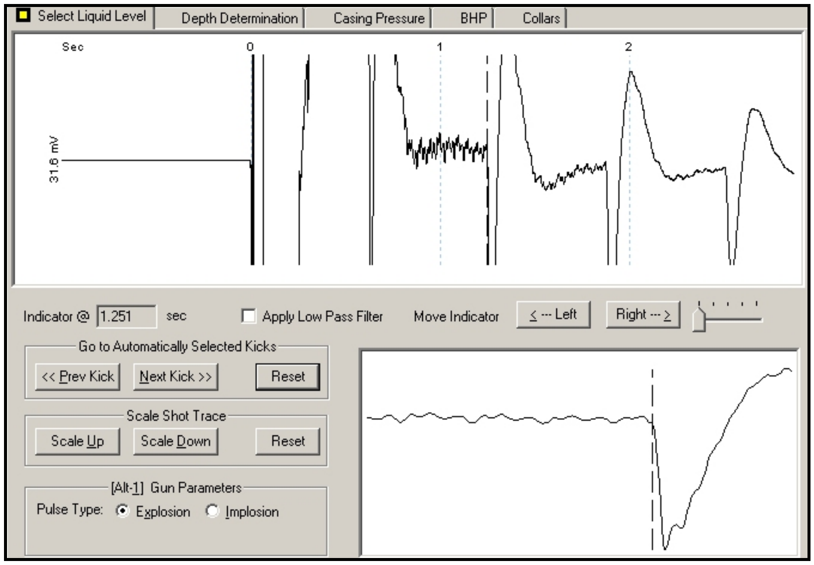
Depending on the length and quality of the signal the Automatic Analysis may determine the depth to the fluid level correctly as shown in the next figure



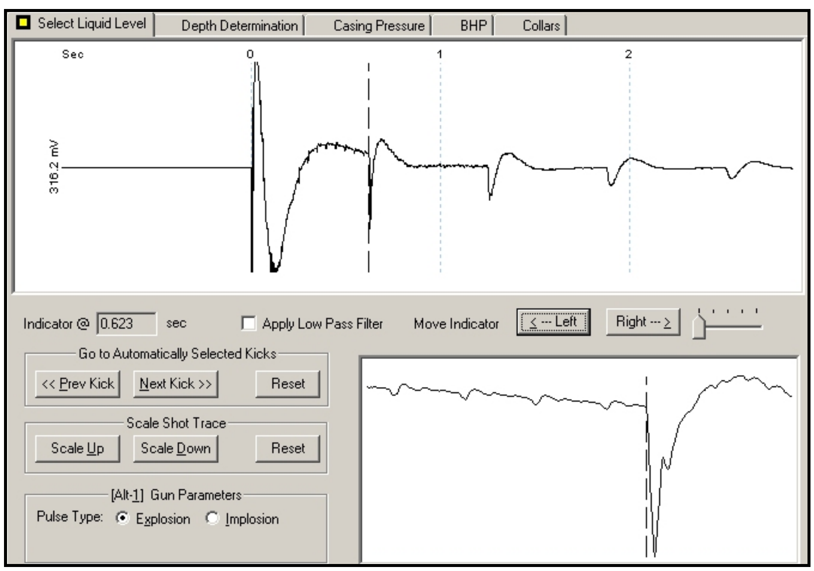
. This may not be the case especially when the fluid level is very close to the surface as is discussed in the next section on Very High Fluid Level.

6.3.2 - Very High Fluid Level – Manual Processing

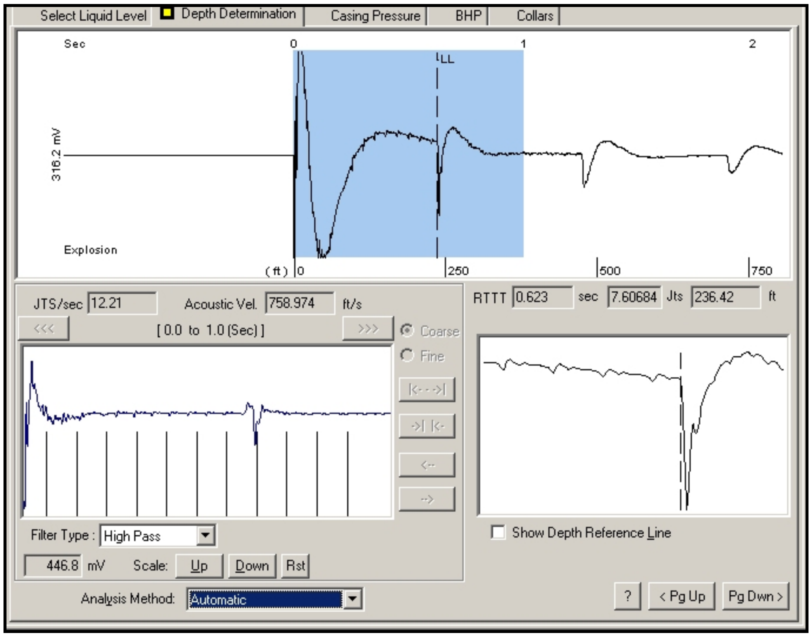
When the fluid level is very close to the surface, such as in shut-in wells with high BHP, the acoustic signal will include a large number of multiple fluid level echoes (repeats) and the signal amplitude may be driven off scale as shown in the following figure:



Notice also that the **software has not identified the correct fluid level signal but a repeat of the liquid level**. The user should first adjust the scale amplitude and then move the marker to the first liquid level reflection:

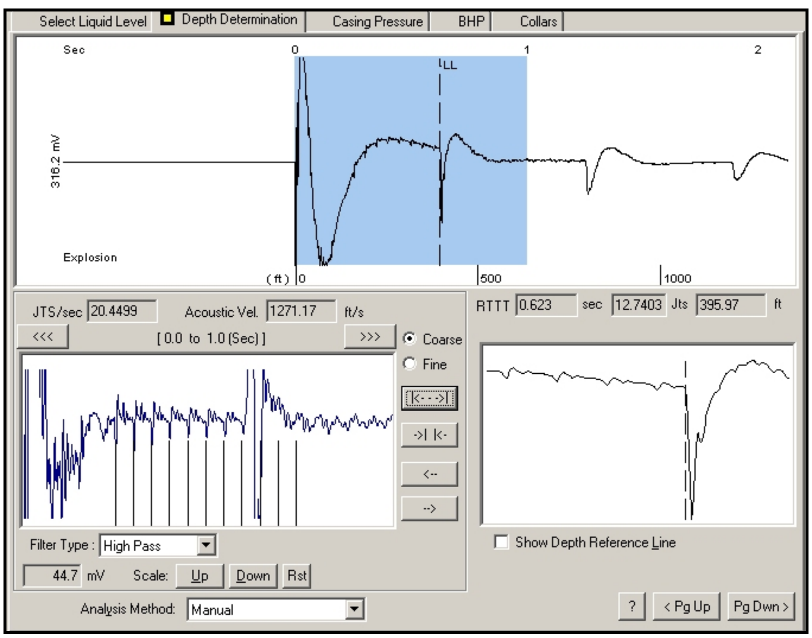


Next, select the Depth Determination tab to obtain an estimate of the fluid level depth:



This is a **wrong** estimate of the liquid level depth because the accuracy of the automatic collar frequency determination is affected by the presence in the time window of the high amplitude and low frequency signal from the liquid level.

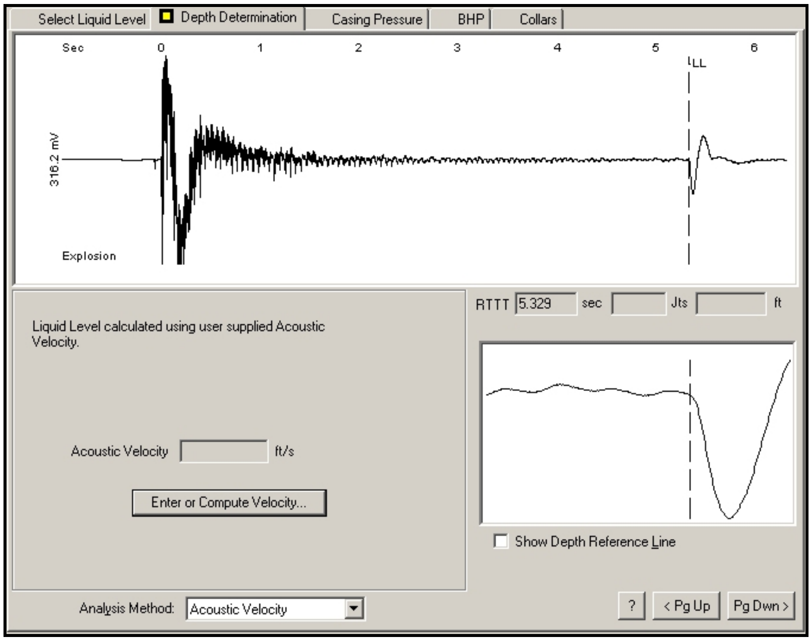
Manual interpretation and filtering will yield a more precise fluid level by adjusting the dividers to match with the collar signals identified in the detailed window as shown in the following figure:



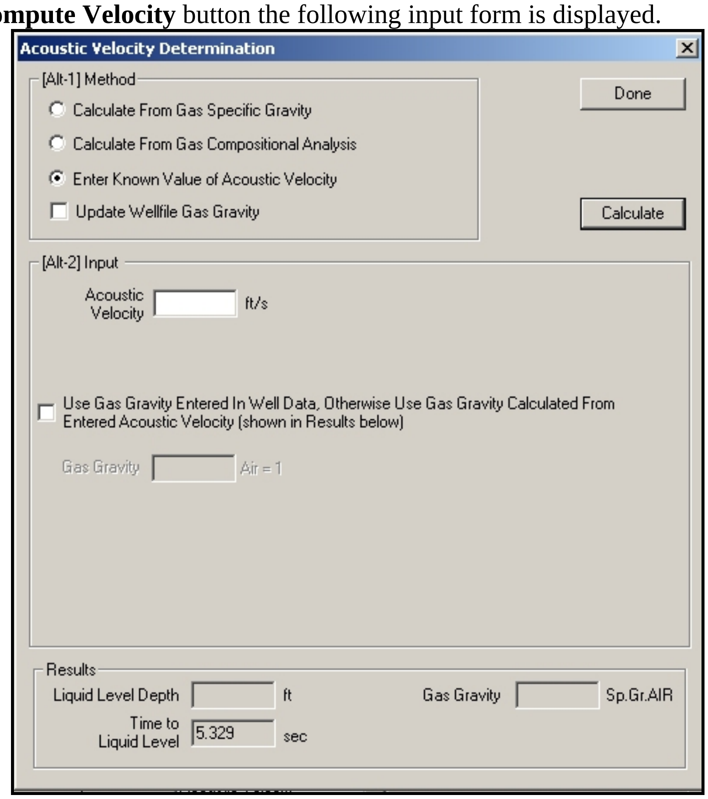
This yields the correct acoustic velocity and fluid level depth.

6.3.3 - SPECIAL PROCESSING - VELOCITY INPUT -

The simplest optional technique available for determining the distance to the liquid level depth is for the operator to enter the acoustic velocity. The velocity can be obtained from prior data measured in the field, from plots of acoustic velocity from computer programs, or calculated. The acoustic velocity of air at 82^{o} F is 1140 ft./sec. The velocity of 0.8 SG hydrocarbon gas at 50 PSI and 90^{o} F is 1175 ft./sec. The velocity of hydrocarbon gas varies from a practical minimum of 600 ft. /sec. to 2000 ft / sec. (at 5000 PSI) to 3500 ft/sec (at 15000 PSI). Information about acoustic velocity of hydrocarbon gases at various pressures and temperatures can be obtained from Echometer's web page www.echometer.com or by contacting the company.



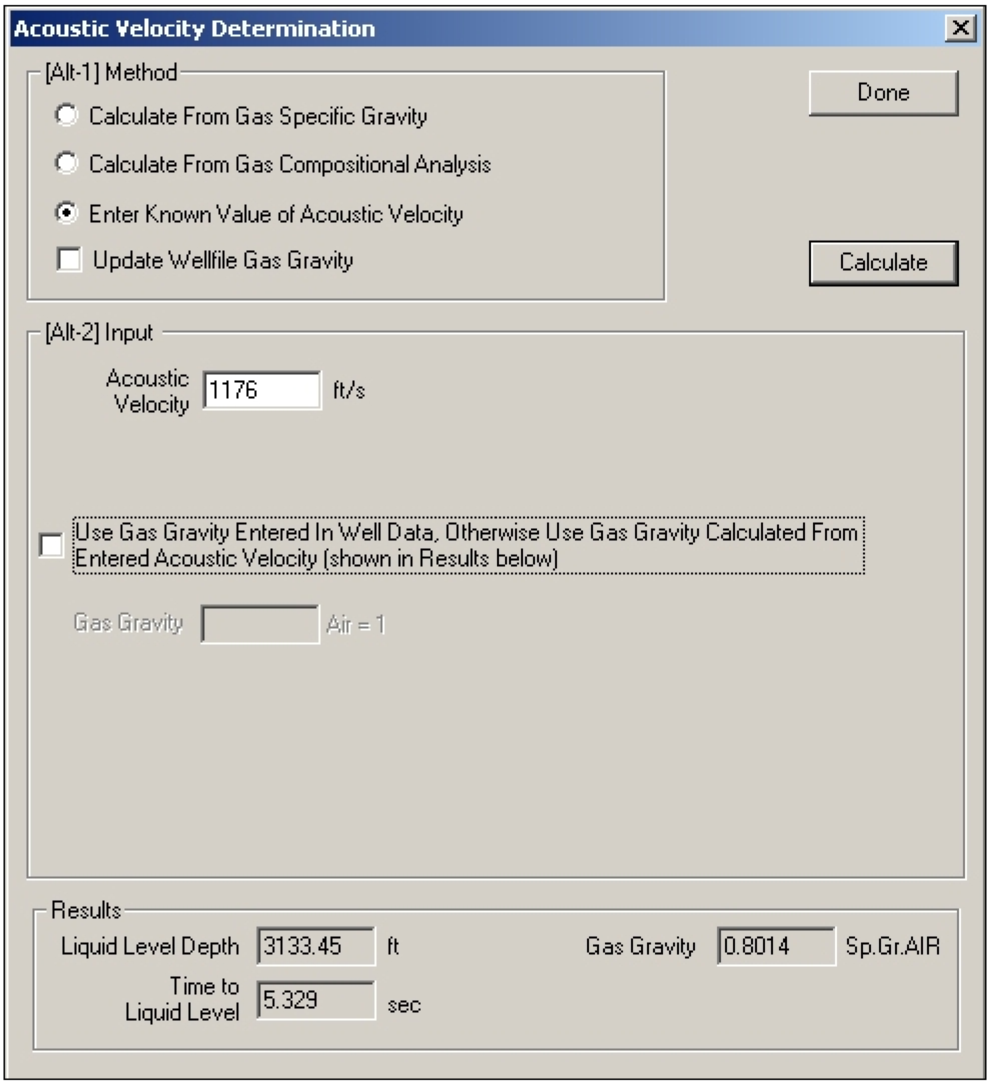
After selecting the **Enter or Compute Velocity** button the following input form is displayed.



This form provides three options:

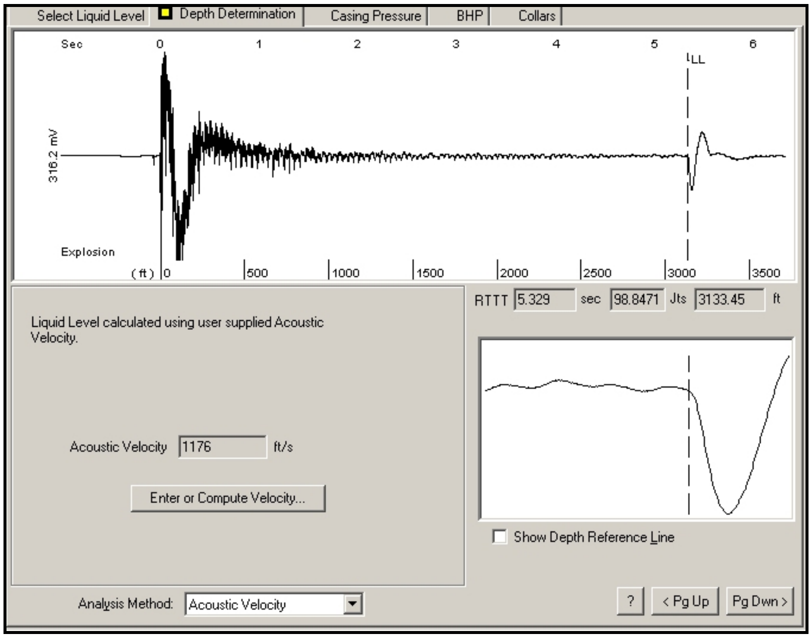
1. Directly input a velocity value if known.
2. Have the program calculate the velocity based on gas gravity, pressure and temperature.
3. Have the program calculate the velocity given a gas analysis, pressure and temperature. These choices are made using the radio buttons.

The **range** of **acoustic velocity** of hydrocarbon gases as a function of pressure and gas gravity is presented as a charts that can be downloaded from Echometer's web page. **Appendix III** shows typical values of acoustic velocity in hydrocarbon gases as a function of pressure and temperature.
After inputting the velocity and selecting the **Calculate** button, the fluid level depth is displayed at the bottom of the form:

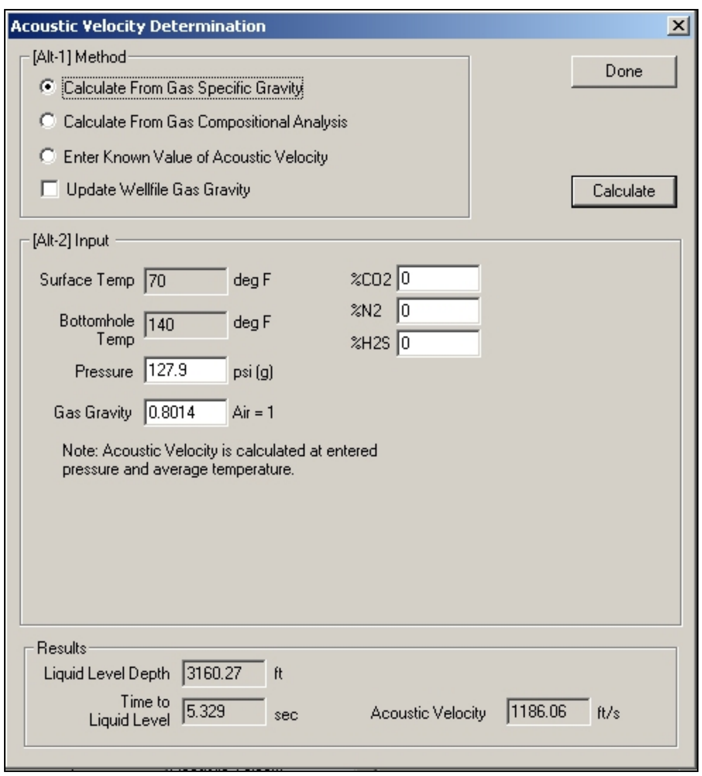


If the gas gravity box is not checked, the program will compute a gravity from the acoustic velocity that is input in this form and use this gravity for subsequent calculation of pressure in the gas column. If the box is checked the program will use the gravity entered in the well data file.

Returning to the Depth Determination Tab, the fluid level depth is displayed with the annotation that it was determined from the User Supplied Acoustic Velocity:

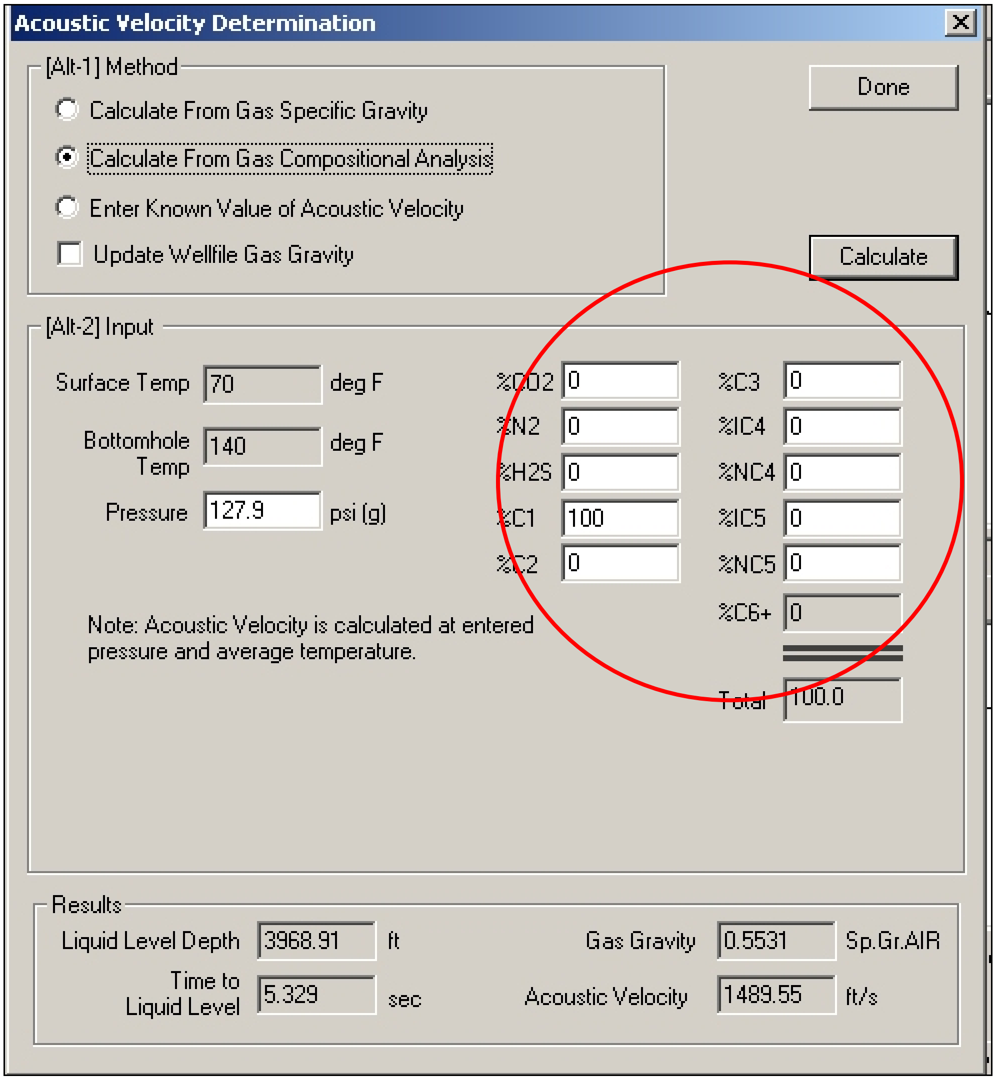


The options to have the program calculate the **velocity from gas properties** generate the following input and calculation forms:



And a known gas gravity is entered from which the acoustic velocity is computed.

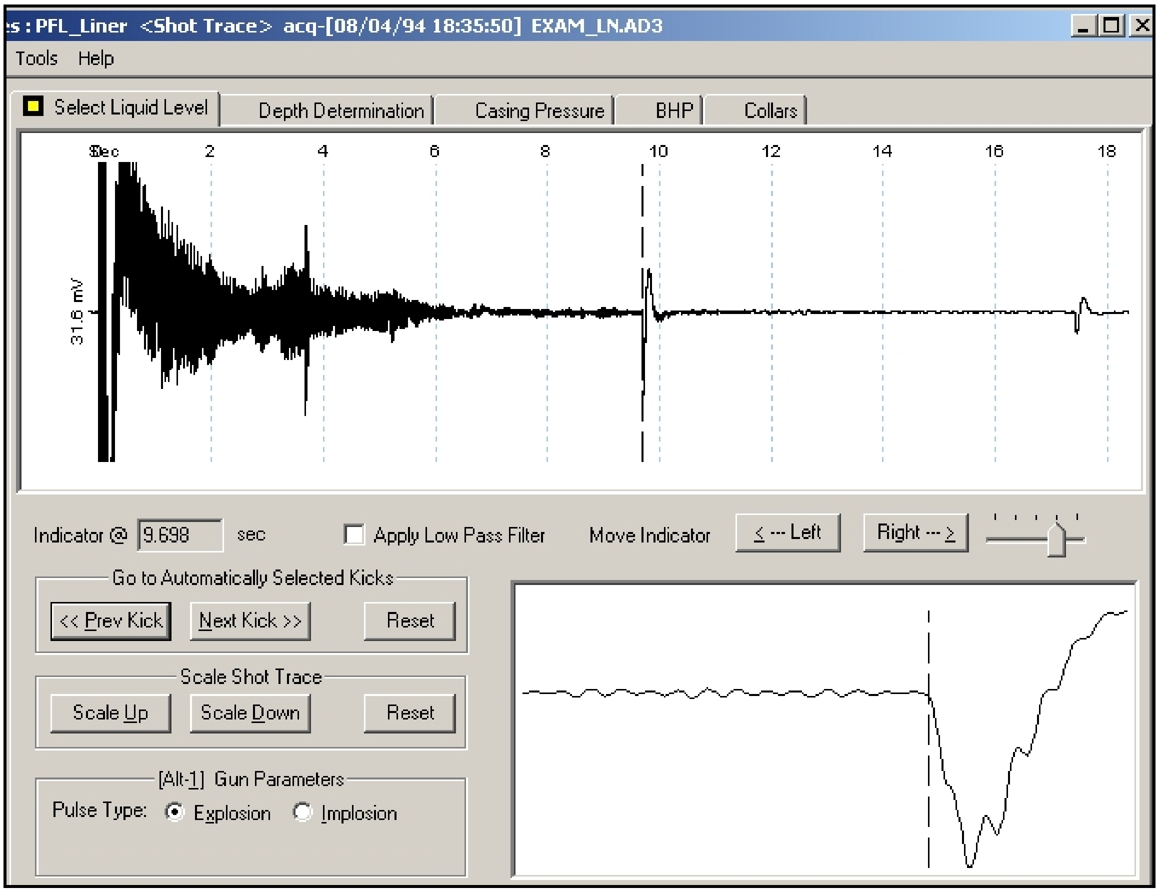
Optionally, the gas composition can be entered in the following form in terms of molar % and the **Calculate** button will display the computed acoustic velocity and gas gravity:



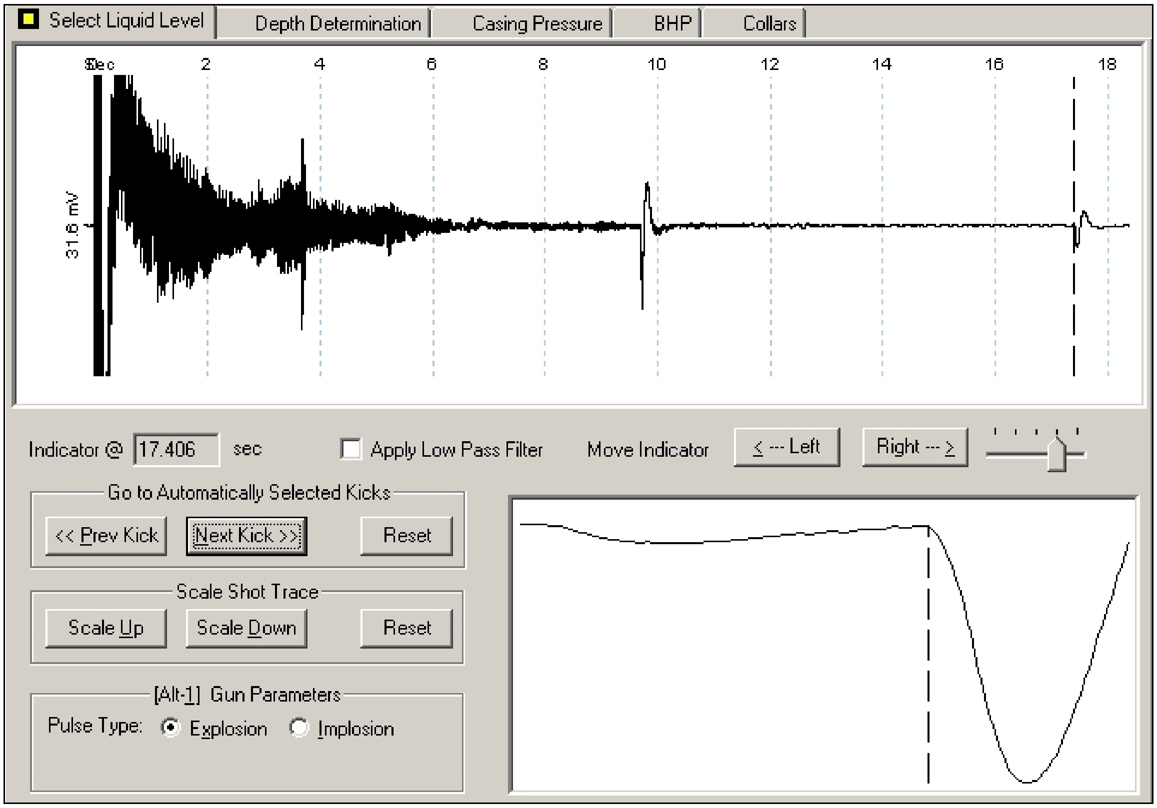
In all cases the gas gravity that exists in the well file is not updated unless the box "Update **WellfileGas Gravity**" is checked by the user.

6.3.4 - Specify Downhole Marker - Indicator in full trace

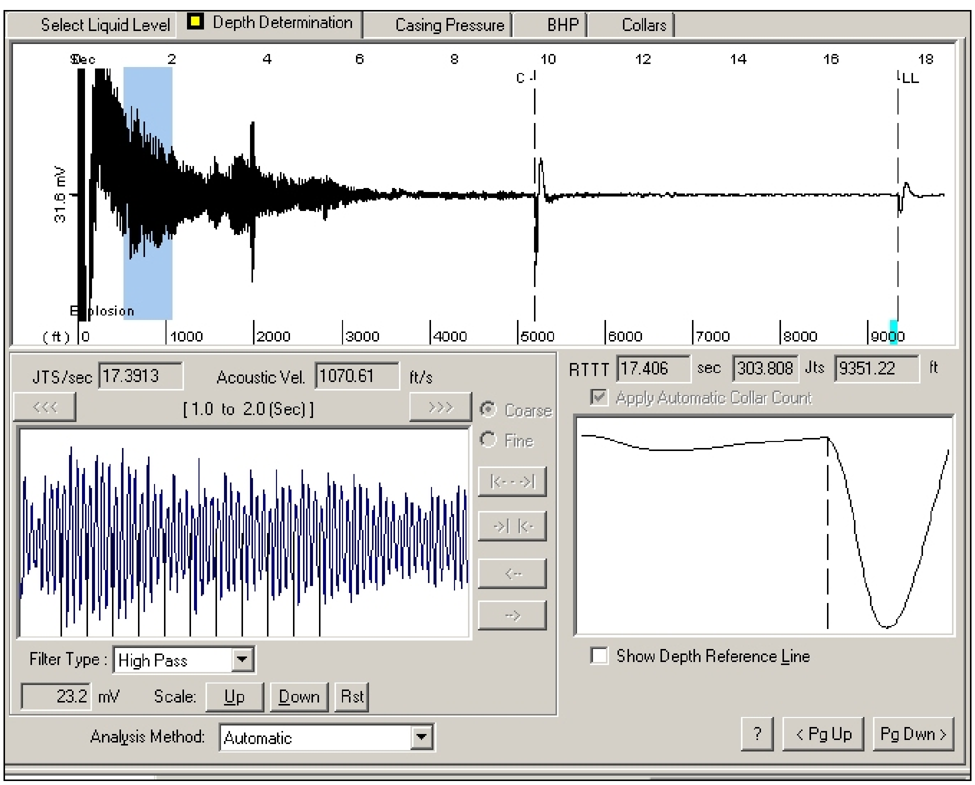
Another optional technique is to locate a second movable indicator on a marker echo such as the top of a liner when the liquid level is below the top of the liner. The operator moves the second indicator to the top of the liner and specifies the number of joints (or the distance) from the surface to the liner. The program will automatically calculate the distance to the first movable indicator, which was located at the liquid level or other anomaly of interest. This technique can be used either with the one second data screen or the full trace. The following shows an example of this mode of processing using a well with a casing liner. The top of the liner is known to be at 5240 feet.



Note that the software flags the liner signal at 9.8 seconds, as being the most likely fluid level signal due to is high amplitude. This is one instance where it is important to know the exact wellbore description in order <u>not to make an error in fluid level determination</u>. Using the **Prev Kick** and **Next Kick** controls to identify other possible fluid level signals the software correctly identifies the signal at 17.5 seconds as being a likely fluid level echo, as shown in the next figure. (This signal at 17.5 seconds cannot be a repeat of the liner echo. The repeat echo would be at 9.8 X 2 = 19.6 seconds and that is past the end of the time scale.)

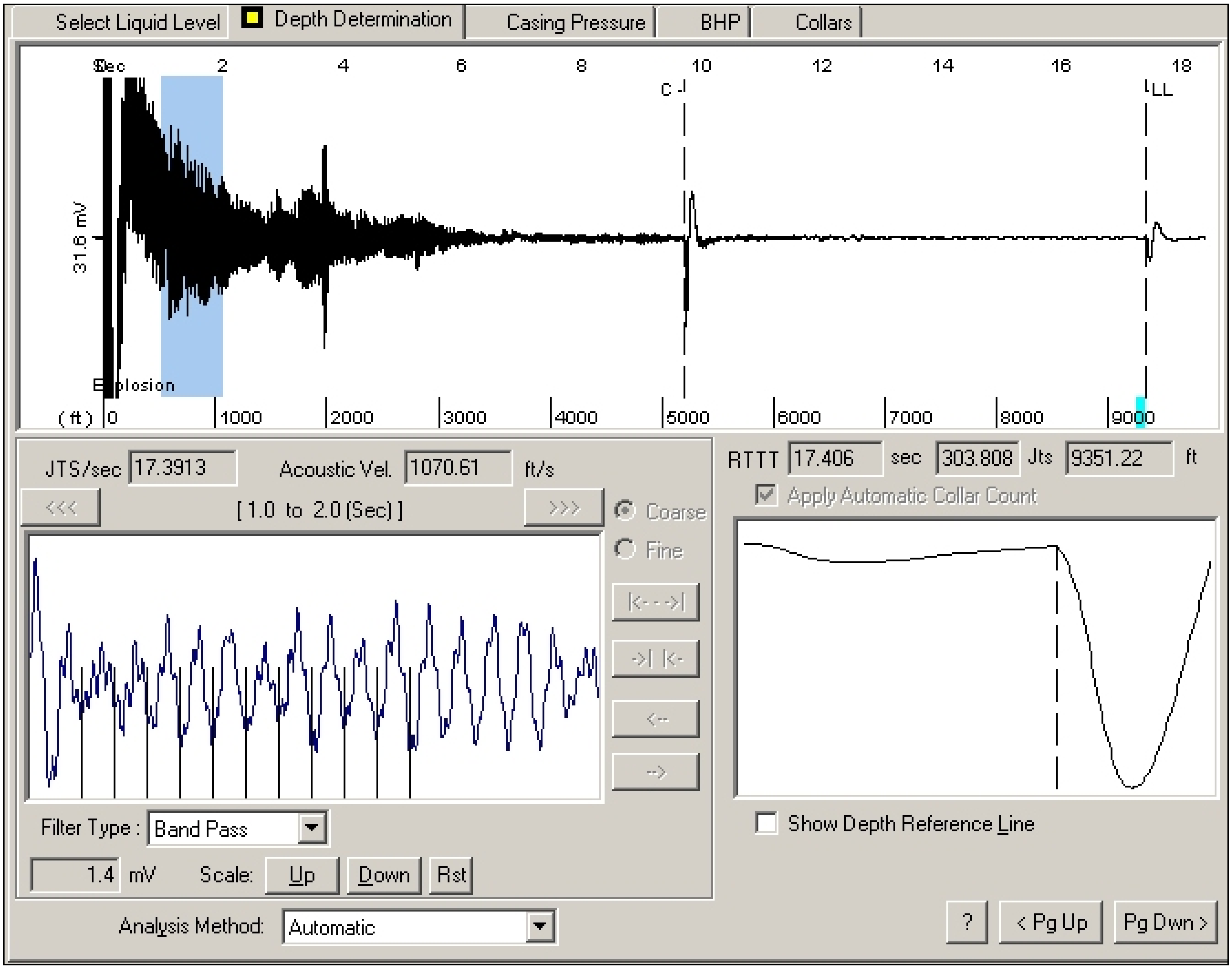


Continuing with the analysis and selecting the **Depth Determination** tab, the following figure is displayed:

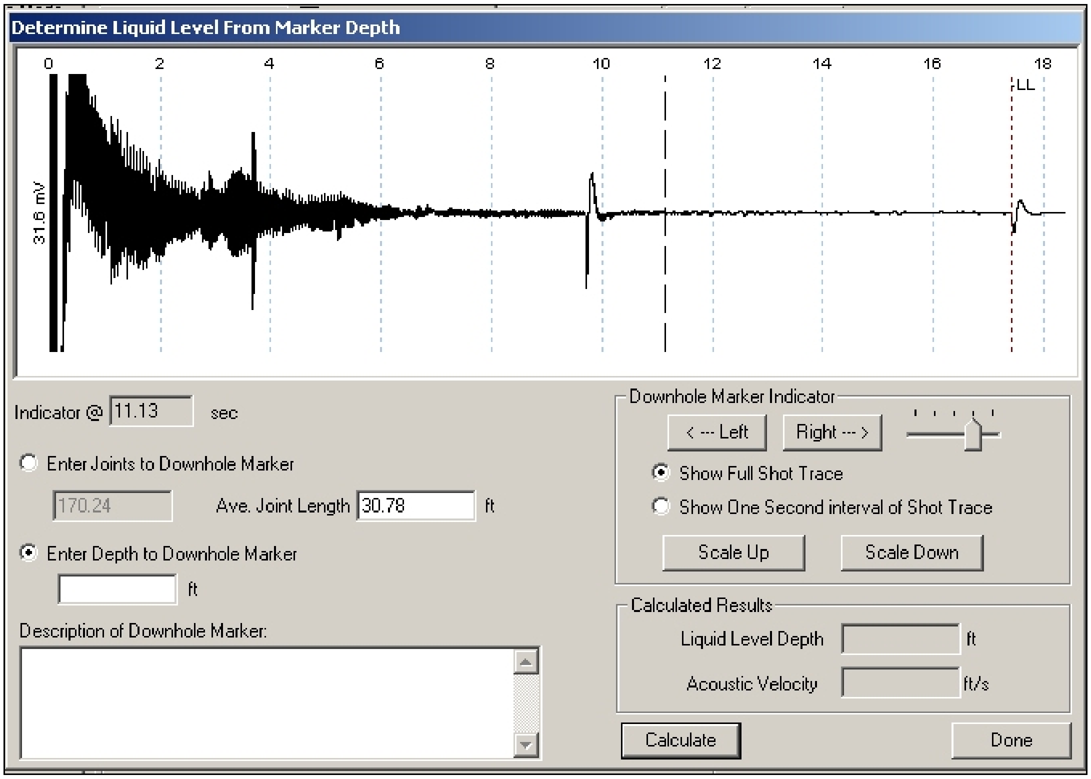


The default **Automatic** Analysis indicates that the collar count gives a fluid level depth of 9351 feet.

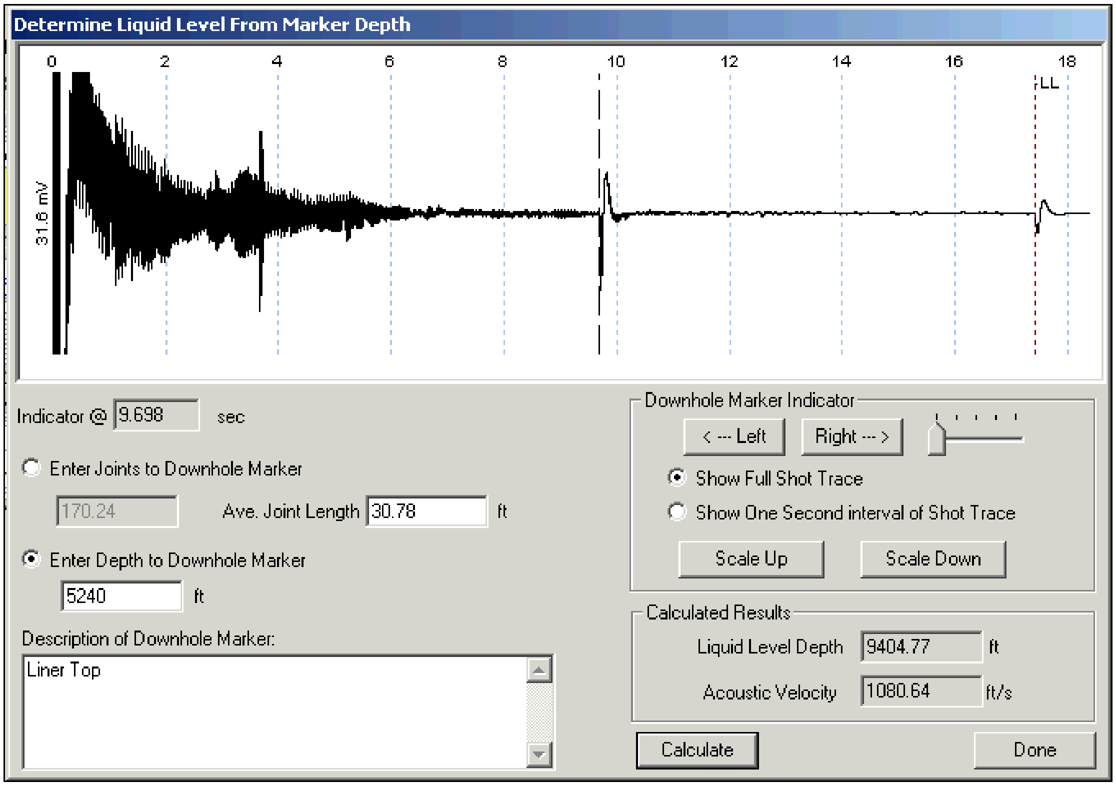
However, inspection of the above figure shows that the last counted collar occurs at 9.5 seconds, which corresponds to less than 60% of the length of the record. Applying the band pass filter improves the collar signal but does not affect the collar count as seen below:

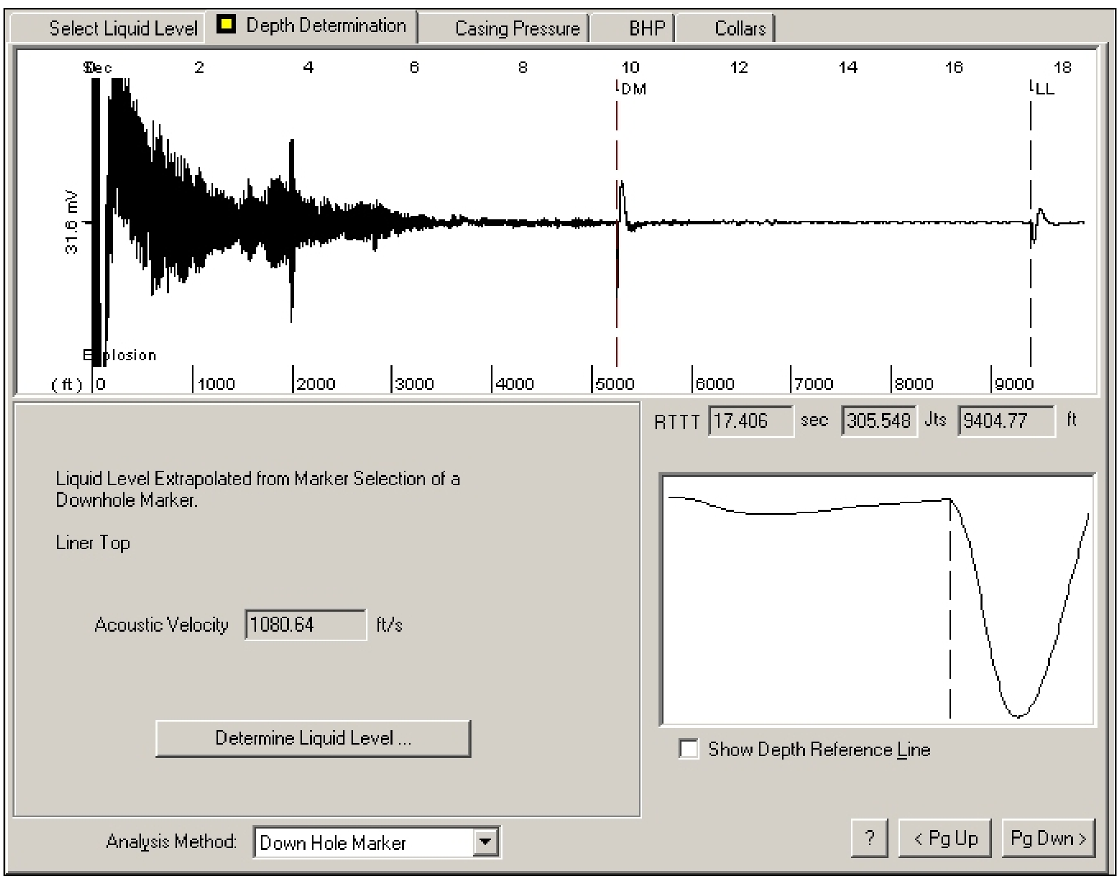


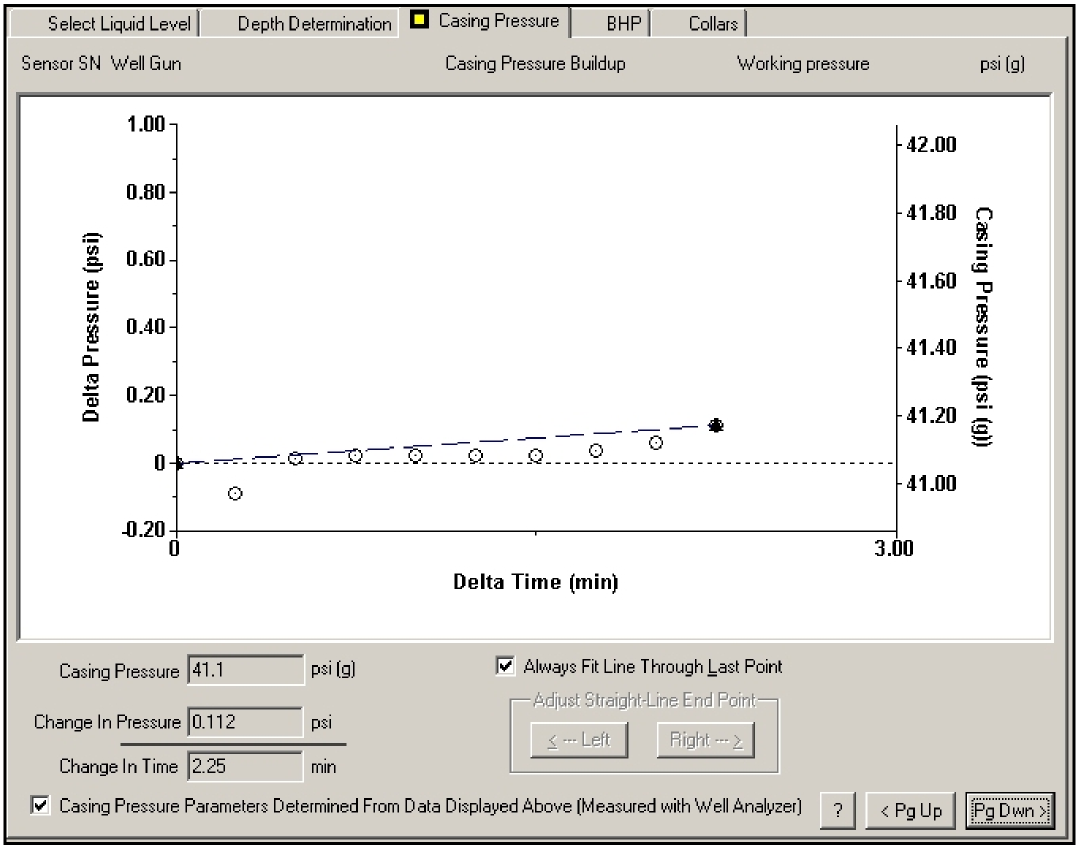
One way to improve the depth calculation is to use the known depth to the liner to estimate a more representative acoustic velocity. This is done by selecting the **Downhole Marker** as the Analysis Method:



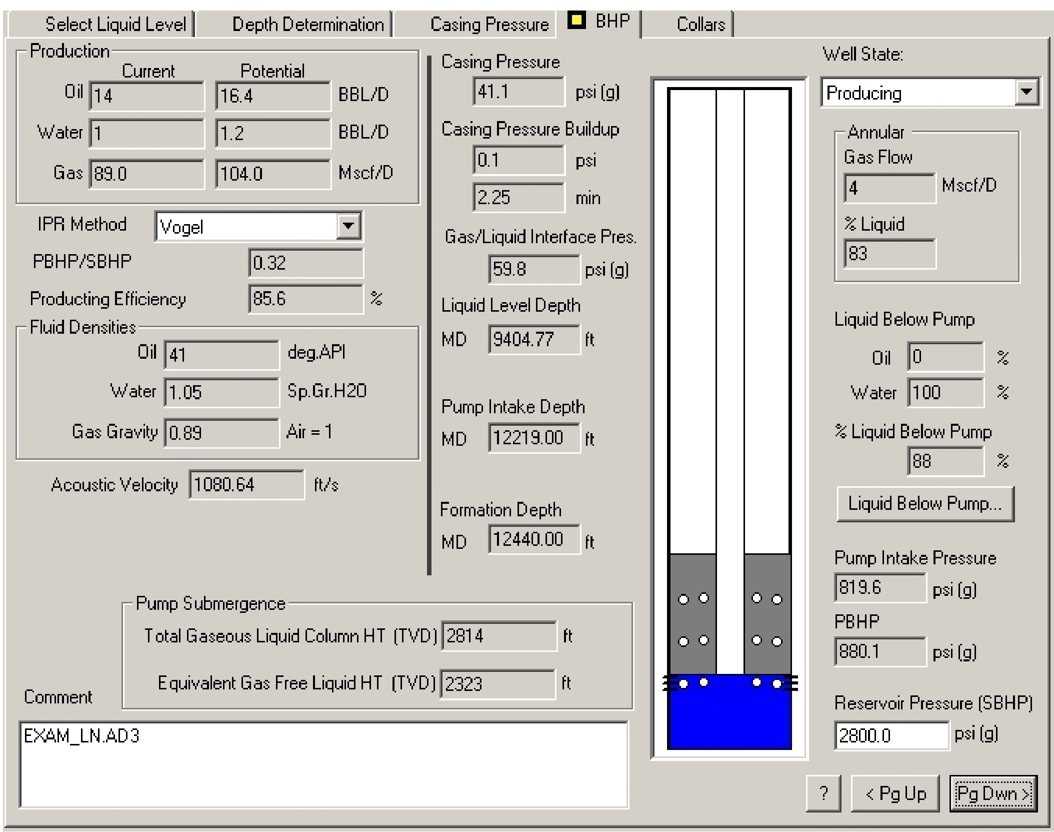
The marker line is adjusted until it matches the signal and the known depth to the marker is input. This yields the acoustic velocity which is then used to compute the fluid level depth from its time.


Determine Liquid Level From Marker Depth
0
2
4
6
8
10
12
14
16
18
LL
31.6 mV
Indicator @ 9.698 sec
Enter Joints to Downhole Marker
170.24
Ave. Joint Length 30.78 ft
Enter Depth to Downhole Marker
5240 ft
Description of Downhole Marker:
Liner Top
Downhole Marker Indicator
< --- Left
Right --- >
Show Full Shot Trace
Show One Second interval of Shot Trace
Scale Up
Scale Down
Calculated Results
Liquid Level Depth 9404.77 ft
Acoustic Velocity 1080.64 ft/s
Calculate
Done


Select Liquid Level
Depth Determination
Casing Pressure
BHP
Collars
Sec
2
4
6
8
10
12
14
16
18
DM
LL
31.6 mV
Explosion
(ft) 0
1000
2000
3000
4000
5000
6000
7000
8000
9000
RTTT 17.406 sec 305.548 Jts 9404.77 ft
Liquid Level Extrapolated from Marker Selection of a Downhole Marker.
Liner Top
Acoustic Velocity 1080.64 ft/s
Determine Liquid Level ...
Show Depth Reference Line
Analysis Method: Down Hole Marker
?
< Pg Up
Pg Dwn >

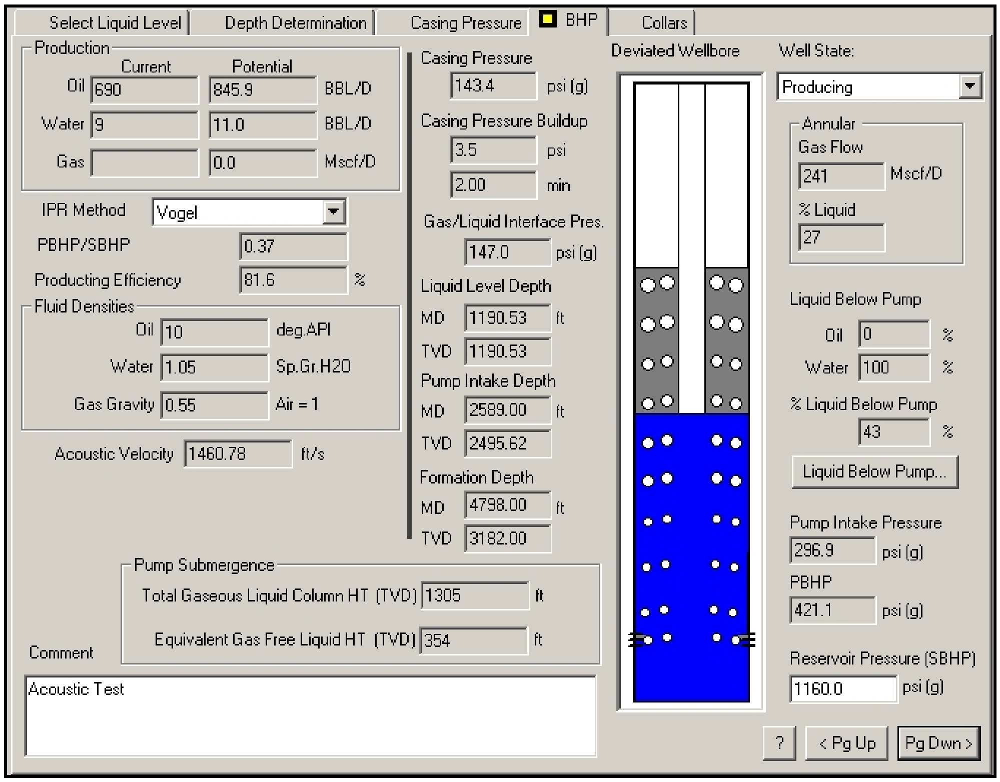


And the wellbore pressures and producing efficiency are displayed:



6.3.5 - Deviated Wellbores

In certain instances the well may not have been drilled vertically. In the case of a deviated well it is necessary to describe the wellbore geometry by entering a number of points at which both the measured depth and the true vertical depth are known. This is generally available as part of most directional surveys. A table of values can be generated as shown in section 5.24 of this manual.
This relationship is used in the calculation of the wellbore pressures in the well when converting the acoustic data to pressure values. After entering the deviation data, the Bottom Hole pressure screen will indicate the deviated nature of the well. Also note that the depth to the gas/liquid interface and of the pressure datum are expressed both in terms of measured depth and true vertical depth (TVD) as shown in the following diagram:



6.4 - Printing Well Data and Test Results

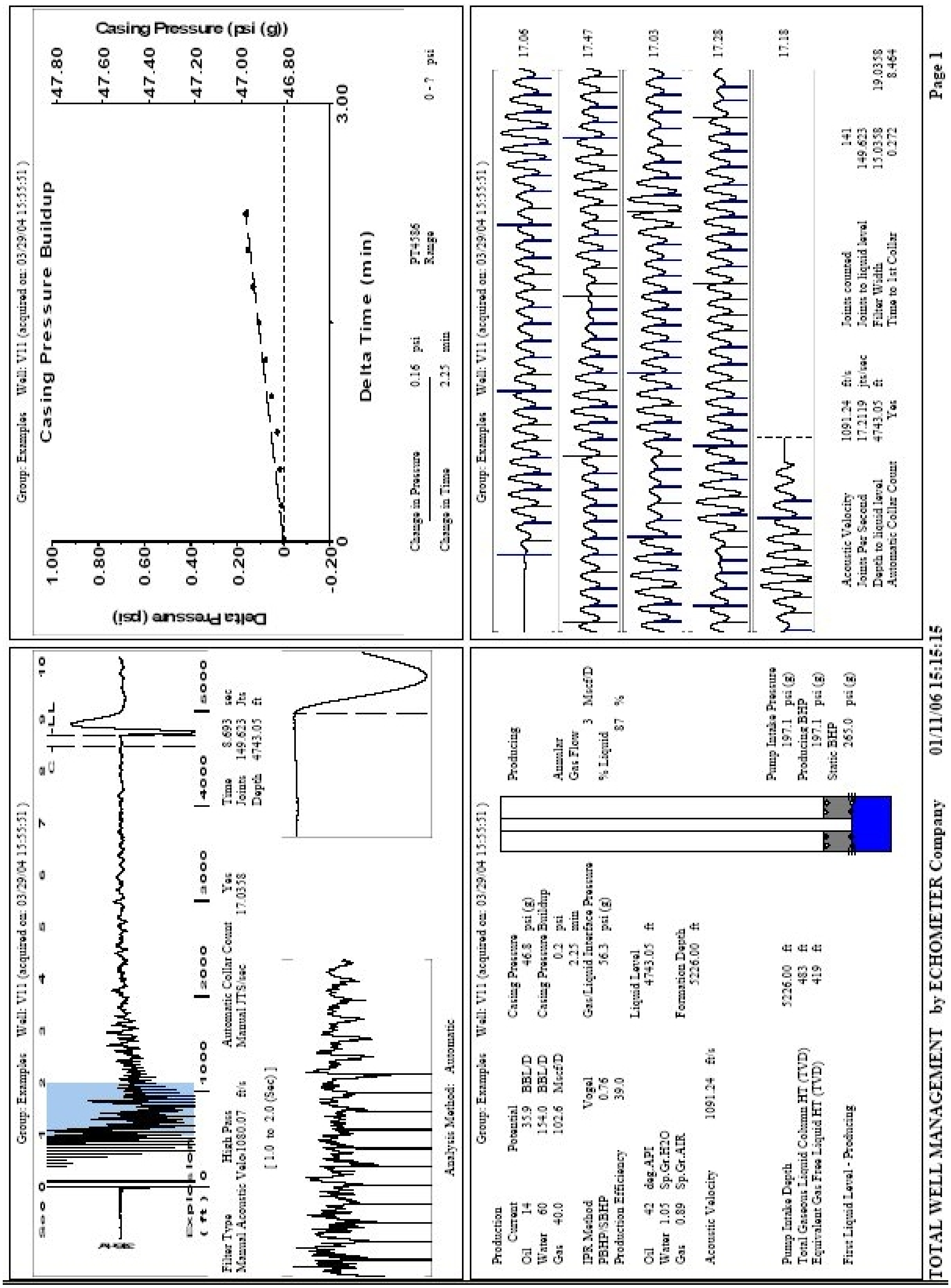
After data has been acquired and saved in the field, it can be recalled and reprocessed at any time. This is especially useful when changes or corrections have to be made to the well data file or when the values of some parameters were initially rough estimates and have later been defined with more accuracy.

6.4.1 - Printing Standard Acoustic Test Report

The Program remembers the last data processing undertaken by the operator and saves the results in a disk file. This file is printed by selecting the **Print** command from the **File** menu. For a single well and data set, the results obtained for the last processing will be printed. The **Batch Print** option is used to print results from several wells or data sets. The report can be previewed using the **Print Preview** option.

In order to obtain hard copies of the well data and the calculated results you must attach the computer to an appropriate printer connected to the port as specified in the Windows printer set up. You should refer to your printer's manual for instructions on printer set-up. The following pages show examples of printed reports.

This figure shows the printed report for an acoustic test:



A printout of the specific well data file can be obtained by selecting the **Print** option while viewing the **F2 -Data Files** screen. The following figure shows the well data printed format.

General

Well ID	- * -	
Well	V11	
Company	ECHOMETER	
Operator	BILLY	
Lease Name	EASTEND	
Elevation	0.00	ft
Production Method	Rod Pump	
Dataset Description		
	Example data	

Comment
This is an example of a well with un-anchored tubing with the Pump Intake set below perforations.

4 3CRO Master Weights 40" from end of Crank 8495B
Master weights weigh 5308 Lbs.

71sec/10 strokes = 8.45 spm

Surface Unit

Manufacturer	Lufkin Conventional	
Unit Class	Conventional	
Unit API Number	C-320D-256-100	
Measured Stroke Length	100.000	in
Rotation	CCW	
Counter Balance Effect (Weights Level)	11.2039	Klb
Weight Of Counter Weights	5308	lb

Prime Mover

Motor Type	Electric	
Rated HP	30	HP
Run Time	24	hr/day
MFG/Comment		
	TOSHITA RATED RPM = 1110	

Electric Motor Parameters

Rated Full Load AMPS	38	
Rated Full Load RPM	1100	
Synchronous RPM	1200	
Voltage	480	
Hertz	60	
Phase	3	
Power Consumption	5	
Power Demand	8	$/KW

Tubulars

Tubing OD	2.375	in
Casing OD	5.500	in
Average Joint Length	31.700	ft
Anchor Depth	5100.00	ft
Kelly Bushing	0.00	ft

Pump

Plunger Diameter	1.500	in
Pump Intake Depth	5226.00	ft

Polished Rod

Polished Rod Diameter	1.250	in

Rod String

	Top Taper	Taper 2	Taper 3	Taper 4	Taper 5	Taper 6	
Rod Type	D	D	D	- * -	- * -	- * -	
Rod Length	1100.00	3875.00	225.00	- * -	- * -	- * -	ft
Rod Diameter	0.875	0.750	0.875	- * -	- * -	- * -	in
Rod Weight	2433.2	6290.9	497.7	- * -	- * -	- * -	lb

Total Rod Length	5200
Total Rod Weight	9221.75
Damp Up	0.05
Damp Down	0.05

Conditions

Pressure

Static BHP	265.0	psi (g)
Static BHP Method	GAUGE	
Static BHP Date	07-12-90	
Producing BHP	197.1	psi (g)
Producing BHP Method	Acoustic	
Producing BHP Date	03/29/2004	
Formation Depth	5226.00	ft

Surface Producing Pressures

Tubing Pressure	58.0	psi (g)
Casing Pressure	46.8	psi (g)

Casing Pressure Buildup

Change in Pressure	0.2	psi
Over Change in Time	2.25	min

Production

Oil Production	14	BBL/D
Water Production	60	BBL/D
Gas Production	40.0	Mscf/D
Production Date	09/21/1998	

Temperatures

Surface Temperature	70	deg F
Bottomhole Temperature	136	deg F

Fluid Properties

Oil API	42	deg.API
Water Specific Gravity	1.05	Sp.Gr.H2O

TOTAL WELL MANAGEMENT by ECHOMETER Company 01/11/06 15:20:45 Page 1

6.4.2 - Printing Word Report Summary of TWM Tests

The following **one-page standard report summary** that includes all measurements taken with the Well Analzer, can be generated via a macro for MS Word, as shown below and as discussed in section 11 of this manual.

(((ECHOMETER)))

Total Well Management System

Well: V11FEB24	**Operator: CAPPS**
Well Flow Test: Production Date: - * -	**Potential: IPR Method: Vogel**
Oil Production (BBL/D): 27	Production Efficiency (%): 85.1
Water Production (BBL/D): 60	Oil Production Potential (BBL/D): 31.7
Gas Production (Mscf/D): 40	Water Production Potential (BBL/D): 70.5
Gas Flow (Mscf/D): 34	Gas Production Potential (Mscf/D): 47
Wellbore:	**Fluid Level Survey: Date 07/29/98 - 12:07**
Tubing OD (in): 2.375	Tubing Pressure (psi (g)): - * -
Casing OD (in): 5.5	Casing Pressure (psi (g)): 127.9
Anchor Depth (ft): 5035	Gas Gravity (Sp.Gr.AIR): 0.79
Pump Intake Depth (MD) (ft): 5115	Main Depth to Liquid Level (ft): 3127.73
Producing Interval Top (ft): - * -	Equivalent Gas Free Liquid HT (TVD) (ft): 843
Producing Interval Bottom (ft): - * -	Total Gaseous Liquid Column HT (TVD) (ft): 1987
Formation Depth (ft): 5221	Pump Intake Pressure (psi (g)): 445.7
Static BHP (psi (g)): 1485.3	Producing BHP (psi (g)): 472.2
Pumping Unit Data:	**Pumping Unit Performance:**
Unit API Number: C-320-256-100	SPM: 8.7
Cranks: NONE	Existing Gearbox Load (%): 51.9
Manufacturer: Lufkin Conventional	In-Balance Gearbox Load (%): 47.0
Measured Stroke Length (in): 100.5	Beam Loading (%): 46.8
	Rotation: CCW
Surface Dynamometer: Date: 02/24/95 - 22:31	**Pump Dynamometer: Stroke 1**
PPRL (lb): 11994	Plunger Stroke (in): 94.2
MPRL (lb): 6594	Plunger Diameter (in): 1.25
Min PRL / Max PRL (%): 55.0	Pump Displacement (BBL/D): 96.6
Motor Input Power (HP): 8.2	Pump Volumetric Efficiency (%): 65.00
Polished Rod Power (HP): 4.3	Standing Valve: 9733 BAD
Polished Rod / Motor Eff. (%): 52.5	Leakage (BBL/D): 0.1
	Rod Loading:

Type	Diameter (in)	Length (ft)	% Goodman 1.0	0.85	0.6
D	0.875	1200	57.1	65.2	85.2
D	0.75	3875	60	68.5	89.6

Motor Type: Electric	**Monthly Operation Costs (30 Days/Month)**
Motor Description: 30 hp/ TOSHIBA NEMA D	HP Required/Recommended (HP): 15.1
Rated Full Load AMPS: 38	Thermal Amps Used: 23.2
Run Time (hr/day): 100.0%	Cost w/No Gen. Credit ($): 295.3
Power Consumption: 5	Cost w/Gen. Credit ($): 220.3
Power Demand ($/KW): 8	Demand Cost ($): 82.3
	Oil Prod. Cost (¢/bbl): 46.6
	Average Power With Generation Credit (KW): 6.1 No Generation Credit (KW): 8.2 Average Power Factor (%): 25.1 System Efficiency (%): 31.8

Recommendation/Follow-up:

6.5 - Acoustic Record Quality

The quality of the acoustic recording is determined by well conditions and the energy contained in the acoustic pulse. To get an adequate acoustic record, the signal to noise ratio should always be maximized. If needed, in order to get a larger acoustic pulse and a better signal-to-noise ratio, use a higher pressure in the volume chamber. When the well noise data is displayed before the acoustic pulse is fired, the operator is alerted if the well noise exceeds 5 mV. The operator is prompted to use a higher pressure in the volume chamber.

The background noise is generally a result of well conditions such as pumping unit vibrations, gas bubbling through the annular liquid column, etc. Some noise may be eliminated by shutting down the pumping unit. The gas gun should be connected within 3 feet of the casing annulus using 2" connections. Smaller diameter connections result in poor signals from collar reflections.

An ideal acoustic record would contain clearly identifiable collar reflections all the way to the liquid level, which itself would be a distinct reflection. Such a record can generally be achieved in the following manner:

- Determine the current casing pressure and charge the gun's volume chamber pressure to 100 PSI above the casing pressure.
- Acquire an acoustic record and examine the screen. A distinct, easily discernible liquid level signal should be observed.
- If a distinct liquid level is not detected, raise the volume chamber pressure an additional 200-PSI and try again. If necessary, repeat this step until the equipment's pressure rating is reached. The pumping unit should be running during the test.
- If the pressure in the volume chamber has been raised to the maximum pressure rating and an adequate record has still not been obtained, turn off the pumping unit and acquire another record.
- If necessary, pump the well with the casing valves closed for a sufficient time to observe an increase in the casing pressure. Often, a small increase in casing pressure will improve the acoustic trace while not significantly affecting the well's performance or the analysis.

Guidelines for ranges of collar frequencies as a function of casing pressure are given in Table 1.

HELP

If following the above steps still do not provide an adequate record, **you should E-Mail or FAX** a copy of the data files to Echometer Co.
(**Fax No 940-723-7507**)

BEFORE calling for further assistance, **940-767-4334**.

If possible, the Acoustic Data Files should be transmitted to **info@echometer.com**

Echometer Company regularly holds schools on operating this equipment and using the TWM software. A list of these free schools is available upon request and on the Echometer web page: www.echometer.com .

6.5.1 - Liquid Level Detection

The program may select a number of signals that meet the specific characteristics of a liquid level reflection. The largest and widest pulse of those that have the standard characteristics is flagged with the vertical indicator. The user should always verify that this is the correct liquid level reflection and not a signal caused by wellbore anomalies such as casing splits, cross-overs, liners, paraffin rings, etc.

Whenever there is a question whether the correct liquid level has been identified, it is recommended that the position of the **liquid level be moved** by depressing it through casing pressure increase or by shutting-in the well and letting the liquid buildup in the annulus.

6.5.2 - Collar Rate Selection

One of the methods for checking that the computer's interpretation of the acoustic record is correct is to check the calculated value of the collar rate (joints/sec or Hertz) that is displayed, and to make sure that it is within reasonable values. This rate is a function of the distance between tubing couplings (average joint length) and the velocity of sound in the casing gas. Sound speed is a function of gas gravity, pressure and temperature as can be seen in figure 12 in the “Acoustic Static Bottom Hole Pressure” paper (SPE 13810). Using values corresponding to gases with gravity between 0.6 and 1.5, the following table was calculated.

TABLE 1
Expected range in collar frequency as a function of casing head pressure for hydrocarbon gas with specific gravity ranging from 0.6 to 1.5, for an average joint length of 31.7 feet:

Casing pressure, PSIG	Range of Collar Rates, Hertz	Acoustic Velocity Range, ft/sec
0-1000	11 - 25	697 - 1585
2000	17 - 23	1077 - 1458
3000	21 - 27	1331 - 1712

For higher gravity gases and when CO2 is present, the collar frequency can be lower than indicated in the table.

6.6 - Bottom Hole Pressure Calculation

The bottom-hole pressure is calculated by summing the casing pressure, gas column pressure, and liquid column pressure. Given the gas and liquid gravities and the producing water/oil ratio, this calculation is straightforward except when casing head gas flow aerates the liquid column above the pump. The problems associated with gaseous liquid columns and bottom-hole pressure calculation is discussed in detail in the SPE papers "Producing Bottom-hole Pressures" and "Static Bottom-hole Pressures". A brief discussion of how the software computes the gradient of gaseous/liquid columns is presented below.

6.6.1 - Gaseous Liquid Columns

Most pumping wells produce gas up the casing annulus into the flow line. When a liquid column exists in the annulus, this gas will cause that column to become aerated and rise in height. The acoustic pulse will be reflected by the top of the aerated liquid column. The bottom-hole pressure calculated using this height and assuming a 100% liquid column would be too high. In order to correctly calculate the BHP, the percentage of liquid present in the aerated liquid column must first be determined.

One common misconception is that a gaseous liquid column looks somewhat like a glass of beer with a layer of foam on top of 100% liquid. In actuality, the gaseous liquid column is a continuous mixture of gas and oil. The gas enters the wellbore as bubbles that flow vertically through the liquid. The liquid level recorded by the Echometer is indeed the top of the gaseous liquid column; however, this column is not 100% liquid but a mixture of moving gas bubbles and oil.

An easy way to understand the concept of gaseous liquid columns is to think in terms of the height of an equivalent column of liquid if it were possible to remove all of the gas from the column. Ex.: a 1000 ft. gaseous liquid column composed of 50% free gas and 50% oil weighs the same as a 500 ft. column of pure oil.

Echometer Co. has developed a correlation for this purpose. The correlation requires a measurement of the depth to the top of the gaseous liquid column and the casing pressure buildup rate. The correlation predicts the percent liquid present in the gaseous/liquid column. The depth is obtained acoustically and the casing pressure buildup rate is obtained automatically by reading the pressure transducer output at short time intervals. Details of the correlation and calculation procedure are published in "Acoustic Determination of Producing Bottomhole Pressure," SPE Formation Evaluation, September 1988, pp. 617-621. Copies may be obtained from Echometer Co. or SPE or the Echometer web page.

The Well Analyzer obtains this data automatically when used in conjunction with the pressure transducer. The resolution of the transducer is much better than that of hand-held gauges and allows a much shorter time to be used when monitoring the buildup rate. The initial casing pressure measurement is taken immediately after the acoustic data is acquired. Additional points are recorded every 15 seconds to determine the buildup rate. The pressure buildup data and the liquid level are then used in conjunction with the gaseous liquid column correlation to estimate the percentages of oil and gas present in the column. Two minutes of casing pressure buildup rate are generally sufficient to determine an accurate gas flow rate when using the pressure transducer.

After the acoustic record has been obtained, the operator should inspect the plot of casing pressure buildup vs. time. It should be very close to linear. The operator should terminate pressure data acquisition when satisfied with the pressure data. If the data points show pronounced scattering, or if the values seem abnormal, the stabilized condition of the well should be verified. Two minutes is a normal data acquisition time for casing pressure.

Pressure transducers are available with full scale ranges of 375, 900, 1500, 3000 and 6000 psi. If a pressure transducer is not available, the casing head pressure buildup rate may be determined by closing the casing valves, leaving the unit pumping, and waiting either 10 minutes or until a 10 PSI increase has been recorded. This data is then entered in the **Conditions** Tab of the well data screen.

6.6.2 - Bottom Hole Pressure Program AWP2000

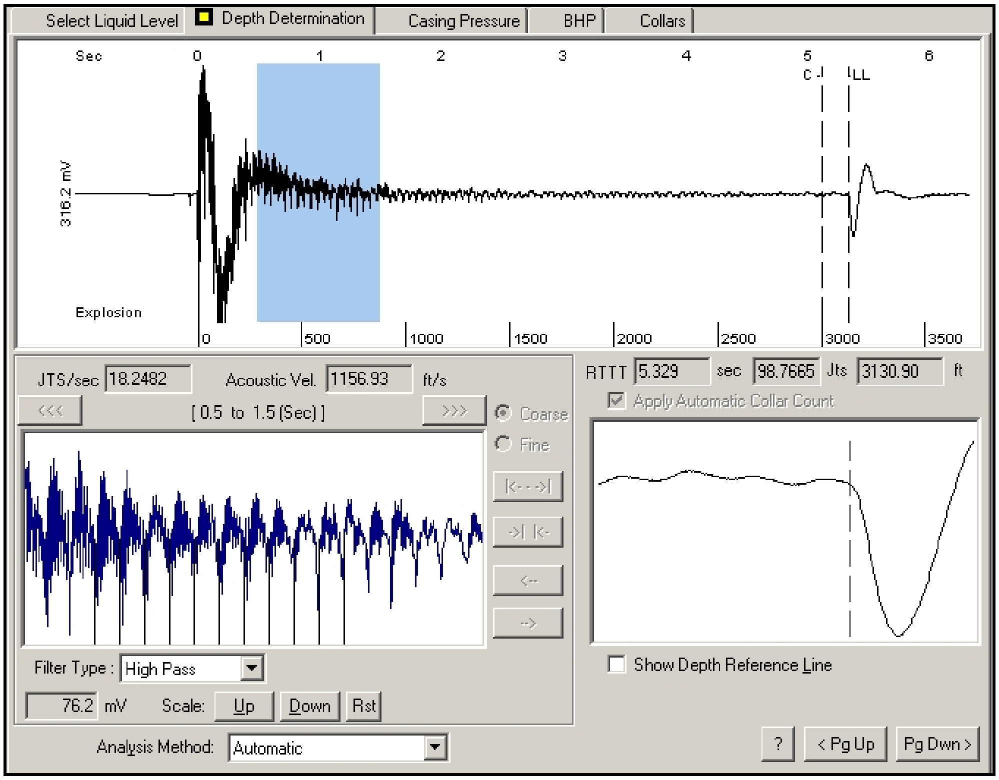
This program, which is included with the Well Analyzer utilities, provides the user with the capability to calculate static and producing bottom whole pressure from data obtained with other fluid level instruments such as the Echometer Model -M or the SONOLOG instruments. This user-friendly program is easy to use. The required data is input through interactive screens.

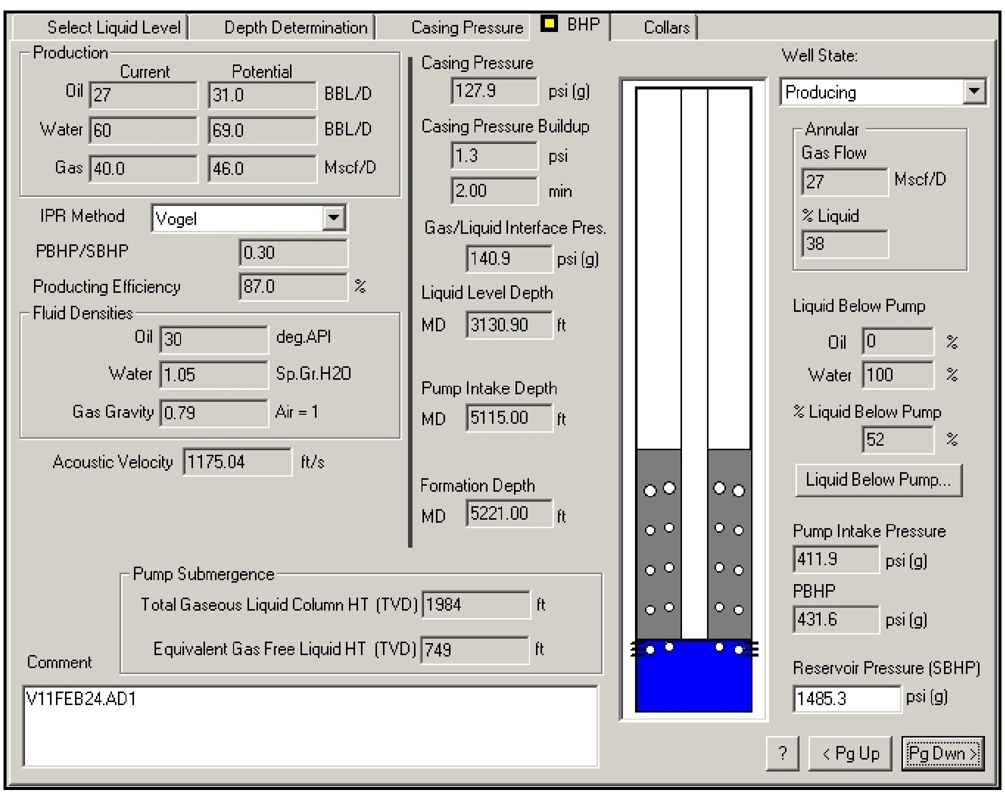
The program may be downloaded from the **Software Downloads** section of the Echometer web page:
(http://www.echometer.com/software/index.html).

6.7 - Example Wells

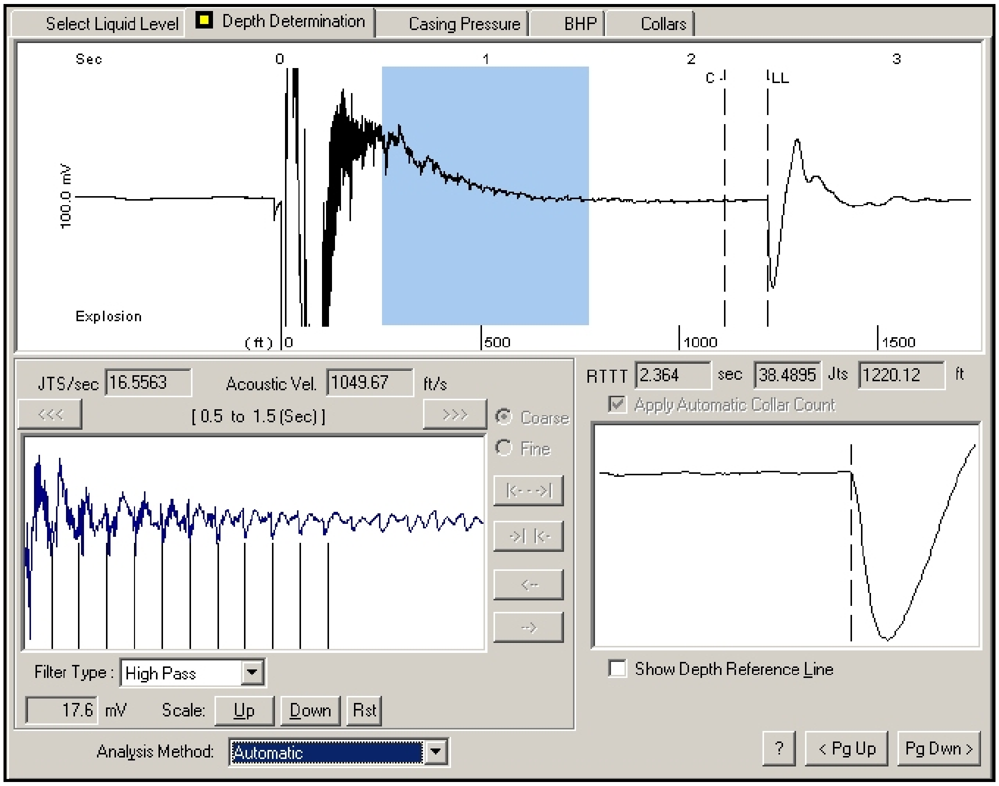
The following figures illustrate the type of acoustic traces that have been recorded for some typical wells. They are presented here with the objective to give some idea to inexperienced operators of the variation of acoustic traces.

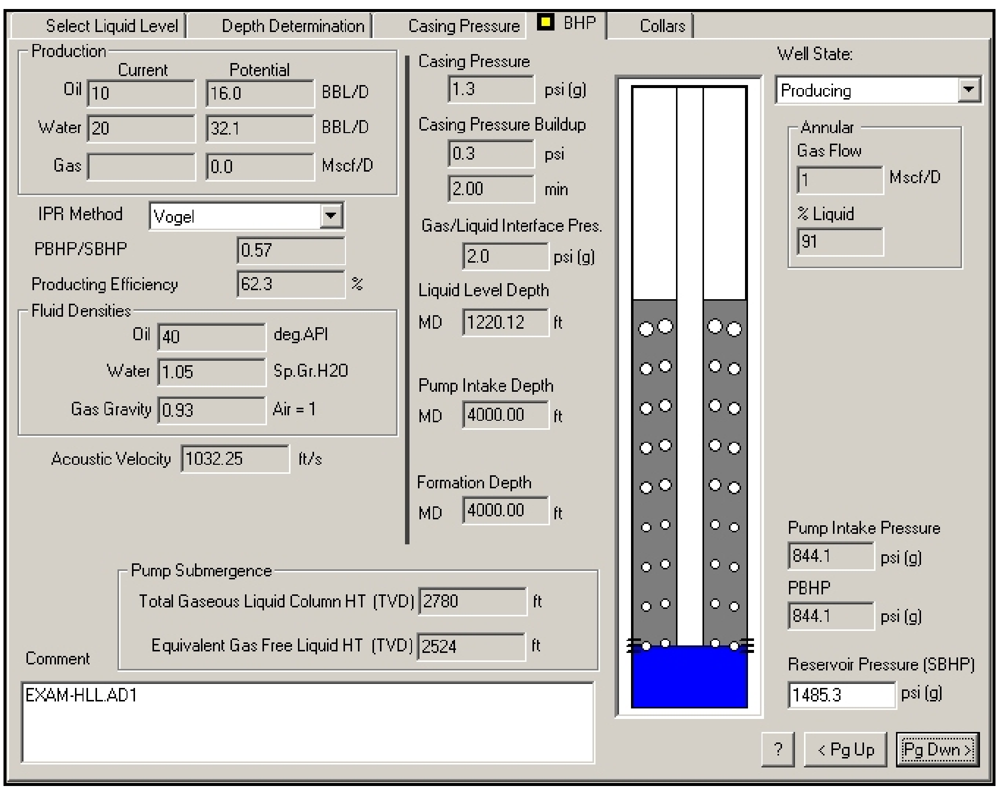
6.7.1 - Average well



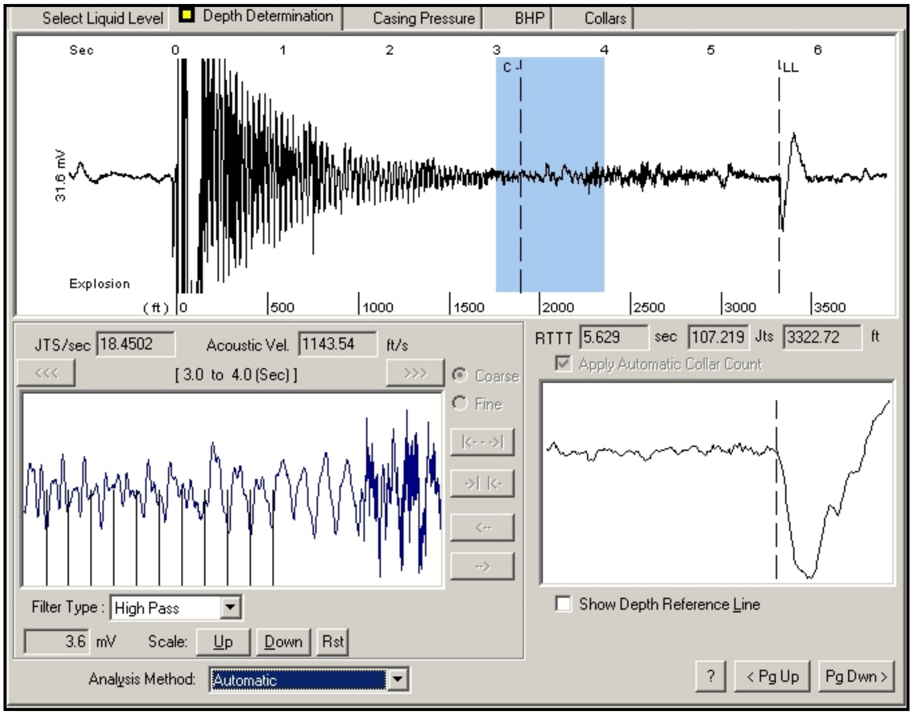


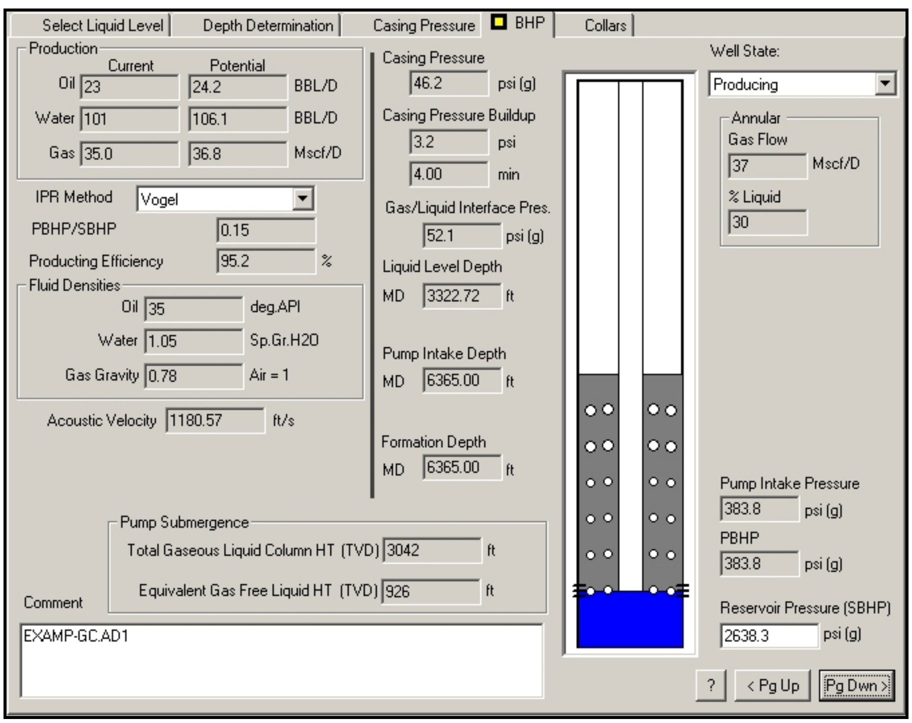
6.7.2 - High liquid level, little or no annular gas



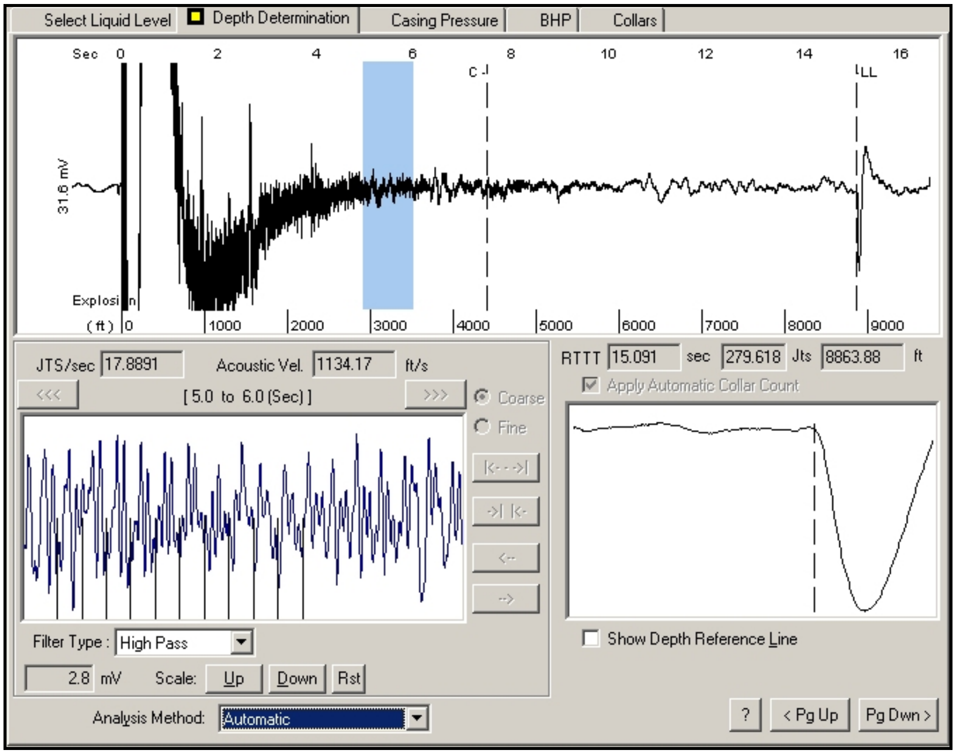


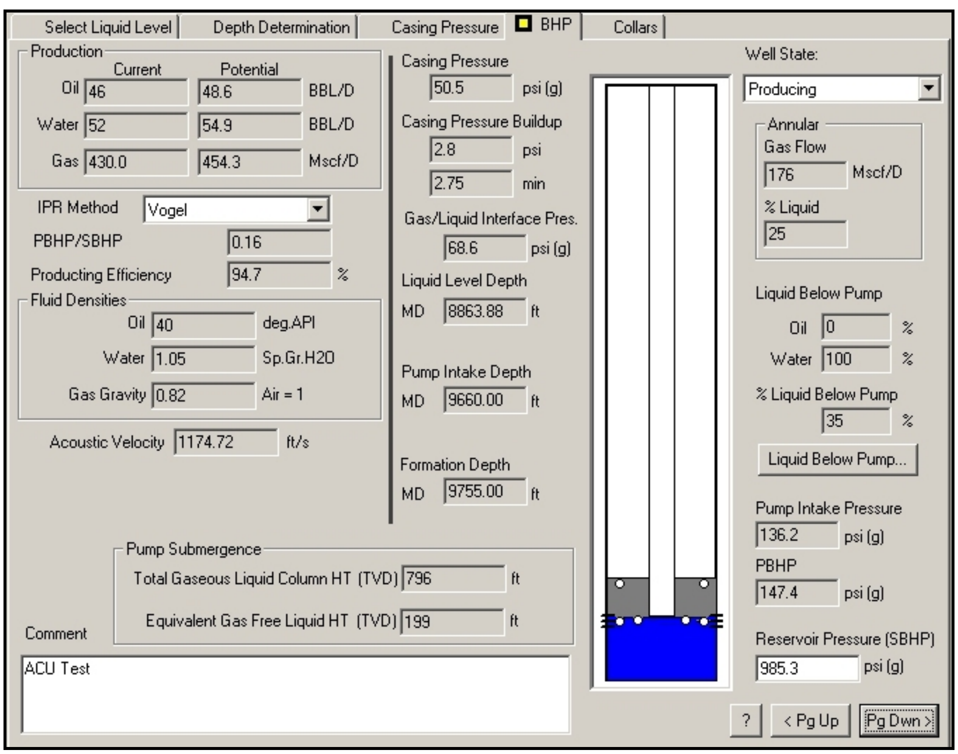
6.7.3 - High liquid level, gaseous column, noisy well.



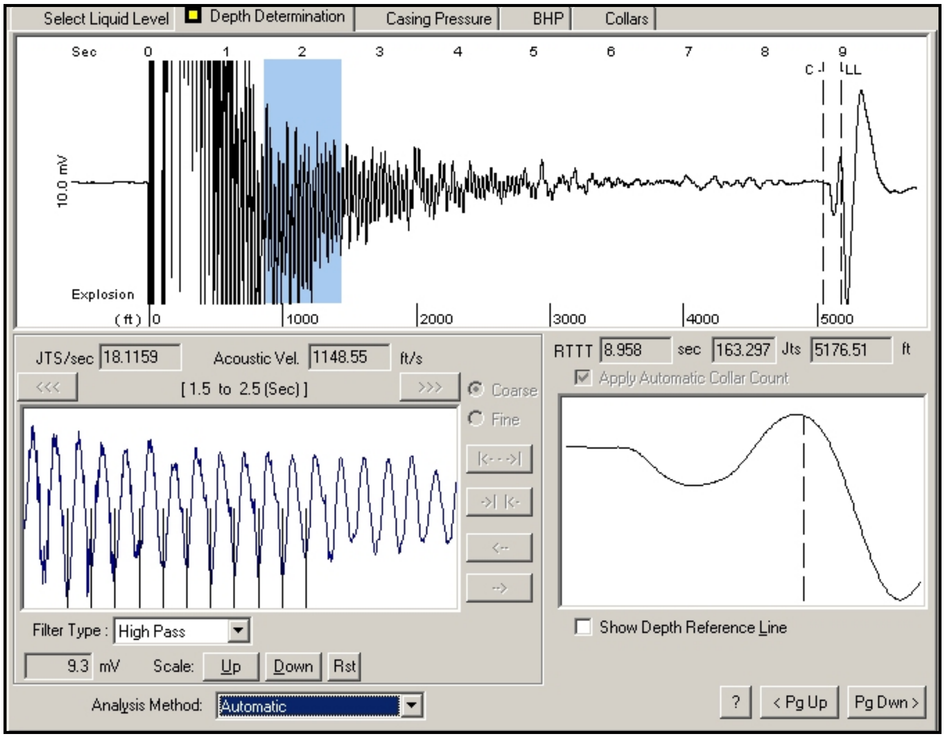


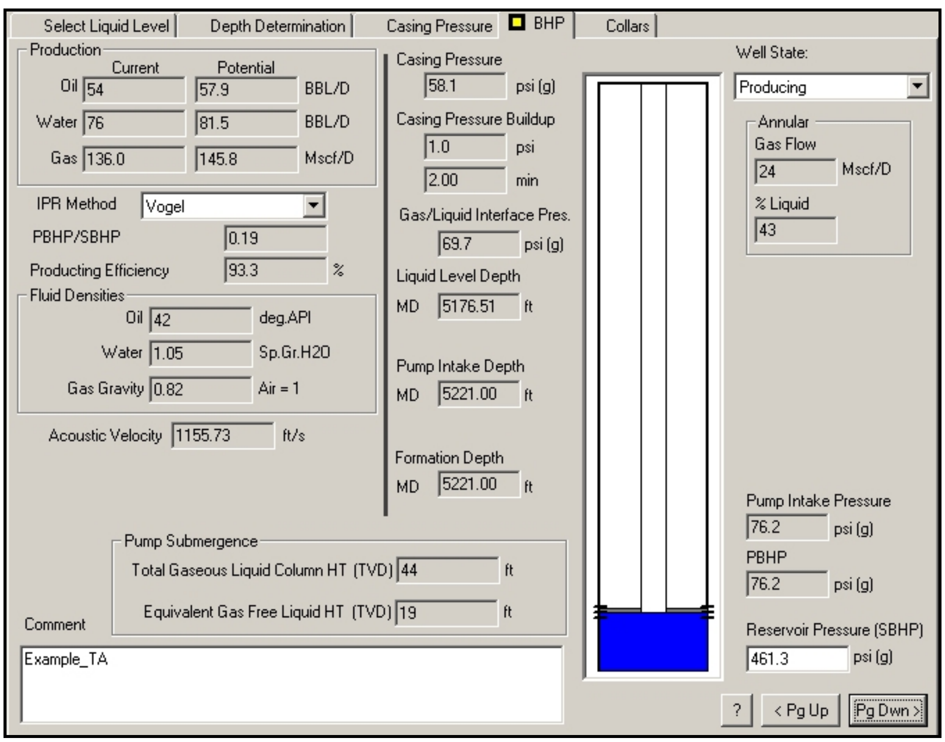
6.7.4 - Deep well





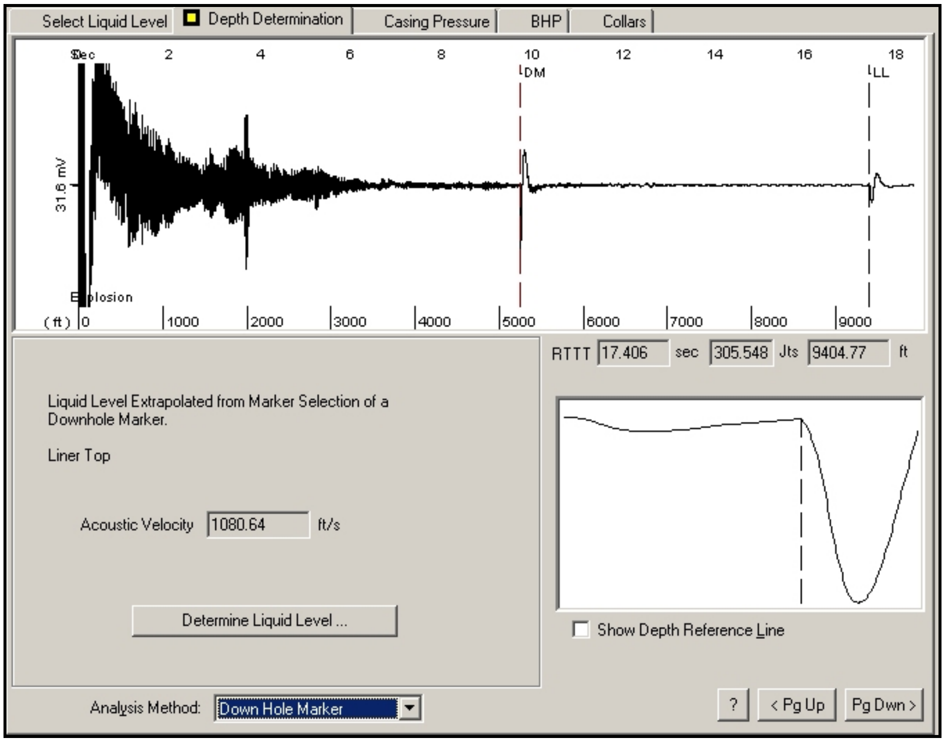
6.7.5 - Tubing anchor

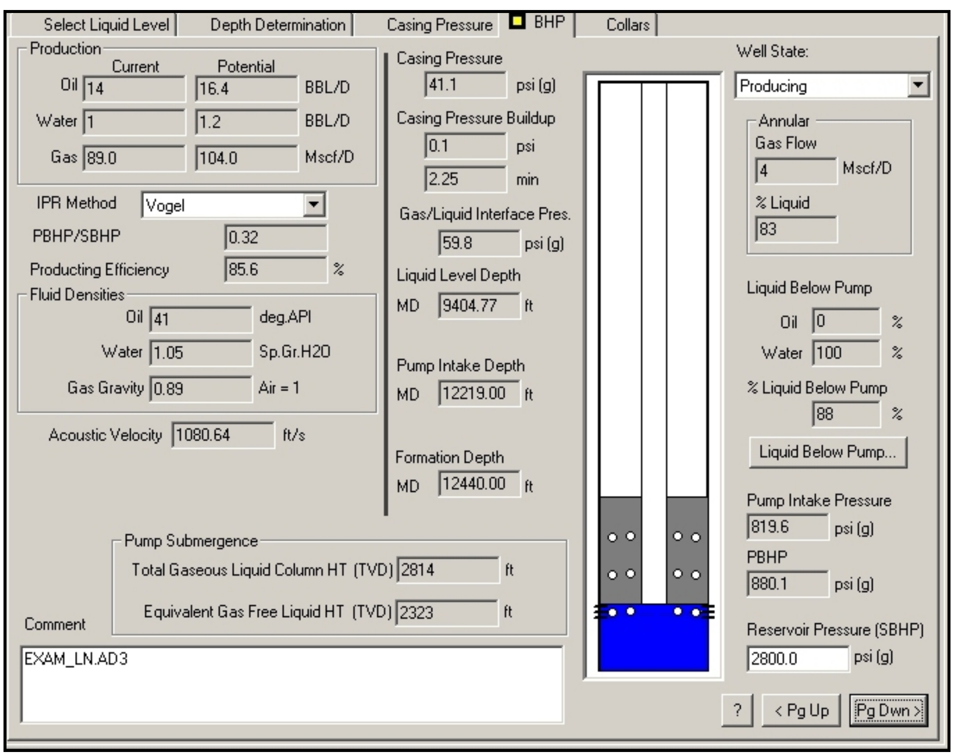




6.7.6 - Liner at 5240 feet

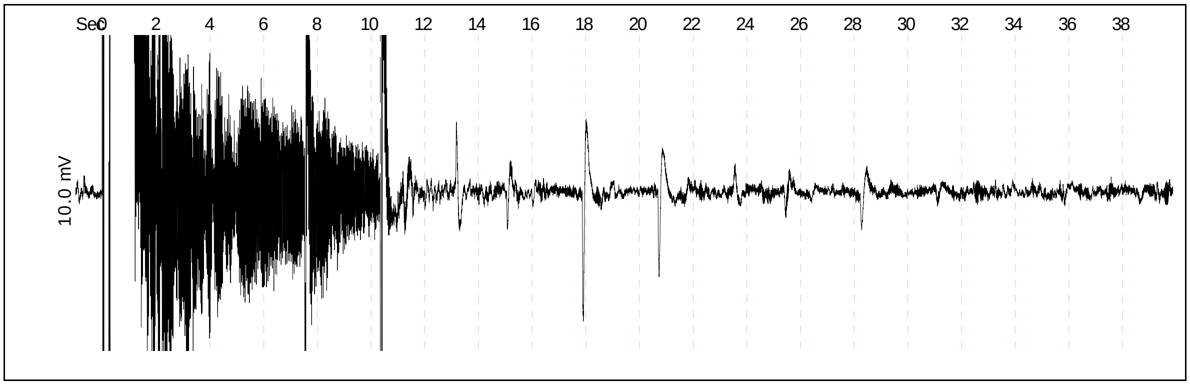
Data was processed using the option of locating a marker in one-second interval. The echo signal at 9.7 seconds is caused by the change in cross section between the 7-1/2 inch casing and the 5-1/2 inch liner. Note that its amplitude is much larger than the amplitude of the liquid level reflection at 17.392 seconds.



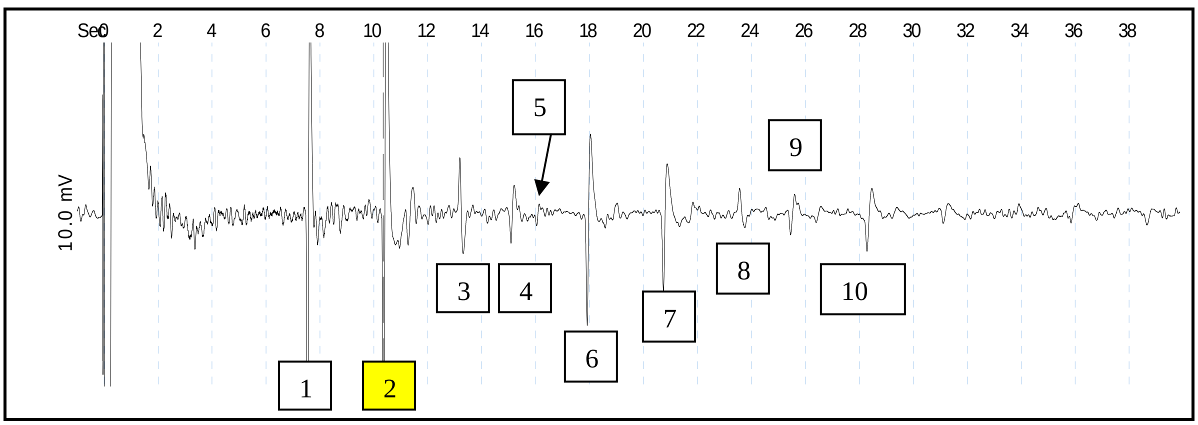


6.7.7 Liquid Level Below Liner Top

The following data was acquired in a well with a liner set at 9250 feet with the liner top at a depth of 4543 feet. Note that there are numerous echoes present in the record. A second liner is set at 13,229 feet with the top of the liner at 7469 feet.



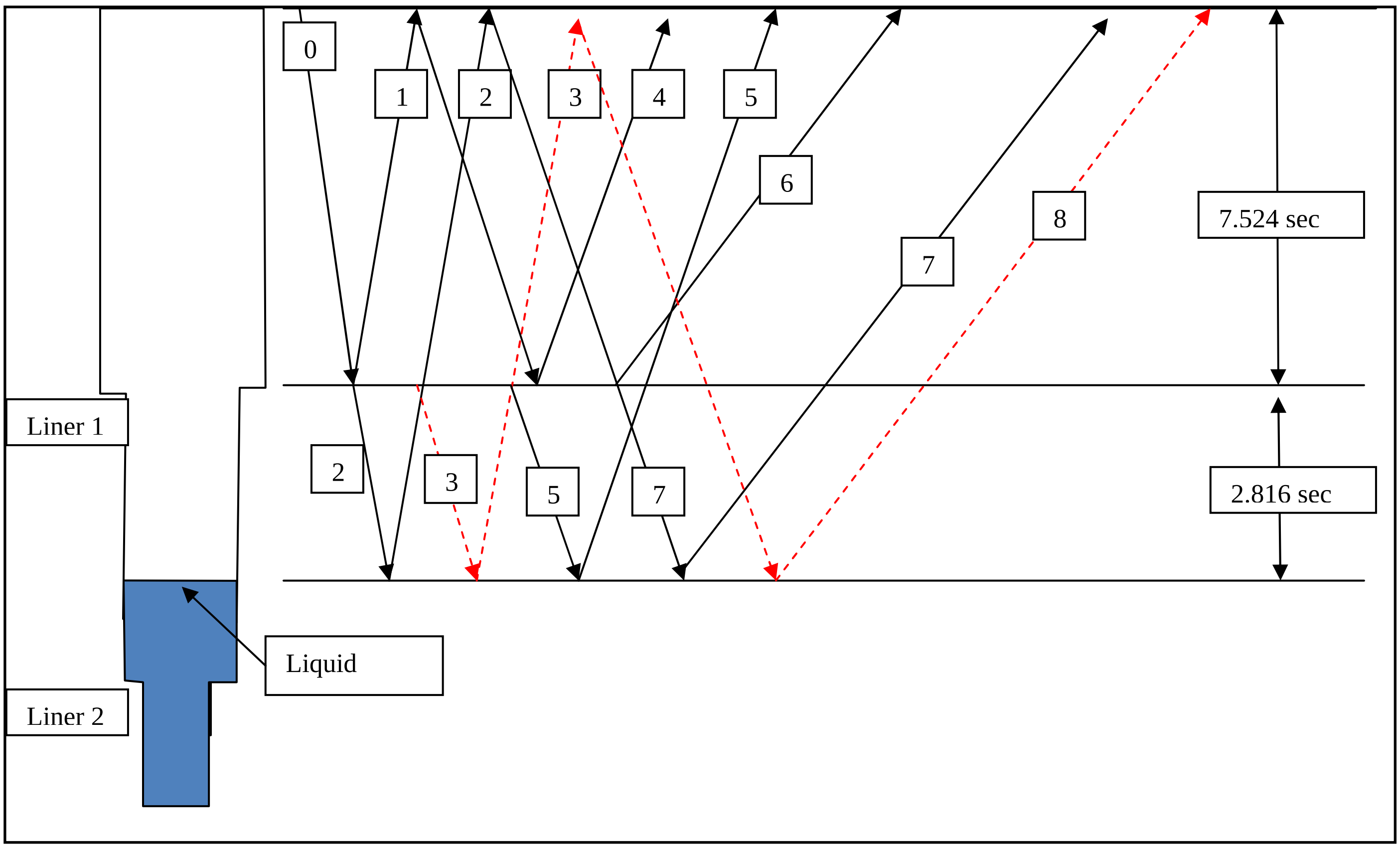
The record is quite noisy and in the figure below the echoes have been highlighted by checking the "Apply Low Pass filter" option box at the:



The program has automatically flagged the second echo as the most likely liquid level. If this interpretation is correct, then all subsequent echoes have to be repeats of the previous echoes. One question is whether the second echo could be the top of the second liner with the liquid level below that depth. Following is a listing of the times and polarities of the first 10 echoes:

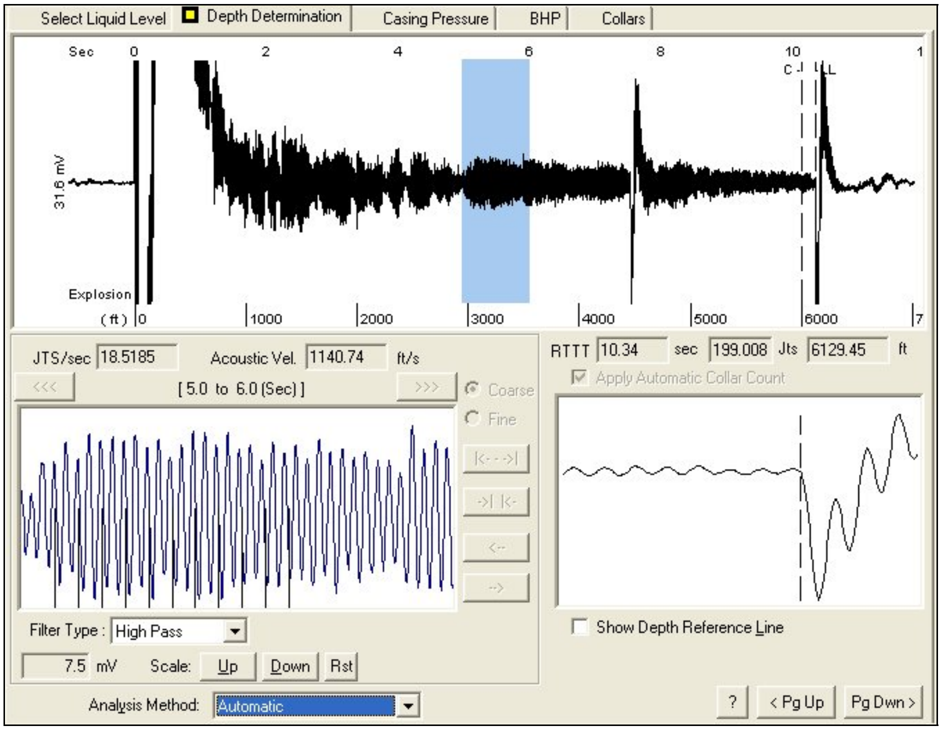
Echo Number	Round Trip Travel Time, seconds	Polarity
1	7.524	Down kick
2	10.34	Down kick
3	13.156	Up kick
4	15.048	Down kick repeat of No. 1
5	15.972	Down kick
6	17.864	Down kick
7	20.68	Down kick, repeat of No. 2
8	23.496	Up kick
9	25.387	Down kick
10	28.236	Down kick

The following wellbore and wave path diagram is used in understanding the time relationships of the various echoes. The round trip travel times in seconds, for sound to travel in the corresponding wellbore section are shown at the right side of the diagram. Sound pulse is generated at (0) and travels from the surface to the top of the liner where a portion is reflected (1) by the diameter reduction and a portion is transmitted (2) to the liquid level where it is totally reflected. Wave (1) reaches the surface after 7.524 seconds and is a down kick. When wave (2) propagates upwards and reaches the liner top it is partially reflected by the diameter increase creating wave (3) of inverted polarity (dashed line).

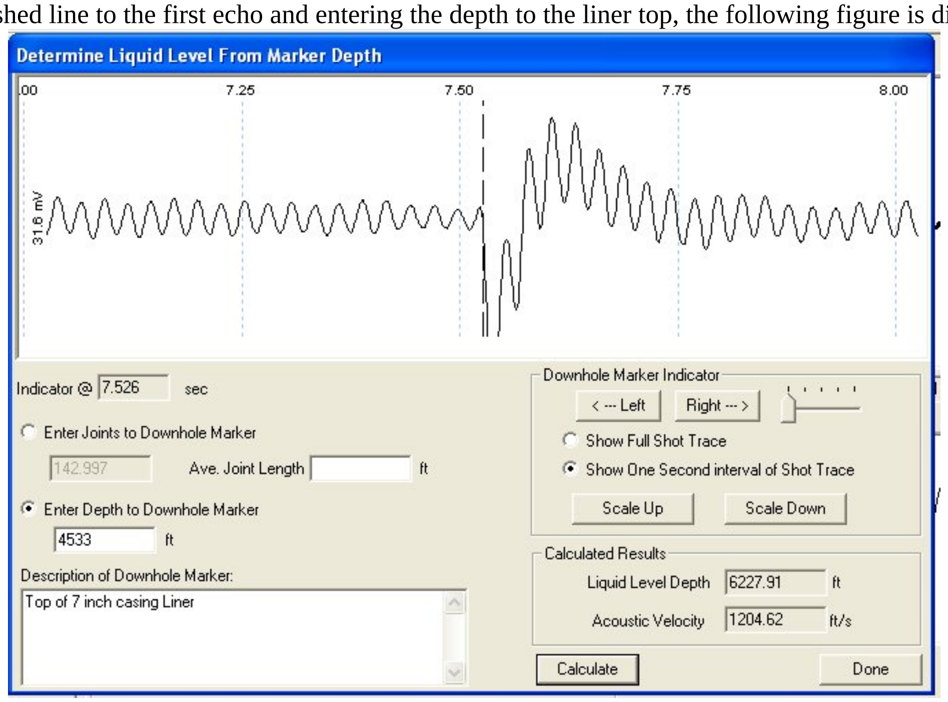


Wave (2) reaches the surface after 7.524+2.816 = 10.34 seconds and is a down-kick.
Wave (3) propagates downwards and is totally reflected at the liquid level and reaches the surface as an up-kick after 7.524 +2.816+2.816= 13.156 seconds
Wave (4) is a repeat of wave (1) reflected at the liner top and reaches the surface at 7.524+7.524= 15.048 seconds
When wave (3) reaches the liner top a portion is reflected back down, creating wave (5) that is of reversed polarity by the diameter enlargement.
Wave (5) reaches the surface after 7.524 + 3x (2.816) = 15.972 seconds
Wave (2) is reflected at the top of the well then is partially reflected at the liner creating wave (6) that reaches the surface after 2x7.524 + 2.816 = 17.864 seconds.
Wave (7) is a repeat of wave (2) from total reflection at the liquid level.
Wave (3) is reflected back down at the top of the well and the portion that travels to the liquid level is reflected as wave (8) that reaches the surface after 2x7.524 + 3x2.816 = 23.496 seconds
As an exercise, the reader should complete the calculations for waves (9) and (10).
Apparently, the second signal was correctly identified by the program as the liquid level echo since all subsequent echoes are caused by multiple reflections between the liner, the liquid level and the surface.

Proceeding to the determination of the liquid level depth the following figure shows the Automatic interpretation:



Note that although the collar count is near the liquid level, the high level of noise yields a questionable collar frequency. This casts doubts about the accuracy of the computed liquid level depth of 6129.45 feet. Since the depth of the top of the upper liner is known, we should use this point as a downhole marker to get a more precise depth to the liquid level. Choosing the marker option and adjusting the dashed line to the first echo and entering the depth to the liner top, the following figure is displayed:



This yields a more accurate liquid level depth of 6227.91 feet which is well above the top of the second liner so that there are no doubts that the liquid level has been correctly identified.

7.0 - ACOUSTIC PRESSURE TRANSIENT TESTING IN PUMPING WELLS

Safety

Please observe all safety rules when operating this equipment. The pressure ratings of the Echometer gas gun and all fittings, hoses, etc. should always exceed actual well pressure. Because the casing pressure normally increases during a build-up test, caution should be exercised that the well pressure does not exceed equipment pressure ratings. Do not use worn or corroded parts which will not withstand well pressure.

All safety precautions cannot be given herein. Please refer to all applicable safety manuals, bulletins, etc. , relating to pressure, metal characteristics, temperature effects, corrosion, wear, electrical properties, gas properties, etc. before operating this equipment.

Echometer Standard Pressure Transducers for Pressure Transient Data Acquisition
375 and 1500 PSI
Echometer Remote-fire Gas Gun Operating Pressure
1500 PSI

Gas Gun and pressure transducer ratings to 3000 PSI and higher, are available upon request. Please contact Echometer Company engineers.

Disclaimer

The calculations are based upon information obtained from the tests and are furnished for your information. In furnishing such calculations and evaluations based thereon, Echometer Company is merely expressing its opinion. You agree that Echometer Company makes no warranty expressed or implied as to the accuracy of such calculations or opinions, and that Echometer Company shall not be liable for any loss or damage, whether due to negligence or otherwise, in connection with such opinions.

NOTE:

Normally the pumping unit can be running during the set-up phase of the test. However, if the pumping unit vibrates excessively and causes signals which are larger than the background noise, the pumping unit may need to be shut down briefly during the portion of the pretest when the setup trace is being acquired.

SUMMARY OF OPERATING INSTRUCTIONS

Pressure Transient Test

1. Attach the Echometer gas gun to the well. **Use an upright 90 degree elbow** to place the Echometer gas gun in a vertical position. This prevents moisture from accumulating in the gas valve of the Echometer gas gun during a test.

2. Connect the power cable, pressure transducer cable and microphone cable.

3. Connect the regulator to the nitrogen bottle. Connect the hose from the gas gun to the regulator. The connection on the gas gun has a 1/4 inch NPT threaded nipple which contains a 0.006 inch orifice to control gas flow to the volume chamber. Set the regulator to a pressure 150 PSI greater than the maximum surface pressure anticipated during the build-up test. Check for gas leaks at all connections.

4. Verify that the casing valve between the Echometer gas gun and the casing is closed. Open the casing pressure bleed valve on the gas gun.

5. Turn on the Well Analyzer computer. Verify that the TIME and DATE are set correctly. Start the TWM program. Select **Acquire Mode**, select the correct pressure transducer coefficients and obtain the zero offset. Open the **Base Well File** and verify that the data is up to date. The parameters in the **Pressure Transient Tab** are used for transient pressure analysis. These parameters may be entered at a later time

6. Choose the **Select Test** option and the **Pressure Transient Tab**. The screen provides an input to specify the type of test (Buildup, Fall Off) and whether this is a new test or continuation of a test in progress via the **append** option.

7. Choose the **Acquire Data** option with the **Schedule Tab** to select the shot frequency and the frequency of recording of the shot traces.

8. Select the **Acquire Shot Tab**, check the casing pressure and adjust the nitrogen regulator to 150 psi in excess of the maximum casing pressure expected during the buildup. Follow instructions displayed, then **Fire Shot**.

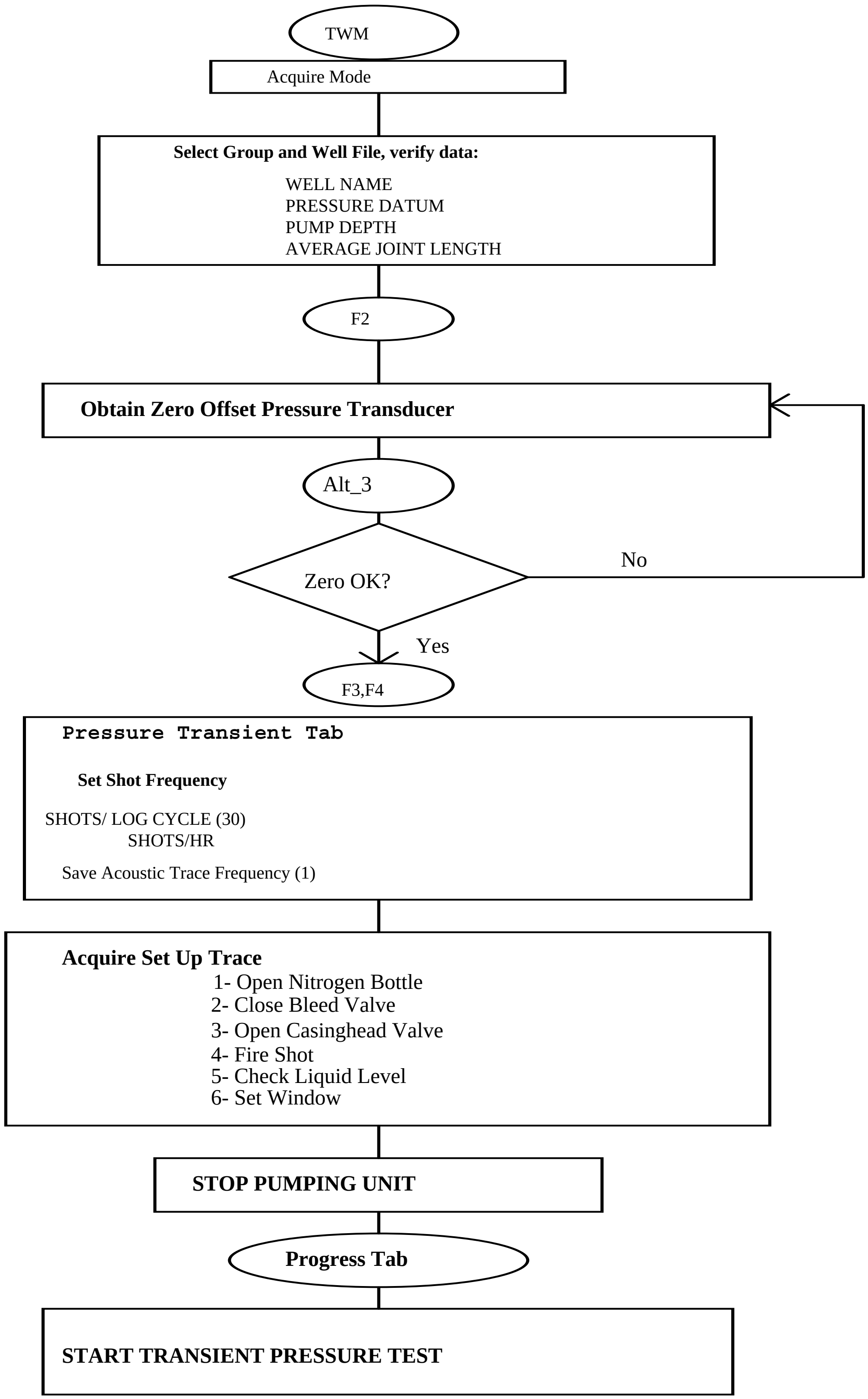
9. Select **Liquid Level Tab**, identify the liquid level and adjust marker and window as needed.

10. Select the **Depth Determination Tab**. Verify that the Automatic depth calculation is correct or select an optional manual analysis.

11. Select the **Progress Tab** and accept the **Settings**. If the set up shot is to be repeated then do not accept the settings and return to step 7.

12. The progress of the test is monitored from the **Progress Tab**. Test setting, data analysis and recording may be modified during the test by selecting the appropriate tabs. Start acquiring data clicking on **START**: Transient Test.

THE FOLLOWING FLOW DIAGRAM SUMMARIZES THE PROCEDURE FOR INITIATING AN ACOUSTIC PRESSURE TRANSIENT TEST.



7.1 - Hardware Configuration

There are a number of possible configurations depending on the pressure level of the well being tested. The following discussion pertains to the situations where the standard **Remote Fire Gas Gun** is used in conjunction with a permanently connected external gas supply source.

7.1.1 - Gas Gun

The Remote Fire Gas Gun should be attached to the casing annulus valve. Preferably, the distance between the Remote Fire Gas Gun and the casing annulus should be 3 feet or less. Also, all the connections should be 2 inch. Do not permit an U-tube to exist in these connections or a liquid trap may occur. A short nipple and a 90 degree elbow (ell) should be attached to the casing valve. The opening of the elbow should be up. The gas gun assembly should be attached to this ell with the microphone end facing down. This helps to prevent water accumulation in the volume chamber, in the gas valve and in the solenoid valve. This water can freeze when the temperature is below 0 ^{o}C and prevent gas gun operation.

Nitrogen gas is commonly used. Carbon dioxide has a low vapor pressure at cold temperatures and the pressure may be less than the well pressure and thus prevent gun operation. The volume chamber pressure should be set approximately 150 PSI in excess of the maximum casing pressure expected during the pressure buildup test.

7.1.2 - Pressure Transducer and Thermistor

The standard pressure transducer has a working pressure range of 0 to 1500 PSI. A thermistor is located inside the housing to measure temperature. The pressure transducer output is corrected for temperature effects and the calculated pressure is displayed on the computer screen. (Pressure transducers with ranges of 375 and 900 psi can be ordered and are recommended for lower pressure wells)

It is recommended that a section of tubular foam insulation (commonly used for insulating air conditioning tubes) be used to shield the pressure transducer from direct sunlight since alternating cloudy and sunny conditions may generate large variations in temperature which may not be fully corrected by the software.

7.1.3 - Gas Valve and Solenoid

Refer to Section 4.21.

7.2 - Electrical and Mechanical Connections

All connections and connectors should be clean and in good condition. The electrical connection to the microphone must be dry and not have salt water on it. The connections to the solenoid and transducer must remain clean. Cover or protect from the environment if necessary. Be sure that the fittings are tight on the external gas supply so that a leak does not deplete it prematurely. Use a soap-water solution to detect very small leaks.

7.2.1 - Battery

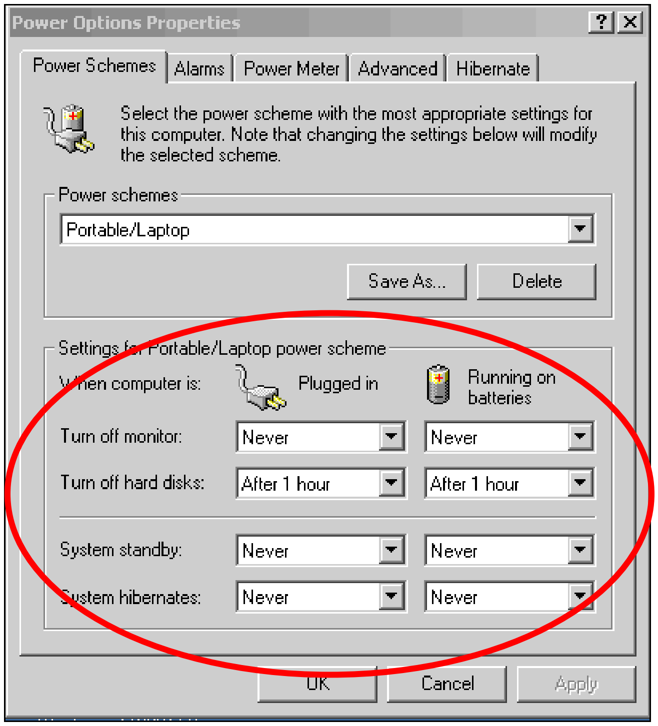
An external, 12 volt deep-discharge, car size battery is necessary. The current drain of the Well Analyzer including the computer averages approximately 1 amp. The external battery should have a capacity of 80 to 120 AMP-HOURS. This permits 3 to 4 days of operation before recharging is necessary. For extended periods, use several batteries in parallel simultaneously if desired. When the battery voltage drops, the computer and A/D converter will cease to operate properly and the solenoid will not discharge the gas gun. A sealed battery is probably safer.

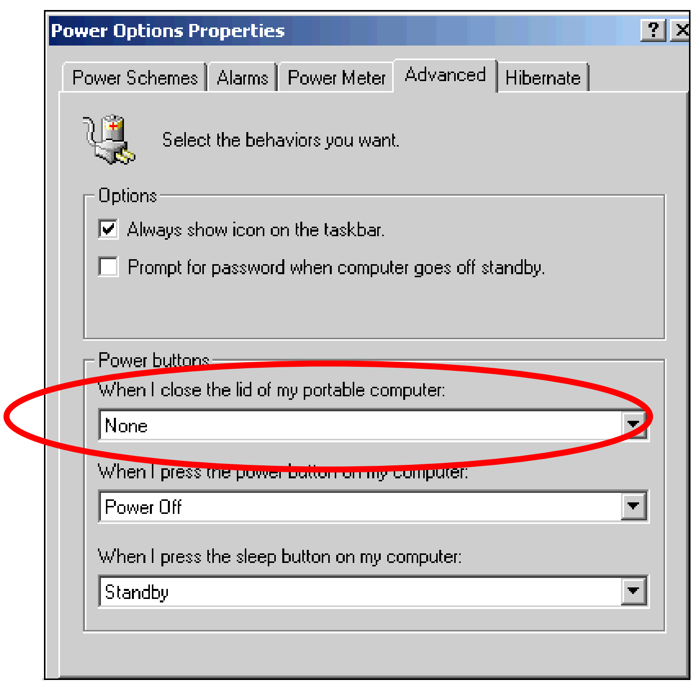
Properly attach the cable from the well analyzer to the battery making certain that the polarity is correct.

Use one battery for operating the Well Analyzer. Charge a second battery to be used for replacement of the first battery. Use a good quality, 10 AMP, deep-cycle battery charger for charging the battery. A fuller charge and also longer battery life will result from using a good battery charger.

The laptop computer power settings should be set so that the computer will NOT HIBERNATE and that it will NOT turn off or go on standby when the lid is closed.

The following figures show the recommended settings for a laptop operating under Windows 2000, the power setting screens are reached through the **Control Panel** folder and may be different for other windows operating systems.





A good 100 amp-hour, 12 volt, deep-cycle battery should be used. A battery that is fully charged will last four days at normal temperatures. The Well Analyzer will drain the battery approximately 0.007 volts per hour or 0.17 volts/day. The initial A/D battery voltage when beginning pressure transient testing is approximately 11.6 volts. This battery voltage is indicated on the main analysis screen that is displayed during the test. A record of A/D battery voltage vs. time is available in the plotting routines. The battery voltage vs. time display screen can be used to estimate the remaining battery life. The voltage drops linearly to 10.2 volts and then drops rapidly. The estimated remaining battery life is calculated by utilizing the battery drain rate, the last voltage reading and then predicting when the voltage will drop to 10.2 volts. Data acquisition ceases when the voltage drops to 10.0 volts. Please use this analysis procedure to verify that the computer, A/D battery and external 12 volt deep-cycle battery are all operating normally and in good condition. The amplifier and A/D converter are not allowed to acquire data when the battery voltage is less than 10 volts.

A protection diode is used between the external 12-volt deep-cycle battery and the A/D converter battery. Thus the A/D converter battery is approximately 0.6 volts less than the external 12 volt battery. The deep-cycle battery will continue to charge the computer battery until the external battery is drained to less than 9 volts. The computer battery is charged using an internal DC-DC converter.

7.2.2 - Pressure Transducer Performance

The pressure transducer used with the buildup system is a precision instrument. Accordingly it should be used carefully and maintained in good condition. The following are suggested practices to be followed to insure the maximum accuracy of the measured pressure data:

1. Shield pressure transducer from direct sunlight and rain. (Use insulating foam tube over transducer)
2. Protect transducer and cables from vibration or movement.
3. Do not permit cable connectors to become wet.
4. Use good quality batteries and maintain a good charge in the batteries

In very harsh environments (Canada, Siberia or tropics) it is advisable to put the well analyzer and the external battery within an insulating enclosure so as to protect them from extreme temperature or humidity.

For maximum accuracy use a pressure transducer with a **full scale range** as close as possible to the maximum casing pressure expected at the end of the buildup test.

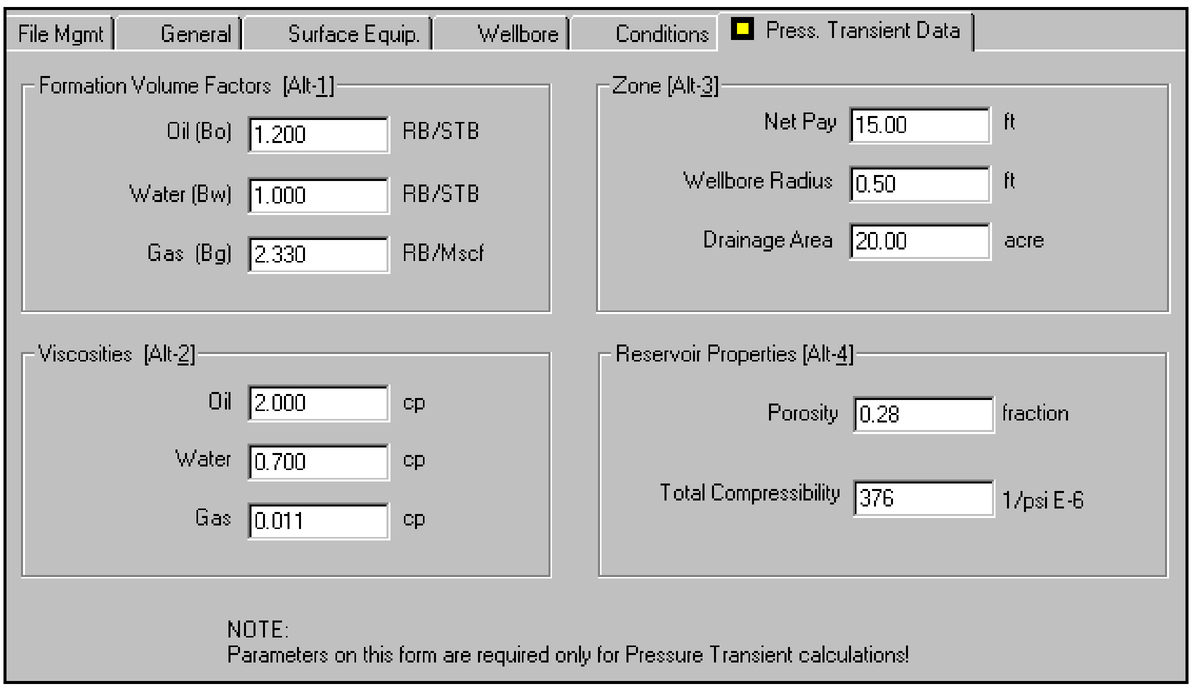
7.3 - PROGRAM TWM- Pressure Transient Test Acquisition

The program is designed for unattended operation of the Well Analyzer while acquiring data for an extended buildup or draw down test. Various flags that can be reset during the test control the type of test and the type of data that is acquired. Frequency of data acquisition is also controlled by the operator and can be modified during the test. Provision has been made to allow editing of the data as well as appending data in the event that the normal sequence of events has to be interrupted (loss of power, loss of gas pressure or mechanical malfunction) so that the overall result of the test is safeguarded. Although the program is primarily designed for use in conjunction with pumping wells it is applicable to flowing wells where there is not a packer in the annulus. Measurements can also be undertaken inside the tubing in flowing wells as discussed in the special testing section.

The operation of the software is divided into a **set-up phase**, an **acquisition phase** and a **data quality control phase**. Various options are chosen from buttons and check boxes which are activated via the corresponding tabs. The TWM program is started in the **Acquire** mode. Upon selection of the **Base Well File** for the well to be tested the Pressure Transient data is entered or checked for accuracy in the corresponding Tab.

7.3.1 - Pressure Transient Data Tab

Selecting the **Base Well File** option (F3) and the **Pressure Transient Data** tab displays the following form which contains the data required for interpretation of the pressure transient test:



While the data in the previous form are required only for analysis the following parameters **MUST** be entered in order to be able to **ACQUIRE PRESSURE TRANSIENT DATA**:

- **Well Name**: The name of the well which will be used to identify the data files.
- **Formation Depth**: Is used to calculate the BHP.
- **Pump Intake Depth**: Is used, in conjunction with formation depth, to determine the length of time during which acoustic data is acquired, and in the BHP calculation.
- **Average Joint Length**: Is used to calculate the depth to the gas/liquid interface from the acoustic reflection time and collar frequency

These data are entered in the corresponding **General, Wellbore and Conditions** Tabs.

Although the rest of the Pressure Transient Data parameters are not required for data acquisition, it is recommended that whenever possible they should all be determined and entered in the data table. This will insure that all the available features of the program can be used during the test to verify the validity of the data and to monitor the progress of the test.

The following three parameters should be obtained from the most recent well test data:

- **BOPD**: Oil production, in stock tank barrels per day.
- **BWPD**: Water production, in stock tank barrels per day.
- **MCF/D**: Gas production in Standard MCF per day.

The values of the six parameters below should correspond to <u>the current average reservoir pressure and temperature</u>.

- **Oil** Formation volume factor for the reservoir oil. (**Bo**)
- **Water** Formation volume factor for the produced water. (**Bw**)
- **Gas** Formation volume factor for the produced gas. (**Bg**)

- **Oil** Viscosity of the reservoir oil. (**μo**)
- **Water** Viscosity of the reservoir water. (**μw**)
- **Gas** Viscosity of the produced gas. (**μg**)

- **Net Pay:** The formation thickness to be used in calculation of permeability from **kH**.
- **Porosity:** Average value of formation porosity (**fraction**).

- **Total Compressibility** The combined compressibility of rock and formation fluids (**1/psi**)
- **Drainage Area:** Estimated drainage area for the well being tested (**Ac**).
- **Wellbore Radius:** Generally assumed to correspond to bit size unless a caliper log indicates a different value or the wellbore has been under-reamed (**rw**).

The following are entered in the **Wellbore Tab**:

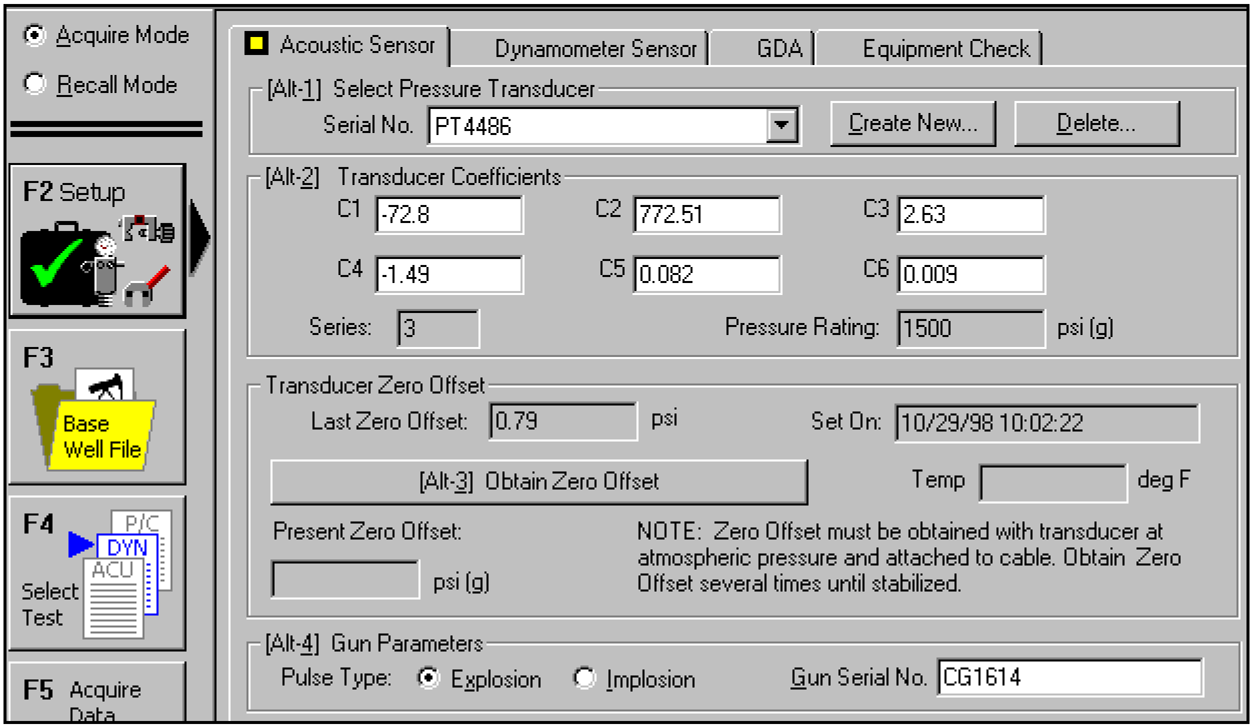
- **Casing ID:** Average inside diameter of production casing string.
- **Tubing OD** Average outside diameter of tubing string.

The following **temperatures**, from the **Conditions Tab**, are used by the program to calculate the temperature gradient in the well:

- **Surface Temperature**: The average temperature in the wellbore at the surface. In pumping wells this is generally assumed to be about 75 degrees F. In wells flowing at high rates or producing by steam injection it may be higher than this value.
- **Bottomhole Temperature**: This is generally obtained from wireline logs. It is combined with the surface temperature to calculate an average temperature gradient for the wellbore. The temperature at various depths is calculated from this gradient. Temperature at a given depth is used in the calculation of the density of the fluids present in the wellbore at that point and consequently it will affect the calculated pressure distribution.

7.3.2 - Transducer Selection and Zero Offset

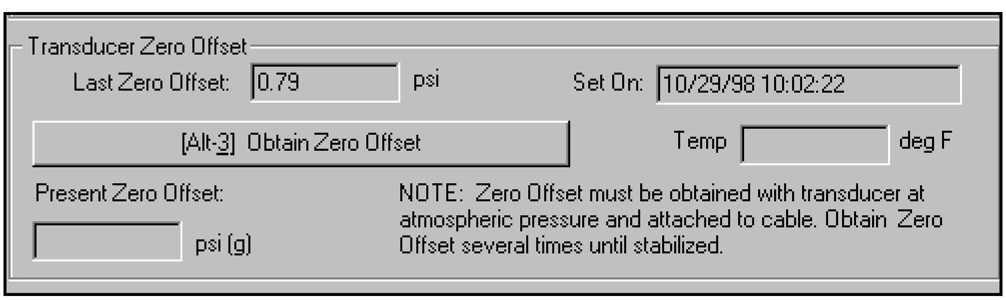
The set-up phase is continued by entering or selecting the calibration coefficients for the pressure transducer, as shown in the next figure. Be sure to enter the correct serial number:



The coefficients should be entered **EXACTLY** as written on the nameplate of the transducer that is to be used during the test.

After connecting the transducer to the Well Analyzer cable and insuring that the valve between the well and the Remotely Fired Gun is closed, **open the gun's bleed valve** to insure that the transducer is sensing atmospheric pressure.

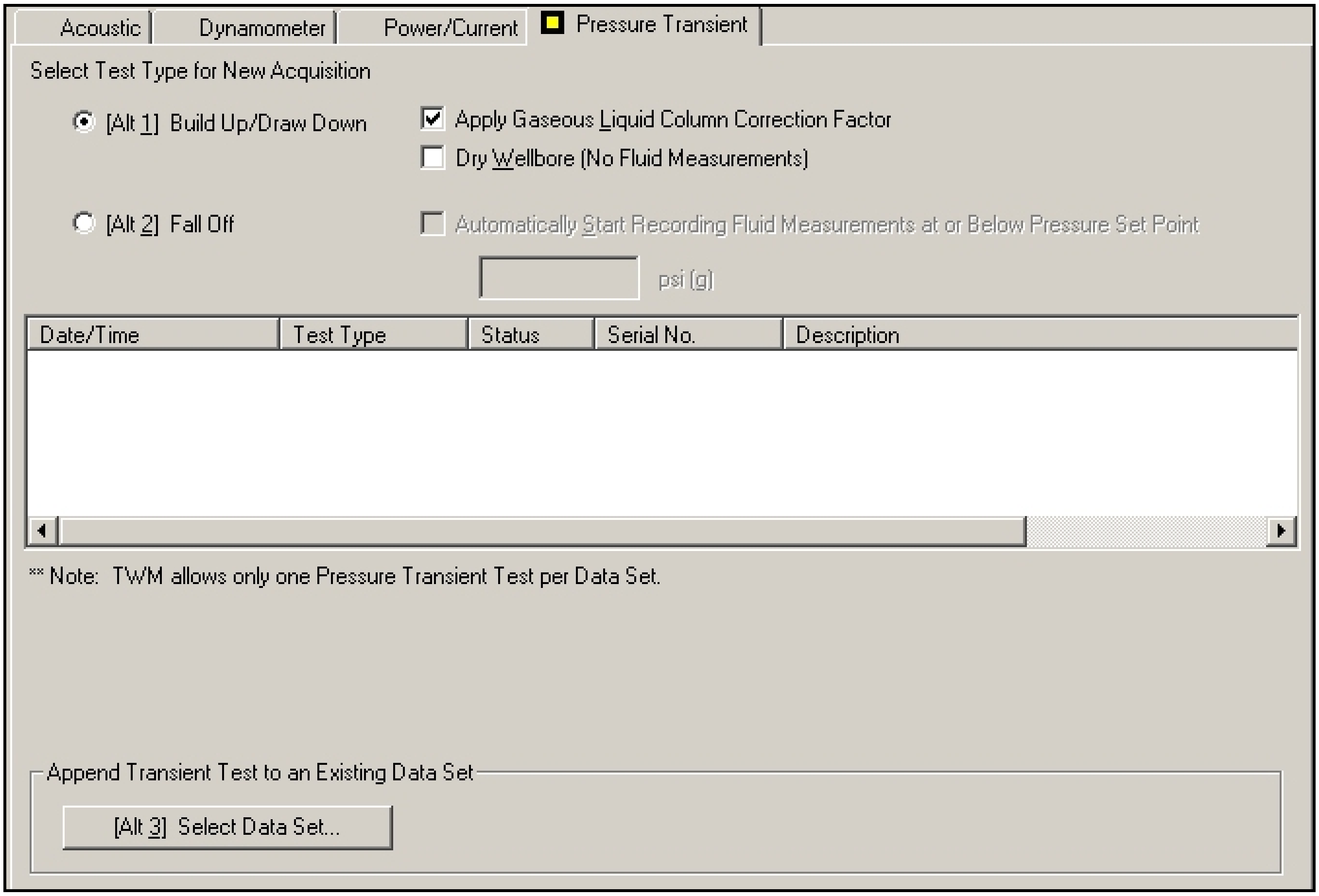
Pressing **Alt 3** will activate the Well Analyzer and acquire the pressure and temperature at the pressure transducer as shown in the next figure:



The zero offset should be **less than 10% of coefficient C2** and should remain relatively stable when **Alt 3** is pressed several times to repeat the measurement. The indicated temperature is the temperature of the pressure transducer. It generally is NOT the temperature of the wellbore.

7.3.3 - Test Programming

After choosing the **Select Test (F4)** option and the **Pressure Transient Tab**, the following screen is presented to the user:



The user has the following choices:

- **Alt 1** - Initialization of a Buildup/Drawdown test which involves entering the necessary data about the well and fluid and setting the flags that will control the test options: **Apply gaseous column correction factor** in a well with gas flowing up the annulus. **Dry Wellbore** when testing a dry gas well which does not produce any liquids (only wellhead pressure readings are required).

- **Alt 2** - Undertake a pressure **fall-off test** in a water or gas injection well.

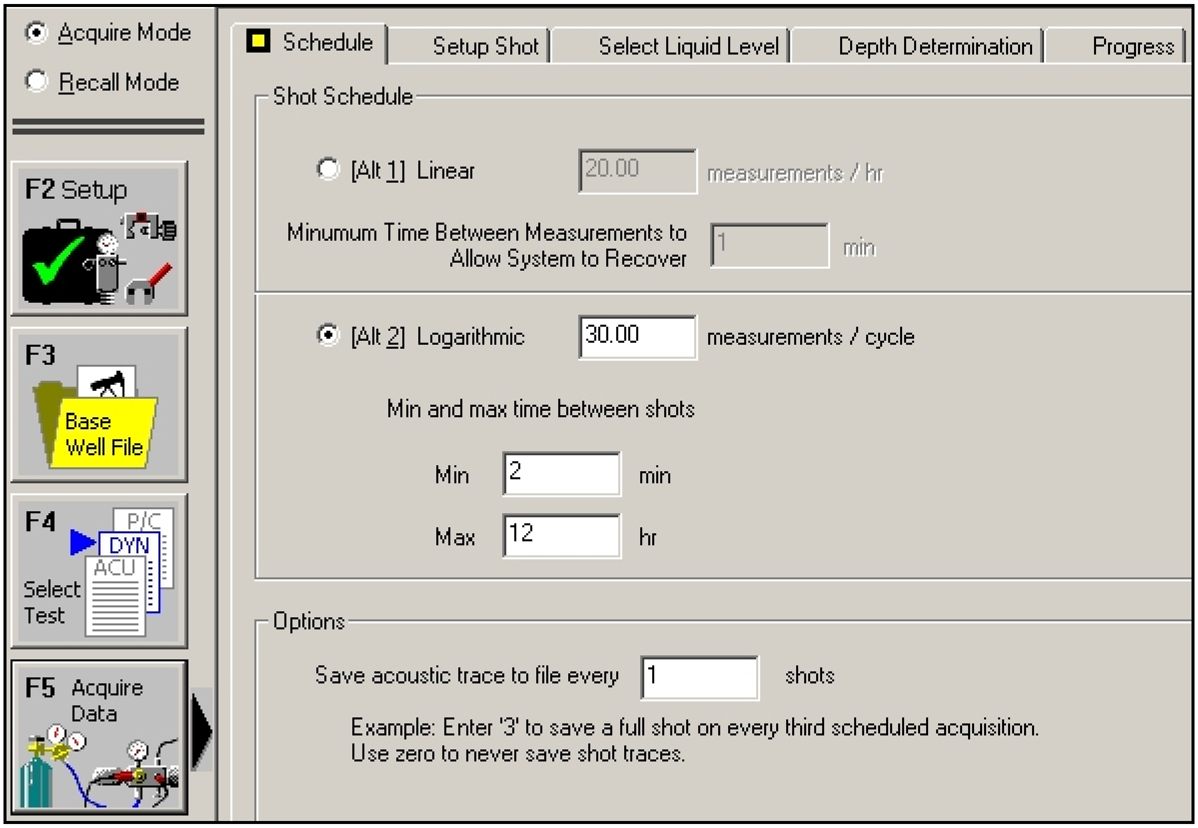
- **Alt 3** - Append test data to old data. **Select Data Set**. This option allows the continuation of data acquisition whenever the normal progress of a test has been interrupted. The data is saved in continuation of the previous data with the correct time stamping so that it is not necessary to perform complicated editing or time shifting.

The **check boxes** are used to define the type of bottom hole pressure calculation and the type of transient test that is going to be undertaken:

Gaseous liquid correction: The default value is **checked**, which implies that the gradient of the annular liquid column is calculated taking into account the gas bubbling through the liquid as determined from the casing head pressure buildup rate and the Echometer Gaseous Column correlation[9]. When this flag is **unchecked**, the annulus gradient is computed considering only the liquid phases (oil and water).

The Falloff Test flag is **checked** to indicate that a pressure fall off test is to be undertaken for an injection well. This disables the gaseous liquid correction and uses water gravity for the liquid column. The default value is **unchecked**, which implies that a pressure buildup test is to be recorded. Acoustic fluid level data acquisition can be automatically started when the measured pressure falls below a threshold pressure, input by the user.

Pressing **F5** and selecting the **Schedule Tab** continues to the definition of the **Test Parameters**, as shown in the next figure:



This data form is used to define the frequency with which measurements will be made and how often the data for a digitized acoustic trace is recorded on disk.

7.3.2 - Data Acquisition Frequency

Two options are available for **Shot Schedule**: Linear and Logarithmic.

Linear:

The user specifies the number of measurements to be made during an hour. The maximum number is 30, corresponding to the minimum time interval between shots of 2 minutes. This quantity can be changed during the test. This is done by selecting the **Schedule Tab** and changing the parameters.

Logarithmic:

[9] McCoy et al.: Producing Bottomhole pressure paper.

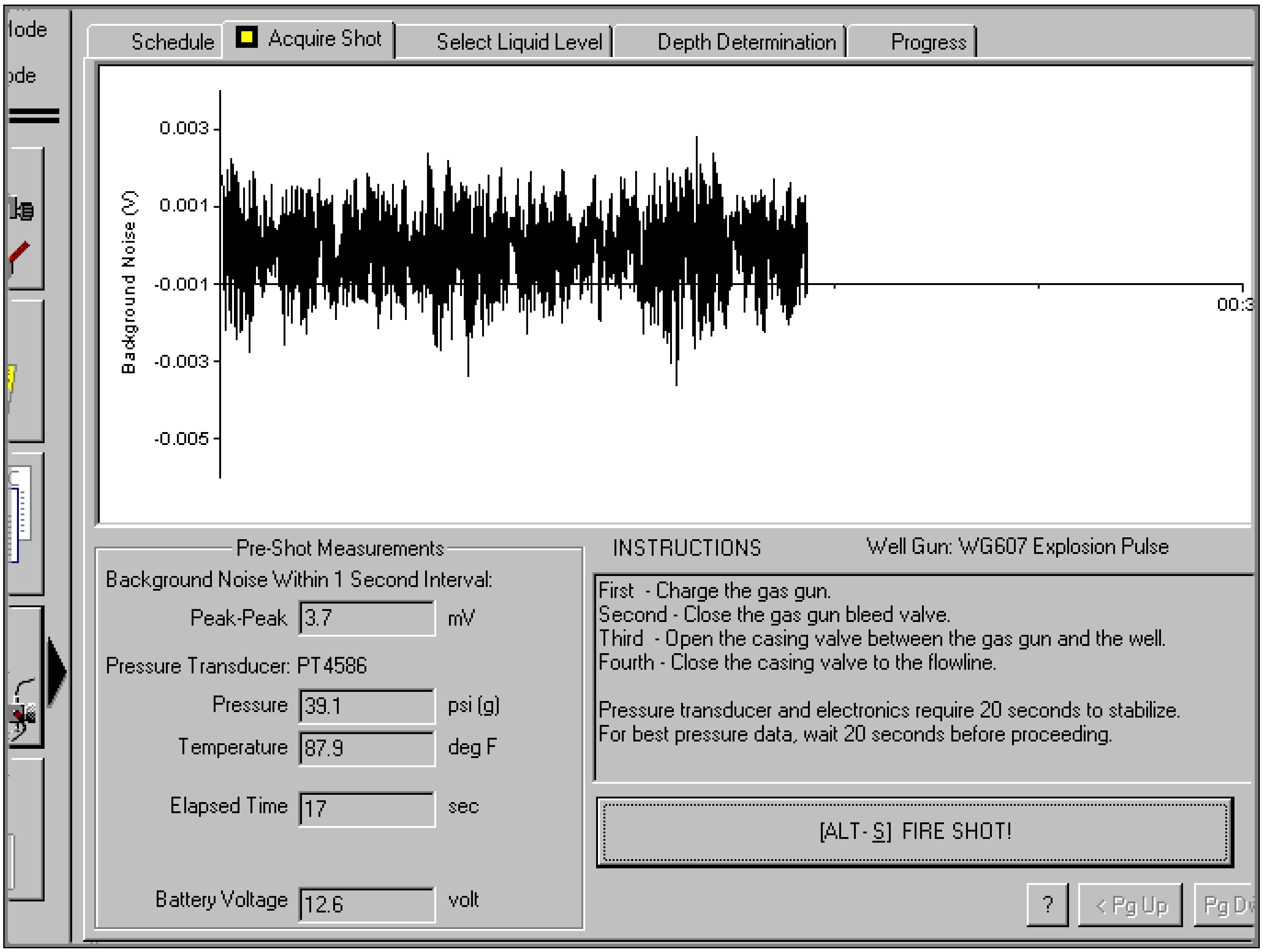
The user specifies the number of measurements to be made per cycle of the logarithmic time base in hours. This will result in the same number of data points to be taken during the first hour, from one hour to ten hours, from ten hours to one hundred hours, and so on. Since the majority of pressure transient analysis techniques involve logarithmic plots, this option will result in a uniform density of data for the whole test. The default value is 30 measurements per cycle. The user can also set **Minimum** and **Maximum** time between shots, to override the logarithmic schedule.

7.3.3 - Frequency of Acoustic Trace Storage

It determines how often the digitized acoustic trace is saved to disk during the test. The default value is set at once every measurement. The purpose of recording the raw acoustic data is to manually overcome difficulties that the software may encounter in automatically determining the depth to the gas/liquid interface. The raw data can be analyzed, off line, using the various filtering and special processing features of the TWM program. Shots are saved in sequence as ***wellname.001e001*** in the same directory as the main data file.

7.3.4 - Pre-Shot Measurement

The next part of the test set-up involves acquiring an acoustic trace in order to determine the appropriate parameters for automatic determination of the liquid level. Select the **Acquire Shot Tab**:



NOTE

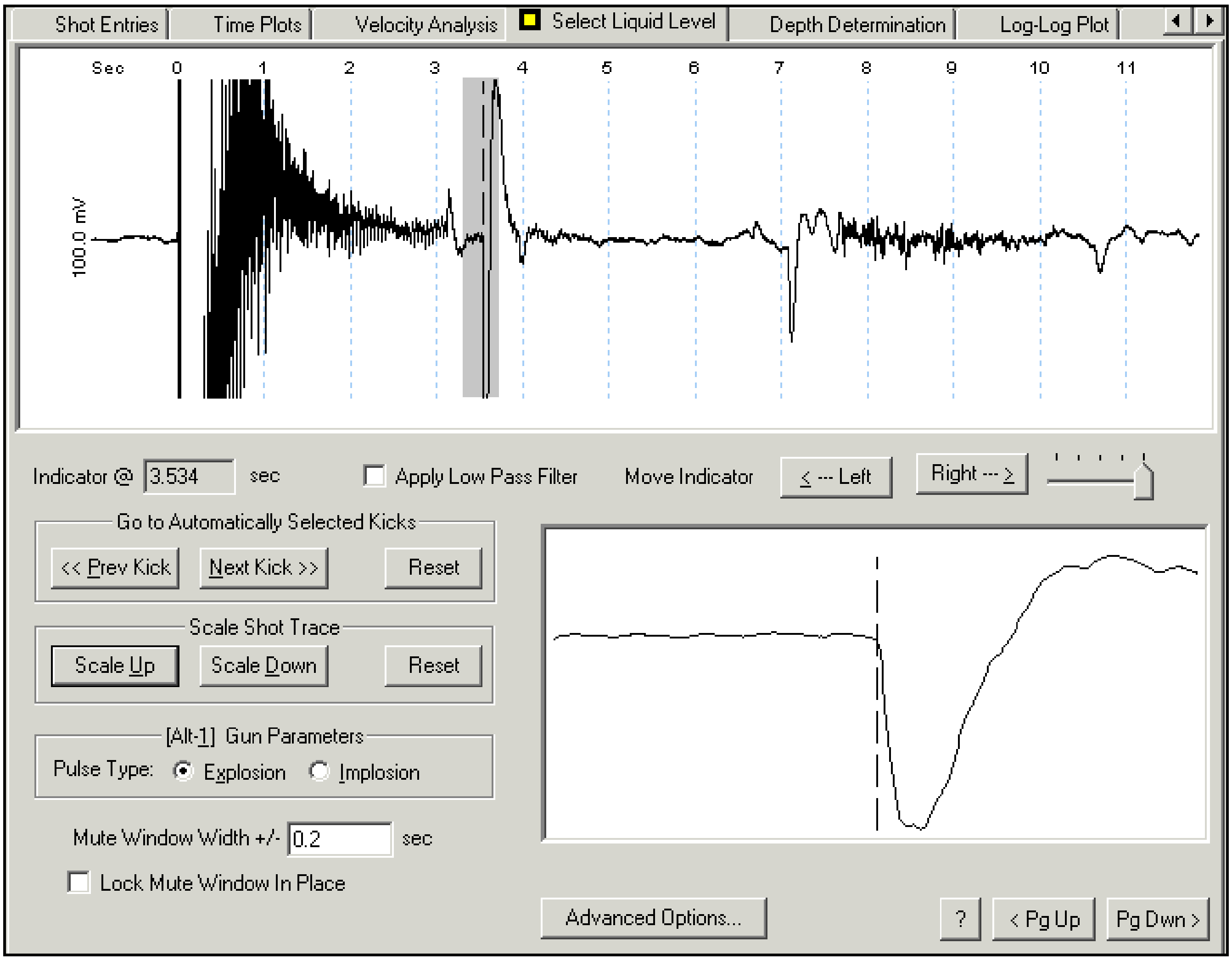
The chamber pressure is controlled by the pressure regulator on the Nitrogen bottle. Generally it should be set to a minimum of 150 PSIG above casing pressure that is anticipated that will be reached during the following un-attended period of the test.

After checking all cables and connections and that the chamber has been charged to the correct pressure, a test shot is fired by striking **Alt-S**.

The length of the data acquisition time is initially determined by the value of the depth to the pump intake that was entered in the well data file. Subsequently it is adjusted depending on the position of the previously recorded liquid level reflection.

Shot Not Detected: Occasionally the amplitude of the acoustic pulse is not sufficient for the software to automatically detect that the shot has been fired. Generally this can be remedied by increasing the volume chamber pressure. If this does not solve the problem, the operator should follow the **troubleshooting** procedure to check the cables and electronics.

After the acoustic trace is acquired, the software makes a best estimate of the most probable signal that corresponds to the liquid level reflection. This signal is flagged by the gray band (liquid level signal window) as shown in the following figure:



In the window on the lower right of the screen the signal that has been flagged is displayed using an expanded time scale. At this point the operator should:

- **Check** that the liquid level is picked correctly by the software.
- **Check** that the selection is contained within the window.
- **Exclude** other possibly confusing signals from the gray window by adjusting its width so as to exclude the other signals if possible.

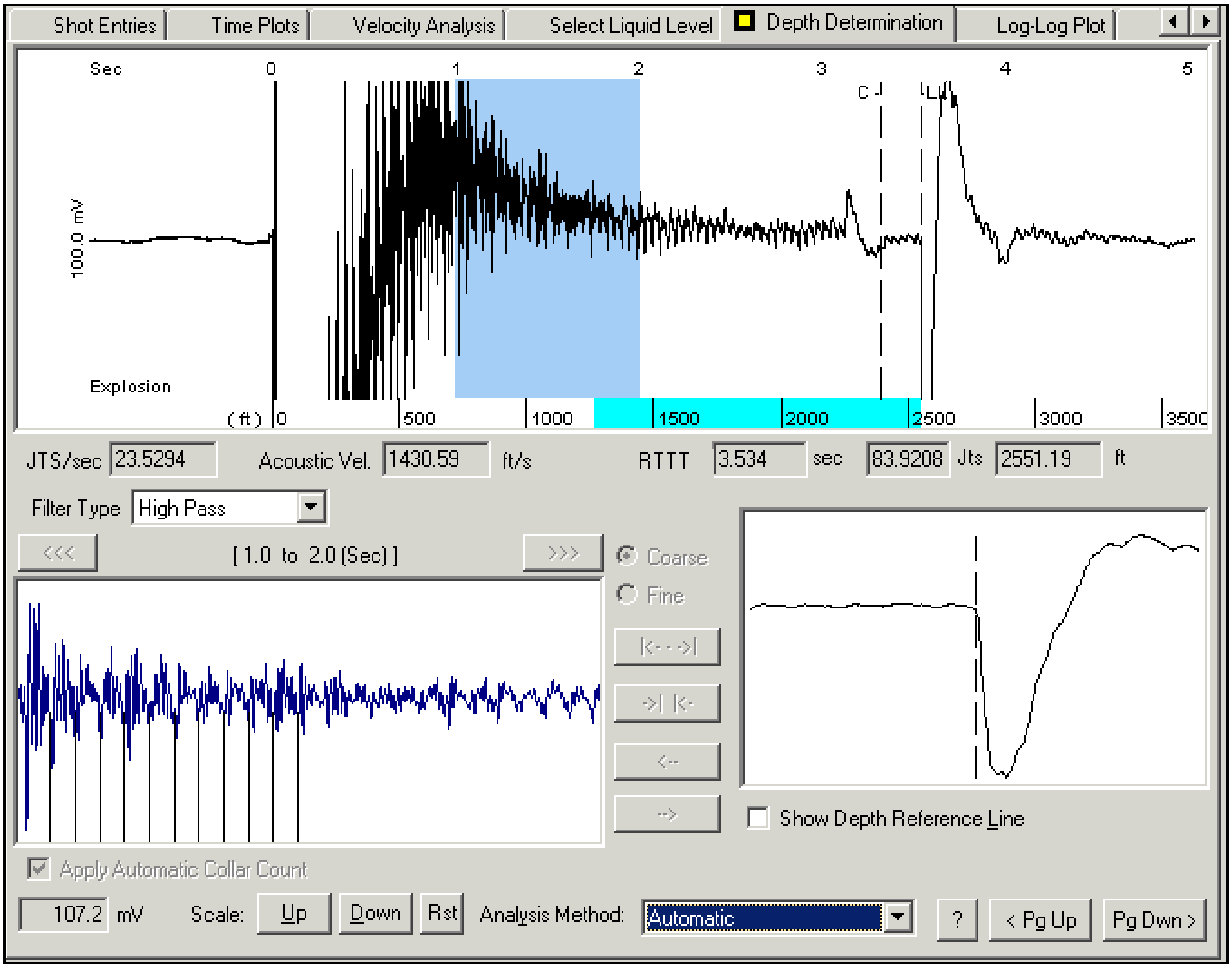
- **Mute Window Width:** the width is set as a fixed number of seconds (0.5 seconds default) on either side of the fluid level marker. It should be as narrow as necessary (0.2 seconds shown above) to exclude other signals (such as from liners) from possible selection as the liquid level.
- **Pulse Type**: the correct type of pulse (implosion/explosion) should be selected.
- **Lock Mute Window In Place**: when this box is checked the mute window is fixed in time and does not follow the movement of the liquid level echo.

NOTE

Before shutting-in the well, it is recommended to use the Acoustic tab of the TWM program to take a few preliminary acoustic traces so as to identify as easily as possible the correct signal corresponding to the liquid level as well as the exact time. The Well Analyzer's signal processing capabilities should be used as needed to identify the correct signal. Also the correct collar frequency should be identified so as to be able to check the collar frequency determined by the Pressure Transient tab of the TWM program.

As a general rule the software should have no problems in correctly identifying the liquid level. The most troublesome wells are those where gas is vented from the casing at very low pressures. Signal to noise ratio will improve significantly as the casing head pressure increases during the test.

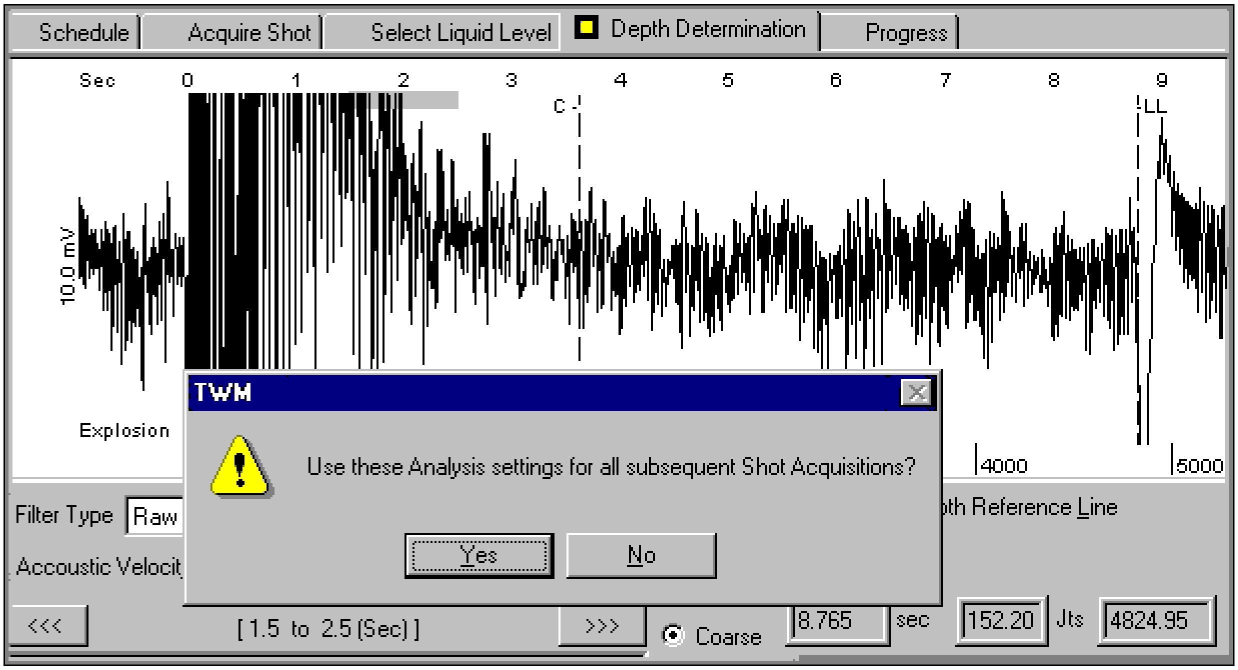
After adjusting the signal window and checking the liquid level reflection time, the set-up procedure is continued by selecting the **Depth Determination Tab**. The software then analyzes the collar reflections to establish the corresponding collar frequency (sound velocity in the casing gas) and presents to the operator the result of filtering the raw signal and automatic selection of collars, as shown in the next figure:



Generally the **Automatic** calculation of frequency is sufficiently accurate. However in very noisy wells it may be more accurate to determine the collar frequency using the multiple processing features of the **TWM program**. After the well is shut-in the increase in casing pressure will cause significant quieting of the wellbore and the automatic processing will be more effective.

Occasionally it may be necessary to use the **Manual** mode of processing the acoustic data to select a different time interval for determination of collar frequency. In this case the subsequent shots will be analyzed by the software using the selected time interval to determine the collar frequency and constructing the filter for the automatic collar count. The operator also has the option of using a fixed acoustic velocity for liquid level depth calculation but this is not recommended since the velocity will change as the casing pressure generally increases during the buildup test.

After the set-up phase has been completed selecting the **Progress Tab** presents the following message:

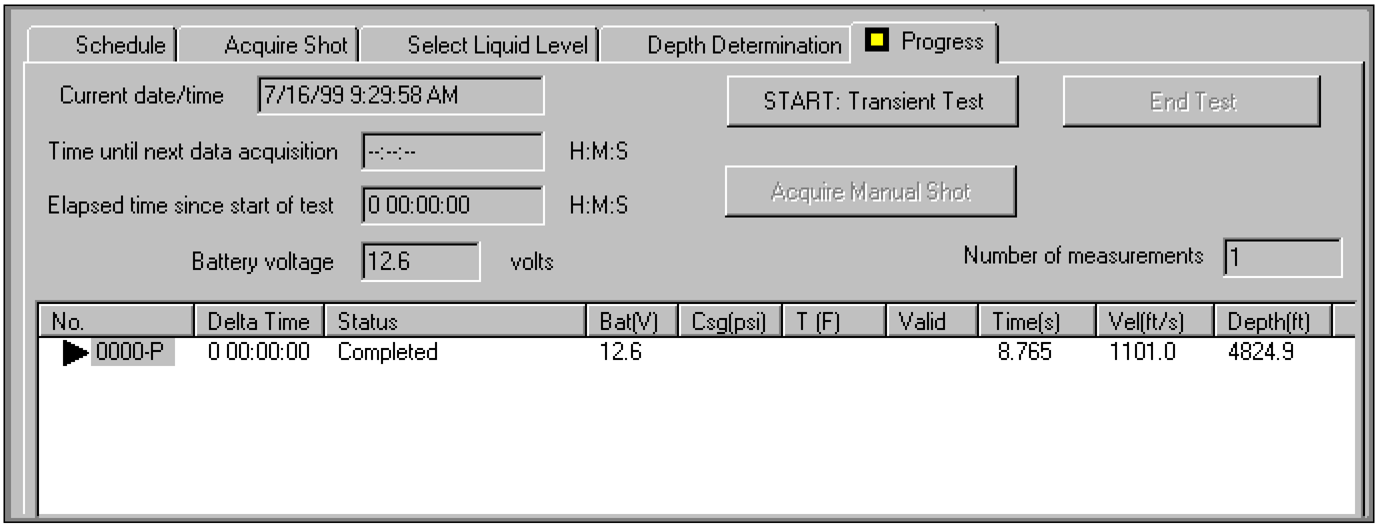


At this point it is possible to repeat the complete set up procedure by pressing **NO**, and repeating the selection of the signal window and depth determination, or pressing **YES** and continuing with the start of the pressure transient test. The liquid level signal selection and depth calculation options can be reset at any time during the test by following the same set up sequence of tab selections.

7.3.5 - Start of Pressure Transient Test

Before continuing, check that all connections are still secure, the cables are protected from accidental damage, the external power source is connected to the **Well Analyzer** and the gas supply is connected (**and checked for leaks**) and the chamber pressure is regulated to the value used during the set-up of the acoustic trace.

After selecting the **Progress Tab**, the following screen is displayed, indicating that the set up shot, assigned the Number **0000-P**, has been completed and the software is ready to begin acquiring the data for the **Transient** test:



Automatic acquisition of the data is initiated by clicking on the **START TRANSIENT TEST** button. The first shot is fired when the unit is operating since it corresponds to the flowing (or static) bottom hole pressure condition. After the data processing is completed the well flow is **stopped when running a buildup test**, or is **started when running a draw-down test.** The test's elapsed time clock is started as well as the timer that indicates the delay to the next data acquisition.

While this screen is active it is possible to manually initiate acquisition of a data point using the **ACQUIRE MANUAL SHOT** button. This will not alter the automatic shot firing sequence. Note that the **START** button has been renamed **PAUSE TRANSIENT TEST**. This allows stopping the automatic acquisition schedule during the test in order to undertake modifications or repairs to the system set up, such as changing the nitrogen bottle, replacing a faulty cable, etc. without disturbing the progress of the transient test. Also the transient test may be terminated using the **END TEST** option.

Shots are identified by a combination of numbers, letters and icons and comments indicating their status:

The four digit number (0001) represents the shot number in sequence.
The letter represents the type of shot:

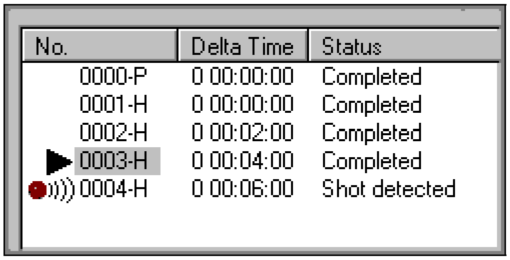
P- Pre-start set up shot
S - Soft shot, the acoustic trace is not saved or liquid level was not identified.
Only time and casing pressure are recorded.
H- Hard shot, the acoustic trace is saved with all the other data.
M-Manual shot fired by user at any time during test, data and trace are saved.

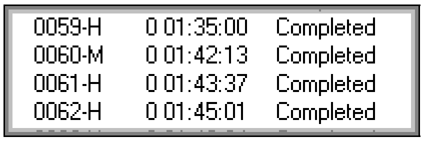
The icons relate to the status of the process:

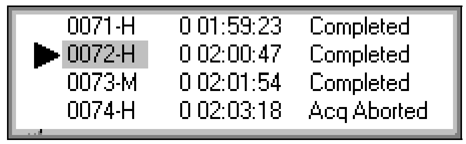
The **triangle** indicates that the particular shot has been selected for analysis or review:

The **microphone** indicates that the shot is being acquired and processing is not completed:

Shown below are examples of these designators including the shot's **Status**:



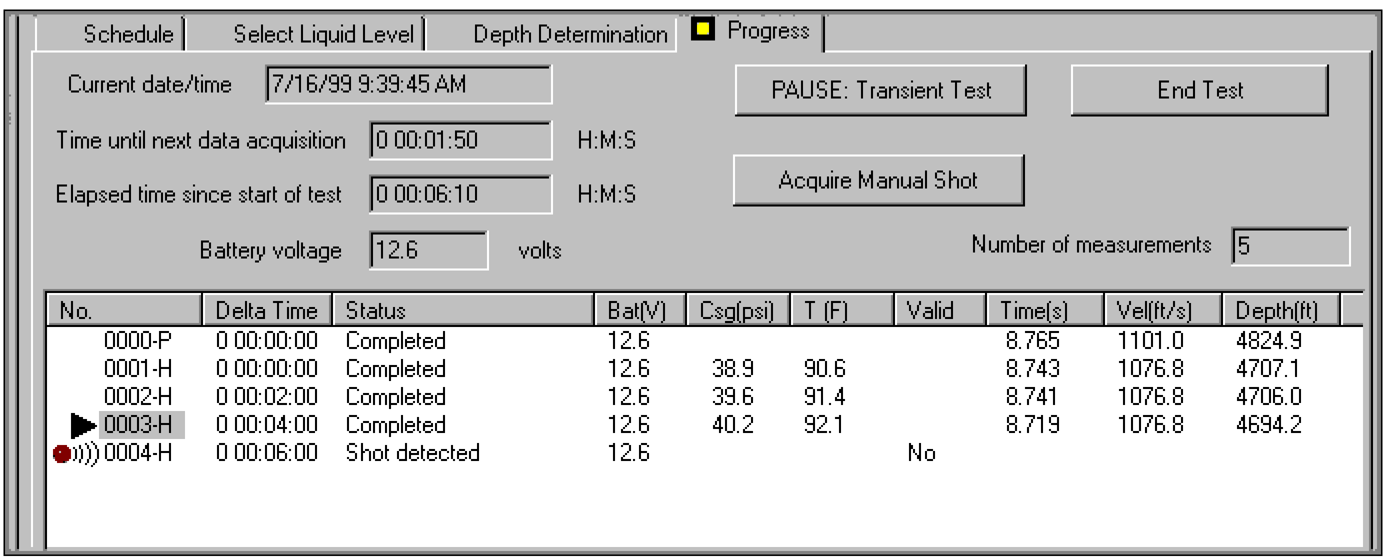




7.3.6 - Test Progress and Control

The **PROGRESS** tab shows the screen which is displayed during the normal progress of the transient test. This screen is used by the operator to monitor the progress of the test, to modify the test parameters and to evaluate the data that has been acquired.

After the acquisition and processing of several shots has been completed the following figure shows the Test Progress and Control Screen at the precise moment when the system is acquiring data from a shot:



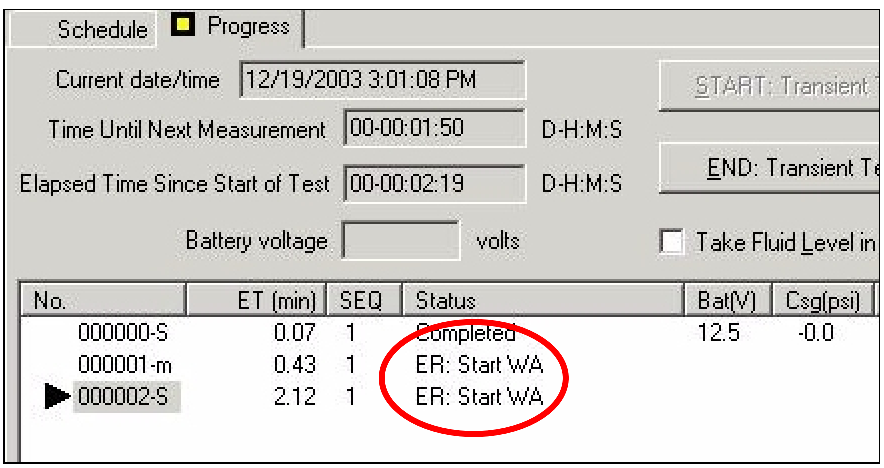
The following data are recorded in the table:

Delta Time: elapsed time since start of test.
Status: information related to the specific shot status.
Bat(V): measured voltage of well analyzer's and external battery.
Csg(psi): pressure reading in casinghead annulus.
T(F): temperature inside pressure transducer housing.
Valid: comment regarding the validity of the shot data.
Time(s): time to liquid level echo signal.
Vel(ft/sec): acoustic velocity of annulus gas.
Depth(ft): computed depth to liquid level.

Following is the same screen after acquisition of one pre-shot, seventeen automatic shots and one manual shot:

No.	Delta Time	Status	Bat(V)	Csg(psi)	T (F)	Valid	Time(s)	Vel(ft/s)	Depth(ft)
0000-P#	0 00:00:00	Completed	12.6	55.3			8.765	1101.0	4824.9
0001-H	0 00:00:00	Completed	12.6	38.9	90.6		8.743	1076.8	4707.1
0002-H	0 00:02:00	Completed	12.6	39.6	91.4		8.741	1076.8	4706.0
0003-H	0 00:04:00	Completed	12.6	40.2	92.1		8.719	1076.8	4694.2
0004-H	0 00:06:00	Completed	12.6	40.8	92.6		8.719	1079.7	4707.0
0005-H	0 00:08:00	Completed	12.6	41.3	93.3		8.699	1079.7	4696.2
0006-H	0 00:09:31	Completed	12.6	41.8	93.7		8.681	1082.7	4699.2
0007-H	0 00:10:56	Completed	12.6	42.2	93.8		8.663	1078.7	4672.3
0008-H	0 00:12:20	Completed	12.6	42.5	94.0		8.661	1081.2	4682.0
0009-H	0 00:13:45	Completed	12.6	42.9	94.2		8.648	1082.7	4681.4
0010-H	0 00:15:09	Completed	12.6	43.2	94.1		8.632	1080.2	4662.1
0011-H	0 00:16:34	Completed	12.6	43.5	94.2		8.616	1084.1	4670.4
0012-H	0 00:19:34	Completed	12.6	44.1	94.4		8.547	1078.7	4609.7
0013-H	0 00:22:34	Completed	12.6	44.7	93.9		8.481	1084.1	4597.3
0014-H	0 00:25:34	Completed	12.6	45.4	93.0		8.421	1084.1	4564.7
0015-H	0 00:28:34	Completed	12.6	46.1	93.0		8.363	1100.2	4600.6
0016-H	0 00:31:34	Completed	12.6	46.7	93.9		8.314	1085.6	4512.9
0017-H	0 00:34:34	Completed	12.6	47.4	94.9		8.268	1101.0	4551.6
▶ 0018-M	0 00:36:25	Completed	12.6	47.8	95.0		8.240	1080.1	4450.1

If during the test the program cannot communicate with the data acquisition hardware the following error message is generated:



Generally this is an indication that there may be a problem with the USB or serial cable or the well analyzer battery has run down below the minimum voltage to operate the electronics.

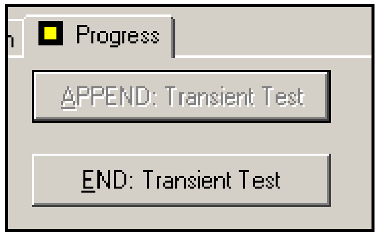
When the battery voltage drops below 10 volts the solenoid valve is not operable and the following status message is recorded:

000146-H	7245.98	7	Completed	10.0	0.0	74.7	4.225	1140.0	2408.3
000147-S	7248.02	7	Low Battery Can't Fire So...	9.9					
▶ 000148-S	7248.65	8	Low Battery Can't Fire So...	9.8					

***** Battery Voltage Level too low to Fire Solenoid. Check Battery. *****

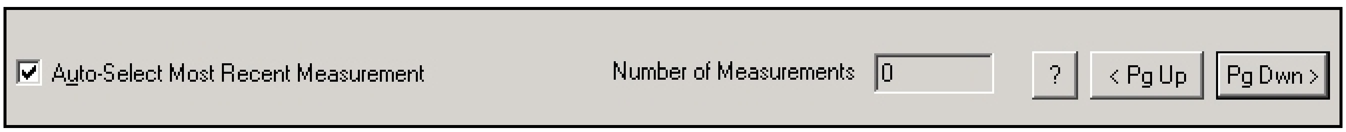
END Test:

This button is used to stop the acquisition sequence but it does not stop the test clock:



After clicking the **END** button the **APPEND** button becomes active. While the acquisition sequence is stopped the user can replace any faulty hardware (pressure transducer, external battery, etc.) or make repairs to the connections to the well as needed. When everything is ready, the test can continue and the user clicks the **APPEND** button initiating the acquisition of a set-up shot to validate the liquid level selection end depth calculation. The test then continues as scheduled.

At the bottom of the screen the check box forces the program to **select the last measurement** in the progress table for possible review by the user. The number of shots taken is also displayed:



7.3.6.1 - Backup of Acquired Data

The program automatically makes a copy of the acquired data in case the main file gets corrupted. The backup file (wellname.001_BU) is stored in the same directory as the main file (wellname.001).

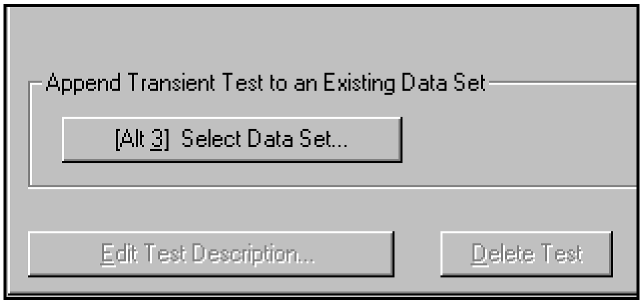
If for some reason the original file gets corrupted (laptop shuts down unexpectedly) then the back-up file can be used to analyze the data or to append a continuation of the test. Windows Explorer is the tool to use as follows:

1. Find the data file wellname.001
2. Rename it to wellname.xxx
3. Find data file wellname.001_BU
4. Copy file wellname.001_BU
5. Paste file wellname.001_BU creating a file named “Copy of wellname.001_BU”
6. Right click on the file wellname.001_BU
7. Rename this file wellname.001
8. Exit Windows Explorer
9. Run TWM
10. Open file wellname.001

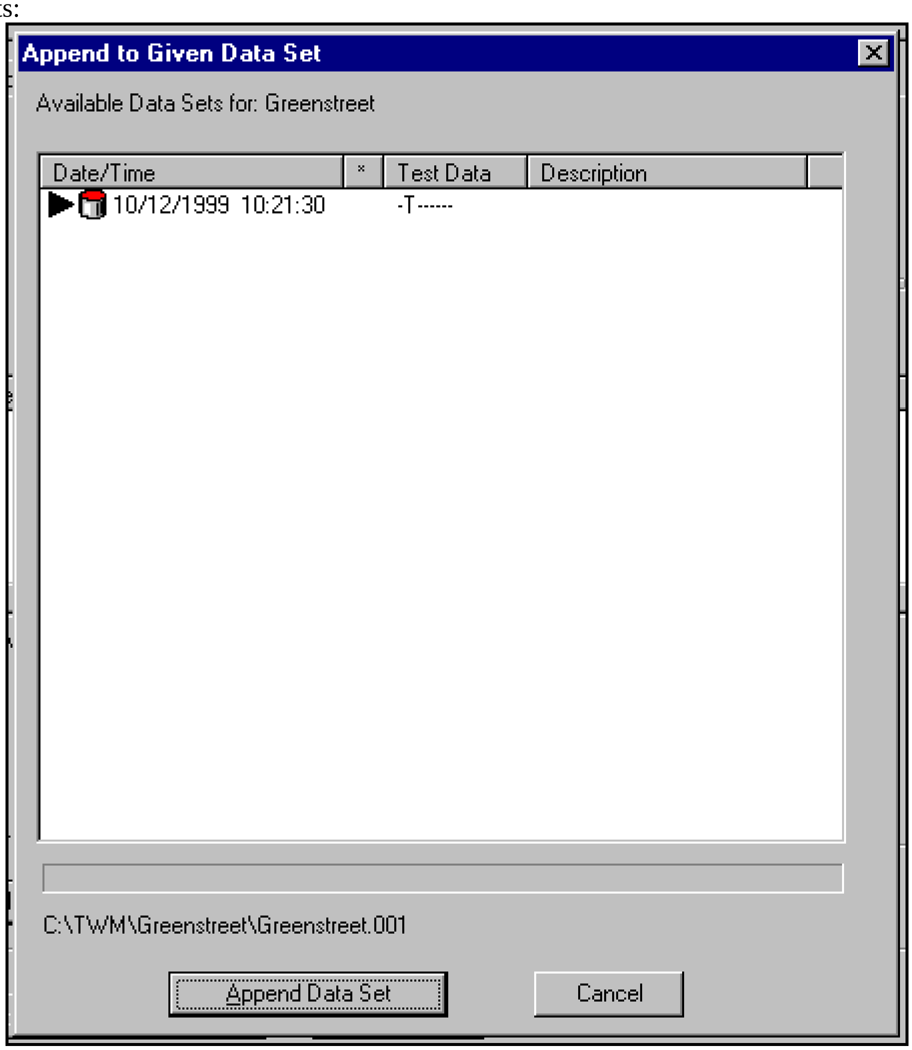
The file should be readable and you should be able to analyze the data or continue test by appending new data to the data already acquired.

7.4 - Append Test Data to Existing Data Set

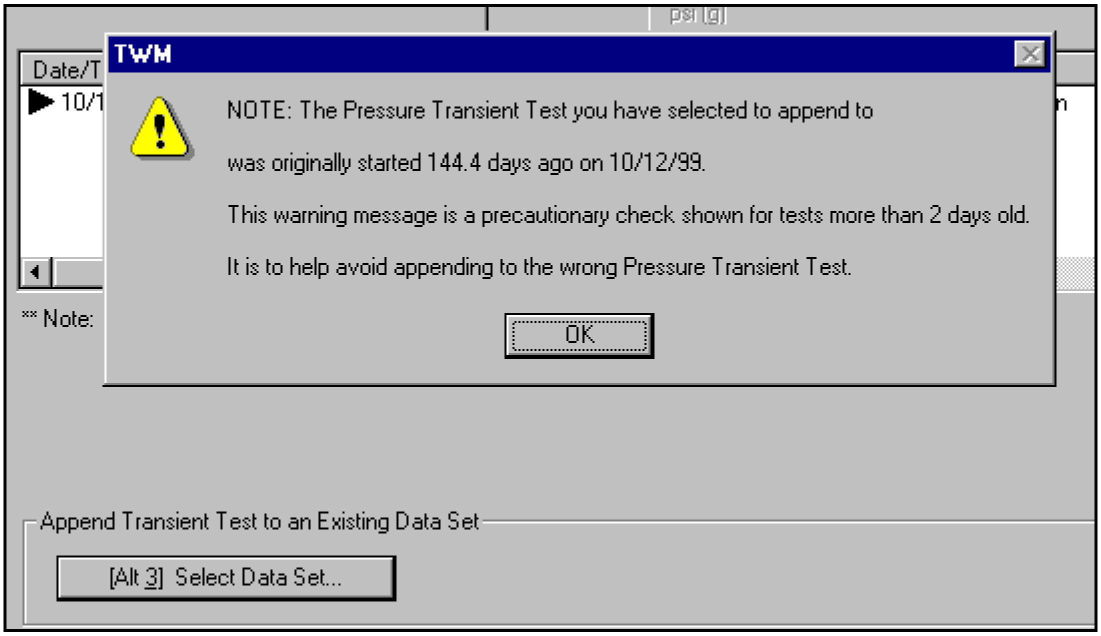
Sometimes it is necessary to interrupt the normal sequence of data acquisition during the test. For example some malfunction, such as a loss of external power source, has caused the program to halt and quit in the middle of a test. In these instances it is necessary to resume the test and append the additional data with the correct elapsed time. This task is performed by using the **Alt3** Select **Data Set** option, in the **Acquire mode, Pressure Transient Test Tab**:



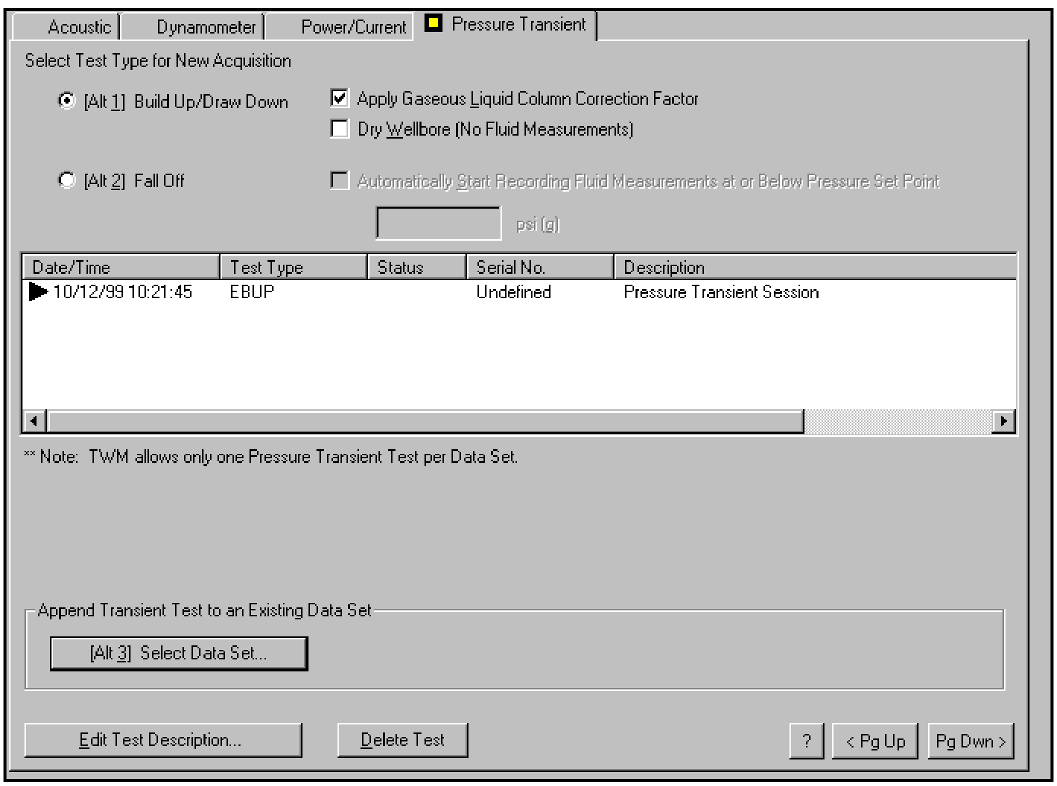
This displays the following directory of existing tests for the given well. The user then selects the test data file that contains the previous measurements:



Clicking on the **Append Data Set**, will set up the data file to accept additional data points. If the elapsed time since the last data point was taken and the current time exceeds two days the following alert message is displayed to minimize the chances of appending the data to the wrong test set.



Clicking **OK** will enter the data file name in the list box as shown in the following figure:

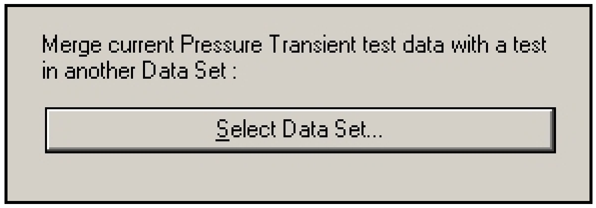


The operator then proceeds with the set up procedure as when initiating a new test.

NOTE: Do not obtain a new zero offset when the same pressure transducer is used during the continuation of the test data acquisition since all the pressure data will be merged and must be referenced to the original zero offset. If a different pressure transducer is used to append to the previous test, then the zero offset of the new transducer must be recorded before continuing with the test.

7.4.1 - Merging Data Sets

If after interruption of a test, the user has restarted a test and **created a new data set instead of appending** to the previous data set then it is possible to merge the two sets of data when recalling the data as shown in the following figure from the Pressure Transient test tab:



Clicking on this button opens a sequence of windows similar to those shown in the previous section.

7.5 - Recommended Procedure for Acquiring Acoustic Pressure Transient Data in Pumping Wells

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 following recommended procedure is designed to provide some guidelines to help reach that objective when testing wells that are produced using beam pumping.

1- Obtain all necessary data for acquisition and pressure transient analysis. Review and update base well file. 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 pump fillage and effective pump displacement.
3- If height of gaseous liquid column is significant perform a short duration (1hour) liquid level depression test (by closing the casing to flowline valve) to estimate the time required to depress the liquid level to the pump intake.
4- Inspect all well connections to flowlines, casinghead, tubing head, stuffing box, condition of valves, leaks etc. and report any problems to the operator so that they may be fixed before date of well test. It is important that the SV is holding otherwise there will be excessive back flow 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 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 pressure transient module 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 batteries are 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 and verify that the pump fillage and operation is the same as was established in step 2 and 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 flow rate for buildup interpretation.
9- Verify that all connections between the gas bottle and the remote fire gun do not have any leaks. Check all electrical connectors for tightness and protect them from rain. Place thermal insulating tube on the pressure transducer. Check connection to external battery and verify that the Well Analyzer (EXT BAT) light is on and the charger cable is connected to the laptop.
10- Start the TWM program and go through the Set Up procedure to get the zero offset of the pressure transducer. Select the Transient Test module and complete the test set up procedure. Use Logarithmic schedule unless there is a reason for selecting otherwise. Take a Pre-Shot and verify that the program is picking the fluid level correctly (adjust the signal window if necessary) and that the acoustic velocity and fluid level depth are computed correctly as established earlier (steps 7 and 8)
11- Start the buildup acquisition (START acoustic transient test) while the well is still pumping (first pressure value corresponds to PBHP). As soon as the program completes the processing 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 test at least for 30 minutes and check that the fluid level is picked correctly and al 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 time to liquid level as described in the TWM 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 test progress. Set the regulator pressure to 200 psi above the estimated future casing pressure to insure that shots will be taken at that time.
14- Check that the EXT. POWER indicator is lit; check all connections before leaving the well. Check that the laptop power management has been set to NEVER turn off the laptop and that the laptop will stay ON even when closing the lid. Close well analyzer case and protect from the environment. Wait until a shot is taken automatically before leaving the site.

15- When returning to the well, open the Well Analyzer and the laptop. Check the Progress screen and verify when the last shot was taken, when the next shot is due, the presence of soft shots (S), the casing pressure, time to liquid, etc. Take a MANUAL shot and observe the liquid level pick and depth calculation. 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- Make necessary adjustments to obtain accurate fluid level and depth values in subsequent shots.
17- Determine casing pressure increase rate and adjust regulator pressure. Check the pressure in Nitrogen bottle and battery voltage and replace them as necessary.
18- Copy all the data recorded to this point to a diskette, CD or USB removable memory as appropriate to the laptop in use. The objective is to transfer the data to an office computer for further analysis to determine if the test has run sufficiently for meaningful buildup interpretation or if the test should be continued.
19- If the test continues go back to step 14.
20- If the test is terminated, take a MANUAL shot and when the computer finishes processing the data select END Transient Test and exit the Pressure Transient Module.
21- Select the Acoustic Test module; select “shut-in” to indicate the well status ad take an acoustic record to establish the present value of Static Bottom Hole Pressure in the well base file.
22- Select Dynamometer Test. Connect the PRT to the polished rod. Open the tubing valve to the flowline, release the brake and start pumping unit.
23- Make dynamometer measurements to determine that the pump is operating normally.
24- Open slowly the casing valve to the flowline to SLOWLY reduce the casing pressure to its normal operating value. See NOTE below for ESP wells.
25- After the casing pressure has stabilized, repeat dynamometer measurements to verify that the pump is operating normally. If not then notify the operator of the problems that may be indicated.
26- If all is normal, stop the unit, disconnect dynamometer and remote fire gun. Transfer all data to external storage.
27- Start unit and verify that all is normal before leaving well site.

For wells produced with ESPs or PCPs the steps related to dynamometer measurements are not relevant.

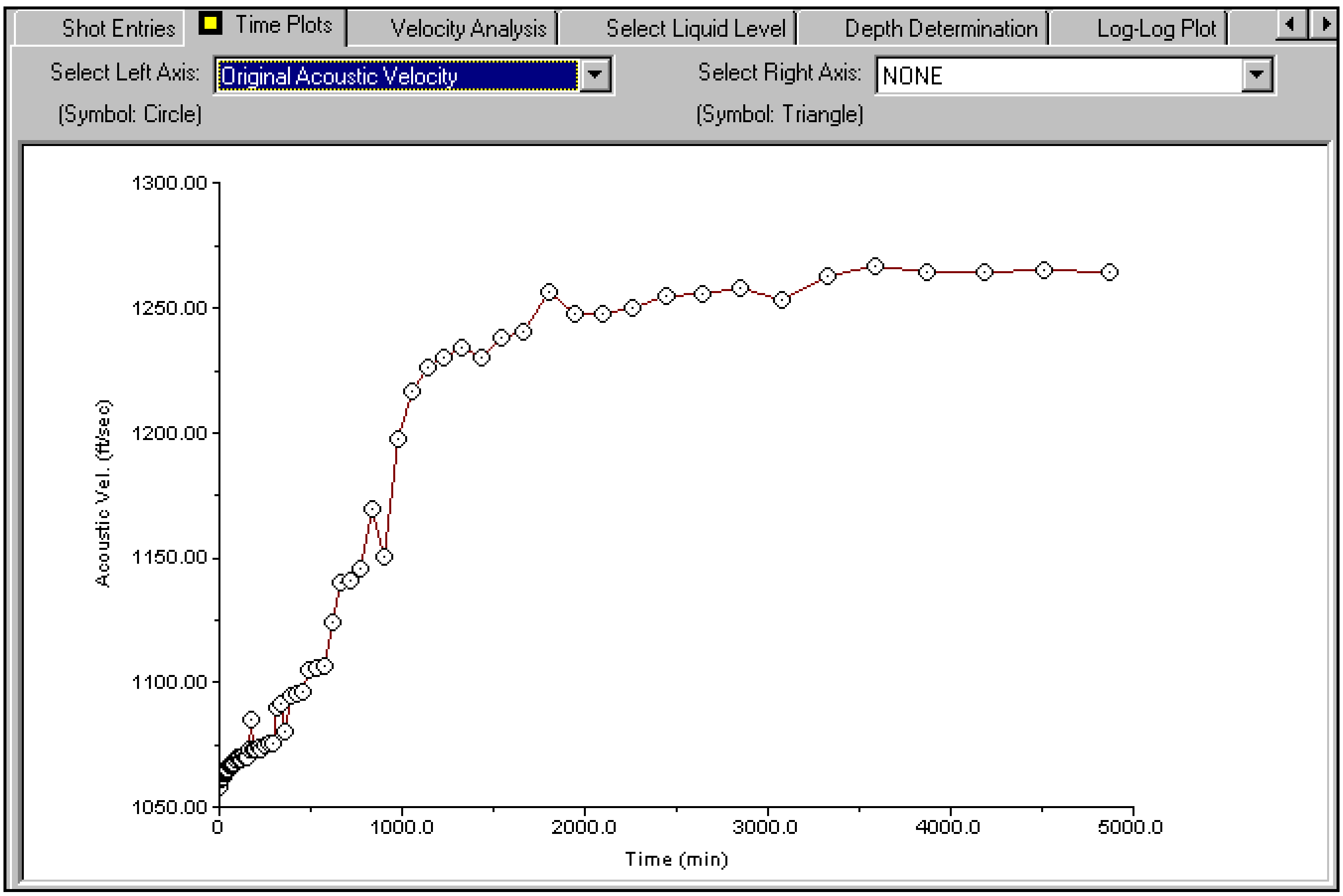
NOTE: For ESP wells it is very important to reduce the casing pressure <u>very slowly</u> since gas will dissolve in the downhole cable’s insulation as the pressure in the annulus increases during the buildup test. A rapid reduction of casing pressure will cause the insulation to swell and possibly damage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

7.6 - Analysis of Acoustic Pressure Transient Data

The first step for analysis of the acoustic data that has been acquired using the Well Analyzer in the programmed automatic acquisition is to verify the quality of the data by looking at the variations of key parameters during the test. In particular the acoustic velocity used to calculate the fluid level depth should be inspected for abnormal variations that do not follow the variation of pressure in the wellbore gas. This is undertaken using the Acoustic Velocity Analysis tab.

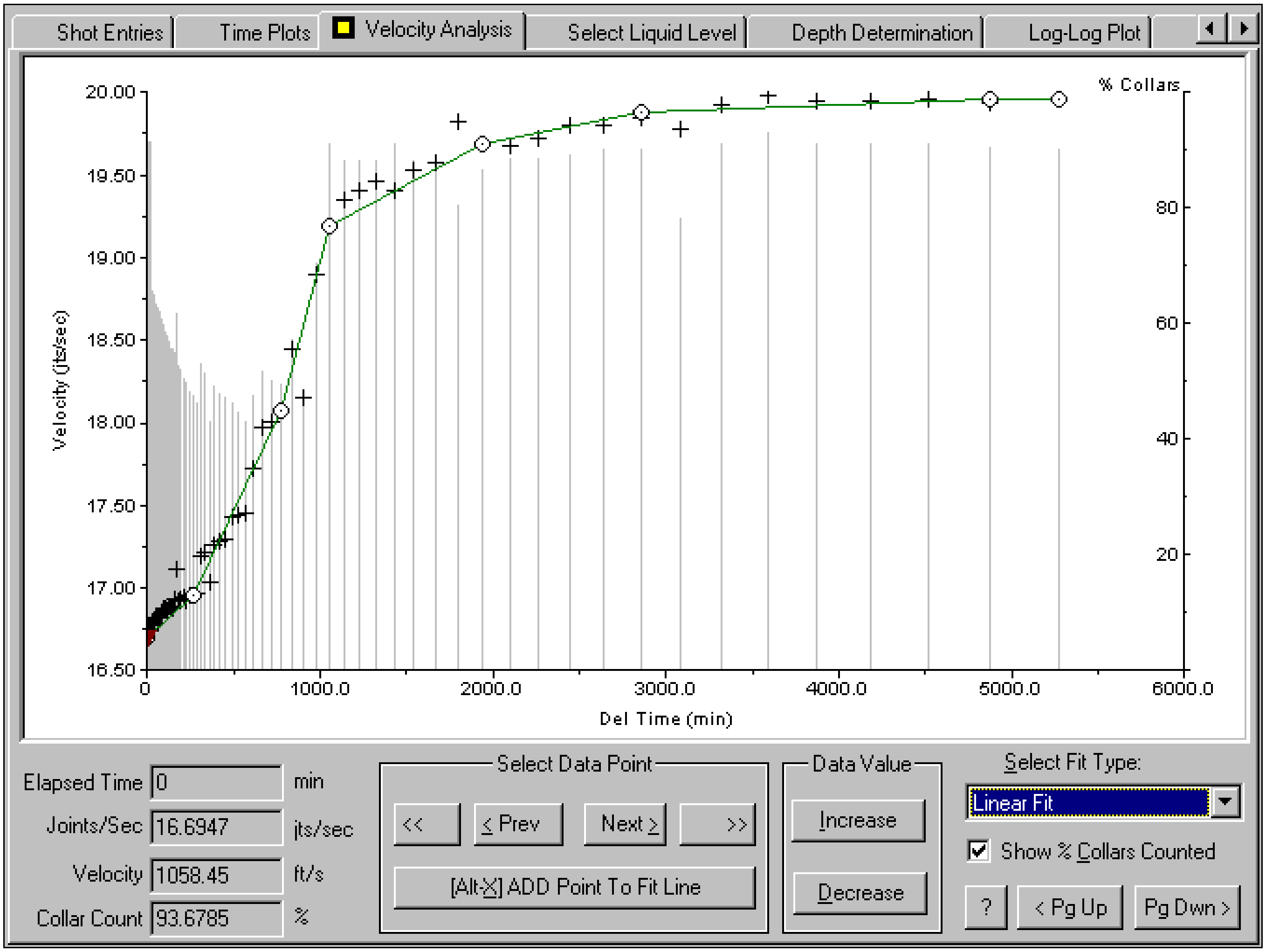
7.6.1 -Acoustic Velocity Analysis

The purpose of this tab is to give to the operator the ability to fit a smooth curve through the velocity data points in order to account for variations in acoustic velocity that have taken place during the test. These variations are due to changes in temperature, pressure and composition of the annular gas. The magnitude of the change will depend primarily on the magnitude of pressure changes. Variations in the noise level in the well may cause random variations in the determination of the collar frequency which show as discontinuities on the velocity vs. time graph as shown in the following figure obtained from the **Time Plots Tab** (which is described in detail in the next section):



These discontinuities in acoustic velocity result in discontinuities in the calculated BHP that do not correspond to the actual variation in bottom hole pressure and need to be excluded from the calculated BHP.

It is necessary, therefore, to eliminate the velocity "bumps" by smoothing the velocity data using the **Velocity Analysis Tab**:



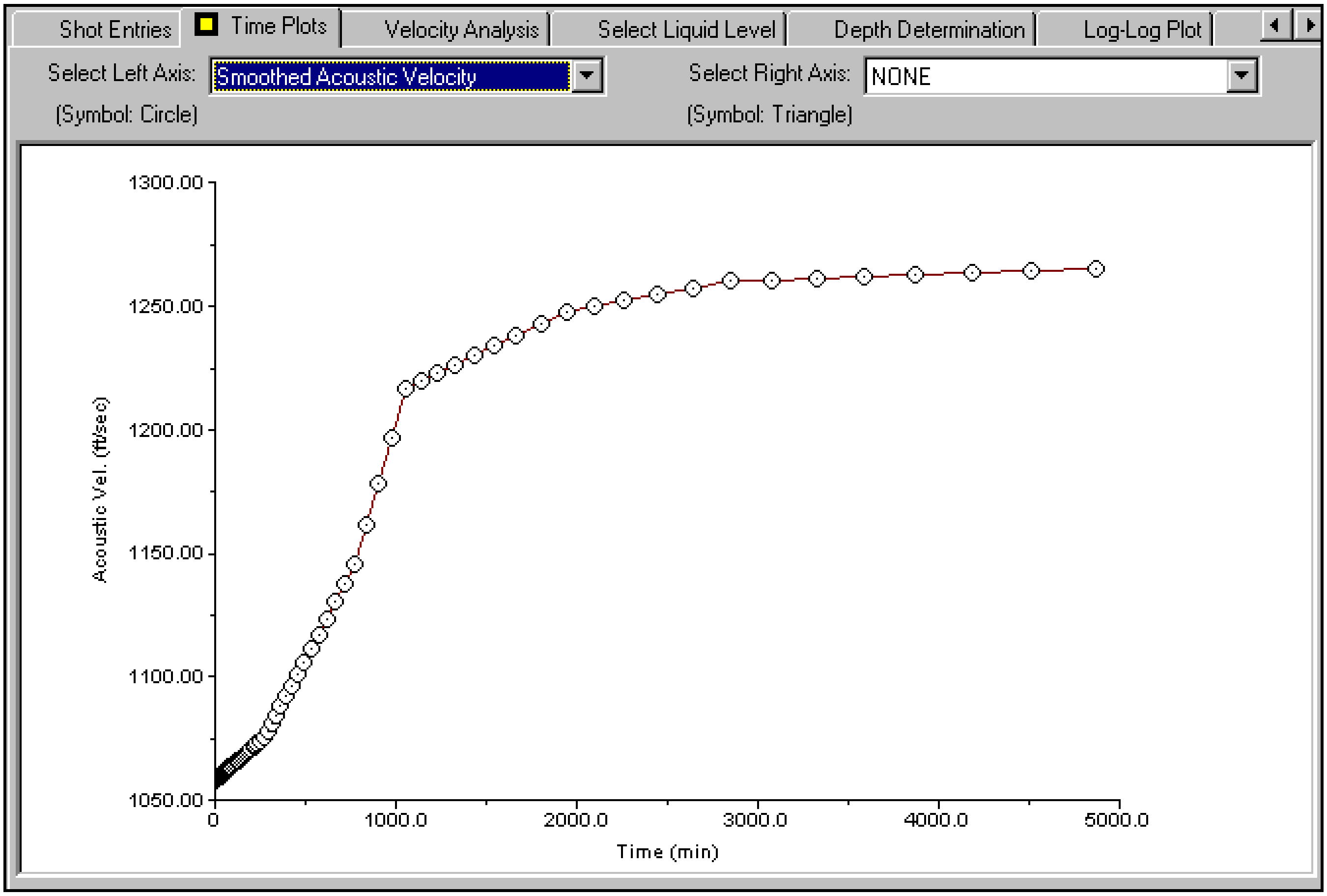
This figure shows all the velocity data points (small crosses) that have been computed from the acoustic traces recorded during the test. Note that although there seems to be a lot of scatter, the vertical scale (jts/sec) is amplified which exaggerates the differences between readings. The small circles indicate the data points that the user has selected to be included in the smoothed velocity variation plot.

The objective is to choose (using the **Select Data Point** buttons) an adequate number of points that will describe smoothly the variation in velocity. In general 5 to 7 points will be more than sufficient. This smoothing operation can be repeated as many times as desired in a trial and error mode, since the original data is not affected.

The bar-graph (vertical thin lines) shows the percentage of collars that were counted for each shot. The user should preferably select only points where this percentage is a maximum so as to insure that the most accurate values of velocity are used in the calculations. The numerical information for the point that is selected is displayed at the bottom left corner of the screen.

The smoothing technique is selected using the **Select Fit Type** pull-down menu at the bottom right. The choices are **No Fit Applied** and **Linear Fit.**

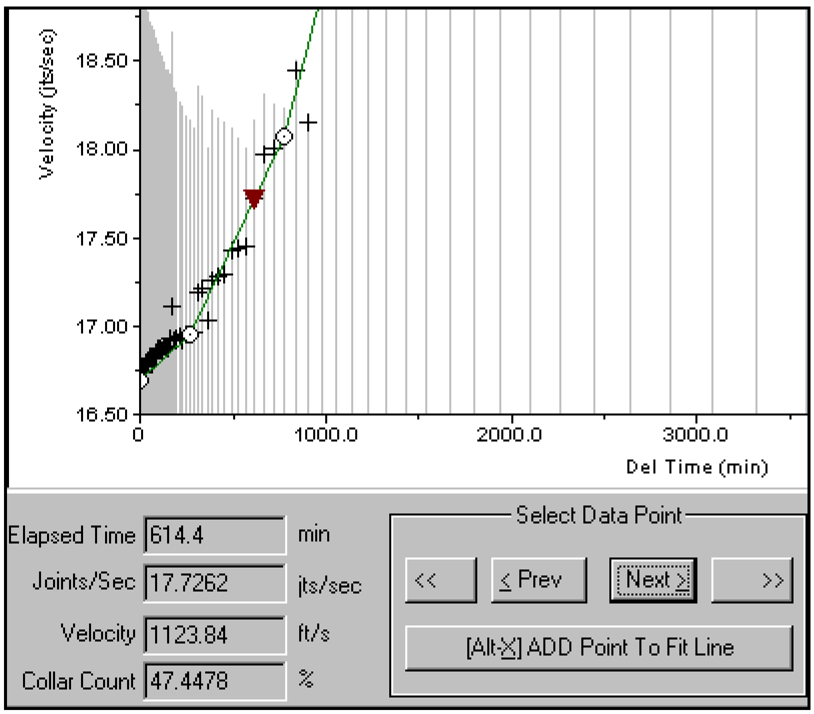
After having selected the points and the fit method, returning to the **Time Plots** window and selecting "Smoothed Acoustic Velocity" shows the result of the smoothing operation, as shown in the following figure in terms of ft/second instead of joint/second:



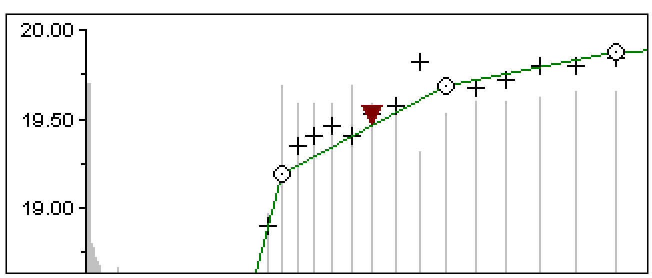
7.6.1.1 - Procedure for Velocity Smoothing

The selection of points to be included in the velocity function is undertaken using the **Next** and **Prev** buttons in the **Select Data Point** controls at the bottom of the screen. The data point currently selected is indicated by the **dark triangle** and the corresponding numeric values of the Elapsed Time, Joints/sec. Velocity and % Collar count are displayed in the boxes to the left of the controls.

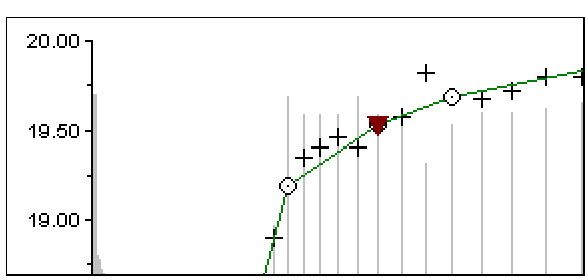
(Since the data is compressed at the beginning of the test, it may be necessary to repeatedly use the **Next** button until the select triangle moves away from the origin and is clearly seen)



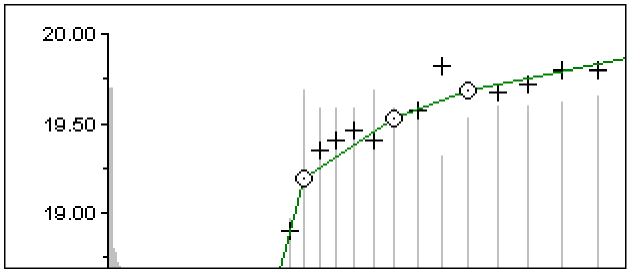
The following figure shows a portion of the data with a new point selected to be included in the fit:



After selecting the point and clicking the **ADD Point to Fit Line** note that the line now passes through the point that was selected:

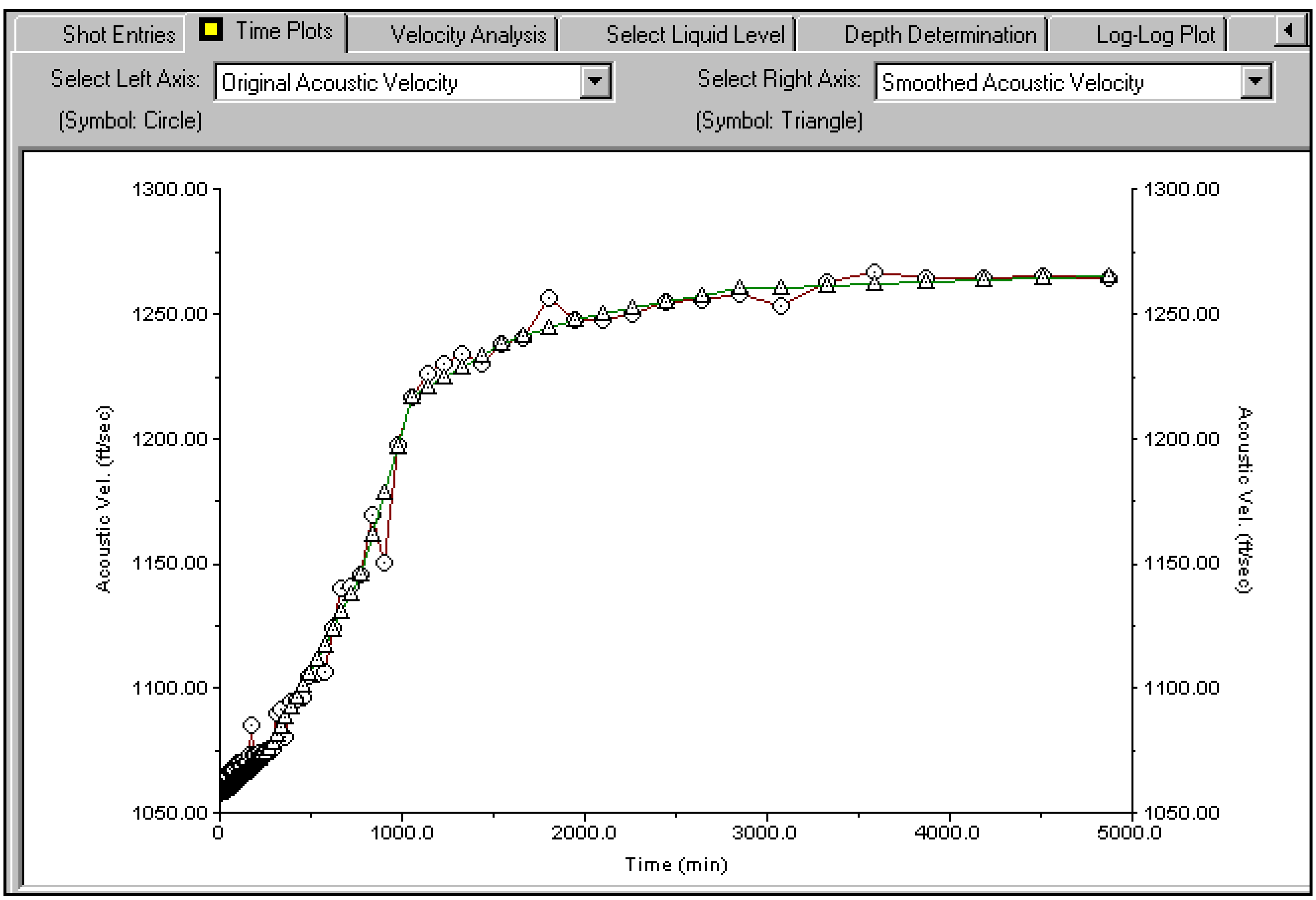


The symbol for the now-included point changes from a cross to a circle, as seen below.



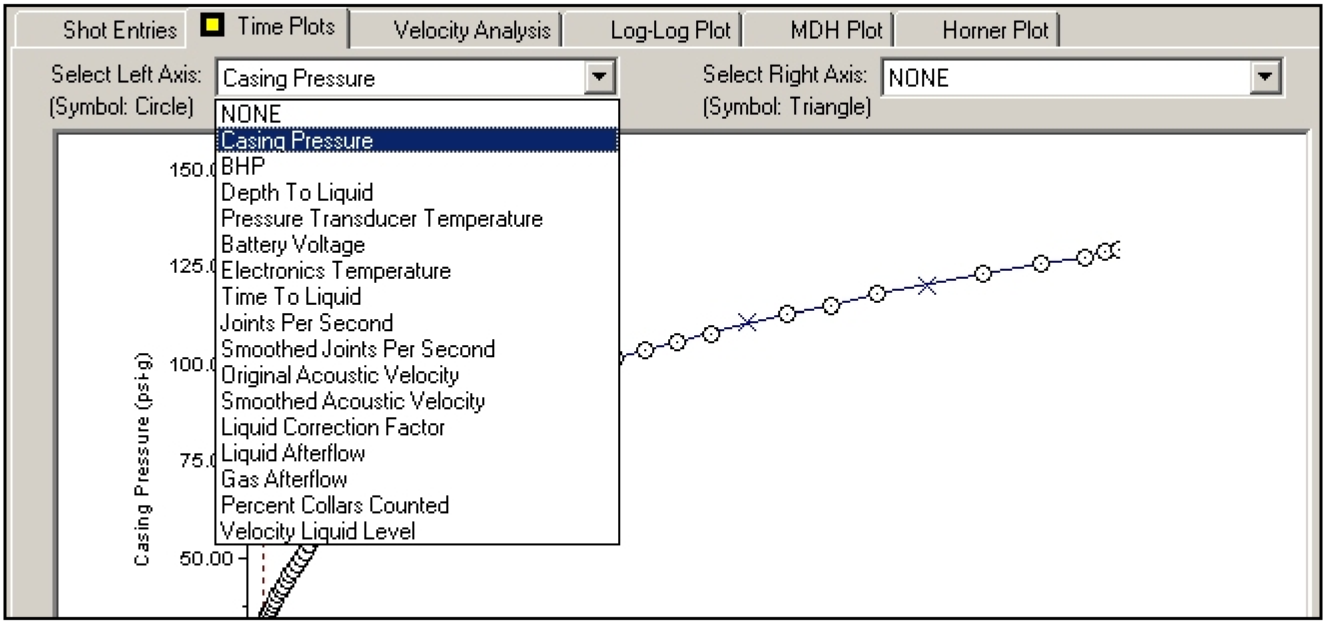
These steps are repeated until the user is satisfied that the line represents the variation of acoustic velocity during the transient test. Note that the original data is NOT MODIFIED but a new relation is generated in terms of **Smoothed Acoustic Velocity** or **Smoothed Joints per Second**.

The original and the smoothed data may be plotted on the same graph using the **Time Plots Tab**, as shown below:

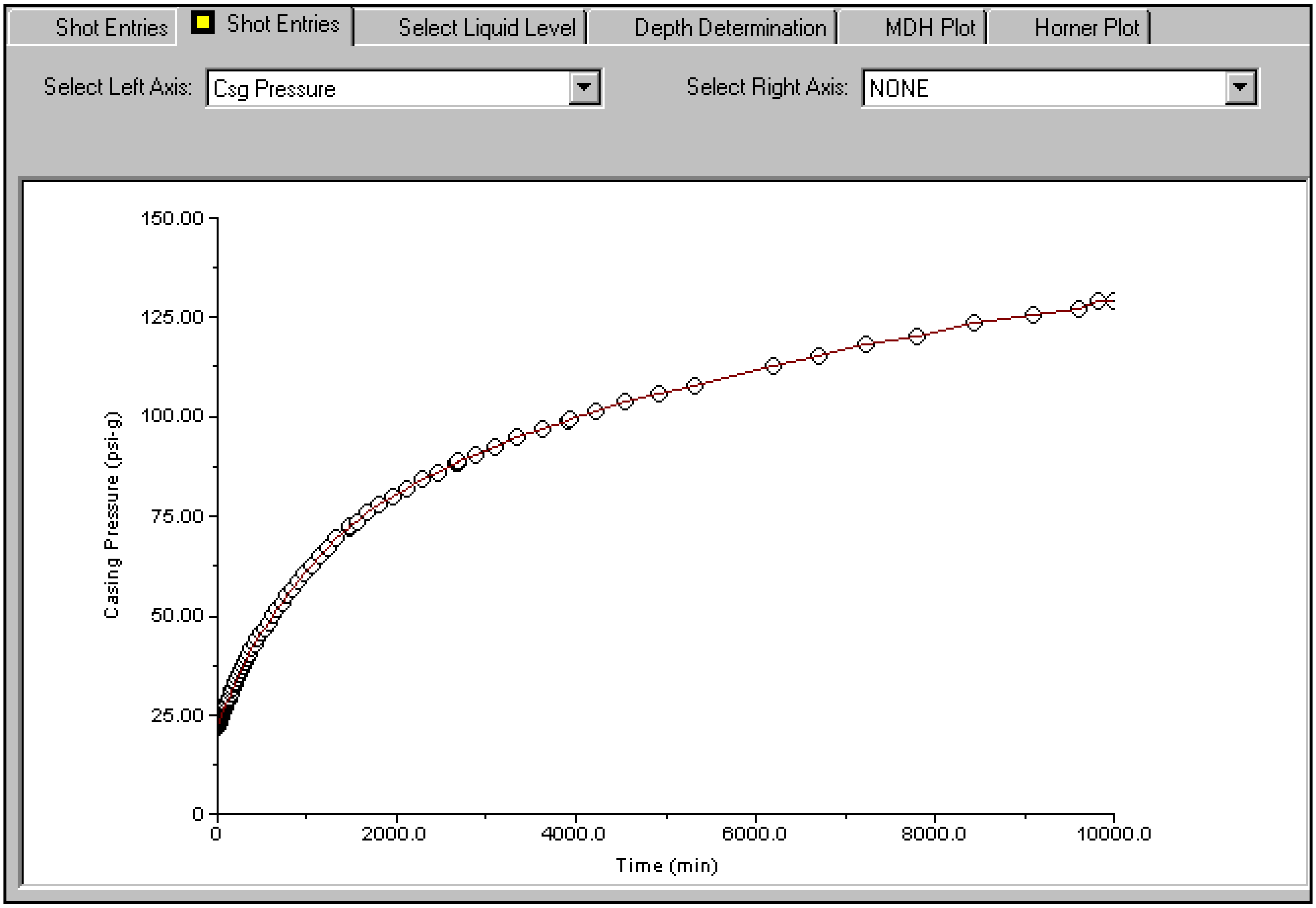


7.6.2 - Plotting of Data and Results vs. Time

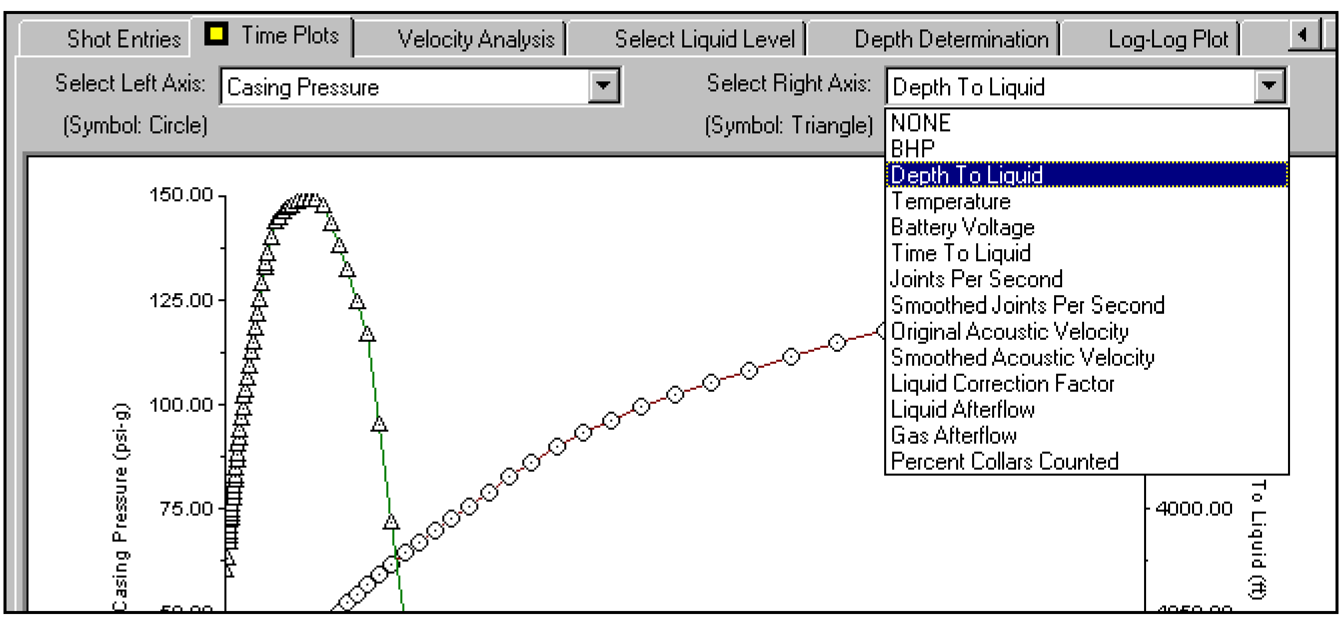
The **Time Plots Tab** accesses all the graphic routines that are used to monitor the progress of the test and the quality of the data that has been acquired. The following pull down menu shows the variables that can be selected for graphing:



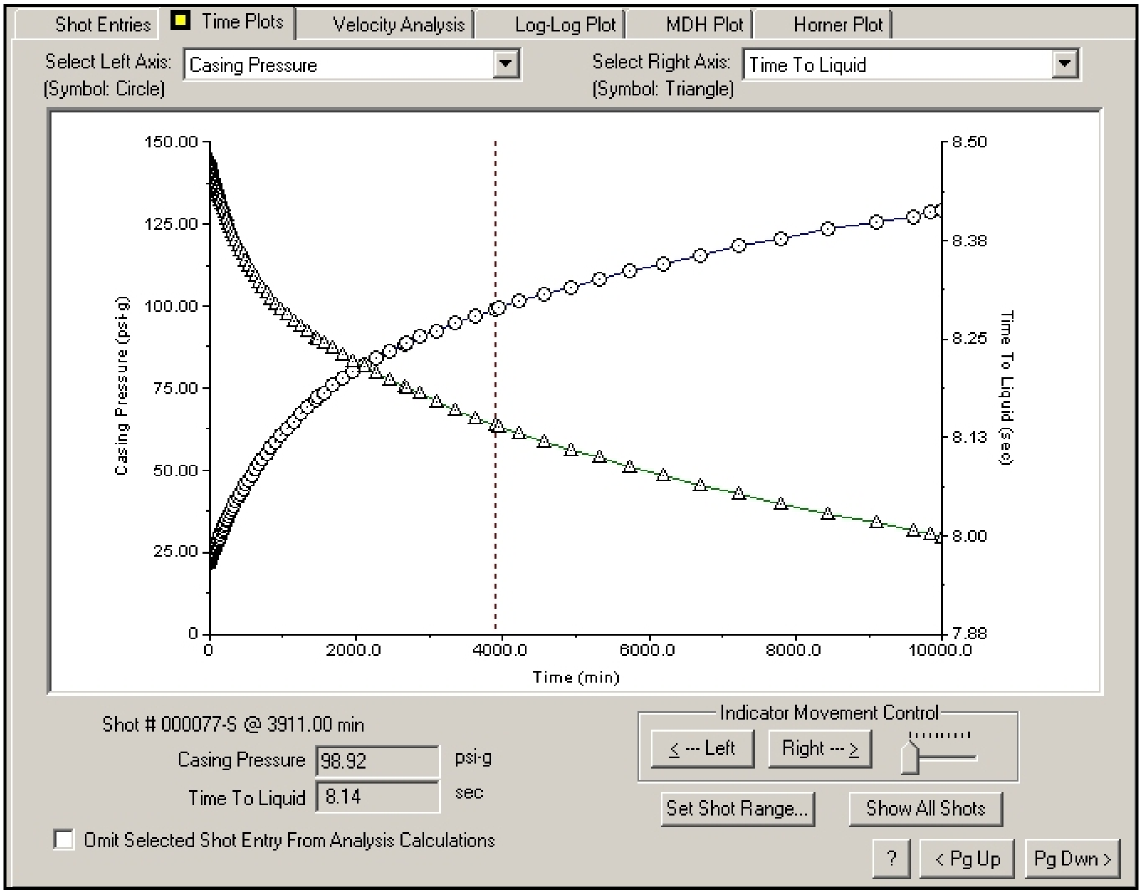
The selection results in the following graph of Casing Pressure vs. Time:



Plotting Two Variables allows correlating the changes of two variables in order to verify that the variations correlate with the expected behavior of the fluids in the wellbore. Each variable is selected with the corresponding pull down menu and is plotted with its corresponding symbol and axis:



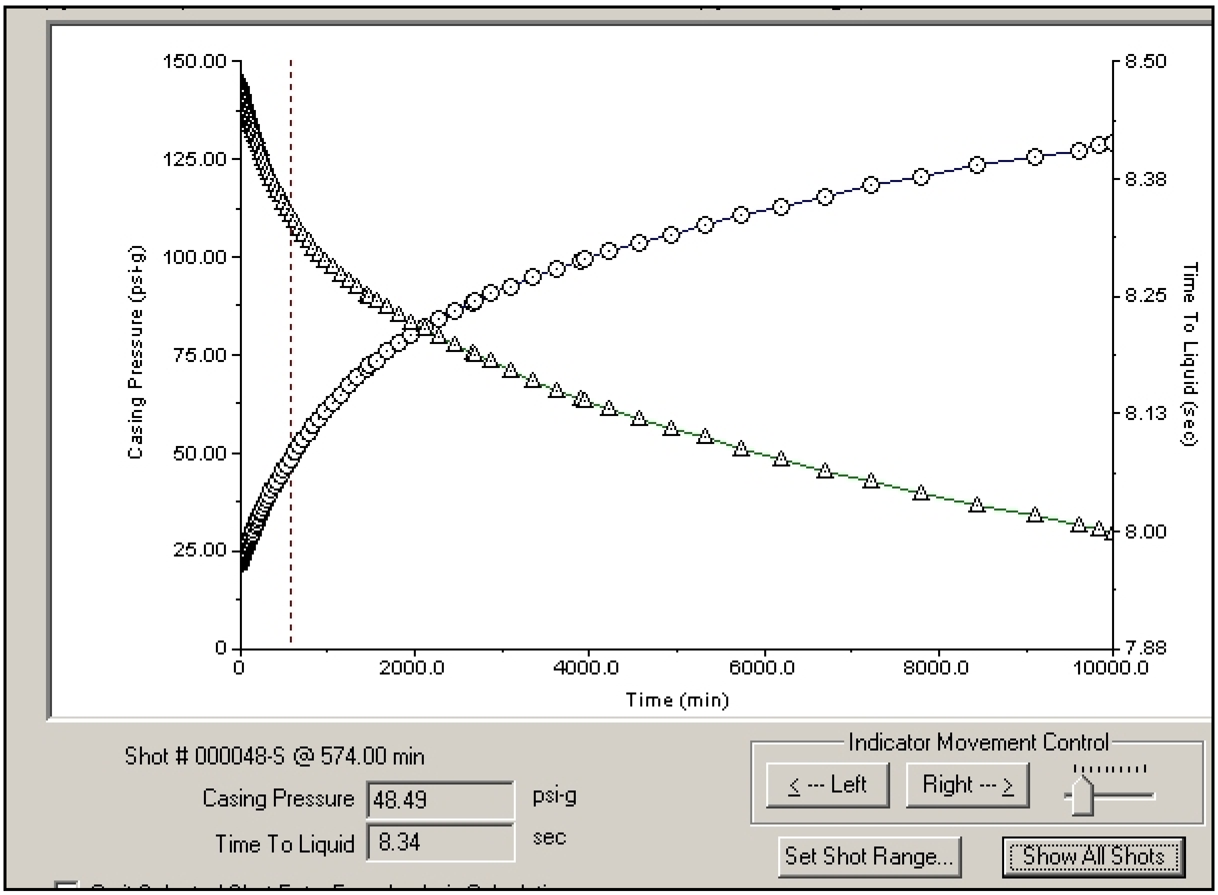
The following plot shows the relationship between the casing pressure and the time to the liquid level reflection:


Shot Entries
Time Plots
Velocity Analysis
Log-Log Plot
MDH Plot
Horner Plot
Select Left Axis: Casing Pressure
(Symbol: Circle)
Select Right Axis: Time To Liquid
(Symbol: Triangle)
150.00
125.00
100.00
75.00
50.00
25.00
0
Casing Pressure (psi-g)
8.50
8.38
8.25
8.13
8.00
7.88
Time To Liquid (sec)
0
2000.0
4000.0
6000.0
8000.0
10000.0
Time (min)
Shot # 000077-S @ 3911.00 min
Casing Pressure 98.92 psi-g
Time To Liquid 8.14 sec
Omit Selected Shot Entry From Analysis Calculations
Indicator Movement Control
< --- Left
Right --- >
Set Shot Range...
Show All Shots
?
< Pg Up
Pg Dwn >

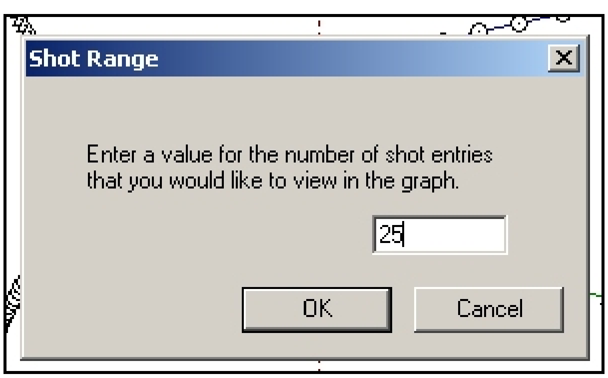
7.6.3 - Editing of Test Points

Note that the previous figure shows a vertical indicator line that can be moved from point to point using the **Indicator Movement Control** buttons. As the indicator is placed on a data point the corresponding shot number (Shot # 000077S) elapsed time (@3911.00 min.) casing pressure (98.92 psig) and time to liquid (8.14) are displayed at the lower left. If such point should be ignored in the BHP calculations then the **Omit Selected Shot** box should be checked. This feature allows editing the data without having to return to the progress screen.

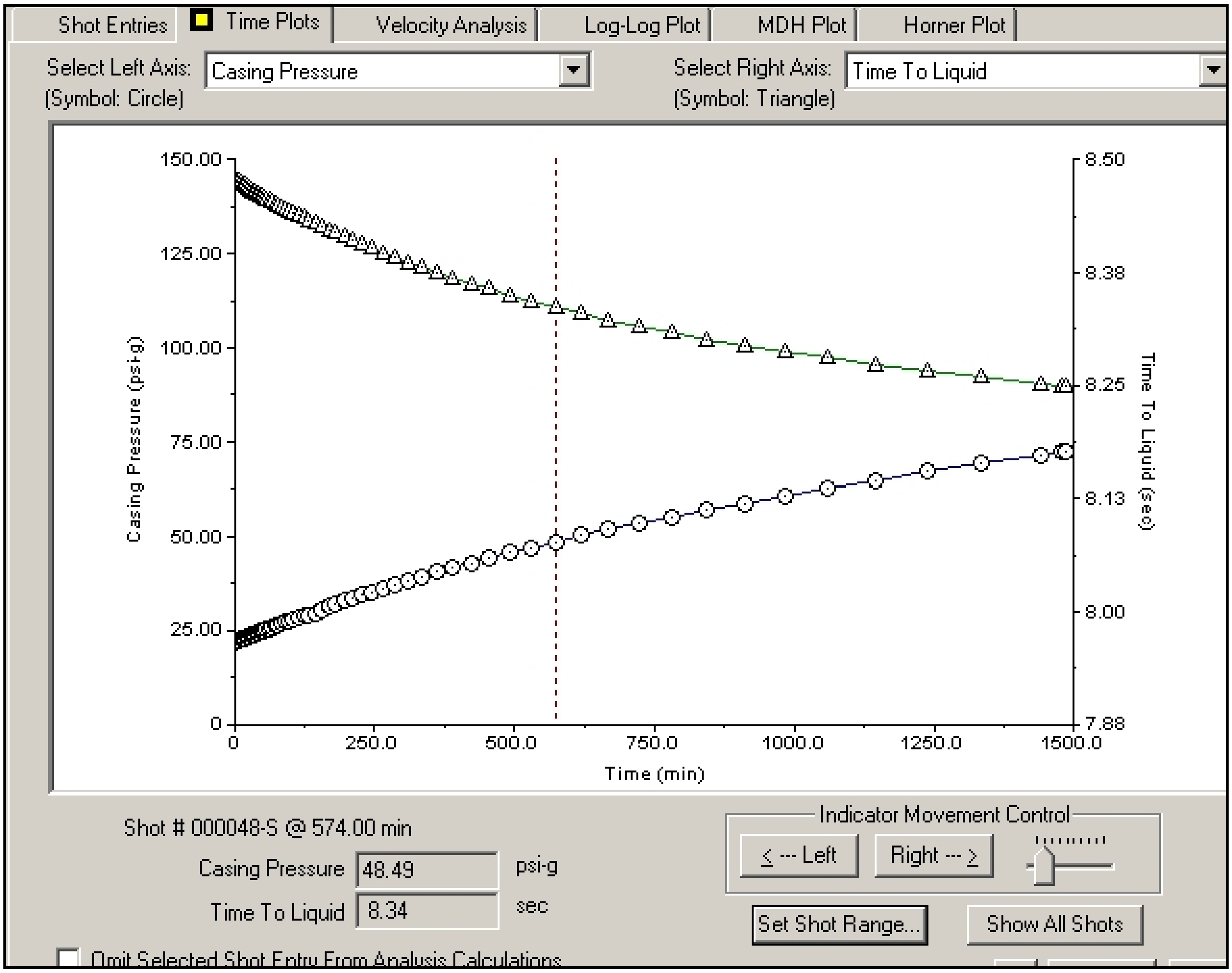
The section of the data that is viewed on the screen can be controlled by selecting the number of points to be displayed in the vicinity of the vertical indicator by clicking on the **Set Shot Range** button:



and entering the number of points to be viewed:



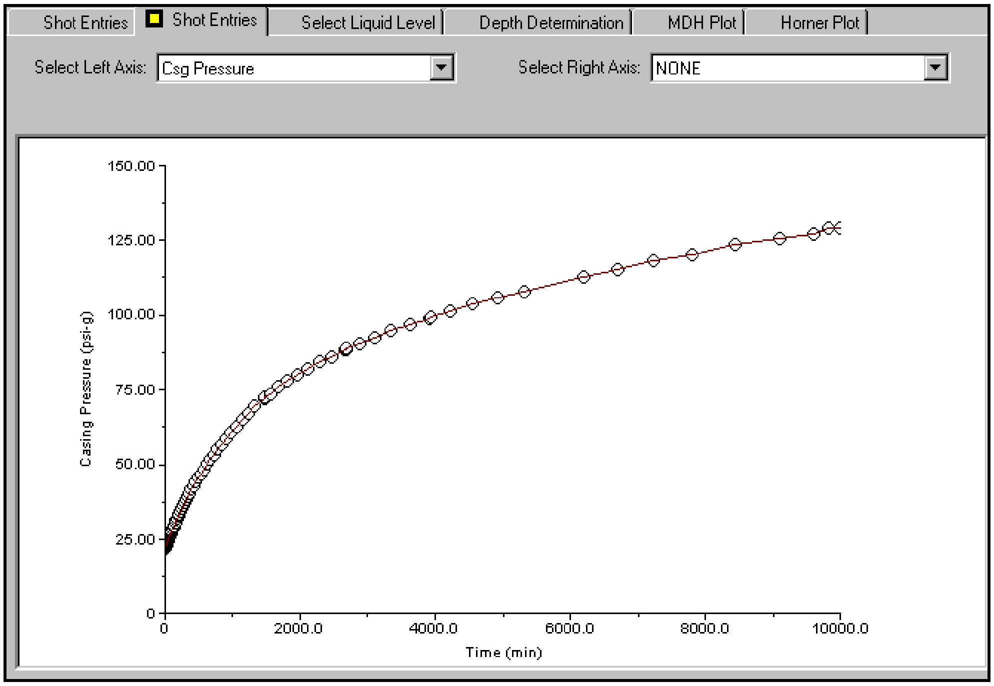
This results in the following display:



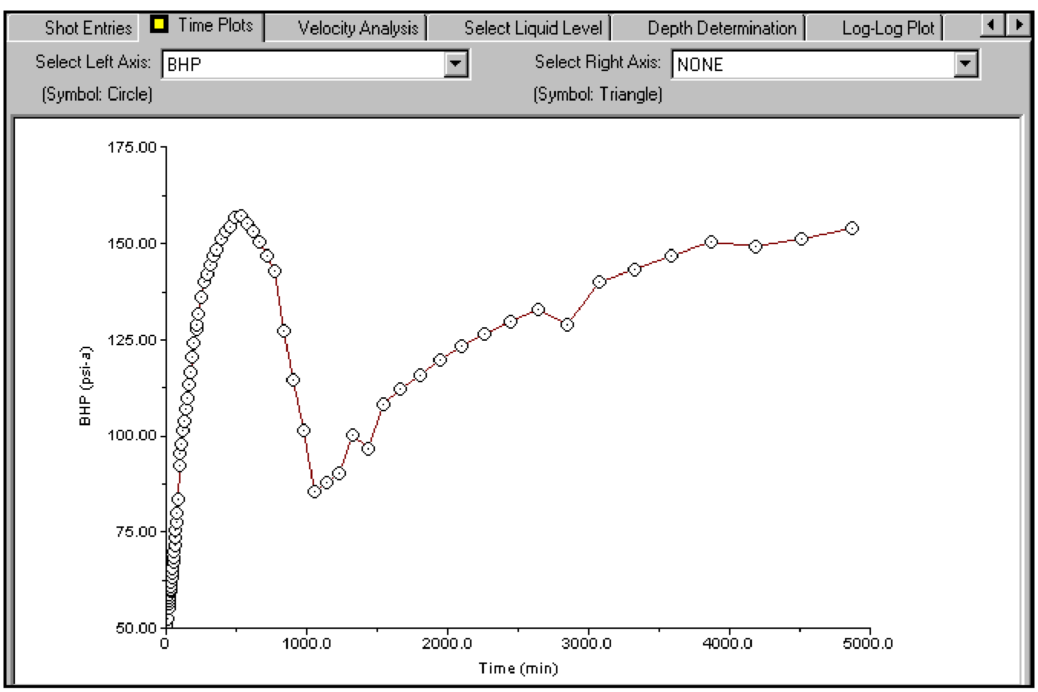
This is especially useful at the beginning of a test where the shots are very frequent. The original display is obtained by clicking on the Show **All Shots** button.

7.6.4 - Samples of Available Time Plots

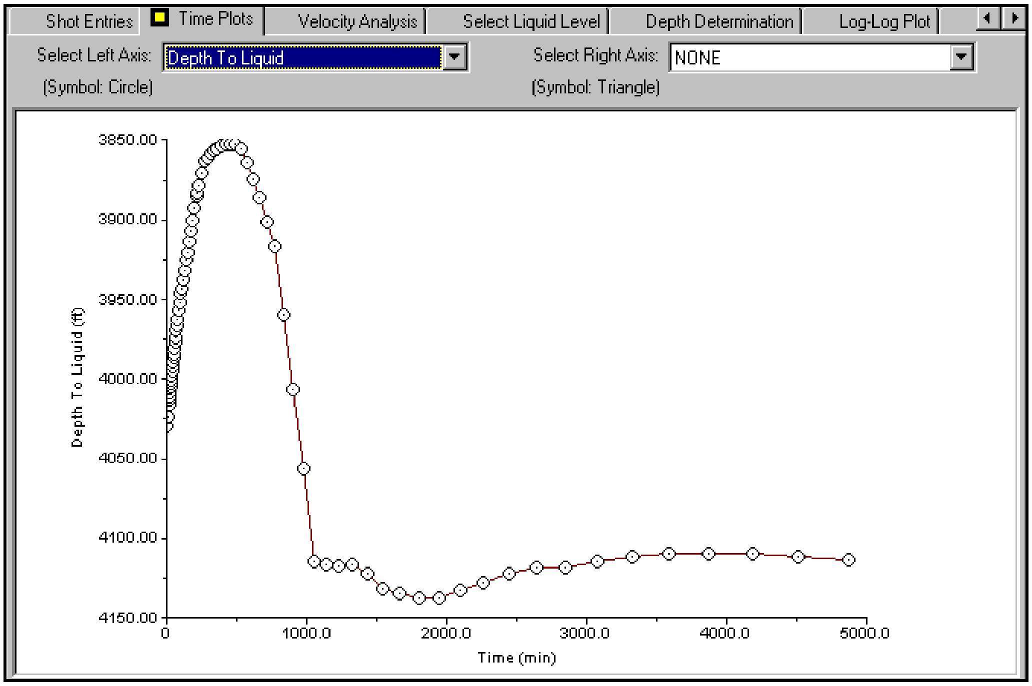
Csg Pressure vs. Time: displays the measured casinghead pressure:



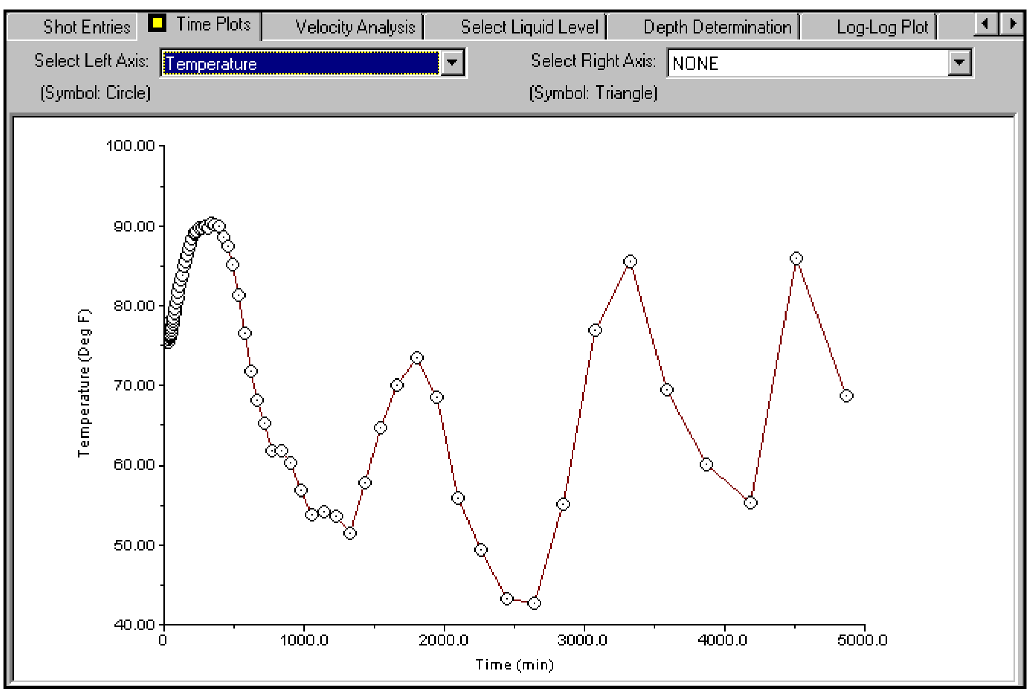
BHP vs. Time: Displays the last set of computed bottom hole pressures.



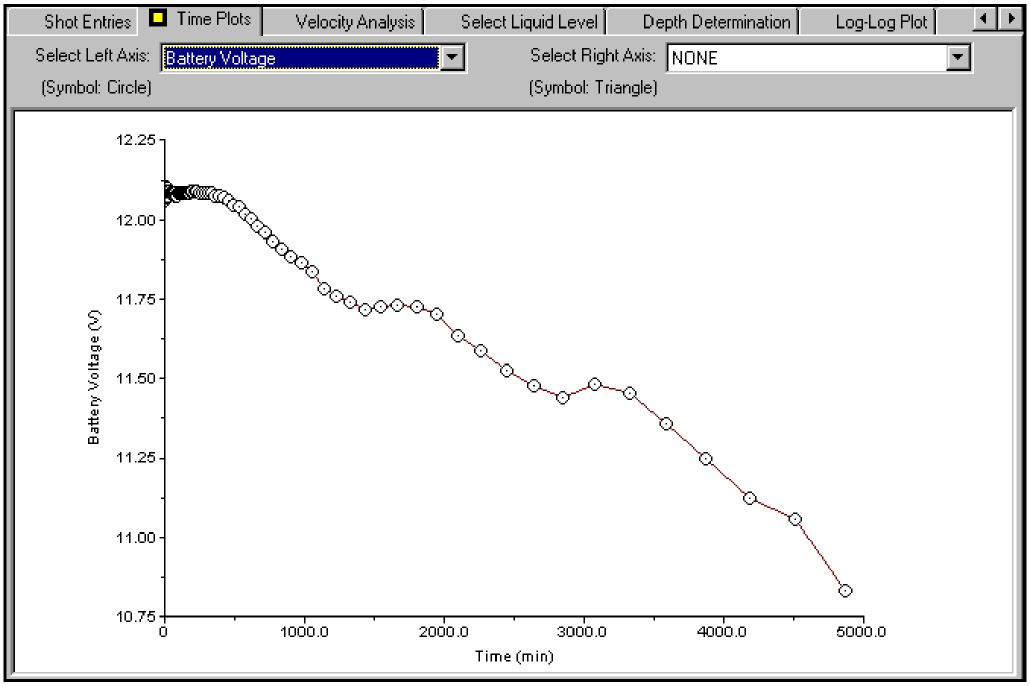
Depth to Liquid: Displays the latest set of computed depths to the gas/liquid interface vs. time:



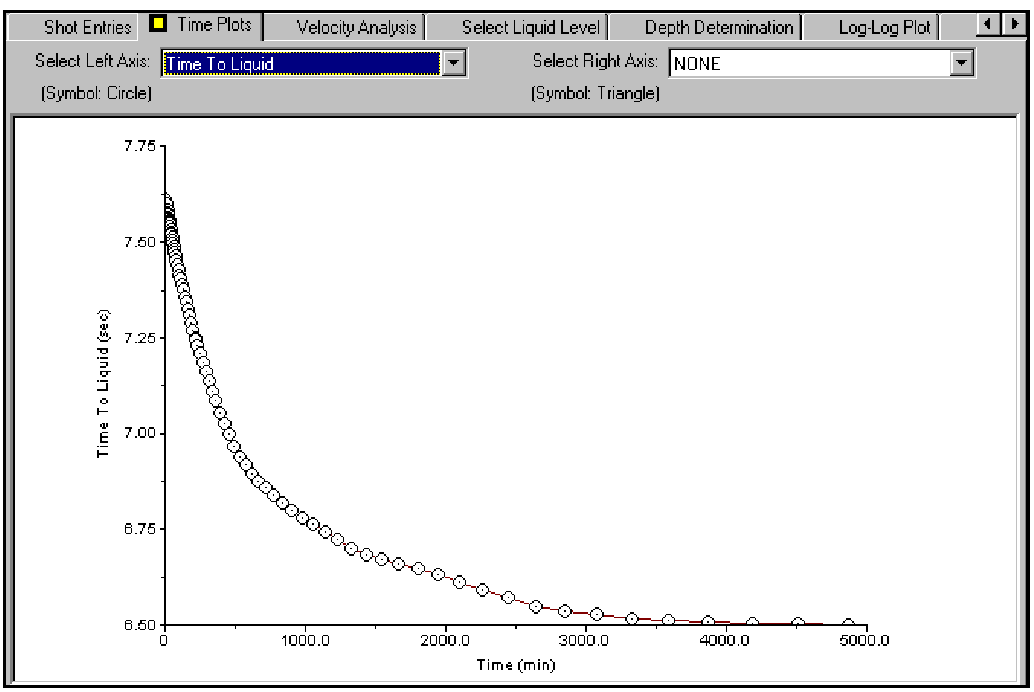
Temperature: Displays the daily temperature variation of the pressure transducer:



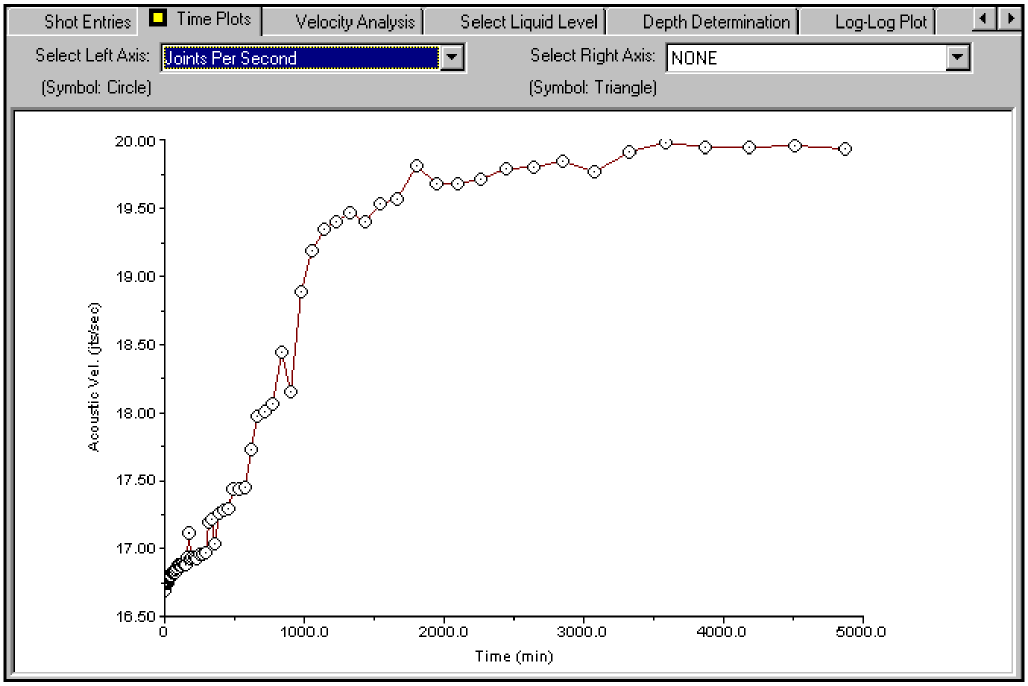
Battery Voltage: Displays the voltage as a function of time, showing the discharge rate:



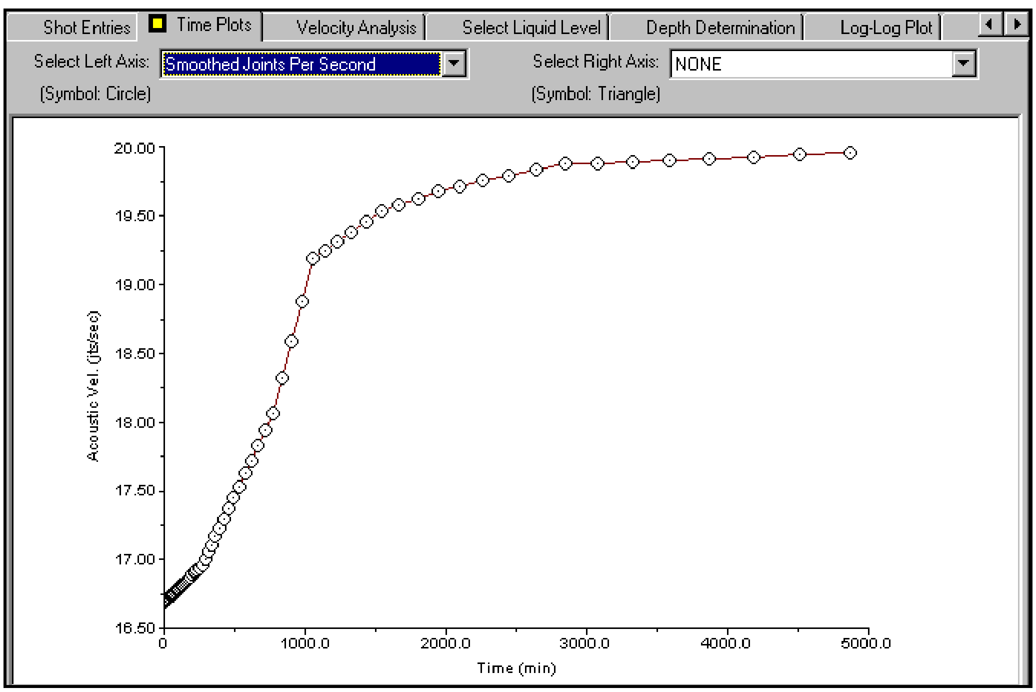
Time to Liquid: Displays the time to the liquid level echo.



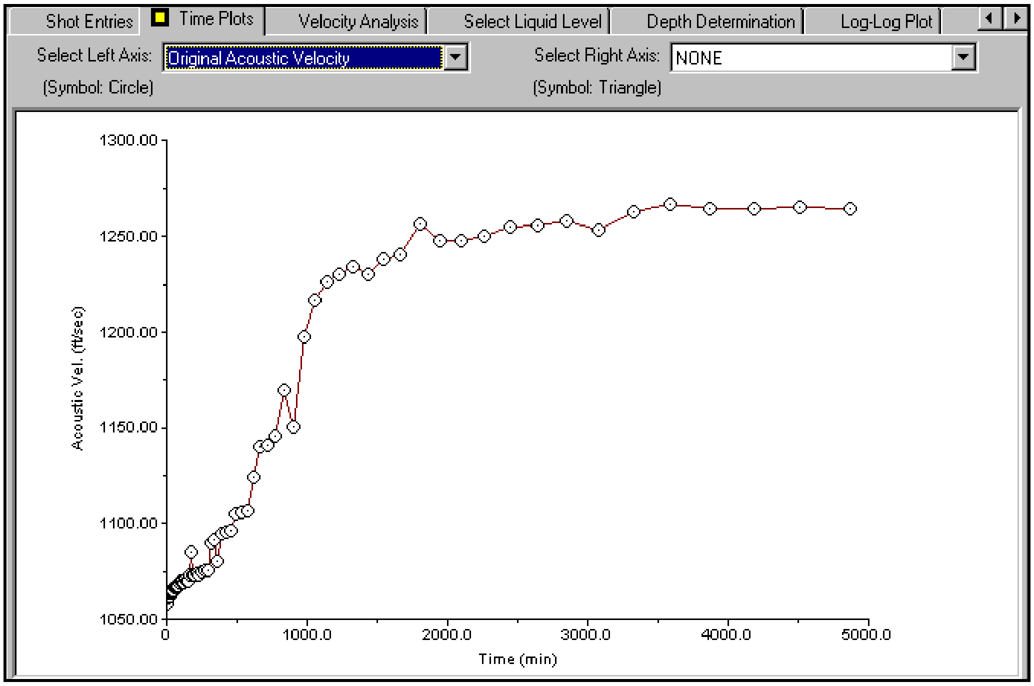
Joints Per Second: Displays the acoustic velocity as determined from the collar count.



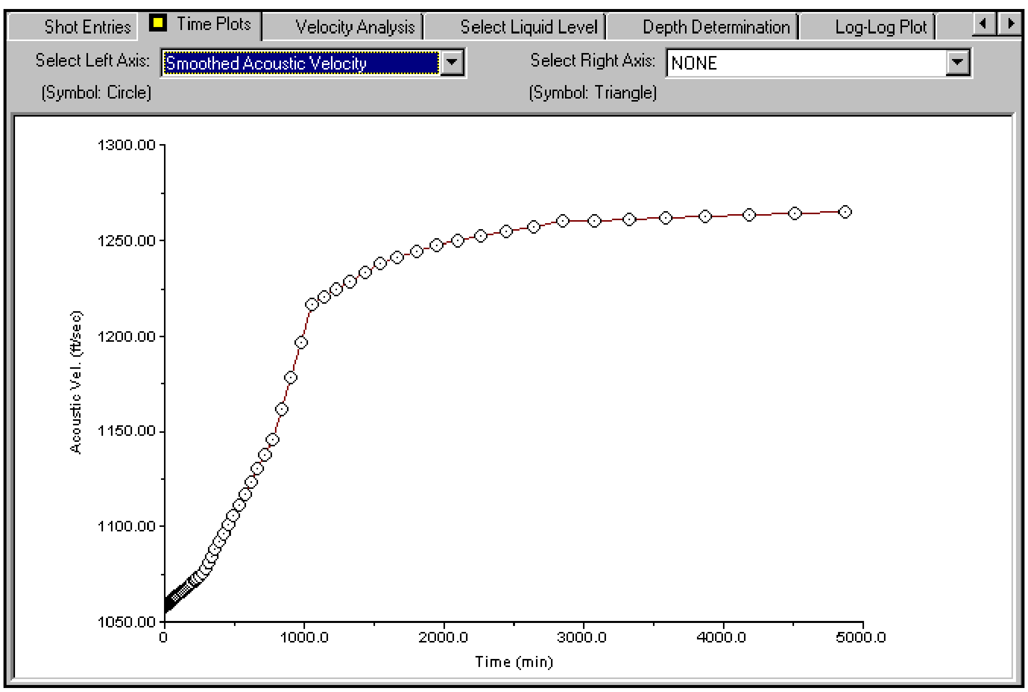
Smoothed Joints Per Second: Displays the collar frequency corresponding to the curve fit selected by the user.



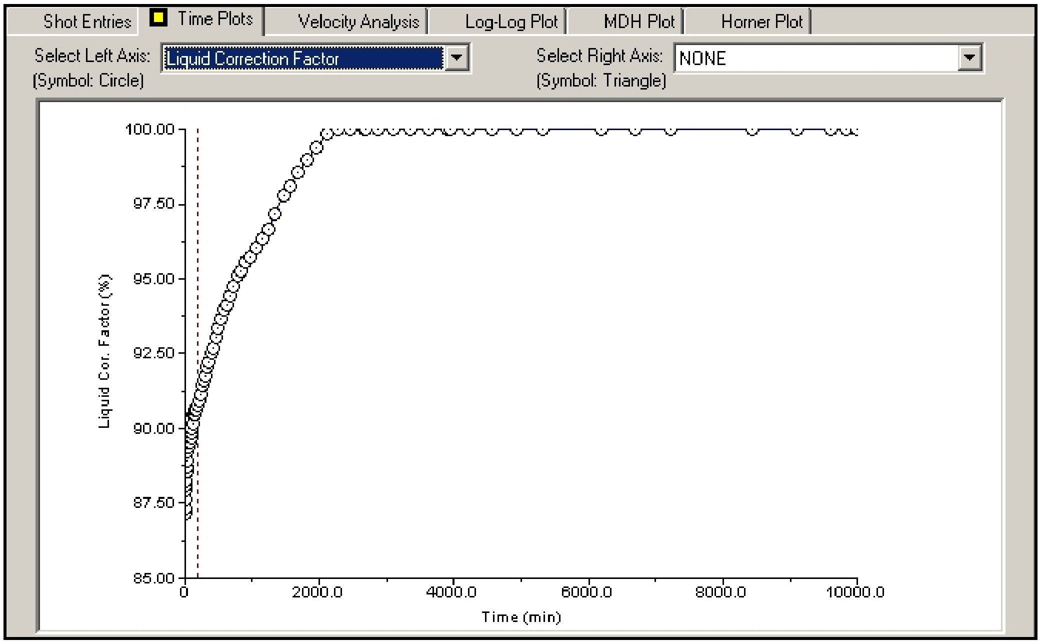
Original Acoustic Velocity: Displays the acoustic velocity as computed from the collar count.



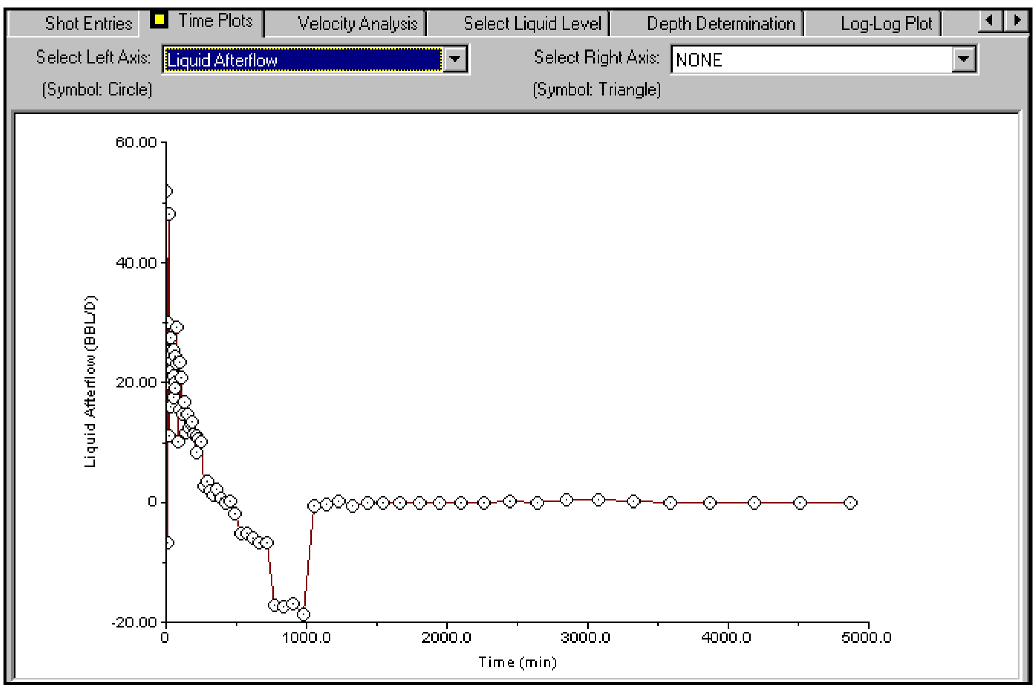
Smoothed Acoustic Velocity: Displays the last computed set of acoustic velocities vs. time fitted to the user's selection.



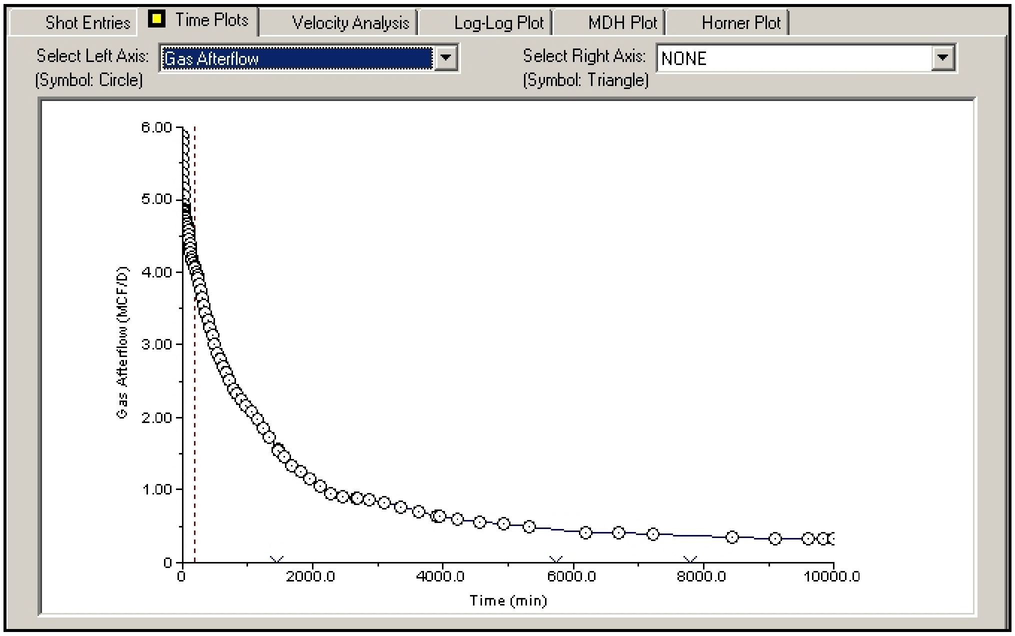
Liquid Correction Factor: displays the % Liquid in the annular fluid column as a function of time:



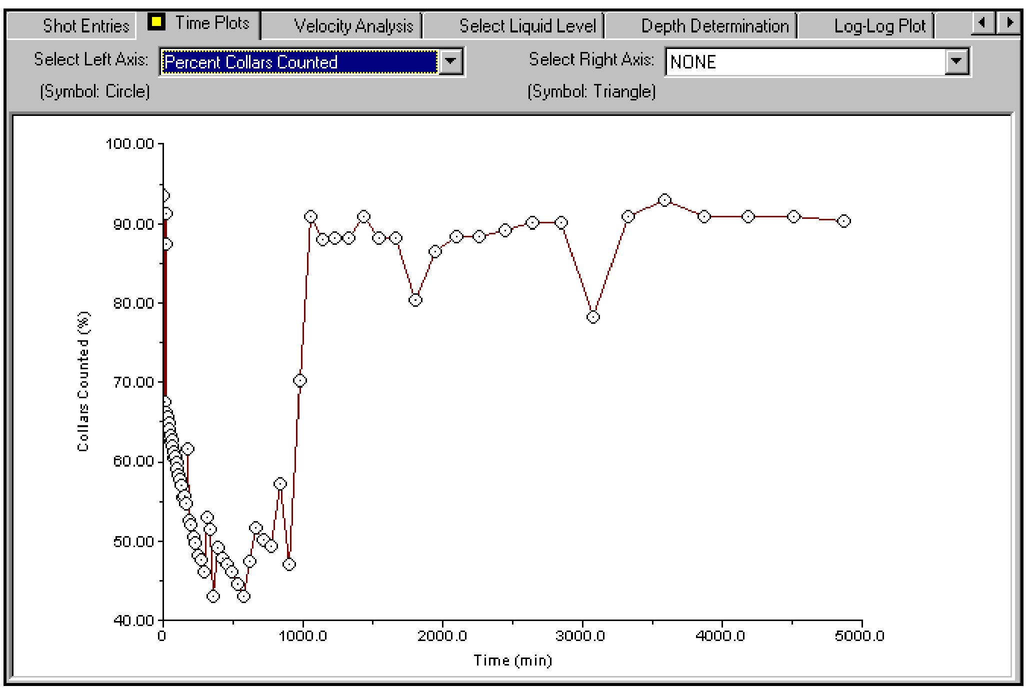
Liquid Afterflow: Displays the rate of liquid entry/exit in the well after shut-in.



Gas Afterflow: Displays the rate of gas accumulation in the well after shut-in:



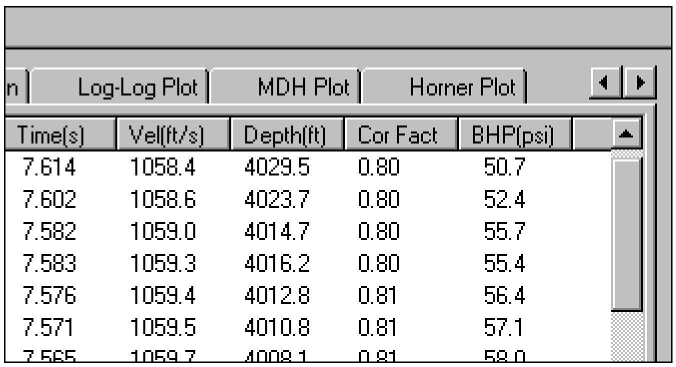
Percent Collars Counted vs. Time: displays the number of counted joints as a percentage of the total number of joints:



7.7 - Diagnostic Graphical Output

Although these plots provide some analysis of the transient pressure test data, they are intended to be primarily for DATA QUALITY CONTROL at the well site. Further detailed analysis of the transient test may be undertaken off-line using specialized transient pressure analysis packages to which are fed the results of the TWM pressure transient program through the EXPORT file command described in section 6.7 of this manual.

The diagnostic plots are displayed by using the tabs located at the far right of the screen. The arrows allow displaying the additional tabs:

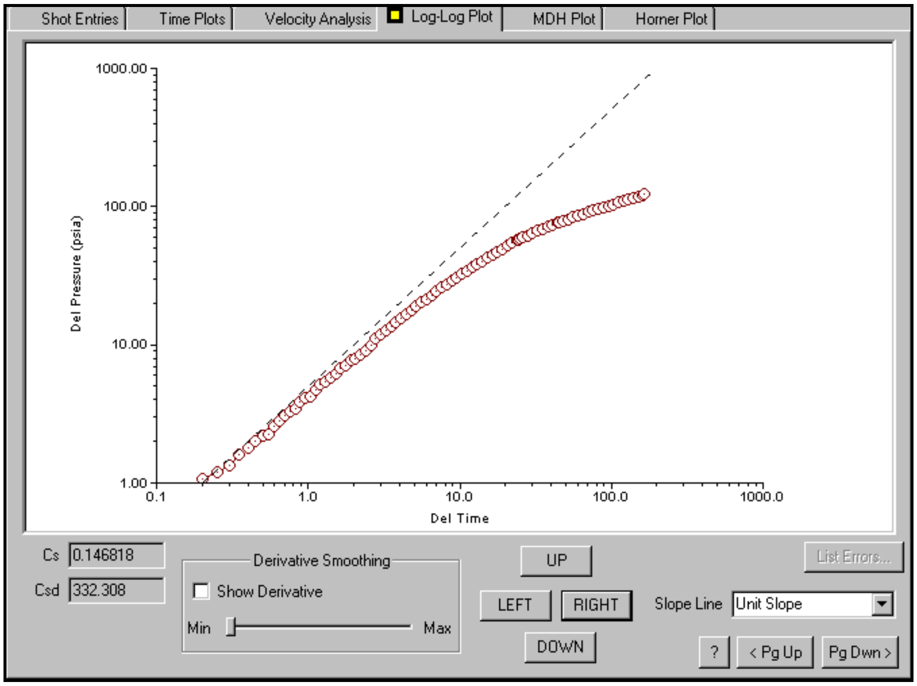


Note
Many PC-based transient pressure analysis software packages are available. In particular the PT3.0 software package offered by the ComPort Computing Co., (http://mars.comportco.com/pt_1.html) and also available through SPE, provides a very cost effective way of analyzing the TWM Buildup data in great detail.[10]
The Pansystem by Edinburgh Petroleum Development Services LTD is commonly used for well test design and analysis

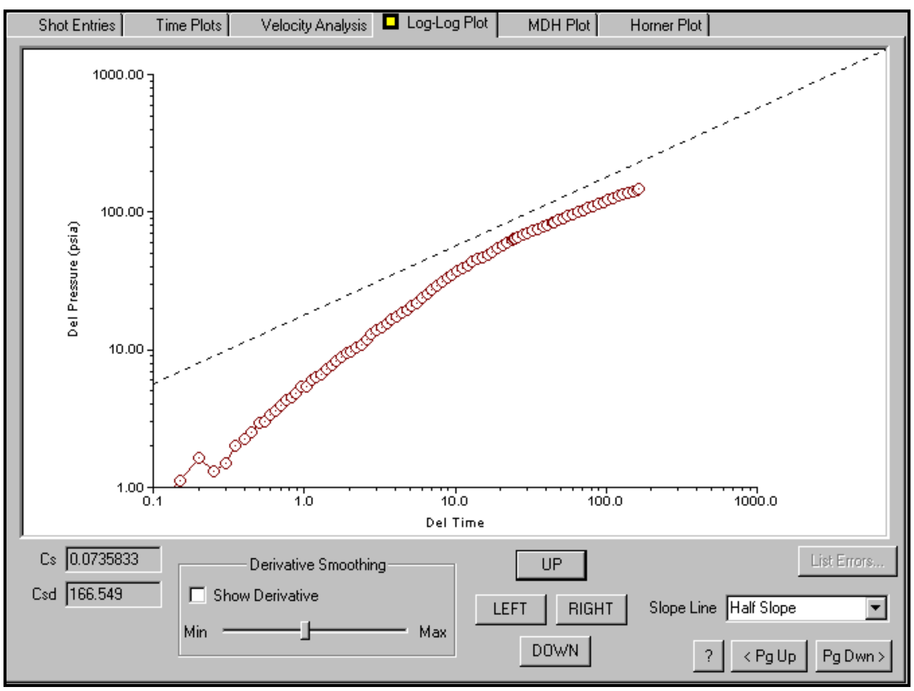
[10] ComPort Computing Company, 12230 Palmfree St., Houston, TX 77034. Telephone (voice or Fax) 713-947-3363. Data can also be submitted for analysis by computer modem and results transmitted for fast turn around. Contact Walter Fair for more information (wfair@comportco.com)
Edinburgh Petroleum Development Services LTD, Research Park, Riccarton, Edinburgh, EH14, 4AS, UK. Telephone (031) 449-4536.(http://www.e-petroleumservices.com/PanSystem/PanSystem_home.htm)

7.7.1 - Log-Log Plot

A unit slope trend is indicative of wellbore storage.

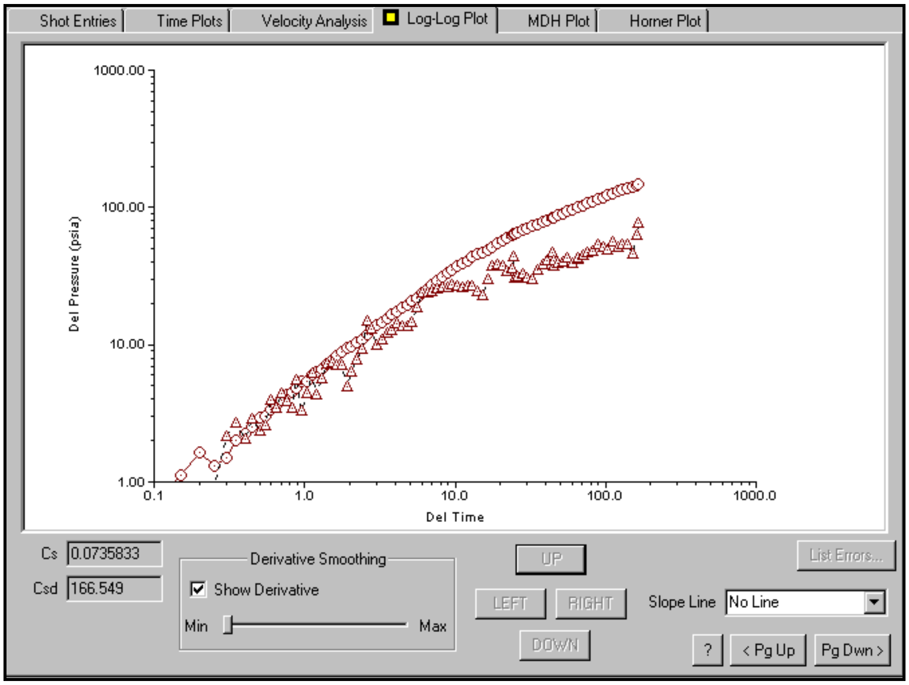


A half slope trend indicates an infinite conductivity fracture:



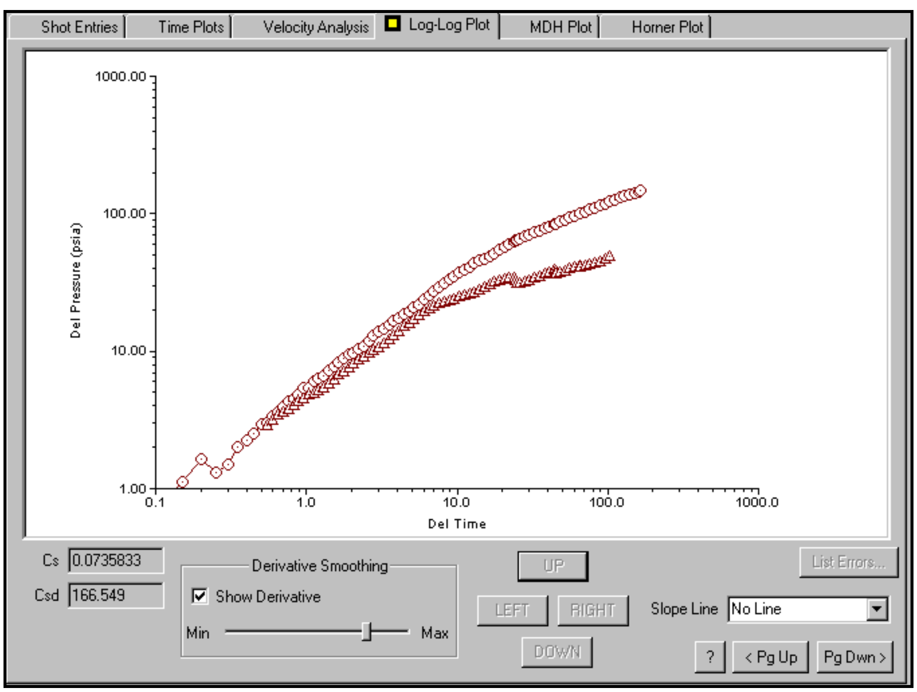
7.7.2 - Unsmoothed Pressure Derivative:

The derivative function is displayed by checking the **Show Derivative** box, at the lower left. This function is indicative of the rate of change of the pressure transient and is used as a diagnostic for the interpretation of the test and in using the Type Curve Analysis.



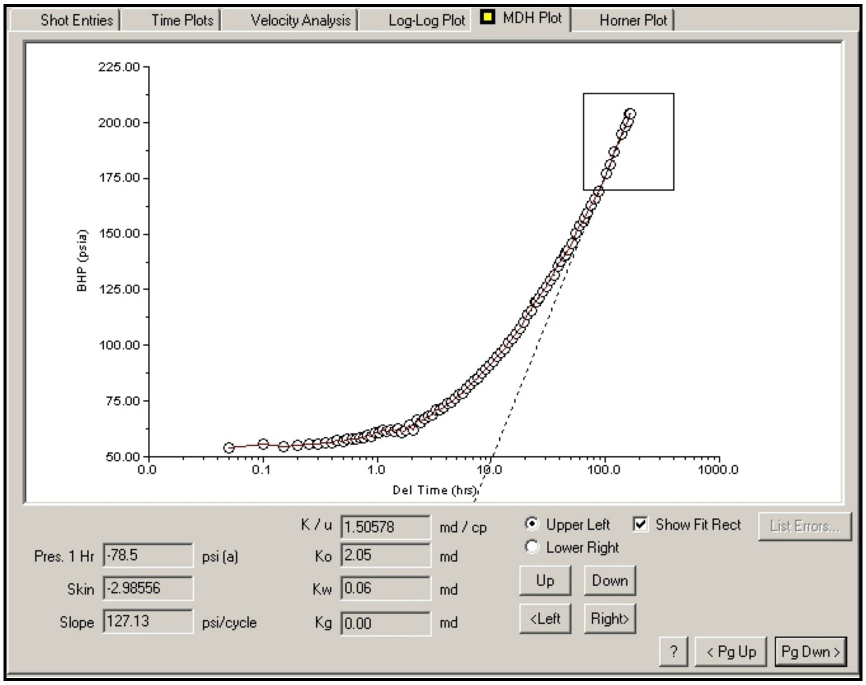
7.7.2.1 - Pressure Derivative with Smoothing

The pressure derivative function is very sensitive to small changes in pressure from reading to reading. Since the derivative trend is the important diagnostic, it is best viewed with some degree of smoothing of the derivative plot. This is controlled by the user with the slider control and adjusting it between Min and Max:



7.7.3 - MDH Plot

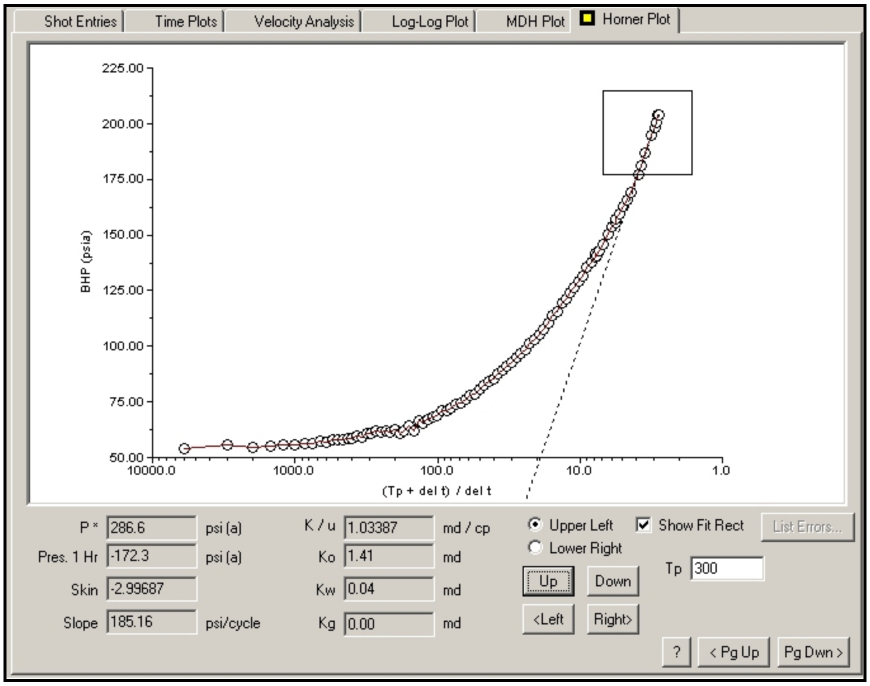
This is a plot of the pressure as a function of the logarithm of time elapsed since the beginning of the pressure transient test.



Interpretation involves analyzing the trend by fitting a straight line to the data. The region and points to be fitted are selected by checking the **Show Fit Rectangle** box, and adjusting the position of the corners of the box using the appropriate buttons (**Up,Down,Left,Right**) until the data is enclosed by the rectangle. You can also select a rectangle by using the mouse and drag/drop a rectangle over the relavent points in the MDH plots and the Horner plots.

7.7.4 - Horner Plot

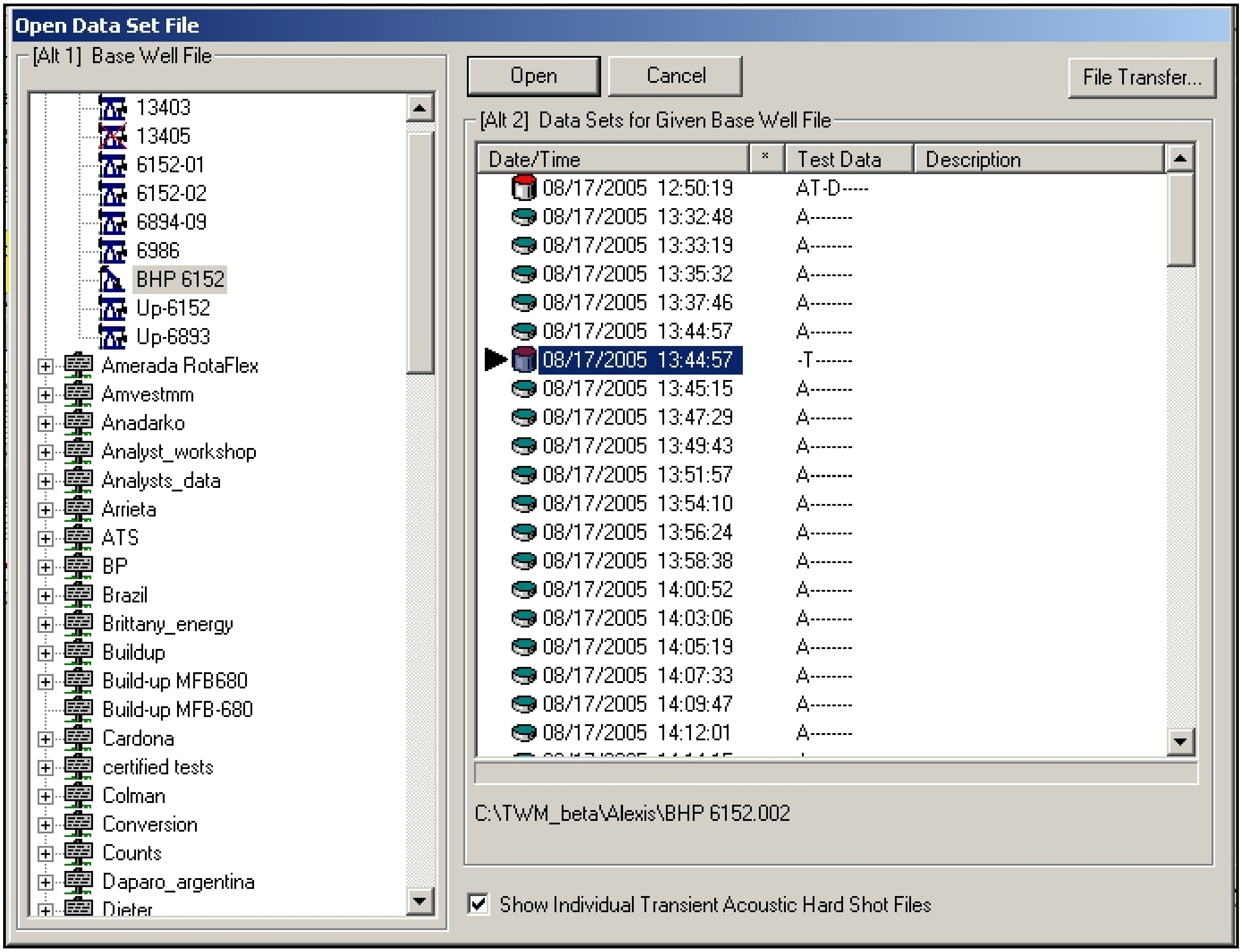
It is a plot of Pressure vs. the logarithm of (t+dt)/dt where t is the production time (or Horner time) and dt is the time since shut-in. The Horner time may be estimated by dividing the cumulative production by the average production rate since the last time that the well was shut-in.



Interpretation involves fitting a linear trend to the portion of the data that corresponds to radial flow in an infinite reservoir. The corresponding data points are selected by means of the **Fit Rectangle** box.

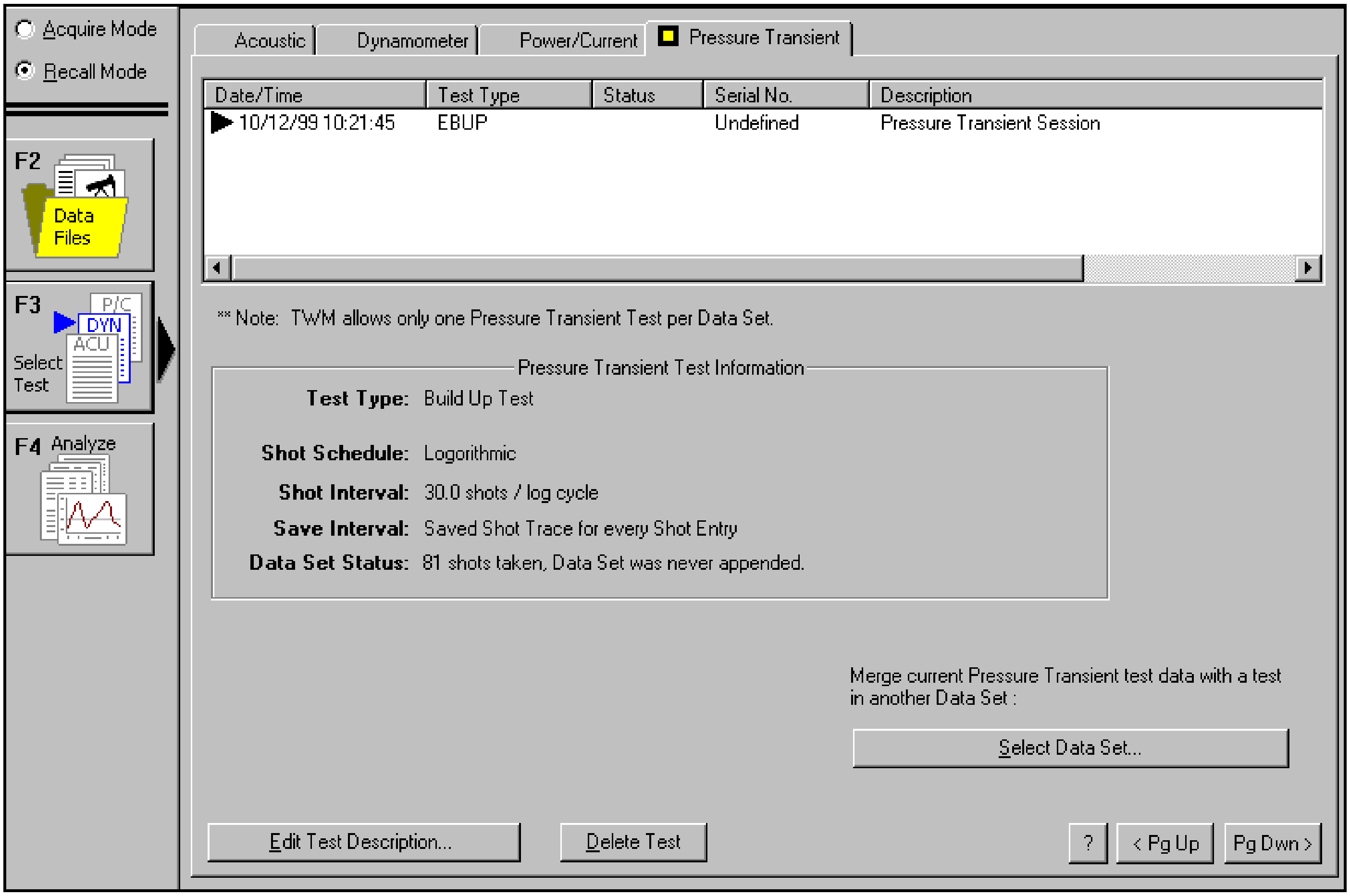
7.8 - Recall Old Data

This option permits recalling and analyzing a transient test's data files after the test has been completed or while the test is in progress and the data has been transferred to an office computer. Selecting the **Recall** mode and opening the corresponding group and selecting the particular well displays the following screen:

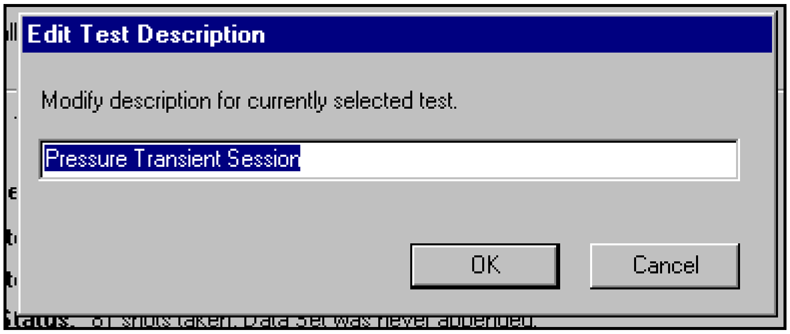


Note that the well data set description contains a "T" since it includes Transient data. Also checking the box "**Show Transient Type Data Sets**" displays a listing of all the individual shot acoustic records that were saved during the test. These can be analyzed individually in case there is some question about the validity of the liquid level depth or the BHP calculation.

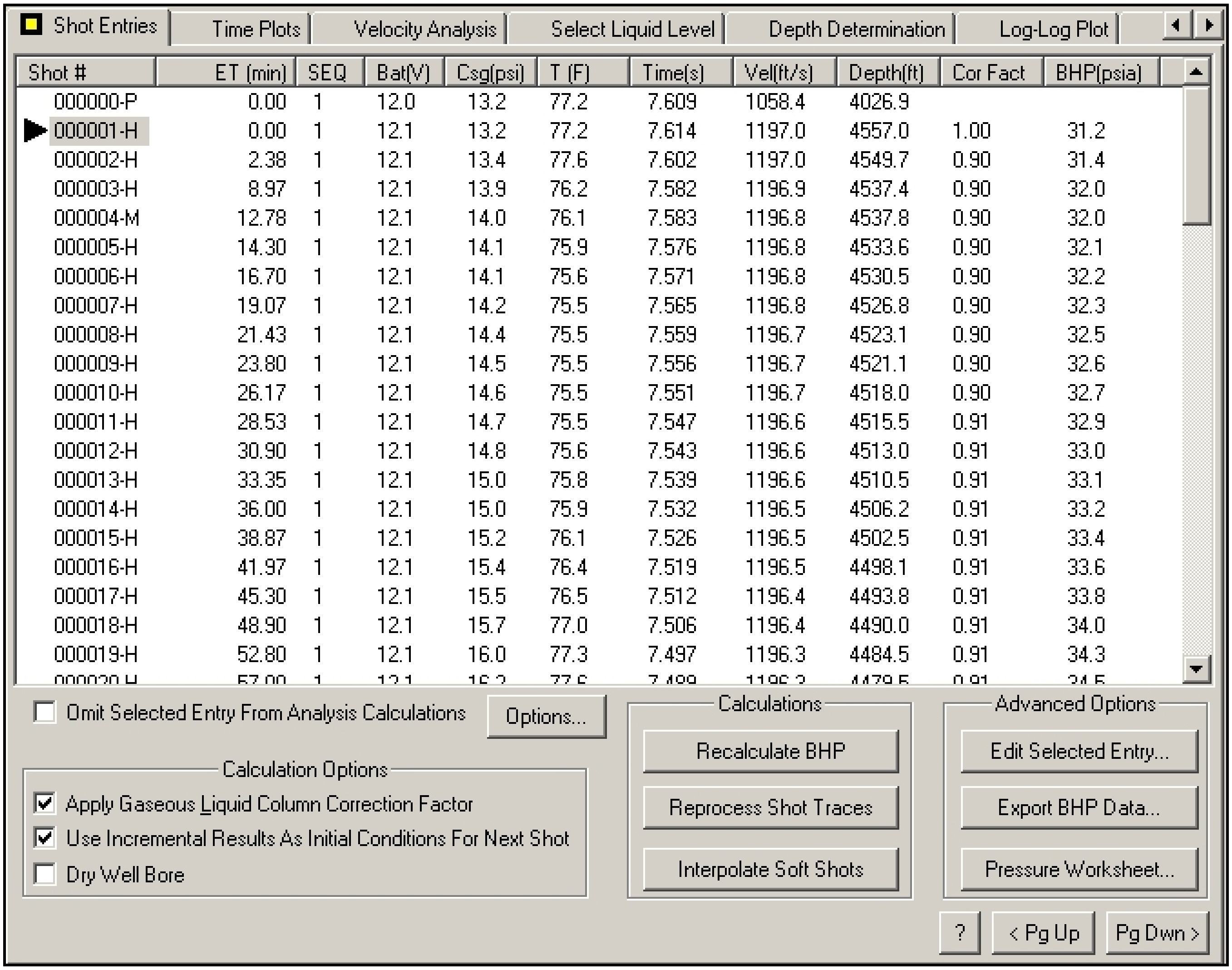
Opening the data set and selecting the test type **Pressure Transient Tab** displays the following screen:



The test date and type, the schedule of shots and saved data files and the total number of data points are displayed on the screen. If the test was interrupted accidentally or due to loss of power or gas, then restarted and saved as a separate data set, the screen allows merging the two data sets in a continuous file by clicking on the Select data set button. It is also possible to Edit the Test description and/or delete the test.



Normally the user will want to review and analyze the pressure transient data set. This is done by selecting the **Analyze (F4)** button and results in the display of all the data as shown in the next figure:

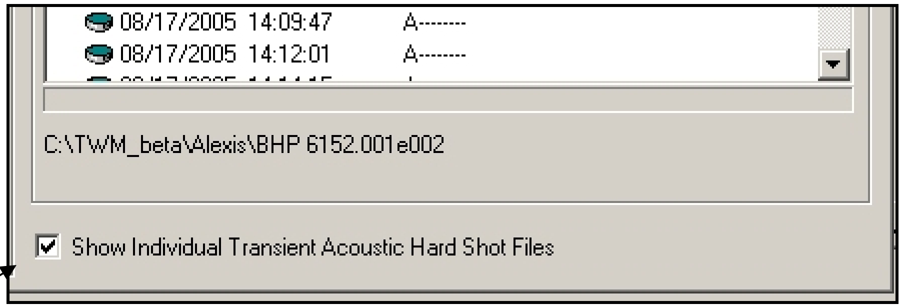


This is the first of several Tabs which are used for analysis and interpretation of the data. Note that if the shot traces were recorded **<u>but are not present in the directory</u>** where the data set is saved then the shot number will displat a lower case (h) as shown below:

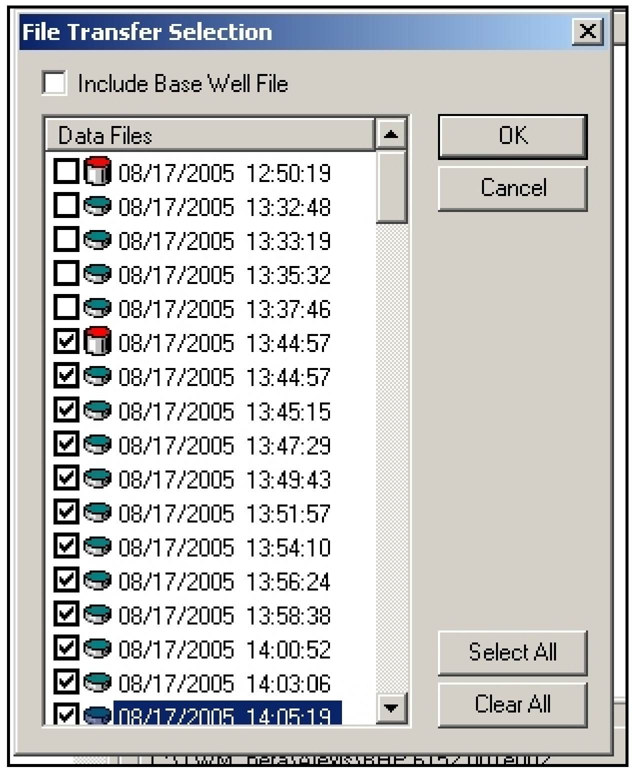
000032-h	312.05	1	11.5	7.9	62.3	9.482	1088.1	5158.7	0.97	25.5
000033-h	336.88	1	11.4	8.0	55.5	9.483	1036.1	4912.7	0.97	25.7
▶ 000034-h	362.80	1	11.4	8.2	51.4	9.482	1011.7	4796.5	0.97	25.9
000035-h	390.87	1	11.4	8.6	49.1	9.483	1064.1	5045.6	0.97	26.3

This generally occurs when the data is transferred from the laptop where it was acquired to another computer without transferring also the individual shot records.

To display and transfer the individual acoustic records first the box “Show Individual Transient Acoustic Hard Shot Files” should be checked. Then when the File Transfer Selection window is displayed, the individual files are displayed. All the files with the boxes checked will then be transferred. See following figures.



The check box activates listing all the indivitual acoustic records saved during the transient test. If the acoustic data is to be transferred to another computer then the File Transfer mode is selected:

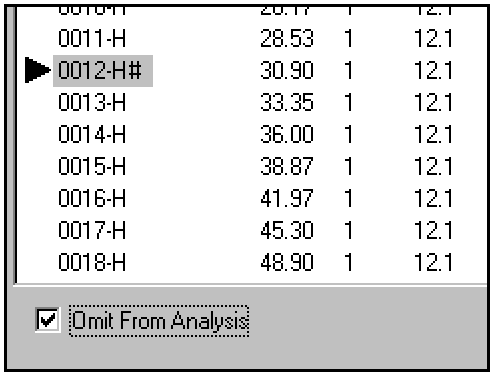


The data files that are checked will be included in the transfer:

Se section 3.3.4 for more details on file transfer options.

The following are the functions of the various buttons and check boxes in the **Shot Entries Tab**:

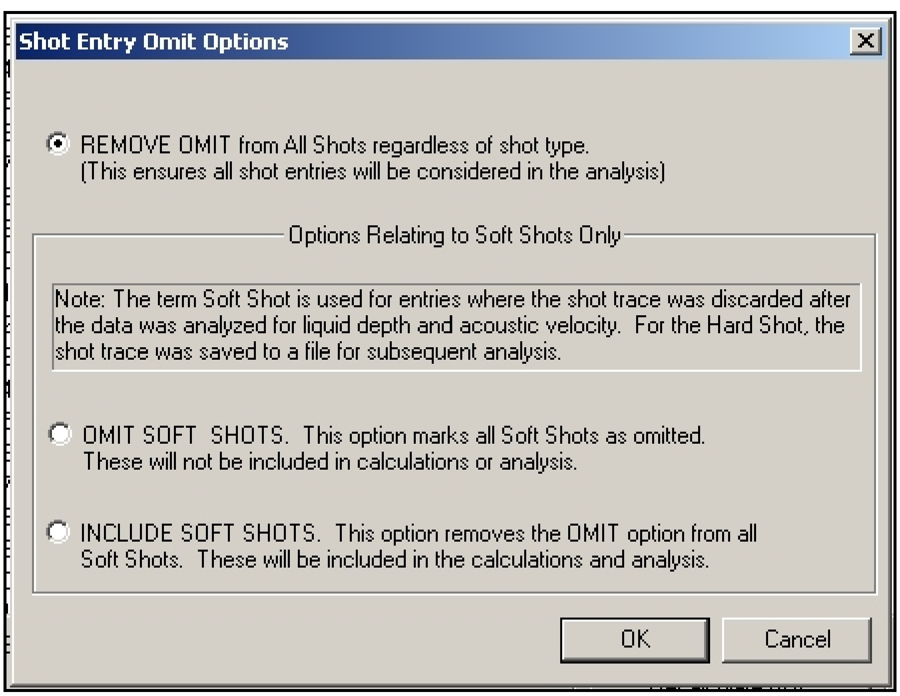
Omit from Analysis: allows exluding any data point from the subsequent analysis. The specific data point is selected first, then the box is checked.



The corresponding data point is flagged on the Shot Entries tab by appending a # sign to the sequence number as shown in the figure above.

The **Omit** function has several options that are displayed by clicking on the **Options** button:

This opens the following dialog:



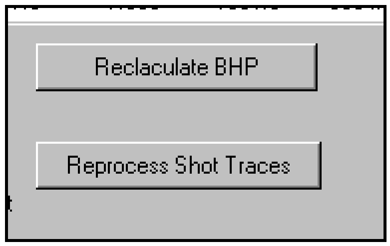
The user selects the appropriate option by selecting the corresponding radio button.

Apply gaseous liquid column correction factor: the BHP is computed using the gaseous column correction factor. (default).

Use Incremental Results as initial Condition For Next Shot: the change in pressure per unit time is determined by comparing adjacent shots. If unchecked, the data for the first shot is used as the reference value.

Recalculate BHP

After editing the data set such as marking some points not to be included, or after reprocessing the fluid level traces, the user should **Recalculate** the bottom hole pressure using the corresponding button:

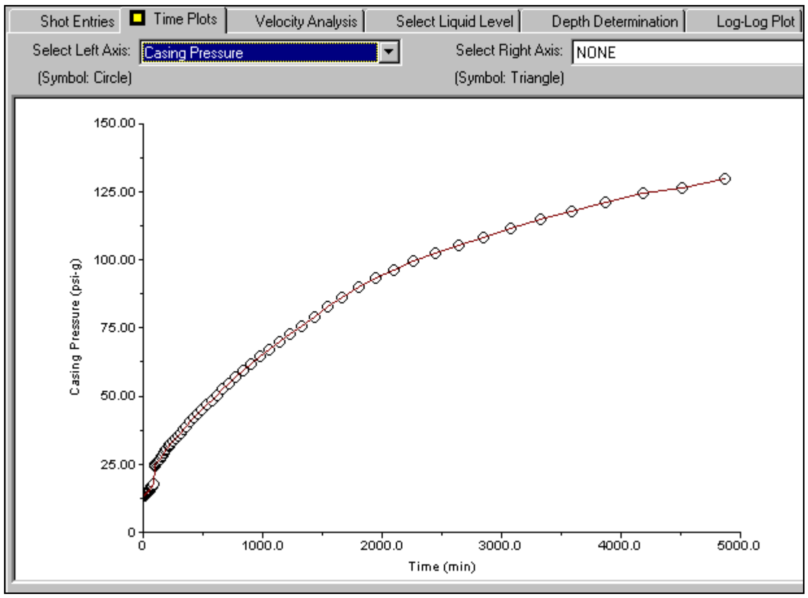


Reprocess Shot Traces:

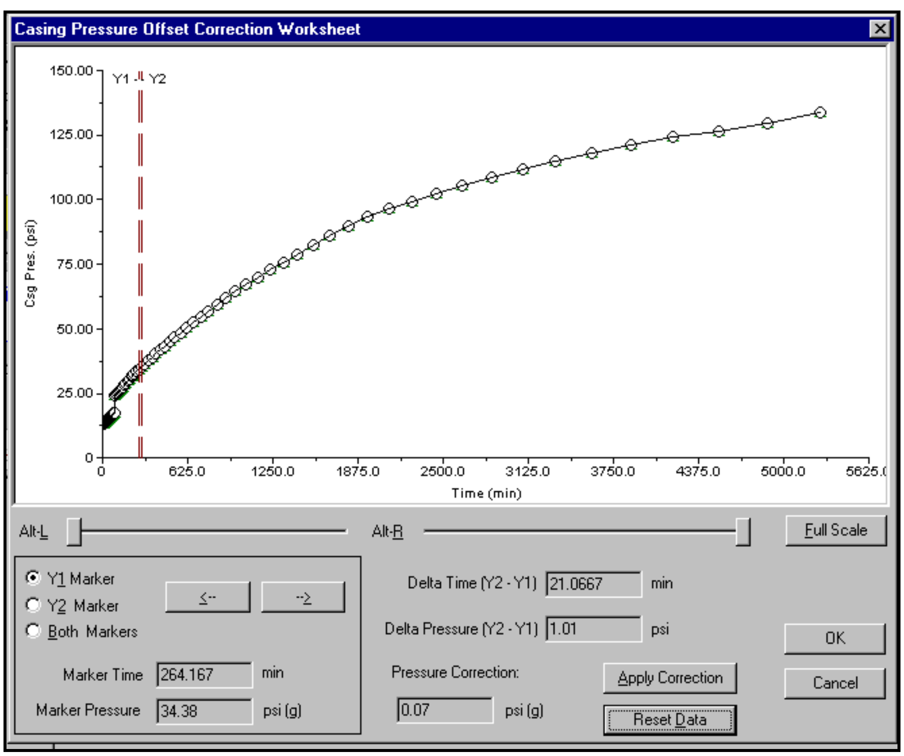
This option is required when the method for determination of the depth to the liquid level is changed from the default **Automatic** mode. The settings selected by the user, such as method of depth determination, mute window width and position, collar frequency, collar count, etc. are applied to <u>all the subsequent shots</u> and the fluid level depths are recalculated accordingly. The reprocessing will <u>start at the shot being viewed</u> and leaves the precending shots unchanged. This allows to process differently various sections of the data depending on conditions that may require alternate procedures (for example change in noise level, presence of interfering liners, etc.)

7.8.1 - Pressure Worksheet:

Occasionally it may be necessary to apply corrections to the measured casing pressure due to discontinuities caused by changes in the hardware or interruption of the transient test. For example, it may be necessary to substitute the pressure sensor or cable due to malfunction. The change may introduce a shift in the pressure level due to a zero shift that was not compensated correctly. The following figure shows such an instance:

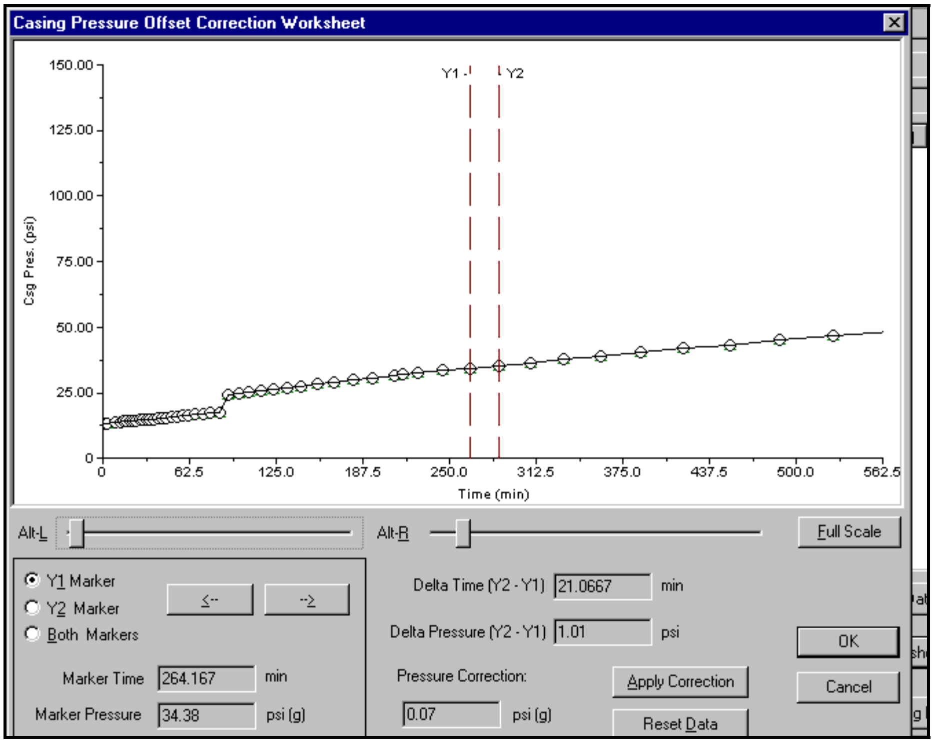


Note the shift at the beginning of the test, caused by changing the pressure transducer. The data needs to be adjusted so that a continuous trend can be established for interpretation. The **Pressure Worksheet** button (in the **Shot Entries** tab) provides the tools to undertake this shift in an efficient manner by opening the following display. The vertical markers, labeled **Y1** and **Y2** should be positioned to indicate the section of the data series where the shift is to be applied.

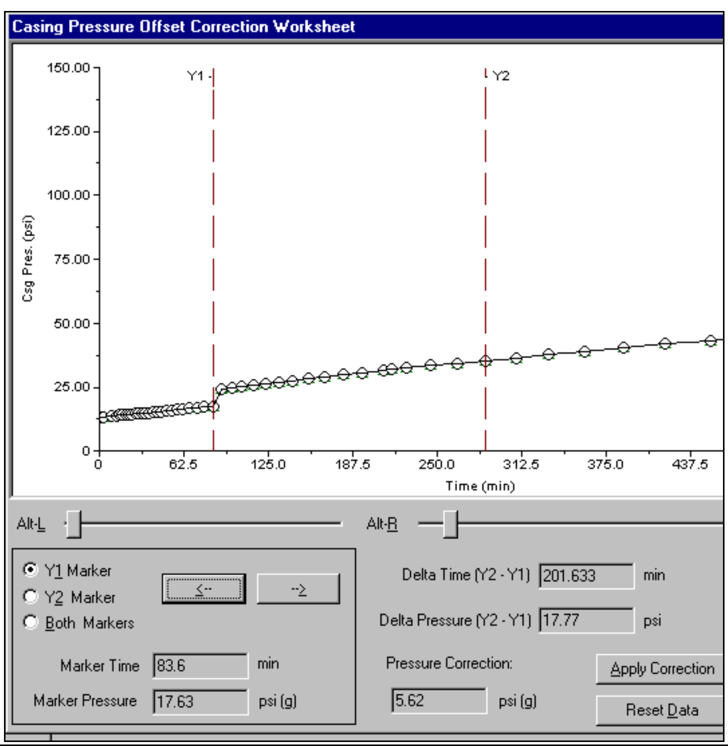


7.8.1.1 - Time Scale Expansion

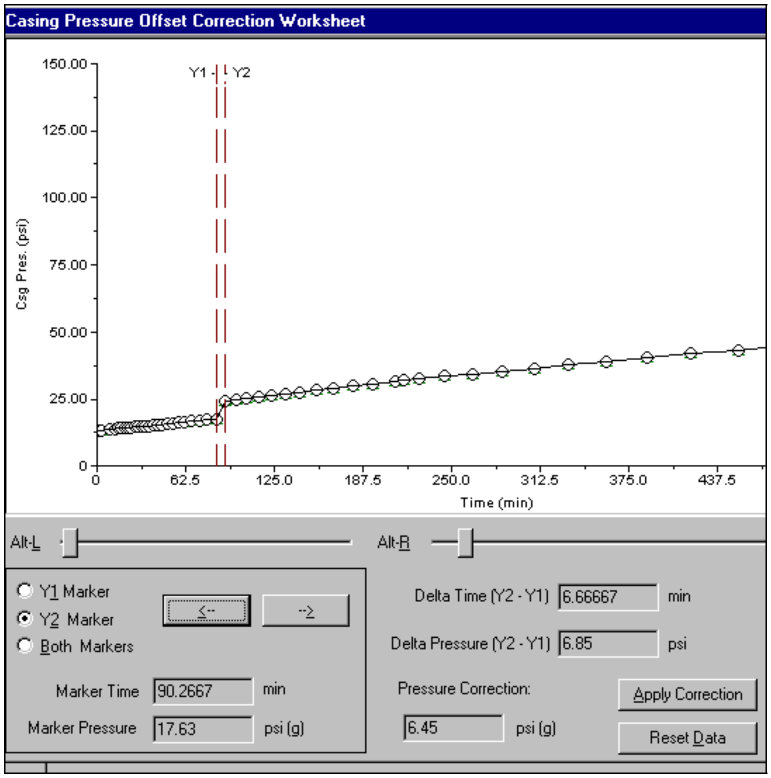
The time scale is easily expanded using the right (**R**) and left (**L**) slider controls until the section of the data where the pressure shift has to be made, is clearly shown on the screen. This procedure is shown in the following figures:



In the figure above the right range of the time axis has been decreased to 562 minutes.
Then the first marker (**Y1**) is placed on the last data point before the pressure shift:

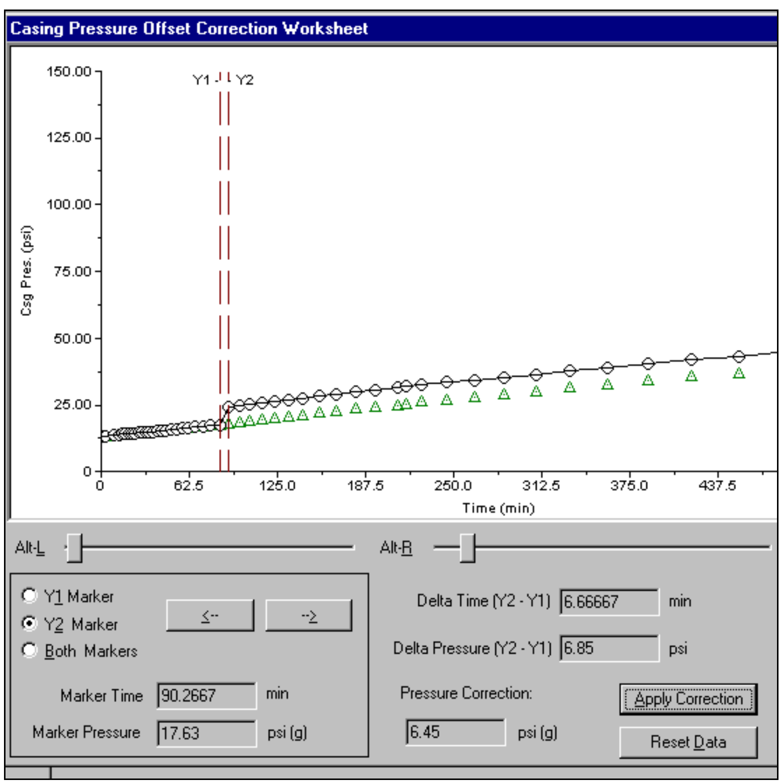


The second marker (Y2) is placed on the data point after the pressure shift:



At the bottom right the readout indicates that a pressure correction of 6.45 psi needs to be applied to the data series following the shift. This is done by clicking on the **Apply Correction** button.

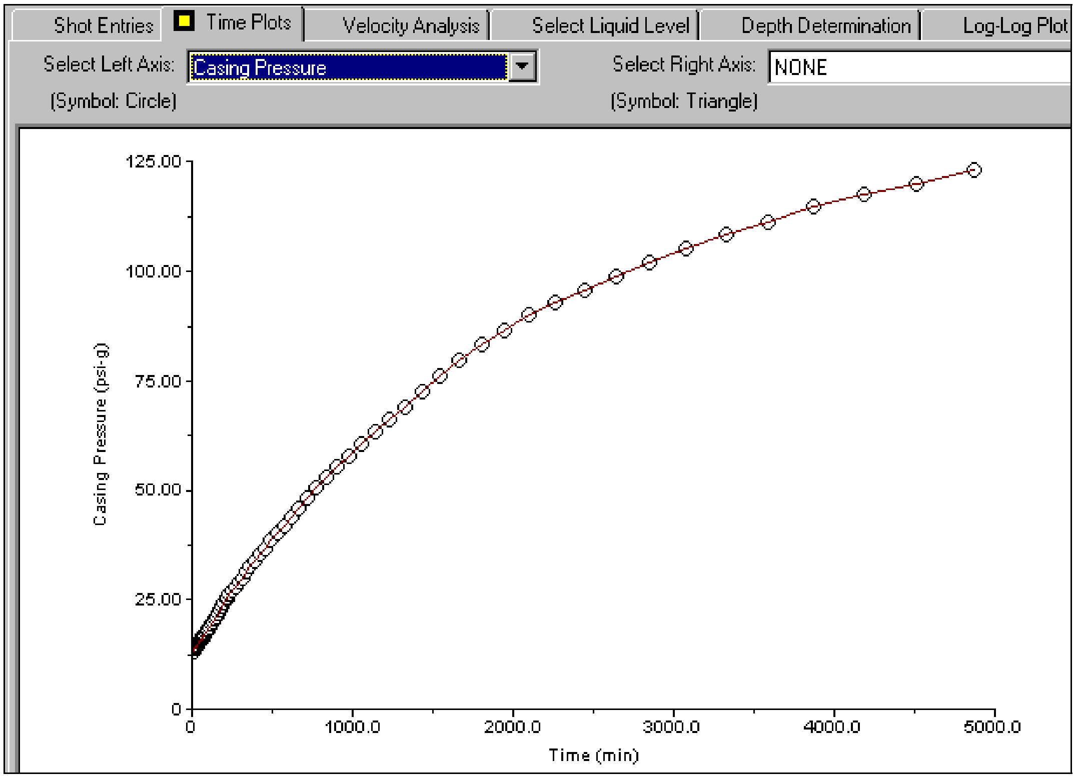
The pressure data, corrected for the shift is then displayed using the triangle symbols as shown in the following figure:



The **Reset** button returns the pressure data to the original values.

7.8.2 Corrected Pressure Data

The corrected **Casing Pressure** series is now displayed whenever the **Time Plots** tab is selected and this data is used in all subsequent calculations:

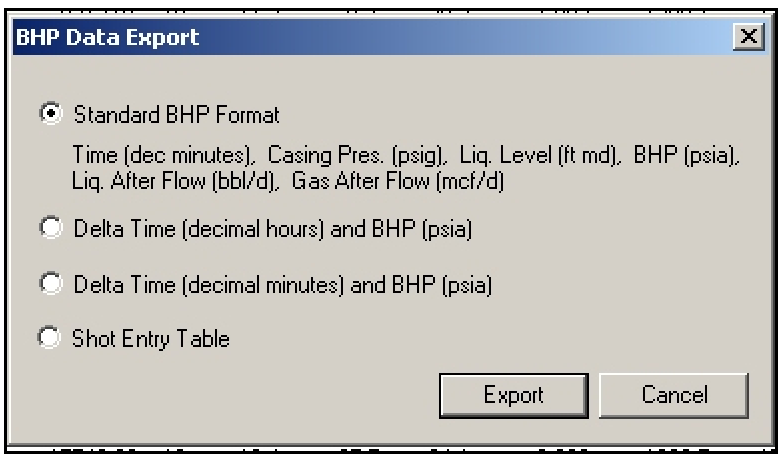


NOTE: After performing this correction the user should **Recalculate BHP** by selecting the **Shot Entries** tab, viewing the first shot and clicking the corresponding button

7.9 - Export a BHP File

This control generates a **TEXT** file containing the calculated BHP values separated with a **delimiting** character. This file can be read into most word processors and spreadsheet programs so as to manipulate its format or use the data directly. The file corresponds to the most recently calculated values of the parameters.

After selecting this option the following menu is displayed



The standard BHP format is as follows:

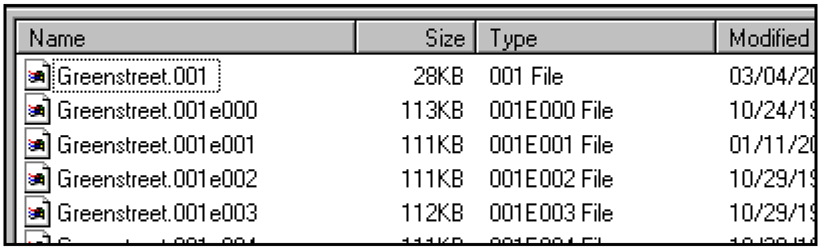
Elapsed Time, Casing Pressure, Liquid Depth, Bottom Hole Pressure, Liquid Afterflow, Gas Afterflow

Thecomplete **Shot Entry Table** is exported as a space-delimited text file that can be easily imported into a spreadsheet or other programs.

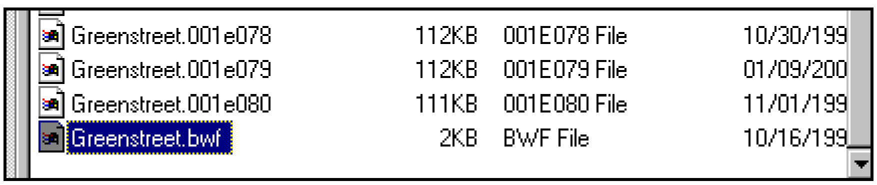
NOTE: all pressures are reported as psia (psi absolute)

7.10 Office Processing of Pressure Transient Data

The acoustic signals acquired by the **TWM Pressure Transient** program are saved periodically onto the disk (at the rate specified in the set-up procedure, default being once every shot). They are labeled with the name "Wellname" followed by the extension .NNNeMMM, where NNN is the pressure transient test number for the particular well and MMM is the sequence shot in the series of shots. The file Wellname.NNN contains the setup information.



Copying these files and the base wellfile



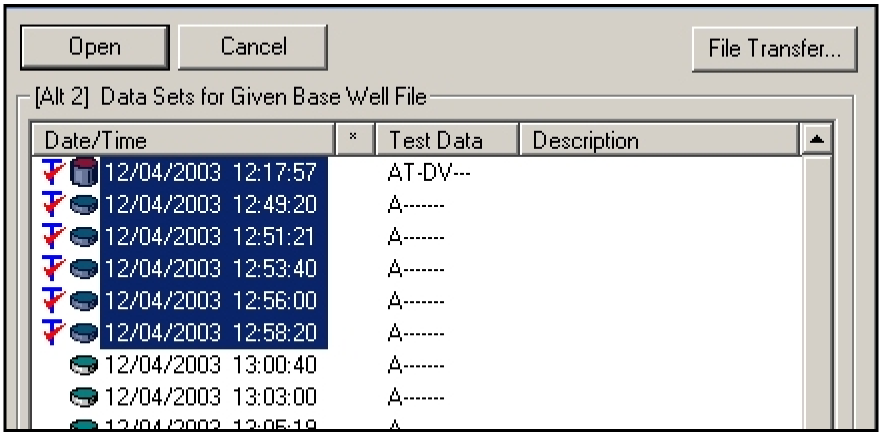
allows transferring the data to an office computer for processing and detailed analysis.

7.10.1 - File Transfer Options

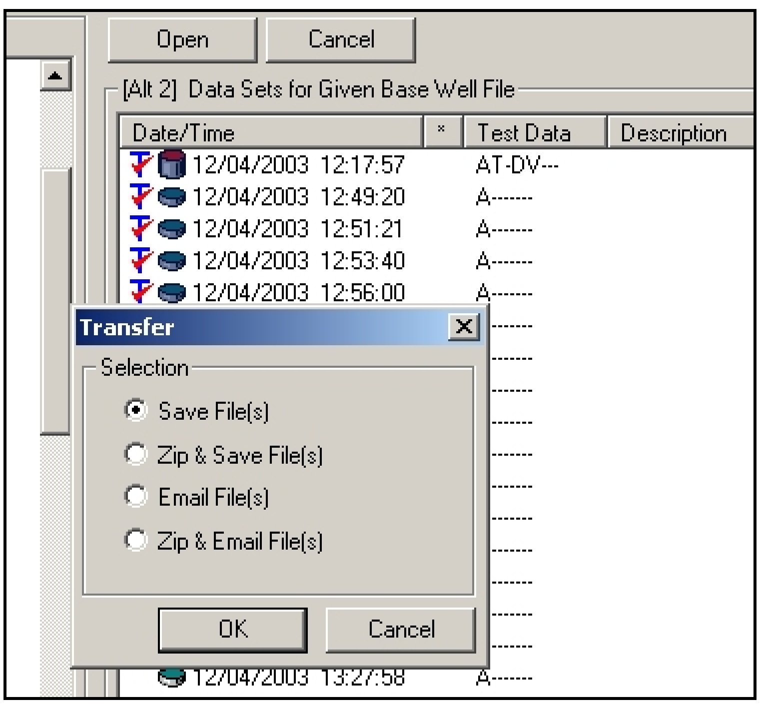
The user has two options: 1-select some files only or 2-Transfer all the data files for that well

7.10.1.1 - Selected File Transfer

The file transfer option can also be used for transferring files especially when the laptop is connected to a network. The files to be transferred are selected by **RIGHT Clicking** on the file name (use Ctrl-Right Click for multiple selections) marks the files for transfer:



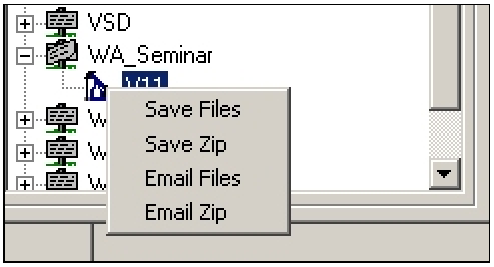
Then clicking the File Transfer button opens the following menu:



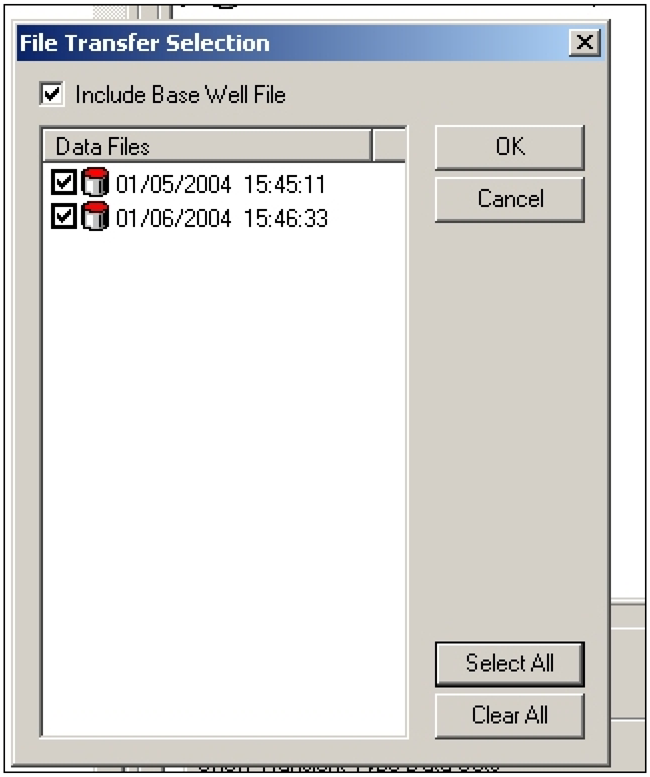
This allows saving the files to a disk or e-mail them using the default e-mail application.

7.10.1.2 - Global File Transfer

When several or **ALL** files associated with **a well** are to be transferred the user has the option of selecting them by **RIGHT clicking** on the **Wellname** as shown below:



The user then selects the option and files desired to be transferred:



8.0 - ACOUSTIC LIQUID LEVEL TRACKING MODULE

This program is used in conjunction with the Well Analyzer and the Remote Fire gas gun (although manual fire guns may be used) with the objective to **continually monitor the position of the liquid level** in a well at intervals as short as once a minute. The program acquires the fluid level data, processes it and displays the position of the liquid level vs. time. Then it checks whether the liquid level is within given high and low depth limits and generates an alarm when either limit is exceeded.

8.1 - Applications

The program has numerous applications in drilling, workover, completion and production operations. Some of these include:

- Monitor fluid level in offshore risers.
- Monitor fluid level while drilling with no returns.
- Keep fluid level within limits to minimize formation damage.
- Monitor position of batch treatments.
- Follow progress of continuous gas lift unloading.
- Generate a permanent record of fluid level during delicate workover or completion operations.

8.2 - Hardware Installation

Since in the majority of these applications the system will operate in a noisy environment, the remote fire gun should be installed as directly as possible to the wellbore with the shortest section of full bore pipe available. Installation should consider the pressure rating of the remote fire gas gun, which is typically 1500 psi (manual fire guns with pressure ratings of 3000, 5000 and 15000 psi are also available) in relation to the pressure rating of the rest of the installation. Connection to the wellbore should be through a full opening shut-off valve so that the gun can be removed from the well at any time if it becomes necessary to service it during the test and pressure is present in the wellbore. When using the remote fire gun, the Well Analyzer electronics and computer can be located several hundred feet from the wellhead. (Measurements have been made over several decks in offshore platforms). The preferred gas source is a Nitrogen bottle with sufficient volume and pressure to last for the estimated duration of the tests.

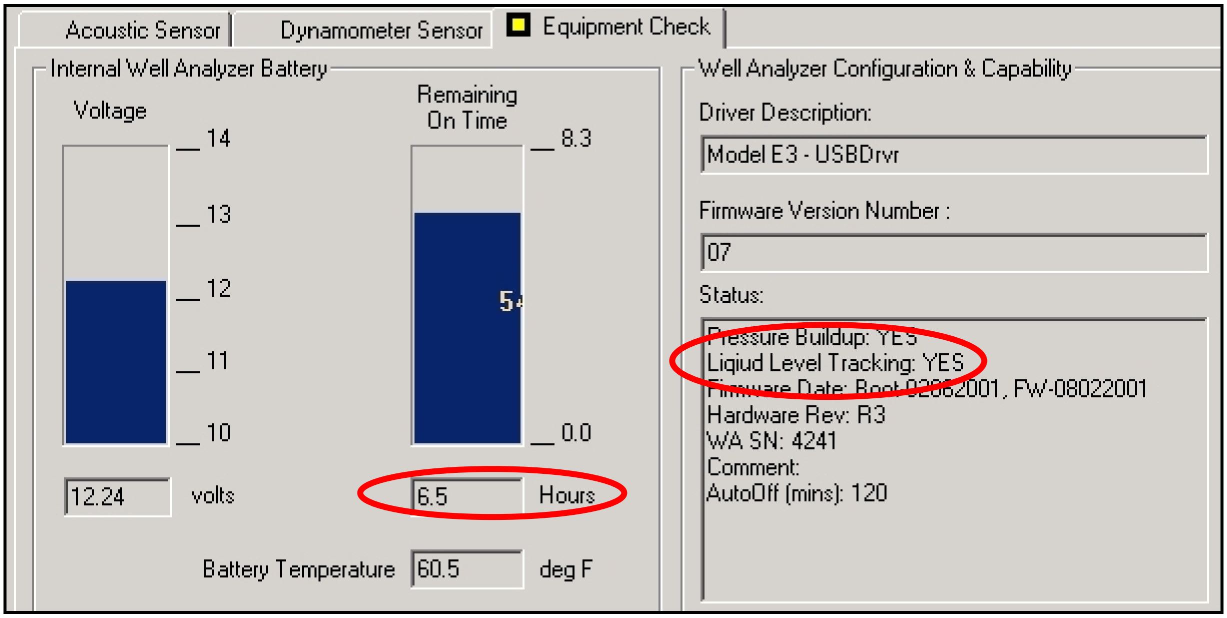
8.3 - System Set Up

Since the liquid tracking program is designed to be used for liquid level monitoring in open hole as well as in closed wellbores with variable wellbore configurations it calculates the depth to the fluid level from the pulse travel time and the acoustic velocity of the wellbore gas. The Liquid Level Tracking program is used in the Shot-Set_Up data acquisition mode to determine the correct acoustic velocity prior to the initiation of the liquid tracking tests. The automatic mode or the special processing features of this program are used in conjunction with known depth markers (changes in pipe cross section, tool joints, spools, cross-overs, etc.) to calibrate the acoustic velocity for the particular installation. This acoustic velocity can then be used as the default method for depth calculation during the test.

8.4 - Operation

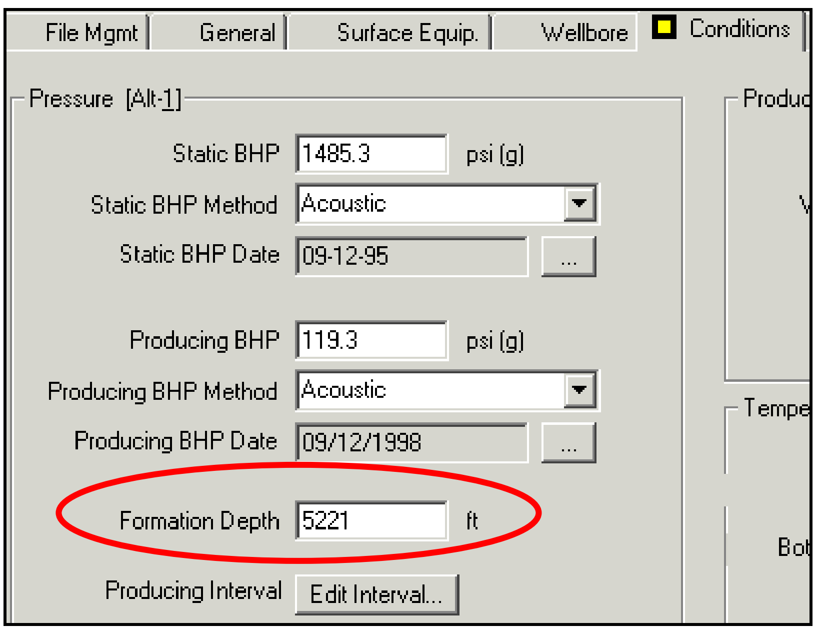
After the connections to the remote fire gun and the external gas supply are made the TWM program is started in the Acquire mode and the correct operation of the system is checked using the System Set UP option of the TWM program as is discussed in the Acoustic Data acquisition section of this manual. Although the Liquid Tracking Program does not use the casing pressure reading since most of the applications are in wellbores where the casing is open to atmosphere, if it is used to monitor liquid level in a closed annulus (gas lift well unloading or monitoring batch treatments) a knowledge of the casing pressure is needed to properly set the gun's chamber pressure. In these instances the Acoustic liquid level mode of the TWM program is used to acquire pressure and liquid level data before initiating the liquid level monitoring.

System operation and communication are checked using the Equipment Check Tab:



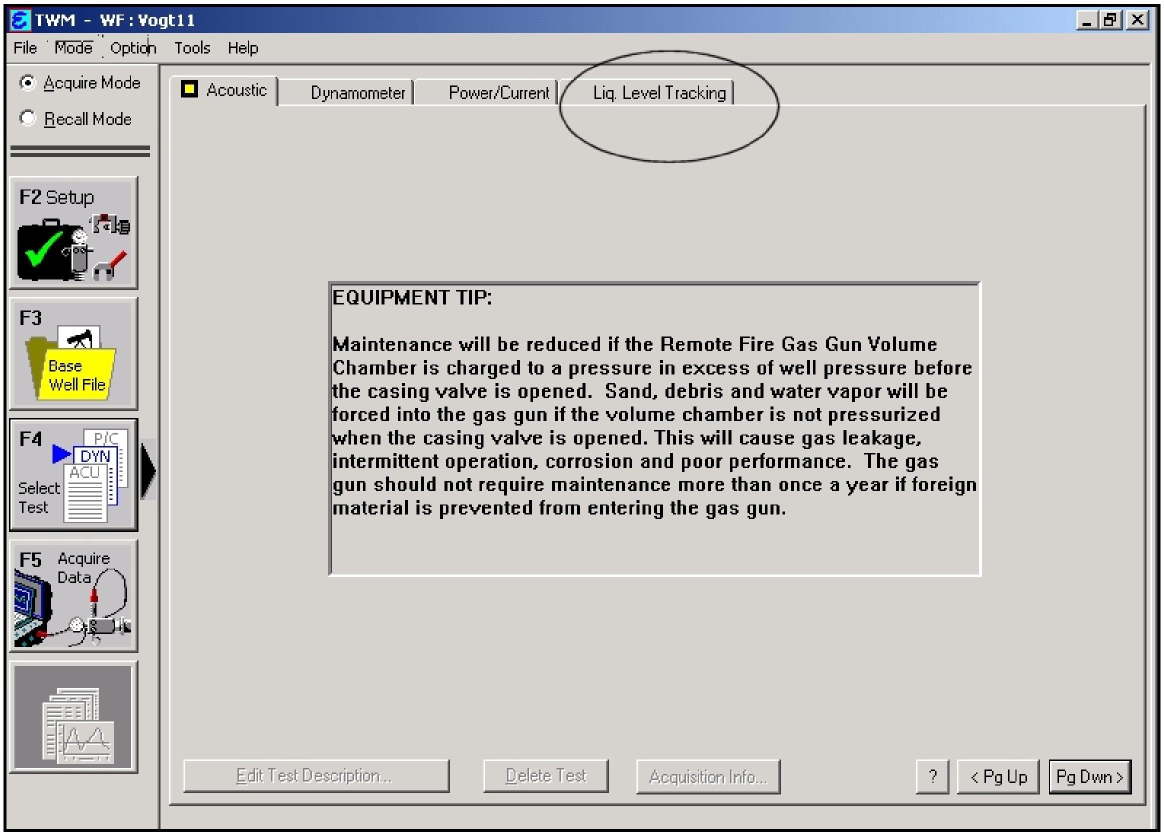
The battery voltage should allow for several hours of operation. Note also that the hardware status should indicate that Liquid Level Tracking hardware has been installed in the Well Analyzer (Liquid Level Tracking: YES). If necessary the Well Analyzer should be connected to an external 12 Volt supply, such as a car battery or other constant voltage source.

The next step is to select the appropriate **Base Well File** and check that the well data is correctly entered in the **Wellbore and Conditions** tabs. The program uses the **Formation Depth** to calculate the maximum time for acoustic data acquisition.

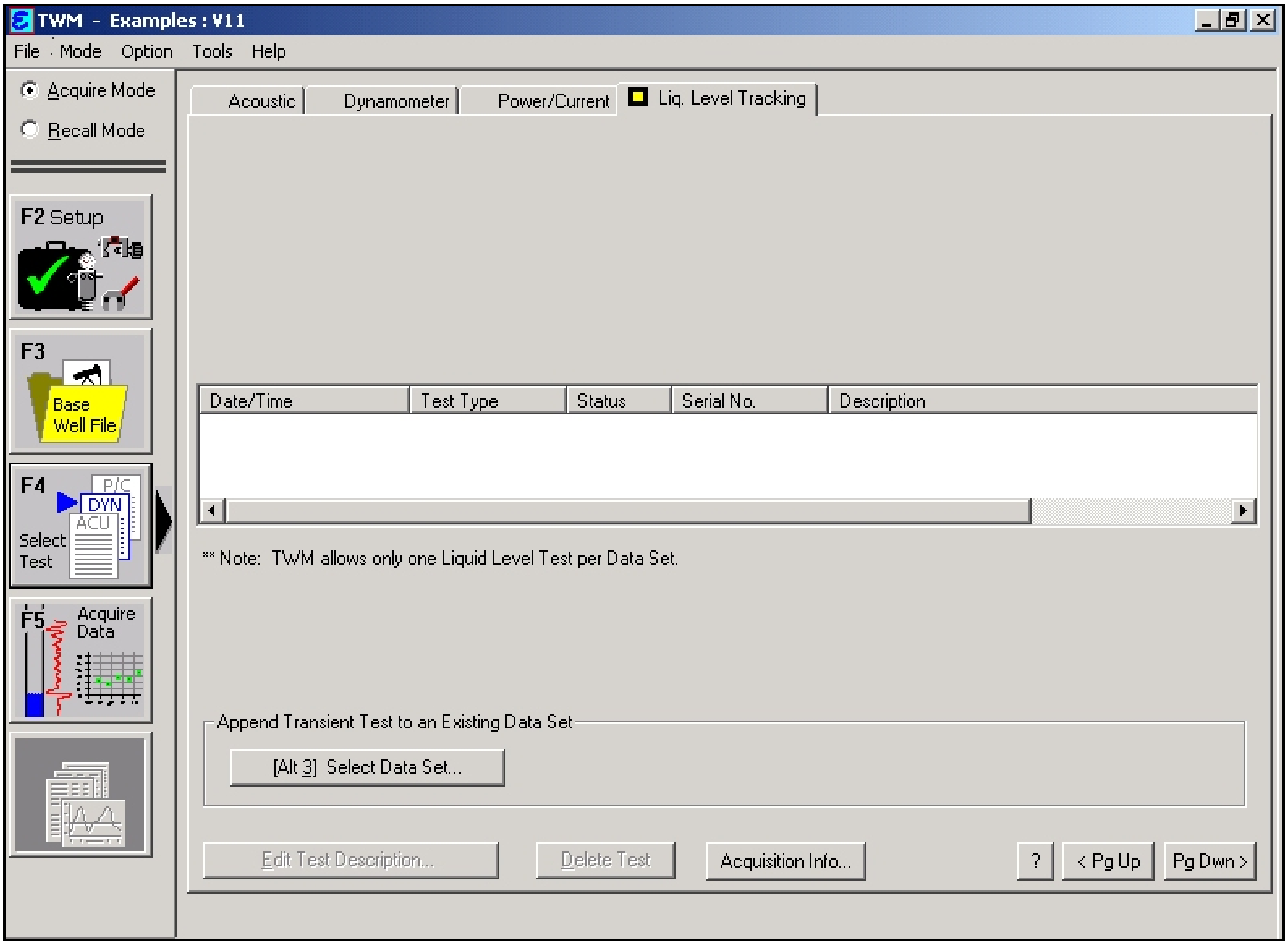


The operator can set a value of the acquisition time, during the test set-up procedure, when it is known that the liquid level will generally be in the upper part of the wellbore and the time to the liquid level reflection is short.

The next step is to click on the **Select Test** button:



Choosing the **Liq. Level Tracking** tab will bring up the following display, which gives the user the option of starting a new test or appending data to a test in progress:



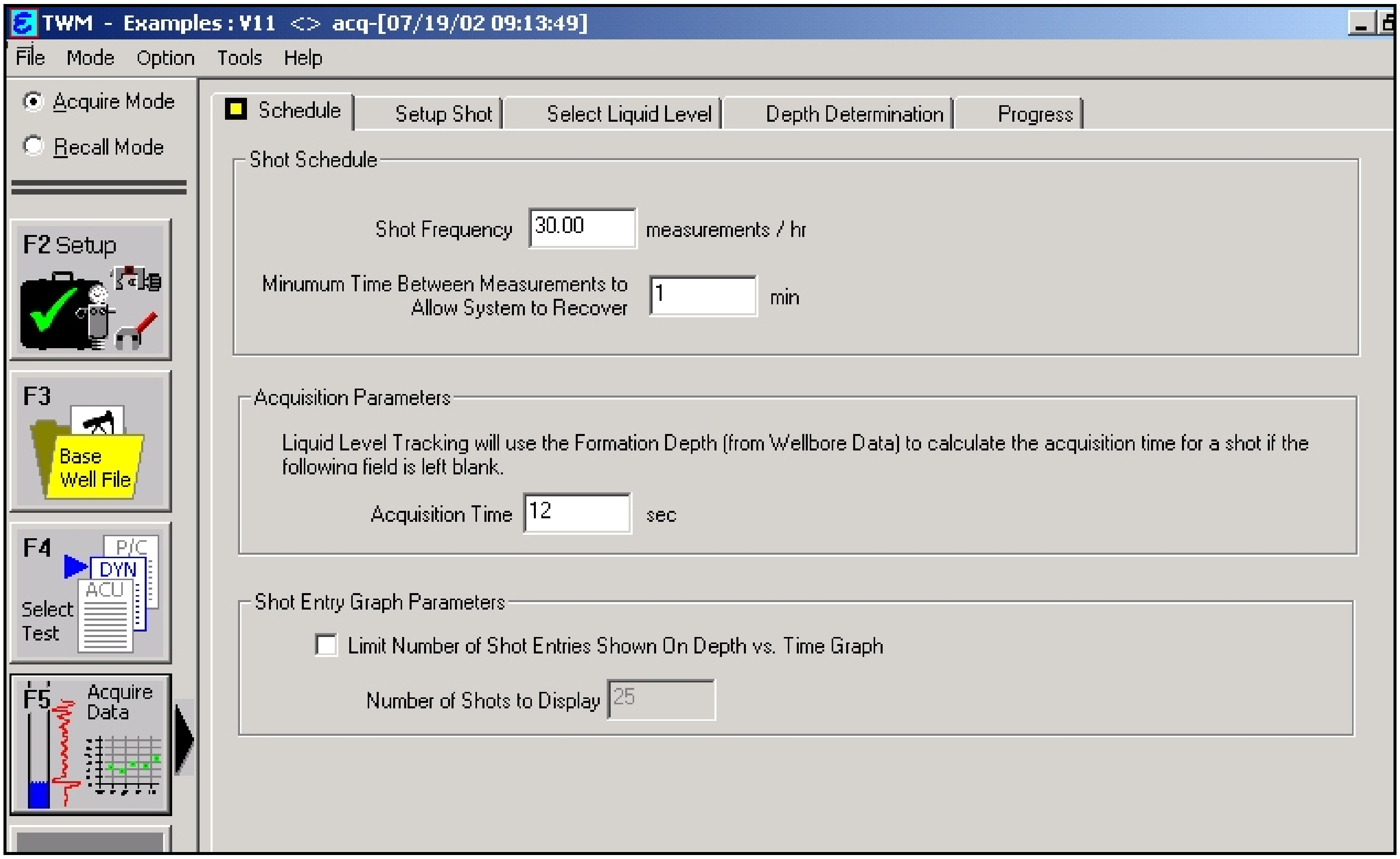
Selecting the option to **Acquire Data** a new test the user is presented the following screen for data input, setting up the test and monitoring the test progress. The five tabs can be accessed in any sequence although the normal operation is to move from left to right:

Schedule Tab: used to set the time interval between shots
Setup Shot Tab: used to acquire an acoustic shot to set up the liquid level detection parameters.
Select Liquid Level Tab: used to verify correct identification of the liquid level
Depth Determination Tab: used to set the mode of liquid depth calculation.
Progress Tab: Used to monitor the progress of the test as a function of time.

During the test, the **Progress Tab** is the active screen and is continually displayed unless the operator wants to modify the parameters of the test.

8.4.1 - The Schedule Tab:

The main function is to set the Shot Frequency, the minimum time between shots and the Acquisition Time. The default value for shot frequency is 20 measurements per hour or a time interval of three minutes between measurements. This value should be adjusted to a larger number in those instances where the fluid level is expected to vary rapidly.



Acquisition Time: This is the length of time during which acoustic data will be acquired. It is a function of the depth to the fluid level and the acoustic velocity. It is best determined from a fluid level measurement taken with the Acoustic Test tab during the set up phase. Since the acoustic velocity in air is approximately 1000 ft/sec, three seconds of data are acquired for each 1000 feet of well depth or estimated liquid level depth.

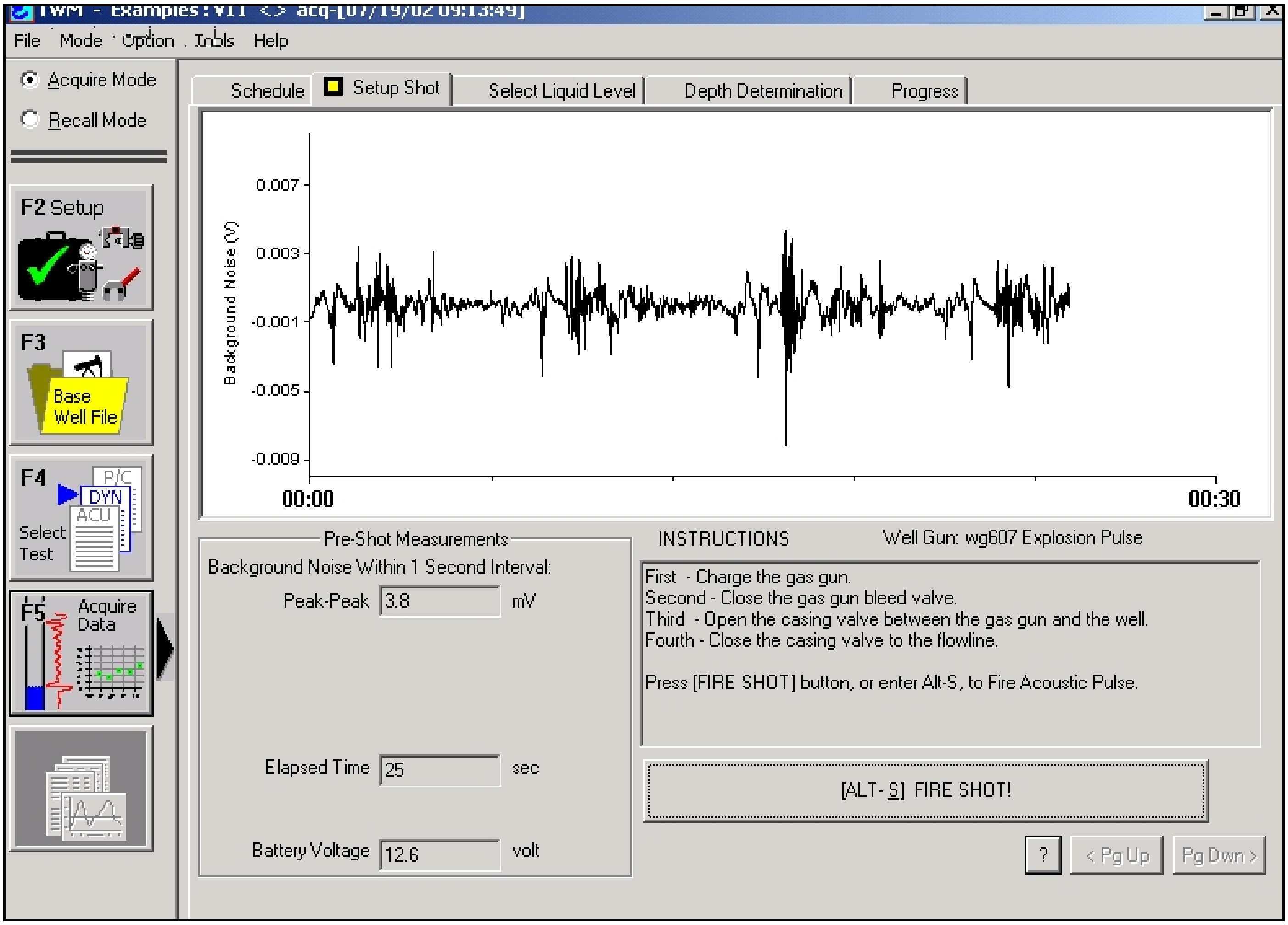
Leaving the acquisition time blank will result in acoustic data acquisition for a length of time proportional to the depth of the formation based on an average acoustic velocity of 1000 ft/sec. If it is known that the fluid level is high the operator can enter a smaller value. This will speed up the acquisition and processing of the data and allow taking more measurements per hour.

Shot Frequency: The frequency of liquid level data acquisition in shots/hour.

Shot Entry Graph Parameters – If checked it limits the number of shots displayed on graph

8.4.2 - Setup Shot

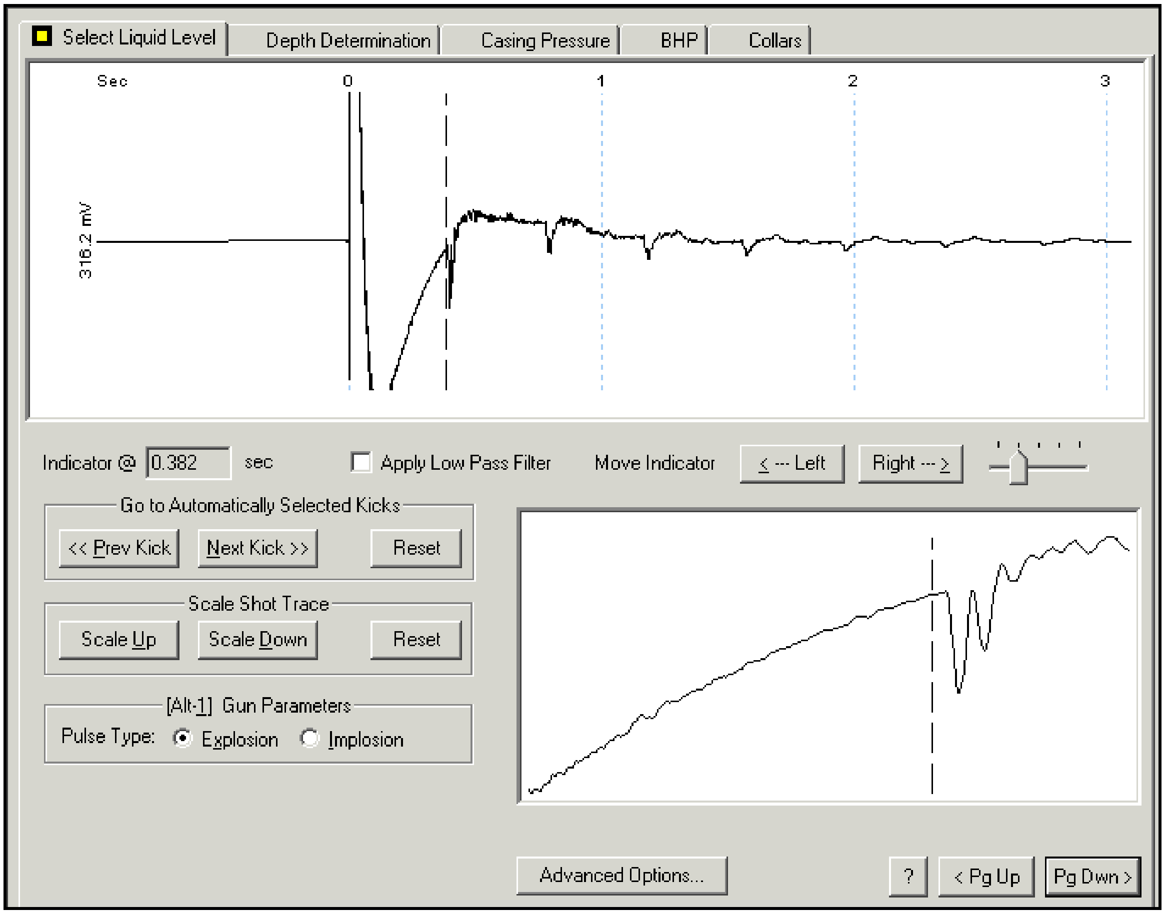
The next step is required to set up the initial shot to verify that the correct signal is identified as the liquid level and that extraneous signals do not interfere with the desired liquid level reflection. Selecting the Setup Shot tab the following screen is displayed, showing the well's background noise:



Upon striking the ENTER key (or Alt-S or clicking the "FIRE SHOT" button), the Well Analyzer initiates the firing sequence and records the fluid level signal that is used to set up the rest of the test.

8.4.3 - Select Liquid Level

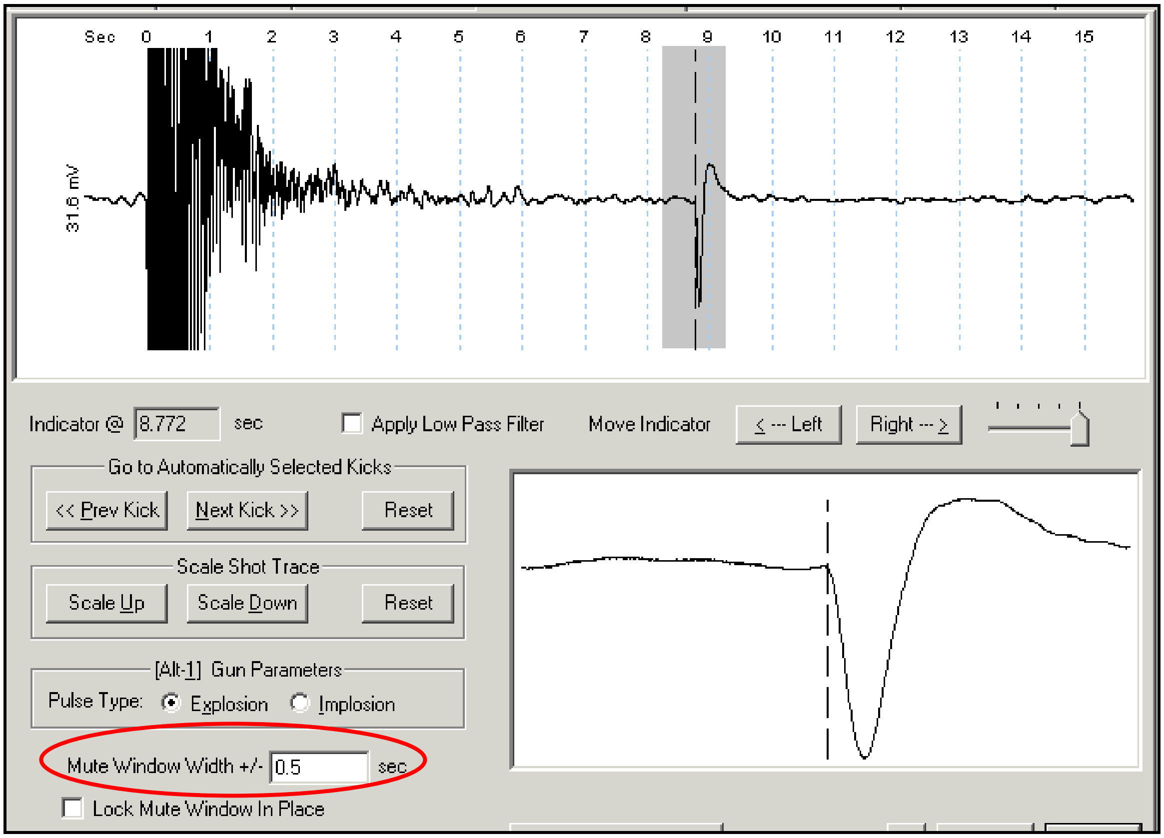
The following screen shows the display after the set up shot is taken.



This screen is designed to verify that the correct signal is identified by the software as the echo from the liquid level. It also allows the operator to over-ride the software and force the selection of a particular liquid level echo.

The gray band indicates the portion of the signal where the software has detected the liquid level. This band is centered at the liquid level marker and has a default width of +/- 0.5 seconds, which is adequate for most tests. Occasionally it may be necessary to modify the width of the window if the liquid level is changing position rapidly and the shot frequency is low so that it may be possible for the liquid level to move out of the signal window from shot to shot.

Identification of the liquid level may be masked by well noise. In these instances it may be advantageous to filter the signal to improve the liquid level detection.

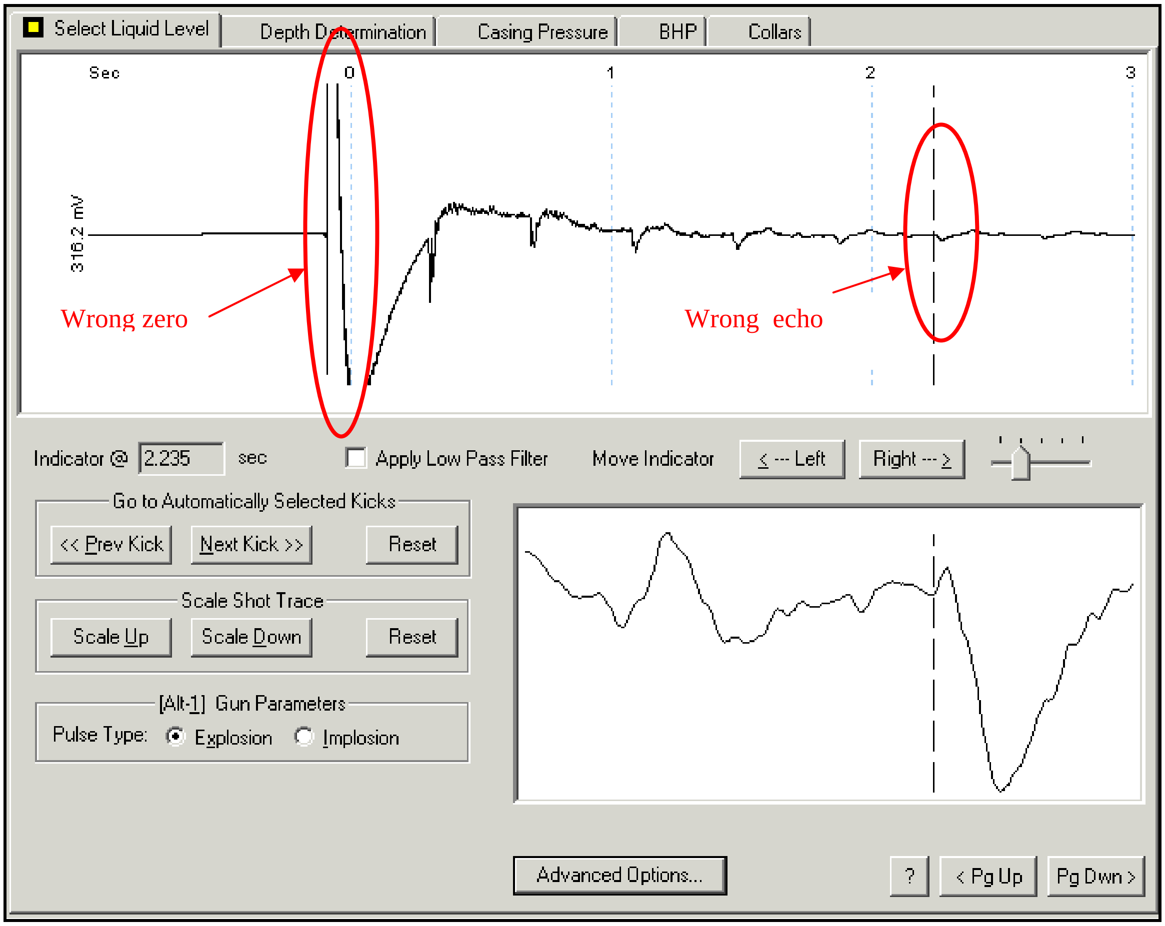


8.4.4 - Quality Control of Liquid Level Measurement

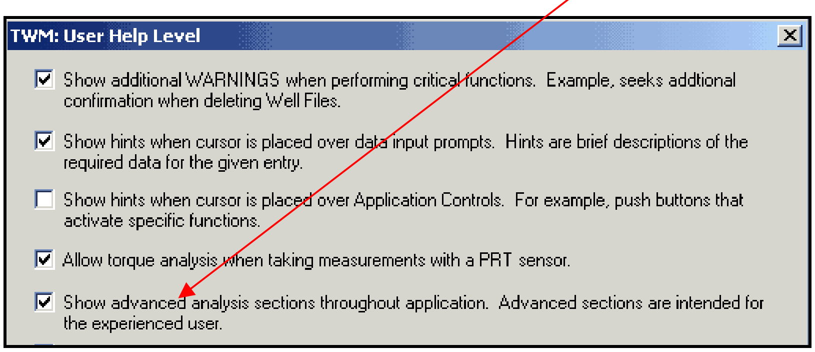
The accuracy of the liquid level measurement may deteriorate in certain well conditions such as very high liquid levels, noisy environments or extraneous signals caused by non-optimum piping. The operator should verify that the correct liquid level is detected and also that the ZERO time coincides with the onset of the pulse.

In the following example, both the liquid level and the zero time are selected incorrectly and need to be adjusted before proceeding with the test.

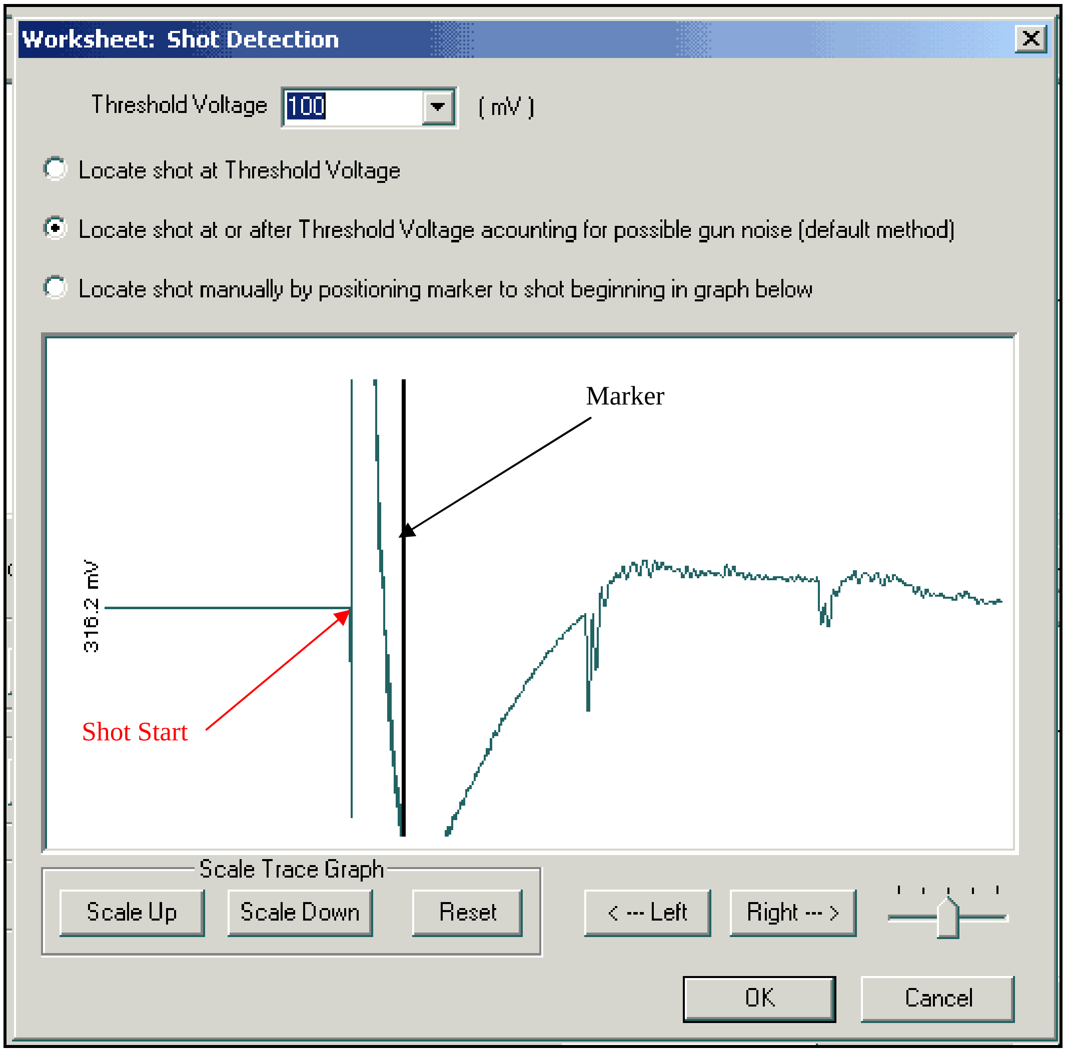
Generally the software should select the first echo. If this is not the case the user has the option of moving the marker to the first echo or alternately to indicate to the program that the marker is located on a multiple of the liquid level echo and to enter the number of the echo (6 in the example below) so that the software can calculate the correct distance to the liquid level.



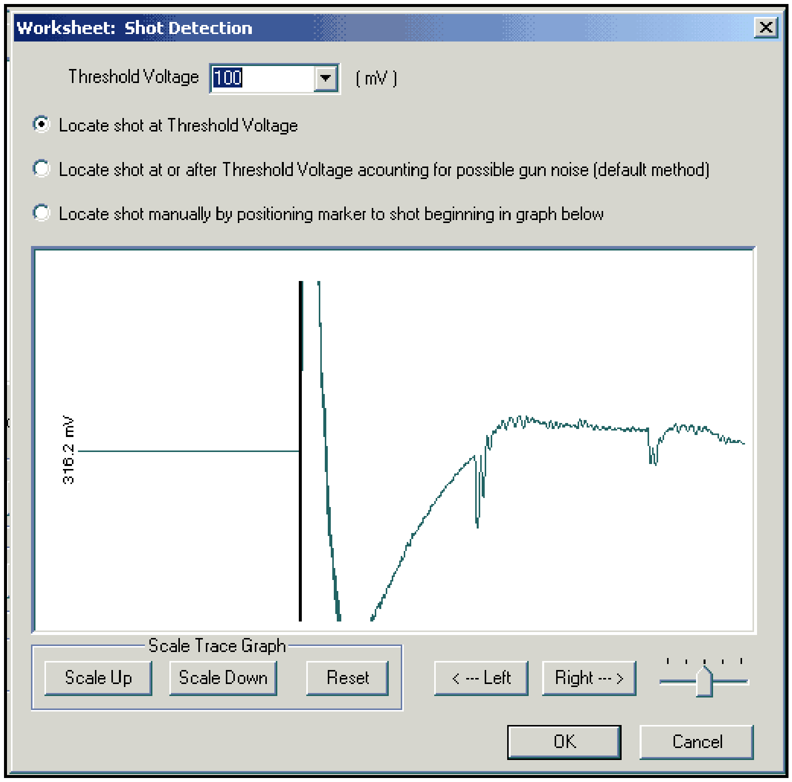
Clicking the Advanced Options button at the bottom of the window allows adjusting the ZERO to match the firing of the shot. (The **Show advanced analysis** should have been selected in the User Help Level window of the Help menu)



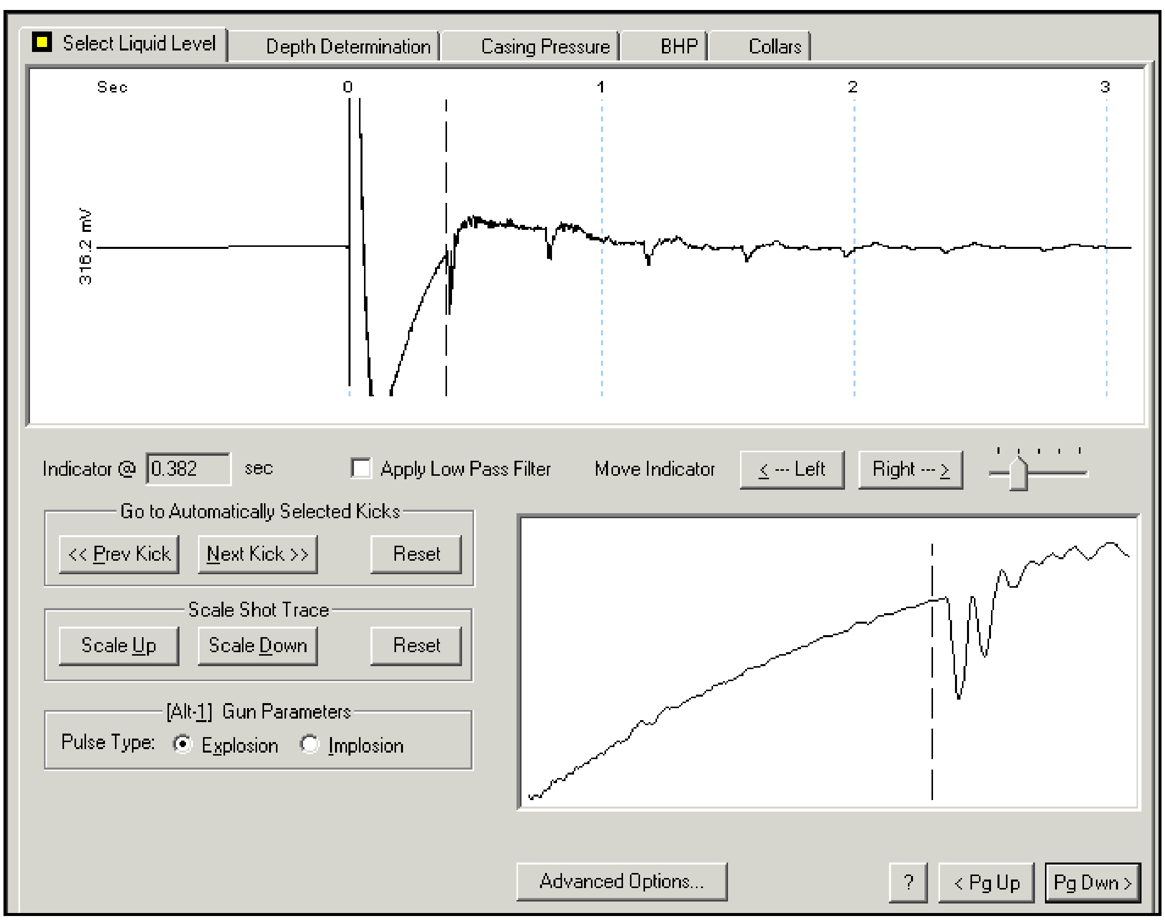
The Advanced Options button opens the Shot **Detection Worksheet** that allows resetting the method by which the software detects the shot. The default method is shown in the figure below which also shows that the zero marker is not located correctly.



In this case the default method misses selecting the start of the shot and places the zero marker a fraction of a second after the start of the shot. In this case choosing the first option: "Locate shot at threshold voltage" solves the problem and the software marks the zero point correctly as shown in the next figure. Sometimes it may be necessary to change the value of the threshold voltage in order to automatically select the correct start. The user can also locate the marker manually at the start using the arrow buttons.

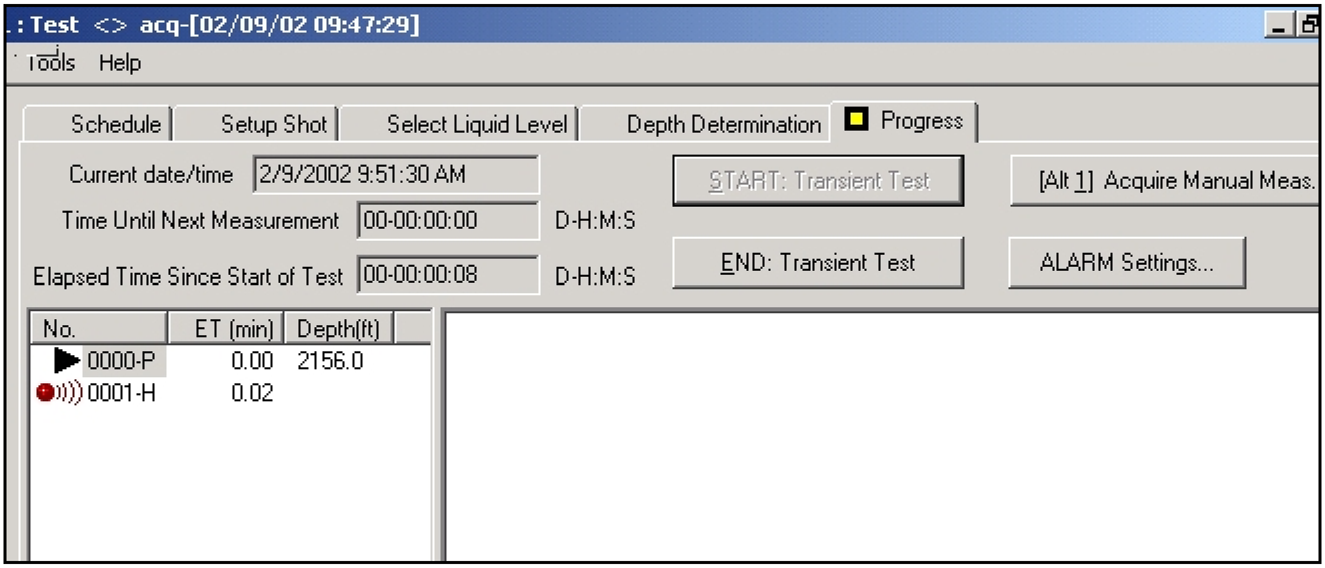


The figure below shows the corrected ZERO and Liquid Level Selection:



8.4.5 - Test Progress

The progress screen is used to monitor the liquid level position. Initially it will be blank and display only the result of the Set Up Shot (Labeled 0000-P). As soon as the START transient test button is clicked, the program will initiate the test and fire the first shot (labeled 0001-H) indicating the software is actively acquiring and processing the data:



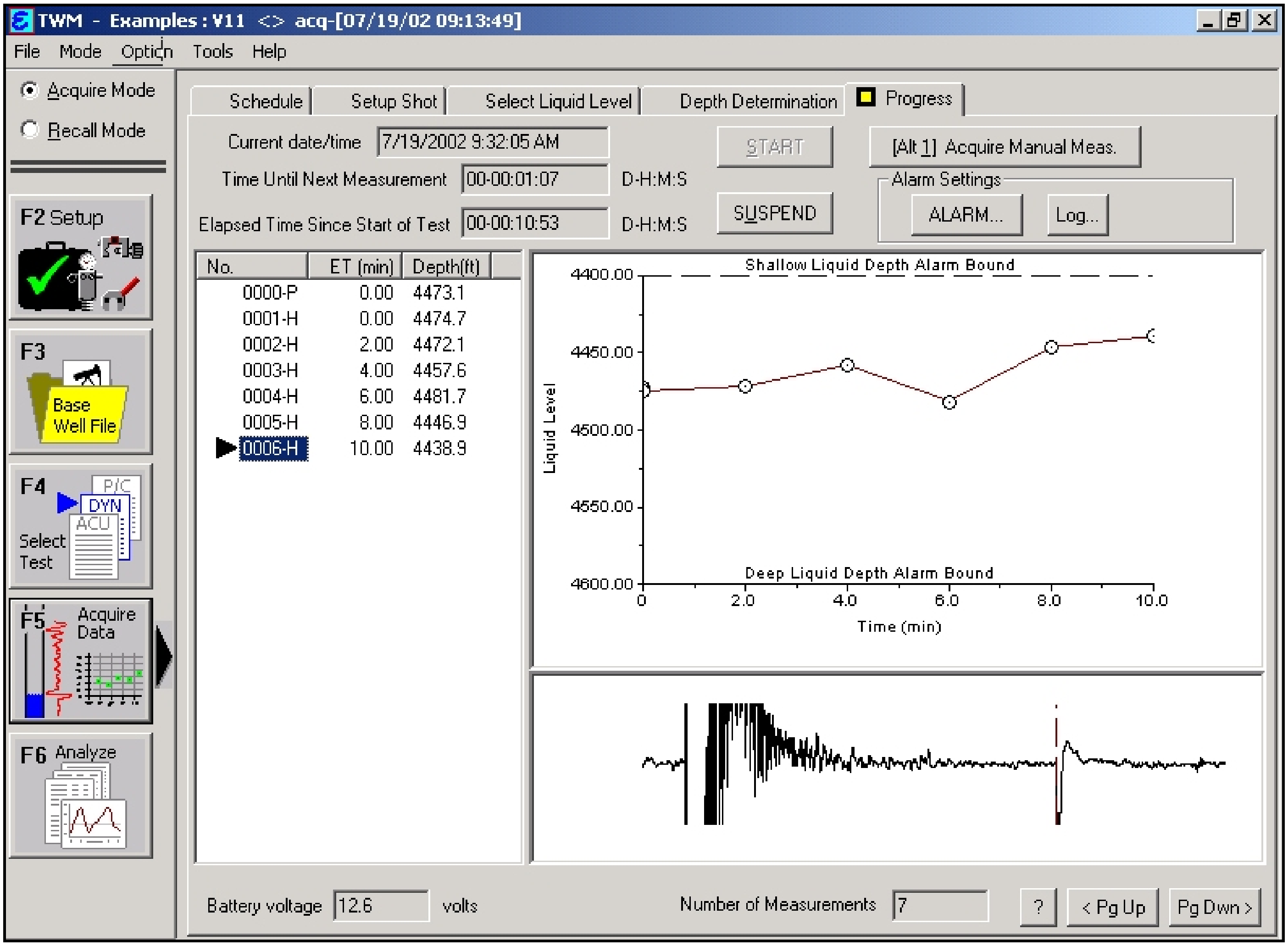
After the first shot is processed the liquid level position is graphed as a function of time as shown in the following picture. The scale is set automatically and although it appears that the liquid level has changed drastically, one should note that the scale is set between 4400 and 4600 feet.

The record of the shots gives the shot sequence followed by an extension, which indicates the type and quality of the shots according to the following convention:

P – Pre-test or set-up shot
H – Hard shot, or a shot where the liquid level was detected.
M – Manual shot, or a shot that was made out of the programmed sequence, manually by the operator.
S – Soft shot, or a shot where either the shot or the liquid level were not detected.

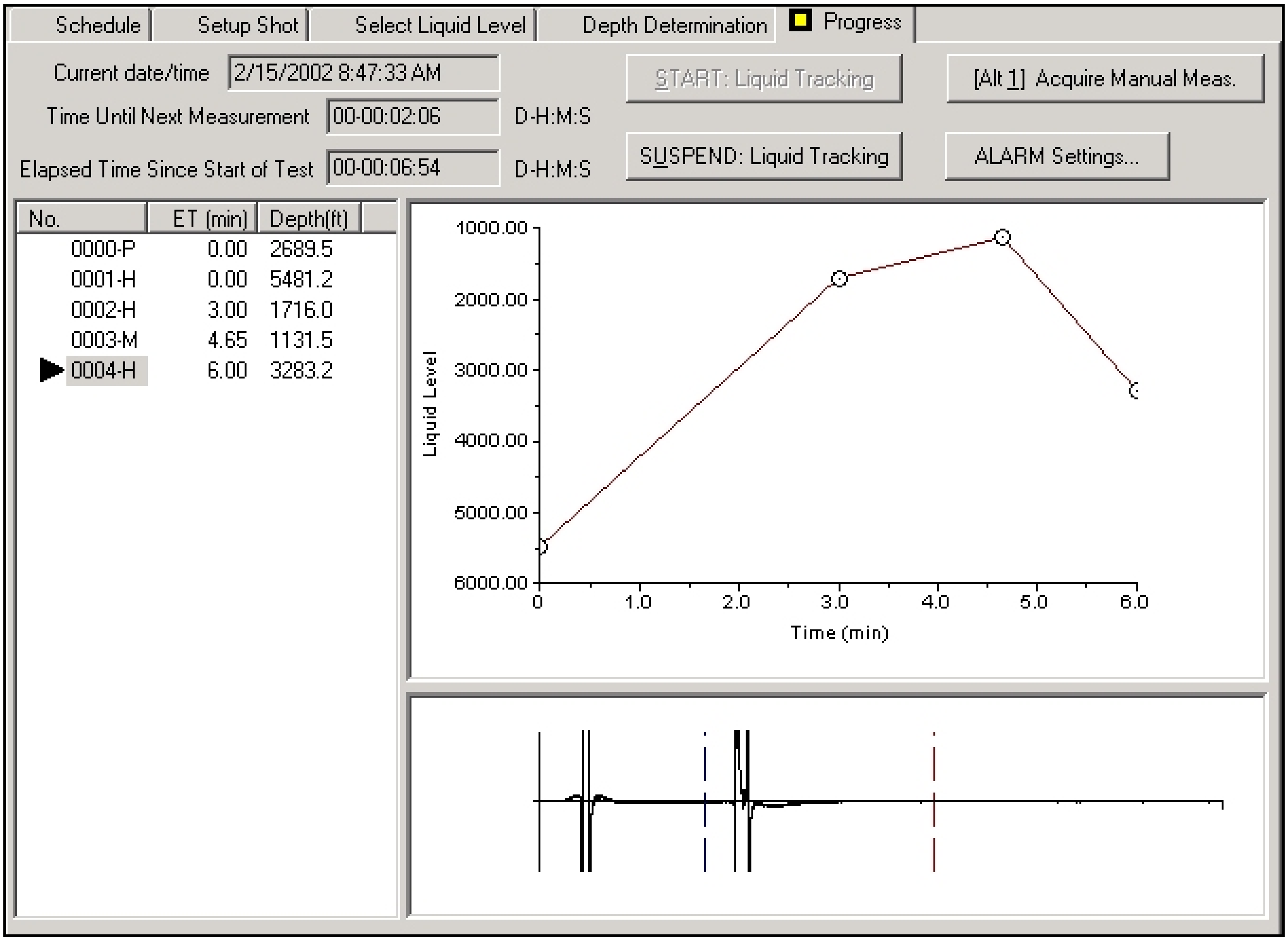
The screen also shows the **time elapsed** since the start of the liquid tracking test and the **time to the next** programmed shot.

Clicking on the **Suspend Liquid Tracking** button can interrupt the test and then it can be resumed by clicking the **Continue Liquid Tracking** button.


TWM - Examples : V11 <> acq-[07/19/02 09:13:49]
File Mode Option Tools Help
Acquire Mode
Recall Mode
F2 Setup
F3
Base Well File
F4
P/C
DYN
ACU
Select Test
F5
Acquire Data
F6 Analyze
Schedule
Setup Shot
Select Liquid Level
Depth Determination
Progress
Current date/time
7/19/2002 9:32:05 AM
Time Until Next Measurement
00-00:01:07
D-H:M:S
Elapsed Time Since Start of Test
00-00:10:53
D-H:M:S
START
SUSPEND
[Alt 1] Acquire Manual Meas.
Alarm Settings
ALARM...
Log...
No.
ET (min)
Depth(ft)
0000-P 0.00 4473.1
0001-H 0.00 4474.7
0002-H 2.00 4472.1
0003-H 4.00 4457.6
0004-H 6.00 4481.7
0005-H 8.00 4446.9
0006-H 10.00 4438.9
Shallow Liquid Depth Alarm Bound
Deep Liquid Depth Alarm Bound
4400.00
4450.00
4500.00
4550.00
4600.00
Liquid Level
0
2.0
4.0
6.0
8.0
10.0
Time (min)
Battery voltage
12.6
volts
Number of Measurements
7
?
< Pg Up
Pg Dwn >

8.4.6 - Liquid Level Control

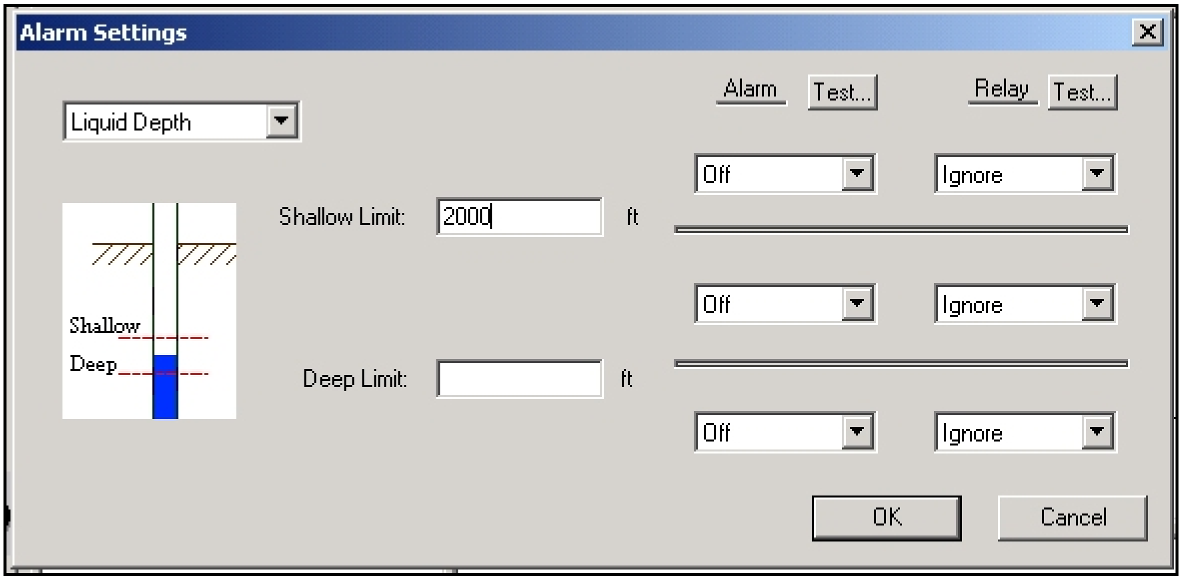
In order to verify that the liquid level is picked correctly from shot to shot, the most recently acquired acoustic signal is plotted at the bottom of the screen:



The vertical markers show the location in time of the liquid level for the previous shot (red) and the current shot (blue). The figure above shows that the software is erroneously flagging a signal which is not the liquid level, and also that the liquid level has changed position from the previous shot. In this case the user should suspend the test and reset the acquisition parameters to insure that the liquid level is detected correctly on the next shot.

8.5 - Setting of Alarm Limits

In the previous figure only the computed values of the liquid level were displayed. It is also possible to set alarm limits so that if the fluid level is not within the specified depth interval an alarm will be displayed on the screen with an audible signal. In addition a solid-state relay will be closed to provide an external control to additional alarm annunciators. The relay is accessed through the appropriate connector on the right side of the Well Analyzer. Clicking on the **Alarm Settings** button will bring up the following screen, to enter the alarm limits:

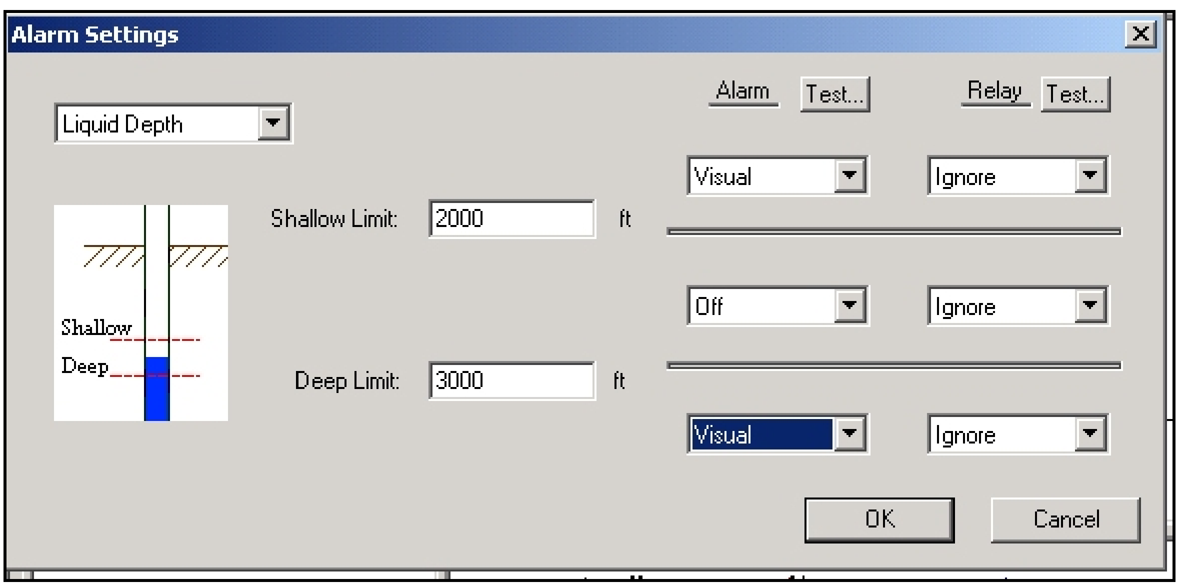


Shallow Limit: is the depth to the highest allowable position of the liquid level in the wellbore. If the liquid **rises above** this point the alarm will be triggered.

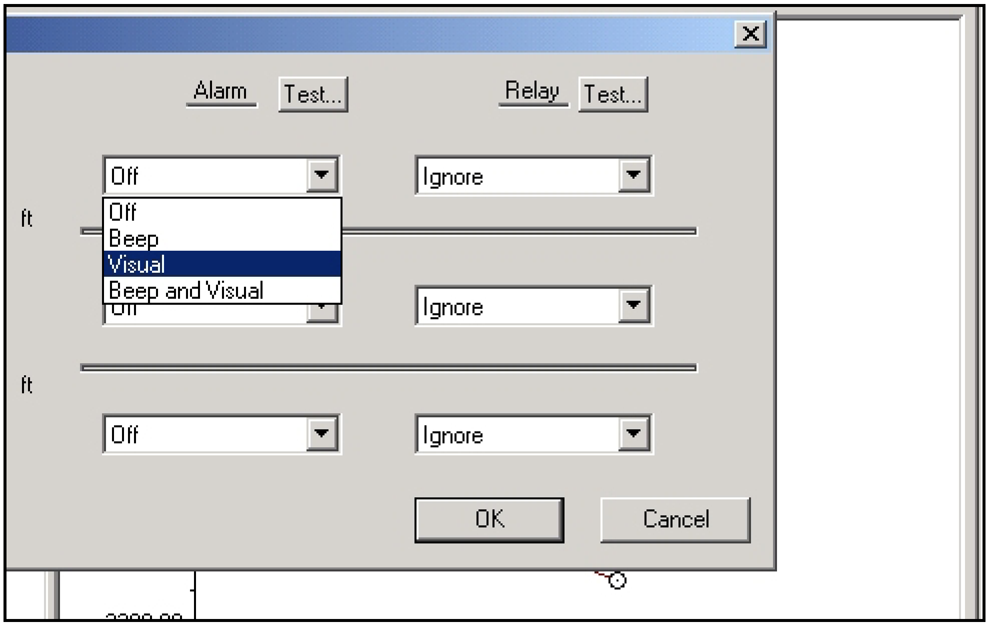
Deep Limit: is the depth to the lowest allowable position of the liquid level in the wellbore. If the liquid **falls below** this point the alarm will be triggered.

The default condition is for the alarms to be Off as indicated in the figure above. The pull down menu offers the following choices:

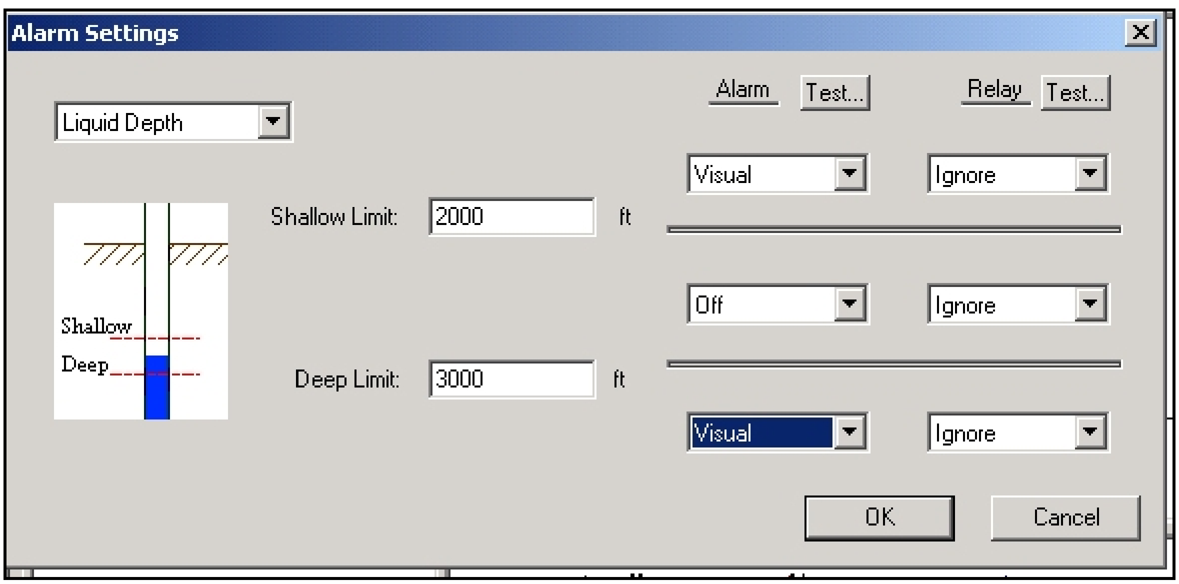
Off: no alarm limit
Beep: the computer will beep
Visual: an alarm message will flash on the screen
Beep and Visual: beeping and alarm message simultaneously



These options can be selected for either limit as shown below.

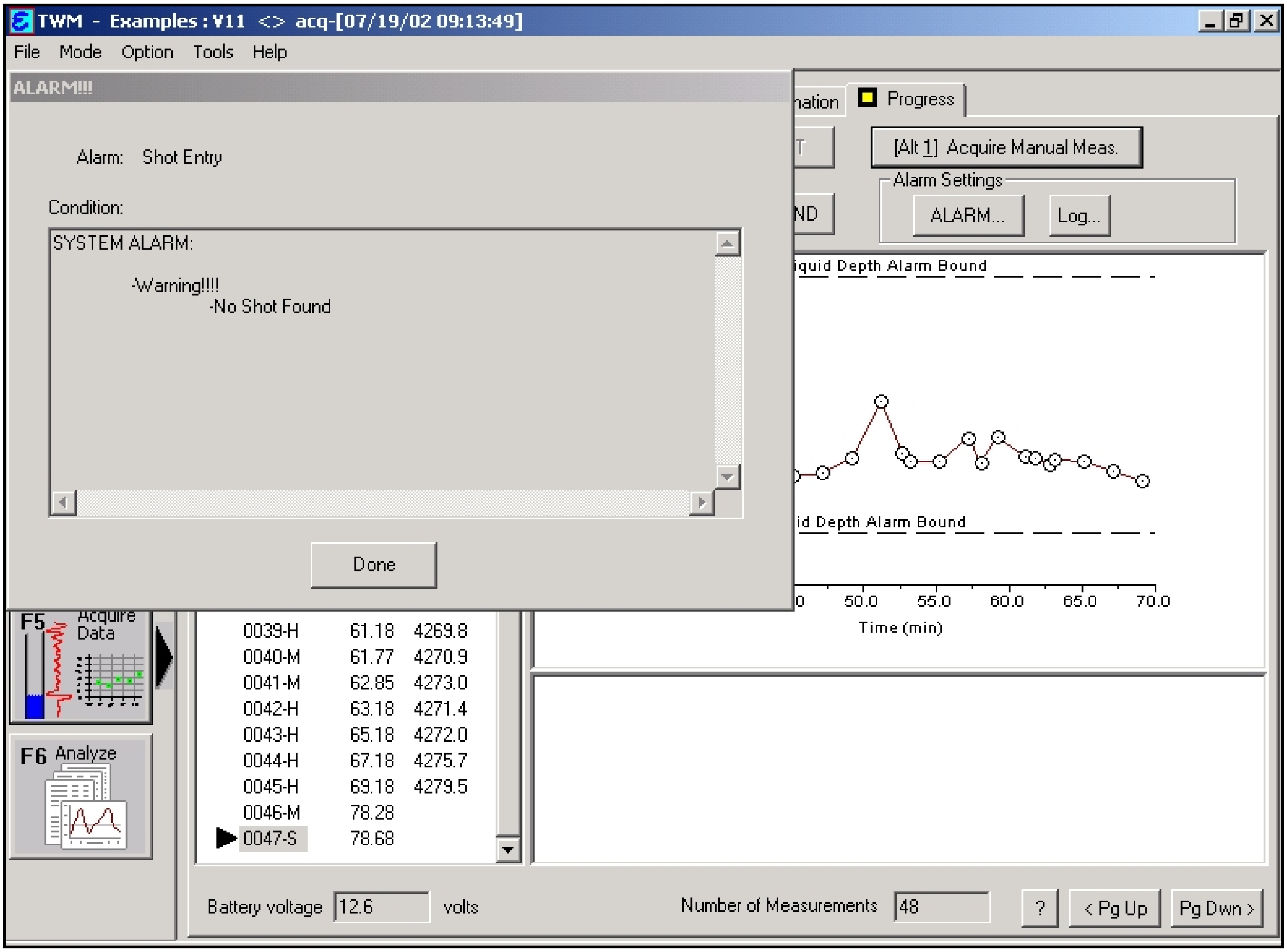


The figure below shows that the limits have been set to 2000 and 3000 feet and the alarm modes have been set to visual.



8.5.1 - Shot Not Found Alarm

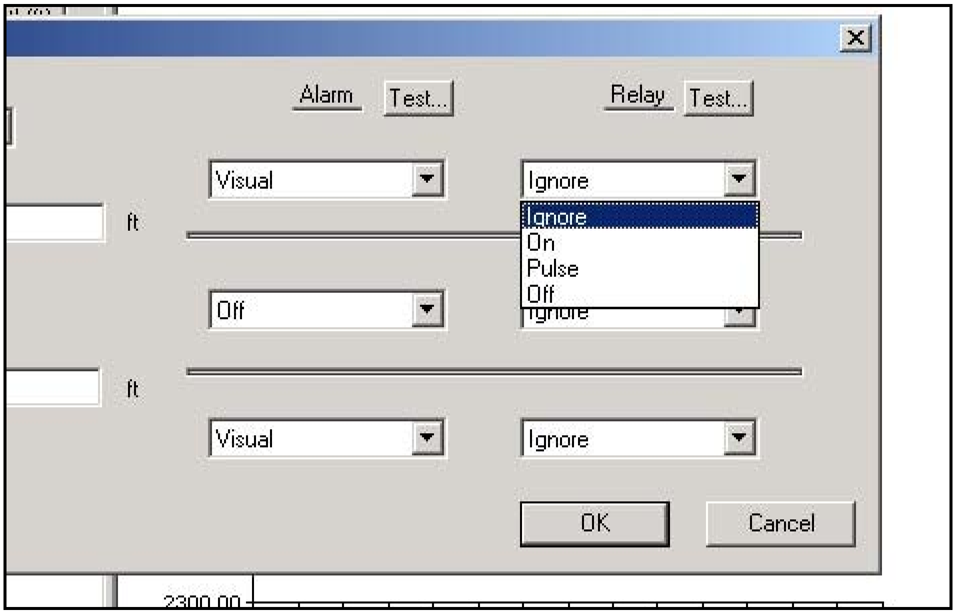
An alarm is also generated if the software fails to detect a shot, either due to insufficient gas pressure in the chamber or any other reason. The following figure shows such an instance:



8.5.2 - Switched 12 Volt Output Relay Actuation:

A solid-state relay will be closed to provide an external control voltage to additional alarm annunciations. As shown below the relay corresponding to each alarm can be closed (ON) opened (OFF) or alternate between open and closed (PULSE)

The default condition is IGNORE where the relay will not be actuated.

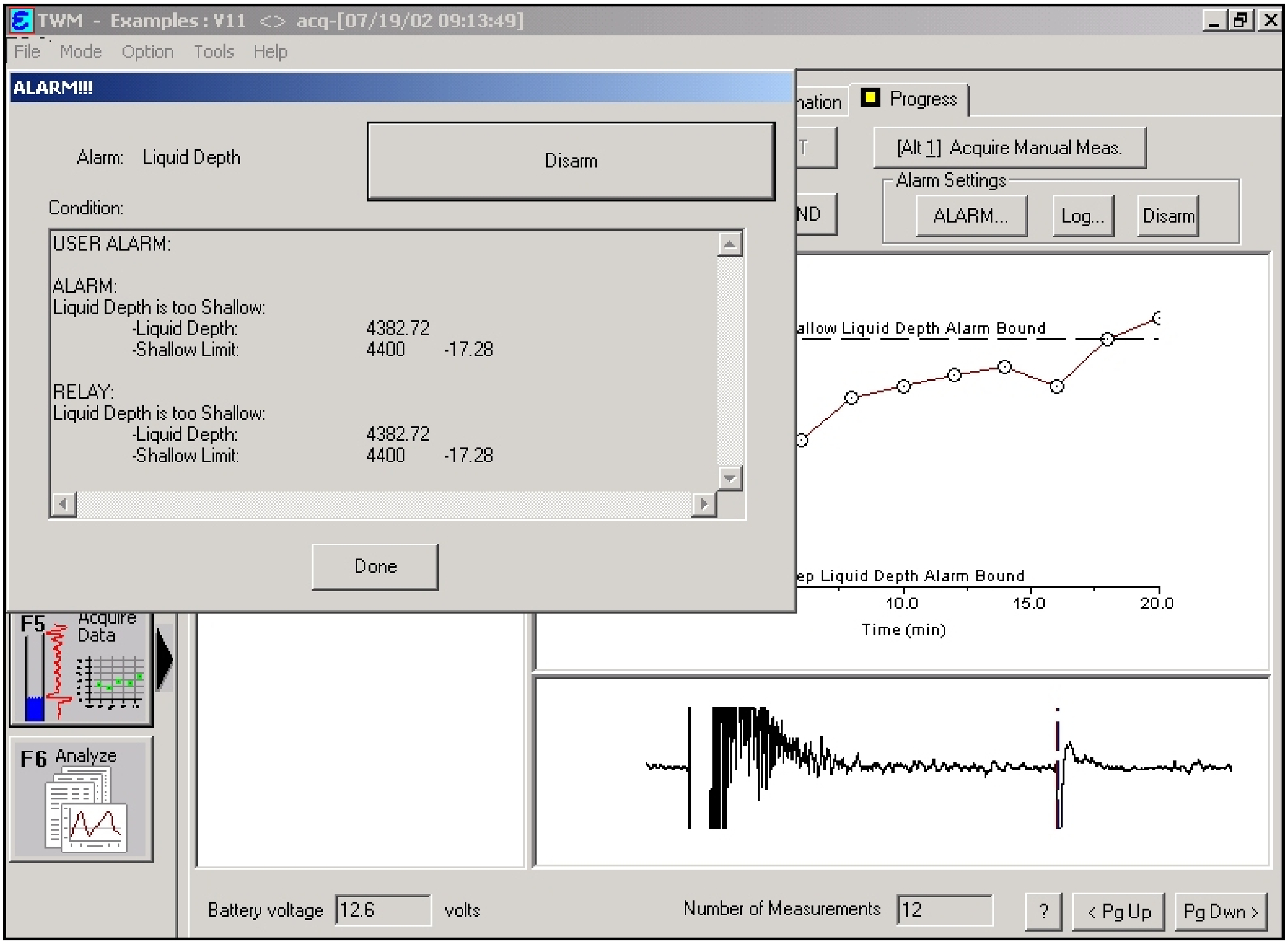


8.5.2.1 - Relay Output Characteristics

The relay output should be considered as a switched 12 Volt power supply with a maximum output of 2 amps continuous service. Depending on the well analyzer model it is connected to an individual connector labeled Relay Output (models E1 and E2) and is part of the Auxiliary connector in model E3 where the 12 Volt output is applied between Pin G of the 7-pin connector and the ground pin (center pin). In the model E3, the output current is instantaneously limited to a maximum of 5 amps.

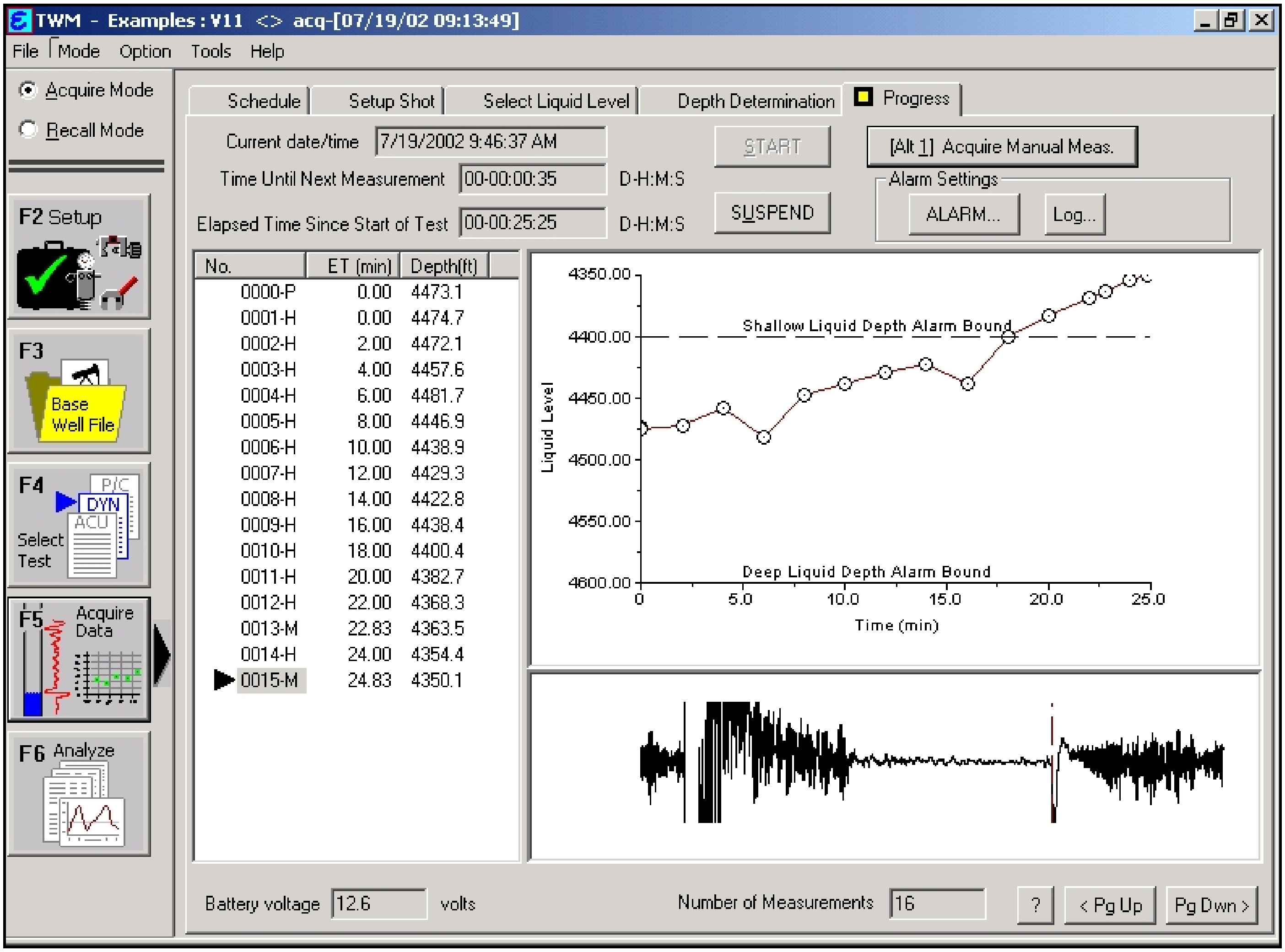
NOTE: The following screens are provided for illustration purpose only and do not necessarily represent actual fluid level variation.

The following figure shows that two shots have recorded a liquid level above the Shallow Liquid Alarm

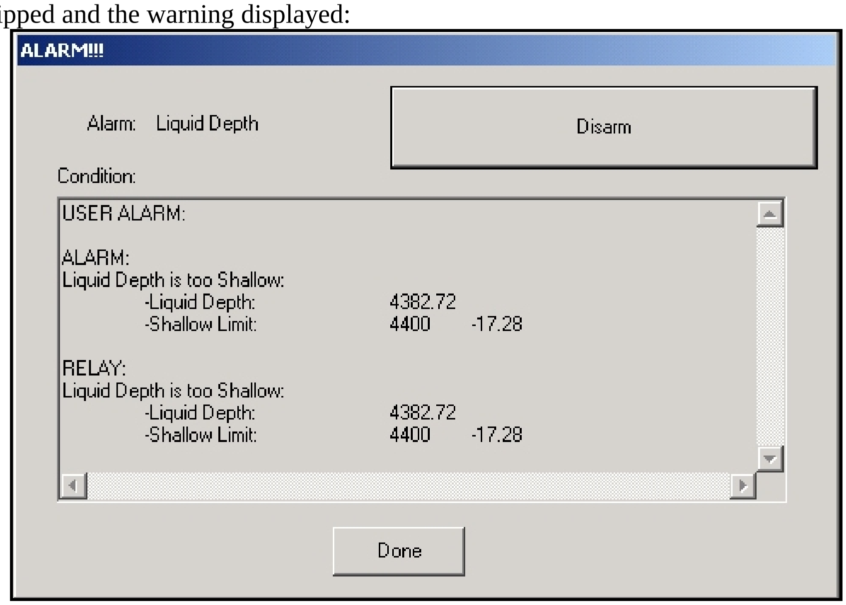


Correspondingly the Alarm flashes on the screen.

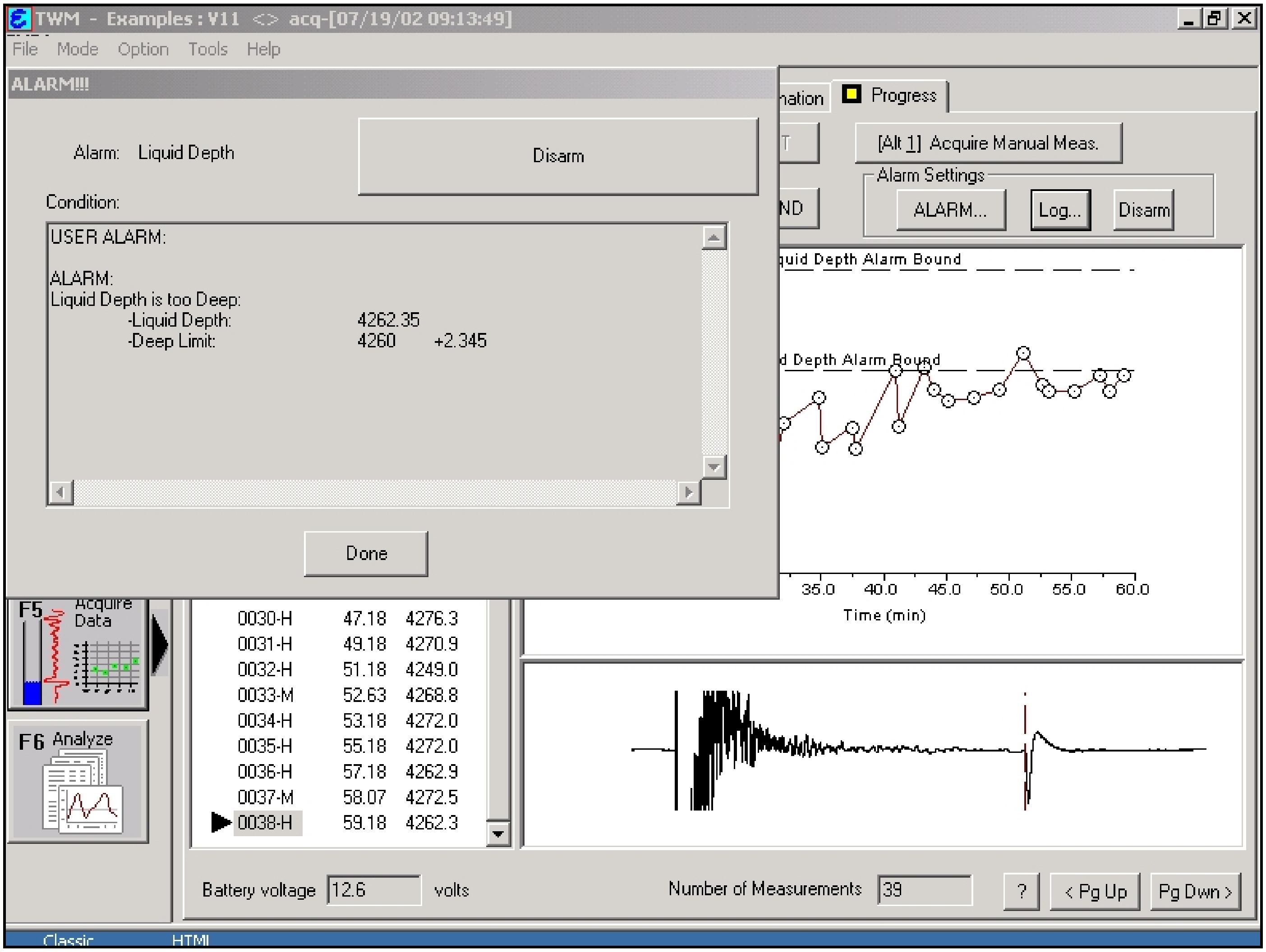
The position of the liquid level can be **verified** after the alarm has been tripped by firing a **MANUAL** shot, as shown in the following figure:



And again the alarm is tripped and the warning displayed:

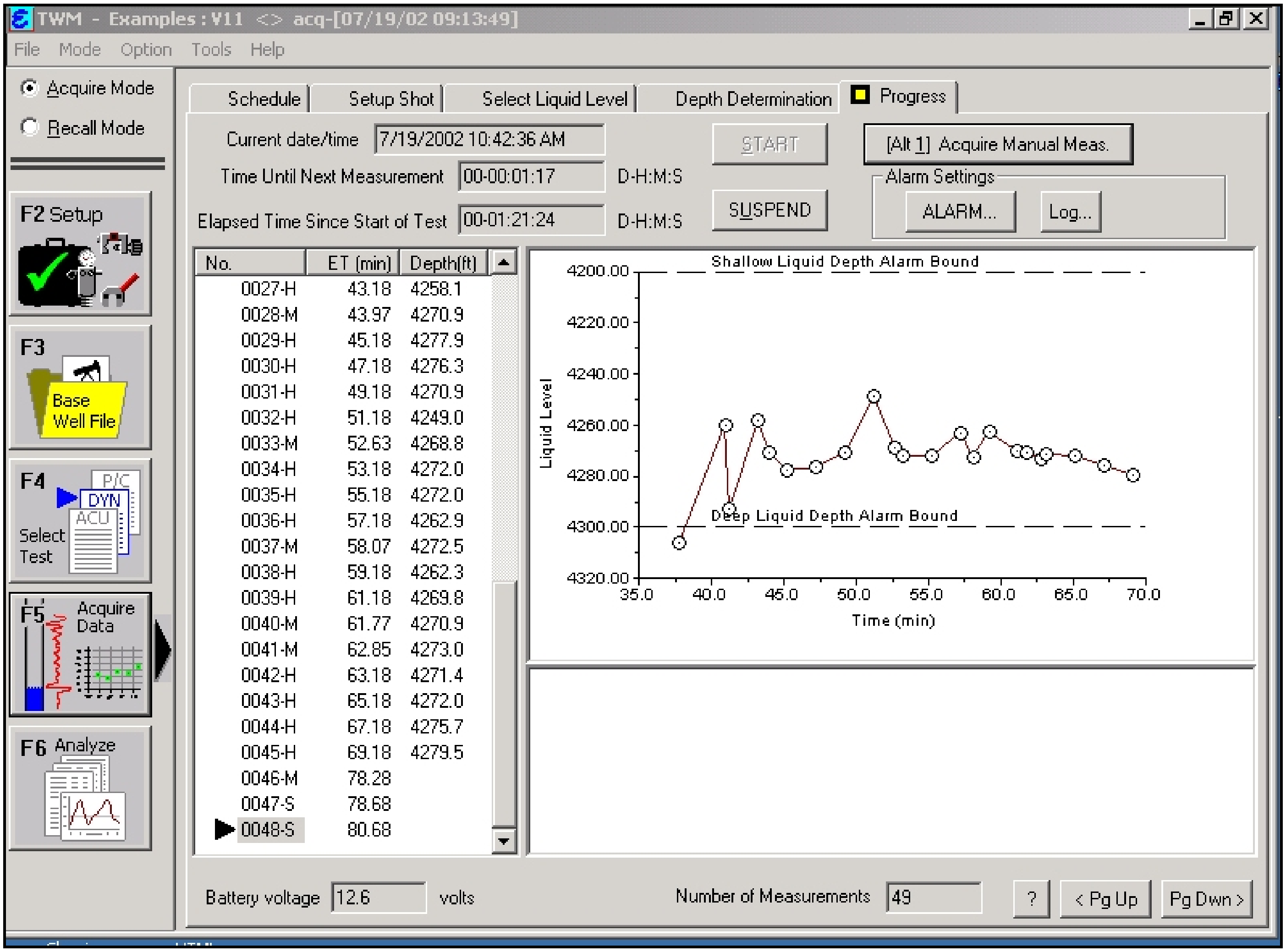


The following example shows a case where the liquid level has fallen **BELOW the Deep Liquid alarm** depth:



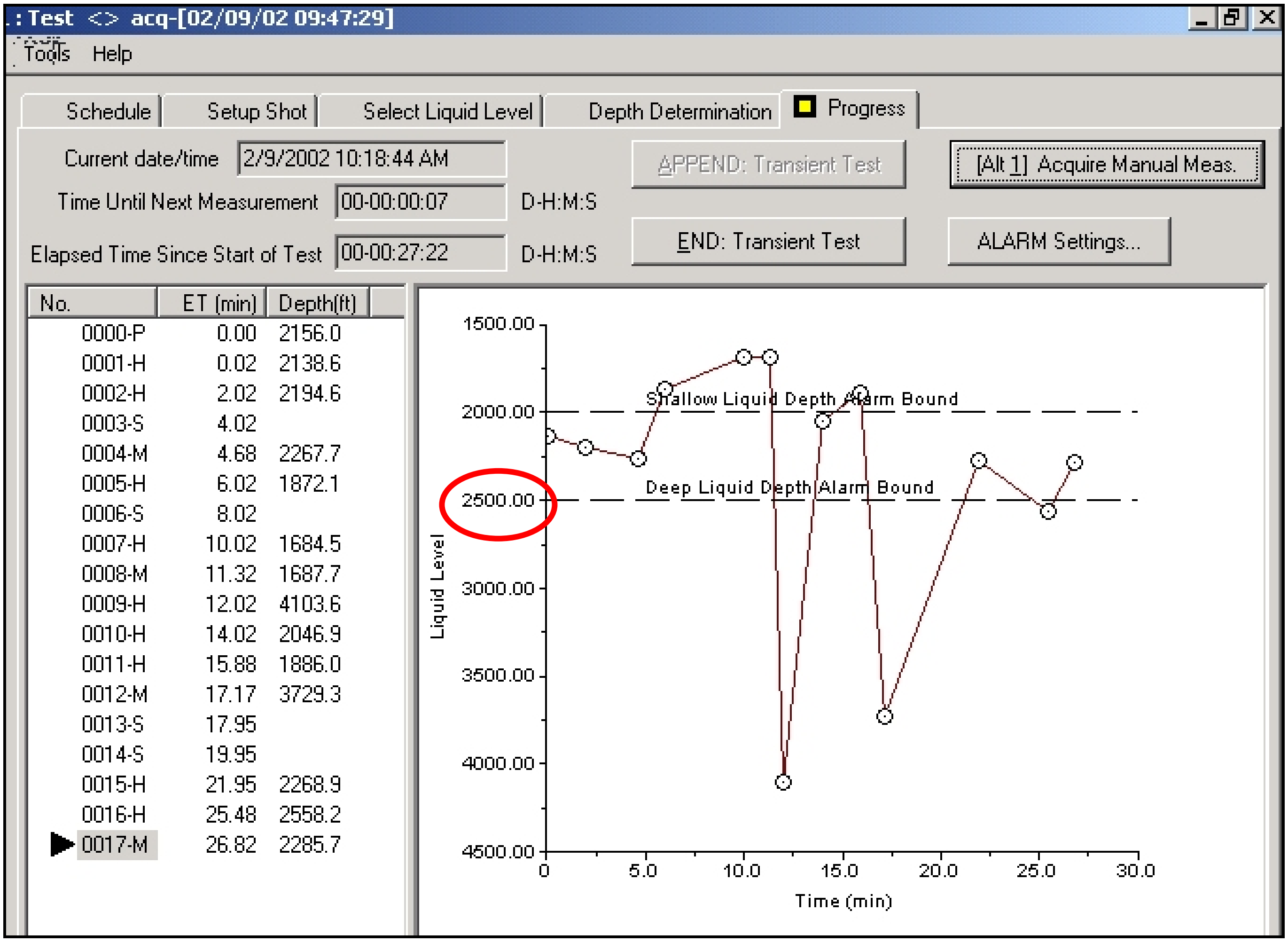
And the warning message flashes on the screen.

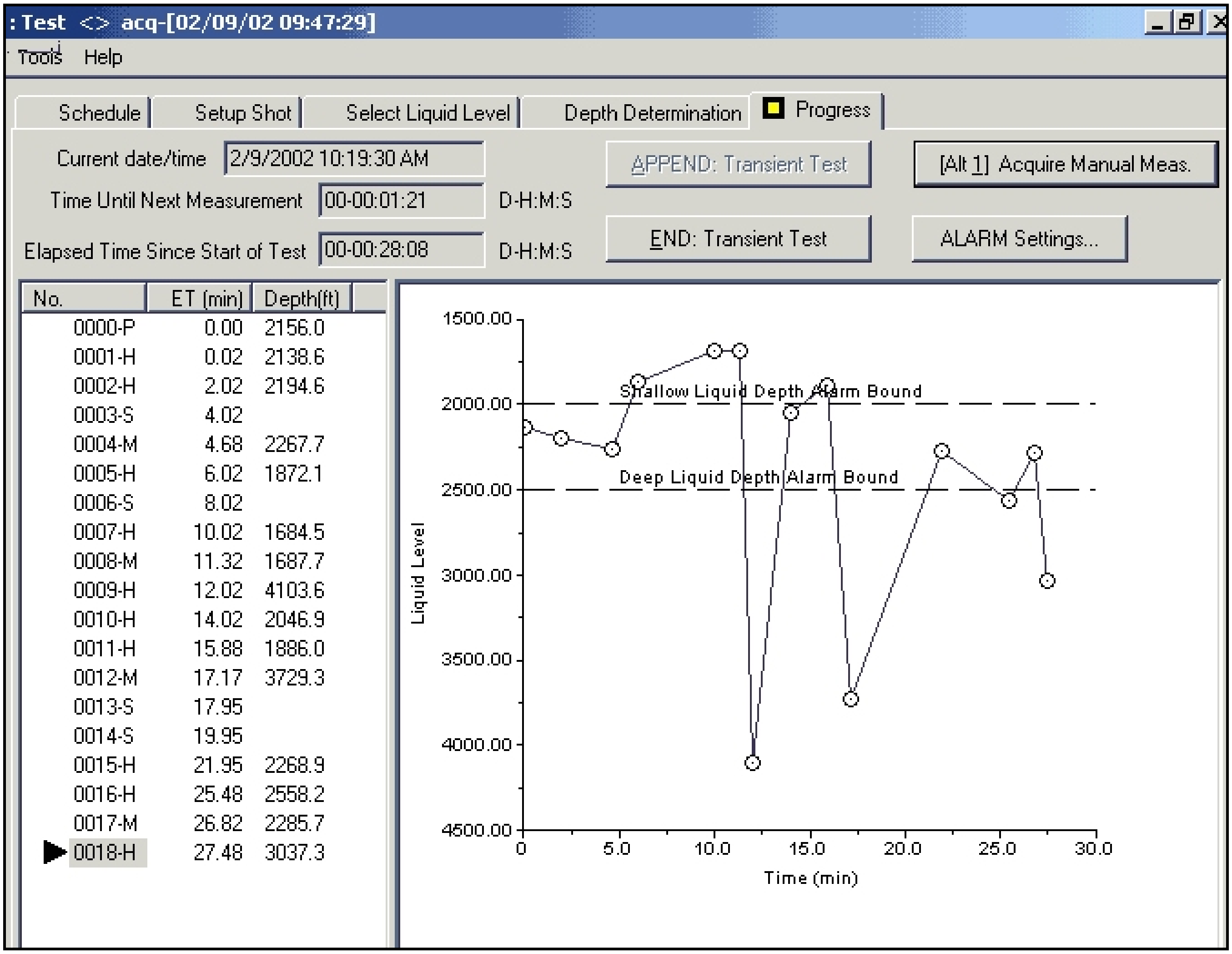
The following figure shows that the liquid level has returned within the alarm boundaries and the software continues to track the liquid level.



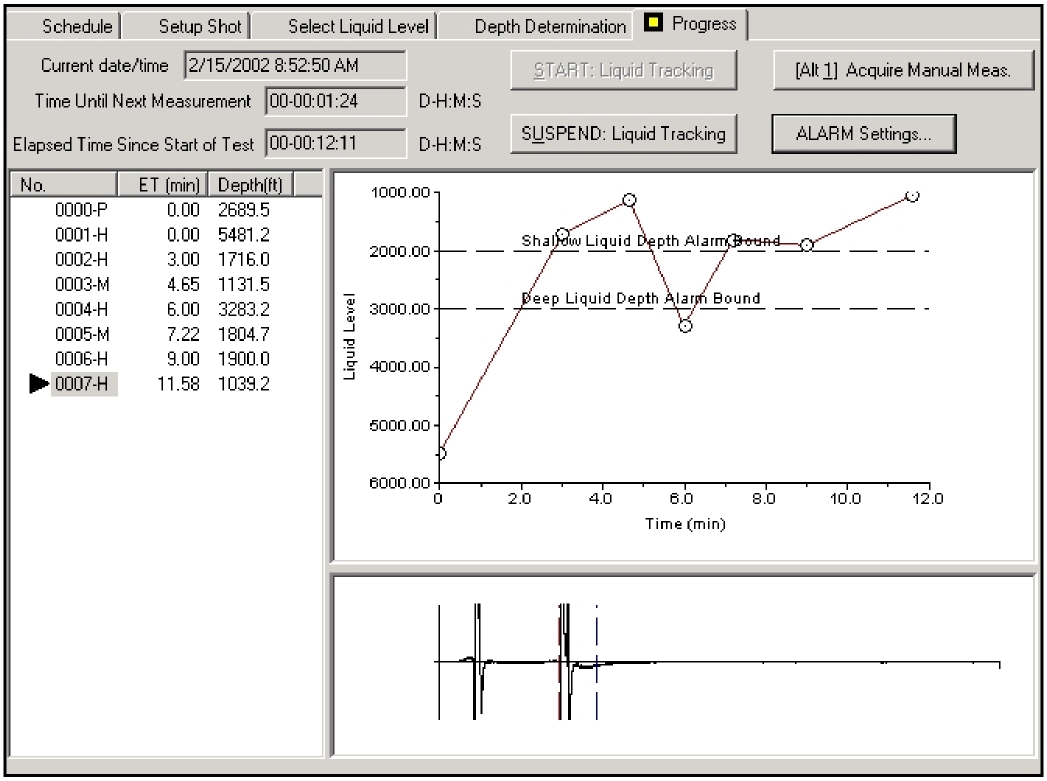
Resetting of the alarm limits

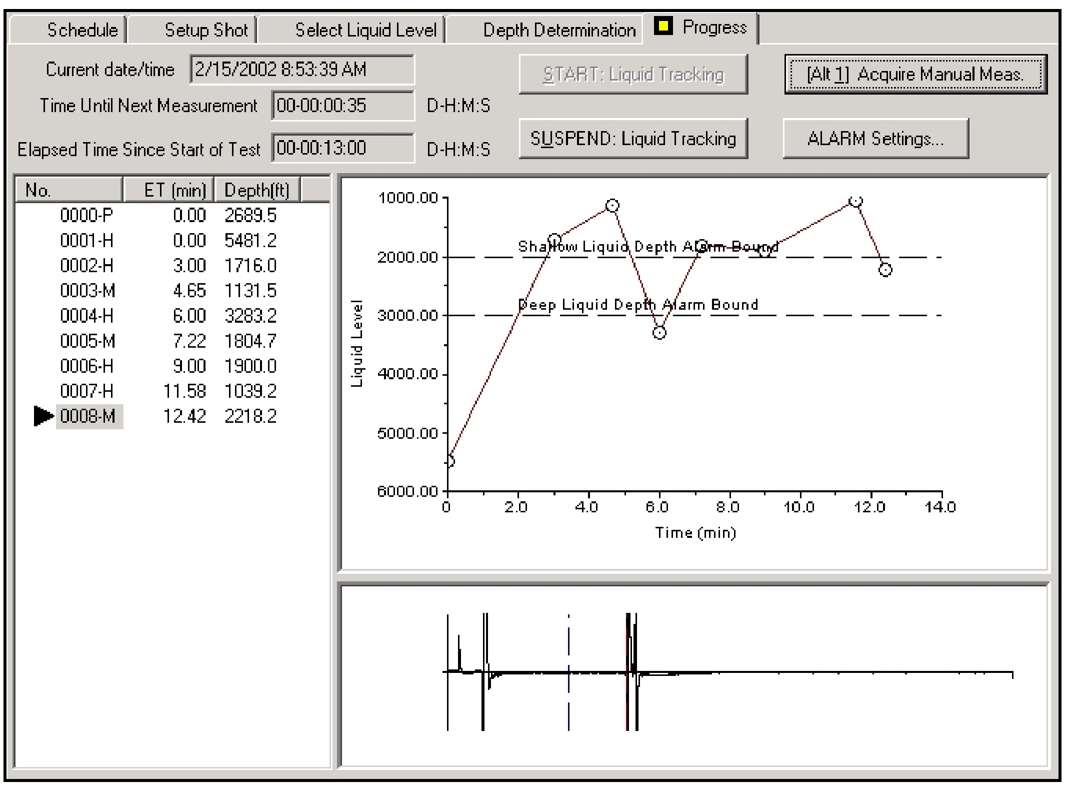
At any time during the test it is possible to change the alarm limits by clicking on the ALARM Settings button. The appropriate form for input of the new limits is displayed, and the limits are updated upon exiting the form as shown in the following figure where the Deep limit has been changed to 2500 feet from its original position of 3000 feet:

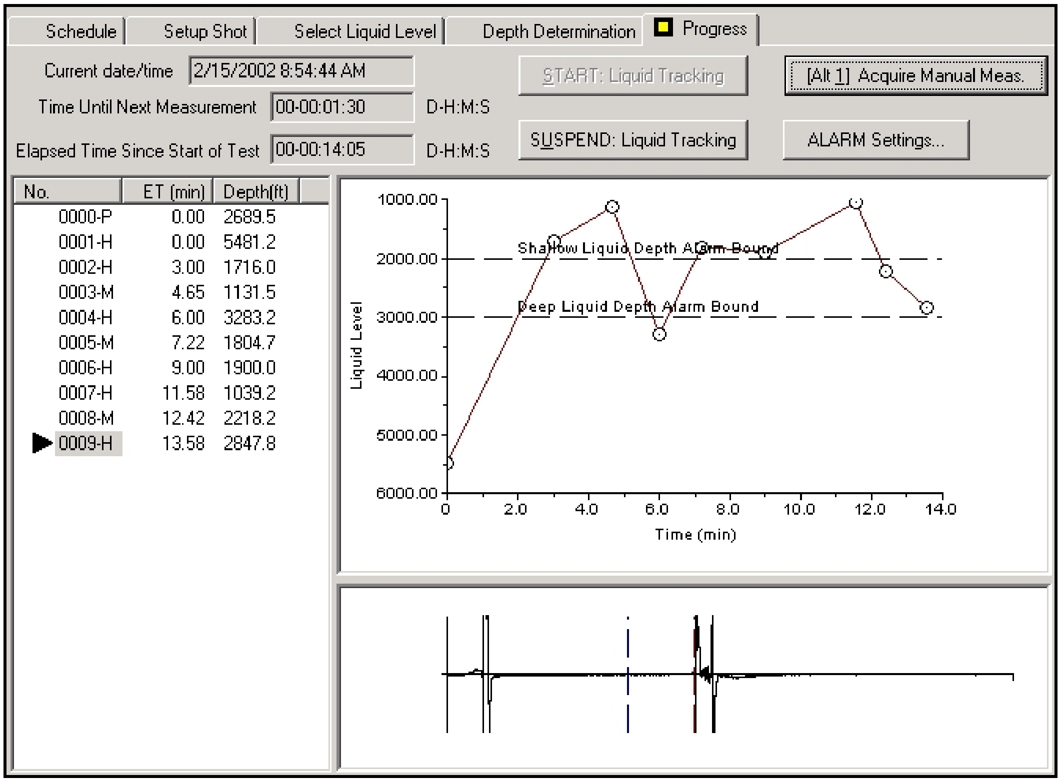


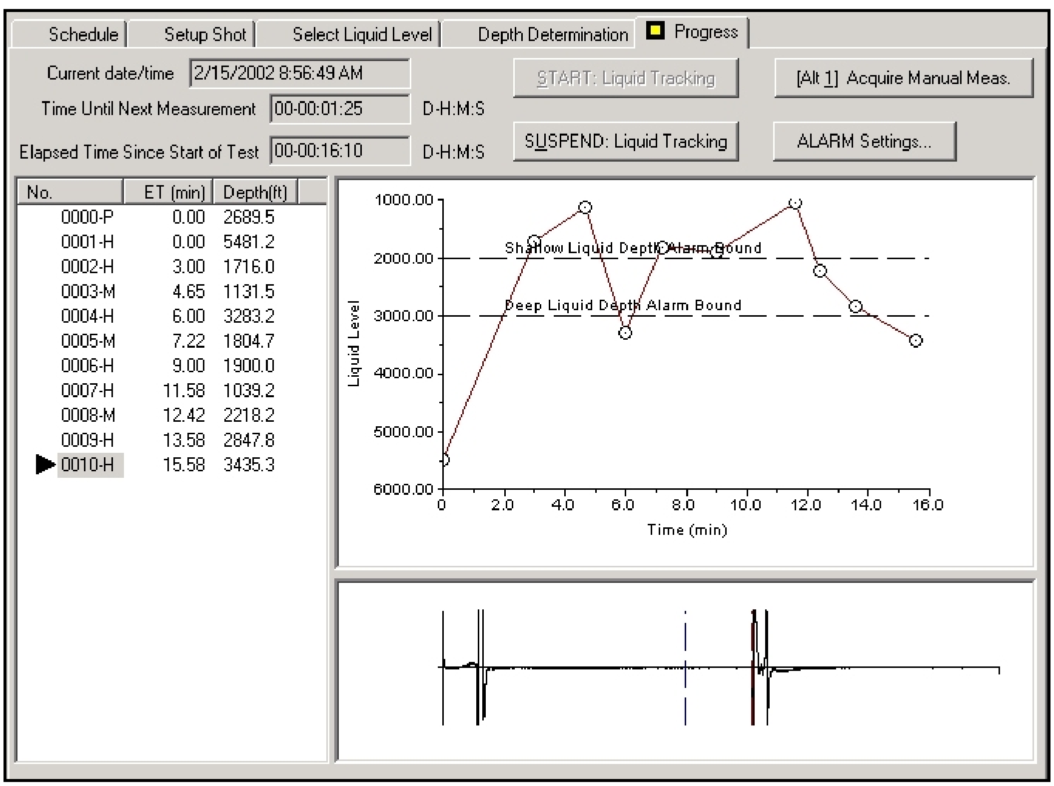

: Test <> acq-[02/09/02 09:47:29]
Tools Help
Schedule
Setup Shot
Select Liquid Level
Depth Determination
Progress
Current date/time 2/9/2002 10:19:30 AM
Time Until Next Measurement 00-00:01:21 D-H:M:S
Elapsed Time Since Start of Test 00-00:28:08 D-H:M:S
APPEND: Transient Test
END: Transient Test
[Alt 1] Acquire Manual Meas.
ALARM Settings...
No. ET (min) Depth(ft)
0000-P 0.00 2156.0
0001-H 0.02 2138.6
0002-H 2.02 2194.6
0003-S 4.02
0004-M 4.68 2267.7
0005-H 6.02 1872.1
0006-S 8.02
0007-H 10.02 1684.5
0008-M 11.32 1687.7
0009-H 12.02 4103.6
0010-H 14.02 2046.9
0011-H 15.88 1886.0
0012-M 17.17 3729.3
0013-S 17.95
0014-S 19.95
0015-H 21.95 2268.9
0016-H 25.48 2558.2
0017-M 26.82 2285.7
0018-H 27.48 3037.3
Shallow Liquid Depth Alarm Bound
Deep Liquid Depth Alarm Bound
Liquid Level
1500.00
2000.00
2500.00
3000.00
3500.00
4000.00
4500.00
0
5.0
10.0
15.0
20.0
25.0
30.0
Time (min)

The following sequence shows the liquid level decreasing continuously from a point above the High liquid level alarm to a point below the Low liquid level alarm:



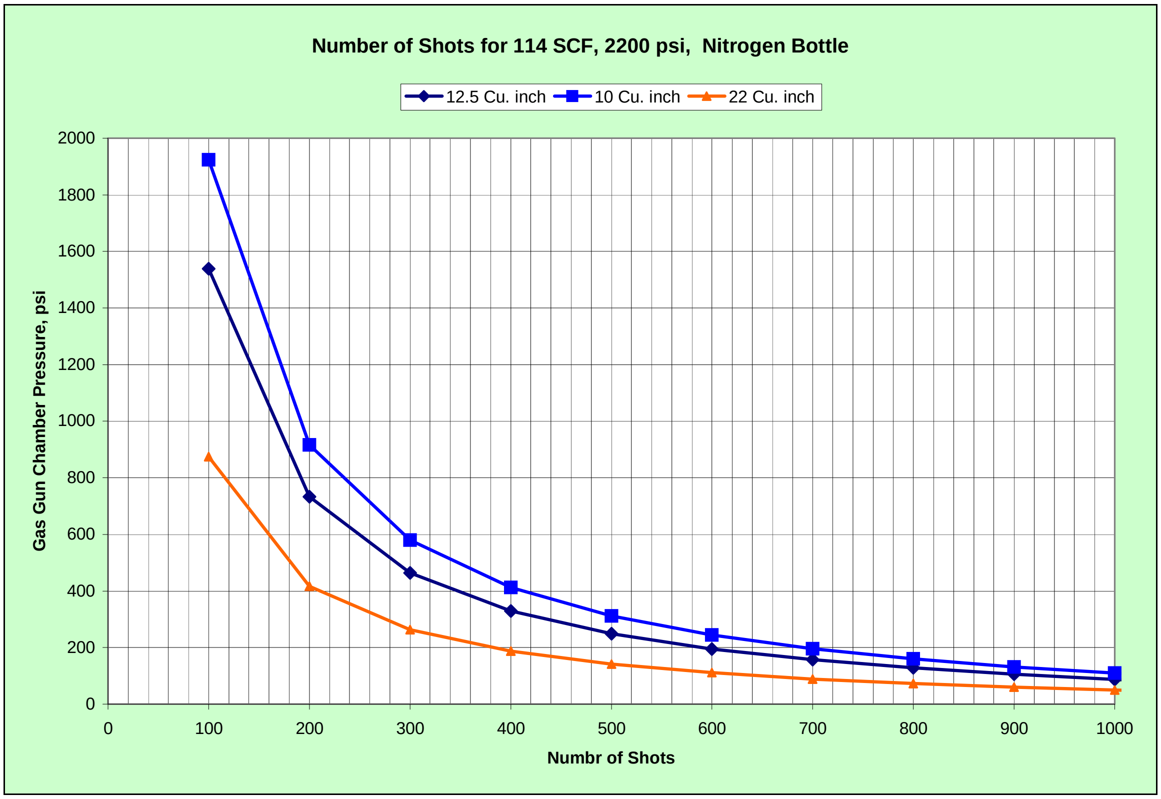



Schedule
Setup Shot
Select Liquid Level
Depth Determination
Progress
Current date/time 2/15/2002 8:54:44 AM
Time Until Next Measurement 00-00:01:30 D-H:M:S
Elapsed Time Since Start of Test 00-00:14:05 D-H:M:S
START: Liquid Tracking
SUSPEND: Liquid Tracking
[Alt 1] Acquire Manual Meas.
ALARM Settings...
No. ET (min) Depth(ft)
0000-P 0.00 2689.5
0001-H 0.00 5481.2
0002-H 3.00 1716.0
0003-M 4.65 1131.5
0004-H 6.00 3283.2
0005-M 7.22 1804.7
0006-H 9.00 1900.0
0007-H 11.58 1039.2
0008-M 12.42 2218.2
0009-H 13.58 2847.8
Shallow Liquid Depth Alarm Bound
Deep Liquid Depth Alarm Bound
Liquid Level
Time (min)


Schedule
Setup Shot
Select Liquid Level
Depth Determination
Progress
Current date/time 2/15/2002 8:56:49 AM
Time Until Next Measurement 00-00:01:25 D-H:M:S
Elapsed Time Since Start of Test 00-00:16:10 D-H:M:S
START: Liquid Tracking
SUSPEND: Liquid Tracking
[Alt 1] Acquire Manual Meas.
ALARM Settings...
No. ET (min) Depth(ft)
0000-P 0.00 2689.5
0001-H 0.00 5481.2
0002-H 3.00 1716.0
0003-M 4.65 1131.5
0004-H 6.00 3283.2
0005-M 7.22 1804.7
0006-H 9.00 1900.0
0007-H 11.58 1039.2
0008-M 12.42 2218.2
0009-H 13.58 2847.8
0010-H 15.58 3435.3
Shallow Liquid Depth Alarm Bound
Deep Liquid Depth Alarm Bound
Liquid Level
Time (min)

8.6 - Long Term Usage of External Nitrogen Gas Supply

The following figure illustrates the number of shots that can be obtained using a standard nitrogen gas bottle (N122) for various gas gun chamber sizes:



The same information is shown in the following table:

Chamber Pressure psi	Number of Shots 10 cu inch	Number of Shots 12.5 cu inch	Number of shots 22 cu. inch
1800	20	16	9
1700	27	22	12
1600	34	27	16
1500	43	34	19
1400	52	42	24
1300	63	51	29
1200	76	61	35
1100	92	73	42
1000	110	88	50
900	132	106	60
800	160	128	73
700	196	157	89
600	244	195	111
500	311	249	142
400	412	330	187
300	580	464	264
200	916	733	416

The following table lists the capacities of standard Nitrogen cylinders and their corresponding Echometer part number:

Part No.	Volume (Standard ft^3)	Length (in)	O.D.(in)	Service Pressure (psi)
N22	20.8	16.8	5.25	2216
N24	22.3	25.6	4.38	2015
N33	31	15.6	6.89	2216
N60	57.2	23.5	7.25	2216
N88	83.3	32.9	7.25	2216
N122	114.5	36.8	8	2216
N150	141.7	47.9	8	2015
N155	144.4	46.7	8.6	1800

The following shows the volume of the chambers for various Echometer gas guns:

8.7 - Volume Chamber Sizes in cubic inches:

- Compact Gas Gun 10
- Standard Remote Fire Gas Gun 12.5
- Special order Remote Fire Gas Gun 20 and 35

Test Duration

Assuming that the Liquid Level Tracking program has been set up to record 20 shots per hour and that the chamber of the standard remote fired gun is being charged to a pressure of 300 psi then it would be possible to record liquid level position for a period of 464/20 = 23 hours, staring with an N122 Nitrogen Bottle filled at 2200 psi. (NOTE: this assumes that there are no leaks in all the gas connections)

9.0 - ECHOMETER DYNAMOMETER SYSTEM

The Echometer dynamometer consists of a laptop computer, an analog to digital converter (Well Analyzer Electronics), a load cell with an accelerometer and a motor current and/or current/power sensors. The load cell uses a strain gauge sensor to measure the load on the polished rod. The load cell can either be of the horseshoe type which is positioned on the polished rod between the carrier bar and the polished rod clamp, or of a special design which easily clamps directly onto the polished rod. The sensor’s output signals are sent to the converter for conditioning and digitizing. The digital data is then routed through a computer interface card to the computer's memory where the signal can be processed and displayed by the software. Each component of the dynamometer system is discussed below.

9.0.1 - Computer and Programs

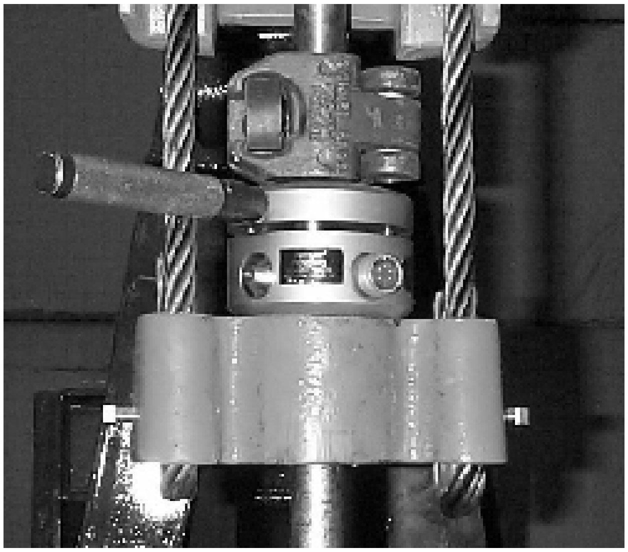
The Well Analyzer is controlled by a notebook computer. The computer operates from a program on the hard drive. Turn the computer on. The TWM icon will be displayed with the other icons on the desktop. Double click on the TWM icon. See Section 3, "General Considerations About Computers" for additional information about computers, disks, programs and files.

9.0.2 - Analog to Digital Converter

The A/D converter conditions and digitizes the signals from the load cell, accelerometer and motor current sensors. The digitized signals are transmitted to the computer for processing and recording. The A/D converter is connected to the computer by a cable. The converter contains an internal 12-volt battery. The converter should be plugged into the appropriate charger to maintain the battery in good condition. The converter has an indicator light to show when the electronics are ON and communication is established with the computer. The electronics are turned ON and OFF by the computer as needed to acquire data. The converter and the computer batteries are **both** charged **ONLY** when the well analyzer cigarette lighter adapter is plugged into the car lighter connector. It is necessary to use both AC battery chargers: the one for the computer and the 110V (220V) AC Echometer charger supplied with the Well Analyzer when charging batteries in the office. The 110V (220V) AC charger used with the Echometer Models D and M amplifier/recorders can also be used to charge the A/D battery. The battery cannot be overcharged using any of these charging techniques.

9.0.3 - Horseshoe Type Load Cell

The horseshoe type load cell is a highly accurate transducer designed to provide a precise load value when necessary. This load cell is placed on the polished rod between the permanent polished rod clamp and the carrier bar. It also houses an accelerometer which measures the acceleration of the polished rod. The software calculates the velocity and the position of the polished rod by numerical integration of the acceleration signal vs. time.

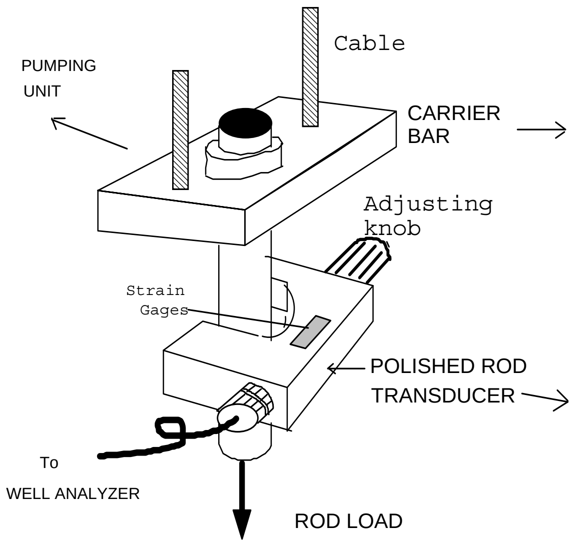


The picture above shows how the Horse Shoe Transducer is installed on the carrier bar.

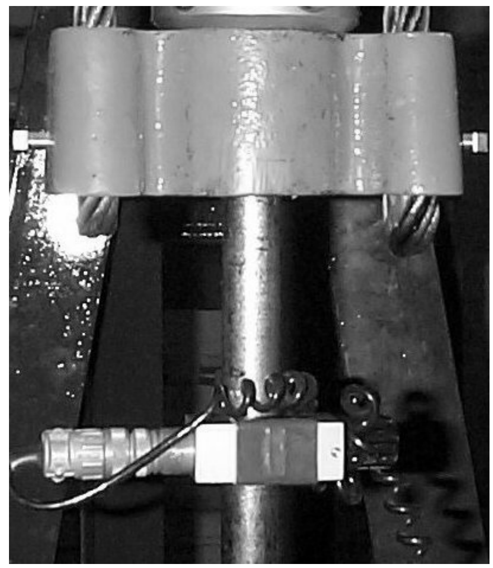
9.0.4 - Polished Rod Load Cell

The polished rod transducer is a very convenient sensor for quick and easy dynamometer measurements. It consists of a small "C"-clamp which is placed on the polished rod, about 6 inches below the carrier bar. It is instrumented with extremely sensitive gages that measure the change in diameter of the polished rod due to the load variation during a pump stroke. This transducer also houses the accelerometer sensor.

Schematic Diagram of Installed Polished Rod Transducer



Typical Installation on Polished Rod Below Carrier Bar



WARNING

Although the accelerometer which is housed in the load transducer is capable of sustaining an impact of 40g, **it is likely to suffer permanent damage if it is dropped onto a hard surface**. These precision instruments should be handled with care at all times.

9.0.5 - Hydraulic Lift Load Cell

This system is designed to facilitate installation of the horseshoe load cell and to eliminate measurement errors caused by changes in pump spacing resulting from installation of a horse-shoe transducer between the carrier bar and the polished rod clamp.

The hydraulic lift horseshoe dynamometer requires the permanent installation of an inexpensive spacer spool onto the carrier bar. The dynamometer and the hydraulic lift are easily inserted into the spool and then the load cell is activated using a small portable hydraulic pump which transfers the polished rod load to the load cell of the dynamometer. Insertion of a thin spacer plate and release of the hydraulic pressure allow removal of the hydraulic pump and acquisition of the data.

NOTE: This load cell does not fit the standard **Leutert** dynamometer spacer. The conventional Leutert dynamometer instrument, with chart recorder, can be modified to operate with the Well Analyzer and the TWM software. Please contact Echometer Co. for more details.

9.0.6 - Motor Current Sensor

The current sensor is a device to measure the current used by the pumping unit's motor. A plot of Current vs. Time can be used to determine if the unit is properly balanced. A proper torque analysis requires that the current data be acquired at the same time as the load data, so both the current meter and load cell should be installed at the same time on units having an electric motor.

See the next two chapters in this manual for more details about current and power measurements.

9.0.6.1 - Current Sensor Installation

WARNING

USE CAUTION WHEN INSTALLING THE CURRENT SENSOR. IT IS USUALLY NECESSARY TO OPEN THE UNIT'S POWER BOX TO GAIN ACCESS TO THE MOTOR CABLE. THE OPERATOR MAY BE AT RISK OF **ELECTRICAL SHOCK** AND **DEATH**. CONNECT THE SENSOR CAREFULLY.

The current sensor is easy to connect. Open the sensor by pressing the handle and place the jaws around one of the motor's power cables. Install the sensor with the sensor's **jaws clean and completely closed**. Connect the other end of the cable to the Well Analyzer. To facilitate installation and reduce the risk of electrical shock, it is recommended that an electrician run one of the power wires through a plastic flexible conduit outside the bottom of the power box. This will allow connecting the current sensing probe without opening the power box.

9.0.7 - Motor Power Sensor

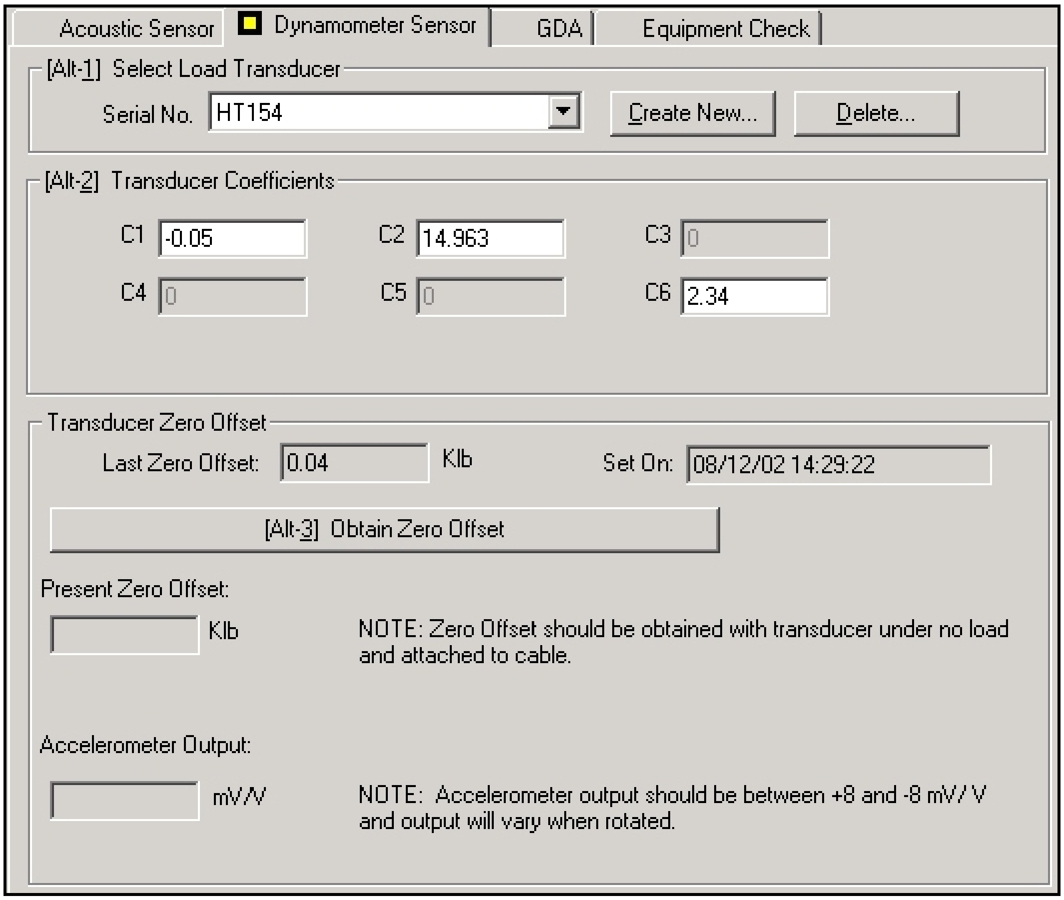
The use of power measurement sensors is described in detail in **Chapter 10**.

9.1 - DYNAMOMETER SOFTWARE

The dynamometer modules of the TWM software are used to acquire digital data, calculate load values, analyze data, plot graphs, and present test information and analysis. A complete description of the software's use and capabilities is given in the following sections.

9.1.1 - System Setup

Using the TWM software in the **Acquire Mode** select the **System Setup F2** option in order to select the dynamometer load cell that will be used for the measurements:



Select the **Dynamometer Sensors** Tab and the **Serial Number** that corresponds to the sensor being used. If necessary the coefficients and serial number for the specific instrument can be entered by selecting the **Create New** option.

The load coefficients C1 and C2 are used to calculate polished rod load using the equation:

$$Load = C1 + V*C2 - C_{zof}$$

where: Load = polished rod load, KLBS

V= transducer output, in mV/V

C_{zof} = Coefficient from zero offset calibration.

It is important that the correct **serial number**, including all the characters, be entered in the correct field. The program uses the serial number to determine the type of load cell that is being used. In particular the program must differentiate between a polished rod transducer and a horseshoe type load cell in order to properly determine the zero offset and the self-calibration procedure. For example enter HT123 (horseshoe transducer) or PRT123 (polished rod transducer).

To **Update** the zero offset of the Horseshoe Load Cell select the button or key (**Alt-3**) while the transducer is lying on a flat surface **and without a load** applied. The values shown on the screen indicate the present value of the zero reading in thousands of pounds (Klbs) and the accelerometer output in mV/V. Repeat this procedure until these values stabilize. Variations in this quantity should be expected when the temperature changes significantly from test to test. The zero offset readout should be less than +/- 5 KLbs. A value significantly different from this may be an indication of a faulty transducer, cable or connectors. The zero offset value is the term C_{cf} in the load equation above.

Coefficient C6 is accelerometer sensitivity and can be adjusted to correct calculated stroke length to actual stroke length.

NOTE

Polished Rod Transducer

The polished rod transducer is designed so that when it is not mounted on the polished rod (and not loaded) its voltage output is at an elevated value. **Therefore it does not require zeroing**.

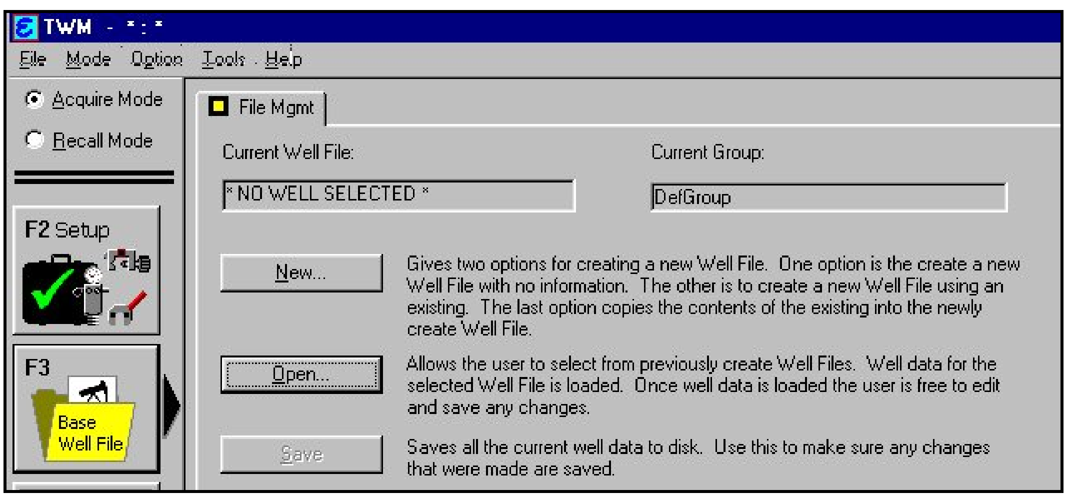
In general this transducer will be used in the automatic scaling and calibration mode, where the program will calculate the absolute load level of the surface dynamometer card from the calculated pump card. This will be discussed in detail later in the section describing the polished rod transducer.

After updating the zero offset of the transducer the set-up procedure is complete.

Although the system parameters are saved on the system disk, the setup procedure should be repeated whenever the Well Analyzer is used to insure that none of the parameters have been changed accidentally.

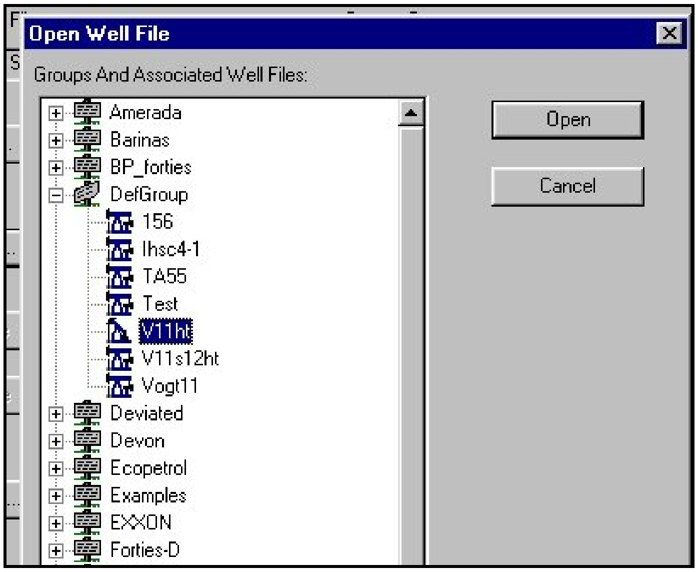
9.1.2 - Acquiring Dynamometer Data

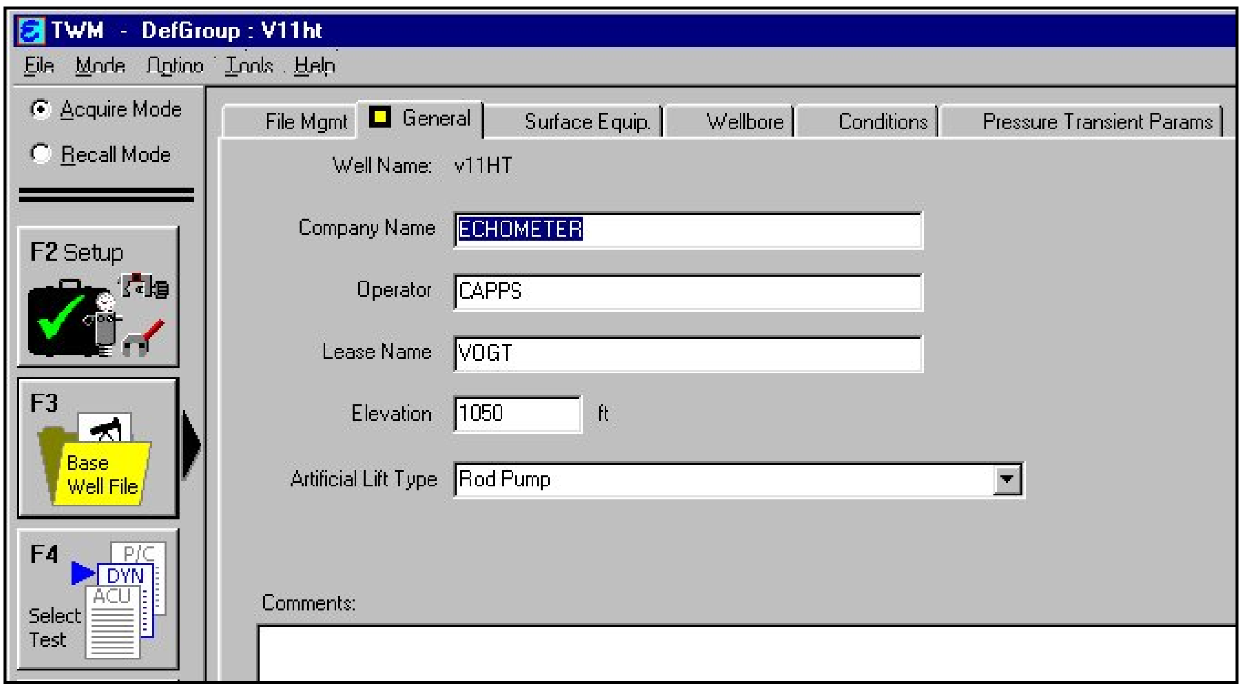
The configuration data for the well to be tested is recalled from the data base or entered in the forms by selecting the **Base Well File.**



It is recommended that the data be entered before going to the field to test the well. In this case the well data is recalled by selecting the **Open** option which will display the catalog of well groups and files.

The specific well is then selected as shown in the following figure. Selecting **Open** will present the well data tabs.





FOR MORE DETAILS AND DEFINITIONS OF ALL TERMS, PLEASE REFER TO THE WELL DATA FILE SECTION PRESENTED EARLIER IN THIS MANUAL BEGINNING AT SECTION 5.22.

For Dynamometer measurement and analysis the following data **have to be entered** and checked for accuracy:

Manufacturer:	pumping unit manufacturer.
API:	model number of the pumping unit.
Rotation:	CW for clockwise rotation of gear box cranks. CCW for counterclockwise rotation of cranks. The polished rod is to the operator's right when viewing the gear box.
Stroke Length:	Polished rod stroke length in inches.
Plunger Dia:	Pump plunger diameter in inches.

Anchor Depth:	Depth to the tubing anchor if present (Feet)
Pump Intake:	Depth to pump's Standing Valve (SV) (Feet)
Motor Type:	Description of the prime mover
Voltage, Hz, Phase:	Voltage and single or 3 phase designation; such as 440 VAC and 3 phase.
Consumption:	Cost of electricity such as 5 cents/KWH.
Demand:	Power demand cost, $/Kw
Counterbalance Effect or Moment:	This number is determined by field measurement or by calculation from the counterweight's description and actual position. The counter balance effect (CBE) is used in torque analysis.
Oil Production:	Result of latest well test
Water Production:	Result of latest well test
Rod String:	Enter the length and diameter of each section of rods. Also, enter rod type such as C, D, K or F for fiberglass.

9.1.2.1 - Pumping Unit Library

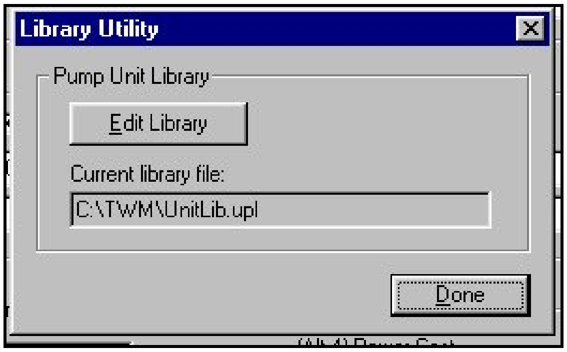
The selection of the pumping unit type and size can be undertaken by referring to the built-in pumping unit library which is part of the TWM software. The library is accessed by the pull down menu which lists the units by manufacturer designation. This results in the following screen being displayed:

On the screen are listed all the manufacturer's for which pumping unit specifications have been entered in the library. Care must be exercised that the correct unit is selected since the software will use the dimensions and characteristics of the selected unit in order to compute the loads, displacements and stresses in the pumping system.

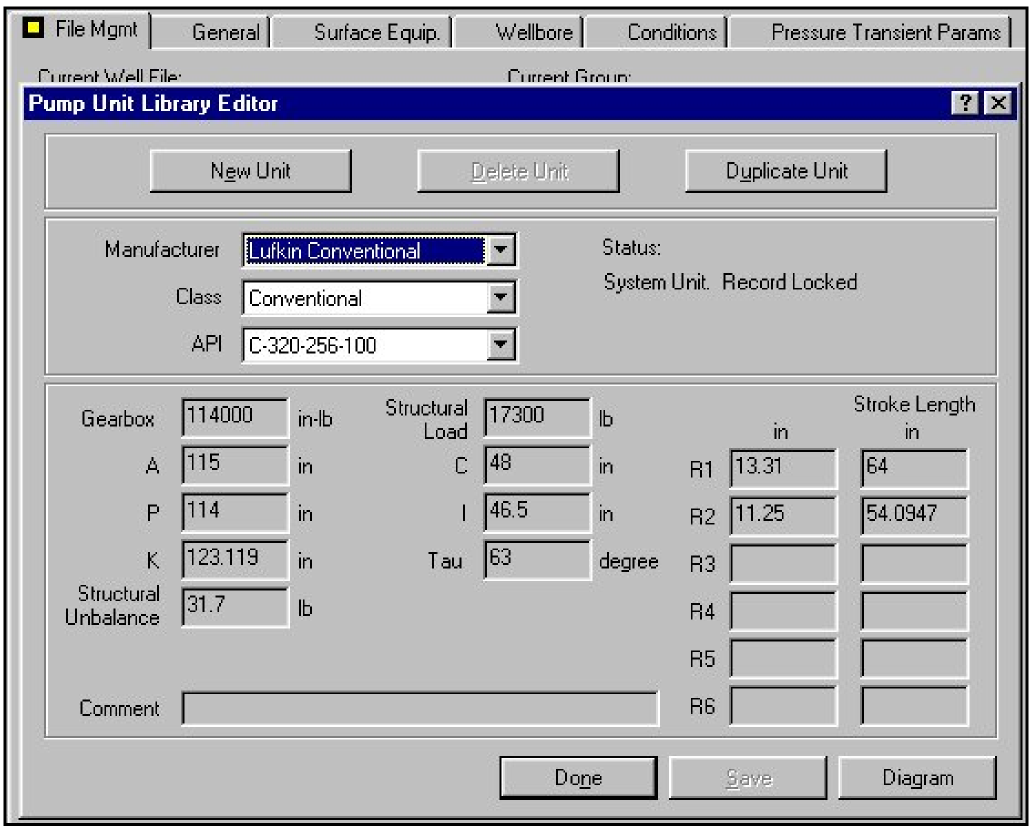
Adding Pumping Units to the Library

The library is a file which can be edited with the **Library Tool**. In order to add more units to the library the user may also send the pertinent data to ECHOMETER Co. for inclusion in updated software.

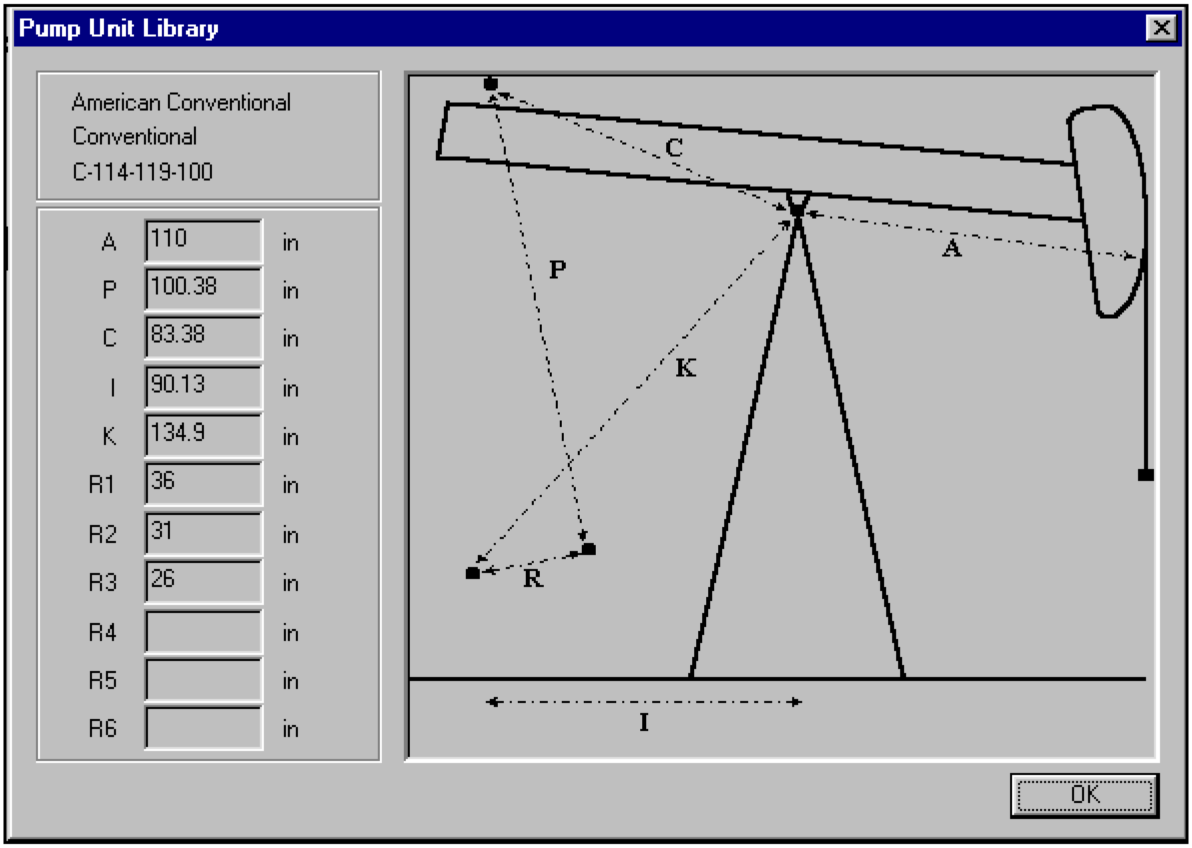
Which brings up the following menu with the path to the unit library:



This menu allows display and editing an existing pumping unit data or modifying the library:

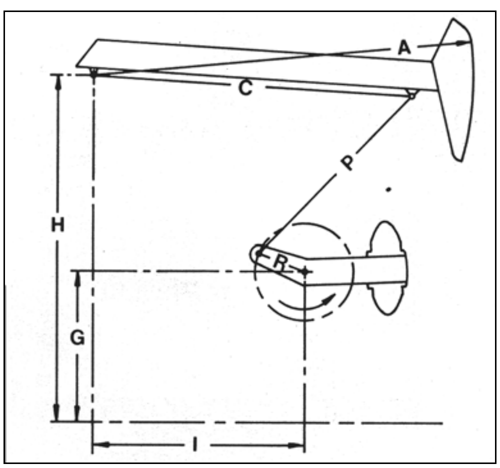


The data follows the API nomenclature and conventions. A schematic dagram of the unit and a form that allows editing the dimensions is displayed by slecting the **Diagram** button

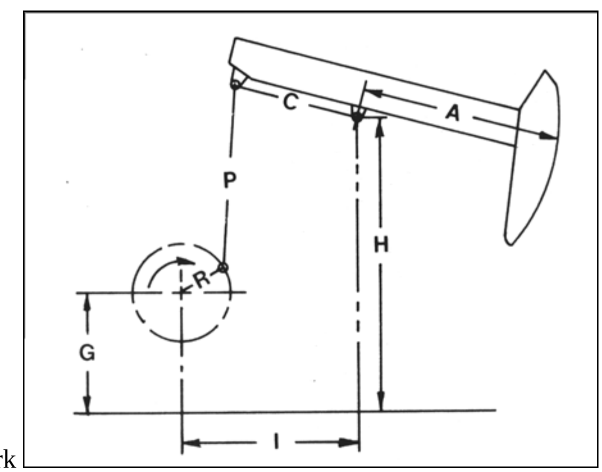


The following diagrams illustrate the dimensions for the other API geometries:

Mark II

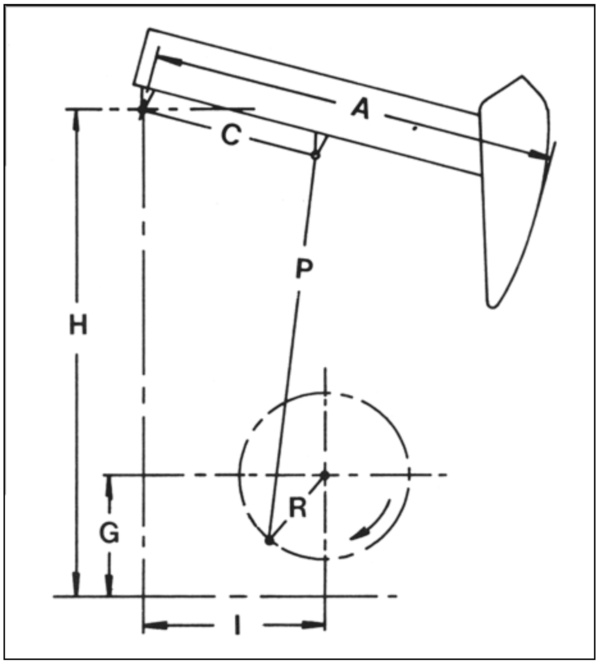


Reverse Mark

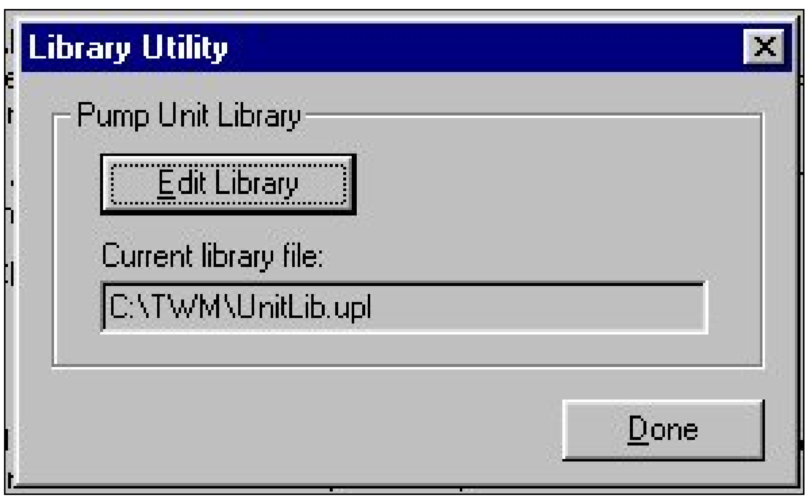


For all geometries the dimension **K** is measured from the center of the crankshaft to the center of the fulcrum bearing on the beam, as shown in the TWM screen for the conventional unit shown above.

Air Balanced



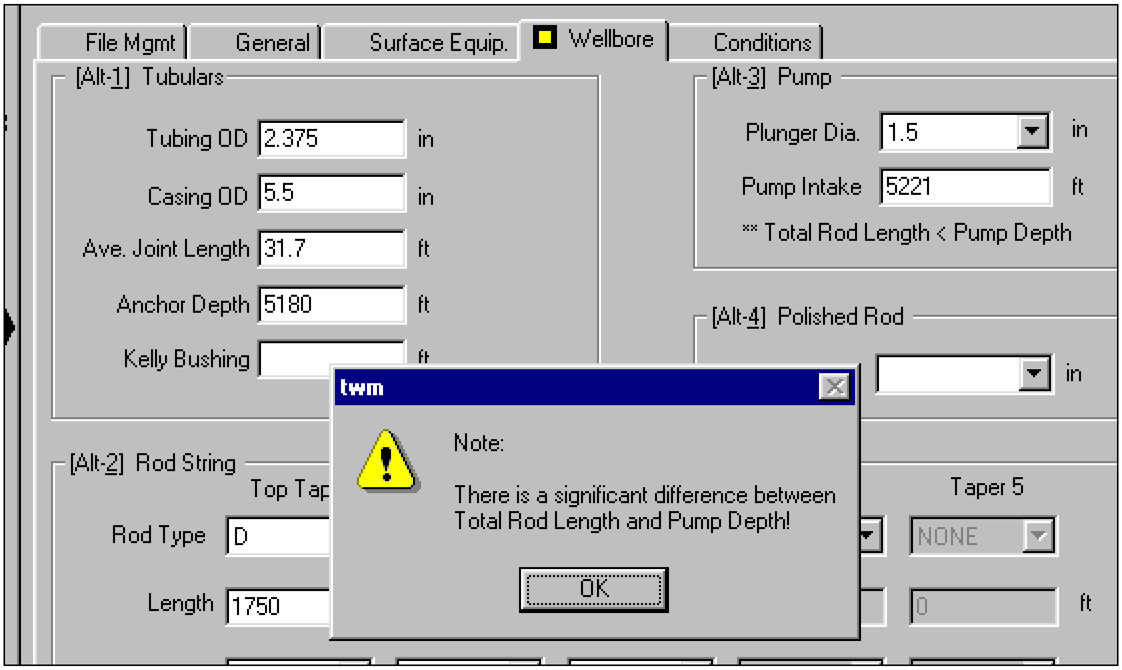
Only the contents of the User's Pumping Unit Library may be modified (UnitLib.upl).



The default library is protected from accidental modification
FurtherdDetails related to library updating are also discussed in Chapter 3

It is important to **acquire and analyze data using the correct unit description**, so it is recommended that whenever the data indicates discrepancies in the results the well data file be reviewed thoroughly.

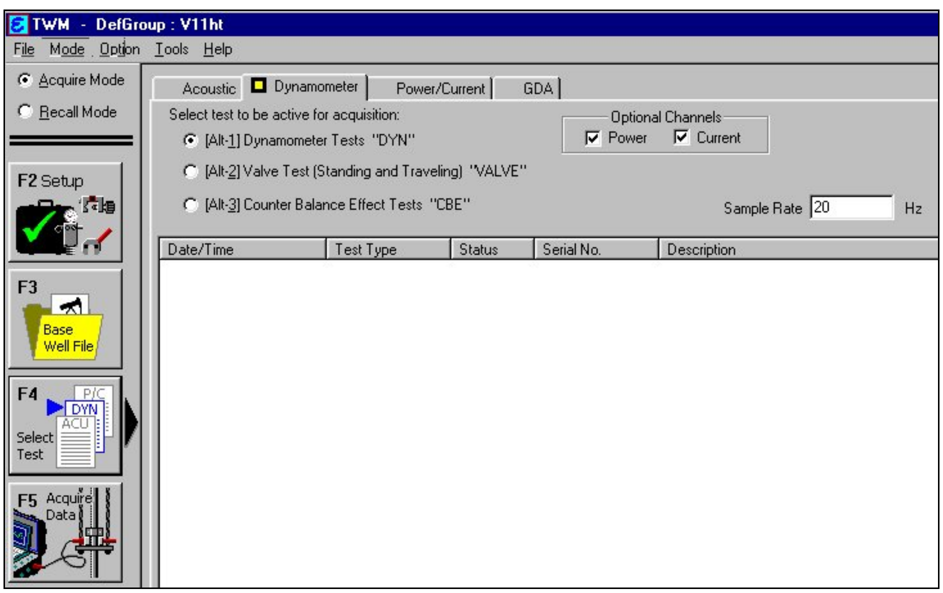
The software does perform some data validity checks, as shown in the next figure:



but it is the **operator's responsibility** to validate the well data before proceeding with acquisition or analysis.

9.1.2.2 - General Procedure for Acquisition of Dynamometer Data

The operator can proceed with acquiring data using the **Select Test**. Option



Within the **Dynamometer Tab**, the program guides or directs the operator in the acquisition and analysis of dynamometer data by offering the three test choices: Dynamometer Test, Valve Test and Counter Balance Effect which are normally run in that order.

First, the operator acquires at least one minute of polished rod load, acceleration, and motor current and/or power data (if present). The pumping unit must be running throughout the one minute of data acquisition time. The acceleration data is integrated twice to obtain position. This is processed to obtain a dynamometer card of all strokes contained during this minute. The operator then has the choice of viewing any one stroke to analyze the downhole pump card. This single stroke data can be exported as a text file in the DYN format, if desired, for processing in other programs.

Second, the operator is directed to acquire traveling valve data, standing valve data, and

Finally, counterbalance effect data is acquired in order to analyze the torque loading based on the dynamometer data obtained with a horseshoe transducer.

Although this is the recommended sequence, the tests may be run in the order that is most convenient for the operator.

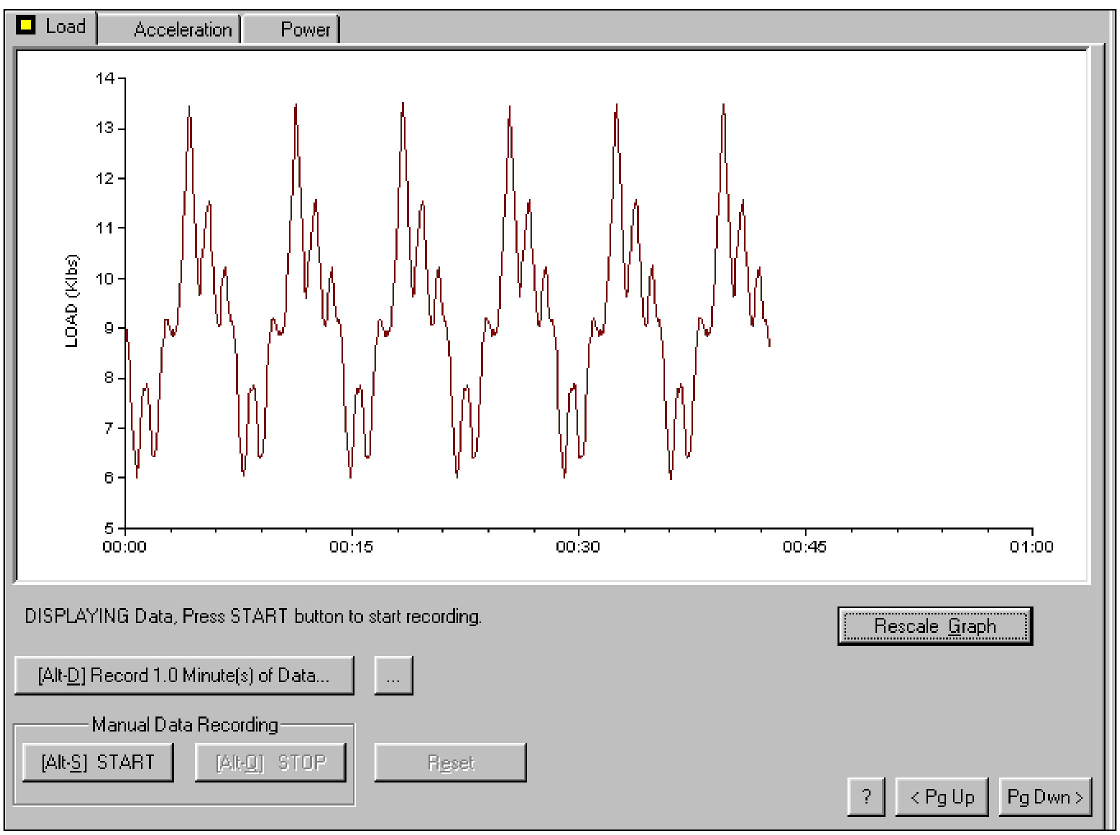
9.2 - MEASUREMENTS WITH HORSESHOE TRANSDUCERS

The following procedure is to be used in conjunction with the Horseshoe type load cell. The first part allows checking that the transducer is operating properly and that the correct scaling and coefficients are being used. This is followed with the actual recording of the dynamometer data. The procedure is different when using the Polished Rod transducer. The polished rod transducer procedure is explained later.

9.2.1 - Initial Acquisition Check

Data is displayed to the operator to insure that the system is functioning properly. The operator has the choice of viewing load, acceleration or motor current if the motor current sensor is attached. Initially, data will not be displayed for 15 seconds. During the first few seconds, the plot is scaled to the data. During scaling the pumping unit **must be running** so that typical load and acceleration data are generated and are used to determine the appropriate scales for plotting. Display of data continues. The data is not stored. The operator should verify that proper data is being displayed for plotting and analysis. The operator can rescale the load axis, if desired, by pressing the **Rescale** button

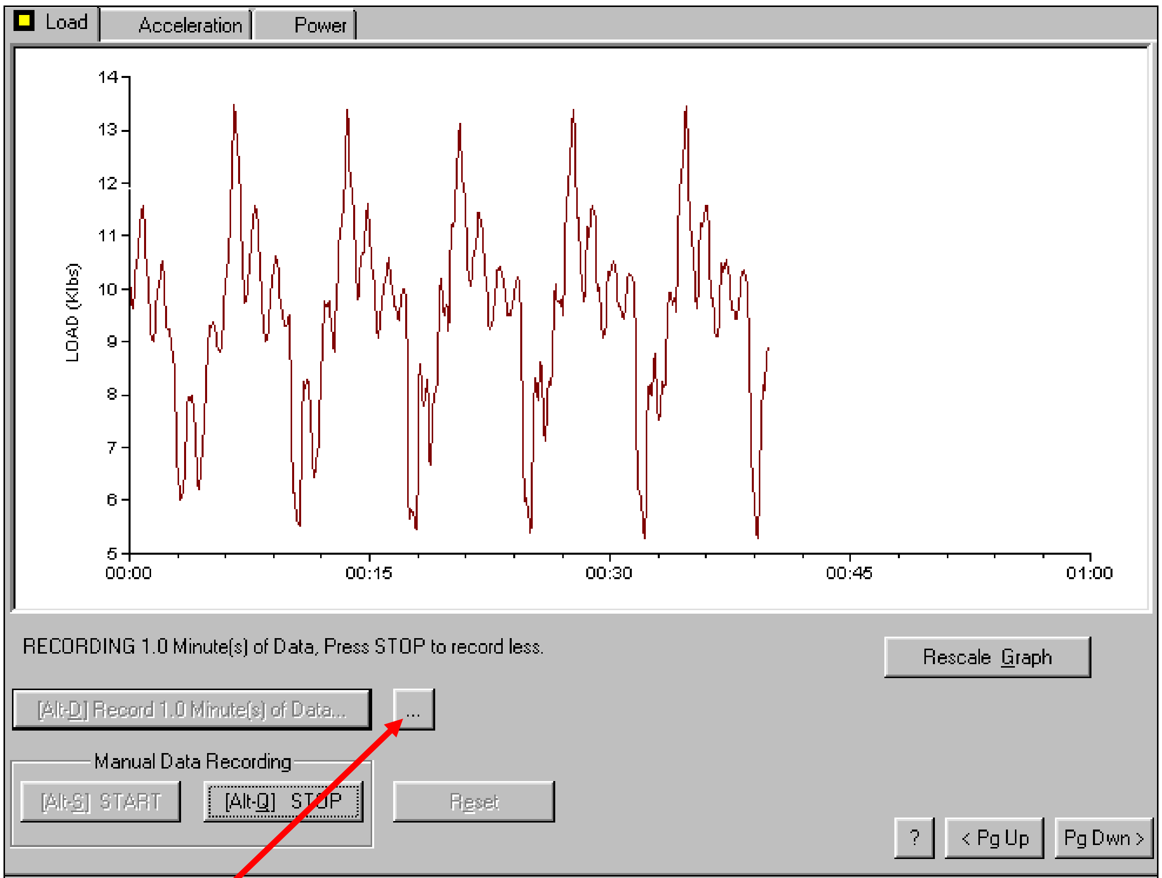
The screen indicates that the data is being displayed only but not recorded



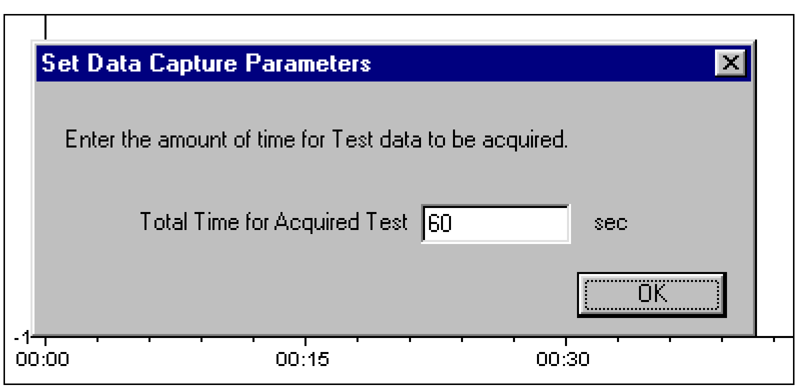
9.2.2 - Data Acquisition

Selecting **Alt-D** (Record 1 minute of Data) will start the acquisition of dynamometer data for one minute of pumping. Alternately the user can start acquisition (**Alt-S**) and quit (**Alt-Q**) acquisition after an arbitrary number of seconds or strokes. A plot of either load, acceleration motor current or power (if connected) will be available for viewing by the operator while the system captures one minute of data.

The following figure shows load data being acquired:

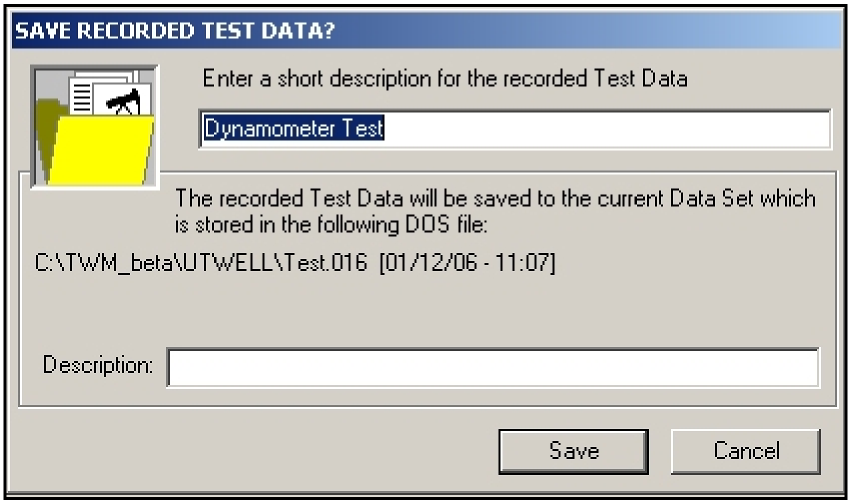


Acquisition of the data will continue for one minute and then stop automatically. The default time of recording can be set by clicking the **control button** to the right of the Alt-D control, to bring up the following form:



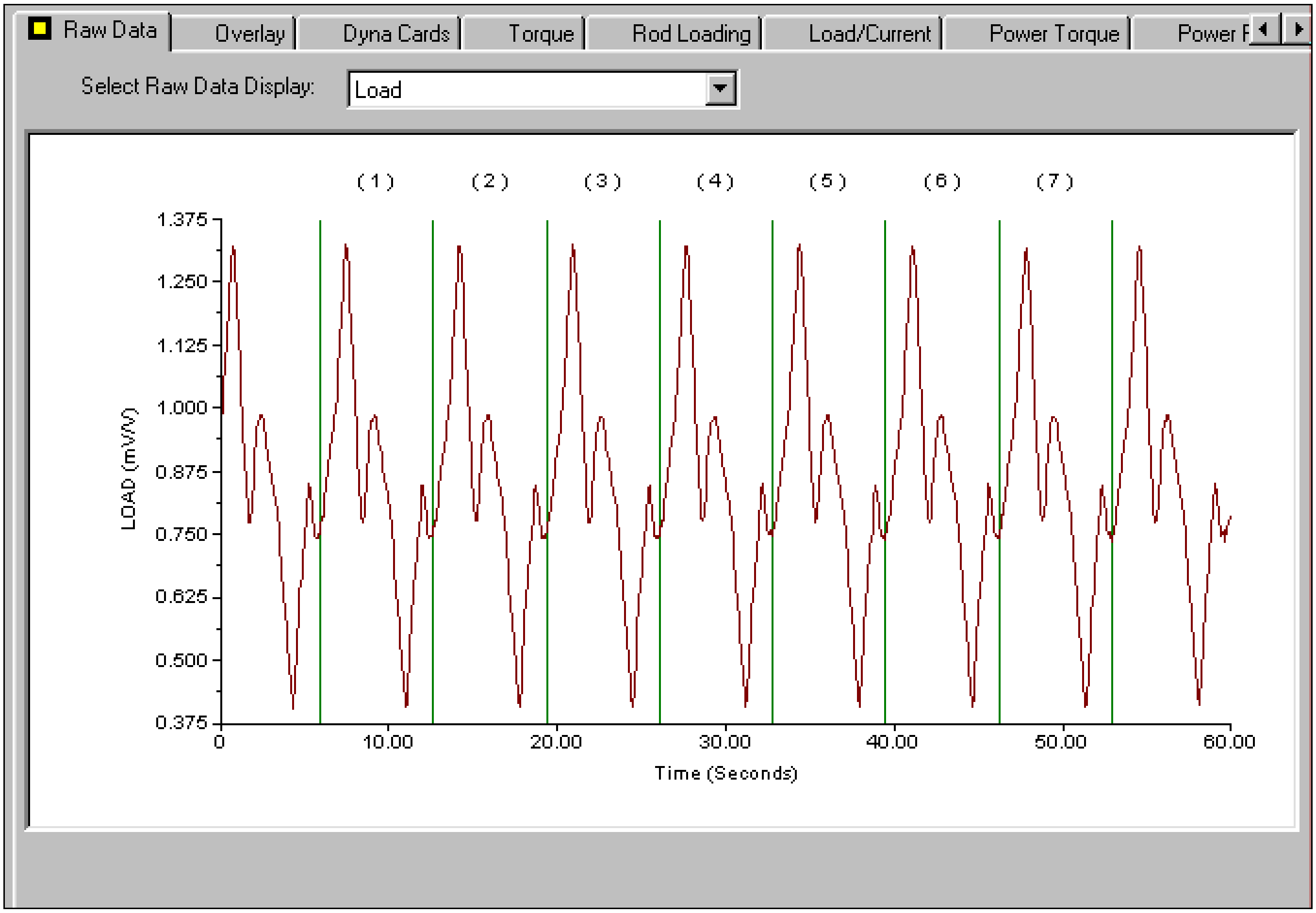
This is especially useful when making measurements with slow-pumping or long-stroke units to obtain data over several strokes.

When one minute of data has been acquired, the operator has the choice of saving the data and to continue with dynamometer analysis or to repeat data acquisition. The operator should view the load, acceleration and motor current for quality of data.

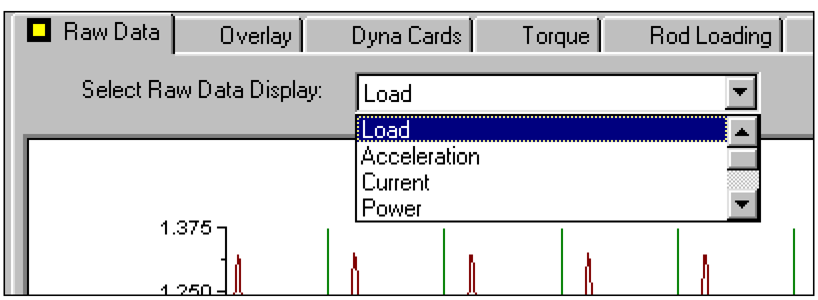


Pressing **Cancel** will continue data acquisition and analysis after the user selects the **Reset** button.

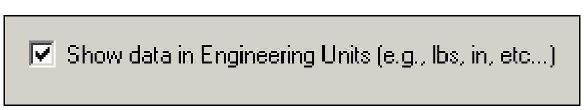
Pressing **Save** will save the data and continue to the **Analyze Data** form which performs a position analysis of the acceleration data by double integration of the acceleration data. This allows correlation of position with load. The operator is alerted if position cannot be calculated from the acceleration signal. The acceleration data should vary from approximately +0.5 mV/V to -0.5 mV/V and exhibit both positive and negative values. If this is not the case the accelerometer may have been damaged or the coiled cable and connectors are defective. The next screen shows the load data analyzed into individual complete strokes (numbered from 1 to 7) as shown in the following figure:

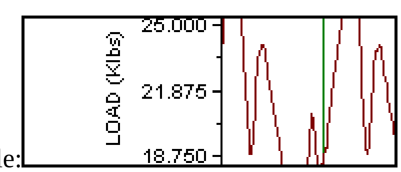


The vertical lines indicate the bottom of the polished rod stroke. The operator can similarly view acceleration, motor current, velocity and position as a function of time by selecting the corresponding variable from the pull down menu:

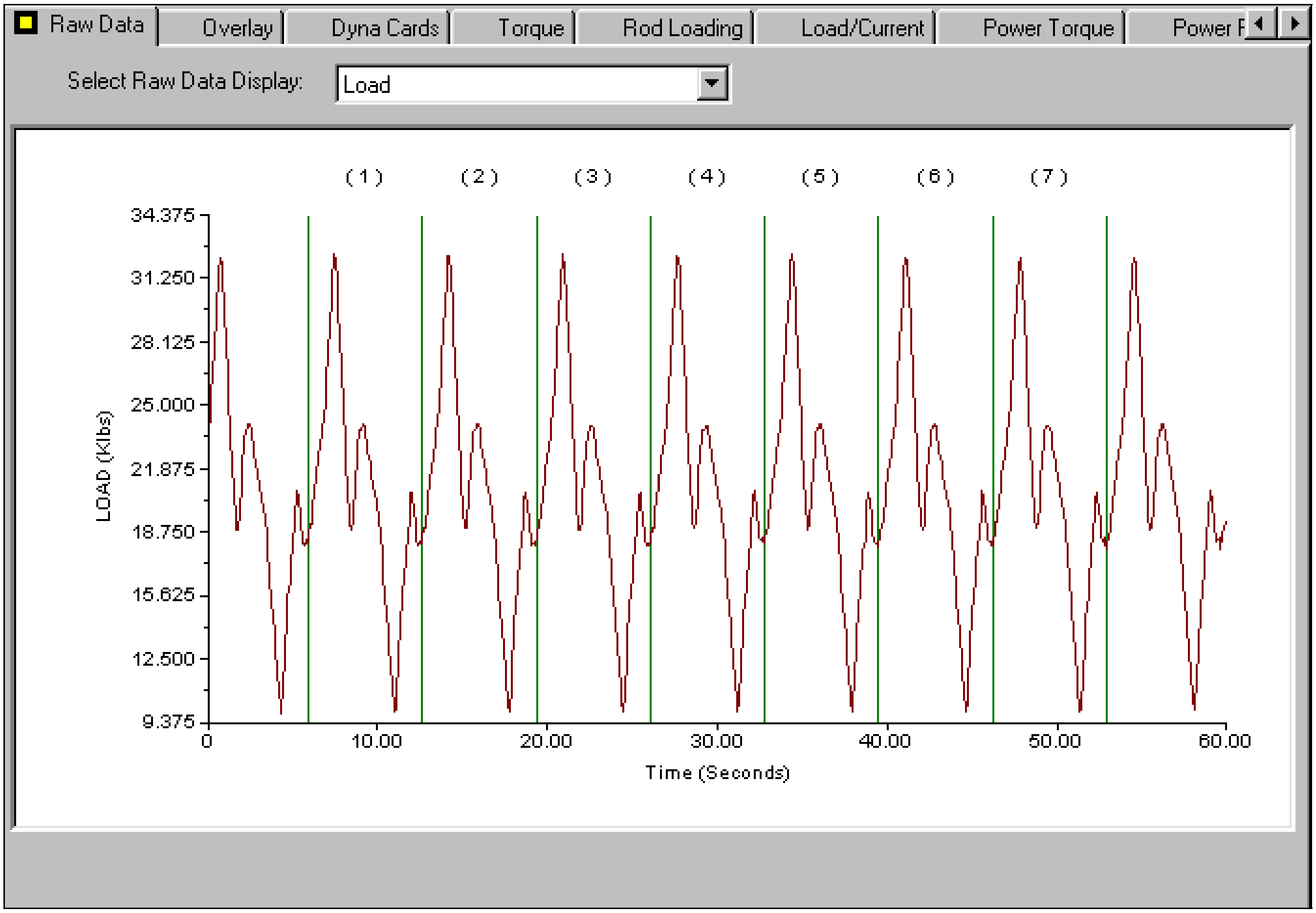


To display the raw data in Engineering units, it is necessary to select the corresponding check box:

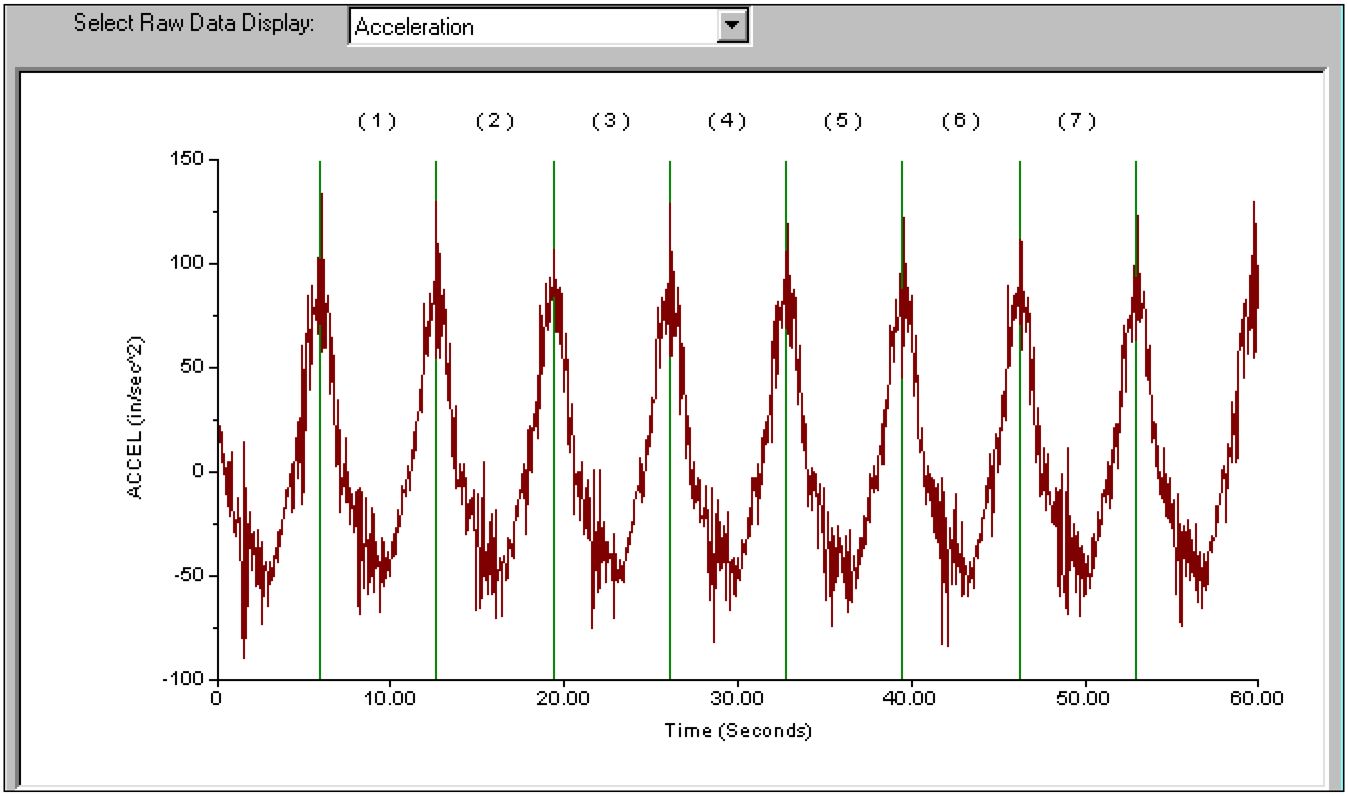


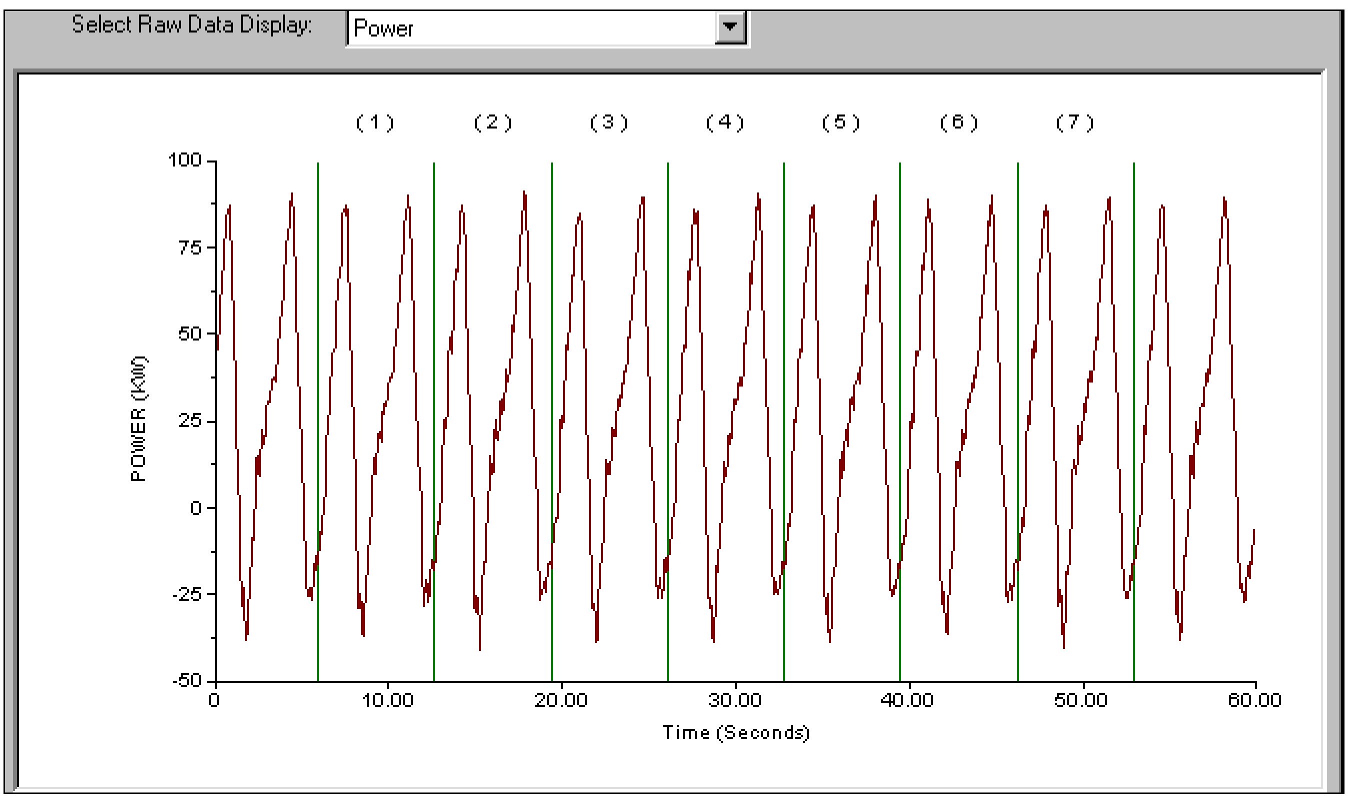
this changes the vertical scale:


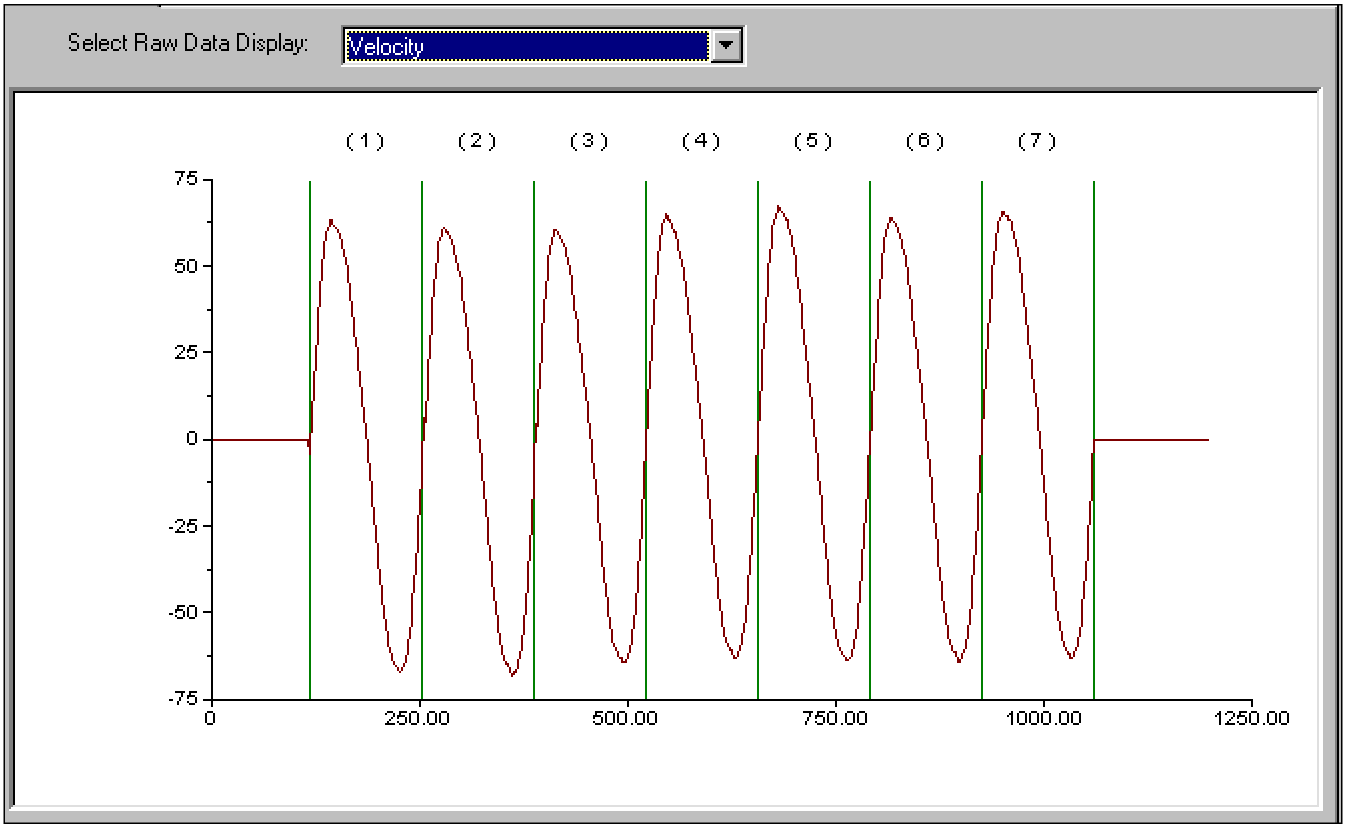
and gives the following figure

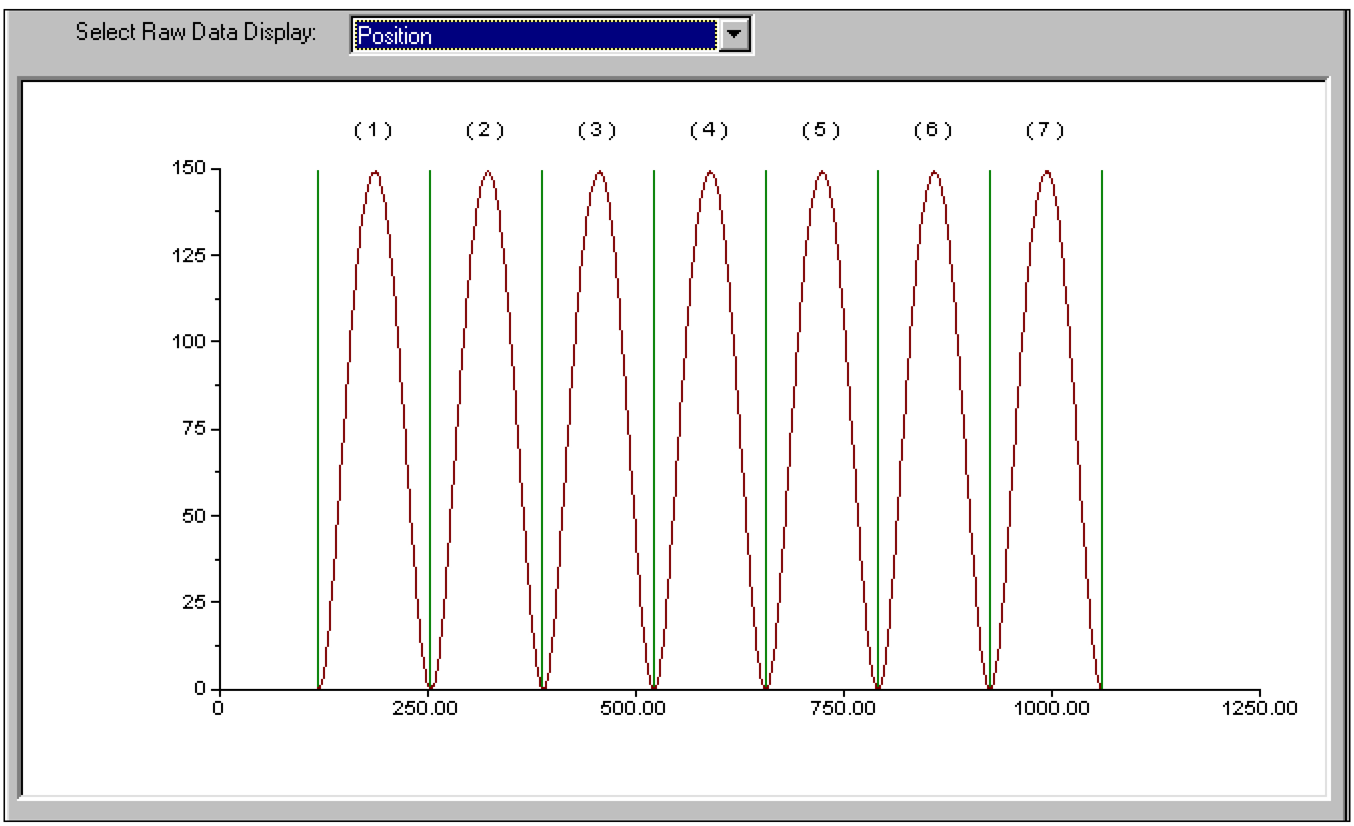


The other recorded variables: acceleration, current and power as well as the computed values of velocity and displacement are viewed in the same manner by selecting the corresponding plot from the pull-down menu as seen in the following figures:

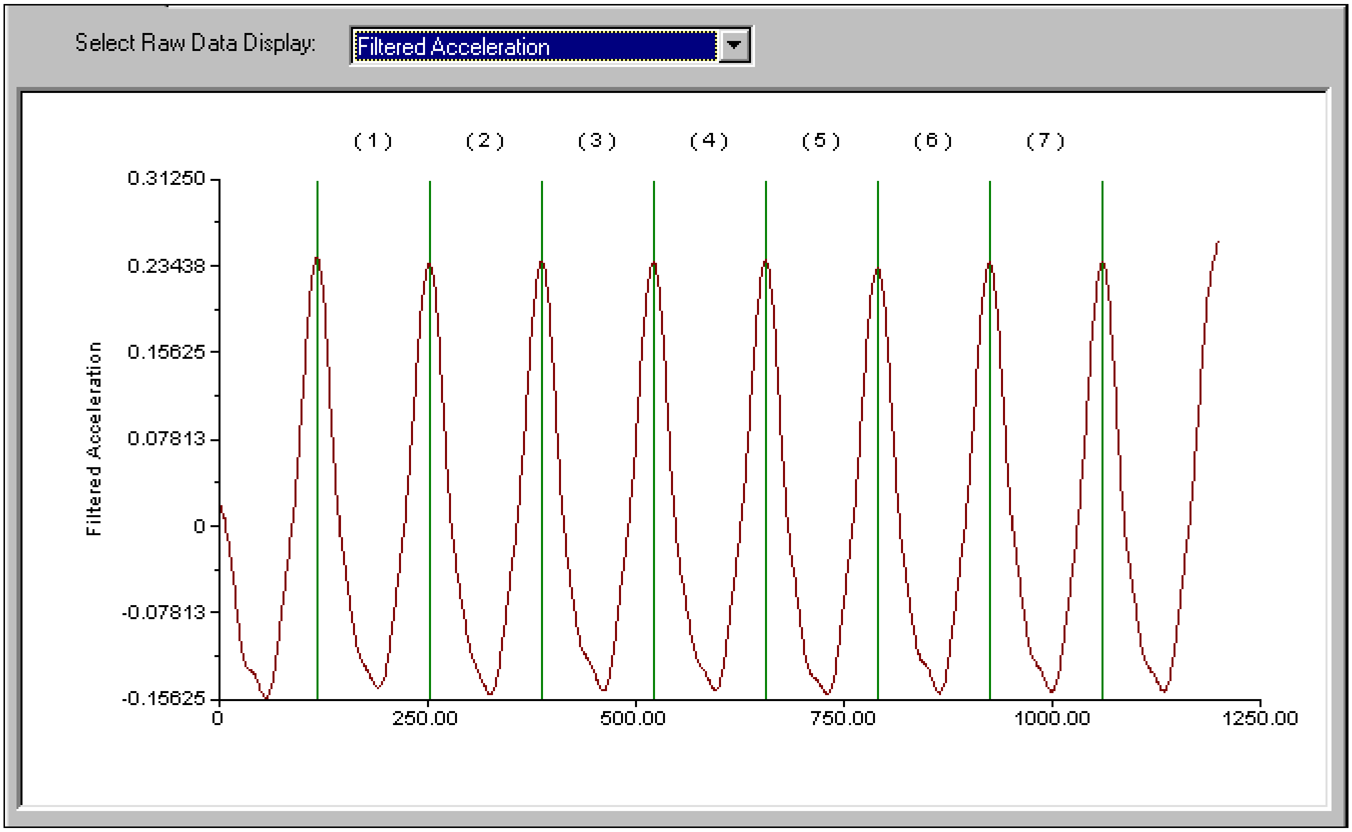

Select Raw Data Display:
Acceleration
(1) (2) (3) (4) (5) (6) (7)
150
100
50
0
-50
-100
ACCEL (in/sec^2)
0
10.00
20.00
30.00
40.00
50.00
60.00
Time (Seconds)


Select Raw Data Display:
Power
(1) (2) (3) (4) (5) (6) (7)
100
75
50
25
0
-25
-50
POWER (KW)
0
10.00
20.00
30.00
40.00
50.00
60.00
Time (Seconds)





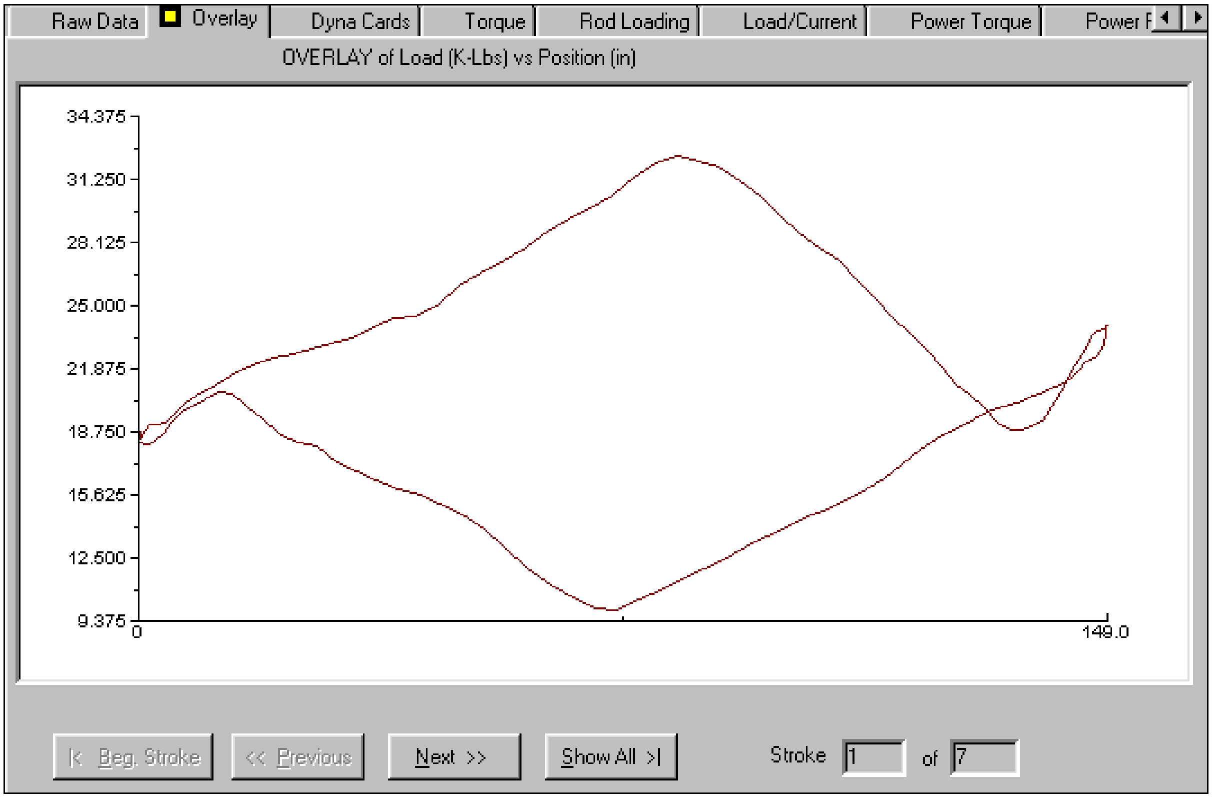
It is also possible to view a filtered version of the acceleration signal in order to check the accuracy of the integration routine in selecting the bottom of the stroke.



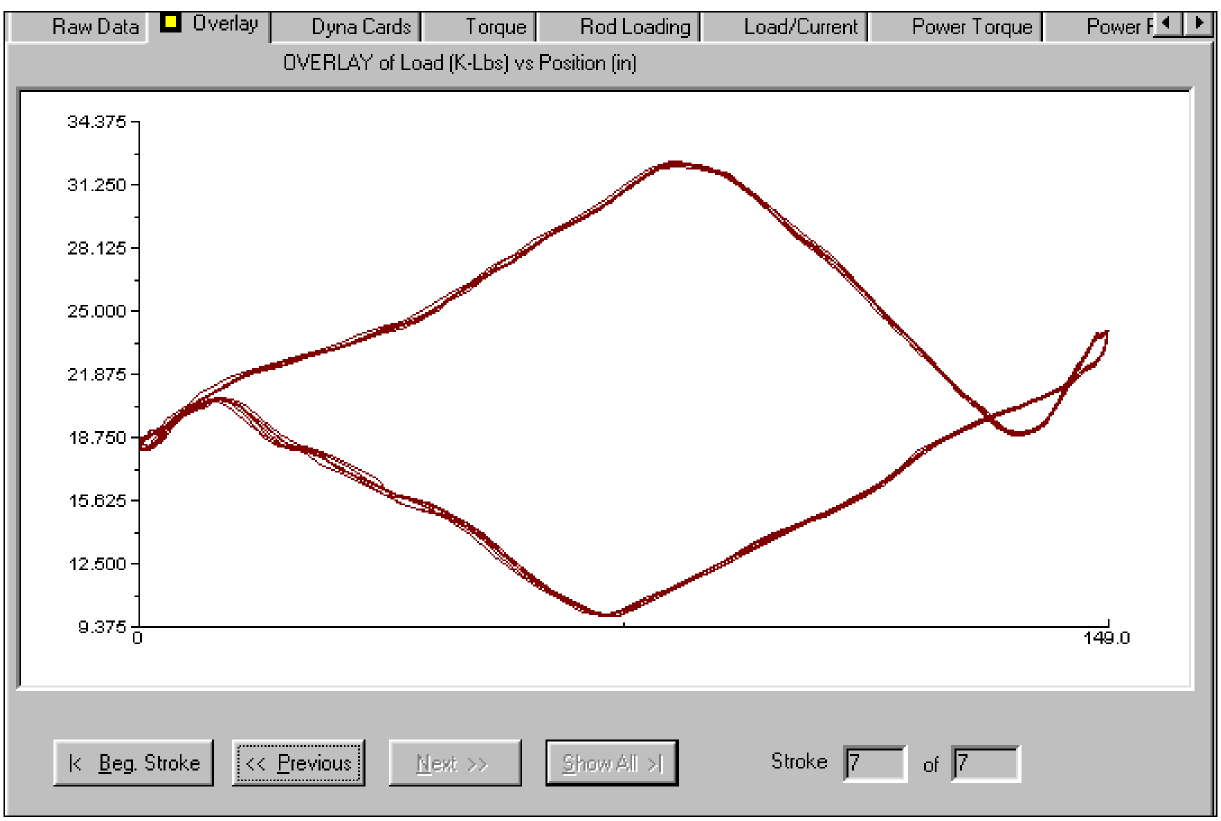
9.2.3 - Dynamometer Card Displays

The operator can view each dynamometer card for every recorded stroke, by selecting the **Dyna Cards** tab or the Overlay tab. The first cycle, second cycle, etc. in sequence, will be displayed on the screen. The operator can view each of these strokes as they are displayed on the screen. After viewing each stroke as the data is plotted the operator determines which stroke should be selected for further detailed analysis.

The **Overlay** display allows superimposing all the recorded dynamometer cards, in the sequence they were recorded, with the purpose of determining how repeatable the operation of the pump is, from stroke to stroke. This is illustrated in the following two figures.



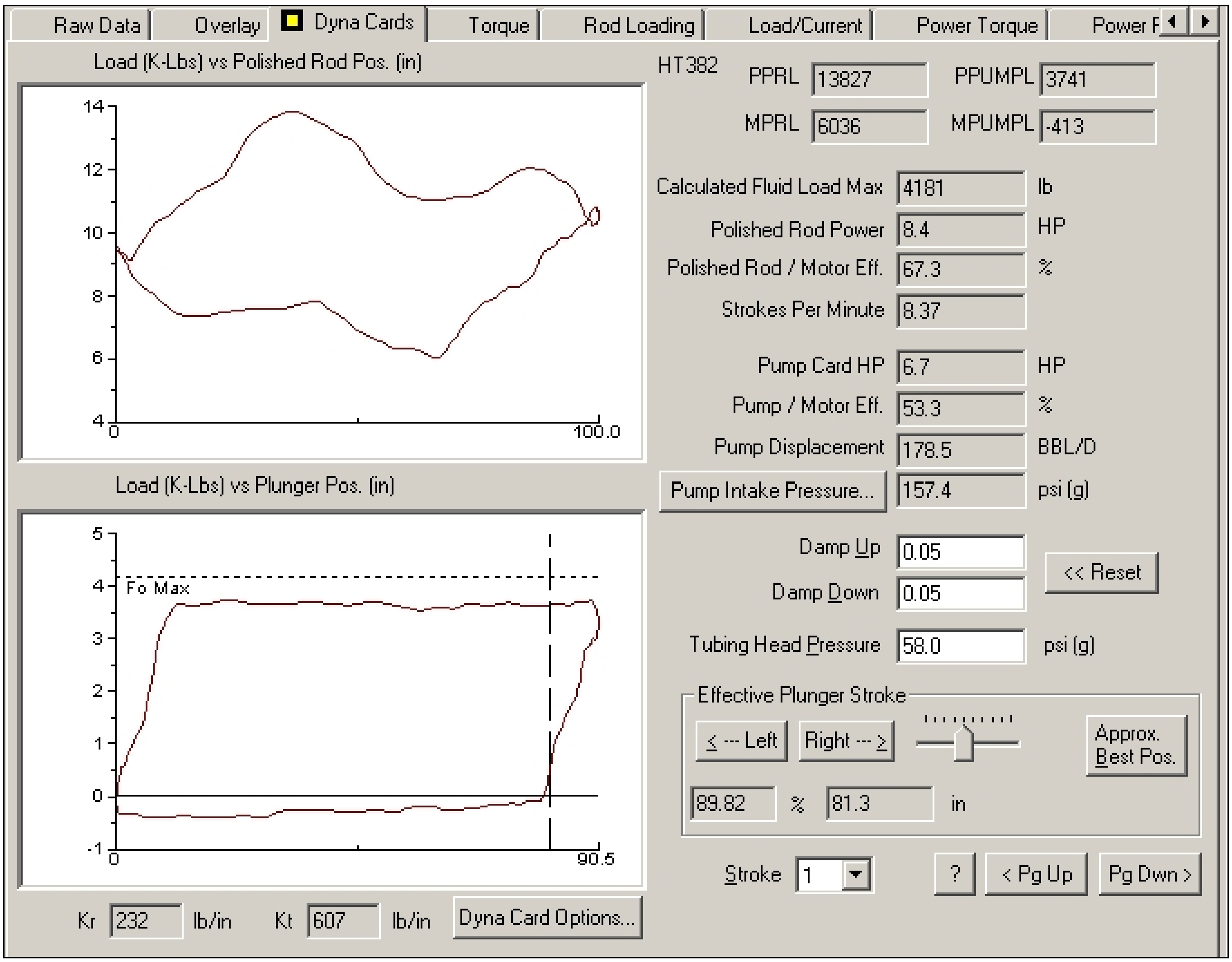
The controls at the bottom of the figure allow displaying and superimposing the recorded strokes in sequence until all the strokes are plotted as shown below for a well that is pumping consistently and uniformly:



Note that the dynamometer cards will overlay each other only when the well's pumping conditions are stabilized.

9.2.4 - Analysis of Individual Dynamometer Stroke

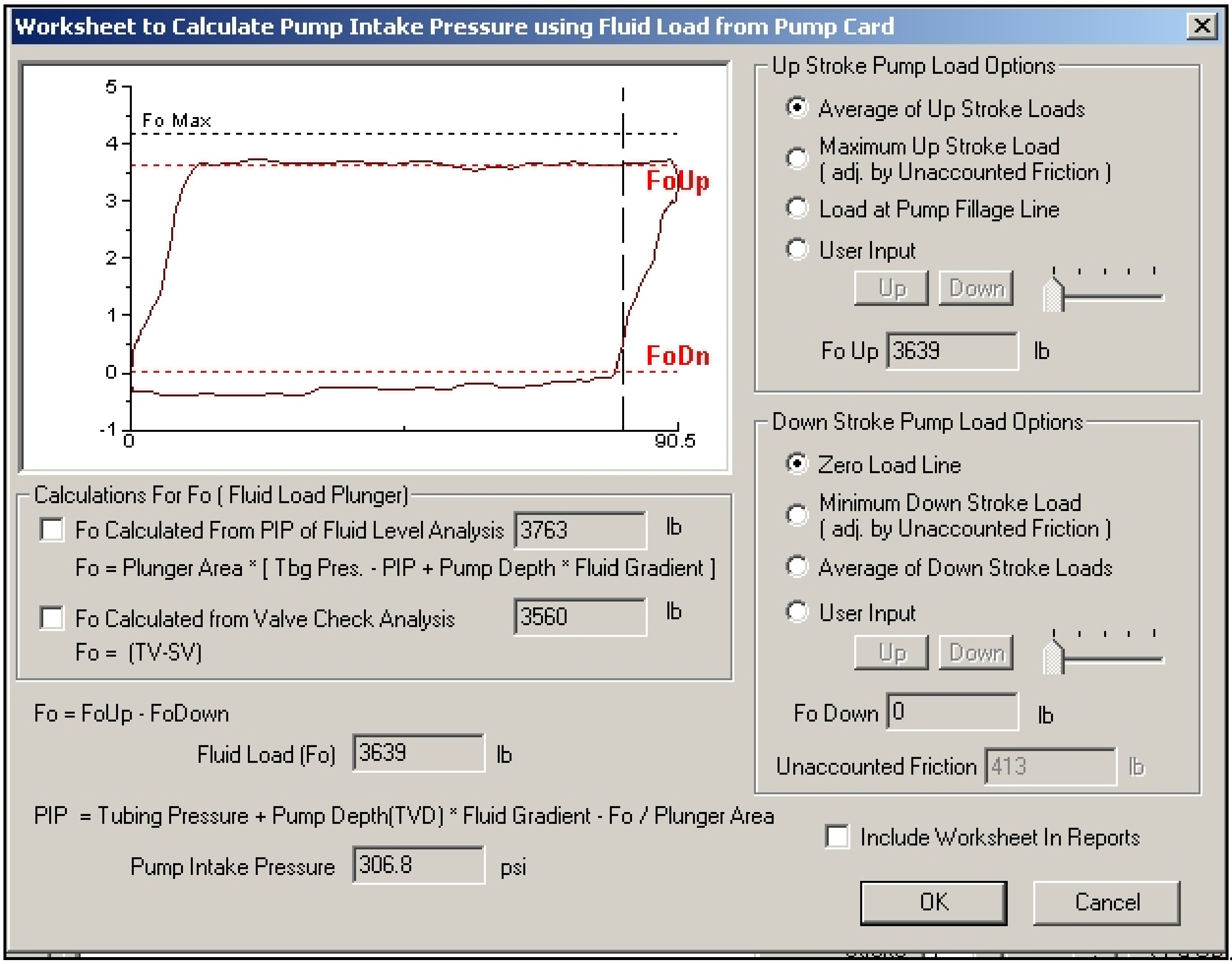
The **Dyna Cards** tab generates a display of the single stroke analysis presented as shown in the following figure:



The upper graph consists of a plot of polished rod load versus position for the selected stroke. The bottom of the stroke is at the far left of the plot (at zero). The top of the stroke is at the far right (at 100 inch). The corresponding downhole pump card is displayed below the surface card. The displacement shows downhole pump stroke (90.5 inch). A movable marker is drawn by the software on the downhole card at a point where it is estimated that the traveling valve opens during the down stroke. This defines the effective plunger stroke. The program then calculates the corresponding volume per day of fluid that should be displaced by the pump and the hydraulic horsepower expended at the pump. The user can use the **Left/Right** arrow keys to relocate the marker as necessary.

The upper plot is a display of surface load versus position (dynamometer card). The stroke length is as given in the well file. The polished rod horsepower (PRHP) corresponding to the work done at the polished rod is shown to the right of the graph.

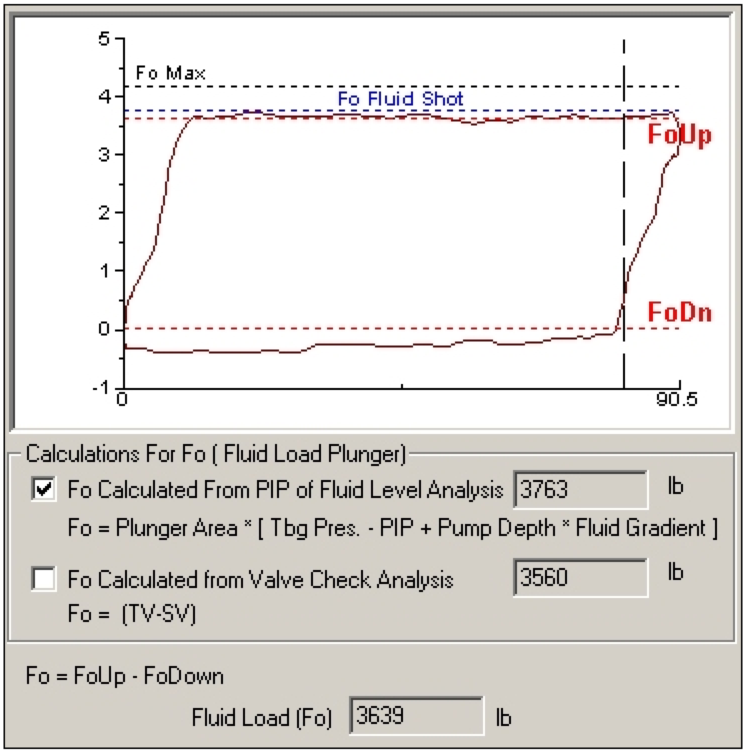
The tubing head pressure should be entered in the appropriate field in order to calculate the pump intake pressure (PIP) estimated from the minimum and maximum values of the pump dynamometer. This calculation requires knowledge of the back pressure on the tubing and an estimate of the friction load on the sucker rods. These quantities are generally not well defined and thus the calculated PIP is somewhat uncertain. The user has various options for the PIP calculation that may be displayed by clicking on the **Pump Intake Pressure** button:



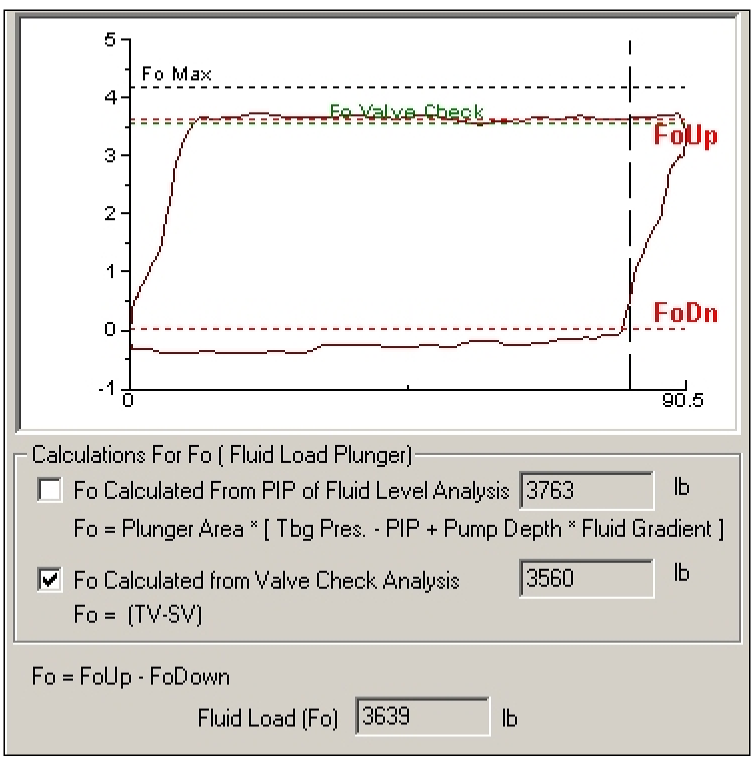
The default calculation uses the average of the upstroke pump load and the zero load line to define the loads used to calculate the fluid load Fo (3639 Lbs). These values yield an estimate of the friction load (413 Lbs) that is not accounted by the damping factor used in the solution of the wave equation in the calculation of the pump dynamometer loads.

The fluid load used in the calculation of PIP is easily checked against the corresponding values based on the acoustic fluid level or the valve check data. As seen above, all these values are in good agreement: 3763, 3560 and 3639, thus giving some confidence to the computed PIP.
For the purposes of quality control of the data, the various estimates of the fluid load Fo can also be displayed on the graph by checking the corresponding boxes:

Display of Fo calculated from Acoustic Fluid Level

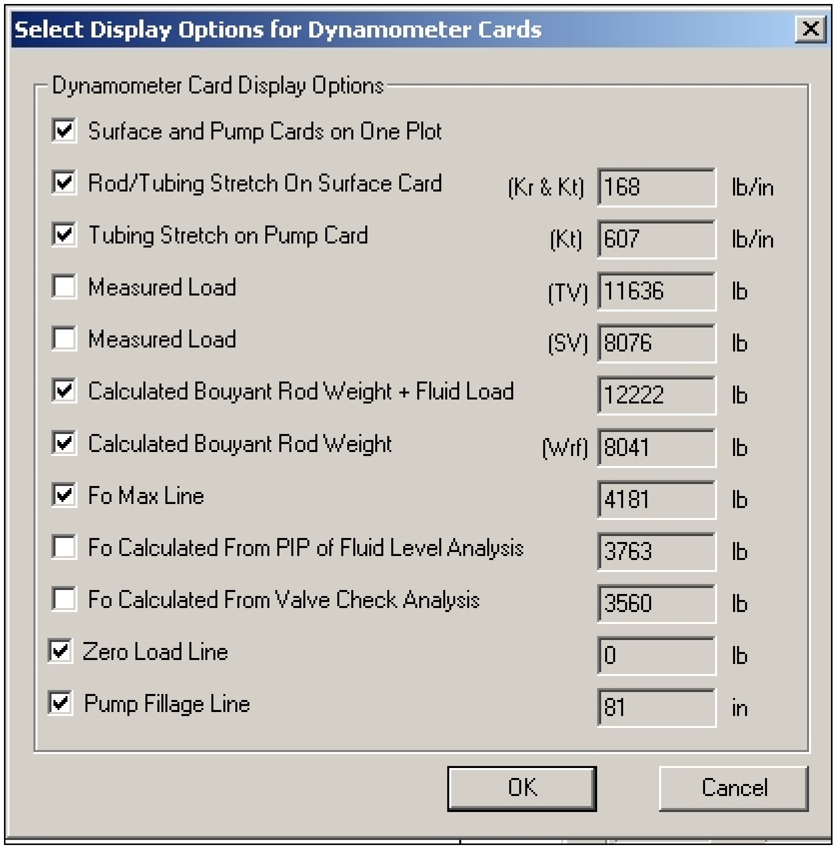


Display of Fo calculated from Valve Check test:



9.2.4.1 - Dyna Card Options

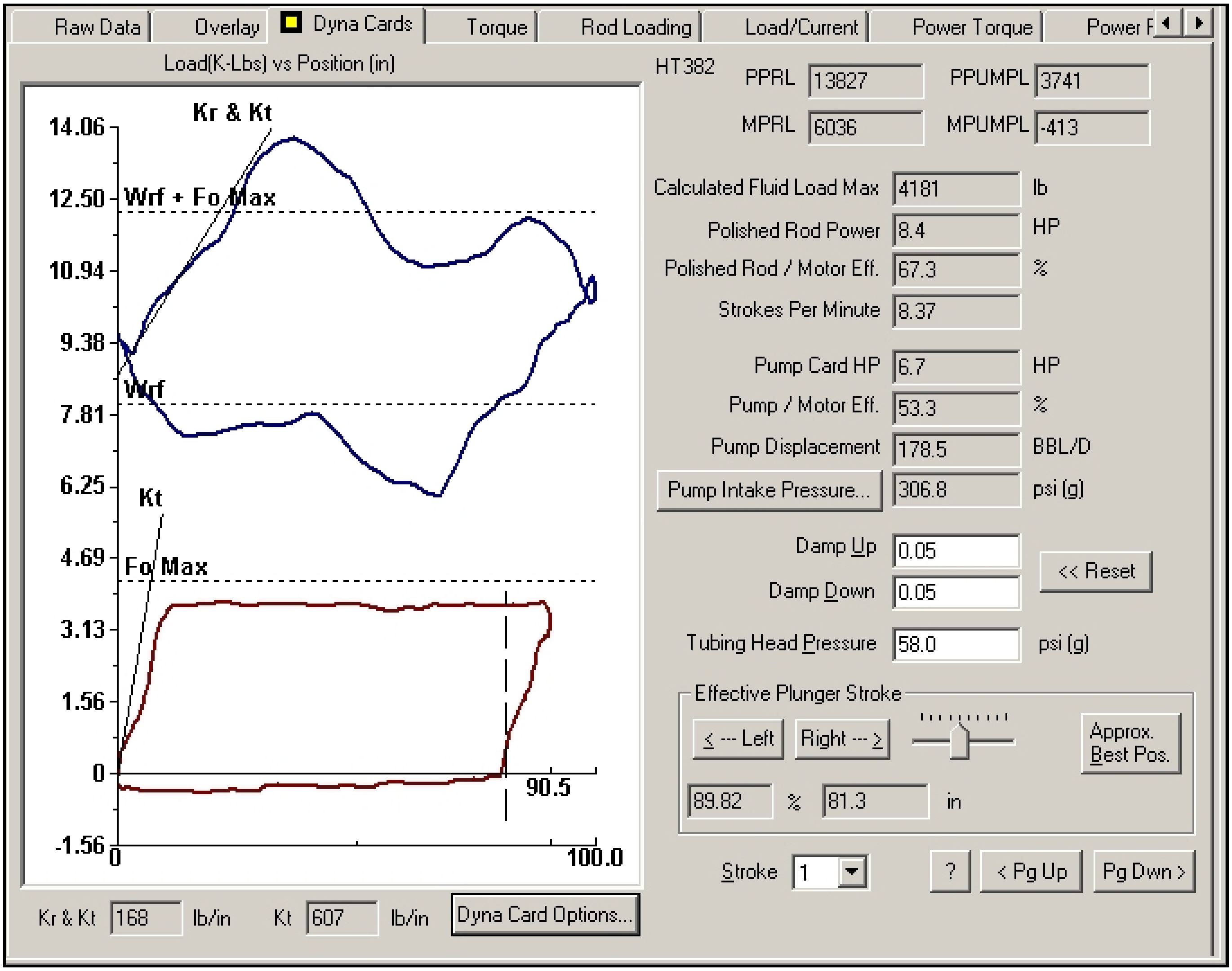
Detailed analysis of dynamometer data is enhanced by displaying the surface and dynamometer cards on the same graph, with common vertical and horizontal scales, and in conjunction with other parameters. Clicking on the **Dyna Card Options** button opens the following menu:



By **checking the first box**, the surface and pump card will be drawn using common vertical and horizontal axes and the values of whatever items are checked will also be displayed as shown in the following figure.

- Kr – rod spring constant is the pounds of load required to elastically stretch the well file rod string for 1 inch.
- Kt – tubing spring constant is the pounds of load required to elastically stretch the well file tubing string for 1 inch.
- Kr&Kt - composite spring constant is the pounds of load required during the upstroke when both tubing and rods stretch 1 inch, assumes unanchored tubing.
- TV - measured polished rod load last selected while analyzing the upstroke valve check load test.
- SV - measured polished rod load last selected while analyzing the down stroke valve check load test.
- Fo – Pump Card Load calculated from the measured surface dynamometer loads and Fo represents the force the pump plunger applies to the rod string.
- Fo(Fluid Level) – calculated fluid load the pump applies to the rods, equal to the area of the pump plunger times the difference between the pump discharge pressure minus the pump intake pressure determined from the last analyzed fluid level shot
- Fo(Valve Test) – load difference between the selected upstroke and down stroke valve check load test
- Fo Max - calculated theoretical max fluid load, occurring when the pump intake pressure is set to zero
- Wrf – calculated buoyant rod weight, where the well file rod string is buoyed in the tubing fluid
- Wrf + FoMax - calculated buoyant rod weight plus FoMax

The figure below shows the display that corresponds to the boxes checked in the previous figure:



The user should select only those items that are most pertinent to the analysis of his interest.

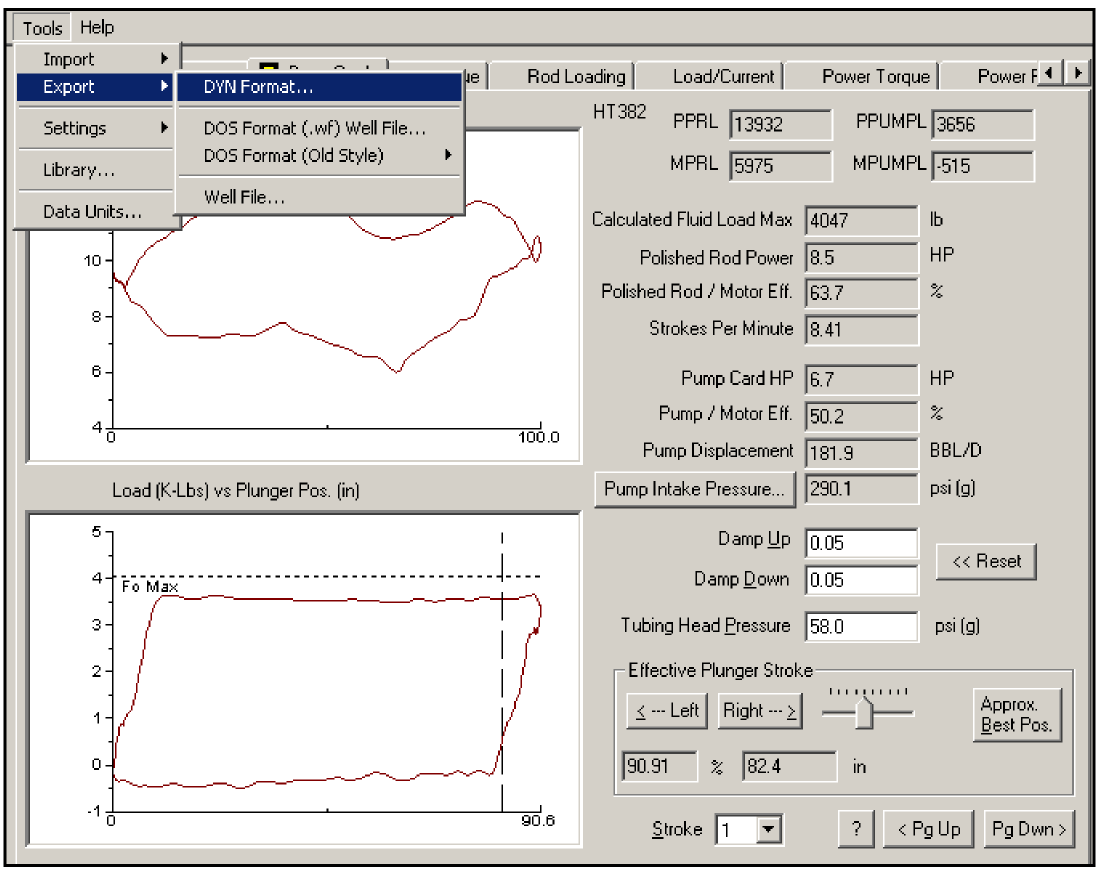
9.2.5 - Damping Factor Adjustment

The default damping factor of 0.05 is generally adequate to describe the friction losses in the sucker rods when calculating the down-hole dynamometer. In certain cases however the appearance of the pump card indicates that a different damping factor may be necessary. In particular whenever the top and bottom boundaries of the pump card are not straight and horizontal the user may want to re-calculate the card using a different factor. This is achieved entering a new damping factor in the Up and Down fields. In general acceptable values of the damping factor should range from 0.01 to 0.15. This is a trial and error procedure which can only be refined with experience. In general the top of the pump card should be a straight line and is more indicative of the correct damping than the bottom of the card.

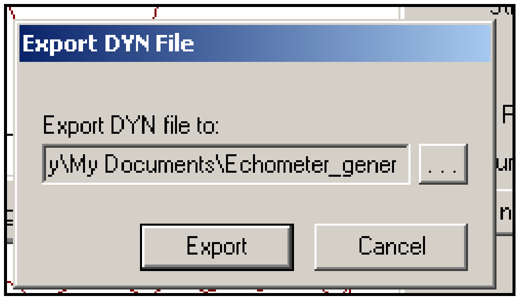
9.2.6 - Saving Single Stroke Data

The single stroke data should be saved if the operator desires to process the dynamometer data in other programs. The operator will normally save dynamometer data for a stroke that is representative of normal pump operation. The digital dynamometer data for this single stroke will be saved to a file called **wellname.DYN**. The file contains load and position for the selected stroke at time intervals corresponding to the sampling rate for the data set. The format of this file is compatible with that of several commercially available dynamometer analysis and prediction programs such as EchoPUMP, RODDIAG, RODMASTER, and others that conform to this format.

The file is written by selecting the **Export** option of the **Tools** menu and highlighting the **DYN Format** option while the corresponding stroke analysis is being displayed:



A dialog box will be opened to select the folder where the file will be recorded.



The user may also select the directory on an external storage device such as USB memory stick, or CDR.

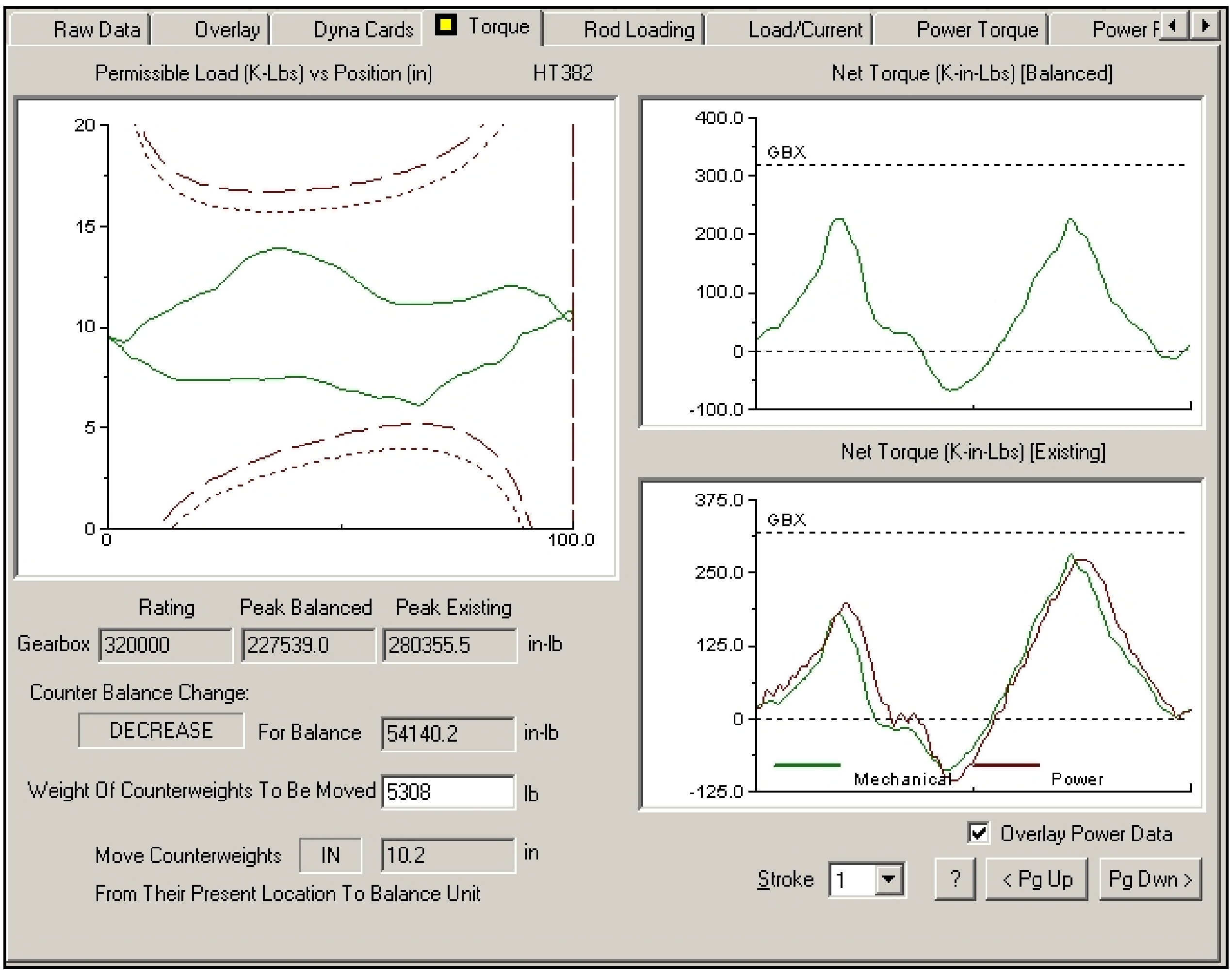
9.2.7 - Torque Analysis

The purposes of this calculation are:

1. To determine the loading of the torque reducer
2. To establish whether the unit is properly balanced
3. To determine the movement of the counterweights, necessary to achieve a better balance.

The calculation requires knowledge of the pumping unit's **geometry** and direction of **rotation**. This information is retrieved by the program from the values stored in the pumping unit library and the base well file. Therefore it is VERY IMPORTANT that the correct unit ID be entered in the well file.

The **counterbalance effect** (CBE) also has to be measured as accurately as possible, as explained in Section 8.6. An alternative is to calculate the **counterbalance moment** (CBM) from the weight of the counterweights and their measured position on the cranks as described in section 5.222 of this manual. When these data are available the user selects the Torque **Tab**, as shown in the next figure:



The left hand figure shows the surface dynamometer card, superposed on a diagram showing the permissible load boundaries. The dashed lines correspond to the loading at the existing balance conditions. If the dynamometer card crosses these lines it means that for that portion of the stroke the rated torque capacity of the gear reducer is being exceeded. The dotted lines show the permissible load boundaries if the unit were properly counterbalanced (equal peak torque during upstroke and down stroke).

Similar information is presented on the panels on the right hand side of the figure, where the torque as a function of time for the single stroke, is shown for both the existing and the "ideal" balance case. If power data was acquired, the power-derived torque is displayed when the **Overlay Power Data** box is checked. **GBX** indicates the gearbox rating in thousand inch-lbs.

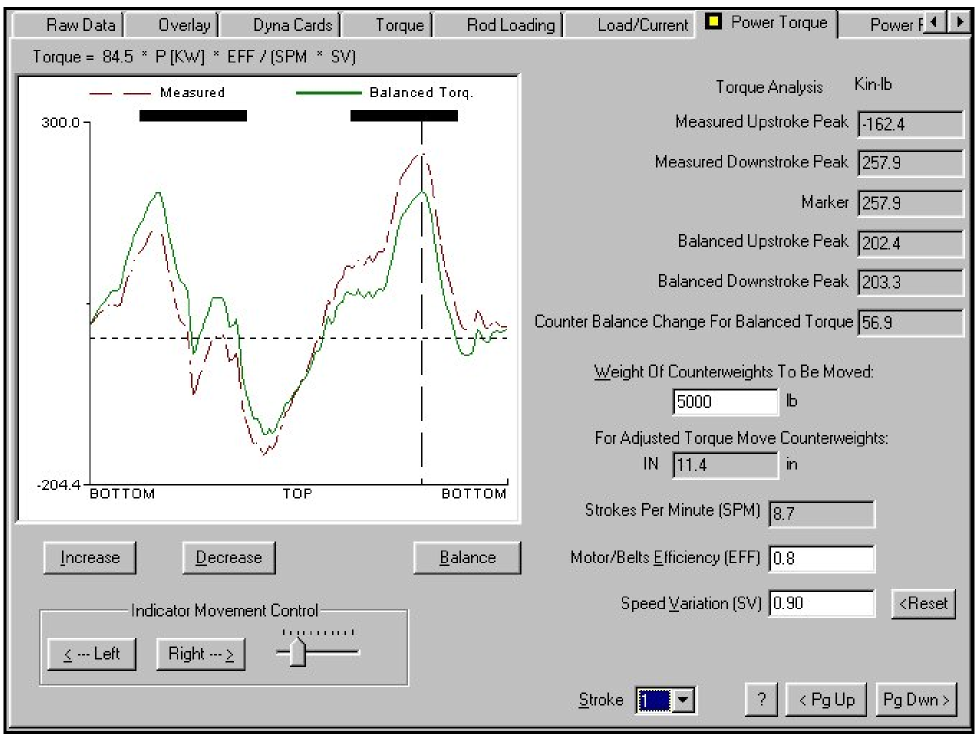
9.2.7.1 - Counterweight Movement

The change in counterweight moment that is required to bring the unit into better balance is shown at the bottom of the figure. This value is expressed as thousands of inch-pounds (K-in-lb). The user decides what number of counterweights can be moved and after referring to a table of counterweight specifications, enters the TOTAL weight of the counterweights to be moved in the appropriate field. The program then displays the direction (IN or OUT) and distance from THEIR PRESENT LOCATION, that the counterweights should be moved in order to adjust the counterbalance by the desired amount. If the distance were larger than the space available on the crank arm, then additional counterweights must be moved or removed or added. The new weight is entered and the new displacement is calculated as before.

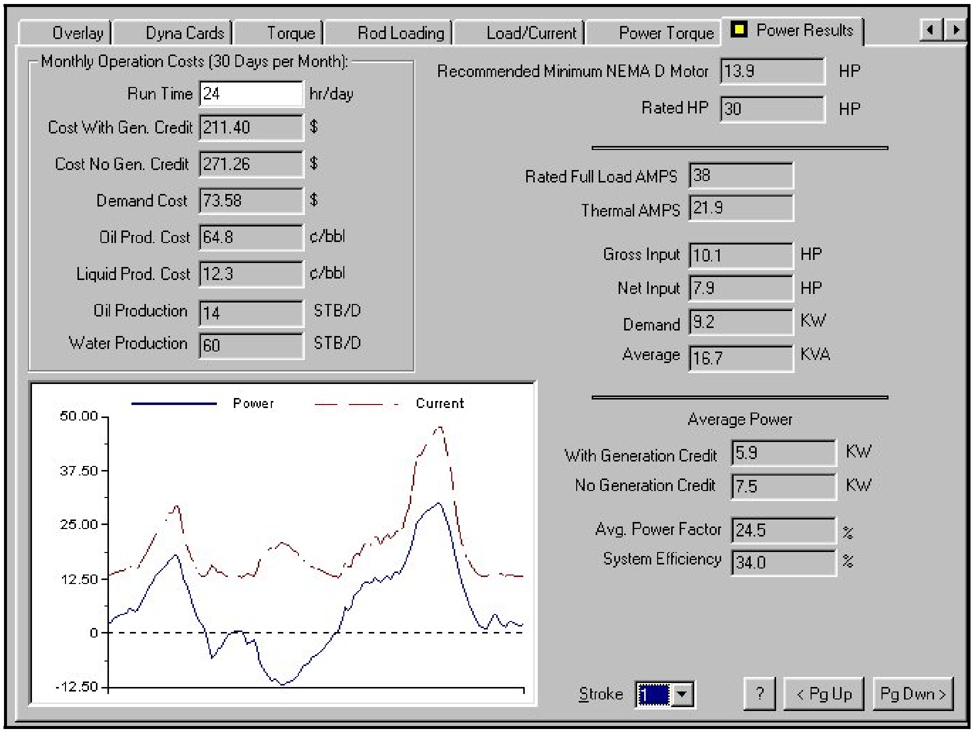
9.2.7.2 - Power Data Acquired with Dynamometer

When POWER PROBES are connected to the electrical switch box, the dynamometer program acquires motor power data as well as current data. The data for a specific stroke can be viewed selecting the Power Analysis Tabs which can present the data in terms of a torque analysis in the **Power Torque** tab or a power analysis in the **Power Results** tab:

Power Torque Analysis



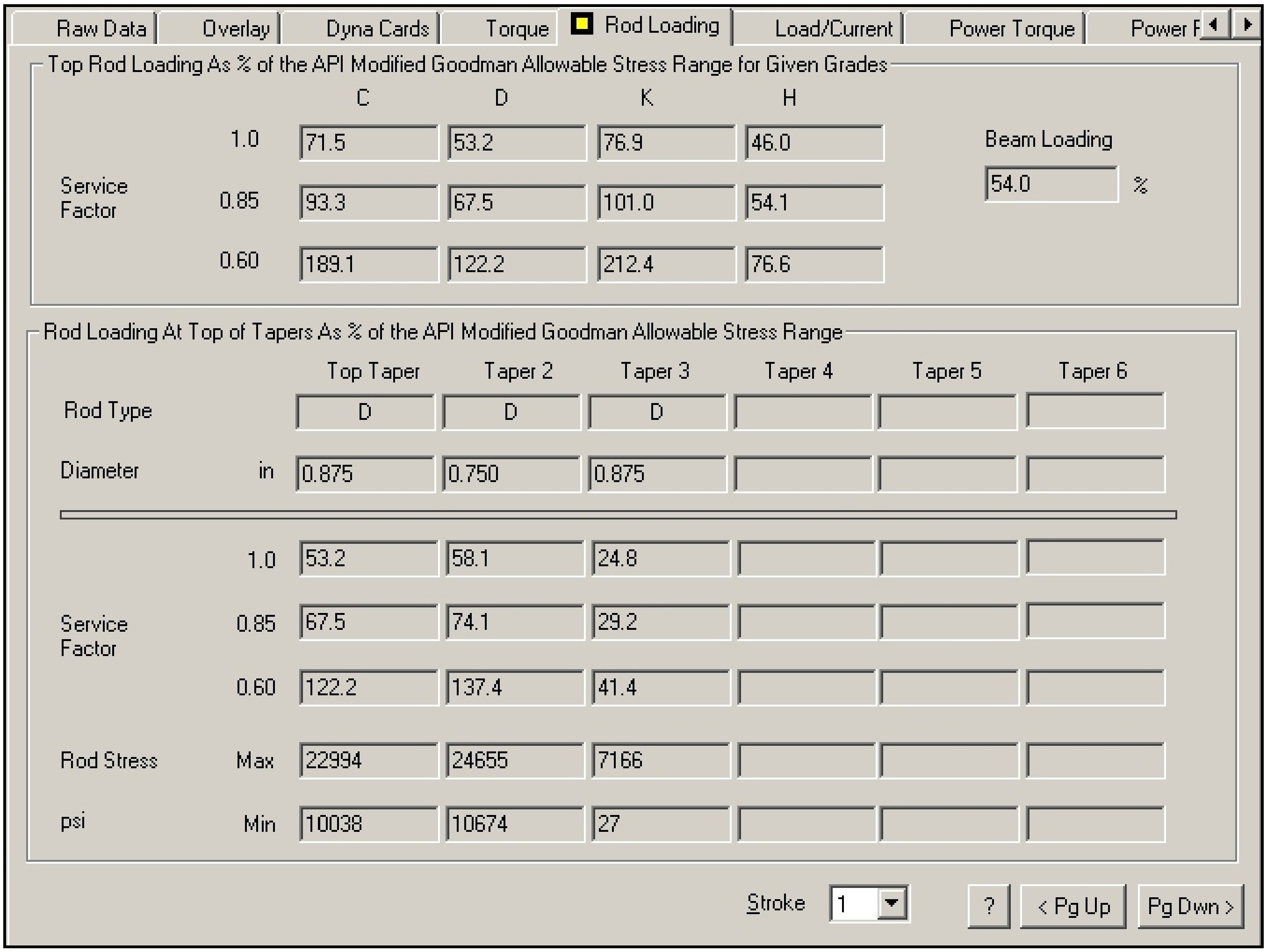
Power cost Analysis



These graphs are discussed in detail in the **Power Probe Measurements** section of this manual.

9.2.8 - Rod Loading

A detailed analysis of the loading of the rod string is displayed by selecting the **Rod Loading** Tab:



Top rod loading for <u>different grades</u> is shown in the upper section of the screen while the loading at each taper intersection <u>for the existing rod string</u> is shown, for various service factors, in the lower section. At the bottom of the table are displayed the Maximum and Minimum stress in psi that are experienced over one pump stroke <u>at the top</u> of the particular rod taper.

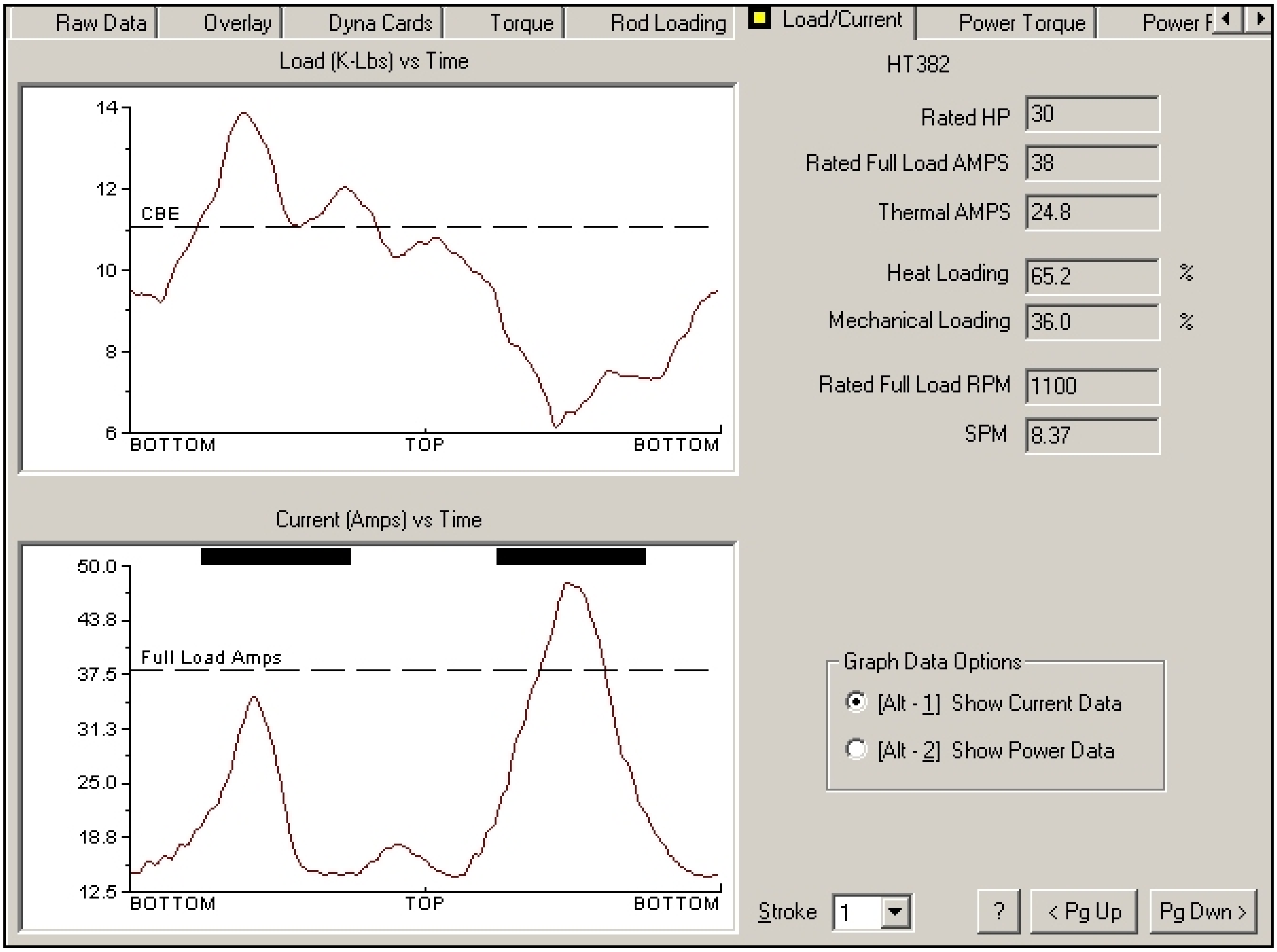
The following table shows the Tensile Strength used in the formulation of the Goodman diagram for the most common grades:

Rod Grade	Peak Tensile Strength, psi
C	95,000
K	85,000
D	115,000
H	140,000

Loading of the beam is indicated as a % of the **Beam Load** capacity based on the API designation for the pumping unit as entered in the base well file.

9.2.9 - Load-Current and Load-Power Analysis

This analysis gives information about motor loading and correlates the current and power usage during a stroke with the polished rod load, as shown in the following figure:

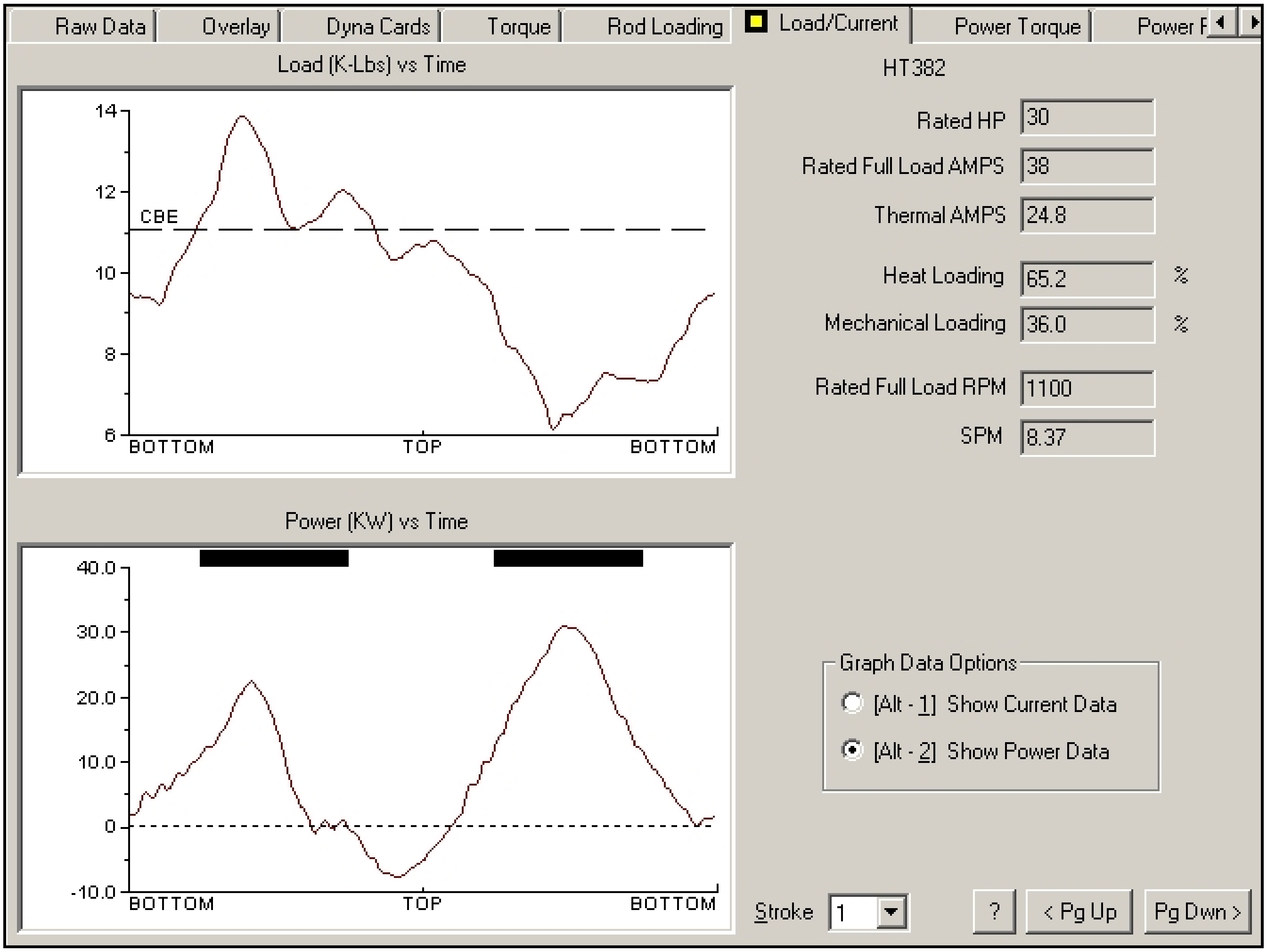


Immediately below the load versus time plot is a plot of the apparent motor current versus time during the same period. Two dark bars are displayed on the motor current screen. These bars show when the cranks are near the horizontal position. The motor current on the left below the dark bar indicates the motor current flowing while lifting the rods and fluid load. The motor current displayed on the right below the dark bar represents the motor current flowing while lifting the crank arms and weights. Using the name-plate rated horsepower and the full load amps (from the well data file) the program computes the mechanical and thermal loading of the motor. These are displayed as percentages. If the motor appears to be under or overloaded, a more detailed electrical power measurement should be made using the power probes as discussed in section 10 of this manual.

> It is important to be aware that the motor current measured in this fashion could either be flowing from the power electrical box to the motor or from the motor to the power source depending on whether the motor is driving or is generating. The current sensor as used cannot detect direction of current flow.

In general, if the motor current is higher when raising the cranks and weights than when raising the rods, the weights should be moved inwards on the cranks to more evenly distribute the loads on the upstroke and the down stroke. The weights should be moved outwards if the motor current is higher when lifting the rods than when lifting the cranks and weights.

When the Power probes are connected to the electrical supply then the following display may be generated by selecting the **Show Power Data** button. The graph shows the instantaneous motor power that corresponds to the polished rod load for that selected stroke:



Power torque and power cost analysis is discussed in **Section 10** of this manual.

9.3 - HYDRAULIC LIFT HORSESHOE DYNAMOMETER

This dynamometer is designed to facilitate installation of the horseshoe load cell and to eliminate measurement errors caused by changes in pump spacing resulting from installation of a horse-shoe transducer between the carrier bar and the polished rod clamp.

The hydraulic lift horseshoe dynamometer requires the permanent installation of an inexpensive spacer spool onto the carrier bar. The dynamometer and the hydraulic lift are easily inserted into the spool and then the load cell is activated using a small portable hydraulic pump which transfers the polished rod load to the load cell of the dynamometer. Insertion of a thin spacer plate and release of the hydraulic pressure allow removal of the hydraulic pump and acquisition of the data.

NOTE: This load cell does not fit the standard **Leutert** dynamometer spacer. The conventional Leutert dynamometer instrument, with chart recorder, can be modified to operate with the Well Analyzer and the TWM software. Please contact Echometer Co. for more details.

9.3.1 - Purpose of the Hydraulic Lift System

The most accurate dynamometer measurements are obtained using a calibrated strain gage horseshoe load cell which measures directly the load on the polished rod. However unless the load cell is permanently attached to the polished rod (such as in most Pump Off Controller applications) the installation of the load cell requires separating the polished rod clamp from the carrier bar for a distance that corresponds to the thickness of the load cell. This thickness is of the order of 3 to 6 inches depending on the type and rating of the load cell. As a consequence the entire rod string is lifted by the same distance such that the pump plunger is further removed from the standing valve and is operating in a section of the pump barrel different from the section where it is normally operating. This will result in a pump performance is slightly different from normal, especially if the pump stroke is relatively short. In particular the different pump spacing will cause a different compression ratio and the pump may have a greater susceptibility to gas interference and gas locking. In order to avoid these effects it is necessary to insert the load cell with a minimum change in position of the polished rod clamp relative to the carrier bar. This is accomplished by using the permanent spacer spool and the hydraulic lift horseshoe dynamometer system.

9.3.2 - Hydraulic Lift Load Cell System Description

The hydraulic lift load cell system consists of five elements: The load cell, the hydraulic lift, the spacer spool, the spacer plate and the hydraulic pump.

9.3.2.1 - Load Cell

It is of the horse-shoe type, rated at 50,000 Lb., and is calibrated to yield an overall accuracy of 0.5% of range. It is manufactured with instrumentation grade stainless steel and incorporates a high accuracy accelerometer from which signal the TWM software computes the velocity and position of the polished rod.

9.3.2.2 - Spacer Spool

This is an inexpensive spacer consisting of two end plates and a central tube sized to fit the polished rod. The spool is located between the polished rod clamp and the carrier bar. The end plates are resting onto the central tube. The distance between the end plates allows inserting the load cell and the hydraulic lift so that the polished rod may be lifted a short distance of approximately 1/4 inch by the hydraulic jack which places the entire polished rod load onto the load cell.

9.3.2.3 - Hydraulic Lift

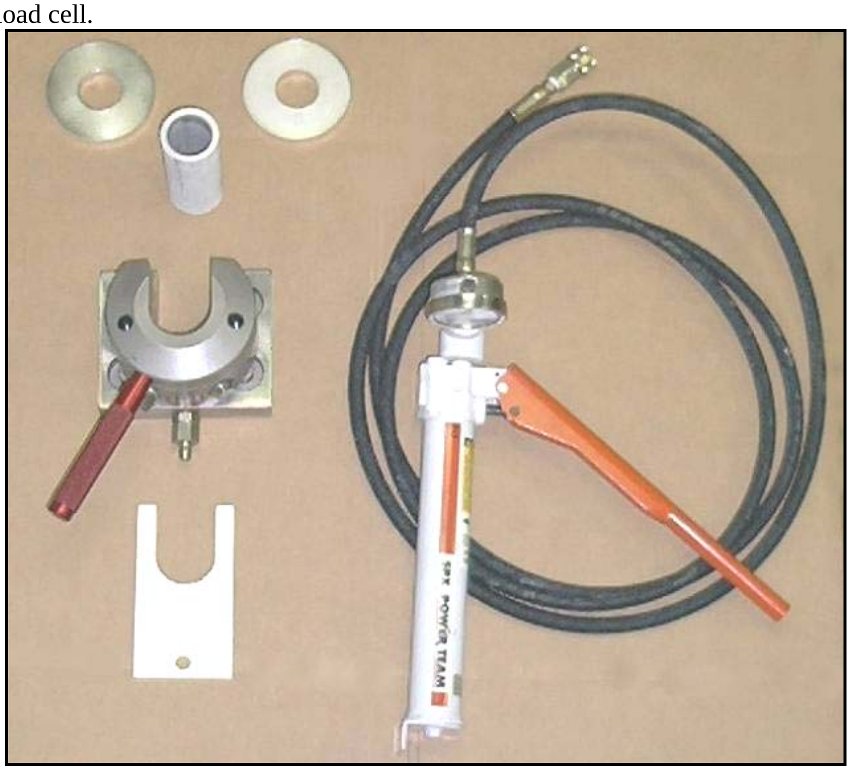
It is a low profile hydraulic jack with multiple pistons designed to fit closely into the spacer spool together with the load cell. When it is pressurized it lifts the load cell the distance sufficient to insert the spacer plate below the load cell. When the pressure is released the polished rod load is applied onto the load cell and the hydraulic hose is disconnected from the hydraulic jack. This allows full movement of the polished rod during normal pumping operations. The total displacement of the polished rod from its normal operating condition is less than the thickness of the spacer plate.

9.3.2.4 - Spacer Plate

It is a steel plate designed to fit precisely between the bottom of the load cell and the body of the hydraulic lift. When the lift's pistons are retracted the load cell is supported by the spacer plate thus rigidly transferring the polished rod load to the load cell. The plate is 1/4 inch thick.

9.3.2.5 - Hydraulic Pump

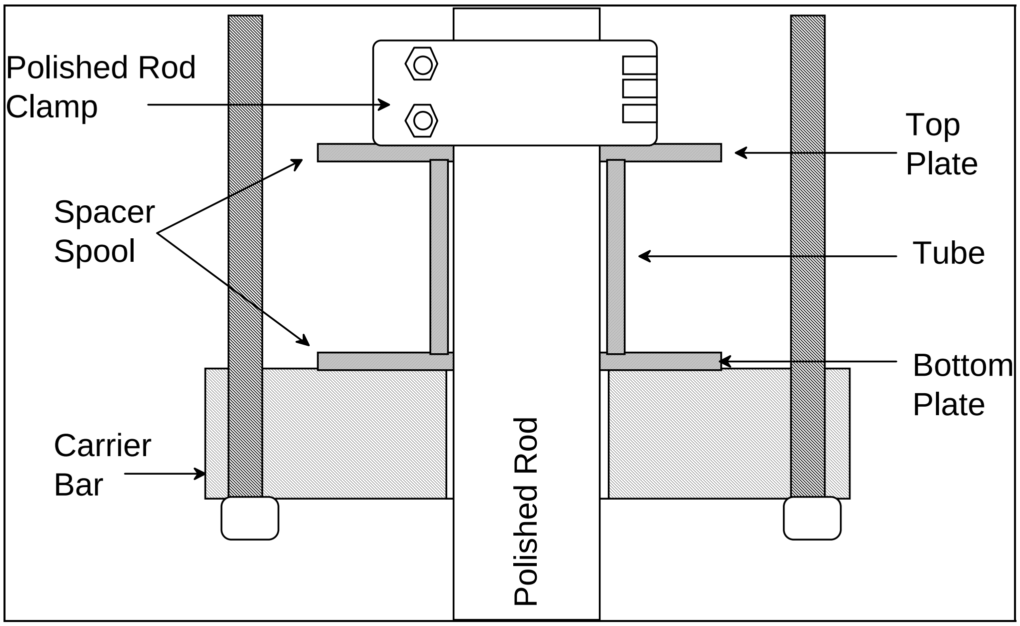
It is connected with a hose and a quick-connect to the hydraulic lift. It is capable of pressurizing hydraulic fluid to a pressure of 5000 psi thus lifting the load cell when the buoyant rod weight is less than 30,000 Lb. and thus placing the entire polished rod load on the load cell.



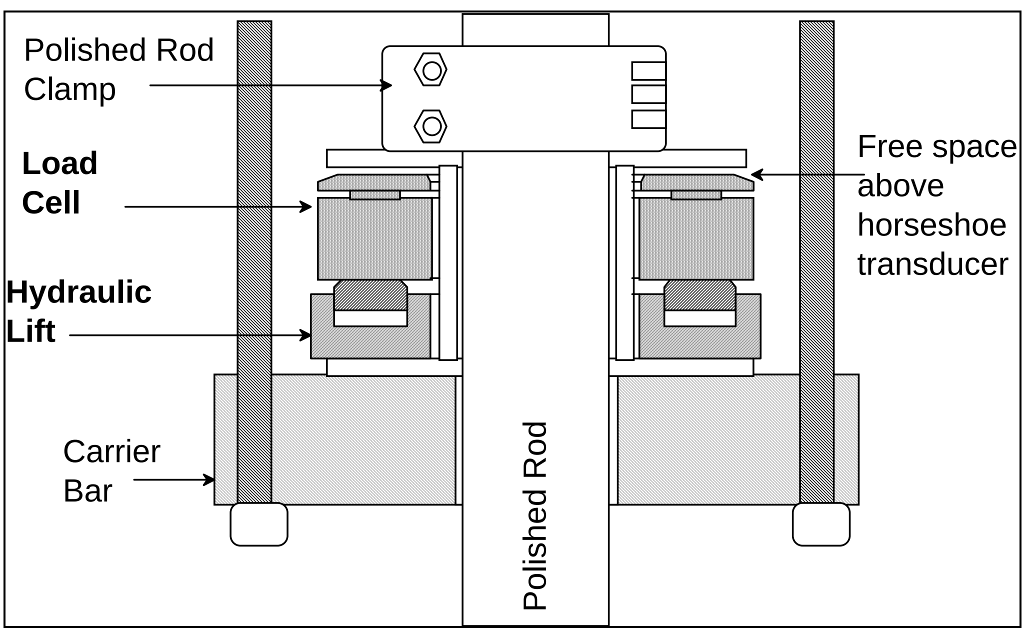
9.3.3 - Installation of Hydraulic Lift Load Cell

The following figures show how the Hydraulic Lift Dynamometer is installed and how it operates:

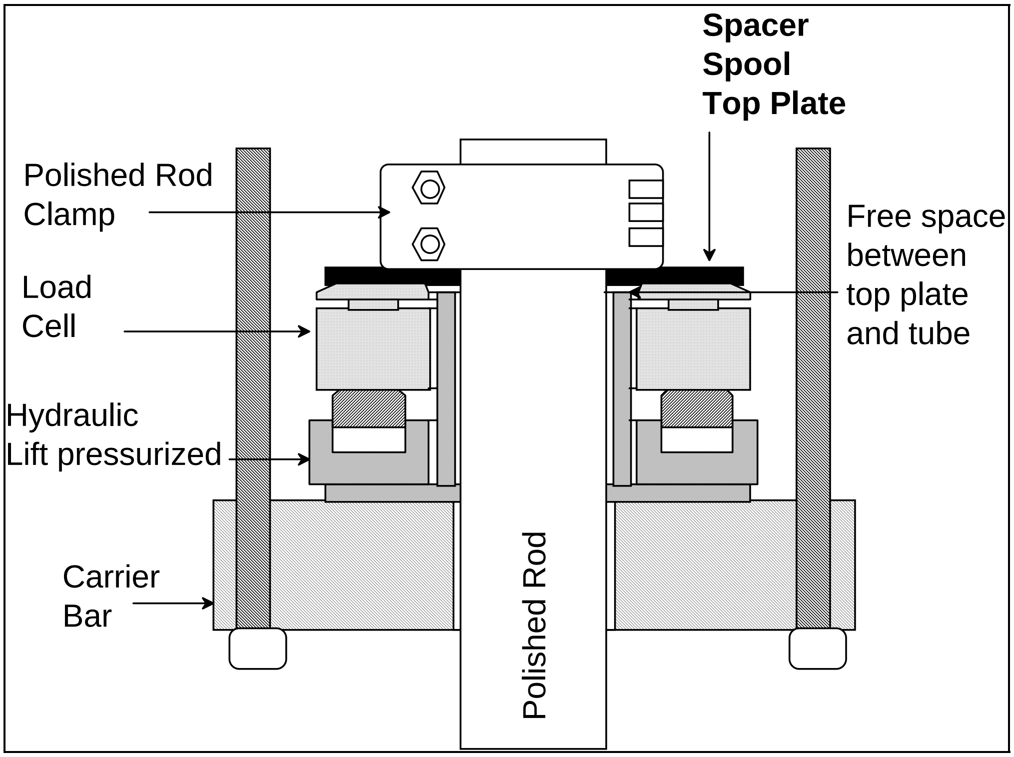
Spacer Spool Installed for Normal Operation



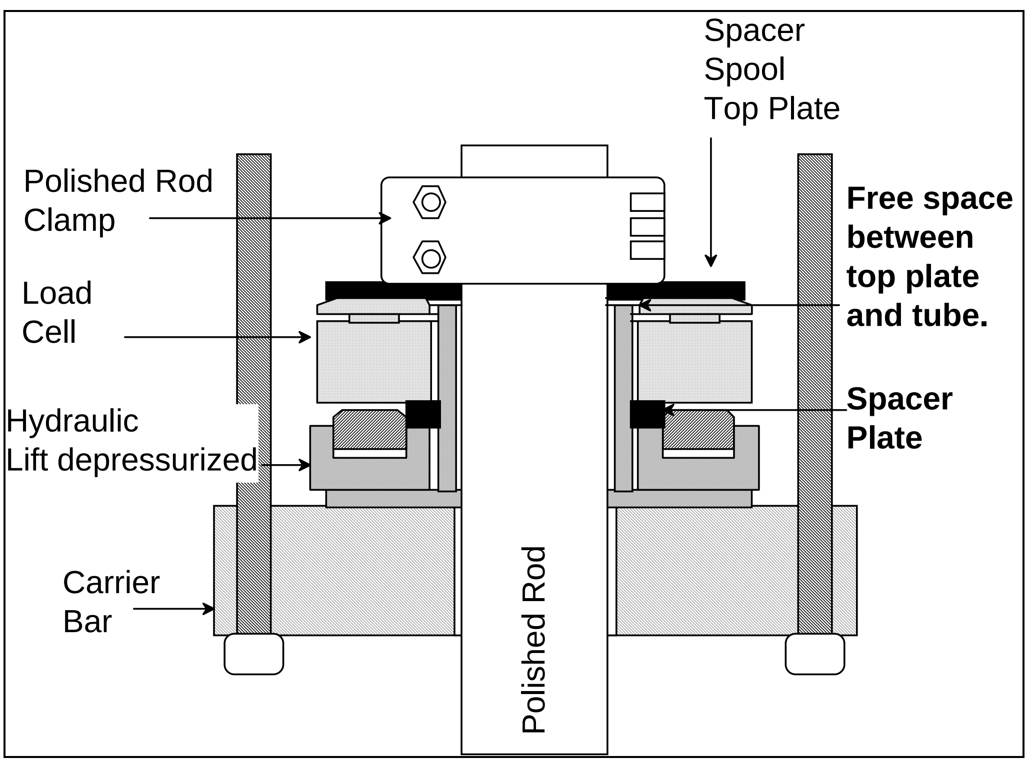
Load Cell on Top of Hydraulic Lift in Spacer Spool



Assembly Drawing Showing Hydraulic Jack Lifting Load Cell, Upper Plate and Polished Rod Load



Assembly Drawing Showing Polished Rod Load on Load Cell



9.4 - MEASUREMENTS WITH POLISHED ROD TRANSDUCER (PRT)

The purpose of this sensor is to provide the analyst with a transducer that can be quickly and safely installed by one person, for the acquisition of dynamometer data. The device is a polished rod clamp-on unit that senses both load and acceleration and transmits the data to the Well Analyzer.

9.4.1 - Objective of PRT Transducer

We have observed that dynamometer technicians often operate alone, especially when they observe that there appears to be a problem with the down-hole pumping system. In addition, they usually want to spend a minimum of time to identify any problem that might be present in the system so that the necessary adjustments or repairs can be done as quickly as possible.

The goals sought by the design of the polished rod transducer are:

- **Quick and easy** attachment of the transducer to the well
- **Safe** implementation. (No need to place the transducer between the polished rod clamp and the carrier bar.)
- **Accuracy** of data suitable for down-hole dynamometer analysis.
- **Minimum of calibration** done by user.

Generally down-hole problems in pumping wells are in one of the following categories:

- Down-hole equipment failure, malfunction or gas interference.
- Mismatch between the productive capacity of the formation and that of the pumping system.

The analysis of the first is usually based on dynamometer information and a calculated bottom-hole dynamometer card.

The analysis of the second requires in addition the annular fluid level, casing pressure, flowing bottom hole pressure and stabilized reservoir pressure.

The Well Analyzer, in conjunction with the polished rod transducer, the motor power probe and the acoustic measurement hardware, provides the complete set of data and interpretative capabilities to study and optimize the performance of most pumping wells.

9.4.2 - Polished Rod Transducer Description

As shown earlier under section 8.0, the transducer is a C-clamp device which is lightly clamped to the polished rod, about 6 inches below the carrier bar but high enough so as not to touch the stuffing box on the down stroke. The device is instrumented with highly sensitive strain gages that measure the change in diameter of the polished rod due to the variation of load during a pumping cycle. In addition the unit houses an accelerometer and suitable electrical connections.

The output of the transducer is linearly related to the change in diameter of the polished rod caused by a change in axial load. The sensitivity is of the order of 1 mV per 3000 LB change in load. This voltage change is easily measured with the Well Analyzer's data acquisition system which has a sensitivity of 2 micro volts.

The extraordinary sensitivity of the PRT makes it also sensitive to changes of its own dimensions due to temperature variations. Therefore a temperature compensation circuit is employed in the transducer to eliminate the practical effects of temperature change. Nevertheless if the device is subjected to rapid temperature changes (from air conditioned car to 120° F in the West Texas Summer or 20° F in Montana winter) a certain time for temperature stabilization will have to be allowed before undertaking measurements. This is taken into account by the installation and calibration procedure.

It is important that the installation instructions, which are clearly displayed to the operator on the Well Analyzer's screen, be followed carefully. Otherwise it is possible to **overload the transducer and cause permanent damag**e.

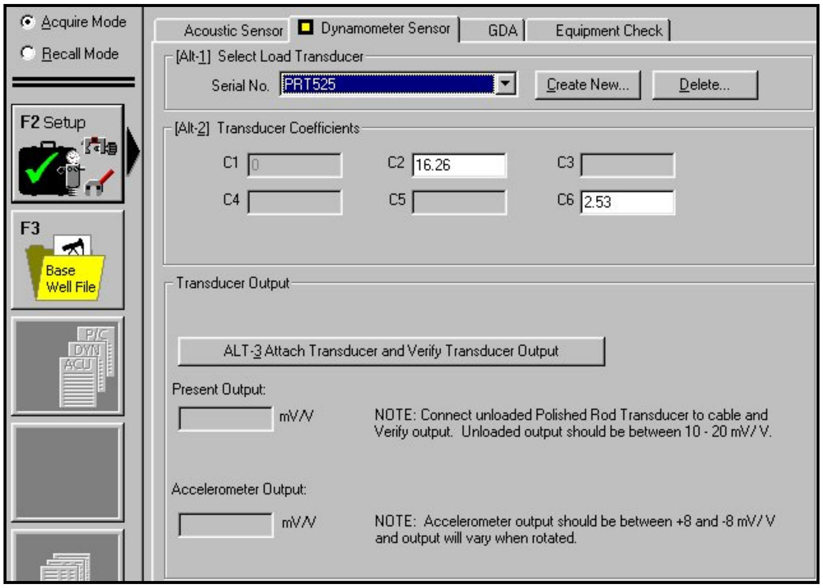
Generally the transducer is installed on the polished rod with the plunger near the bottom of the down stroke. The weight of the rods in fluid is the reference to which the transducer is calibrated. Calibration is done automatically by the software. Calibration is discussed later in more detail. Changes in loading during the pumping cycle are related to the load applied to the polished rod when the sensor is installed. Consequently it is very important to have **accurate** information about the **polished rod diameter**, **rod string make-up**, **length of tapers, size of rods, type of material, pump depth and tubing anchoring**. These data must be input into the well data file in the appropriate fields.

Transducer Serial Number

The Well Analyzer's program recognizes the use of **a Polished Rod transducer by the Serial Number** starting with **PRT** which is entered in the **Set Up** screen. It is **very important** that this full designation be entered **correctly**. Also the transducer coefficients corresponding to the transducer in use must be entered correctly. For example the polished rod transducer serial number could be PRT123.

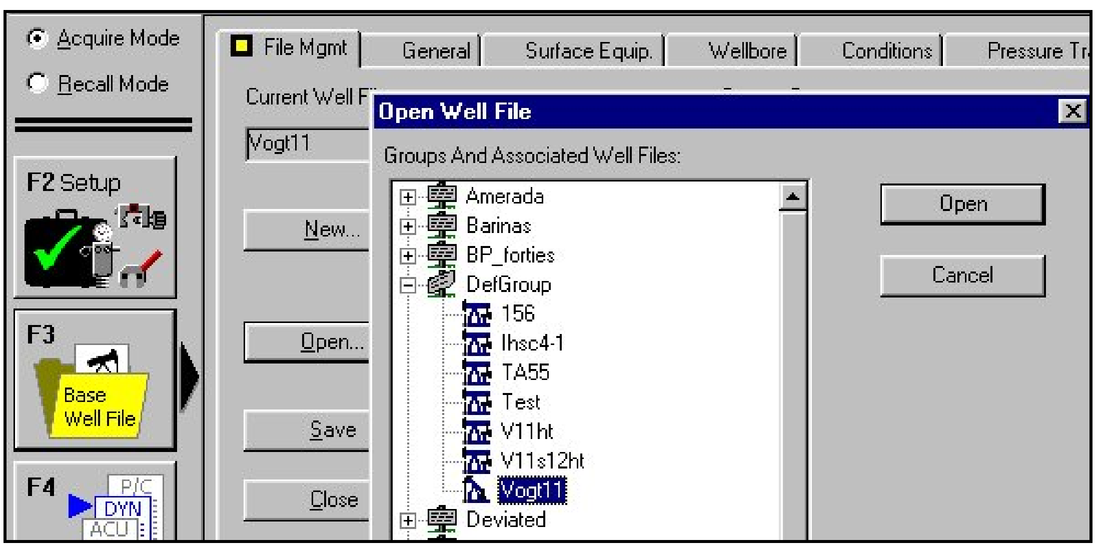
9.4.3 - Data Acquisition with PRT

The TWM software is started following the normal procedure and the **Set-Up** screen is selected in the Acquire Mode.



- Select or enter (Create New) the Polished Rod Transducer **serial number** (PRT123) and **coefficients**.
- The **output values** of the transducer when it is not installed on the polished rod **should be checked** as indicated on the screen.
- Exit the set-up screen.
- Select the **Base well File** option from the menu

This will bring up the **Catalog of Well File Data** as shown in the next figure:

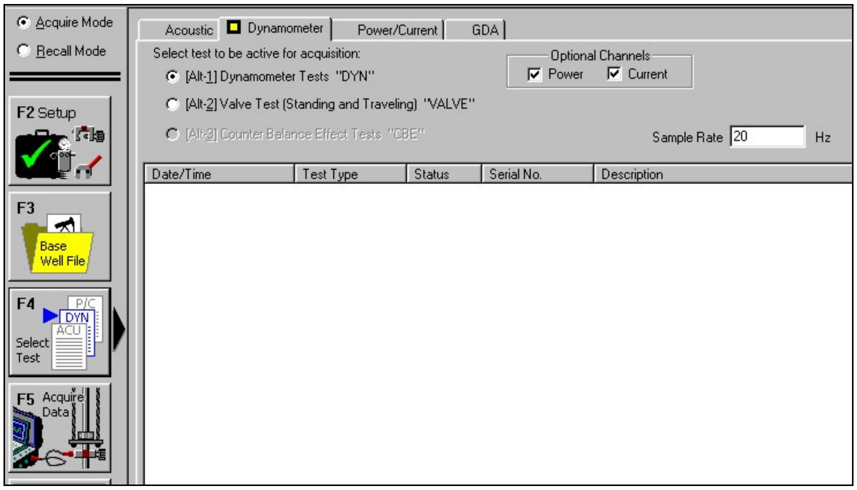


Select the correct well file by highlighting the well name in the corresponding group, and open it and check that the correct well data is being used.

Verify that the correct information is entered throughout the screens but in particular in the following fields:

- **Stroke length**
- **Tubing Anchor Depth**
- **Length of Each Taper**
- **Rod type of Each Taper**
- **Pump Diameter**
- **Pump Intake Depth**
- **Diameter of Each Taper**

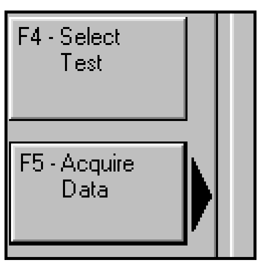
Then select the **Dynamometer** tab in the Select Test screen:



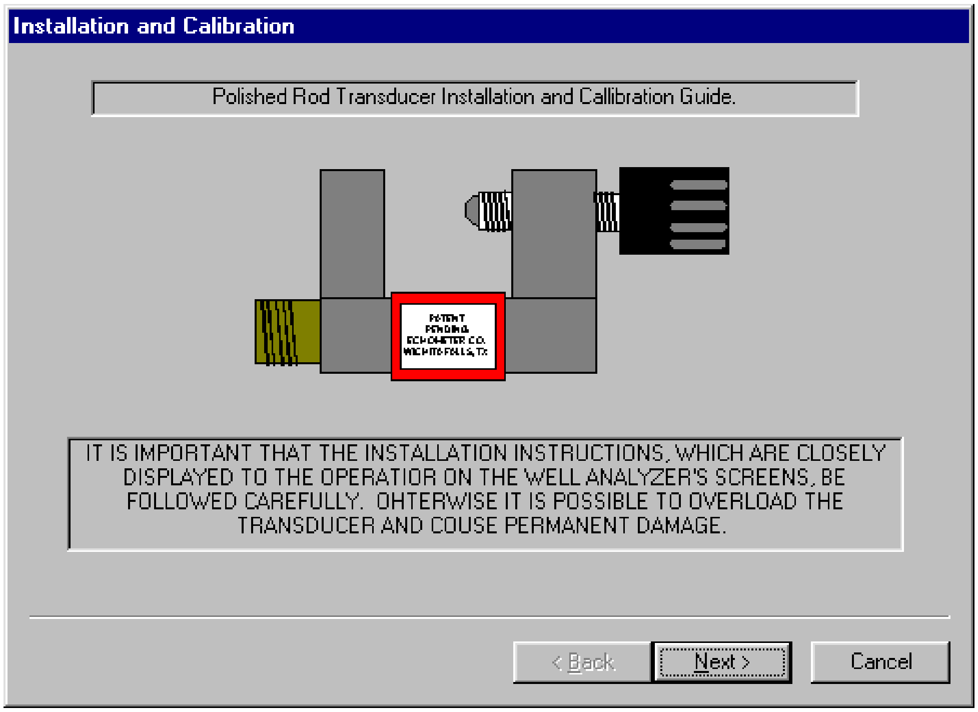
Select the **Acquire Data** option to begin the Polished Rod transducer installation sequence:

The multi-conductor cable should **now** be attached to the Well Analyzer and to the Polished Rod Transducer connector.

DO NOT INSTALL THE PRT ONTO THE POLISHED ROD AT THIS TIME



The following sequence of help screens will be displayed, key **Enter** or click **Next** after reading the instructions:

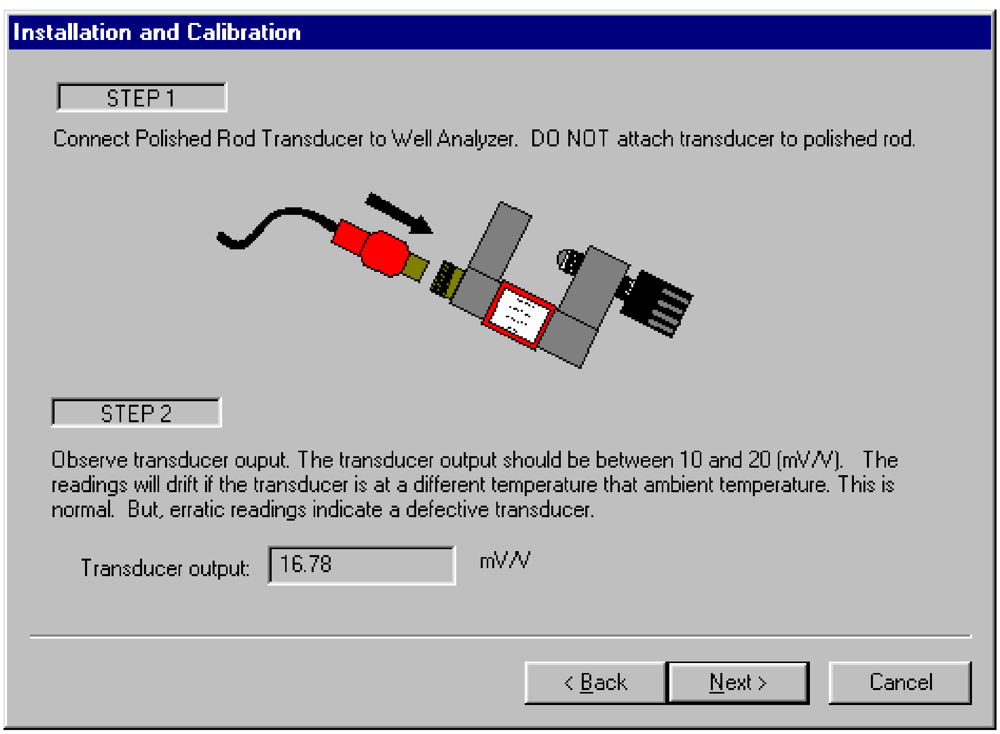


Pressing **Enter** will continue with a display of the installation and calibration procedures, as discussed in the following section.

9.4.4 - Installation and Calibration

It is **important that the operator follow the instructions as given on the screen** to **avoid** the possibility of **damaging the PRT** and to insure that **accurate data is obtained**.

The first step is to insure that the transducer is operating properly and that the battery voltages are within specifications. The following screen is displayed:



A certain amount of drift of the transducer output is normal. It is related to the change in temperature of the transducer.

Drift of the load during data acquisition is minimized by waiting for the PRT temperature to equalize with that of the polished rod, thus it is most efficient to attach the PRT onto the polished rod (with minimum tightening) at the earliest time after the operator arrives at the well. Stop the unit just long enough to attach the PRT and the coiled cable then restart the motor so that pumping continues with minimum interruption.
The next step involves completing the installation of the PRT onto the polished rod and zeroing of the transducer.

The pumping unit should be stopped near the bottom of the stroke and the brake set.

IMPORTANT NOTE

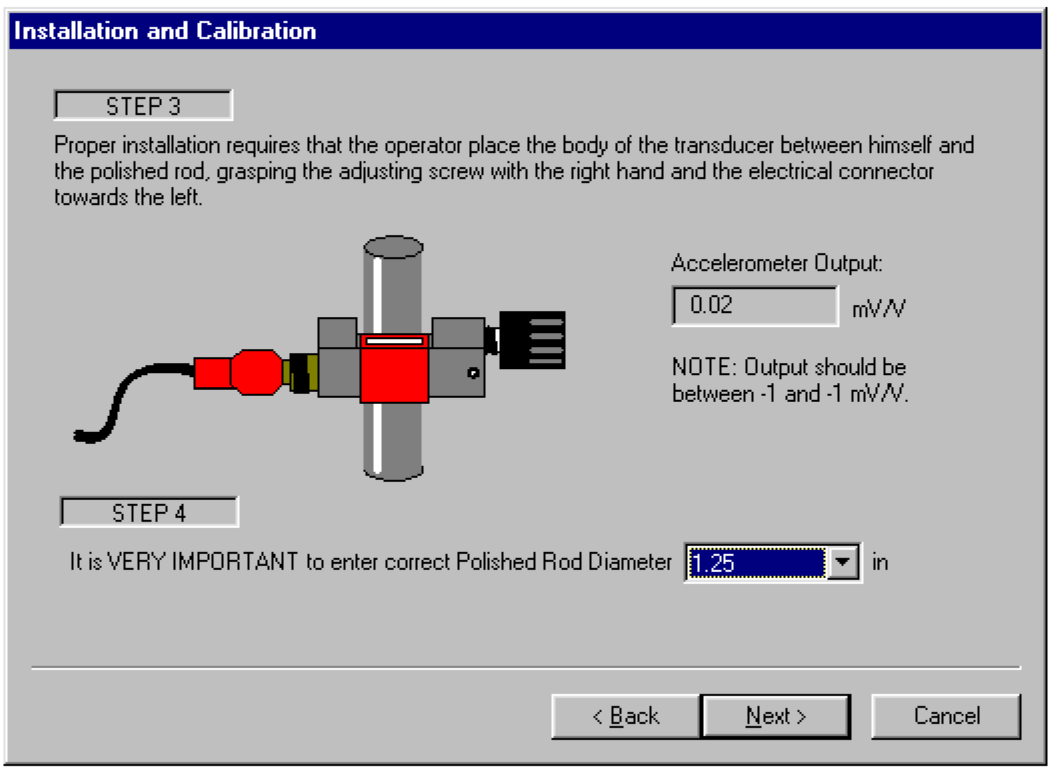
Insure that the point on the polished rod where the transducer is to be clamped is

clean and free of rust and corrosion pits

It is recommended that a small wire brush be used to clean the polished rod if needed.

The following instructions are displayed:

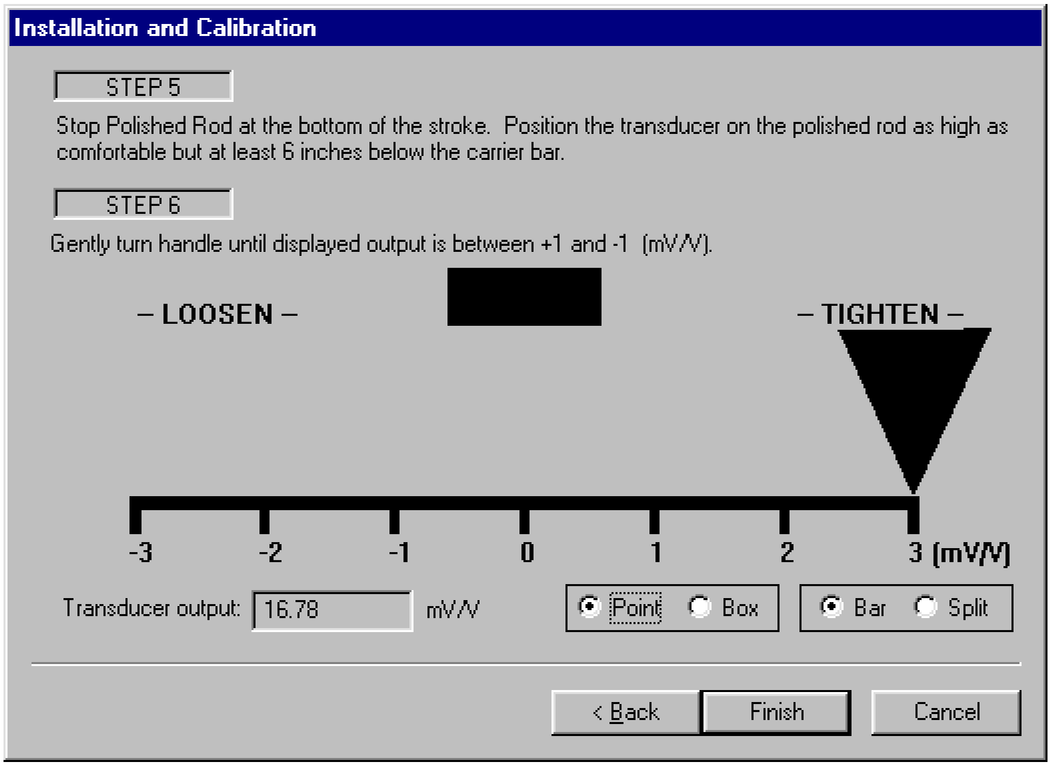
IMPORTANT NOTE: always verify that the polished rod diameter is correctly entered in the form.



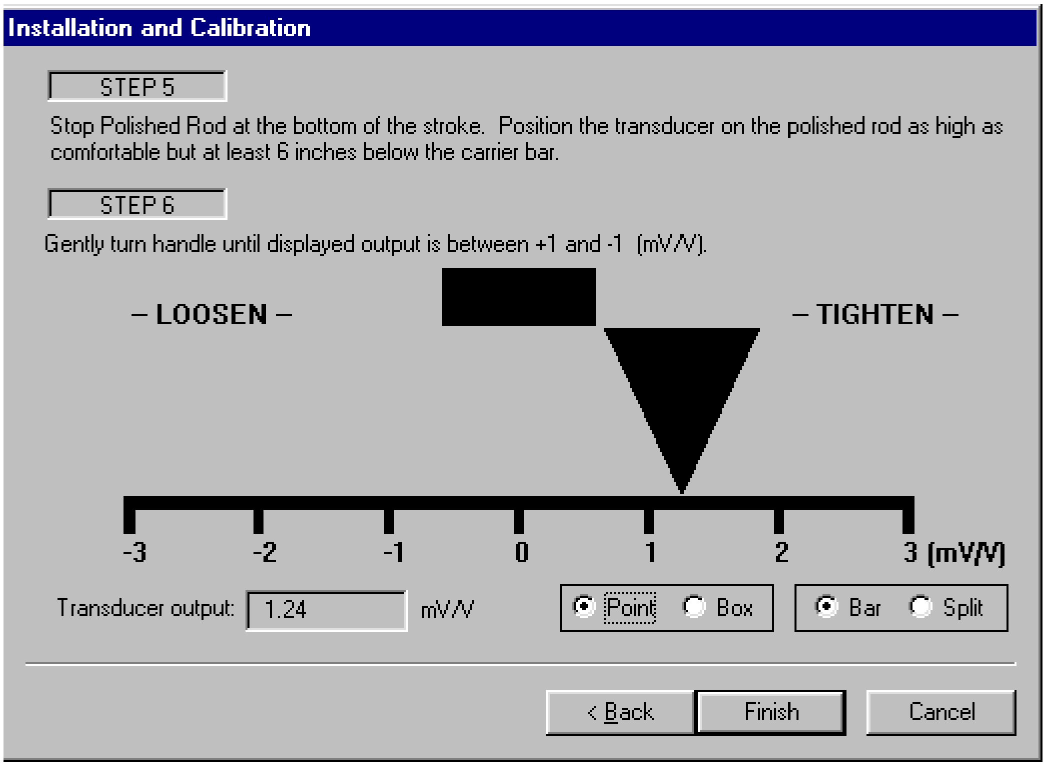
The transducer is designed to produce an output between 10 and 20 mV/V when it is not installed on the polished rod. The clamping action will cause this output **to decrease**. The proper clamping force is such so as to generate an output close to zero. The scale that is displayed on the screen gives a visual indication of the transducer output. Initially the triangular indicator will be at the extreme right, as shown in the following figure.

The program then checks the signal from the accelerometer which is housed within the PRT. This signal is used by the program to calculate the velocity and the position of the polished rod. Normal output with the polished rod transducer facing up is near 0 mV/V output. A value outside the normal limits generally indicates that the transducer has been installed **upside down**.

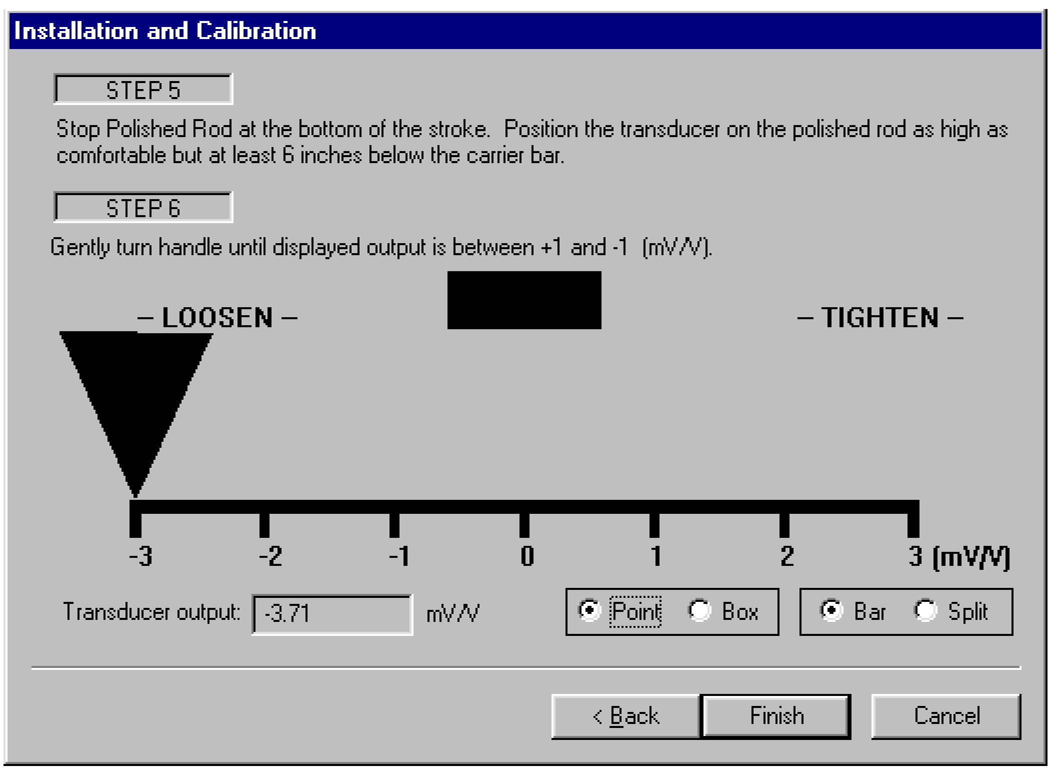
(Proper installation requires that the operator place the PRT between himself and the polished rod, grasping the adjusting screw with the right hand and the electrical connector towards the left). If the PRT is upside down the software calculates the position so that the bottom and top of the stroke are switched. The PRT should be installed right side up and the installation procedure should be repeated from step #1.



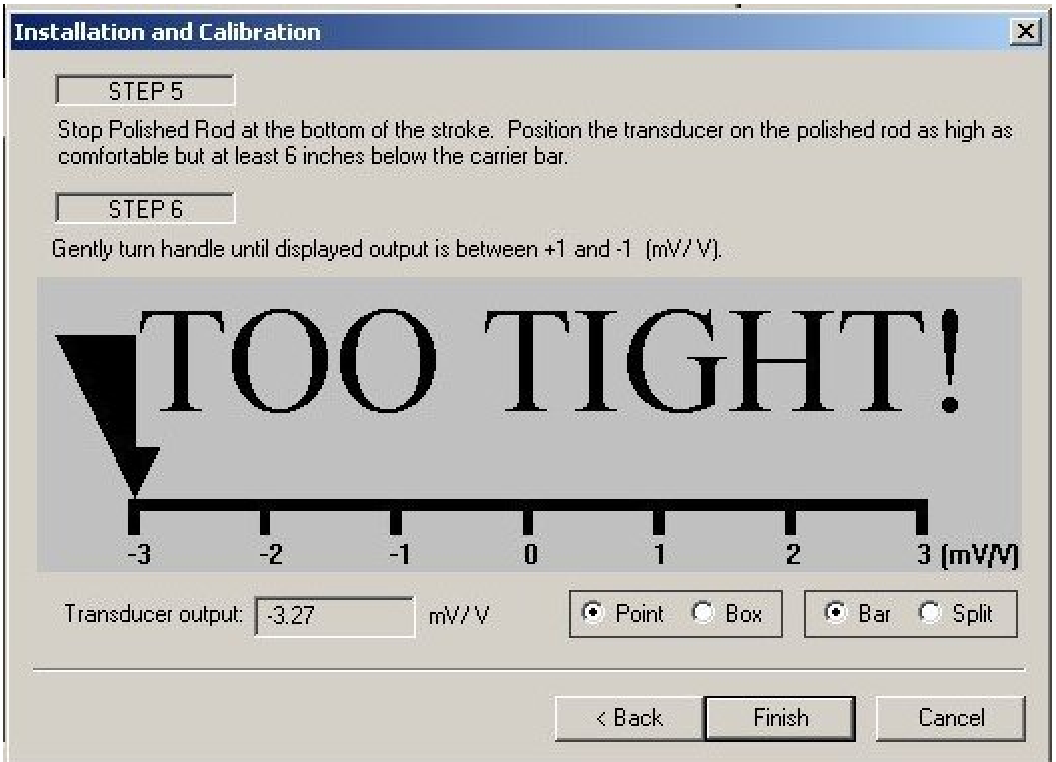
This corresponds to the region where the user is prompted to TIGHTEN the clamp so as to move the indicator towards the zero mark.



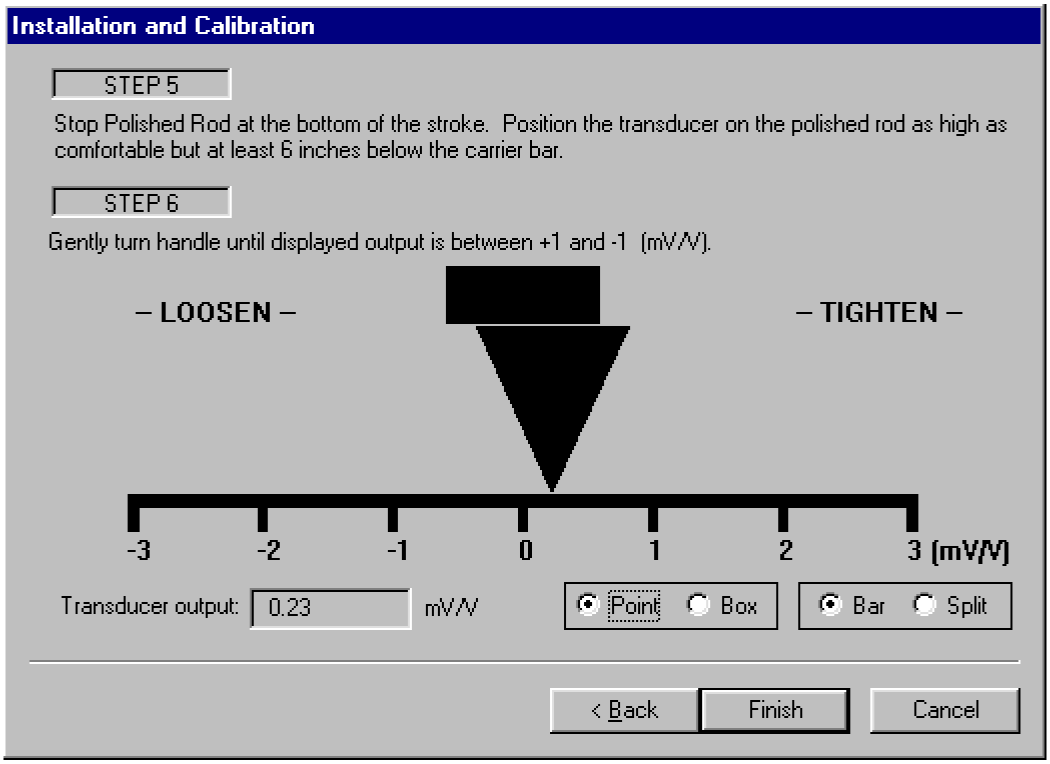
The indicator at this point is near zero but not close enough, additional tightening will generally cause the indicator to go beyond zero, into the LOOSEN region, as follows:



Excessive tightening will cause permanent damage to the transducer. Notice that the transducer output now exceeds the –3 mV/V limit on the left. Continuing past this point will result in a warning being displayed on the screen.

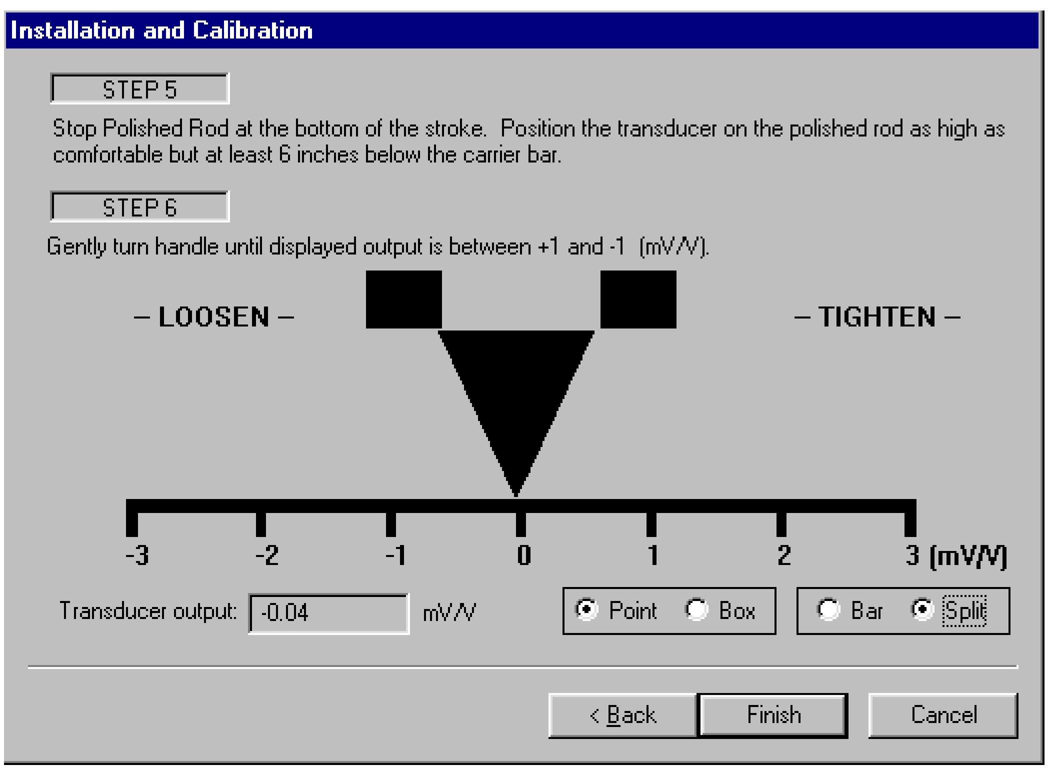

Installation and Calibration
STEP 5
Stop Polished Rod at the bottom of the stroke. Position the transducer on the polished rod as high as comfortable but at least 6 inches below the carrier bar.
STEP 6
Gently turn handle until displayed output is between +1 and -1 (mV/ V).
TOO TIGHT!
-3
-2
-1
0
1
2
3 (mV/V)
Transducer output:
-3.27
mV/ V
Point
Box
Bar
Split
< Back
Finish
Cancel

Proper installation will result in a nearly centered indicator, as shown in the following figure:



With a little practice the operator should be able to install the PRT and obtain the zero reading rapidly.

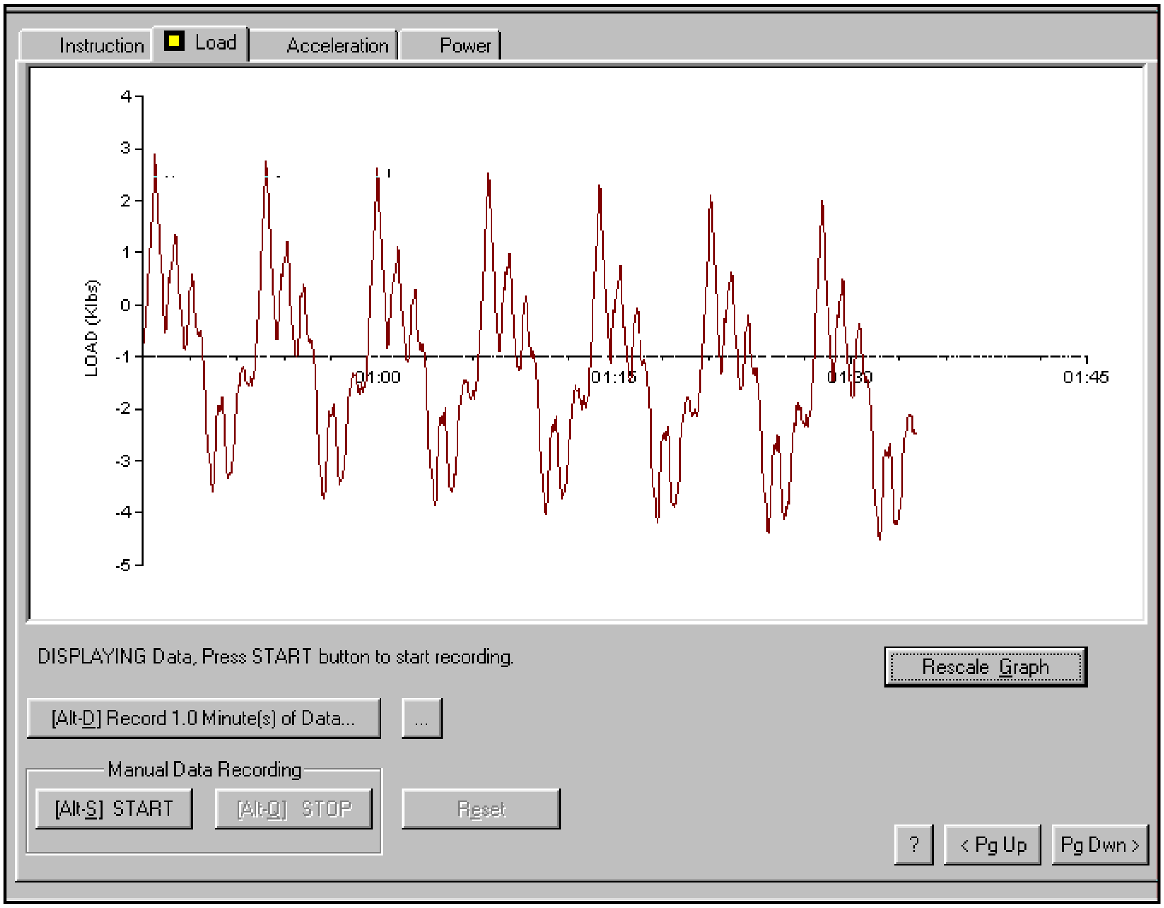
The visibility of the indicator under certain lighting conditions may be improved by selecting some of the other display options from the menu at the lower right of the figure:



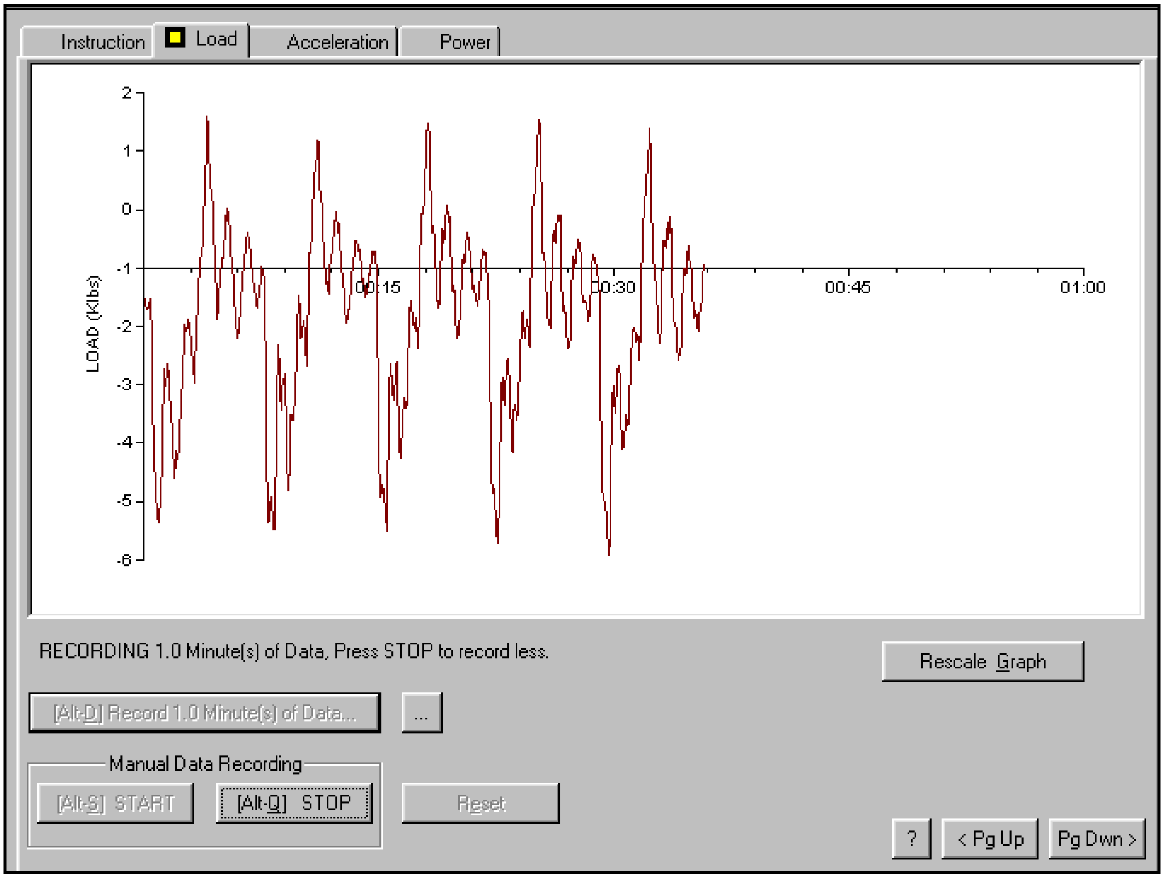
Selecting Finish will display the following figure after the unit is started and the user is ready to record dynamometer data.

9.4.4.1 - Automatic Processing

The program automatically scales and calibrates the load data. The pumping unit should be started **before** selecting **Start Test**, and then the following screen is displayed.

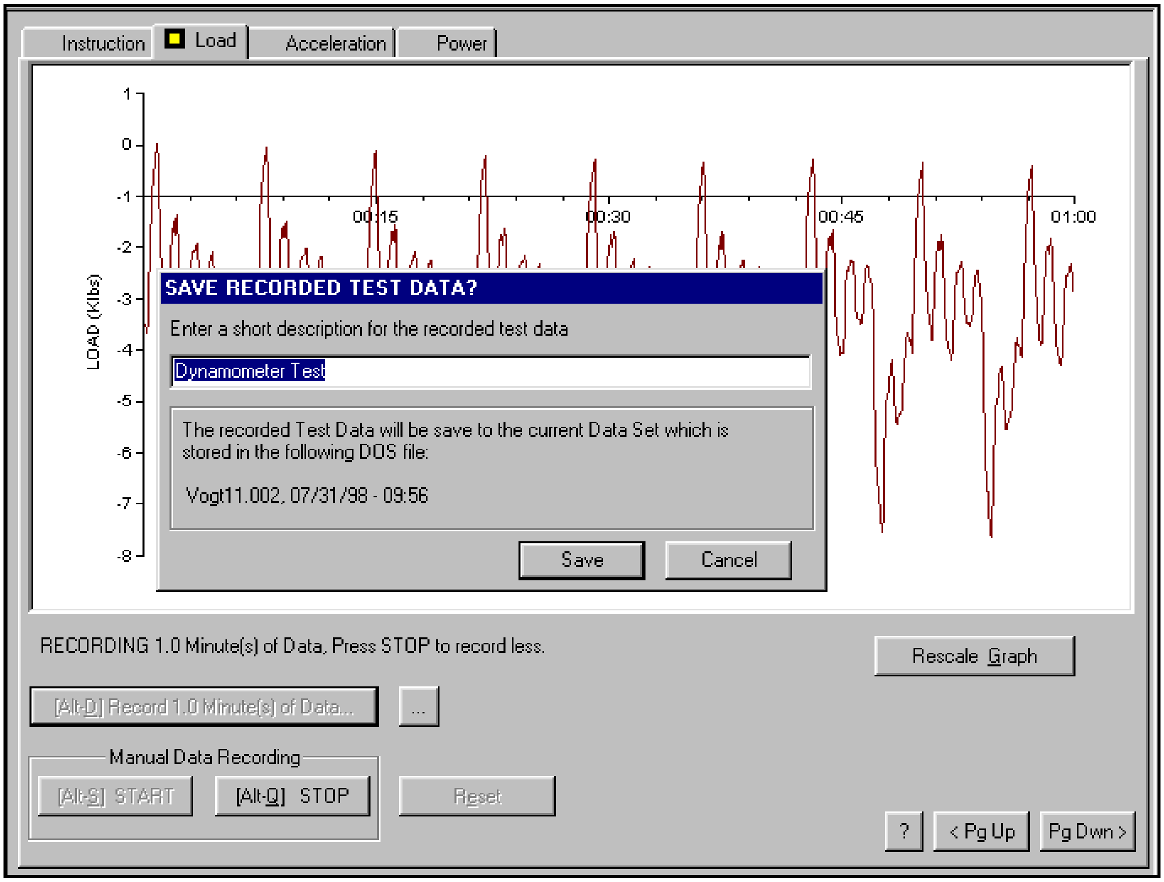


Data is only being displayed. The user has the option of rejecting these data if the transducer has not stabilized and the drift is excessive. The tick marks on the left of the load scale correspond to 1000 LB. intervals and can easily be used to check the level of drift. The user is given the opportunity to wait until the load has stabilized before recording the data either for one minute (**Alt-D**) or an arbitrary length of time (**Alt-S** and **Alt-Q**)

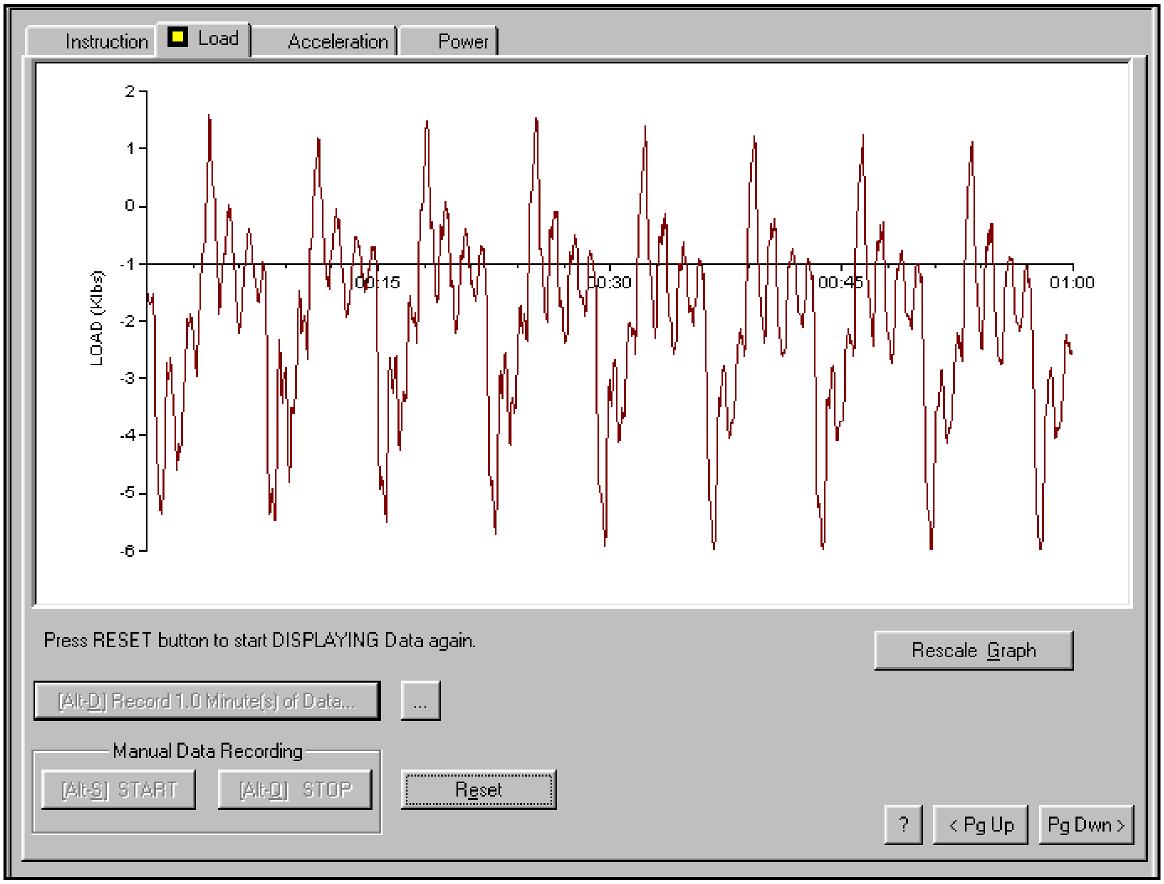


It should be noted that on this figure the vertical axis corresponds to the change in load from the reference load (weight of rods in fluid) determined when the transducer was installed on the polished rod. The absolute value of the load will be computed by the program when the Analysis Tab is selected

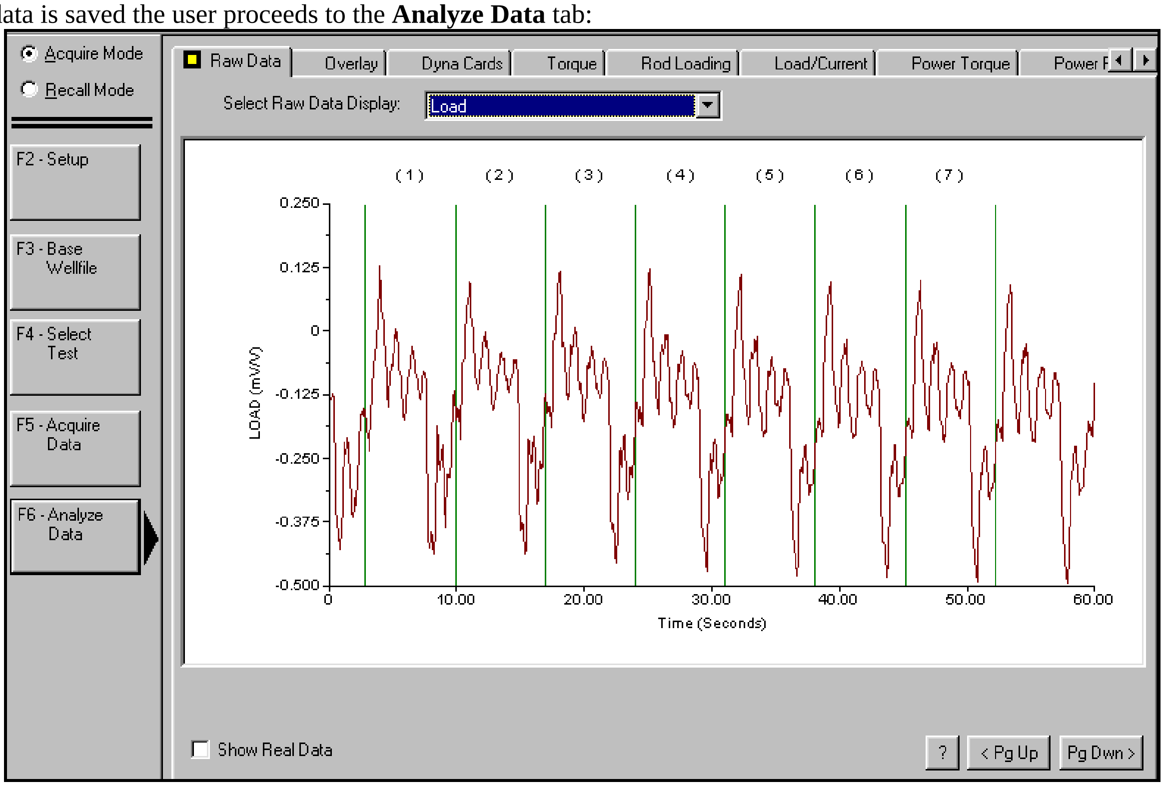
When acquisition has finished the data set is displayed so that the user can decide whether it is usable for analysis or a new set needs to be acquired by selecting the **Reset** option. The following dialog is displayed. It allows to enter a description of the test (if desired) and to save the data set



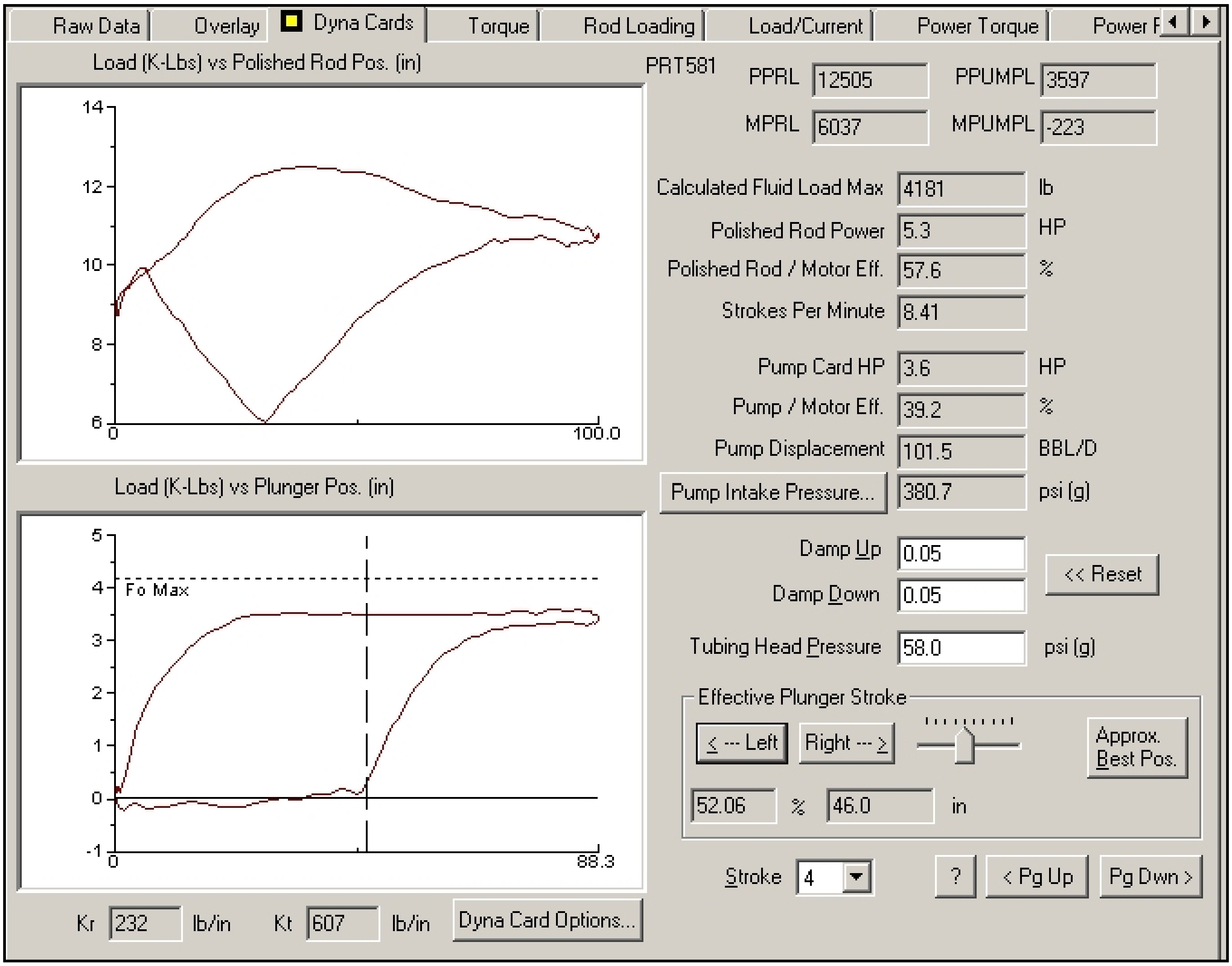
If the **Cancel** option is selected the data is displayed. The user may then return to the acquisition screen and acquire more data.



After the data is saved the user proceeds to the **Analyze Data** tab:



When the **Analyze Data** is selected the program first calculates the position of the polished rod as a function of time (a 10% variation between the calculated and well file stroke length prompts the operator to selects either the well file or the calculated value). The surface data of load change (generally including positive and negative values) and position vs. time is then combined with the rod data to calculate the down-hole pump card. This calculated card will be offset from the actual load by a large quantity (approximately corresponding to the weight of the rods in fluid). Assuming that the resultant axial load on the pump plunger is zero on the down stroke (when the traveling valve is open), the calculated load values are offset to obtain the zero value on the bottom of the downhole card. Neglecting the effect of unaccounted friction, the same amount of offset is applied to the load values of the surface dynamometer card thus yielding the absolute load variation at the polished rod.



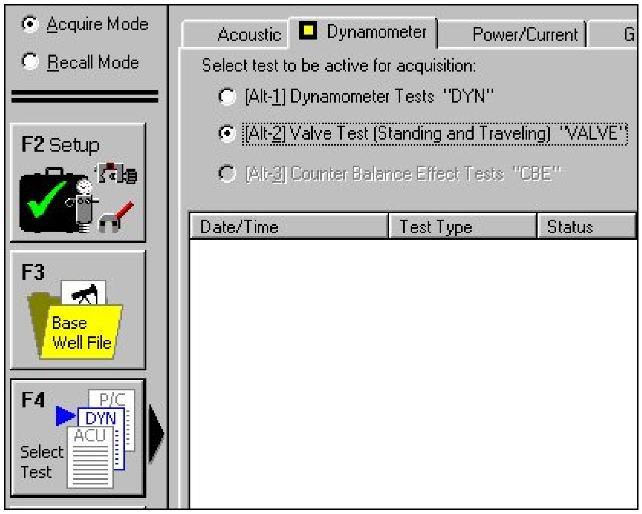
The user should keep in mind the assumption of zero unaccounted friction made in this automatic calibration procedure. Experience has shown that in the majority of the cases observed in the field where the PRT dynamometer loads, calibrated automatically, were compared to those measured with the horseshoe load cell, the maximum deviation was of the order of 7% and in many tests was less than 1% as described in the paper by McCoy[11].

This accuracy is more than adequate to determine whether the pump is operating properly or not. The ease of use and the safety features of the PRT clearly outweigh this small inaccuracy when attempting pump performance analysis.

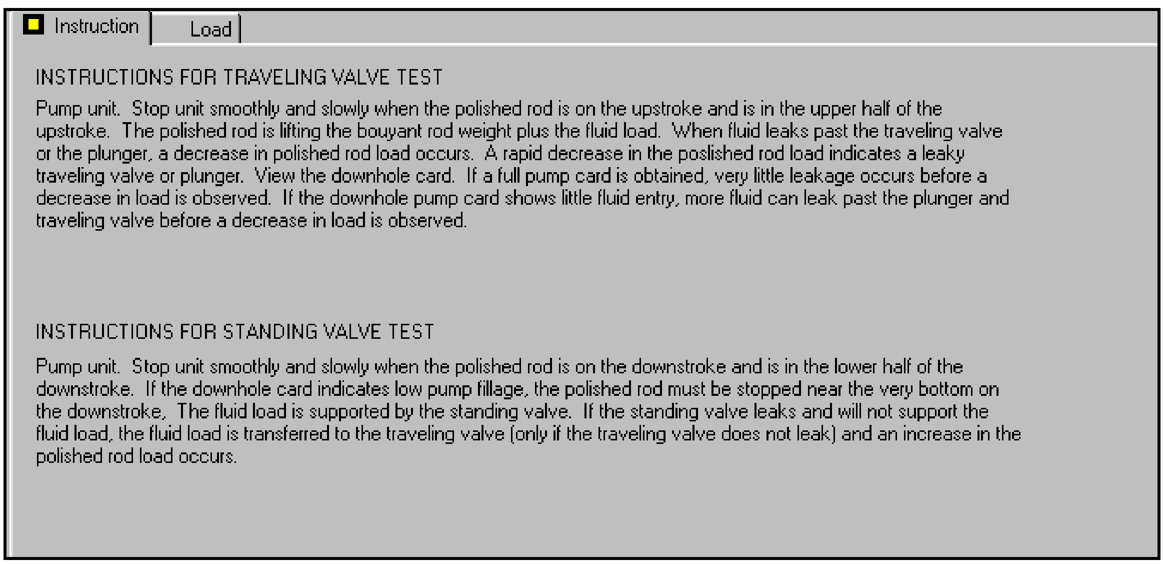
[11] McCoy, J.N., Jennings, J.W. and A. Podio: "A Polished Rod Transducer for Quick and Easy Dynagraphs ", paper presented at the Southwestern Petroleum Short Course, Texas Tech University, 1992.

9.5 - TRAVELING AND STANDING VALVE TEST

Following the dynamometer analysis, the operator has the option to perform a traveling valve test.

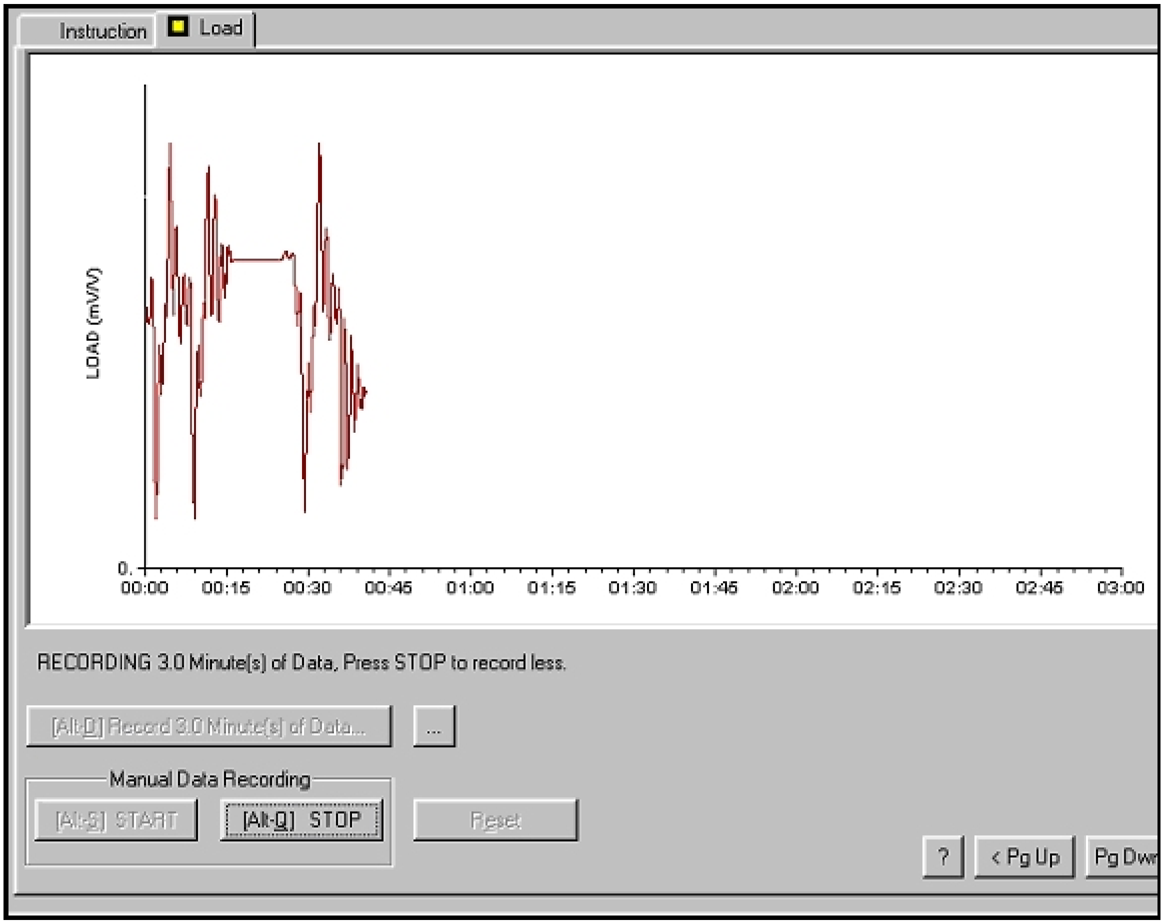


When the **Acquire Data** option is selected, the following instructions are displayed on the screen describing the procedure for the acquisition of the traveling and standing valve data. Data for both tests is acquired in a single screen. Be sure that the test procedure is fully understood before continuing.



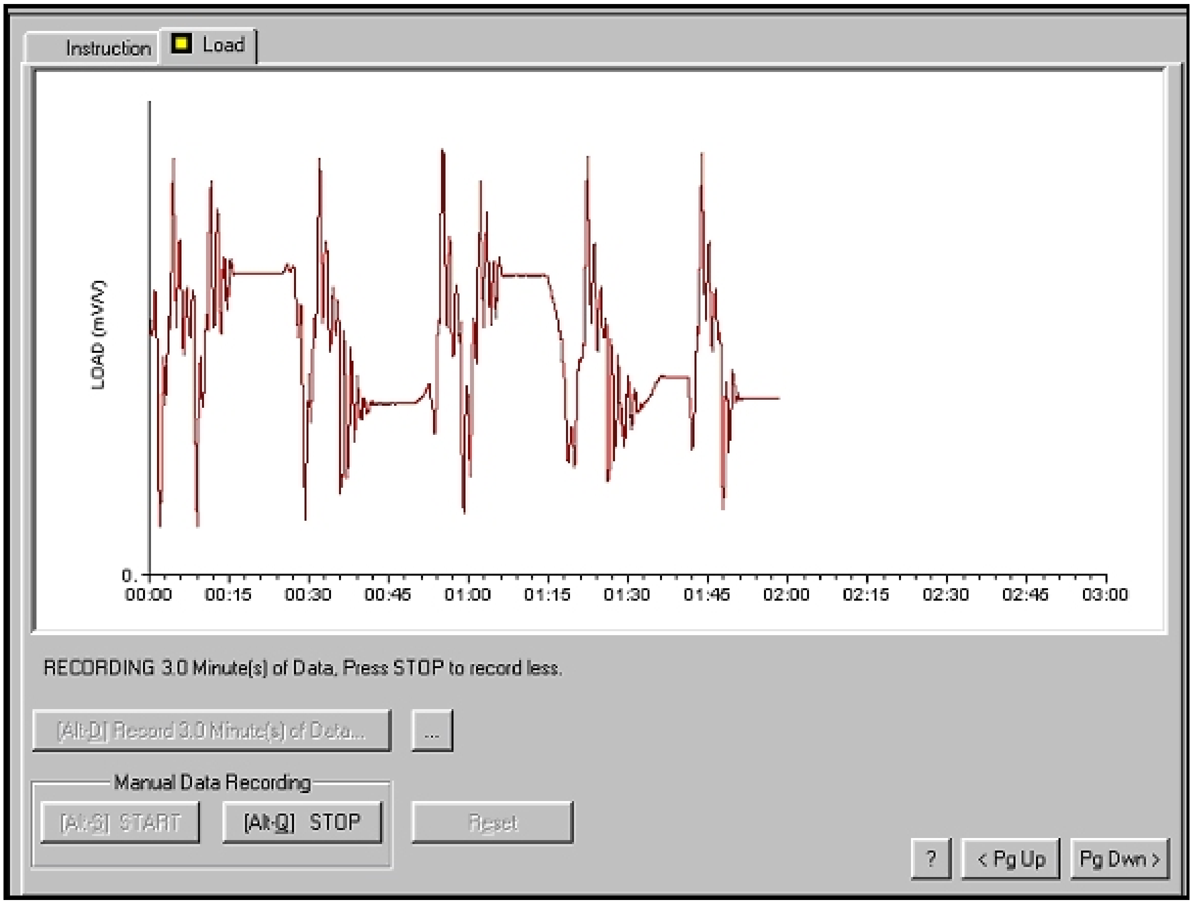
Select the **Load** tab to continue. A display of load as a function of time will be presented to the operator; data is not being recorded at this point.

Data acquisition can be started by selecting **Record Data for 3 minutes**, which starts data acquisition. The operator has 3 minutes (180 seconds) to perform two or more traveling valve and two or more standing valve tests. Acquisition of the data can be interrupted at any time by pressing Stop. The typical display while performing a TV test is shown in the following figure:



An alternative procedure is to use the **Start - Stop** buttons to record the test for an undetermined length of time.

The following figure shows the screen after performing two TV and two SV tests:



In this example each test was repeated once. Each test yields a slightly different value of the valve loads. This variation may be caused by a number of factors such as rod-tubing friction, pump friction, variation in stopping point, etc. In order to establish accurate values of the valve loads, it is recommended that the test be repeated several times.

At the end of this period, the operator is given the choice of repeating the test or continuing data acquisition and analysis. A display of the valve test is shown. The calculated buoyant rod weight plus liquid load is displayed as the horizontal dashed line. The calculated buoyant rod weight is also displayed as the horizontal dotted line.

These two calculated weights are displayed on the screen in conjunction with the measured loads to aid the operator in determining that the measured values are significant.

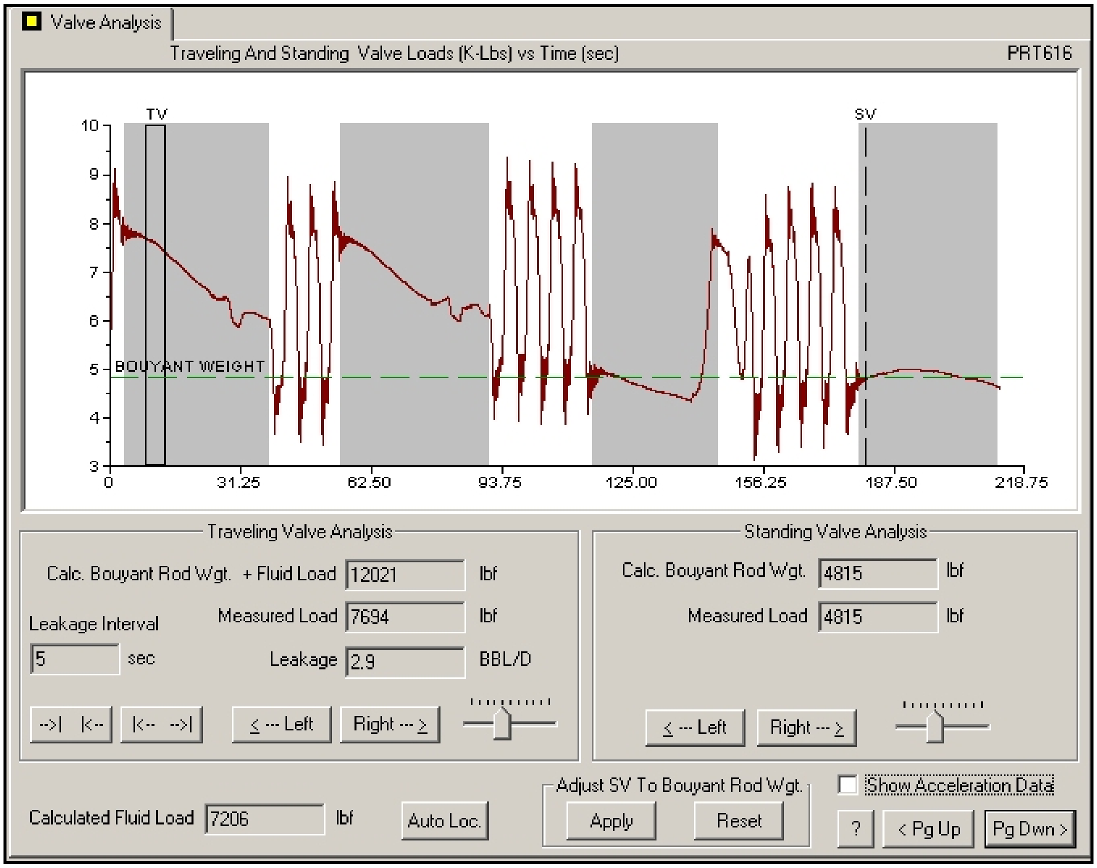
Normally the software will position the solid vertical indicator lines on one of the traveling valve loads and the dashed line on one of the Standing Valve loads. The indicators can be moved using the arrow keys to a position which best represents the valve test load. When several tests have been taken, the largest value is the most representative of the correct traveling valve load.

9.5.1 - Pump Leakage

The right line of the double vertical indicator (labeled TV) indicates the measured load five seconds later than the load indicated by the left vertical line. A decrease in load is an indication that leakage is taking place. The rate of load change (lbs/sec) is converted to an equivalent pump leakage rate and is displayed at the bottom left of the screen in terms of Bbls of liquid per day.

If the leakage is significant it may be necessary to reduce the spacing of the lines from the standard 5 seconds to a smaller value, using the arrow buttons on the screen, so as to calculate a more representative value of the leakage rate.

A difference between the measured and calculated buoyant wt +fluid load is an indication of high fluid level due to the leakage.



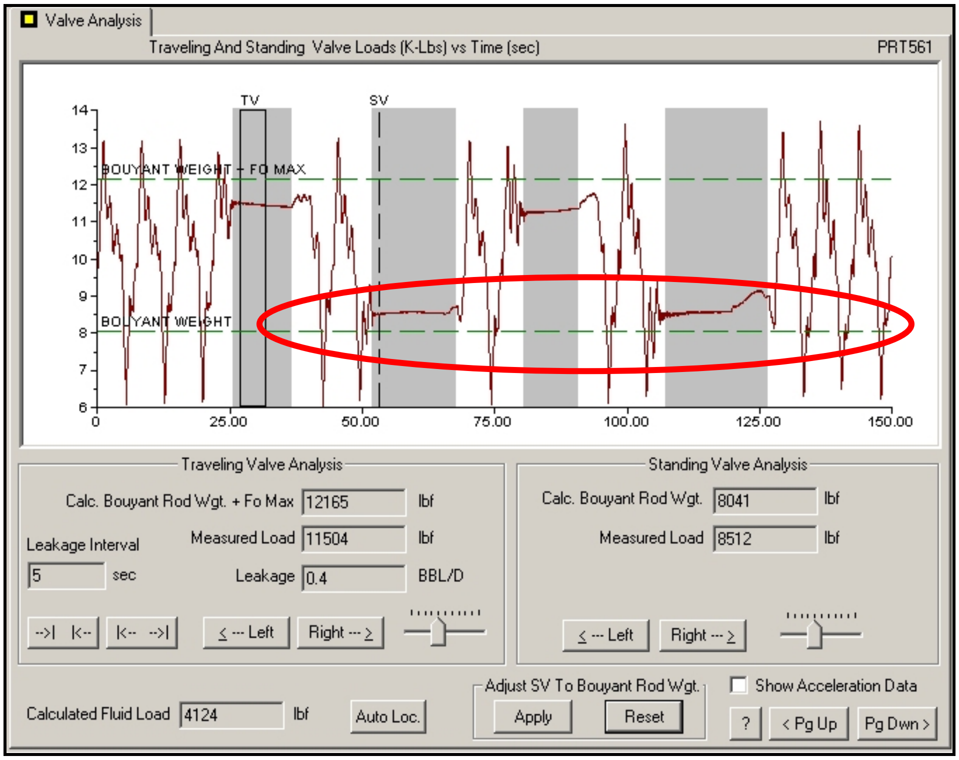
9.5.2 - Standing Valve Test

The vertical dashed indicator line is placed on the standing valve test data. The indicator can be moved by use of the arrow buttons. The measured values are displayed at the bottom right of the figure. Each test yields a slightly different value of standing valve load which are very close to the calculated buoyant weight of the rods. This is an indication that the test results are probably accurate and agree with the rod taper description in the well file.

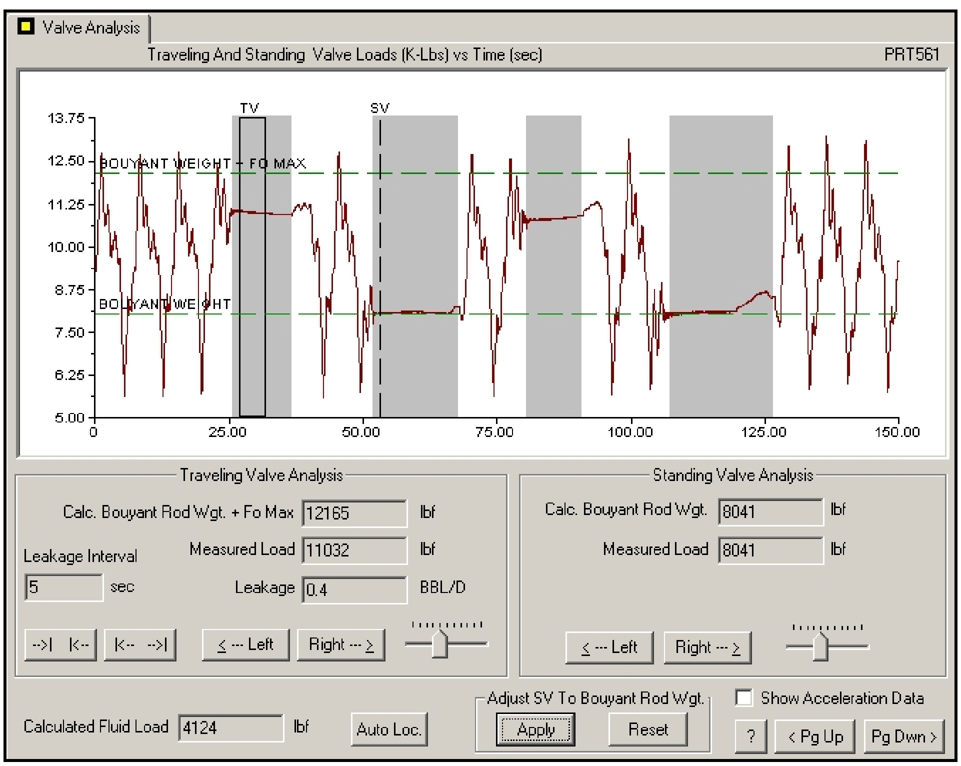
Using the Left/Right arrow keys the indicator should be placed on the section of the trace that more closely represents the load for a properly taken standing valve test. When several tests are taken, this should correspond to the lowest load value (for a stopped unit). The **Auto Locate** button positions the markers automatically to the program's criteria for selecting the TV and SV sections.

9.5.2.1 - Polished Rod Transducer SV Check

Valve check data acquisition with the PRT is often affected by the transducer drift to the point that the SV weight is displayed significantly above or below the computed buoyant rod weight as seen in the following figure:

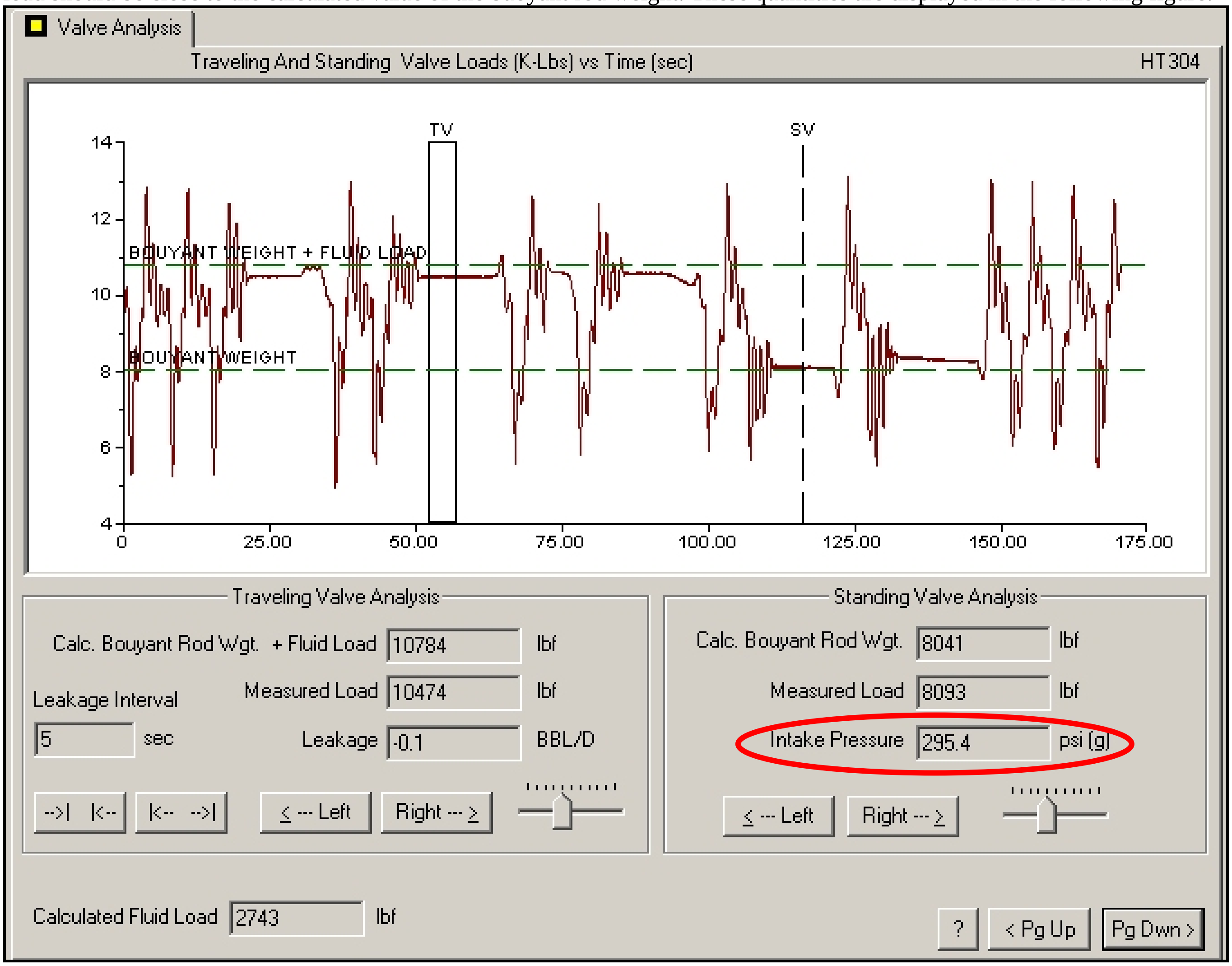


The buttons in the box labeled **Adjust SV to Buoyant Rod Wgt** is used to remove the drift effect by adjusting the measured load to the calculated rod weight when the **Apply** button is clicked as seen below. The **Reset** button removes the adjustment.

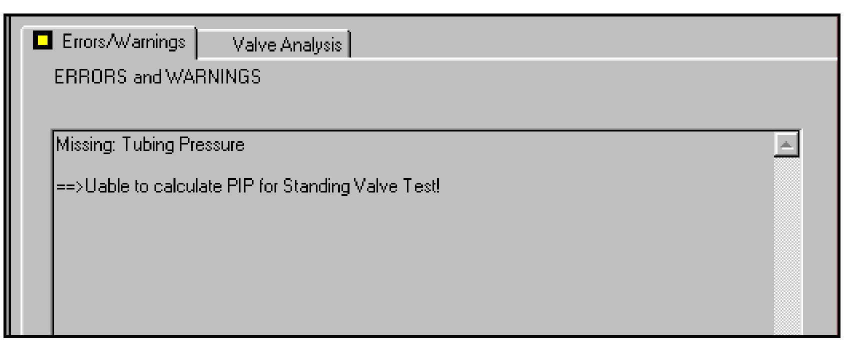


9.5.2.2 - Pump Intake Pressure from SV Check

When the data is acquired **with a horseshoe transducer**, the valve check also calculates an estimate of **Pump Intake Pressure (PIP)** assuming that the unaccounted friction and pump leakage are negligible. On the bottom right side of the screen is displayed the calculated pump intake pressure and the measured load corresponding to the position of the indicator. The measured value of load should be close to the calculated value of the buoyant rod weight. These quantities are displayed in the following figure:

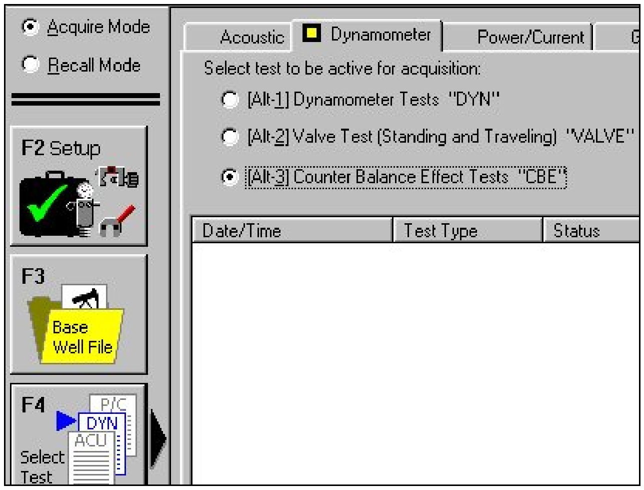


If the tubing pressure has not been entered in the well file, the following message is displayed:

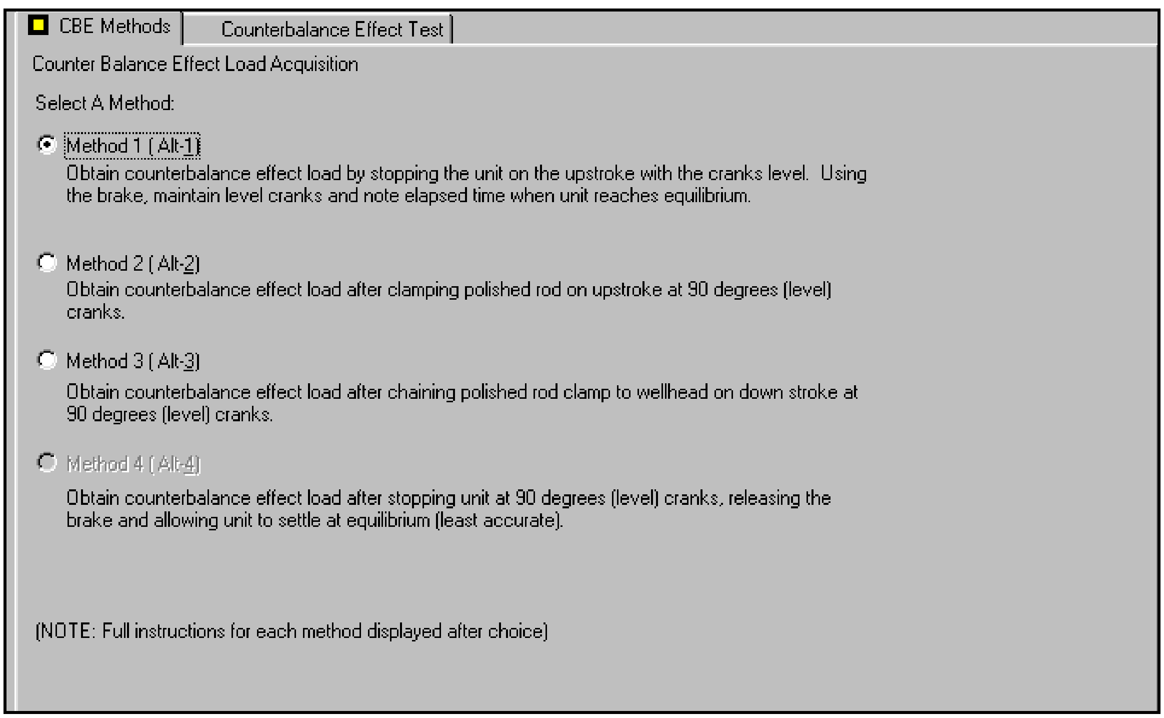


9.6 - COUNTERBALANCE EFFECT TEST

The net load effect of the counterbalance weights at the polished rod is required to correctly calculate the torque on the gear reducer. This value is determined by running the following test. The result is automatically saved into the well data file.



After choosing the **Select Test** option (**F4**) the operator is presented with four methods for performing the counterbalance test. The following screen is displayed.



Method 1 allows the operator to obtain the counterbalance effect by stopping the unit on the upstroke with the cranks level. If the counterbalance effect load is between the buoyant rod weight plus fluid load and the buoyant rod weight, the pumping unit will eventually balance momentarily as the counterbalance and polished rod loads equalize due to leakage. Press **Alt-1** for instruction for performing this counterbalance effect test.

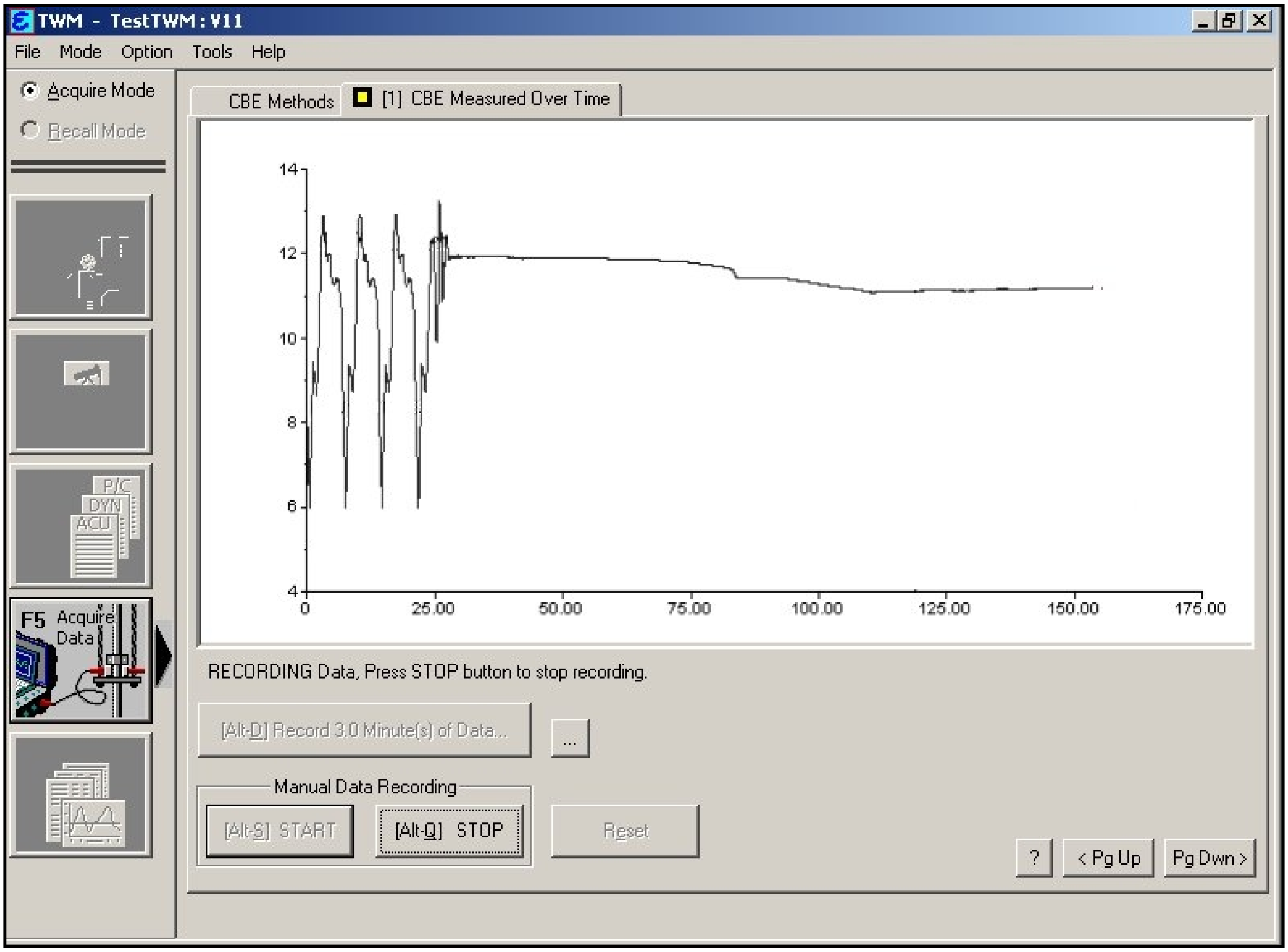
Method 2 option allows the operator to place a polished rod clamp on the polished rod when the polished rod load exceeds the counterbalance effect. Press **Alt-2** to proceed to an instruction screen. The operator is instructed to stop the polished rod on the upstroke when the cranks are level. The polished rod clamp prevents downward movement of the polished rod since the polished rod weight exceeds the counterbalance effect. Release the brake. The current load is displayed on the screen. Press F6 to input the counterbalance effect load into the well file.

Method 3 option allows the operator to acquire counterbalance load when counterbalance load exceeds the polished rod weight. The pumping unit is stopped on the down stroke with the cranks level. A polished rod clamp is placed on the polished rod. A chain is placed around the polished rod clamp and the wellhead to prevent upward movement of the polished rod. The brake is released. The transducer now has the load of the counterbalance effect. Press **Alt-3** to obtain an instruction screen. Follow the instructions previously discussed. After placing the counterbalance effect load on the transducer, press F6 to input the current load into the well file.

Method 4 option allows the operator to stop the pumping unit with the cranks level. After a brief period of time, release the brake and slowly allow the pumping unit to settle to equilibrium. The distance from the bottom of the stroke to the position of equilibrium is measured. The distance from the bottom of the stroke to the point of equilibrium is utilized with the measured polished rod load to calculate the counterbalance effect. This is not as accurate as the 1, 2 or 4 options. Press **Alt-4** to proceed with data acquisition. The operator is instructed to stop the unit on the upstroke with the cranks level. Release the brake slowly. Obtain static load by pressing F6. Then the operator is asked for the distance from the bottom of the stroke. The position and static load are utilized along with pumping unit geometry to calculate the counterbalance effect.

The following instructions and screens correspond to the Method 1 Option

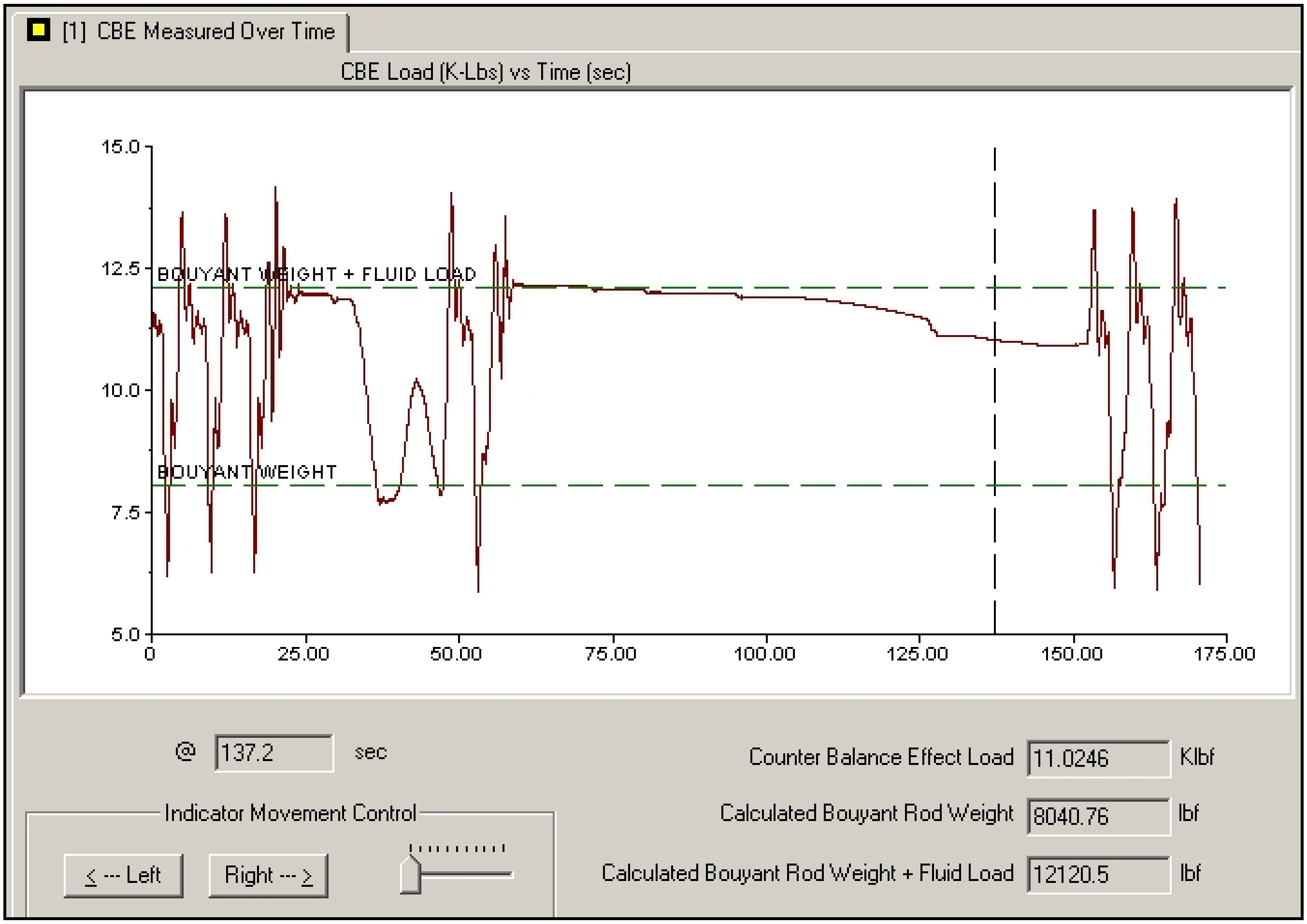
After pressing **Alt-1**, the operator is presented with a display of the load data in order to check that the unit is functioning properly. The program is not recording data at this point.



Press **Alt S** to start data acquisition and note the precise time when the key was pressed. This test acquires up to three minutes of data if desired. It is recommended that **Alt S** be pressed when 0 seconds are displayed on a stop-watch. Data acquisition can be stopped at any time by pressing **Alt-Q**.

The object of this test is to determine the counterbalance effect load (the net load effect at the polished rod caused by the counterbalance moment acting on the gearbox from the cranks and weights). Stop the pumping unit on the upstroke and set the brake when the cranks are level. The polished rod load will approximate the buoyant rod load plus the fluid load the pump is applying to the rod string. To be able to perform the CBE test, the CBE load must less than the buoyant rod weight plus fluid load and greater than the buoyant rod weight. As the fluid leaks from the tubing through pump plunger/barrel clearances into the pump, the polished rod load will decrease to the buoyant rod weight. As this drop in load occurs, the operator should release the pumping unit brake periodically to determine whether the polished rod load is greater or less than the counterbalance effect load. The crank arm should be horizontal when the counterbalance load is determined; so, minimum crank arm movement should occur on each brake release. The brake drum gives a better indication of movement than the crank arm. As the polished rod load drops, the operator can periodically and momentarily release the brake to determine when the counterbalance effect load is equal to the polished rod load (indicated by the cranks having a tendency to remain still with the break released). The operator should record the precise time when the brake can be completely released without any movement of the crank arm. Then lock the brake. The drop in load will continue to be shown on the screen. Unless the counterbalance effect load is greater than the traveling valve load or less than the standing valve load, the operator should be able to obtain the counterbalance effect load using this easy technique.

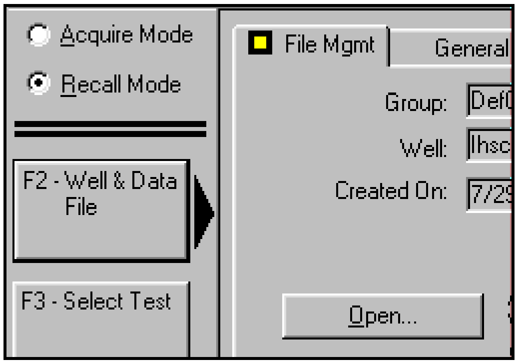
A vertical line indicator will be drawn on the display. The time from the start of the plot to the position of the line will be displayed at the bottom left of the graph. Use the arrow keys to position the indicator **to the exact time that was recorded** when the crank arm did not move with the brake released. The best practice is to enter the elapsed time value in the **Comments** field when saving the CBE data file. Hit **Enter** to select this point as the point corresponding to the counterbalance effect load.



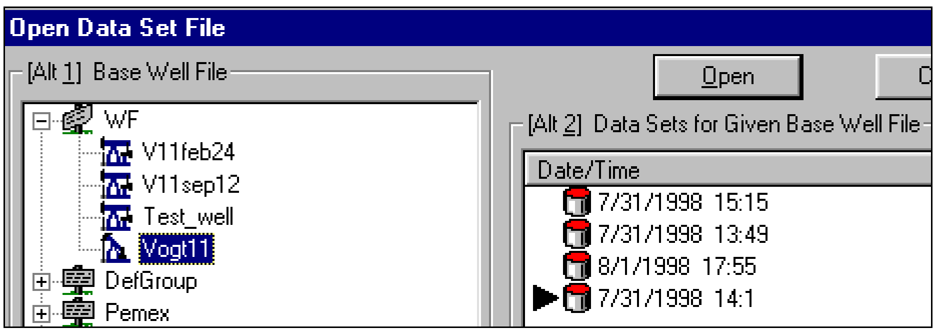
In the figure above the point of balance occurred at 137.2 seconds and the CBE load was recorded as 11.02 Klb.

9.7 - RECALLING DYNAMOMETER DATA

Select the **Recall Option** and select the well file to be recalled using the File Management Tab

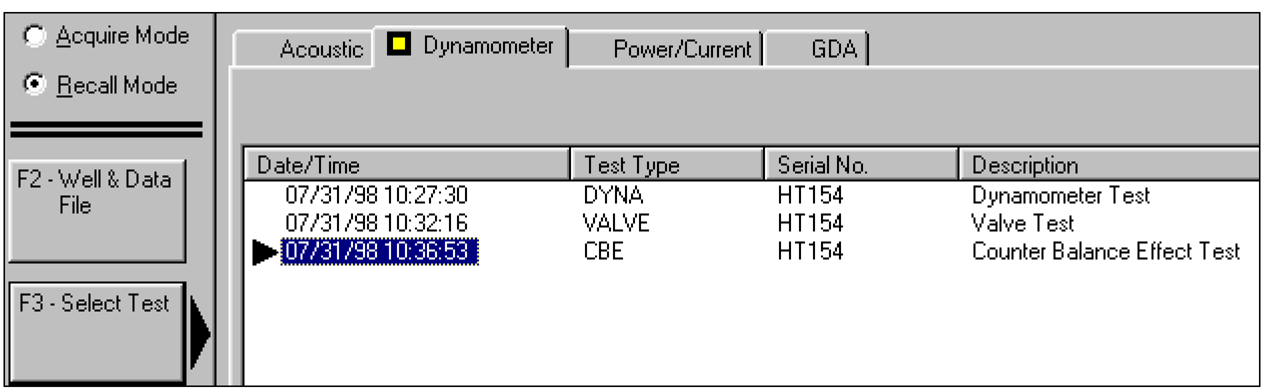


The **Open** command will present a listing of groups and wells. After selecting one of the wells the display to the right will show a list of all the data sets that have been recorded for that specific well. The test set of interest is selected and is opened:

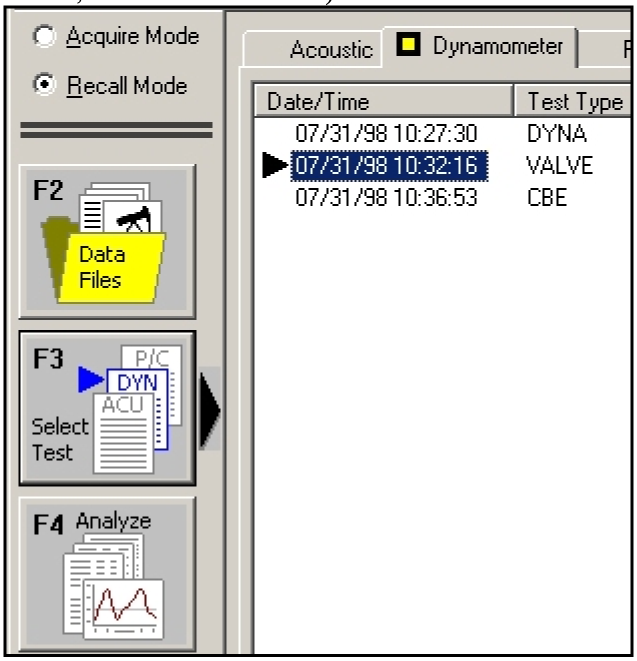


The well data file associated with this test set will be used in the calculations. It is recommended to verify that the well data is accurate.

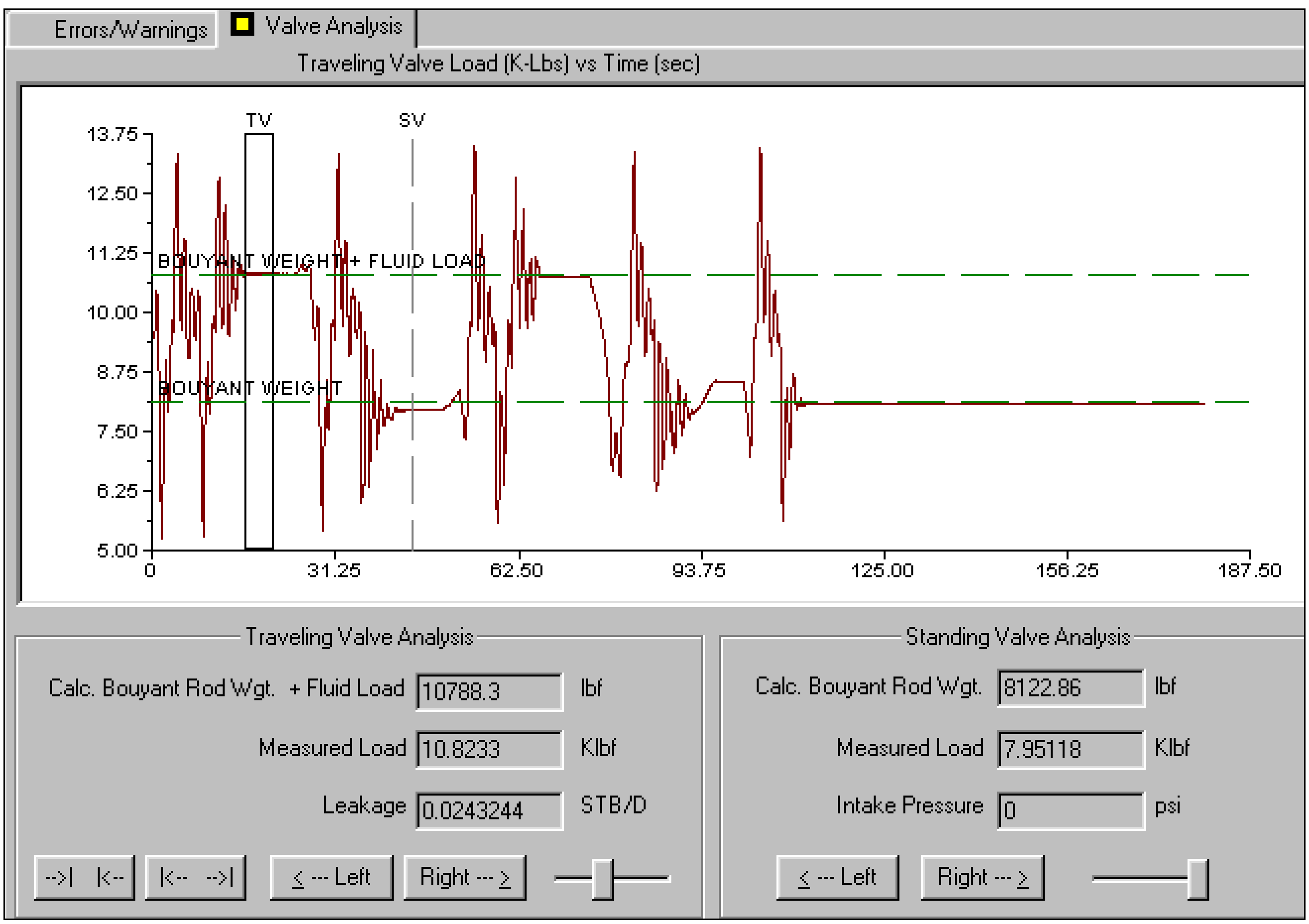
To recall the dynamometer data use the Select **Test (F3)** option and then select the **Dynamometer** Tab. This will result in the following display:



The specific test to be analyzed is then highlighted and the **Analyze Data** option will initiate the analysis that corrresponds to the specific test (Dynamometer, Valve Check, Counterbalance effect)

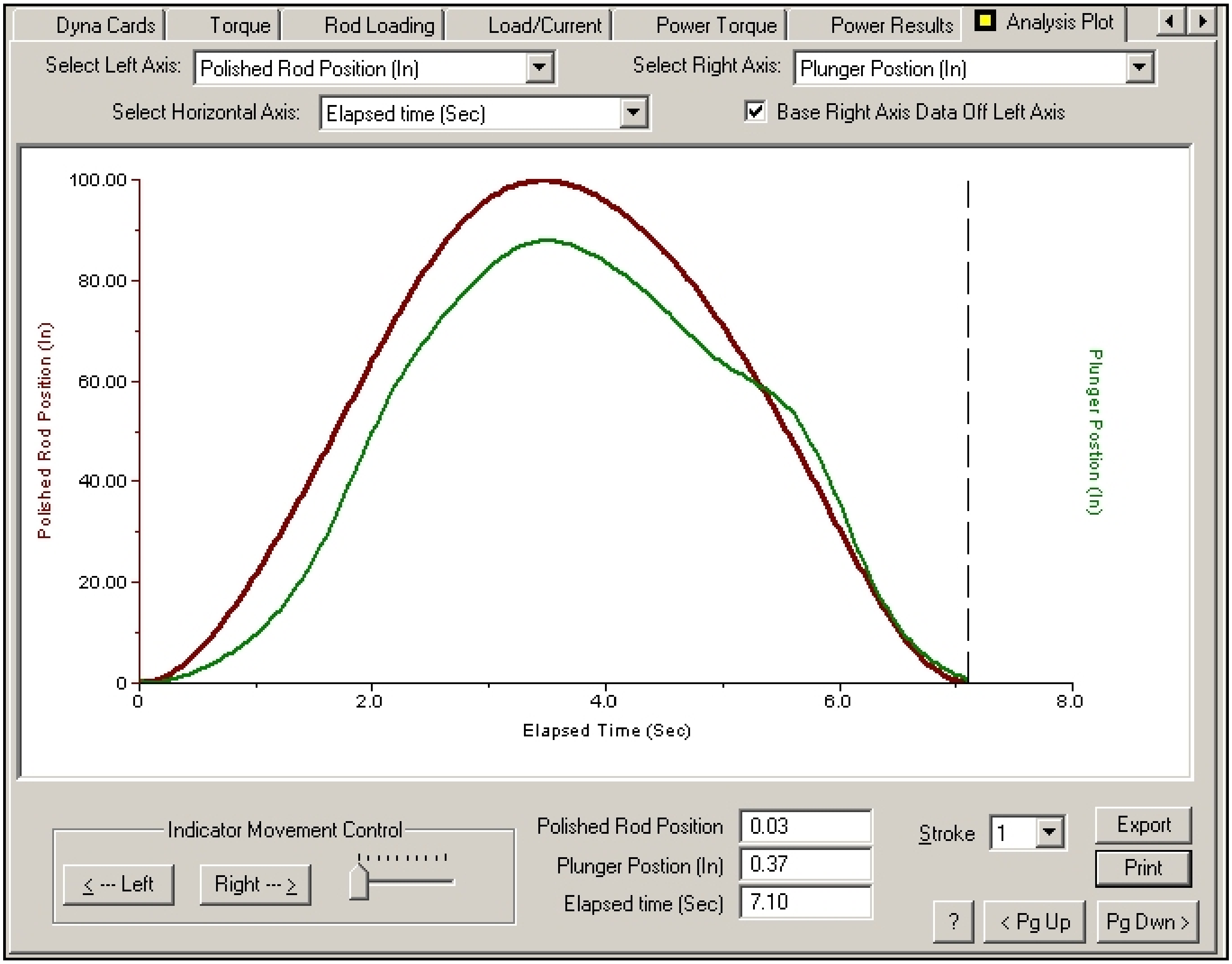


For example the following figure shows the Valve Check analysis:



9.8 - DYNAMOMETER ANALYSIS PLOTS

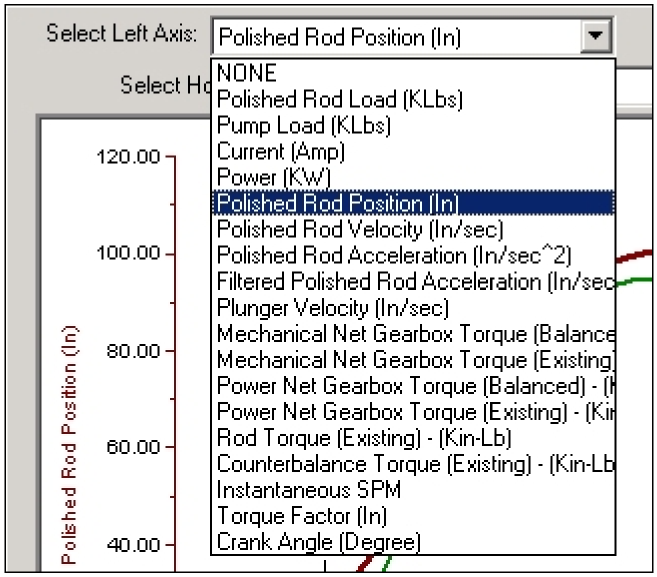
Occasionally it is necessary to study in more detail the pump performance to identify problems which may not be apparent from the usual analysis of the surface and pump dynamometer cards. The TWM program provides the user with the possibility to plot a large number of diagnostic graphs that may be helpful in further analysis. This is the purpose of the **Analysis Plots** Tab



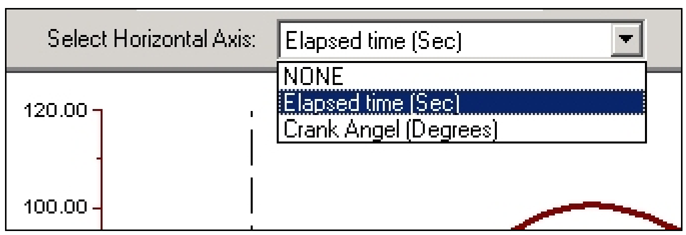
Two variables may be plotted as a function of a common variable on the horizontal axis.

The numeric values of the two variables are displayed in the boxes for the position corresponding to the vertical indicator which is moved by the user with the **Lef**t and **Right** buttons. Plots can be viewed for all the recorded strokes using the scrolling button.

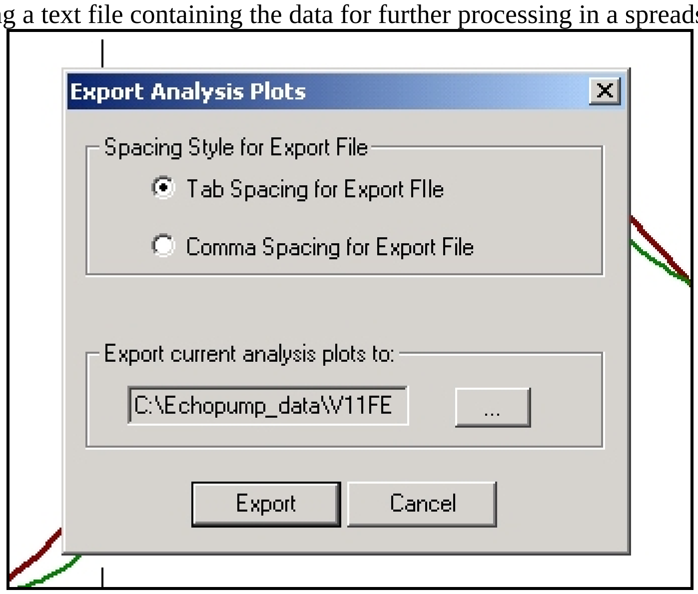
The variables to be plotted on the two vertical axes are selected from the pull down menus:



The variable for the common horizontal axis is selected from the pull down menu:



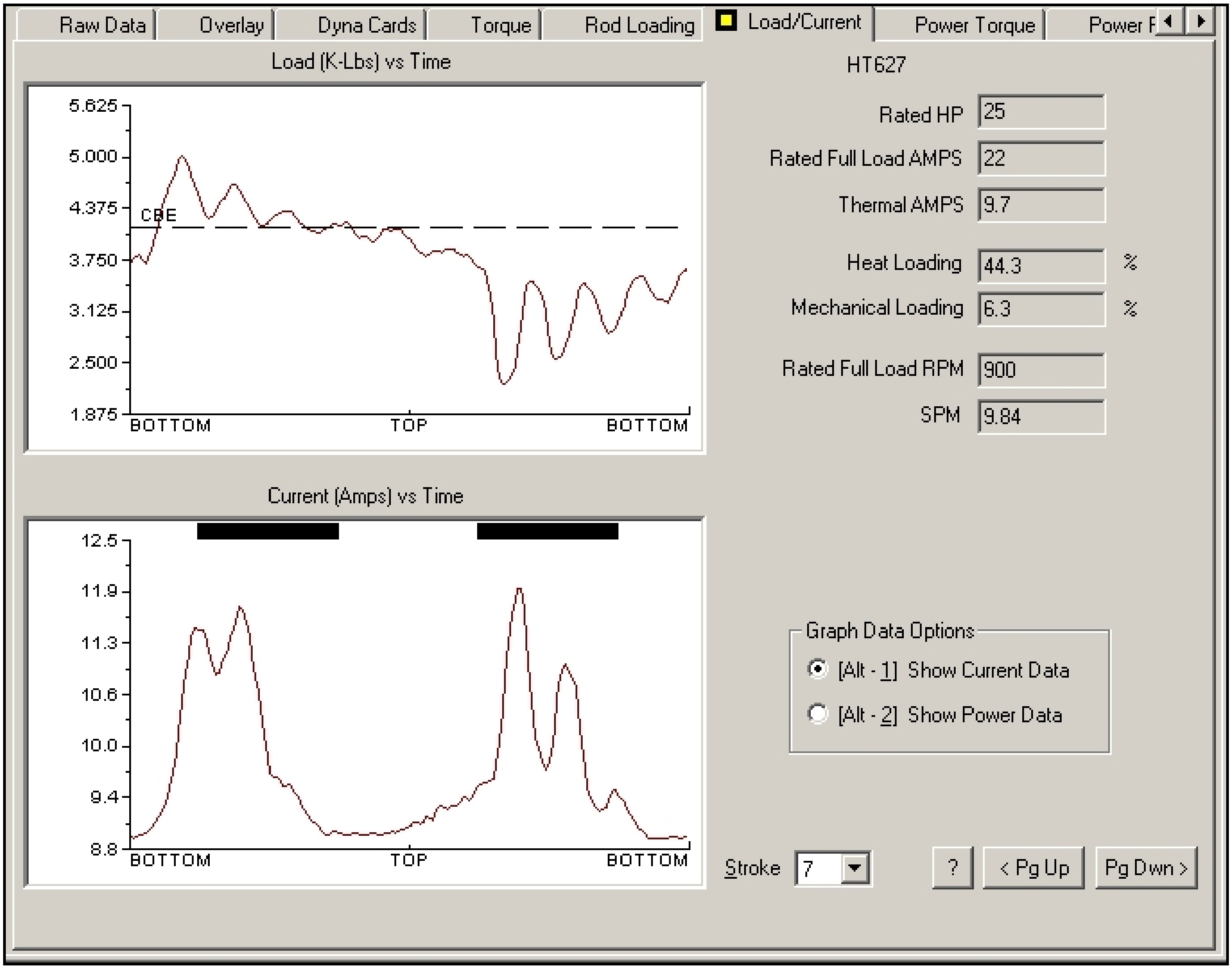
The **Export** Button allows saving a text file containing the data for further processing in a spreadsheet program.



The **Print** button sends the specific graph to the default printer.

10.0 - MEASUREMENT OF MOTOR CURRENT

Motor current can be measured simultaneously with the conventional dynamometer test by connecting the single amp-meter probe to any one of the wires providing power to the electric motor. The current data will be displayed in the **Load/Current** screen of the dynamometer analysis tab:



This shows the electrical and mechanical loading of the motor as well as the current flow during the upstroke and downstroke.

Generally it is more precise to measure the Power supplied to the motor, as described in the following chapter. Due to the mechanical nature of the pumping system and the use of counterbalancing to reduce the torque requirements, the great majority of installations experience torque reversals during the pumping cycle. This means that during portions of the pump stroke the prime mover drives the gearbox and that during other portions the gearbox drives the motor. In the first case the motor is **consuming** electrical power, in the second case it is **generating** electricity.

The very commonly observed "Gearbox Backlash" is the most apparent indication that this reversal in current flow is taking place in a pumping system. The "clanking sound" which may be noted in the gearbox at such times is due to the transfer of load from the front side to the back side of the gear teeth.[12] The conventional clamp-on current meter (transformer) is incapable of differentiating between current flowing from the line to the motor or from the motor to the power line. In order to determine the actual power utilization it is necessary to make additional measurements that can yield information regarding the

[12] J. Eickmeier: "How to Optimize Pumping Wells", Oil and Gas Journal, August 6, 1973.

instantaneous power factor and voltage. Such measurements have not been commonly made because of the complexity and cost of the additional equipment

!!!! C A U T I O N !!!!

Motor current measurements generally require the operator to open the electrical switch box. The operator is thus exposed to dangerous high voltage electricity. The current transducer must be installed around one of the wires of the electrical power. This procedure is dangerous unless the operator exercises precaution and follows the recommended procedures in the attachment of the current sensor.

These measurements should NOT BE PERFORMED if the operator is not in proper condition to operate safely.

These measurements should NOT BE PERFORMED if wet or moist conditions prevail around the well and/or electrical power enclosure.

These measurements should NOT BE PERFORMED if the operator has not been properly trained by his/her company.

These measurements should NOT BE PERFORMED if the operator has not read and understood the Electrical Measurements section of this operating manual.

10.1 - Electrical Safety

The current passing through the body is the key factor in any shock accident. Most of the over 1000 electric shock fatalities which occur in the US every year are due to voltages less than 440 volts, the most common oil field voltage is 480 volts. It is imperative that respect be given all electrical equipment and circuits and that adequate precautions be taken REGARDLESS OF VOLTAGE.

The following table shows that a very small amount of electrical current passing through the body is hazardous:

CURRENT IN MILLIAMPERES	PHYSICAL EFFECT
2 ma AC or 10 ma DC	Threshold of a sensation: a strong tingling.
10 ma AC or 60 ma DC	Let go current, above which one freezes due to muscular contraction.
100 ma AC or 500 ma DC	DEATH due to heart fibrillation and paralysis of breathing.

To increase safety of working conditions YOU should report ALL SHOCKS and defective equipment. A SHOCK means that SOMETHING IS WRONG. The slightest shock when operating an electrical device might, in another situation, result in instant death if part of the body made only slightly better contact with the ground or a grounded metallic object.

10.2 - Installation of Motor Current Meter

The motor current probe consists of a conventional split-jaw transformer which has been modified to operate with the Well Analyzer. It is connected to the **Auxiliary Input** of the Analyzer. The probe is installed around one of the power wires which are feeding electricity to the electric motor. If the motor is operating properly and is wired correctly and the power supply is balanced, any of the power wires will yield approximately the same value of current. The probe generates a millivolt signal which is proportional to the instantaneous current flowing through the wire around which the probe is clamped.

10.2.1 - Switch Box Access

Although all switch boxes, enclosures for motor controllers and motor frames are normally grounded if properly wired, they may become energized under abnormal conditions. This is even more probable in outdoor installations which are subject to the weather and are unobserved for long periods of time. A failure could take place without anyone present to notice the occurrence of the abnormal condition. As a consequence of component or other failure, the metal housing or frame can become energized. Under these conditions there may be no external indication that the fault has taken place. If an operator were to touch such device with a bare hand it is likely that severe injury would take place.

Prudent practice also recommends that whenever dealing with electrically powered equipment such as motors, switch boxes, control boxes, etc. the integrity and grounding of which is unknown by the operator, if the operator has to touch these devices without protective insulating gloves, the contact should always be made with the back of the hand. As mentioned above in the section dealing with electrical safety, a small current of 10 ma AC, will cause a strong muscular contraction. Touching the device with the back of the hand will result in a contraction AWAY from the electrified device rather than possibly "locking" the hand to a main switch handle.

10.2.2 - Current Sensor Installation

Always make sure that the sensor probe is free of moisture before making any connections.

In order to obtain consistently accurate results it is recommended that whenever attaching the current probe the power cable should be kept within the center line of the jaws and perpendicular to the probe as much as possible.

The following steps should be executed:

1. Turn off the pumping unit and wait for the motion to stop and for the cranks to come to rest.

2. Disconnect the main power switch and open the switch box carefully.

3. Visually inspect the wiring, fuses, cables, relays, switches etc. looking for indications of loose connections, or overheating, or damaged insulation on cables and any other clue to possible electrical faults. If you have any doubts about the safety of the wiring, do not proceed with the test and report your findings to your supervisor or have a qualified electrician repair the problem.

4. Attach the current probe with care by clamping it around the cable coming from the line and attached to the **LEFT** switch breaker. For best results the probe should be attached to a section of wire which is straight and fits in the center of the probe.

5. Insure that the jaws are **completely closed** and that the wire is centered within and perpendicular to the jaws. A slight loss of signal can occur if not installed properly.

NOTE

> It is very important that the jaws be closed completely and the probe should be perpendicular to the power wire. This will insure that consistent current magnitudes will be measured.

The output signal from the probe is digitized by the Well Analyzer and recorded in memory with the dynamometer data.

11.0 - MOTOR POWER MEASUREMENT

!!!! C A U T I O N !!!!

Power measurements generally require the operator to open the electrical switch box. The operator is thus exposed to DANGEROUS HIGH VOLTAGE electricity. The power transducer must be installed with voltage sensors attached to each of the three phases of voltage sources and with two current probes clamped around two wires of the electrical power. This procedure is dangerous unless the operator exercises precaution and follows the recommended procedures in the attachment of the voltage and current sensors and uses the safety equipment which is provided with each set of sensors. The safety equipment includes lineman's rubber gloves with leather protectors.

These measurements should NOT BE PERFORMED if the operator is not in proper condition to operate safely.

These measurements should NOT BE PERFORMED if wet or moist conditions prevail around the well and/or electrical power enclosure.

These measurements should NOT BE PERFORMED if the operator has not been properly trained or educated.

These measurements should NOT BE PERFORMED if the operator has not read and understood the Electrical Measurements section of this operating manual.

11.1 - Electrical Safety

The current passing through the body is the key factor in any shock accident. Most of the over 1000 electric shock fatalities which occur in the US every year are due to voltages less than 440 volts, the most common oil field voltage is 480 volts. It is imperative that respect be given all electrical equipment and circuits and those adequate precautions be taken REGARDLESS OF VOLTAGE.

The following table shows that a very small amount of electrical current passing through the body is hazardous:

CURRENT IN MILLIAMPERES	PHYSICAL EFFECT
2 ma AC or 10 ma DC	Threshold of a sensation: a strong tingling.
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100 ma AC or 500 ma DC	DEATH due to heart fibrillation and paralysis of breathing.

To increase safety of working conditions YOU should report ALL SHOCKS and defective equipment. A SHOCK means that SOMETHING IS WRONG. The slightest shock when operating an electrical device might, in another situation, result in instant death if part of the body made only slightly better contact with the ground or a grounded metallic object.

11.2 - Power Probe Installation

Use of the power probe should be limited to installations where the:

MAXIMUM VOLTAGE does NOT EXCEED 600 Volts AC
MAXIMUM CURRENT does NOT EXCEED 300 Amps

It is possible to overload the transducer and cause permanent damage and possibly create a health hazard if it is used in installations where these values are exceeded.

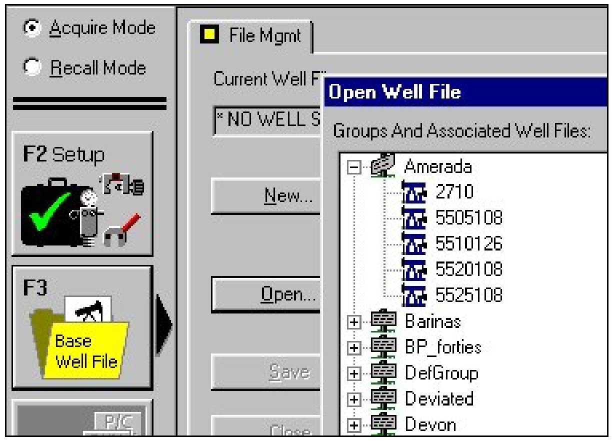
Model 200 Power Probes

Beginning October 2008, the Model 200 version of the power probes will be shipped to new customers. This model has more accurate electronics yielding about 1% accuracy of the power and current readings. The probes are also easier and safer to install in most switch boxes. The following figure shows the new power probes:

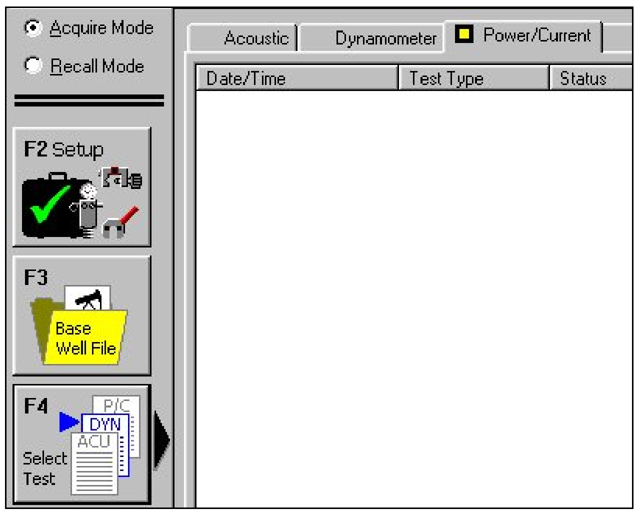
Before proceeding with installation of the power probe, the Well Analyzer should be set up for operation and the TWM program should be started up and the Acquire Mode function selected:

This is required so that the operator will be able to follow the recommended sequence of steps as they are displayed on the screen:

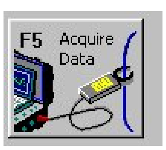
The power probes do not require a set up or calibration procedure so the next step is to select the well file:



After reviewing the well data the **Select Test (F4)** control is selected and the **Current/Power** tab displays the following figure:

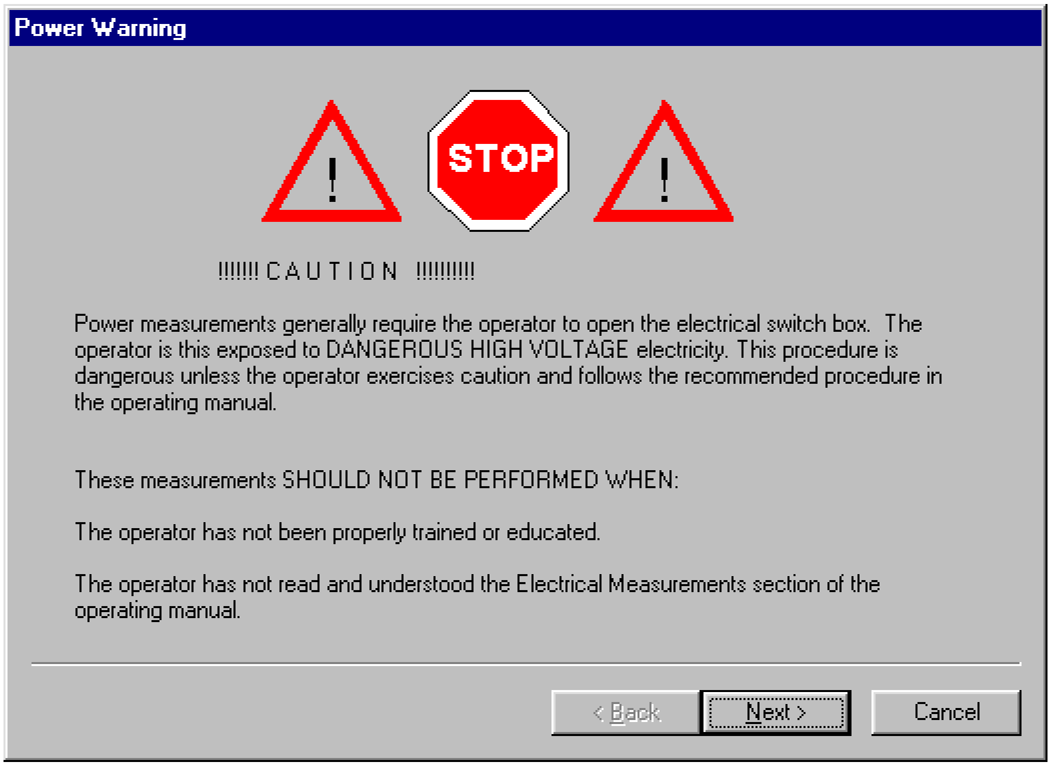


When the **Acquire Data (F5)** option is selected

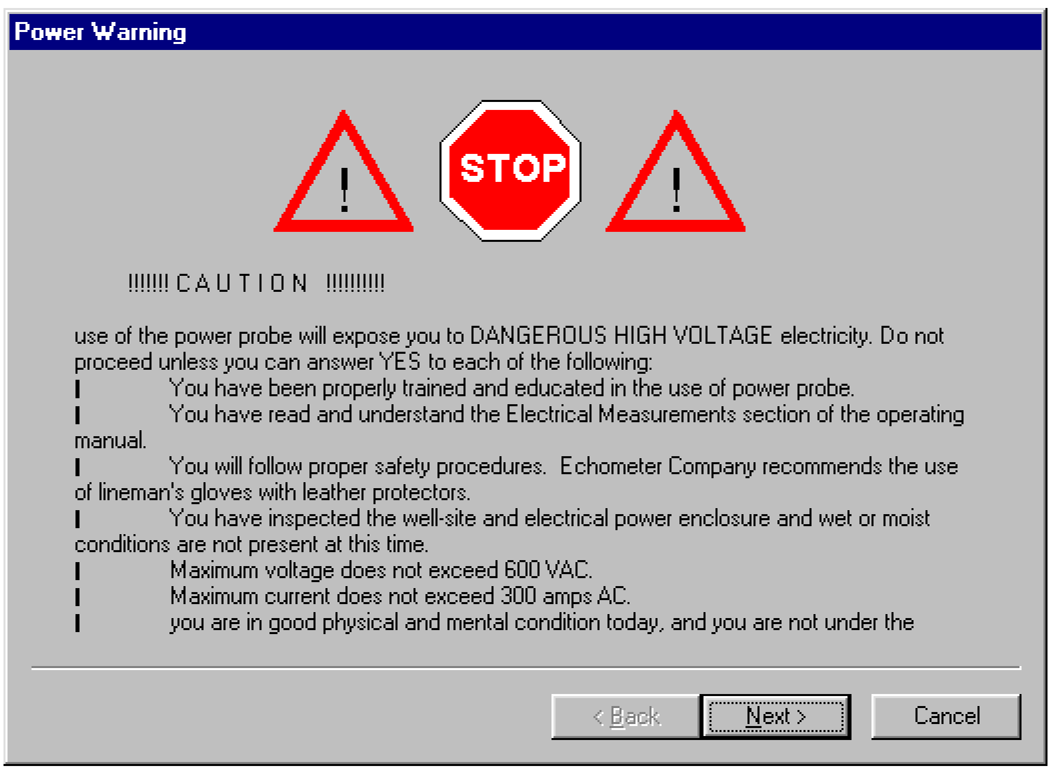


the following sequence of instruction and warning screens is displayed.

The user has to complete the sequence of screens (selecting Next) AND IN SO DOING HE/SHE AGREES TO THE CONDITIONS STATED IN THE SCREENS:



After the operator presses **Next**, the following screen is displayed



This screen asks the operator to assert compliance with the statements by SELECTING NEXT which is equivalent to giving an affirmative response to the set of statements:

Execution of the program will continue only if the **NEXT** response is selected. Otherwise the program stops execution and returns to the Select Test screen.

11.2.1 - Use of Protective Equipment

Echometer Company recommends that protective equipment consisting of a pair of approved linemen’s insulating gloves and a pair of leather protectors be worn whenever operating the electrical box main power switch, opening and closing the switch box, touching any part of the electrical system and during the installation of current probes and voltage leads.

The operator should always follow his/her Company's safety procedures and policies in addition to following the recommended procedures described in this manual and displayed by the software when undertaking the measurements.

11.2.2 - Switch Box Access

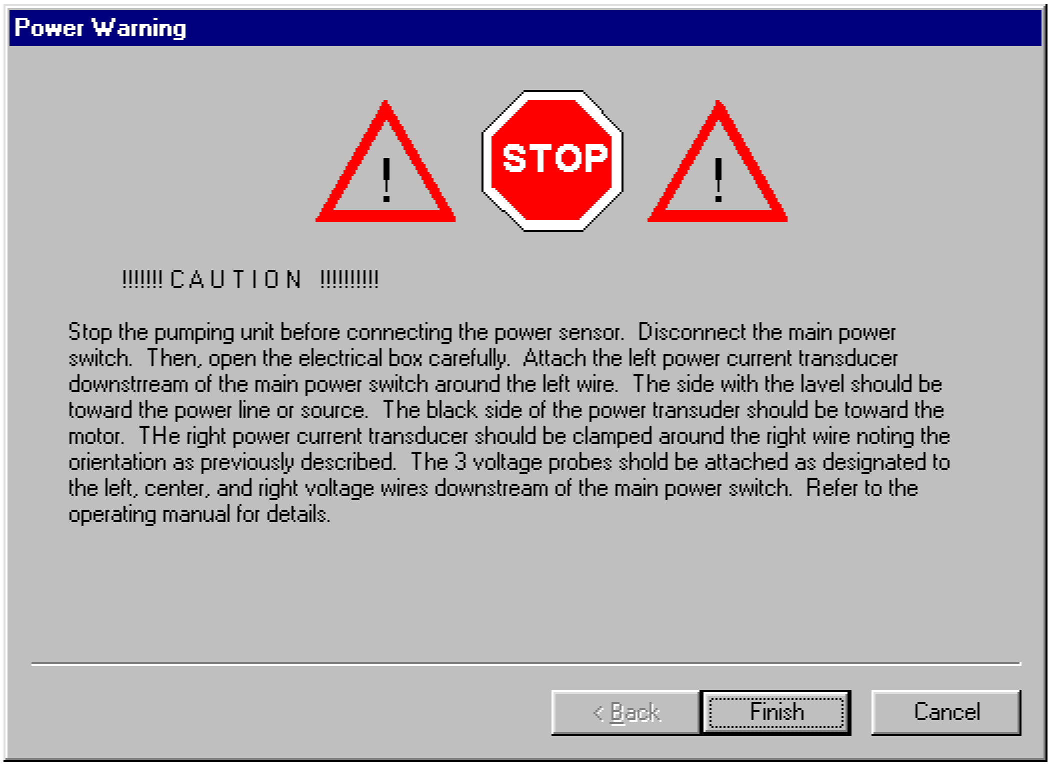
Although all switch boxes, enclosures for motor controllers and motor frames are normally grounded if properly wired, they may become energized under abnormal conditions. This is even more probable in outdoor installations which are subject to the weather and are unobserved for long periods of time. A failure could take place without anyone present to notice the occurrence of the abnormal condition. As a consequence of component or other failure, the metal housing or frame can become energized. Under these conditions there may be no external indication that the fault has taken place. If an operator were to touch such device with a bare hand it is likely that severe injury would take place.

Prudent practice therefore requires that protective insulating gloves be worn BEFORE touching the switch box or grasping the switch box power disconnect lever and that they continue to be worn whenever work needs to be done within the switch box.

Prudent practice also recommends that whenever dealing with electrically powered equipment such as motors, switch boxes, control boxes, etc. the integrity and grounding of which is unknown by the operator, if the operator has to touch these devices without protective insulating gloves, the first contact should always be made with the back of the hand. As mentioned above in the section dealing with electrical safety, a small current of 10 ma AC, will cause a strong muscular contraction. Touching the device with the back of the hand will result in a contraction AWAY from the electrified device rather than possibly "locking" the hand to a main switch handle.

11.2.3 - Current Sensor Installation

Always make sure that the sensor probes and test leads are free of moisture before making any connections.



In order to obtain consistently accurate results it is recommended that whenever attaching the two current probes the power cable should be kept within the center line of the probe's jaws and perpendicular to the labeled surface.

After starting up the program the steps described below, should be followed:

1. Put on the protective insulating gloves

2. **Turn off** the pumping unit and wait for the motion to stop and for the cranks to come to rest.

3. **Disconnect the main power switch** and open the switch box carefully.

4. Visually **inspect** the wiring, fuses, cables, relays, switches etc. looking for indications of loose connections, or overheating, or damaged insulation on cables and any other clue to possible electrical faults. If you have any doubts about the safety of the wiring, do not proceed with the test and report your findings to your supervisor or have a qualified electrician repair the problem.
5. Attach the **LEFT** power current transducer downstream of the main power switch around the **left wire**. The unlabeled side of the power transducer should be towards the motor. It is very important to install the probe in the correct orientation. Otherwise the measured values will be inverted. For best results the probe should be attached to a section of wire which is straight and in the center of the probe. Note that care must be exercised if a 360 degree loop exists in the wire, to insure that the side labeled "towards line" is actually towards the power line.

6. The **RIGHT** power current transducer should be clamped around the **right wire** noting the orientation as previously described. It is very important to install the probe in the correct orientation.

7. Insure that the jaws are **completely closed** and that the respective wires are centered within and perpendicular to the jaws. A significant loss of signal can occur if not installed properly.

11.2.4 - Voltage Leads Installation

The sensors include three voltage sensing leads that must be connected to the corresponding phase terminals. Each voltage lead is labeled with the corresponding position: **"LEFT**", "**CENTER**" and "**RIGHT**". Connections should be made to the appropriate terminal and on the side of the main power switch that is connected to the motor.

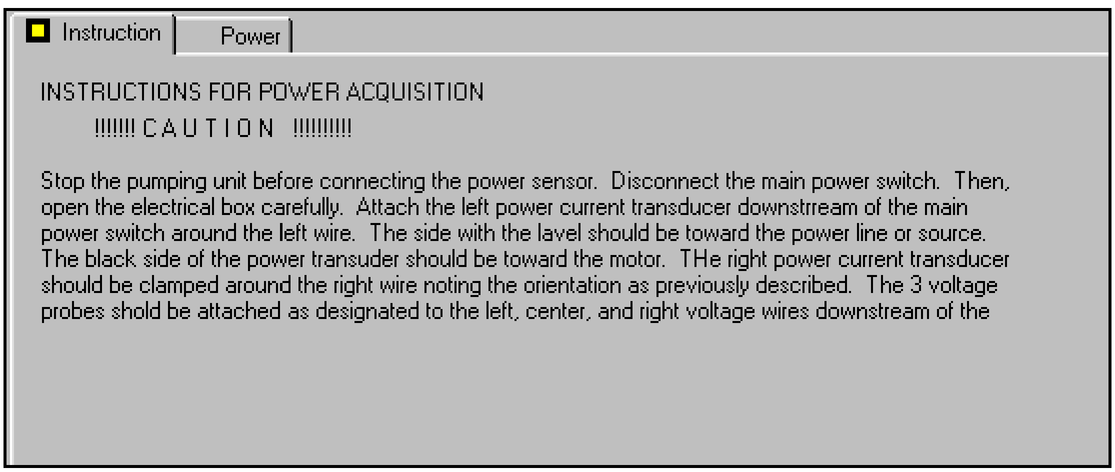
The above picture shows the Model 100 power probes correctly installed in the switch box.

11.3 - Measurement Procedure

The measurement procedure must be followed closely in order to obtain data of good and repeatable quality. The power measurement system is designed to give values of instantaneous power which are within 5% of the actual power used by the motor. This accuracy is achievable provided that the user is careful and follows the recommended procedure. In general the user is interested in establishing the power use of the pumping system when it is operating under steady state conditions. In case that the well is pumping a full barrel and then begins to pump a partial barrel of liquid, the measured power will vary and will not be representative of the normal operating conditions. Therefore it is advisable to insure that the well being tested is produced while testing at the same conditions as normal operations. This can easily be undertaken by running a quick dynamometer measurement with the Polished Rod Transducer prior to installing the power probes. If power measurements are to be made with the purpose of comparing the efficiency of different motor wiring options (low, medium or high torque for example) it is important not to move the current sensors after installation so as not to change the relative position of the wire within the current sensor. Such change would cause small variations in the readings which might invalidate the conclusions of the test. The best practice is to acquire power and current data simultaneously with dynamometer data but if this is not possible then the power/current data may be acquired as a separate test.

11.3.1 - Start of Data Acquisition

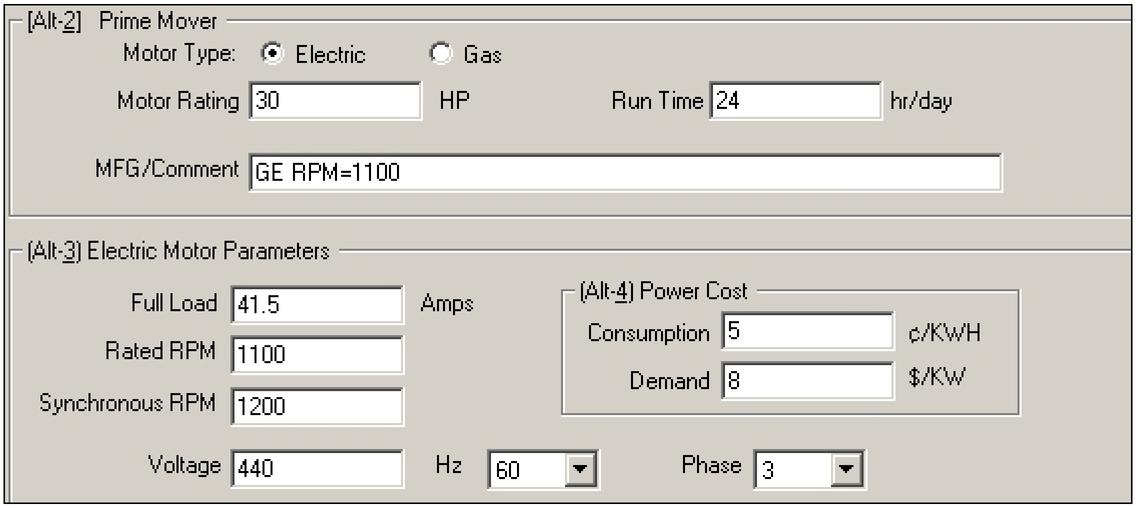
Initialization of the POWER program occurs after the Finish button has been selected. This leads to the following display:



The following data must have been entered in order to be able to analyze motor power measurements:

- Well Name
- Power (voltage, Frequency and number of phases)
- Power cost in cents per KWH
- Motor Manufacturer and model number
- Motor Horsepower
- Well test data (oil and water production)
- Motor Full Load Amp Rating

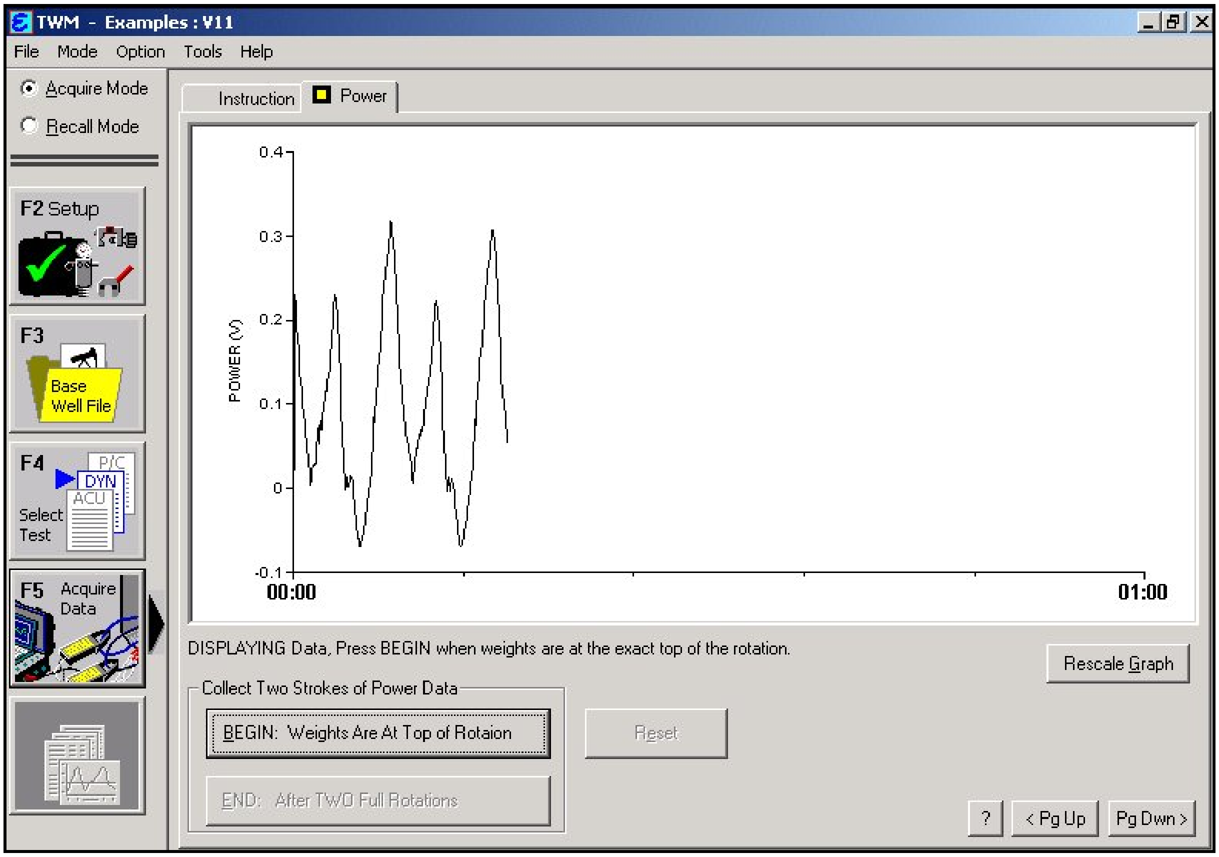
The user should verify that the data regarding the motor characteristics, power costs, etc. are correct as shown in the following screen:



The user can edit the data and may correct the values to match those obtained at the well site. (Motor horsepower rating/size and current are read from the motor's nameplate.)

11.3.2 - Acquisition of Power Data

In order to perform a motor power analysis for a pumping unit, data for two full strokes are needed. This is accomplished by starting acquisition when the polished rod is at the bottom of the stroke or, for a conventional pumping unit, when the counterweights are at the exact top of the rotation. The program will immediately begin to acquire data and continue for 2 full cycles. Stop acquisition again when the counterweights are at the top of the rotation as the second stroke is completed. This is required in order to be able to analyze the data in terms of the pump stroke and pumping speed of the unit.

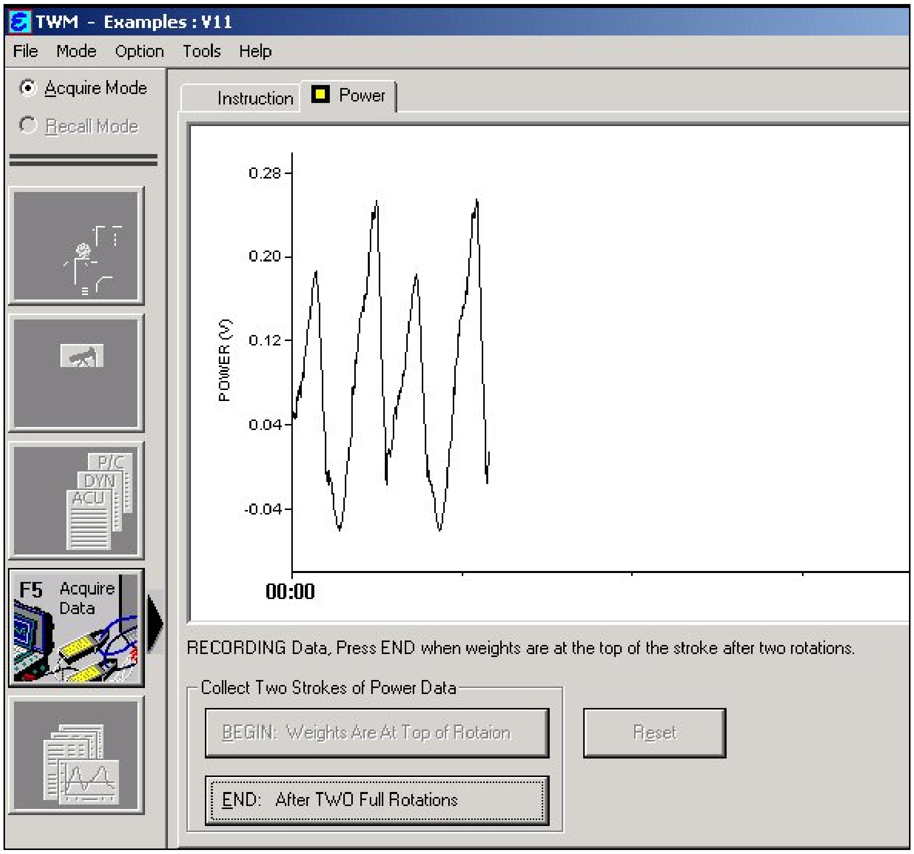


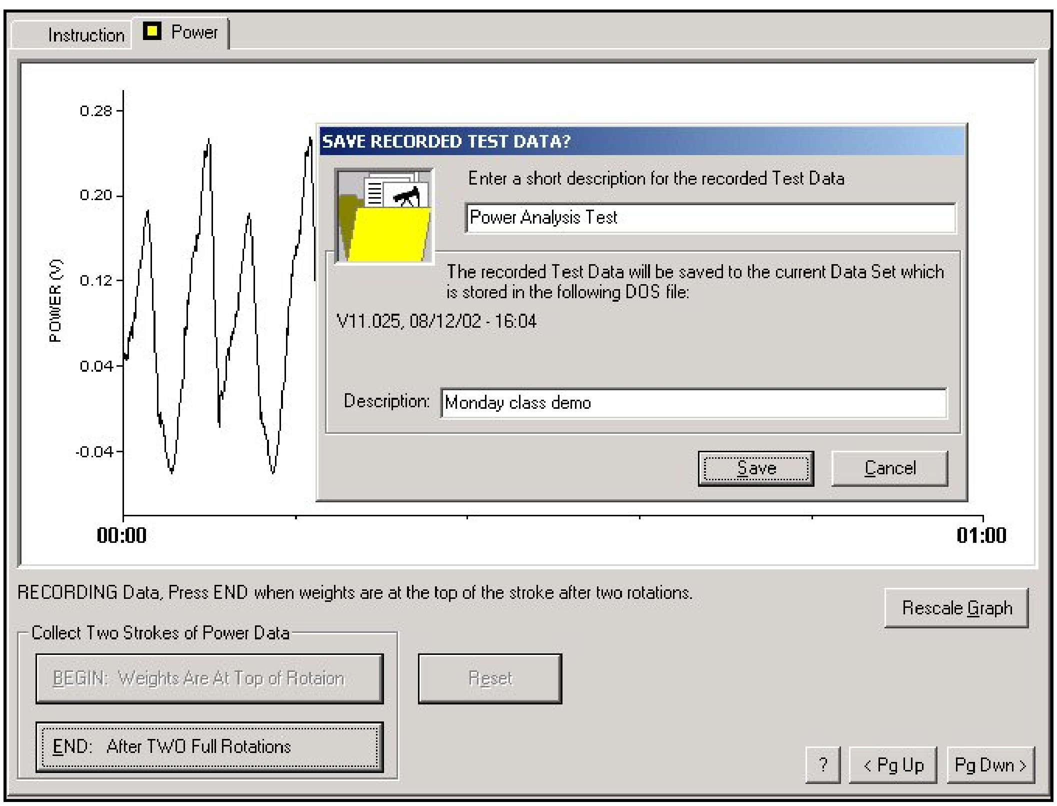
It is very important to consistently begin acquisition of the data when the **counterweights** are directly **above the crank shaft** (at the 12 o'clock position) this insures that the counterbalance effect at the beginning and end of the data set is approximately zero, regardless of the phasing of the counterbalance in relation to the crank and polished rod position.

The **Alt-B (Begin)** and **Alt_E (End)** keys are used to begin and stop data acquisition.

At first the program is only displaying data and not recording in order to allow the user to synchronize with the pumping action.

It is important that the two complete pumping cycles of data acquired be very similar to each other. The similarity refers to the amplitude and shape of the current and power vs. time recordings. The same features should appear in both cycles and exhibit the same amplitude. If this is not the case, acquisition of the data should be repeated.



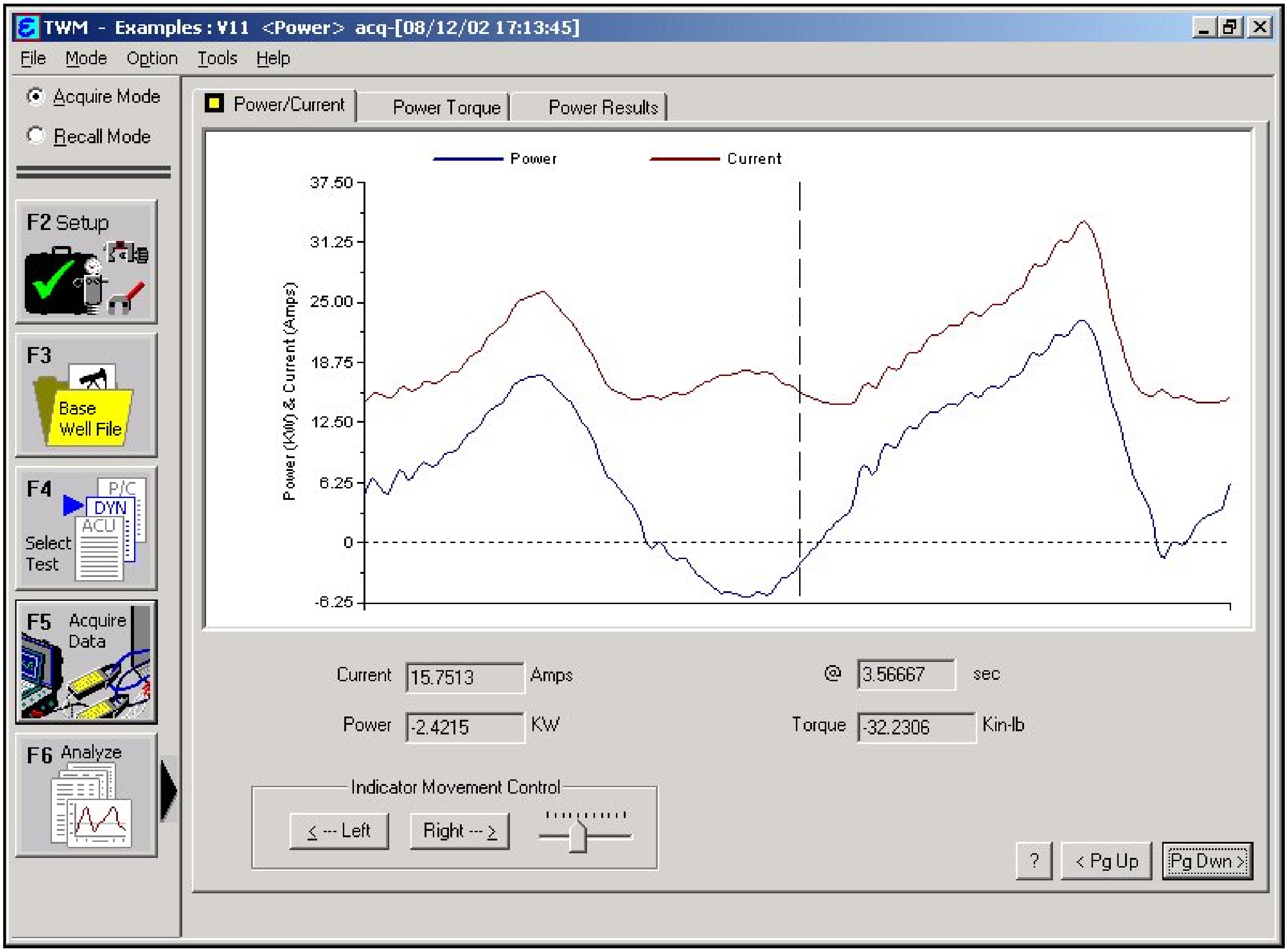


After saving the data the program proceeds to the **Analyze Data** option.

11.3.3 - Data Quality Control

After acquisition the following display is generated:

The user should verify that the data is correct by means of the vertical indicator which can be moved over the trace using the arrow keys. The magnitude of the power and the current corresponding to the position of the indicator are displayed at the bottom of the graph.



The user should determine that the following criteria are met:

- The minimum value of current should coincide with the zero value for power.
- Power and Current peaks should be synchronized
- Minimum current should be greater than zero

When these conditions are met, the user should accept the data as valid. Otherwise the data should be rejected and a new set of data should be acquired after checking that the current and voltage sensors are installed correctly.

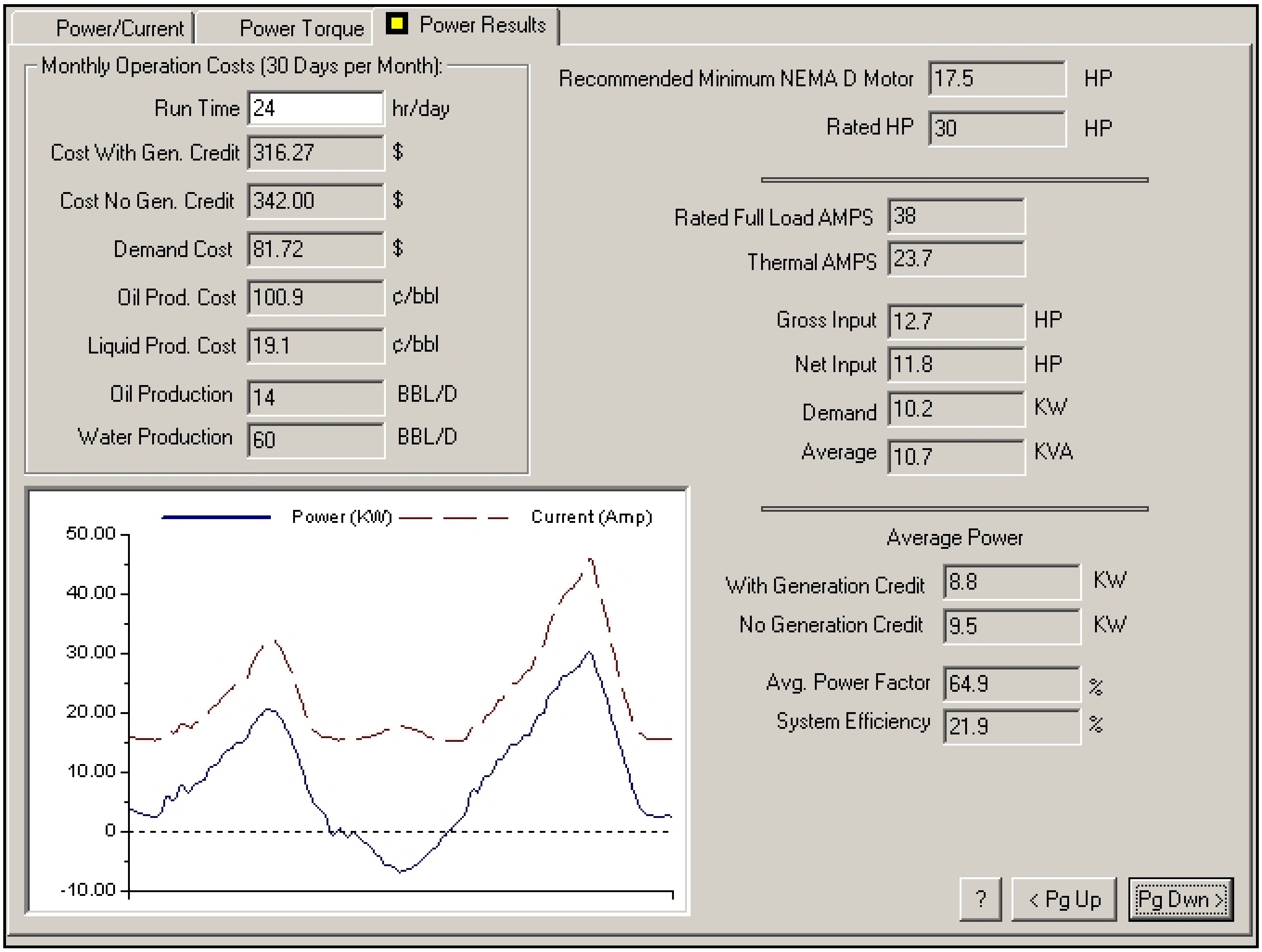
After completing the data check, the program generates the Motor Power Results Screen as shown in the following section.

11.4 - Power and Torque Data Analysis

The main objective of acquiring power data is to determine the efficiency with which the pumping unit is being operated from both standpoints of energy utilization and of mechanical loading. A complete analysis requires that fluid level measurements be made during the session when power is acquired.

11.4.1 - Power Use and Efficiency

The following figure presents the information related to energy utilization. At the bottom left, power and current are displayed as a function of time. Time increases from left to right. Thus the first half of the plot corresponds to the up-stroke and the second half to the down-stroke. The horizontal dashed line corresponds to zero power and current. Values below this line indicate electrical generation.



On this screen are summarized the principal efficiency parameters.

The energy cost per month assuming continuous operation (24 hours per day and 30 days per month).

The operating cost is also calculated on the basis of a barrel of fluid pumped and a stock tank barrel of oil produced. These values are calculated from the production rates which were entered in the well data file and based on the most recent well test. It should be noted that often well test data is not as accurate as one may desire. It is recommended that a dynamometer measurement be undertaken simultaneously with the power measurement using the Polished Rod Transducer to determine the downhole pump displacement. This displacement should be reasonably close to the volume reported from the well test. If this is not true, then the well production may have changed significantly or the well test was not reported accurately. In general the pump displacement from the downhole dynamometer when properly measured is likely to be more accurate than the well test.

11.4.1.1 - Definition of Motor Performance Parameters

The performance of an induction motor subjected to the cyclical loading of a beam pumping system is described by values averaged over one pump stroke.

RMS current is defined as the square root of the average of the squared currents over a pumping cycle. This quantity is also referred to as the **thermal current** since it determines the heating losses in the motor. A motor is a current-rated device and the RMS current should not excessively exceed the nameplate full-load current rating. Motor loading is reflected by the ratio of the RMS current to the nameplate current rating. A ratio of 60% or less is an indication that the motor might be oversized.

CLF: Cyclic Load Factor is an expression of the variation of the instantaneous power in relation to the average power. If a motor were operating with a constant load, the RMS power would be equal to the average power. In a beam pumping system the cyclical loading results in high peak currents which can momentarily exceed the motor's rated current by 100%. The severity of this cyclical loading is expressed by the cyclic load factor which is the ratio of the RMS power to the average power. A motor with a constant loading exhibits a CLF = 1.00. In a pumping system the CLF may range from 1.03 to 1.5 depending on the type of unit, the motor's characteristics, the counterbalance and the pumping speed.

The **RECOMMENDED MIN HP (NEMA D)** is the power rating recommended for NEMA "D" motors used with conventional geometry pumping units and assuming a CLF of 1.375. In general NEMA "C" motors and multi-cylinder engines will require about 38% more horsepower rating. For Mark II units the rating may be reduced by about 20%. The NAMEPLATE HP RATING should be read from the actual motor nameplate or if it had already been entered in the data file it should be verified when the data is recorded in the field. Please refer to Volume 2 of "Artificial Lift" by K. E. Brown, for further details.

The **INPUT HP** is calculated from the measured electrical power including credit for generation. It represents the power supplied to the motor during one pumping cycle. The ratio of the polished rod horsepower to the input horsepower is a measure of the overall efficiency of the pumping unit. This quantity can only be calculated if a dynamometer measurement has been performed.

The **APPROXIMATE OUTPUT HP** is computed from the input horsepower using an average motor efficiency of 85%. The reason that it is labeled "approximate" is that the motor's efficiency varies in relation to the motor's speed and depends greatly on the type of motor that is used. Type "D" motors exhibit greater and more uniform efficiency that Ultra High Slip motors.

The **AVERAGE KVA** is calculated by multiplying the voltage value entered in the well file by the average current for a pumping cycle and dividing by 1000.

The **AVERAGE KW** is obtained by integrating the measured consumed power as a function of time over one pumping cycle and dividing the area by the time elapsed for one stroke. When generation credit is considered, the measured generated power is subtracted from the consumed power.

The **AVERAGE POWER FACTOR** represents the fraction of power that is doing useful work to the total power used by the motor (the difference corresponds to the heating losses due to the magnetization current) It is the ratio of the AVERAGE KW to the AVERAGE KVA.

The pumping speed is expressed as **STROKES PER MIN** and is computed when the software identifies the time between the maximum power peaks that occur in two adjacent strokes.

The most recent production well test data is obtained from the well file and is presented as **BOPD** and **BWPD**.

11.4.1.2 - Motor Load

The load on a motor that drives a pumping unit depends upon the electrical characteristics of the motor as well as the load cycle on the speed reducer of the pumping unit.

Electrical characteristics of available motors include:

- Normal torque, normal slip, normal starting current
- Normal torque, normal slip, low starting current
- High torque, normal slip, low starting current
- High torque, 5-8% slip, low starting current (NEMA D)
- High torque, 8-13% slip, low starting current (NEMA D)
- Ultra High Slip 30-40%, High, Medium, Low torque, low starting current

Motors for oil well pumping should have both high starting torque and low starting current to insure positive starting and minimum cost for distribution lines.

The majority of applications use the NEMA-D design since they have the best starting characteristics and exhibit higher efficiencies relative to the ultra high slip motors and are more cost effective.

High slip motors and ultra high slip motors vary more in speed with change in load than normal slip motors. The greater speed change causes the inertia of the rotating parts of the system to store more energy during the minimum load periods and release more energy during the peak load periods. The result is that input power peaks are always less than with normal slip motors. There is some question whether ultra high slip motors are justified for normal applications in view of their high cost and relatively low efficiency. Ultra high slip motors find applications in those installations where excessive mechanical loading cannot be remedied through adjustments in pumping stroke, speed and/or counterbalance. An under-loaded ultra high slip motor exhibits approximately the same speed variation as a fully loaded, normal slip NEMA-D motor.

11.4.2 - Torque Curve Analysis

Direct measurement of electrical power at the motor as a function of time during a pump stroke permits a very simple calculation of the torque that the gear reducer sustains. Recalling that in a rotating system the instantaneous power is given as:

Power = Torque times RPM

It can be seen that the instantaneous torque can be calculated from direct measurement of the power and the speed of rotation.

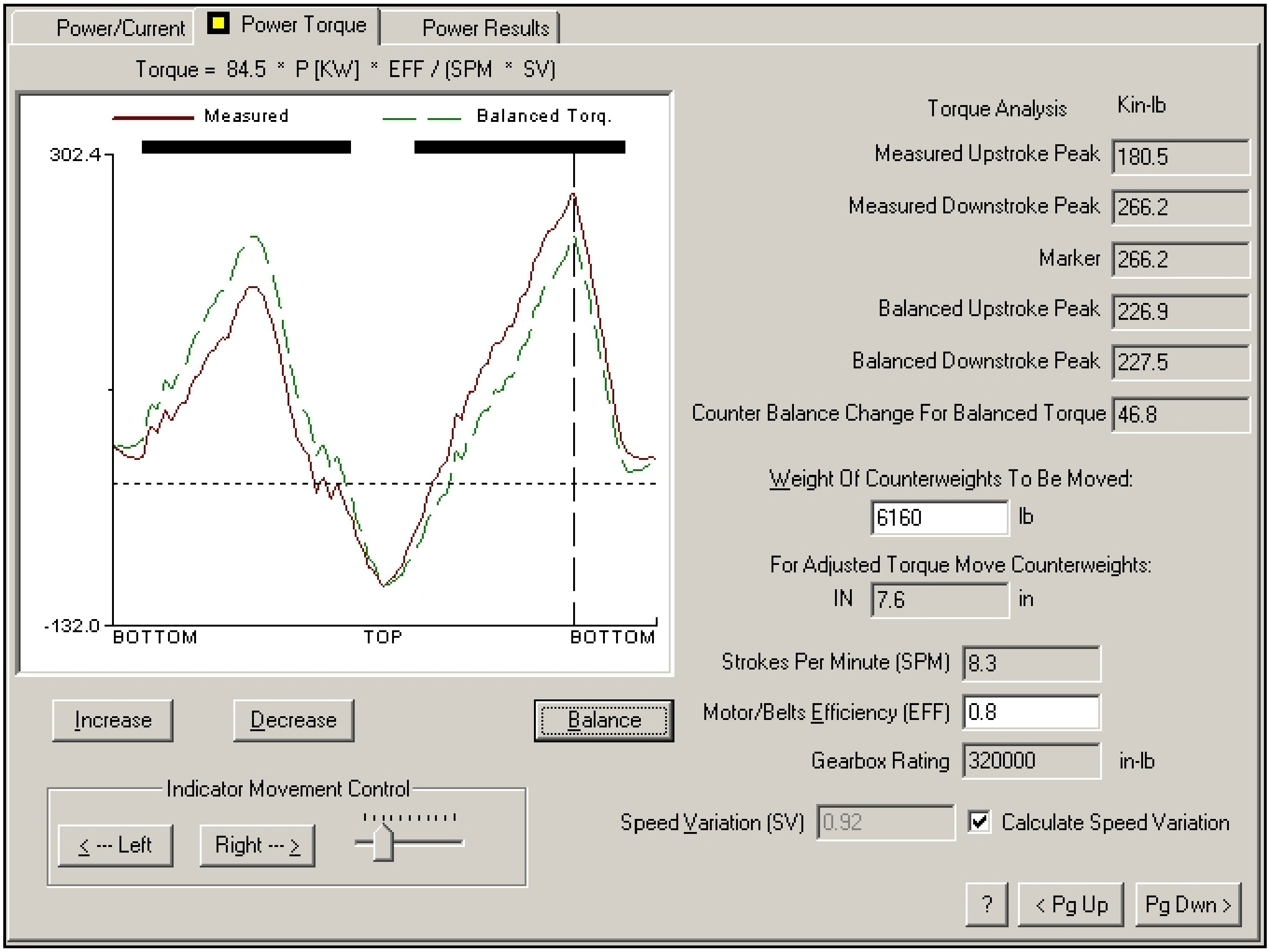
In a beam pumping system we are interested in the torque delivered by the crank of the gear box. In order to calculate this torque from the instantaneous electrical power input to the motor, it is necessary to consider the efficiency of power conversion by the motor and power transmission through the belt drive and the gear reducer. This efficiency varies with each installation and the loading of the system. In general it decreases as the loading decreases. For a normally loaded and properly installed system the efficiency has been estimated at 80%. However because of the uncertainties in this quantity, the user is allowed to enter a value that fits more closely the particular installation.

The calculation also requires knowledge of the instantaneous crank speed. In the calculation this quantity is assumed to be constant and directly related to the pumping speed which is determined by the program from the power data. The operator can estimate the instantaneous SPM at peak power by using current and power data with motor type curves showing the relationship between current/power and RPM.

The instantaneous torque is thus calculated with the following relation:

Torque = (84484)(KW)(Eff)/(SPM*SV)

expressed in inch-lb. and is presented graphically in the next screen:



On the left half of the screen are plotted two torque curves as a function of time: the dashed line corresponds to the calculated actual torque while the solid line corresponds to the torque that would be observed if the unit were counterbalanced in such a way that the peak upstroke torque is equal to the peak down stroke torque. Note that the negative torque corresponds to the portion of the stroke where the gear reducer is driving the motor into the generation region.

The tabulated torque analysis gives the **UPSTROKE PEAK** and the **DOWNSTROKE PEAK** torque values in **thousands of inch-lb**. that occur during the stroke. The difference between these values is a measure of the unbalance of the system. If the upstroke peak is greater, the unit is under balanced or "rod heavy". If the down stroke peak is greater, the unit is overbalanced or "crank heavy." The torque that would be experienced if the counterbalance were adjusted so that two peaks were equal is displayed as the **BALANCED PEAK** value.

At the top of the graph the user is reminded that these values are calculated using the expression:

T=84.5*P*EFF/(SPM*SV)

The utilized value of **EFF** (the ratio of the power input at the motor to the power delivered at the crank which can be changed by user input) and the calculated pumping speed **SPM** are also displayed. The quantity **SV** is a factor that takes into account the motor's speed variation during the stroke. It is the ratio of the minimum speed to the average speed. It is calculated based on the motor’s performance characteristics as entered in the well file. Depending on the specific motor's slip, the user may want to input a different value after un-checking the box.

11.5 - Pumping Unit Balancing

The objective of counterbalancing the pumping unit is to minimize the loading of the gear reducer and reduce energy use by reducing the peak values of torque and equalizing the power requirements over the complete stroke. Perfect counterbalancing of a beam pumping system is not feasible because the loading changes during a stroke by the amount that corresponds to the fluid load on the pump. This load is supported by the rods (traveling valve) during the upstroke and then is transferred to the tubing (standing valve) during the down stroke.

Assuming for a moment that the system is operating at a very slow speed so that the dynamic effect of the rod stresses, the inertia of the unit and the unit's inherent unbalance may be neglected, it can be concluded that the best that one can achieve is to balance the torque that corresponds to the buoyed weight of the sucker rods plus one half of the fluid load. Thus the net torque per pumping stroke corresponds to that developed by applying 1/2 of the fluid load to the polished rod load. This yields an approximate value of the counterbalance that would be required for a given unit.

However, when the system's dynamics are taken into consideration and especially including the effects of pumping speed variation during a stroke, it becomes difficult to estimate the counterbalance requirements without complete knowledge of the geometry of the unit and the motor's torque-speed characteristics.

As explained earlier, the direct measurement of the input power to the electric motor is converted to torque through a simple calculation. Assuming a constant pumping speed it is possible to superimpose to the actual torque an arbitrary sinusoidal torque of the same frequency as the pumping speed and in phase with the counterweights (180 degrees out of phase with the measured torque). The resulting torque corresponds to the torque that would be observed if the counterweights were moved on the crank a distance equal to the applied torque divided by the weight of the counterweight. The software undertakes this calculation automatically adjusting the counterbalance in small increments until the upstroke and down stroke peaks of the torque are equal.

The resulting **Balanced Torque** is plotted on the figure using the dashed lines. Note that at the bottom of the figure are drawn two thick black line segments. These indicate the portions of the upstroke and the down stroke where the program is looking for the torque peaks to balance. In general the portions of the stroke selected by the program correspond to the segments where the maximum torque occurs in each half of the stroke. Occasionally it may happen that the peak torque that the user wishes the program to consider is not enclosed within the automatically picked section. The user has the option to change the adjusted torque by using the **Increase/Decrease** keys. As each key is pressed the amount of counterbalance is changed and the software recalculates the counterbalance and displays the effect on the figure and the table on the right side. Pressing the **Balanced** key returns the display to the automatically balanced condition.

The counterbalance change **CB CHANGE FOR BALANCE** is displayed in thousands of inch-LB indicating whether it should be **increased** or **decreased.**

In conventional beam pumping units it has often been noticed that power usage decreases slightly if the unit is slightly rod heavy instead of being balanced so as to make the torque peaks exactly equal. This is partly due to the increased velocity of rotation during the down stroke that stores slightly more kinetic energy in the system that is recovered during the upstroke. The net effect can be to reduce the overall electrical power consumption by about 5 to 7%. The exact behavior will also depend on the type of motor used and the amount of slip. It is therefore recommended that this adjustment be checked with field measurement.

11.5.1 - Counterweight Identification

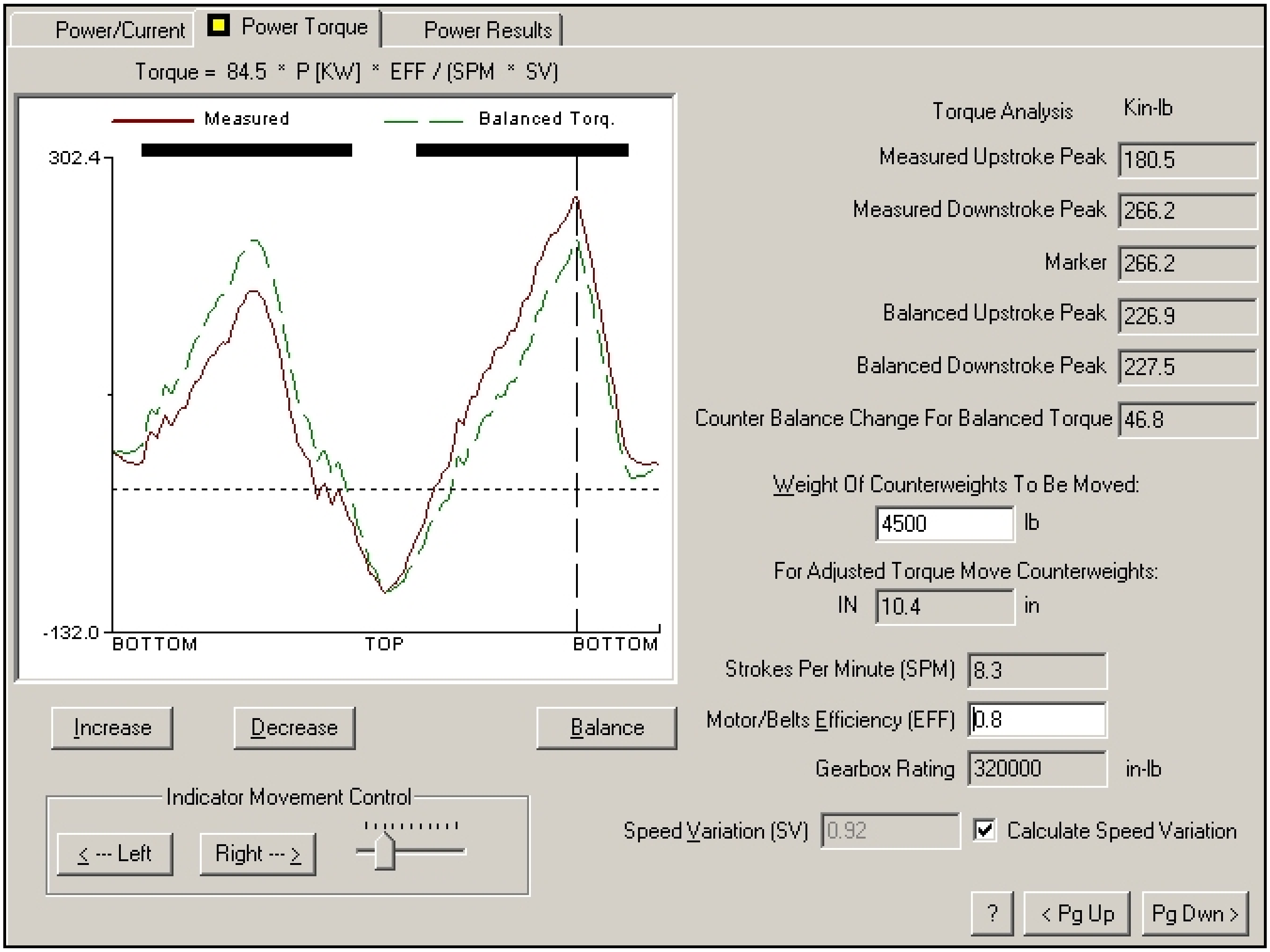
It is important to correctly identify the size of the counterweights that are installed on the unit. This permits the operator to enter the correct value (in pounds) of the counterweight to be moved. This is accomplished by entering the **total weight** of the counterweights to be moved. For example if a unit has four counterweights each of 1125 LB., the total counterweight load available will be 4500 LB. The program would then indicate the movement for each of the four weights.

A text file data base of counterweights is stored in the TWM directory and is accessed through a shortcut on the desktop.

11.5.2 - Counterweight Movement

The program will also indicate the distance and direction of the counterweight movement required to change the counterbalance by the indicated amount of torque.

When multiple counterweights are used, each counterweight will have to be moved by the distance displayed by the program. Having decided the total weight to be moved, the user enters it, as shown in the following figure:



In the example above the program was given a total counterweight of 4500 LB. and it recommends a movement of 10.4 inches IN, then each of the counterweights will have to be moved by 10.4 inches, inwards to the crank shaft..

11.5.3 - Checking of Results

As indicated earlier, a number of assumptions have been made when generalizing the calculation of gear reducer torque from measurement of electrical power used by the prime mover. The principal assumptions are that the speed of rotation is represented by an average value during the pump stroke through the use of the calculated speed variation and the motor/belt efficiency is representative of the installation In addition the effect of changes in rotating inertia of the counterweights is not considered when computing the change in counterbalance torque. On the other hand it is believed that the relative magnitude of the torque peaks derived from the power measurement is more accurate than that derived from dynamometer measurements due to the difficulty in measuring an accurate counterbalance effect and the uncertainty that the correct unit dimensions are being used in the torque calculations.

For these reasons the suggested counterbalance change is to be interpreted as a first best estimate in a trial and error procedure. The adjustment should be undertaken in stages and after each counterweight is moved a power measurement should be taken in order to check that the desired effect is being achieved.

Changing the counterbalance of the unit will also result in small changes in pumping speed. In turn these changes will affect the dynamics of the sucker rods and modify the net pump stroke. After the counterbalance adjustment is completed it is recommended that a dynamometer test be undertaken in order to check that the desired pump displacement is obtained.

It is impossible to obtain consistent results if the well is not pumping at steady state conditions or if it is pumped off. After each change in counterbalance a sufficient length of time should elapse before performing another balance test to insure that the well's producing characteristics have returned to normal.

11.6 - Special Power Measurements

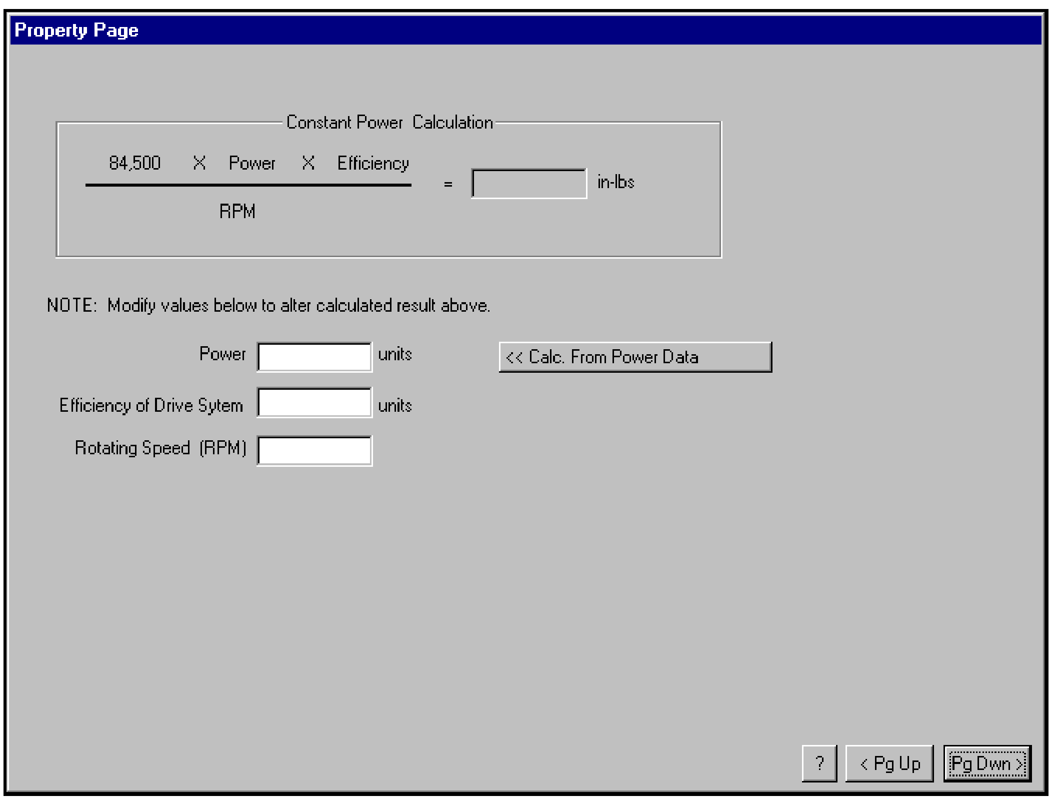
11.6.1 - Single Phase Motors

Installation of the probes and voltage clips is as follows when measuring power in systems using single phase electric motors:
Left Current Probe on Left Cable
Left Voltage Clip on Left Cable
Center Voltage Clip on Right Cable

Right current probe and Right voltage clip are not used.

11.6.2 - Constant Speed Motor

The Power measuring system can be used in calculating the torque loading of a constant (or nearly constant) speed motor such as the drive motor of a **Progressing Cavity** pump or centrifugal pump. The software detects this case by observing that the power signal does not vary during the acquisition time. Automatically then the following screen is displayed:



12.0 - AUXILIARY FUNCTIONS

This chapter discusses utilities for generating reports, exporting data, and troubleshooting the equipment.

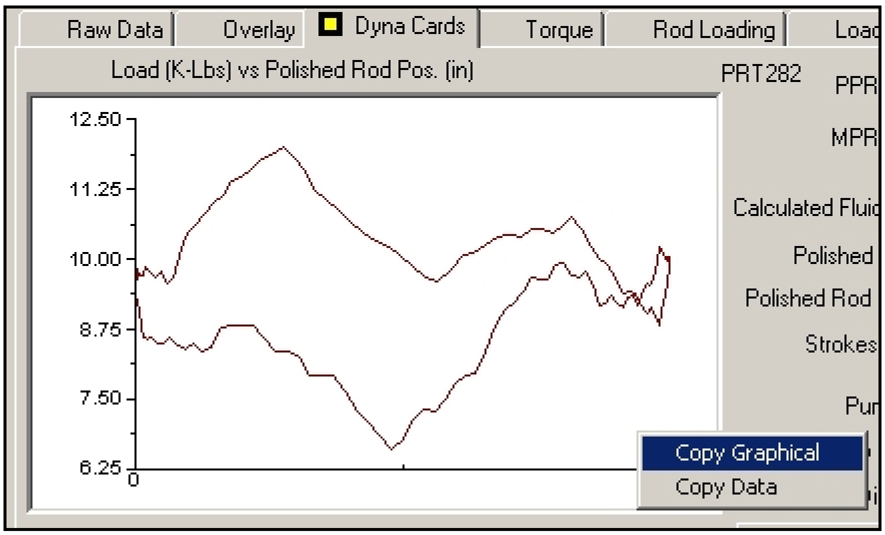
12.1 - Printing of Reports and Exporting Results

12.1.1 - Individual Test Reports

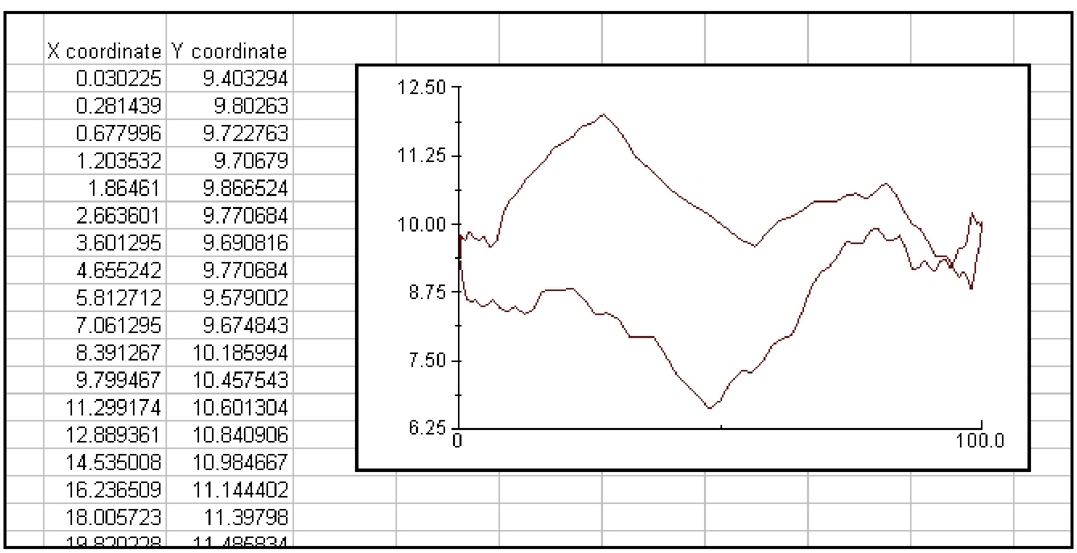
Reports of the processed data are printed using the **Print** option under the **File** Menu. As discussed in section 5.51 of this manual resulting in printed summaries for an individual well set of test data. A one page report can be generated if the user has access to MS Word and allows the execution of macros.

12.1.2 - Copying and Pasting Figures or Data

When compiling reports using MS Word or other applications it may be necessary to include graphical output generated by the TWM program. Also it may be useful to transfer numerical data series to spreadsheets or other mathematical applications for further processing. These tasks are facilitated by being able to copy ANY of the TWM figures or data series to the clipboard simply by pointing to the figure and **Right Clicking** as shown below the dual button **Copy Graphical/Copy Data** is displayed:



Clicking **Copy Graphical** copies the graph so that it may be pasted into the other application. Clicking **Copy Data** generates a numerical matrix in text format that can be pasted in a spreadsheet. The figure below shows the result of pasting a figure and the corresponding data into a spreadsheet:

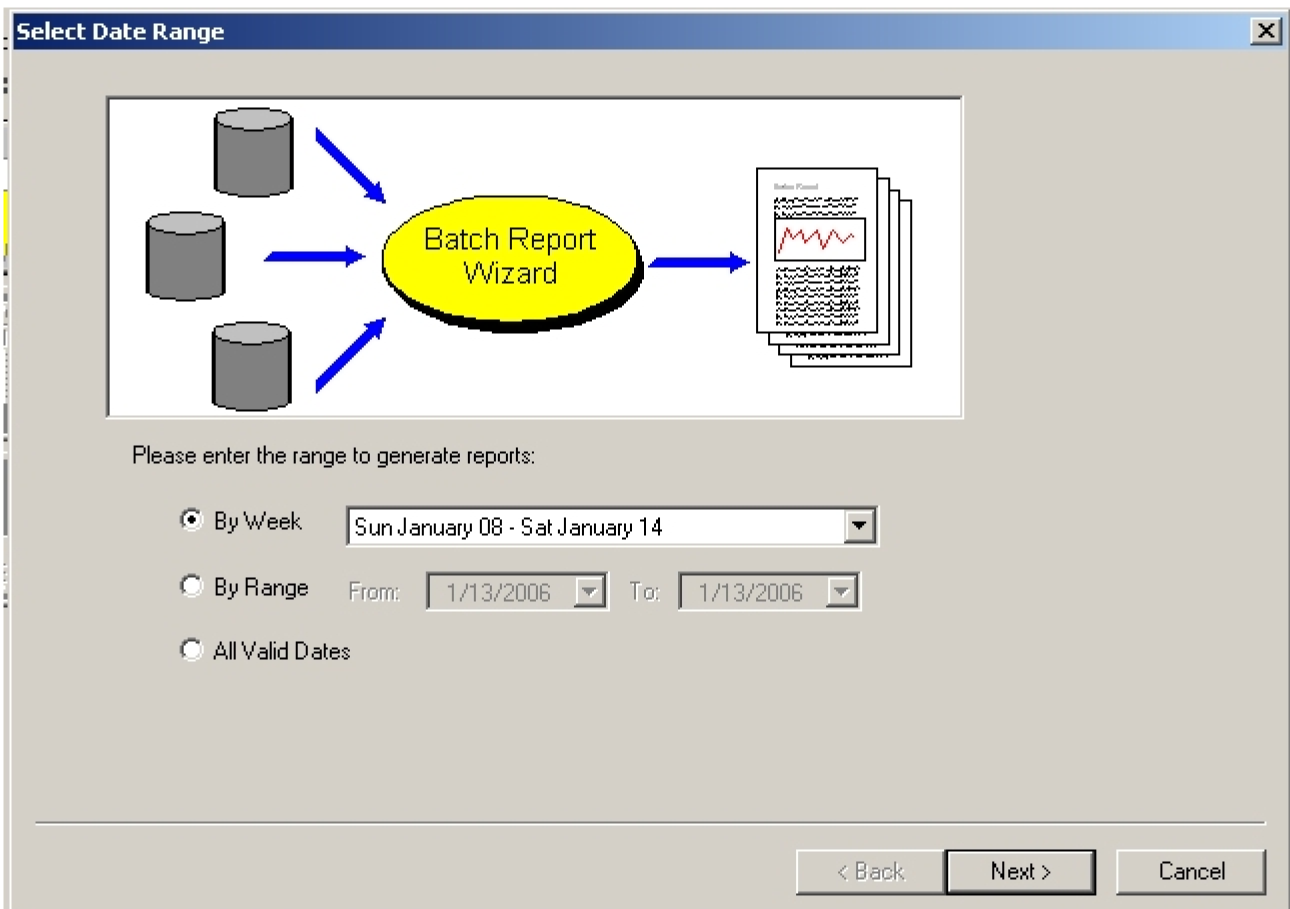


X coordinate	Y coordinate
0.030225	9.403294
0.281439	9.80263
0.677996	9.722763
1.203532	9.70679
1.86461	9.866524
2.663601	9.770684
3.601295	9.690816
4.655242	9.770684
5.812712	9.579002
7.061295	9.674843
8.391267	10.185994
9.799467	10.457543
11.299174	10.601304
12.889361	10.840906
14.535008	10.984667
16.236509	11.144402
18.005723	11.39798

12.1.3 - Batch Report Printing

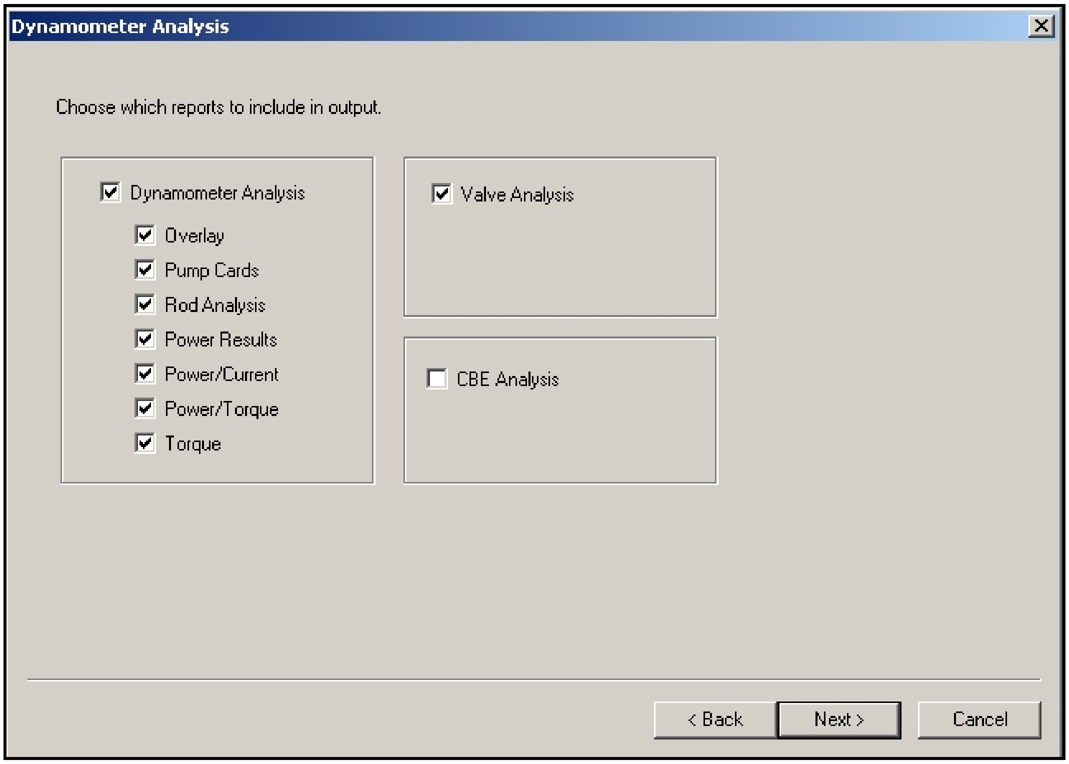
When more than one test or tests for several wells are to be printed then the **Batch Print** option is a more convenient method of generating reports. This option is available from the **File** menu and allows selecting multiple data sets and wells for printing the standard reports:

Selecting Batch Print opens the following form:

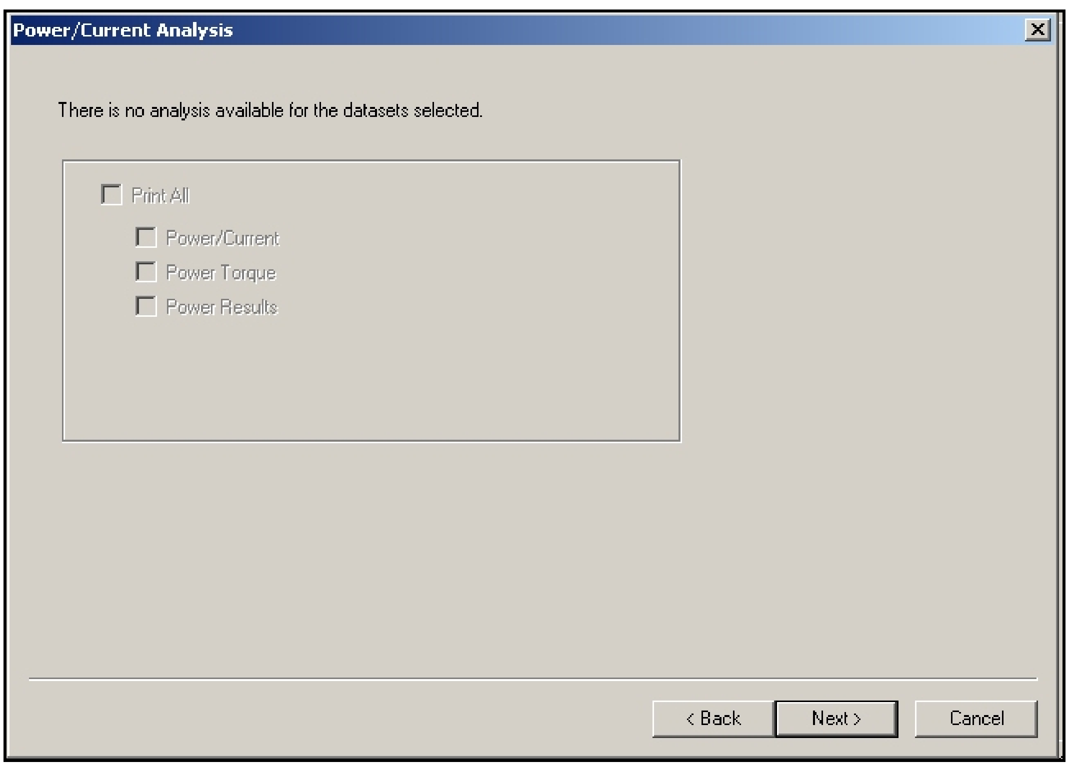


. Data file selection is similar to that described in the following section on **Data Export**. Please refer to section 11.14 for details on selecting the data sets.

Once the data sets have been selected the next step is to generate the format of the report by selecting the analysis screens that are to be included for the various tests as follows:

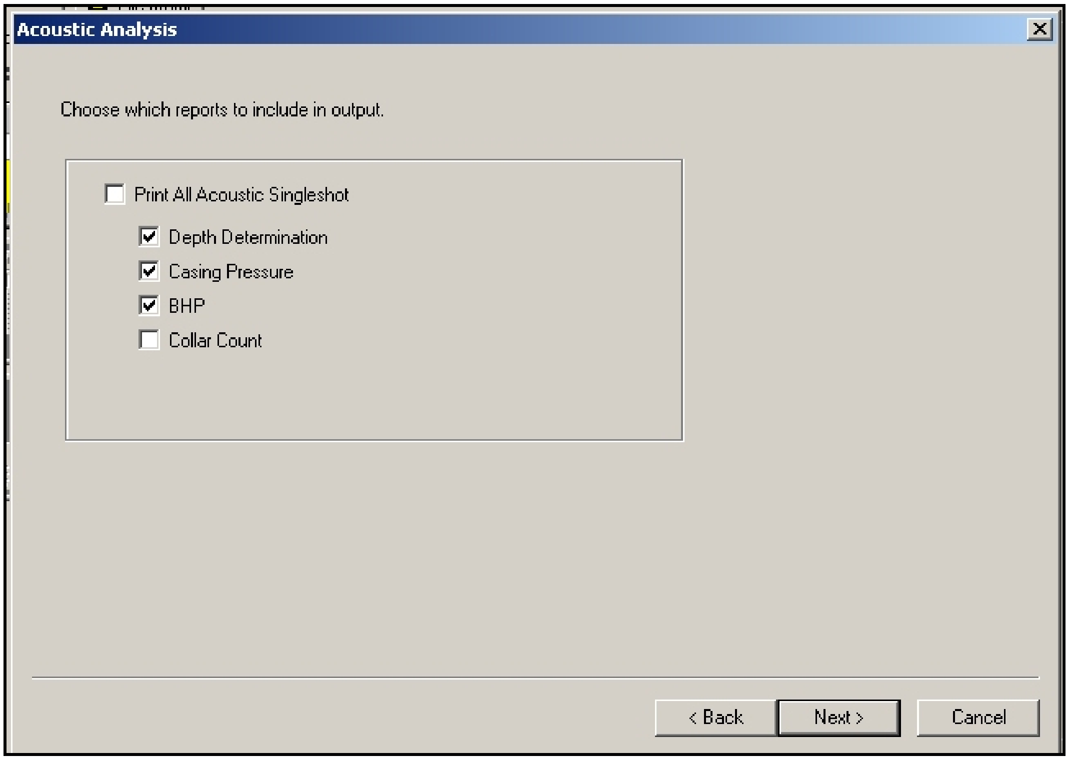


Only the screens with the check marks will be included in the printed reports.

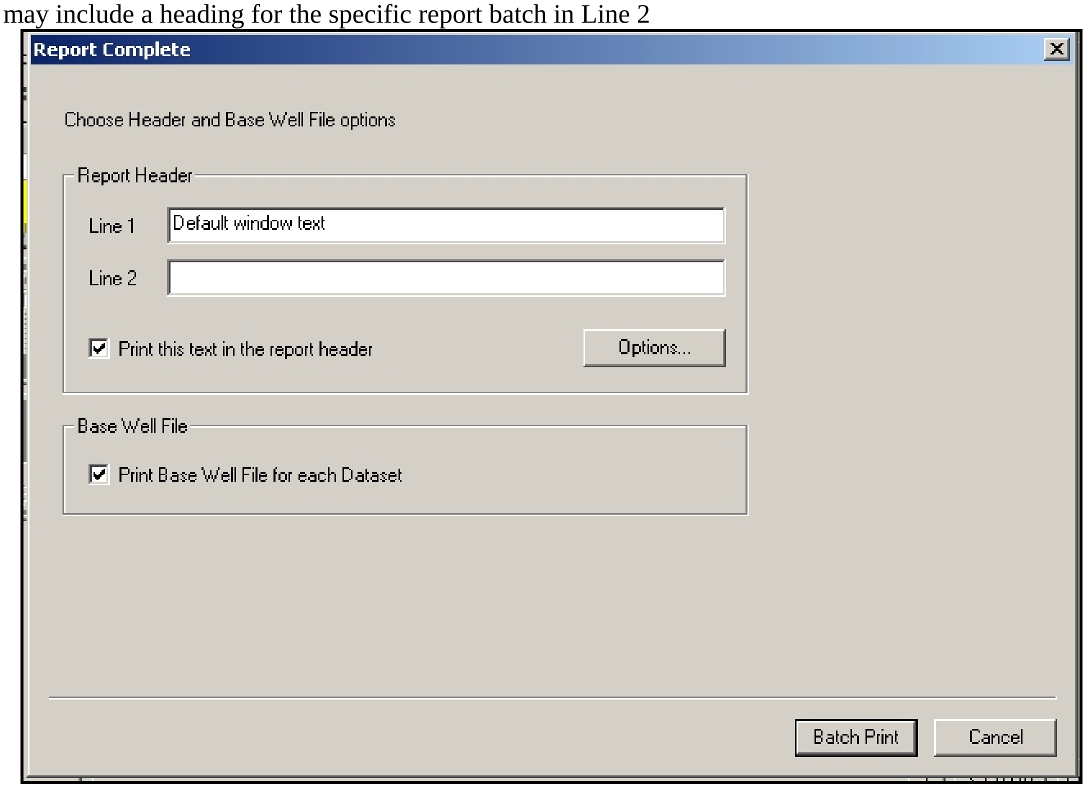


When a test is not present in the data set, the boxes are grayed-out as shown above.

Individual analyses may be selected and will be included in all reports:

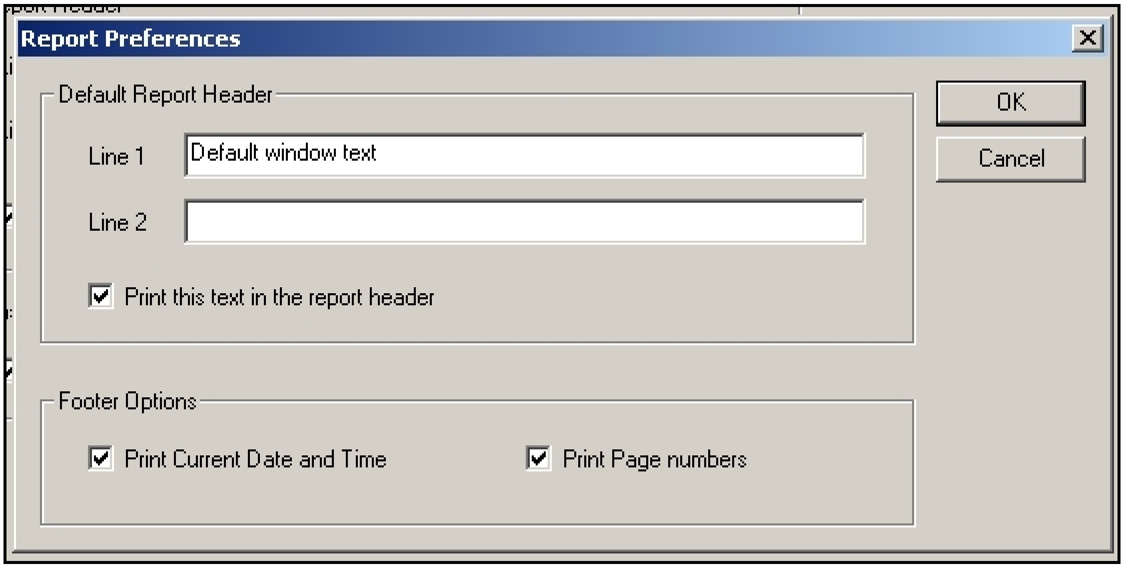


The user may include a heading for the specific report batch in Line 2



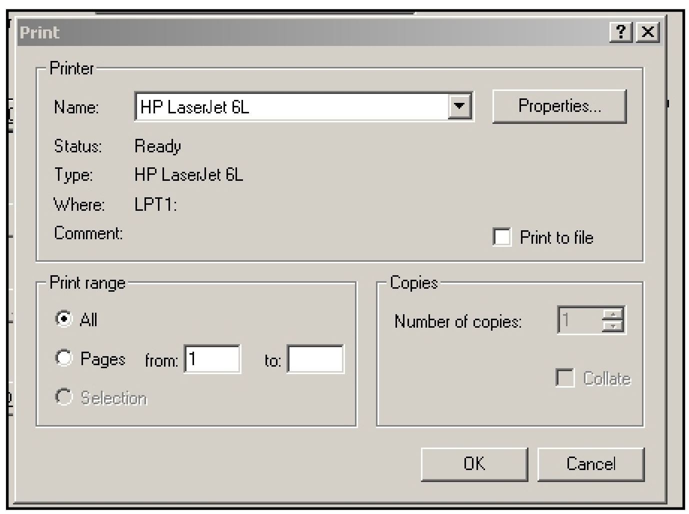
The Options button allows entering a report header that will be used in all reports as a default header:

The user my type two lines of text that will be printed on each report set:



After clicking OK, the following screen is shown indicating the listing of the files for which reports will be printed:

Clicking OK will display the Printer where the reports will be sent. Clicking Cancel will stop report generation and the user may return to the beginning of the Batch print procedure.



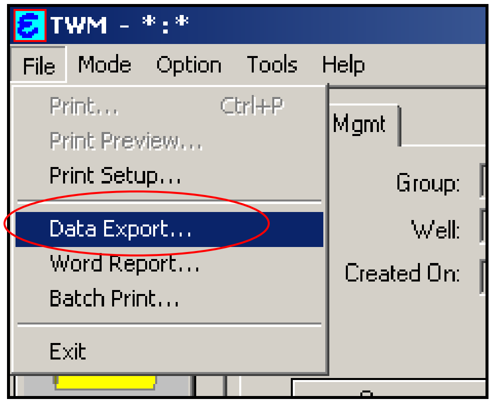
12.1.4 - Data Export

This utility allows the generation of a character delimited file (flat file) containing all or some of the results obtained with the TWM software. The user selects the variables to be output, the sequence of columns and the well tests from where the data is exported.

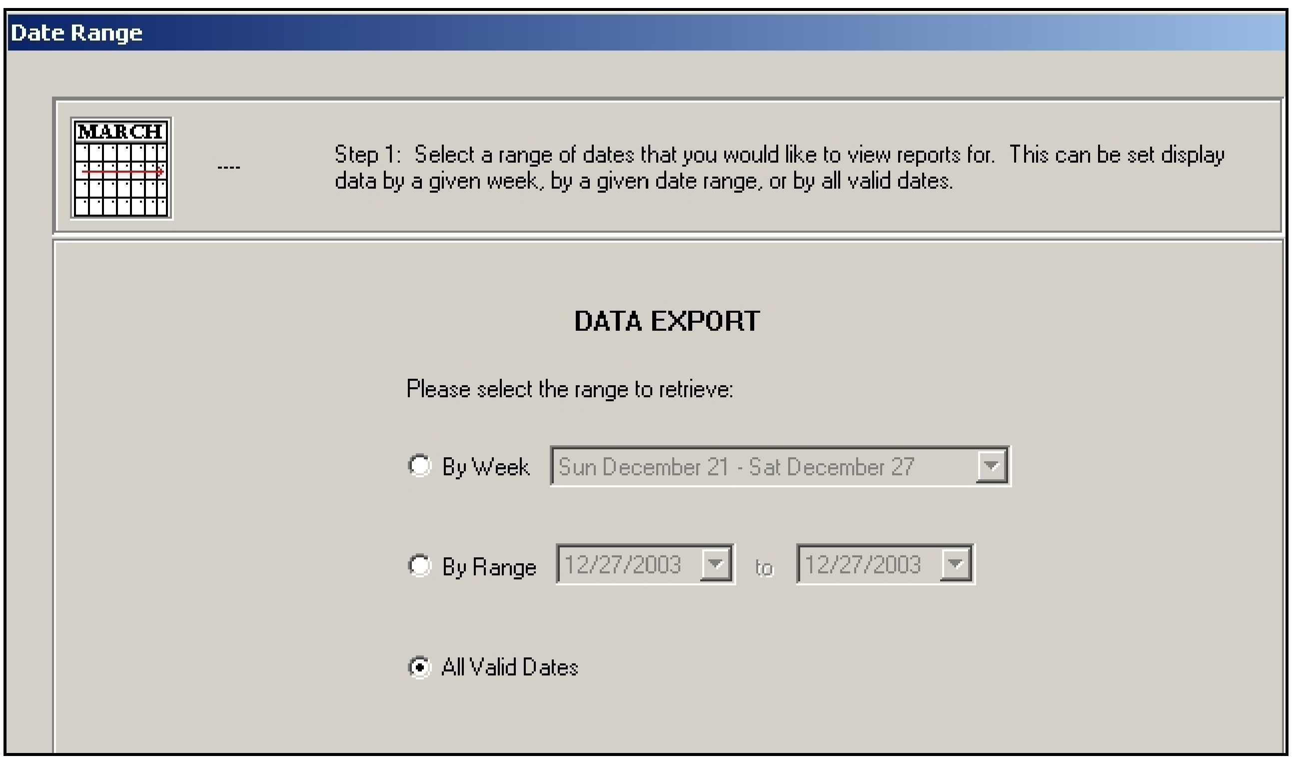
The following outlines the procedure to be used to generate the data export file.

The following are summarized instructions for the use of the **Data Export** of the TWM program.

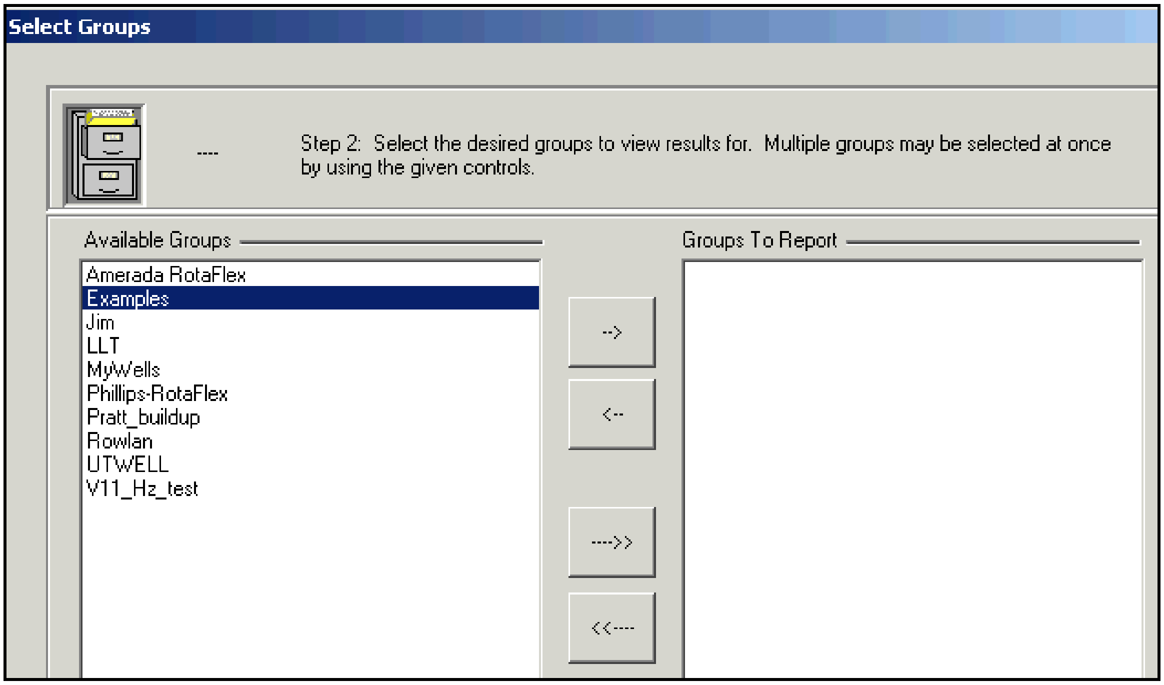
Data export is accessed from the **FILE** menu as shown below:



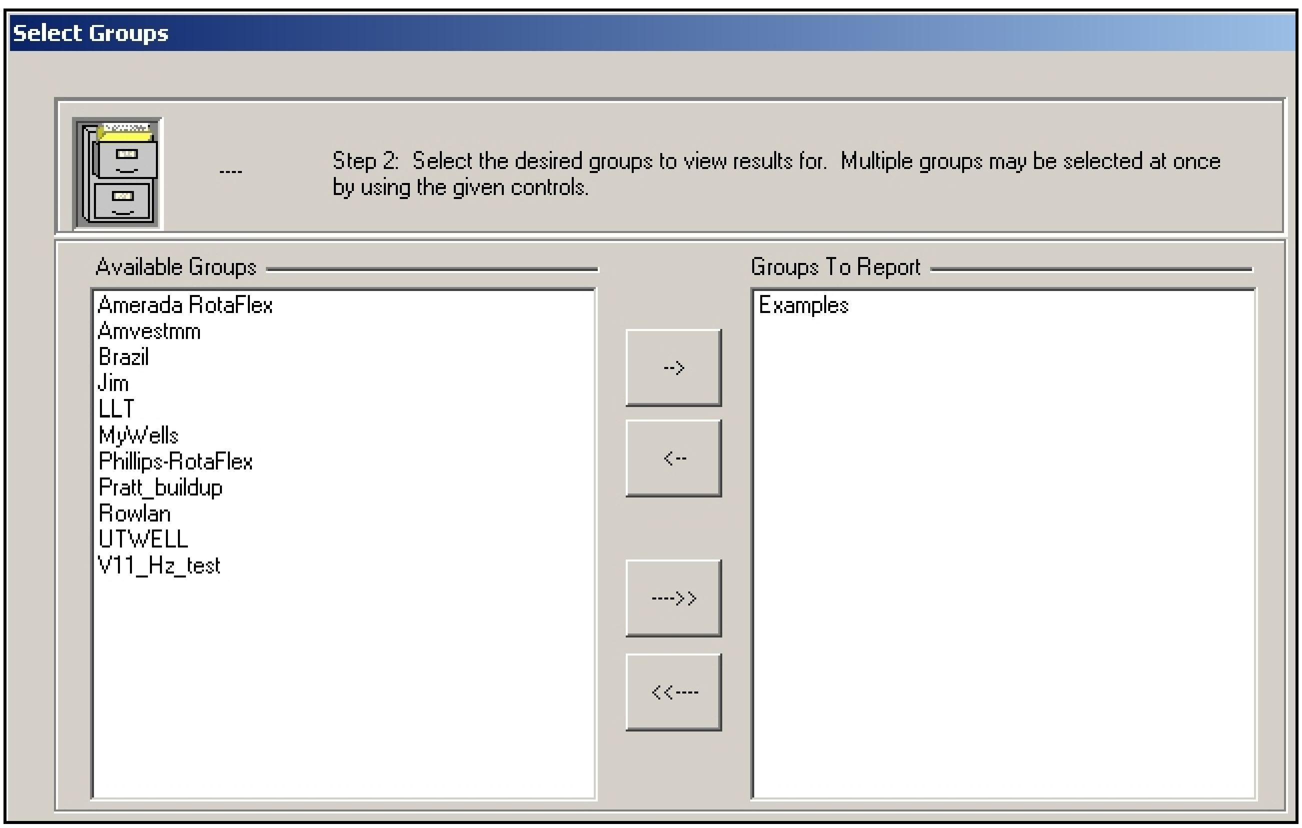
Selecting the Data Export Wizard opens the following window:



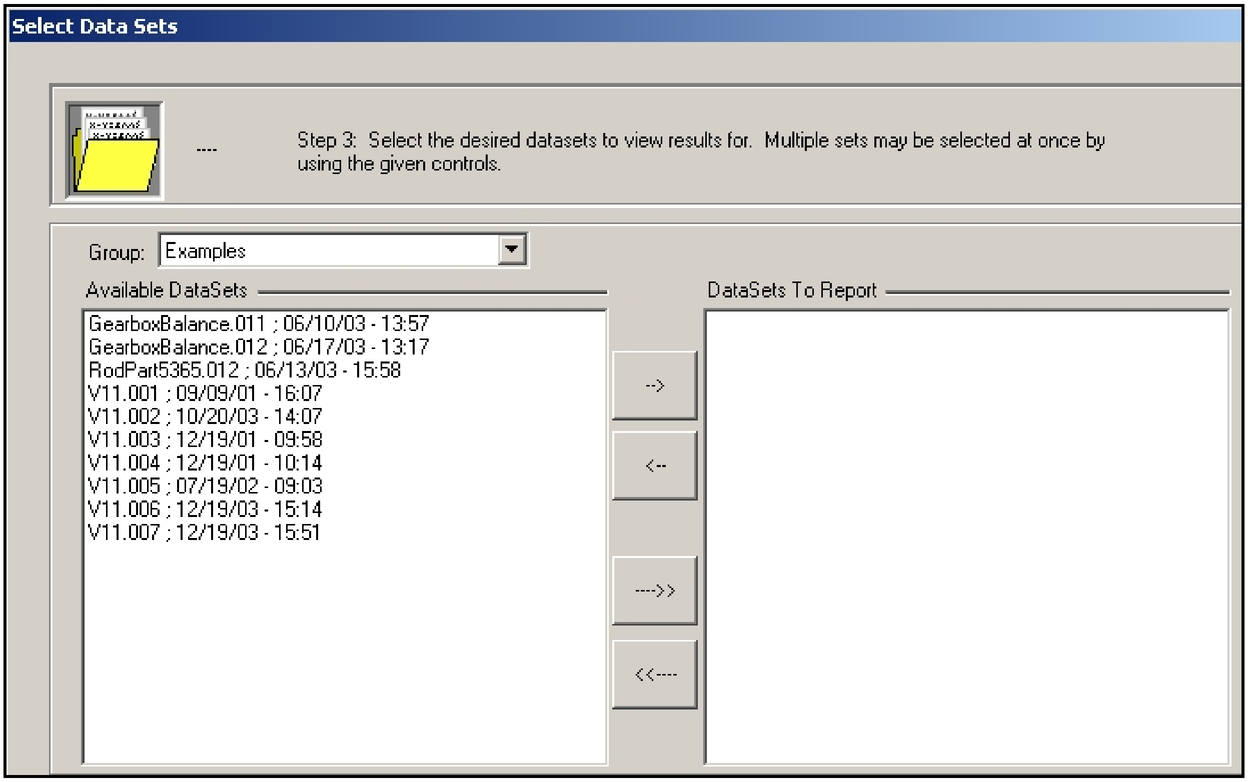
This allows selecting the data to be exported. Choosing **All Valid Dates** and clicking **Next**, will retrieve **all** the TWM groups where data is stored. Selecting **By Week** or **By Range** allows selecting only certain data sets. Following is the screen that shows the available groups:



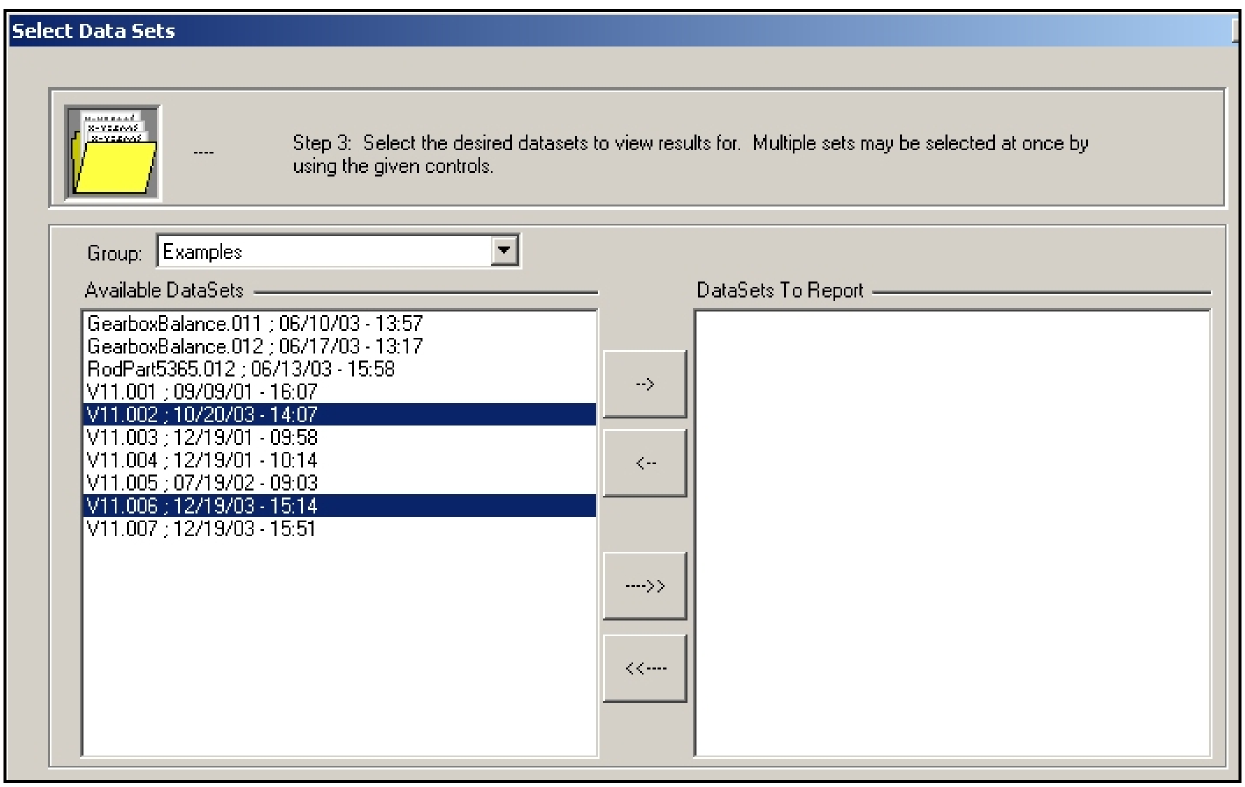
Select the group of interest and click on the **Right Arrow** to move it to the window labeled **Groups to Report** as shown below:



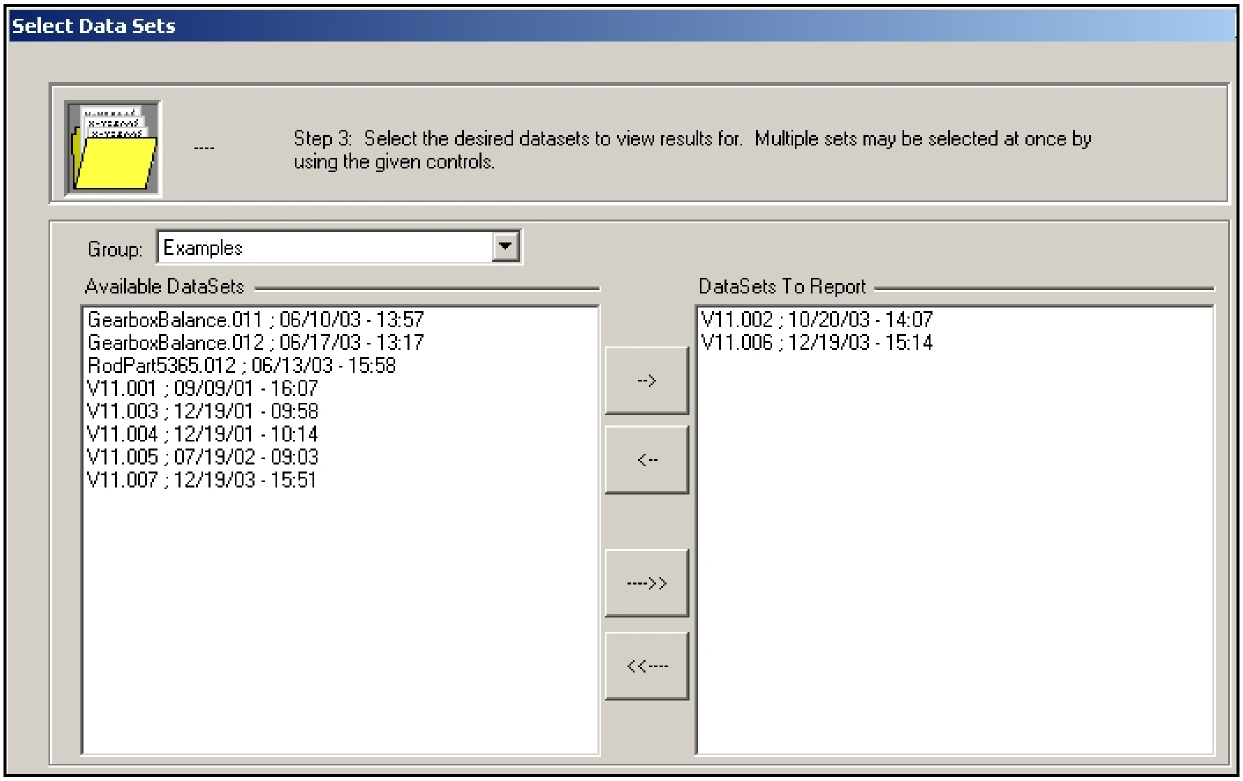
Clicking **NEXT** will display all the Data Sets available for exporting within the selected group:



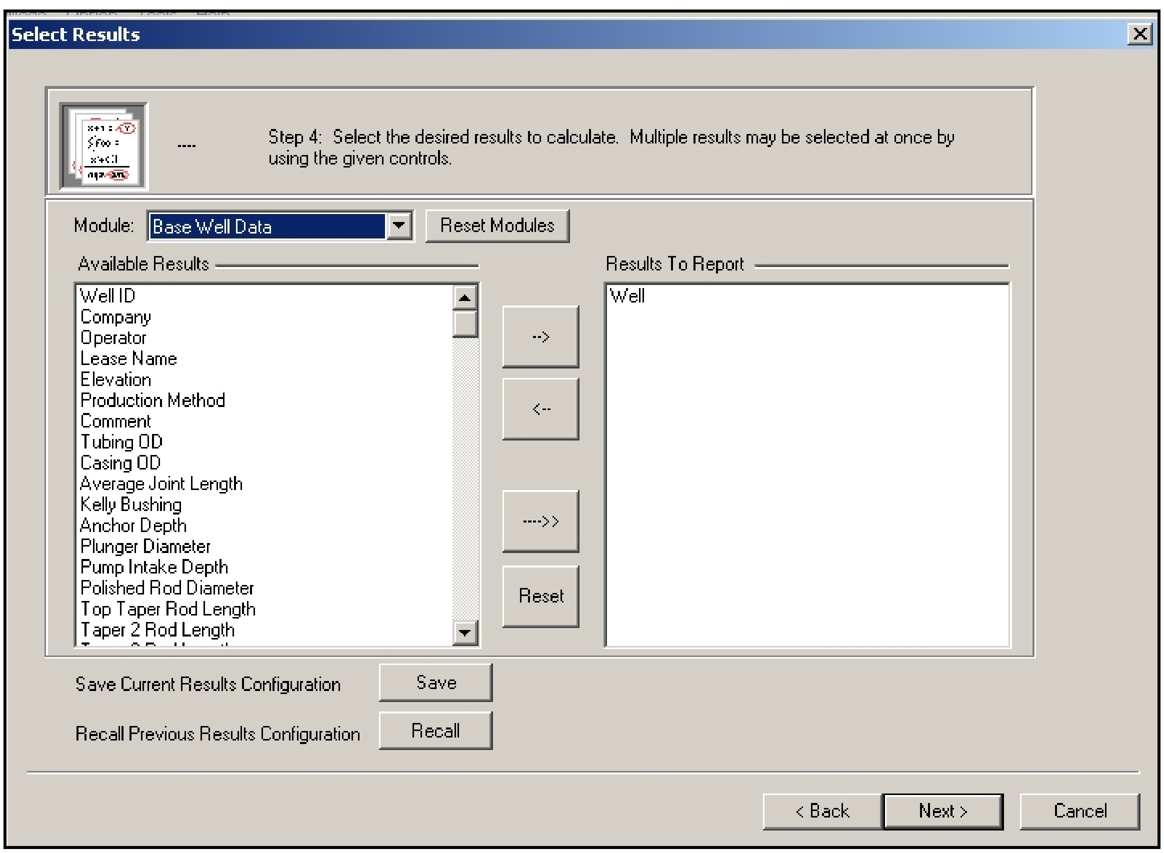
Then select the data set from which the data is to be exported and use the right arrow to move it to the window on the right:



The data sets are date and time-stamped so that the user can select the specific test that he wishes to export to the flat file using the arrow button to move them to the **Data Set to Report** panel:

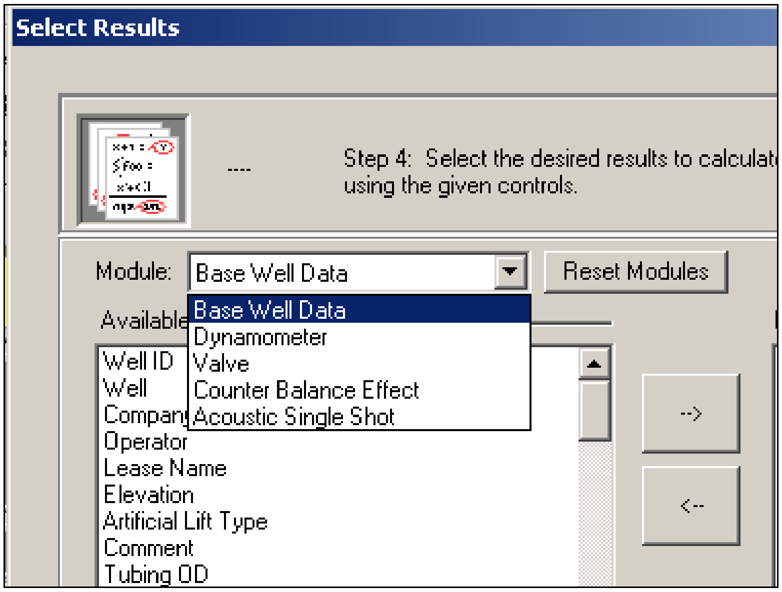


Clicking NEXT will open the windows used to select the specific data items to be exported to the spreadsheet.

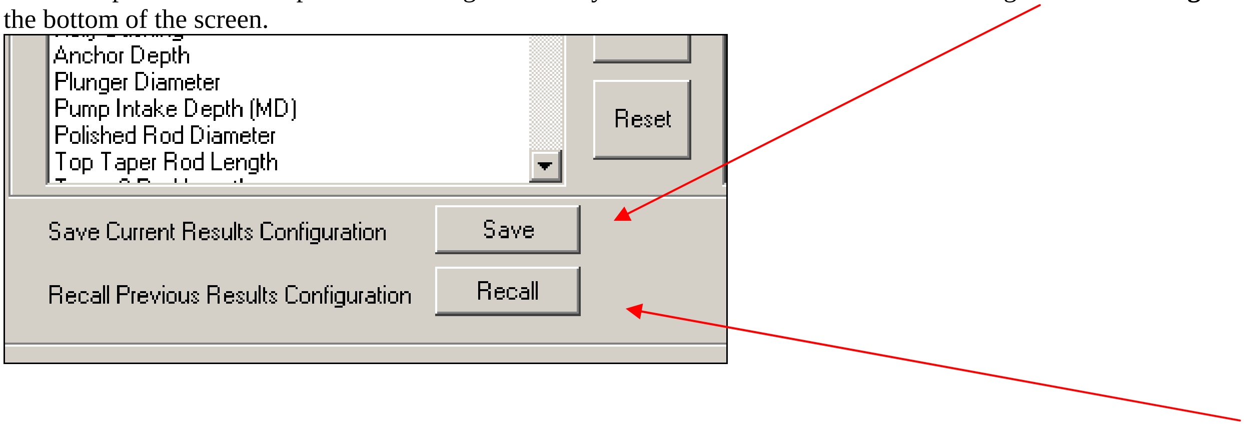


Items should be selected and moved to the right panel to construct the configuration of the spreadsheet to be exported.

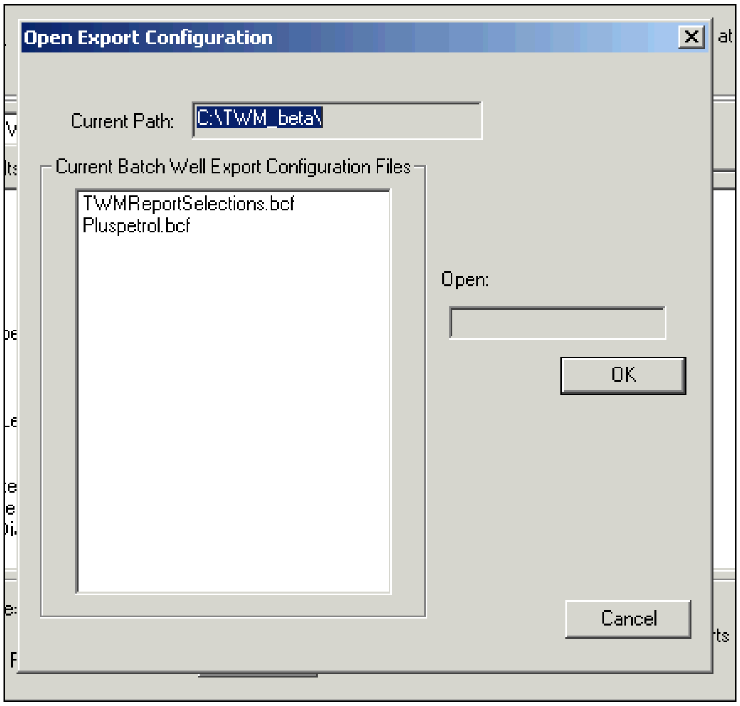
The procedure is repeated for each set of data (Well data, Dynamometer, Valve, Counterbalance effect and Acoustic as selected with the pull down menu as shown below:



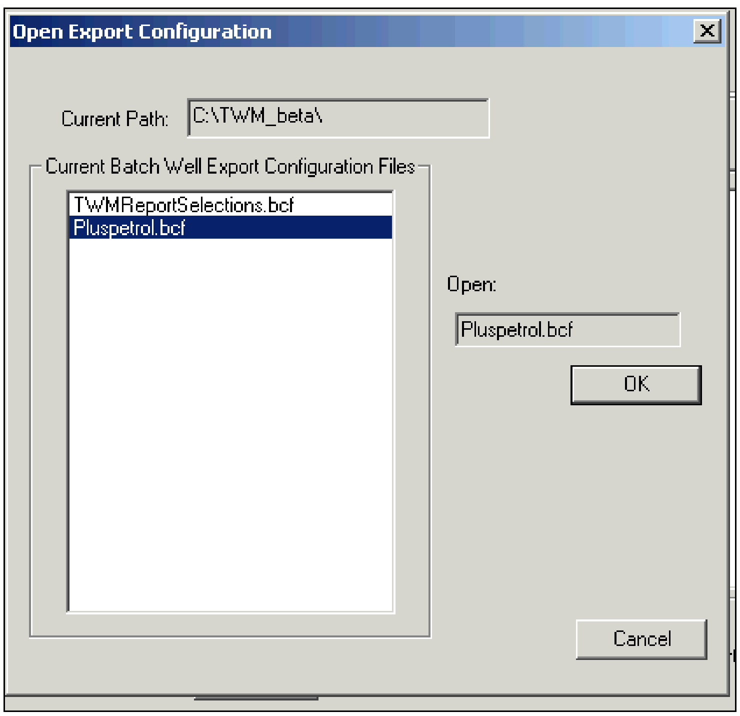
Once this procedure is completed the configuration may be saved for re-use in the future using the **Save Configuration** button at the bottom of the screen.



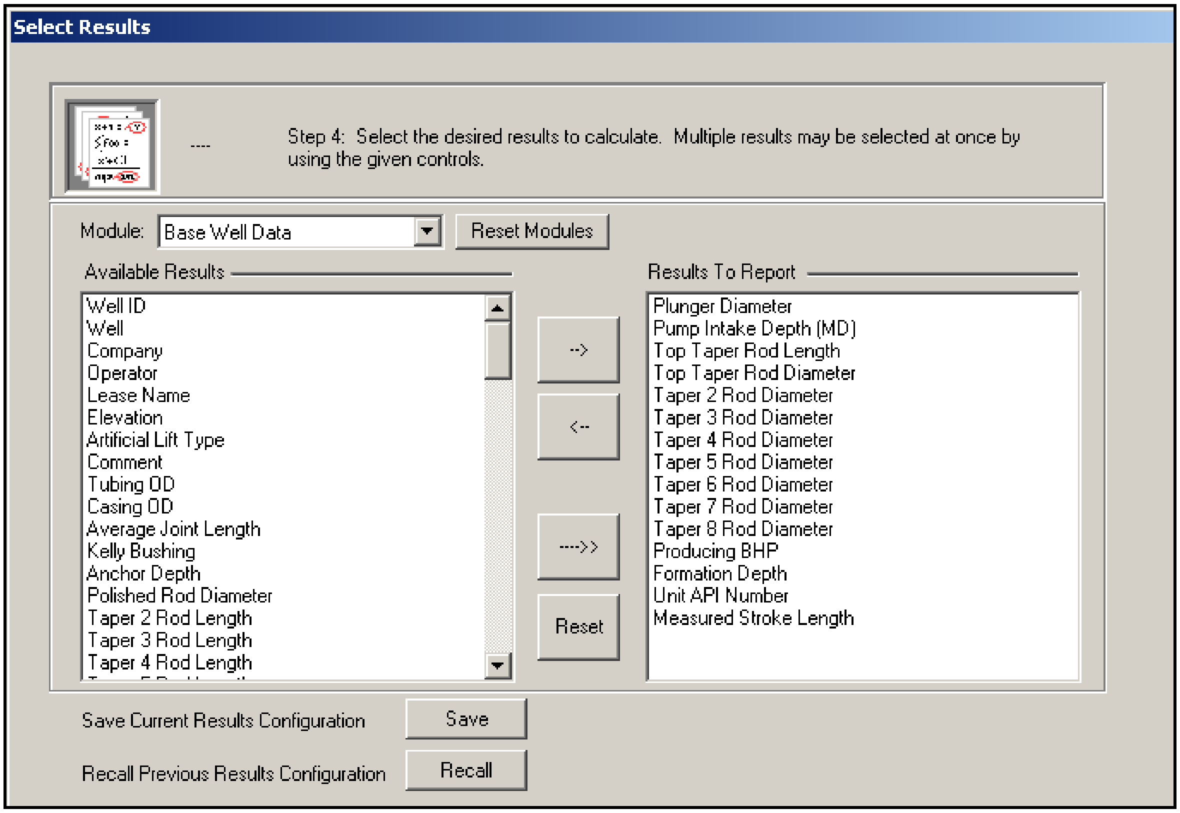
If an export spreadsheet **Configuration** had already been determined and saved, then at this point that configuration can be recalled by selecting **Recall,** and this will open the following window from where the configuration file (with **extension .bcf**) can be retrieved. (These files are stored in the directory where the TWM program is located.



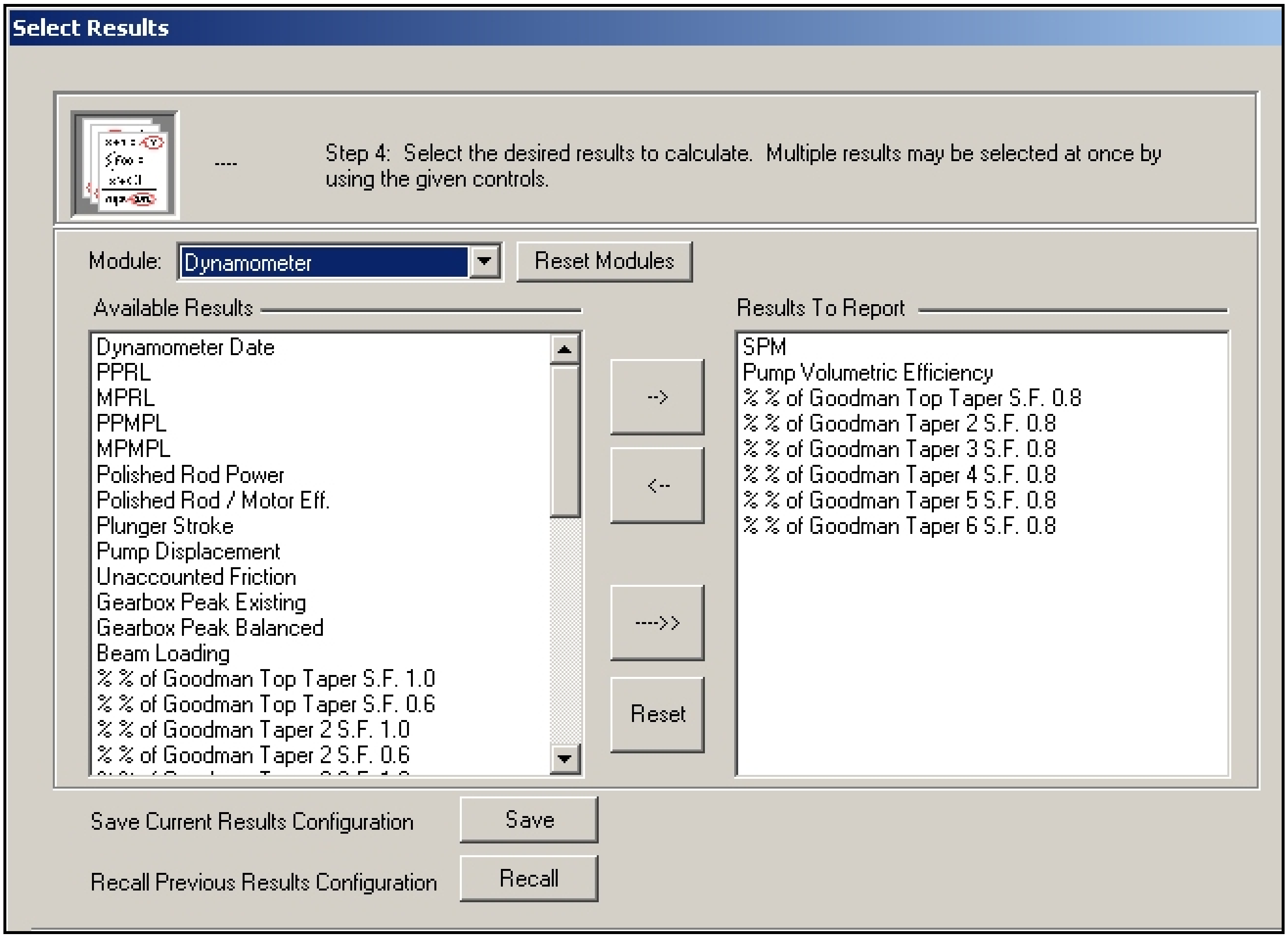
Double click on the configuration file name (with extension bcf) and then click **OK** to select it.



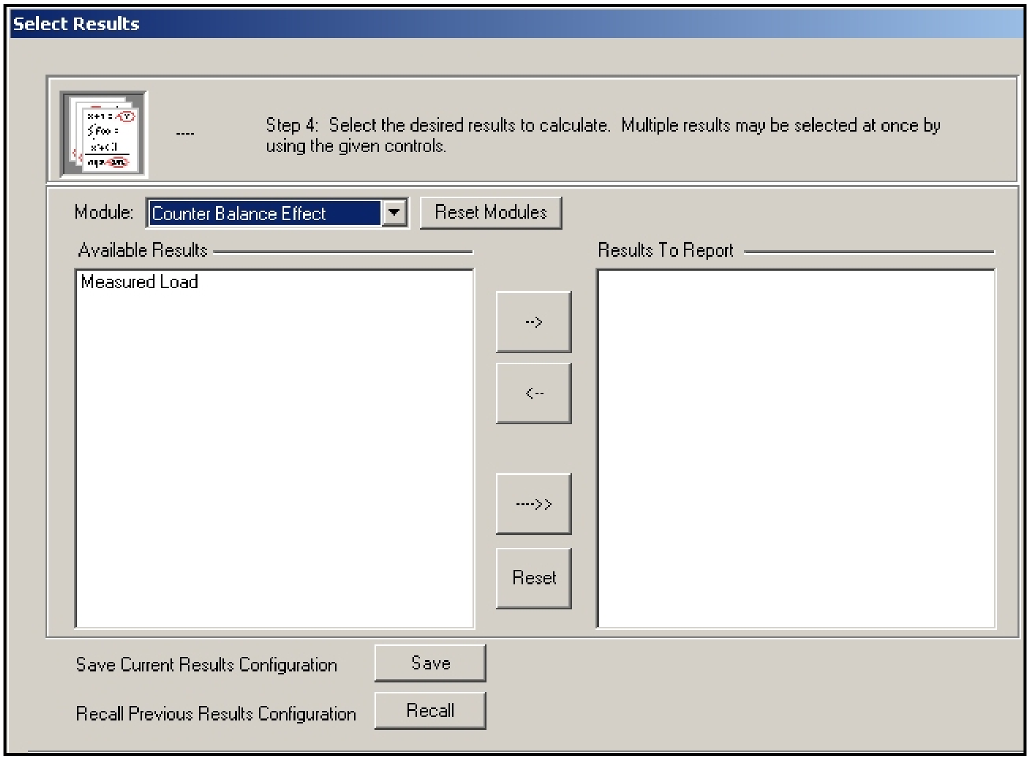
This will bring into the TWM export window the variables that will be exported for this configuration for each module:

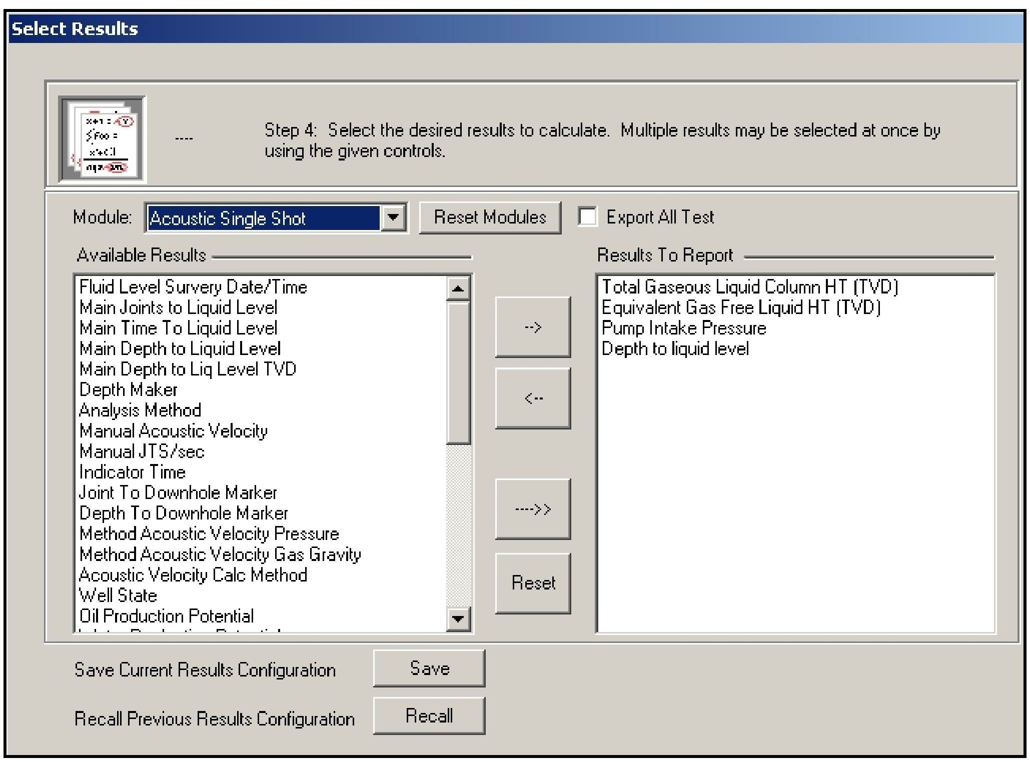


and the data for the other modules will also be selected based on the previously stored configuration.

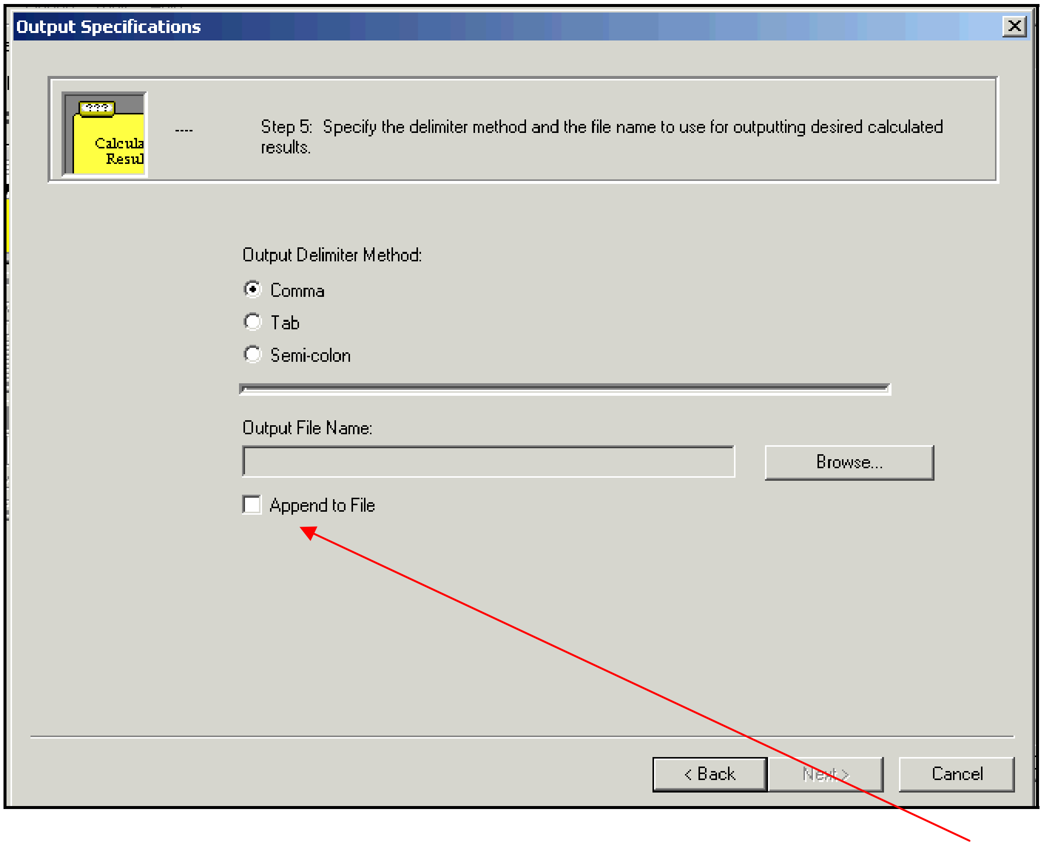


(Note that in this example, some of these modules do not output any data)

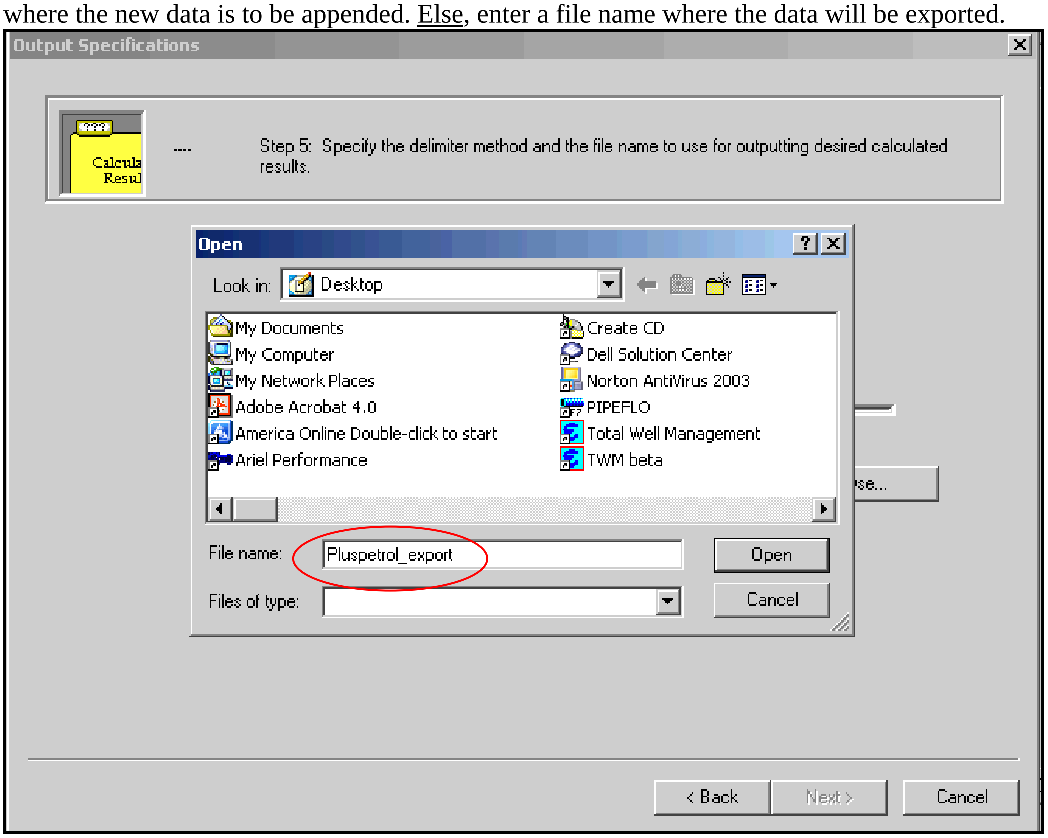




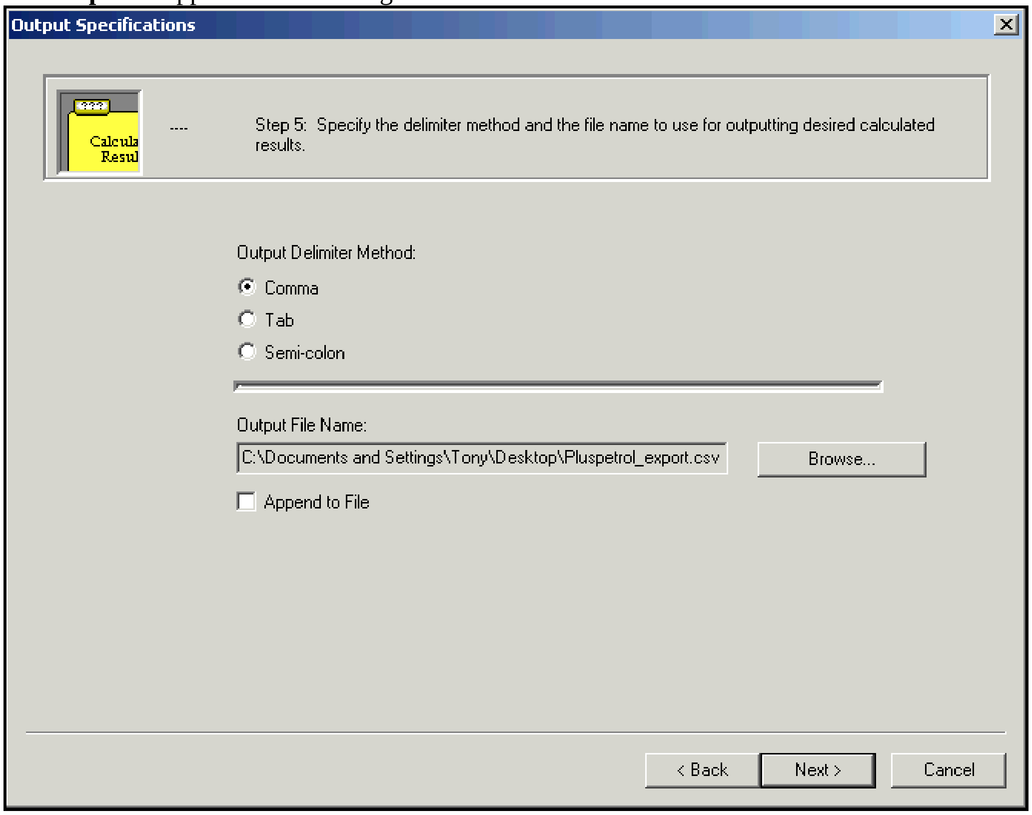
Clicking NEXT will display the following figure to select the type and name of the exported spreadsheet:



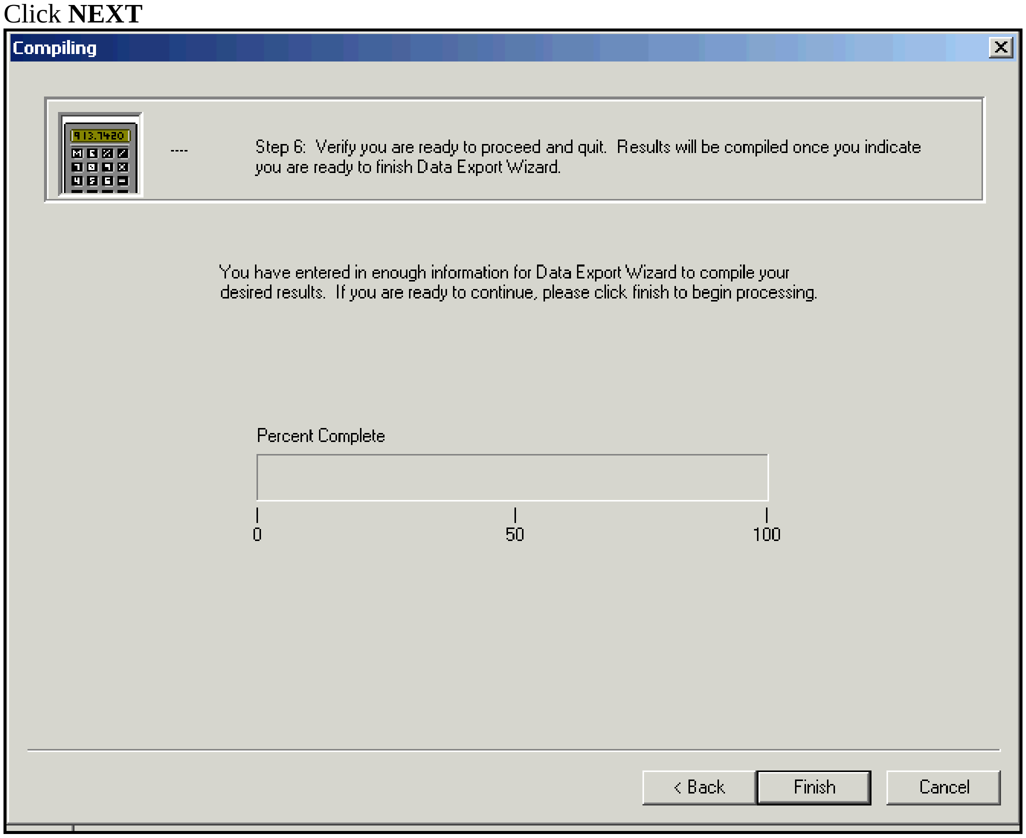
NOTE: If data had previously been exported to a given file, then **checkmark** the box **Append to File** and select the existing file where the new data is to be appended. Else, enter a file name where the data will be exported.



Click **Open** to append to an existing file or **Browse** if a new file is to be written:



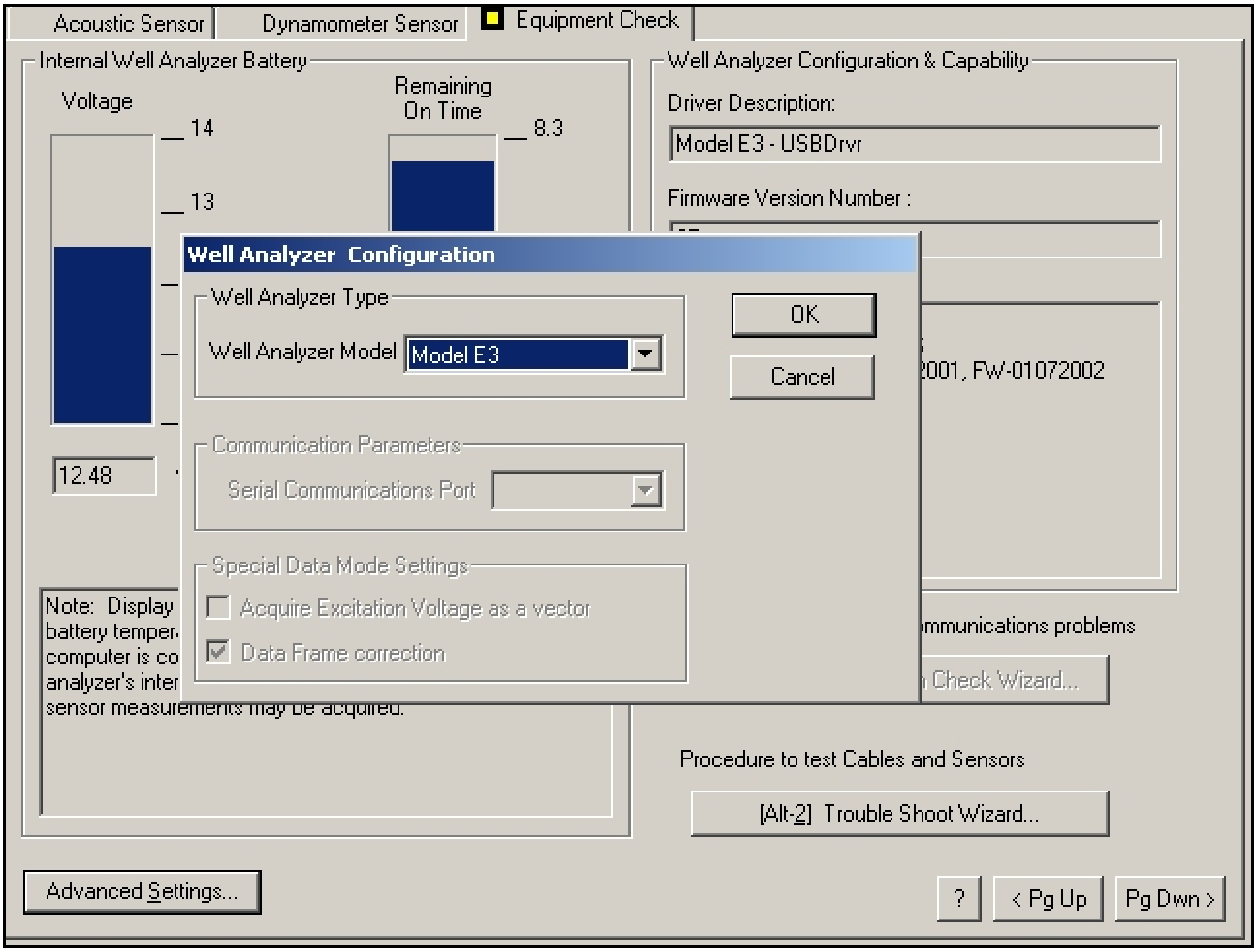
Click **NEXT**



and click **FINISH**. This will generate the exported data file or will append the new data to the existing file.

12.2 - Hardware Testing Model E3

This Well Analyzer model communicates with the Laptop using the **USB** port

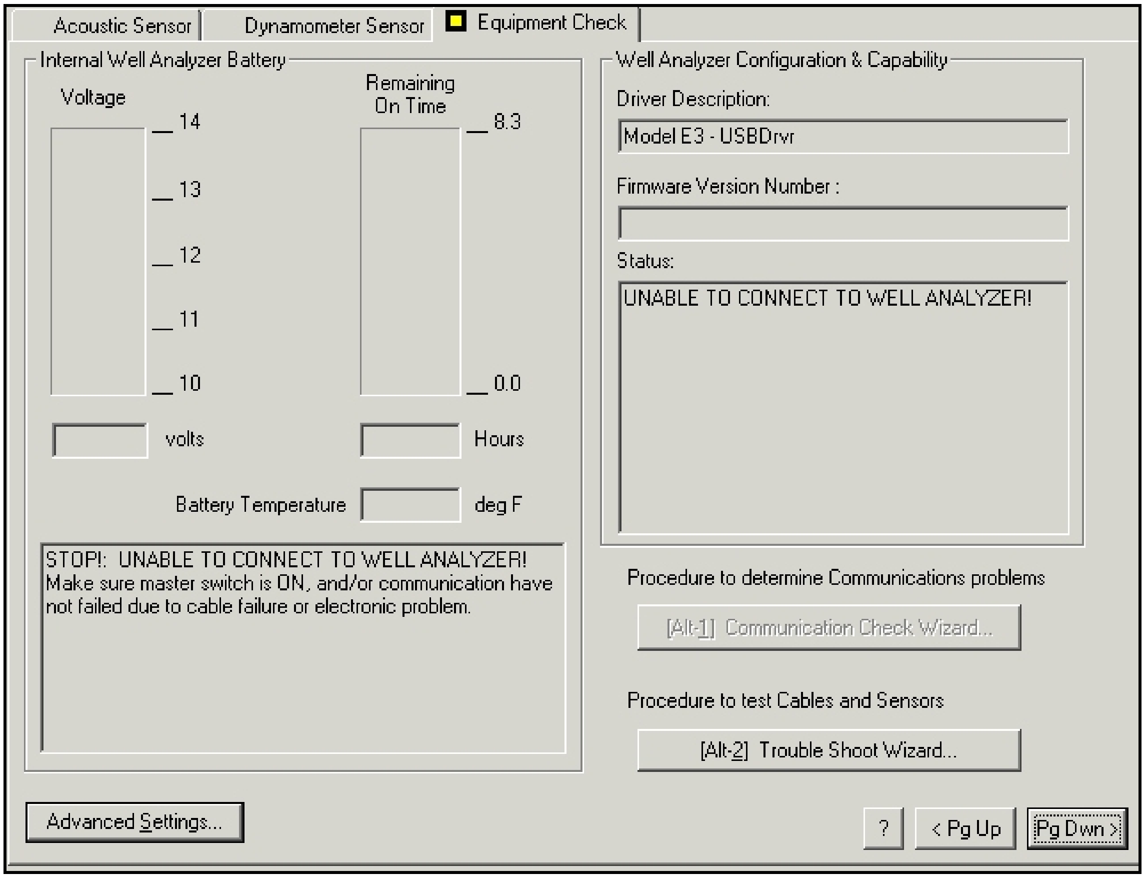


Testing the operation of the electronic hardware and cables is undertaken using the **Trouble Shoot Wizard** in the **Equipment Check** Tab from the SYSTEM **SETUP** module. The purpose of the utility is to quickly determine whether a hardware fault is present and in particular to test that the batteries are properly charged, the transducer circuits are not shorted, the cables and connectors are not shorted or open, and that the Well Analyzer amplifiers are operating within specifications.

12.2.1 - Hardware Testing from Equipment Check Screen

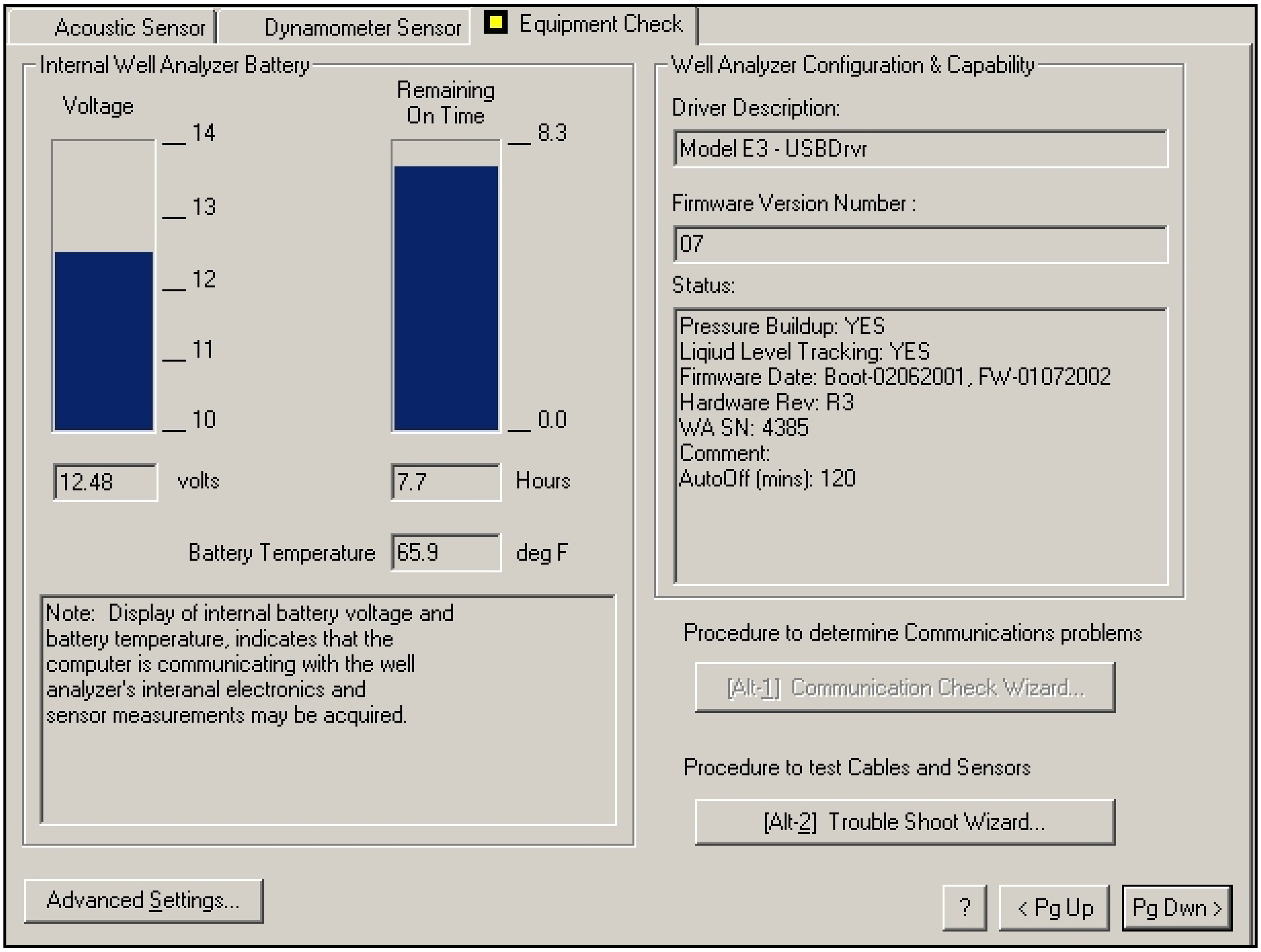
Before entering this screen the user should verify that all the transducer coefficients have been entered correctly as well as all the transducer serial numbers. The user should verify that the voltage values are within the indicated limits. Discrepancies could be caused either by faulty transducers or by faulty electronics or cables and connectors.

The following figure shows the screen when the laptop cannot connect to the Well Analyzer:



- The purpose of the **Trouble Shoot Wizard** (Alt-2) is to help isolate the fault either to the transducers or the electronics.
- The purpose of the **Communication Wizard** (Alt-1) is to identify problems related to data transmission between the computer and the A/D electronics in the E1 and E2 models. IT IS NOT ACTIVE IN THE E3 MODEL SINCE COMMUNICATION IS CHECKED AUTOMATICALLY BY THE SOFTWARE
- If communication fails with the **E3 model**, the problem probably resides in a poor USB connection. The user should exit the TWM program, turn **OFF** the Well Analyzer, unplug the USB cable from the computer, reconnect the USB cable making sure it is not kinked or stressed, turn **ON** the Well Analyzer and then restart the TWM program. If the problem persists contact Echometer Co.

When communication is established correctly the following screen displays the battery voltage, remaining battery life, and a listing of the software and hardware status and characteristics of the Well Analyzer as shown in the following figure:



The **Advanced Settings** button is used to indicate to the software the type of Well Analyzer that is in use (E1, E2 or E3) and select the corresponding communication port. The model type is correlated to the Well Analyzer Serial Number as follows:

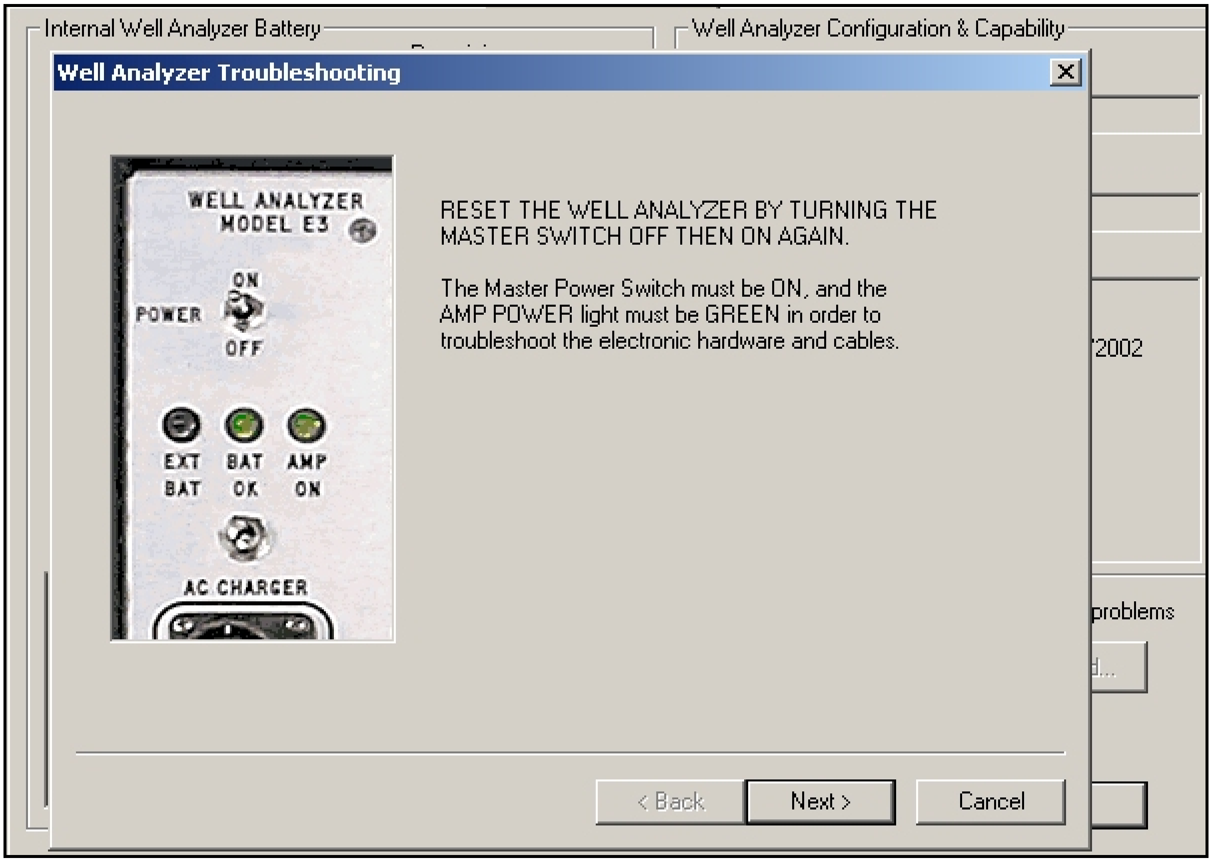
- E1 – Serial numbers up to 2999
- E2 - Serial numbers from 3000 to 3999
- E3 – Serial numbers from 4000 and up

12.3 - Trouble Shoot Wizard (E3)

When communication between the Well Analyzer and the computer is operating properly, the data acquisition functions are tested using the **Troubleshoot Wizard**

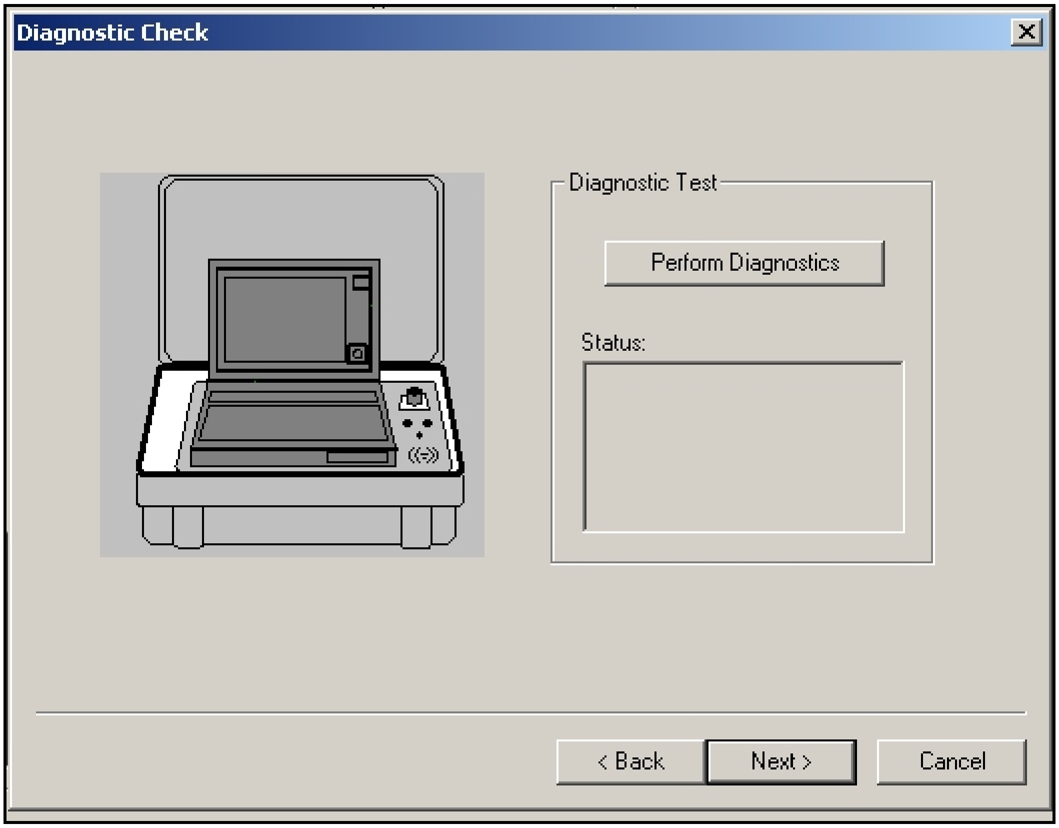
Clicking of the **Trouble Shoot Wizard** initiates a sequence of steps designed to check the operation of the Well Analyzer as follows.

Failure to turn master switch ON:

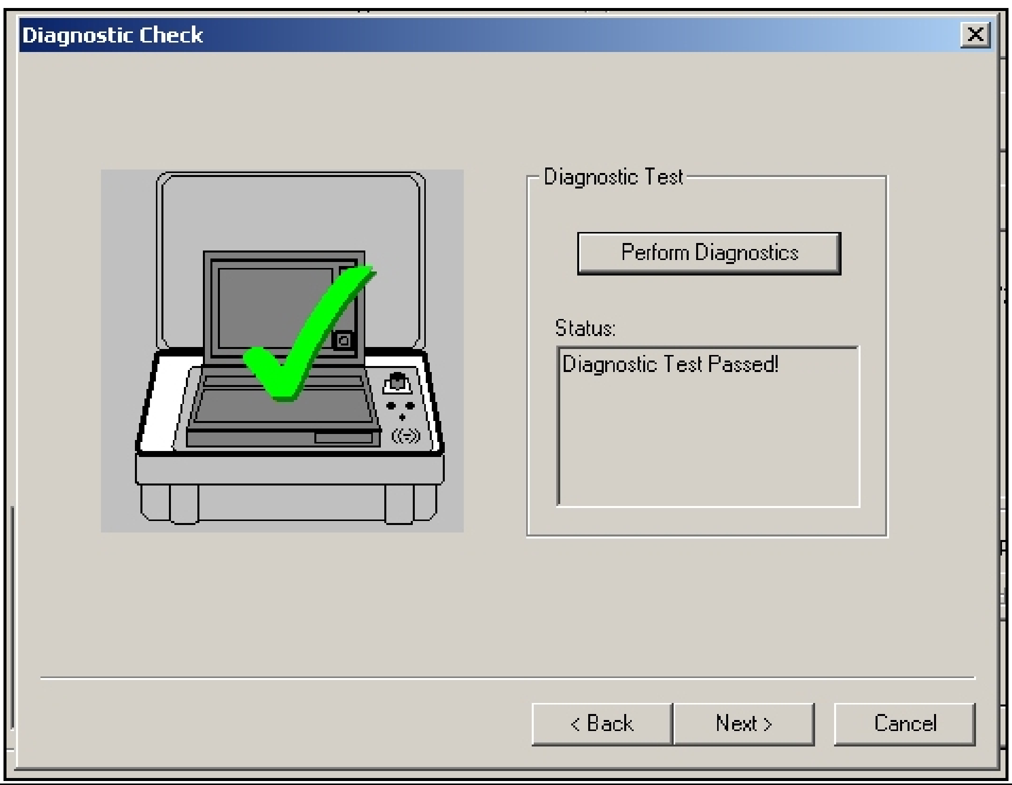


This is the most frequent cause of problems. Make sure that the Power **Switch is reset** any time that the program is terminated abnormally (blows-up!).

The next step is to perform an automatic diagnostic check of the communication and the internal electronics of the Well Analyzer:

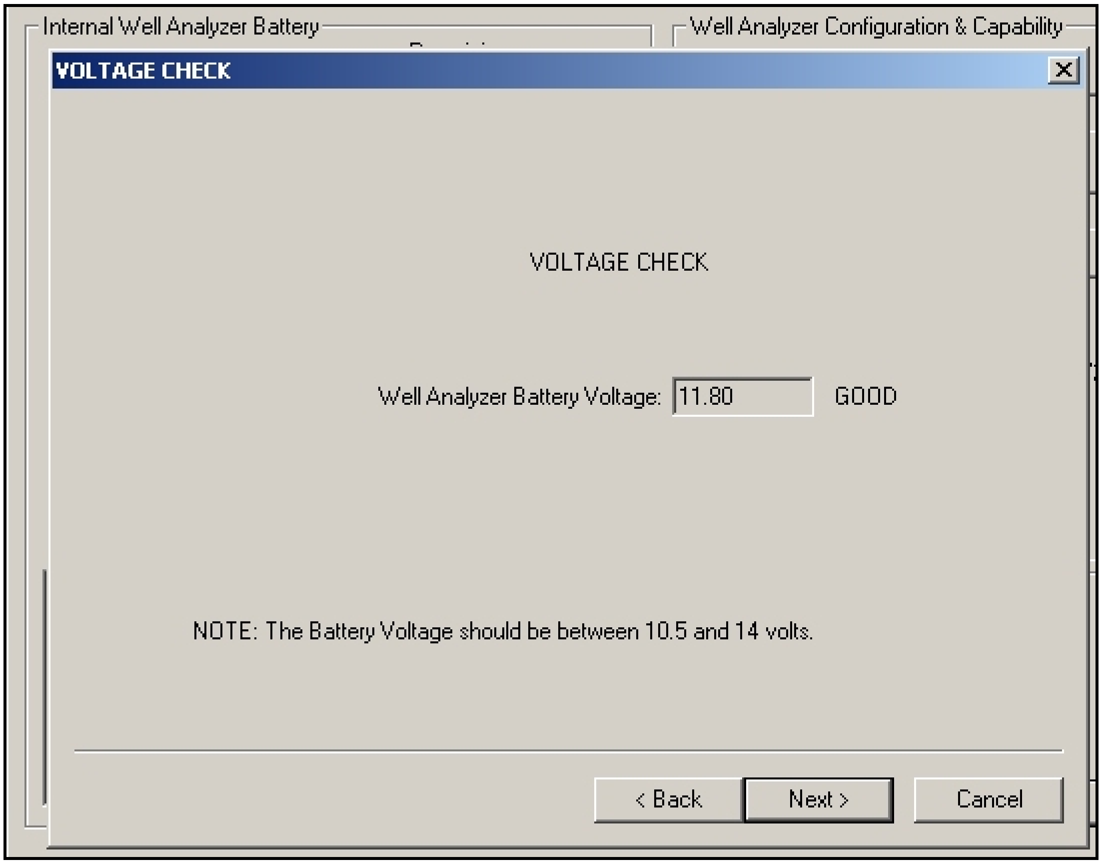


After clicking on the **Perform Diagnostics** button the following screen indicates that all is well with the internal electronics as shown below:



12.3.1 - Voltage Check

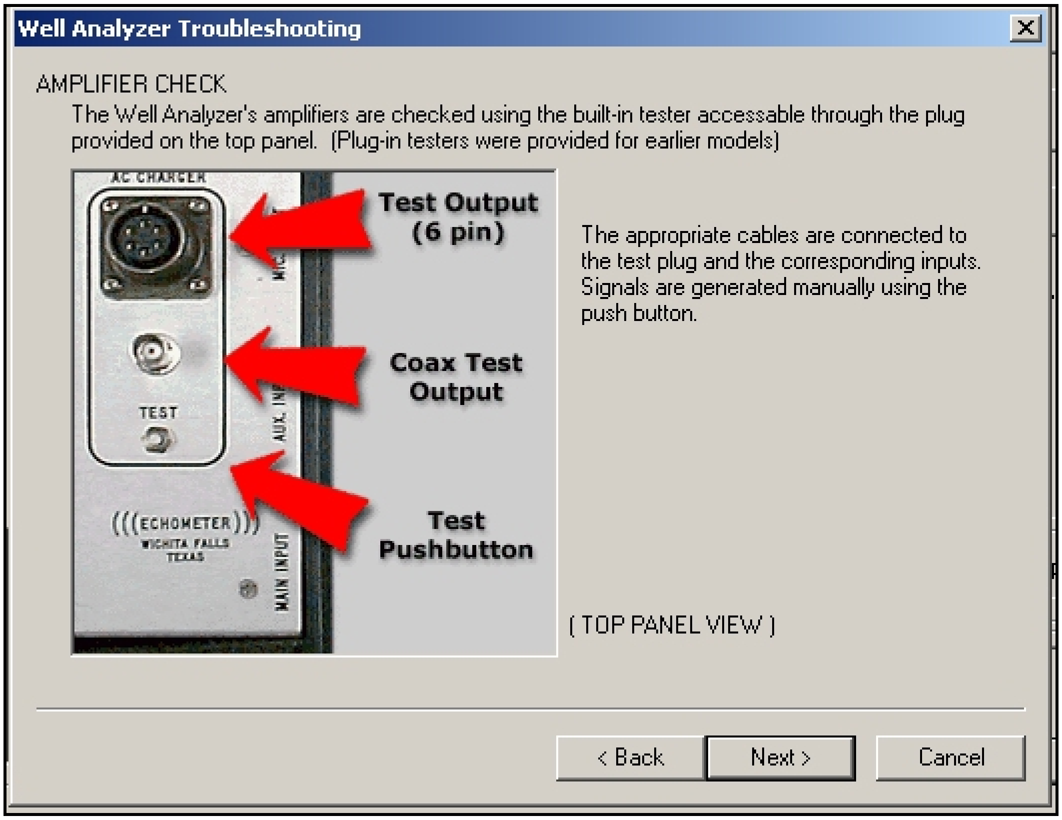
The screen displays the existing Well Analyzer battery voltage if the values were not within the accepted limits, the battery should be recharged and the test repeated later.

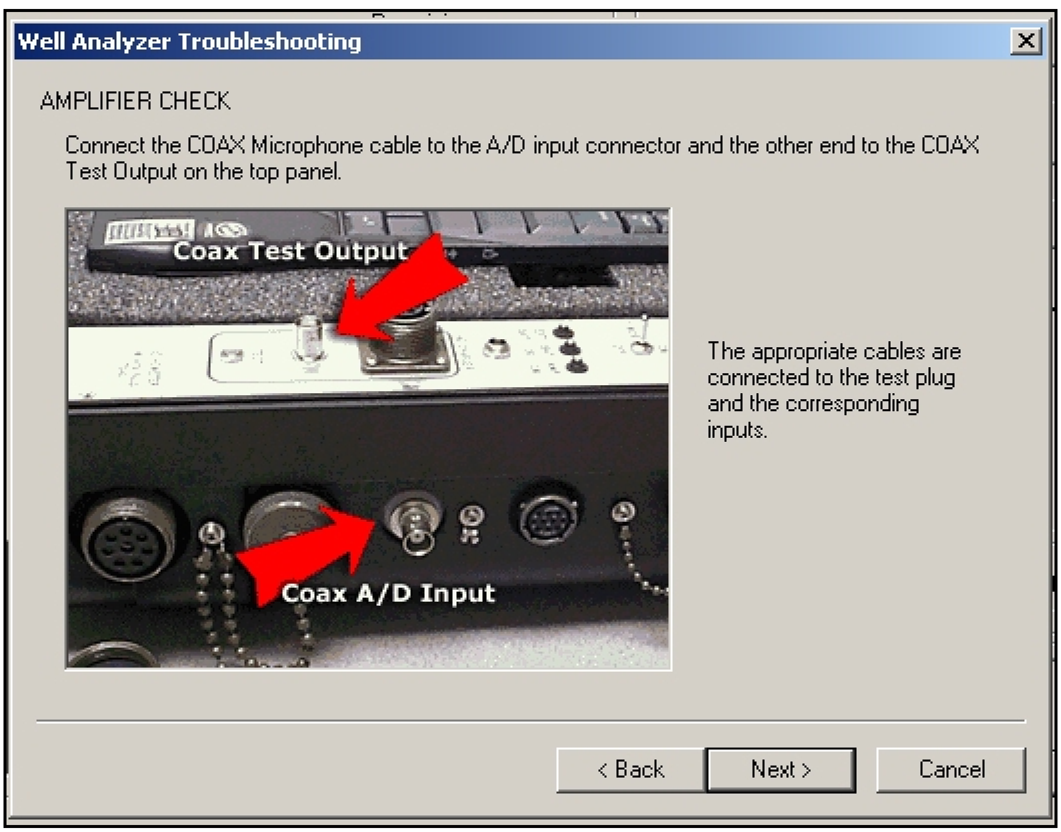


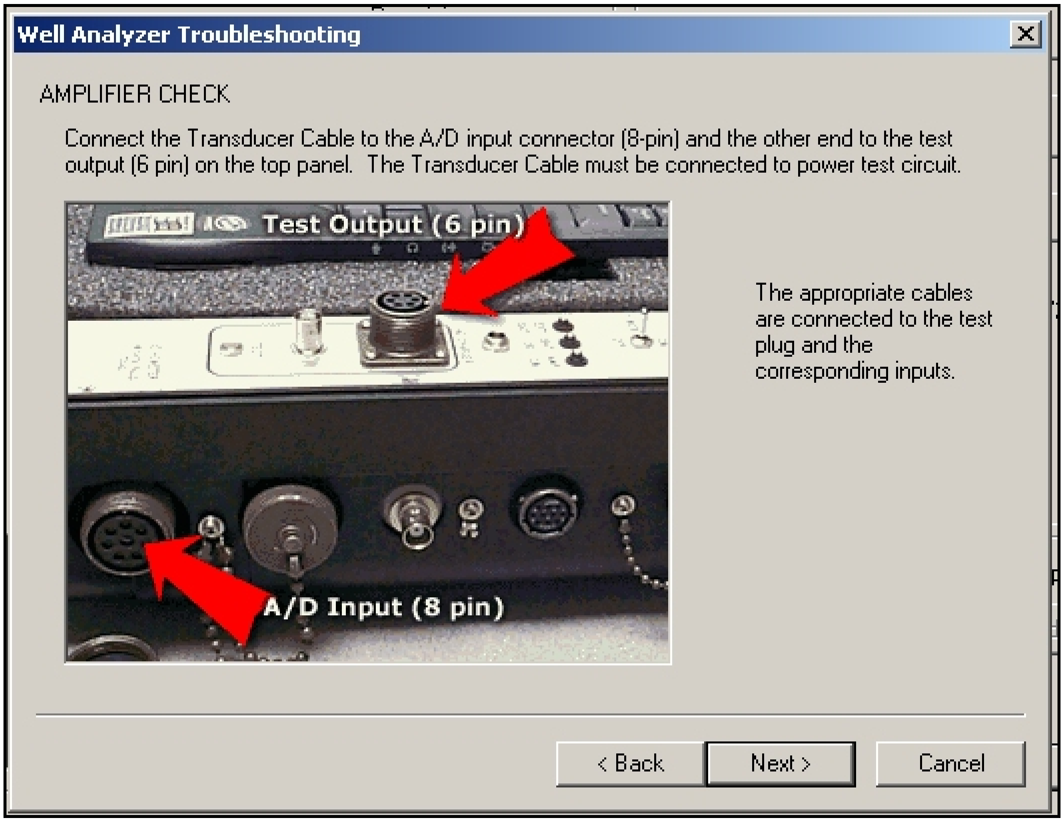
12.3.2 - Amplifier and Cable Checks

The Well Analyzer's amplifiers are checked using the built-in tester (plug-in testers were provided for earlier models) accessible through the plug provided on the top panel. The appropriate cables are connected to the test plug and to the corresponding inputs. Signals are generated manually using the push button. When the appropriate response is not obtained it is important to check that the failure is not due to a faulty cable or connector. Either a spare cable should be used or continuity and ground checks using an Ohm-meter should be made on the questionable cable before concluding that the amplifiers are not operating properly. The instructions presented in the following screens should be followed in order to check both the cables and the amplifiers.

The following instruction screens are presented and show how the cables should be connected to the test ports on the top panel of the Well Analyzer:

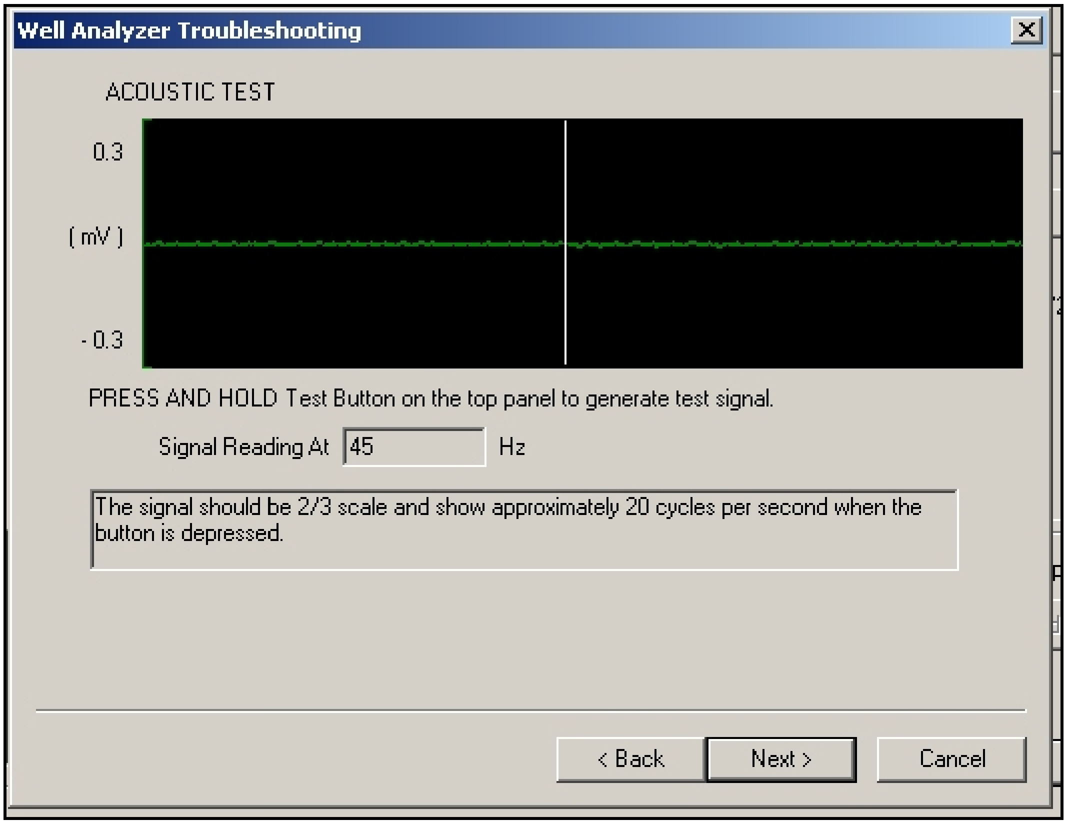

Well Analyzer Troubleshooting
AMPLIFIER CHECK
The Well Analyzer's amplifiers are checked using the built-in tester accessable through the plug provided on the top panel. (Plug-in testers were provided for earlier models)
AC CHARGER
Test Output (6 pin)
Coax Test Output
TEST
Test Pushbutton
AUX. INPUT
MAIN INPUT
ECHOMETER
WICHITA FALLS TEXAS
The appropriate cables are connected to the test plug and the corresponding inputs. Signals are generated manually using the push button.
(TOP PANEL VIEW)
< Back
Next >
Cancel


Well Analyzer Troubleshooting
AMPLIFIER CHECK
Connect the COAX Microphone cable to the A/D input connector and the other end to the COAX Test Output on the top panel.
Coax Test Output
Coax A/D Input
The appropriate cables are connected to the test plug and the corresponding inputs.
< Back
Next >
Cancel

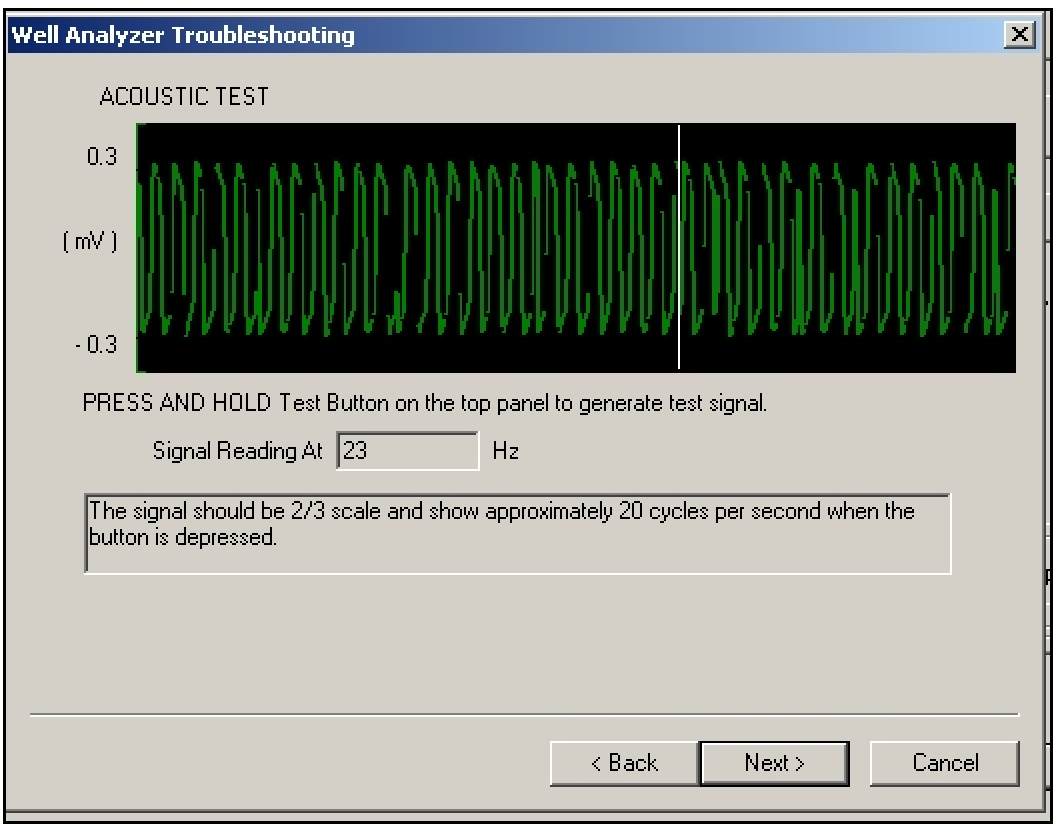


12.3.3 - <u>Acoustic channel Test Output</u>

This tests both the coaxial cable and the Acoustic channel amplifier



Depressing the test button should display a constant amplitude signal of about 20 Hz frequency, as shown in the following figure:

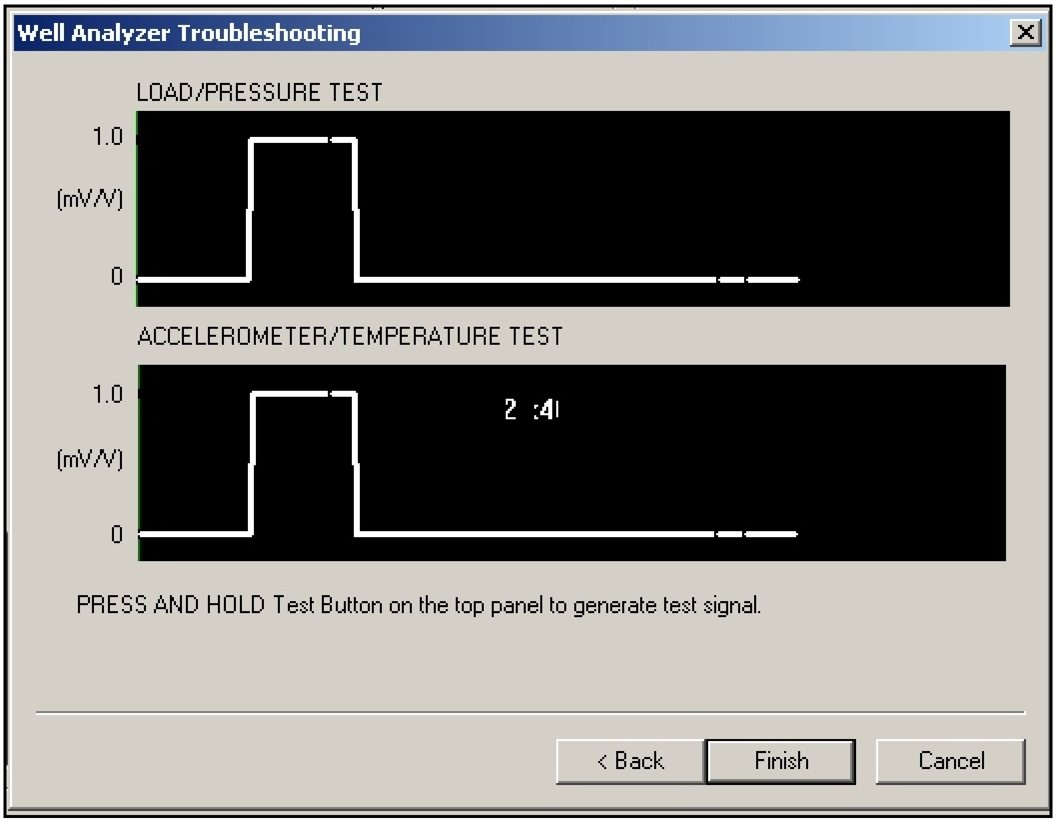


12.3.4 - Cables, amplifiers and A/D converter check.

This test verifies that the main transducer cable and the A/D converter are performing properly. The test should be repeated using **all the cables individually and connected in series** so as to check the connectors as well as the cables.

NOTE: When testing the **coiled cable** it should also be stretched to its full operating length

Whenever the test button is depressed the signal should increase from zero to 1 mV/v as shown below.



This completes the testing sequence.

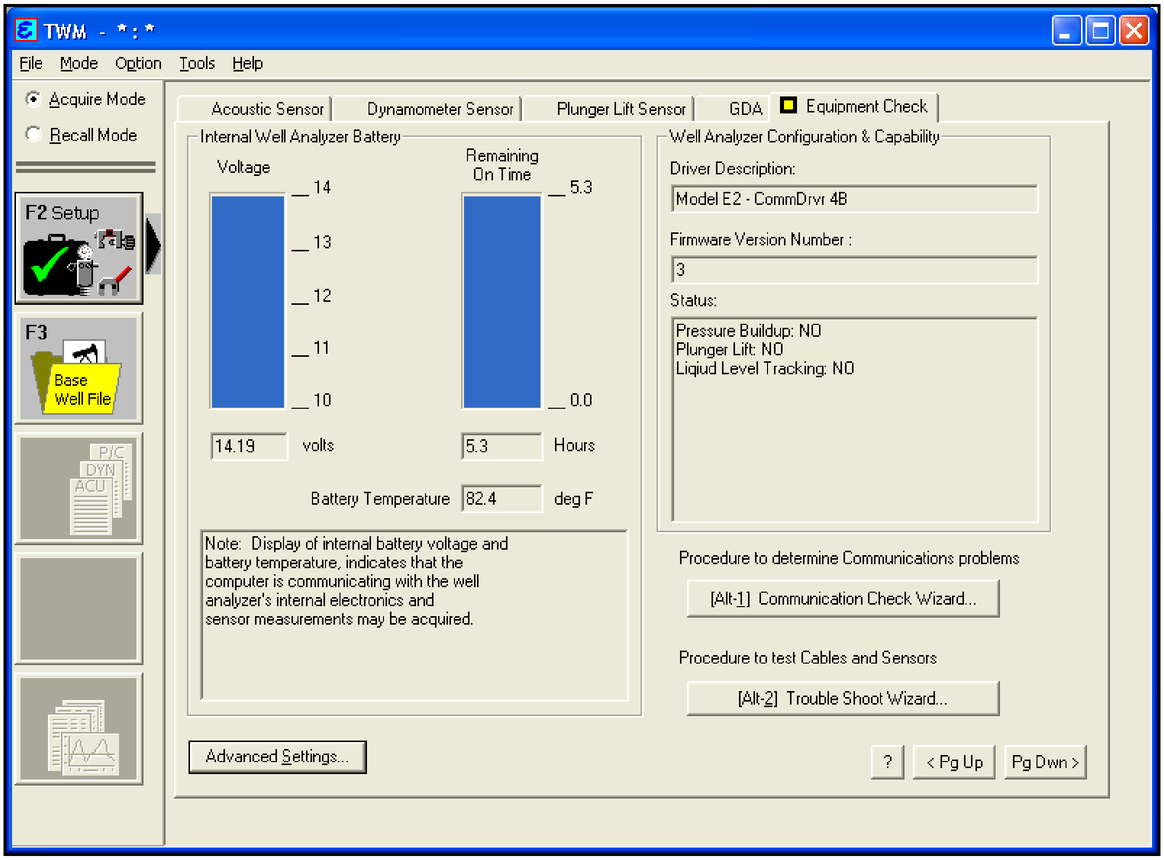
12.4 - Hardware Testing for Well Analyzer Models E1 and E2

These Well Analyzer models communicate with the laptop via the SERIAL Port

Testing the operation of the electronic hardware and cables is undertaken using the **Trouble Shoot Wizard** in the **Equipment Check** Tab from the **SYSTEM SETUP** module. The purpose of the utility is to quickly determine whether a hardware fault is present and in particular test that the batteries are properly charged, the transducer circuits are not shorted, the cables and connectors are not shorted or open, and that the Well Analyzer amplifiers are operating within specifications.

12.4.1 - Hardware Testing from Equipment Check Screen

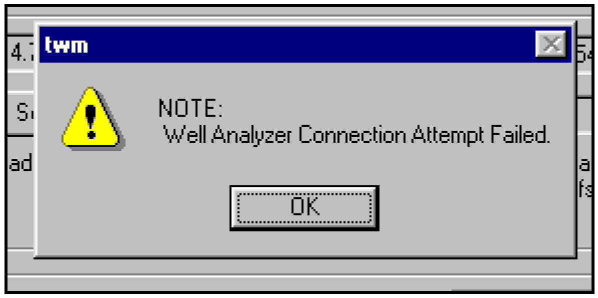
Before entering this screen the user should verify that all the transducer coefficients have been entered correctly as well as all the transducer serial numbers. The user should verify that the voltage values are within the indicated limits. Discrepancies could be caused either by faulty transducers or by faulty electronics or cables and connectors.



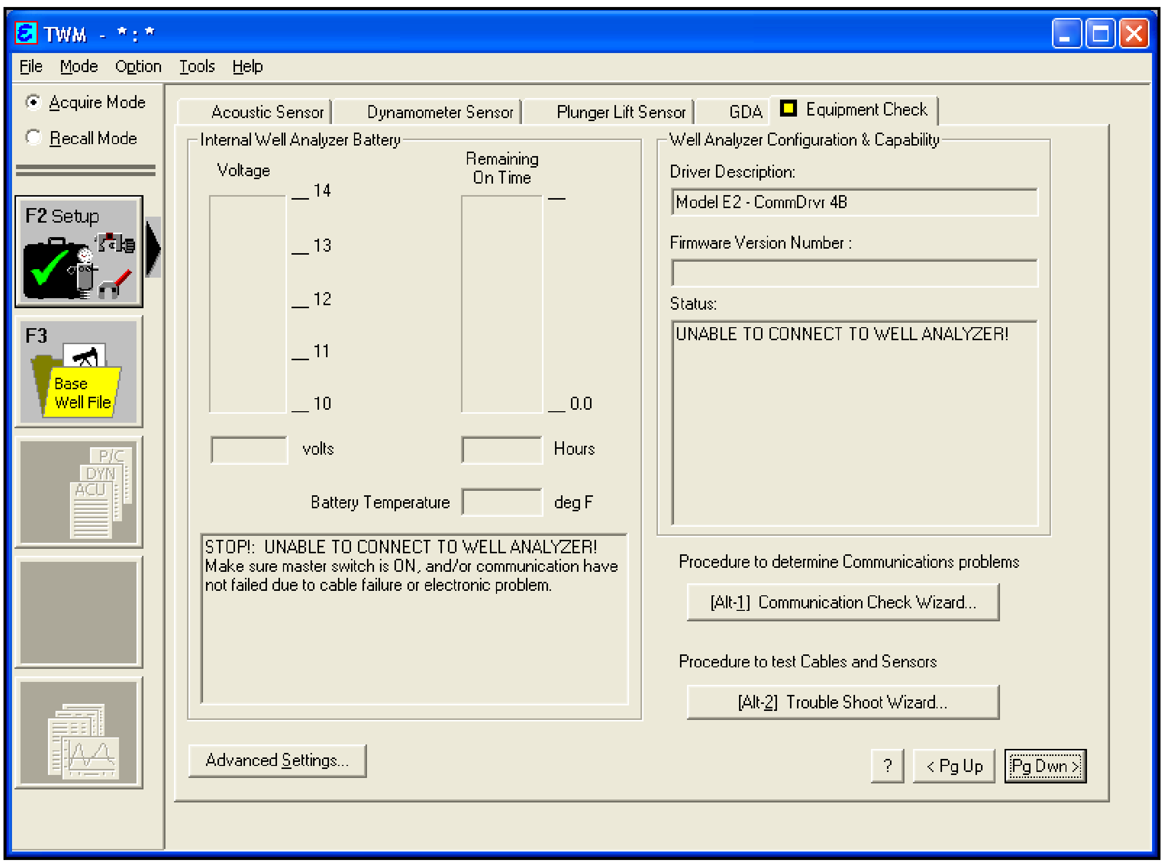
- The purpose of the Communication Wizard (Alt-1) is to identify problems related to data transmission between the computer and the A/D electronics.
- The purpose of the Trouble Shoot Wizard (Alt-2) is to help isolate the fault either to the transducers or the electronics.

12.4.2 - Communication Wizard

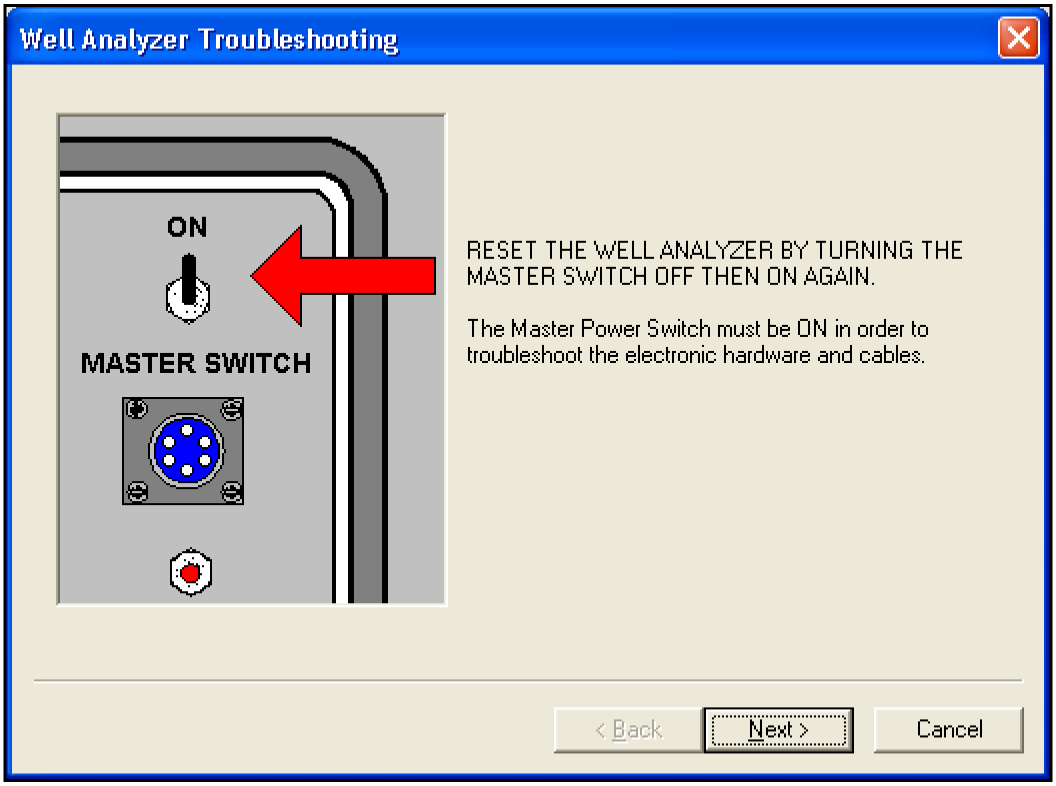
Whenever the Equipment Check Tab is selected the software checks data transmission with the A/D Electronics. The following message will be displayed whenever communication cannot be established:



Selecting OK results in the following display:



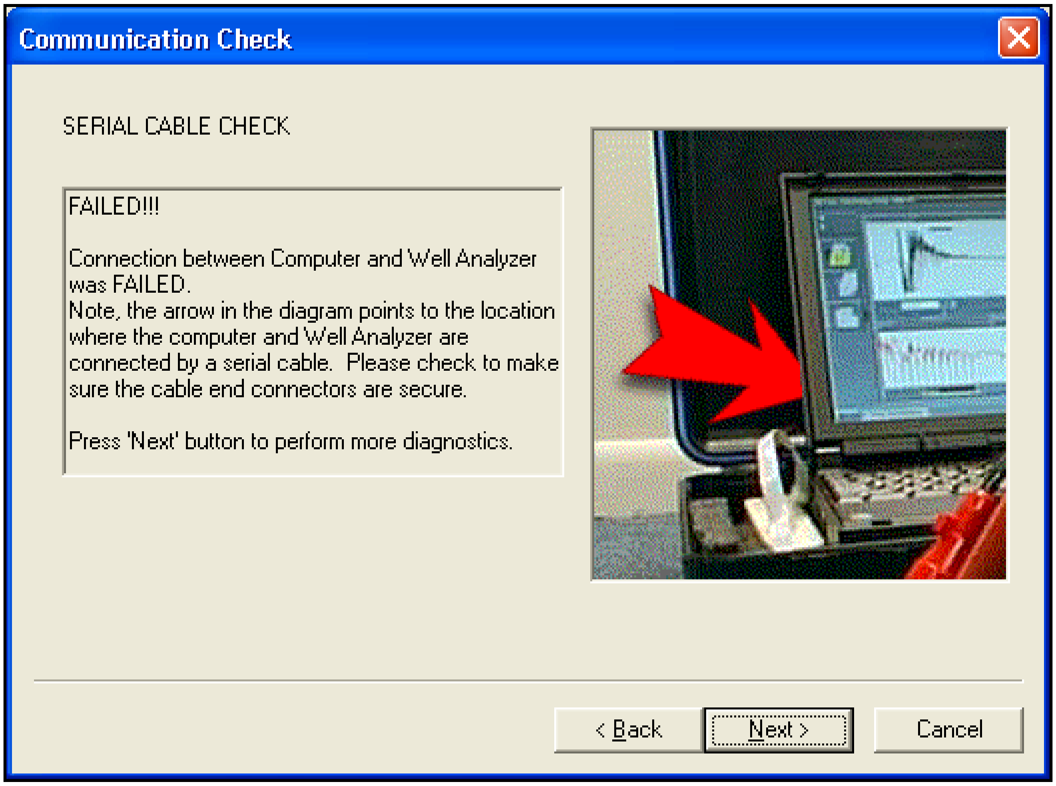
The next step is to use the **Communication Check Wizard** to isolate the problem. Select the wizard by entering **Alt-1** or clicking the corresponding button results in the following series of screens:

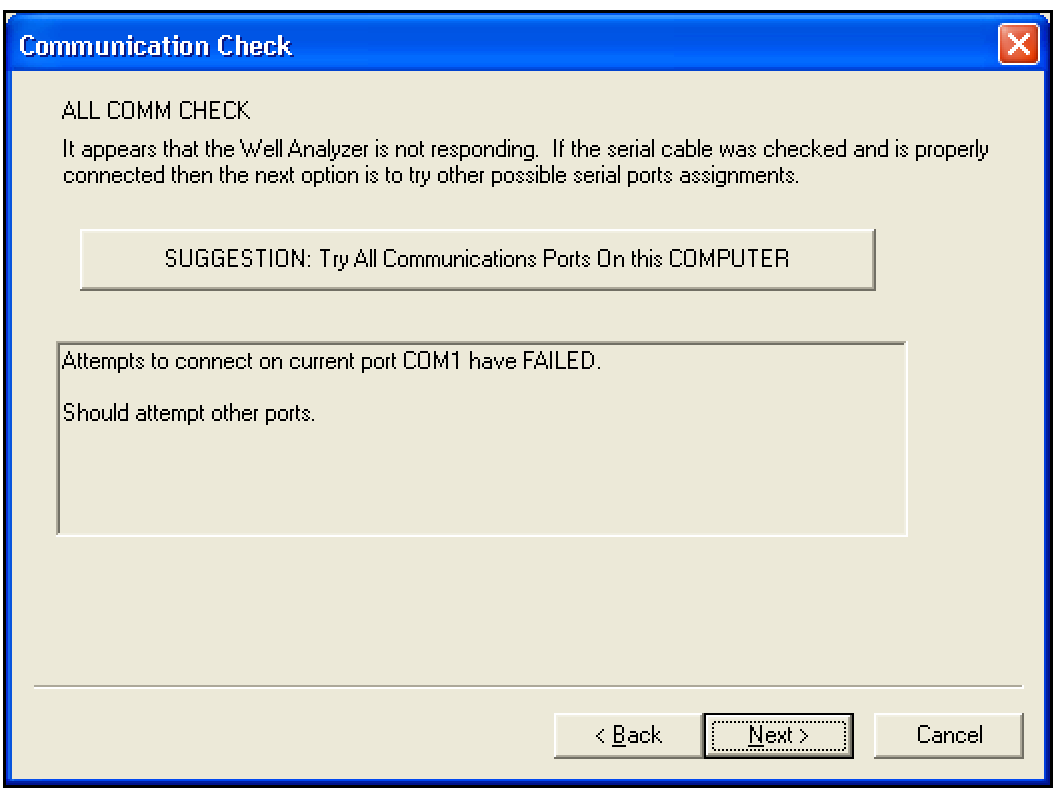


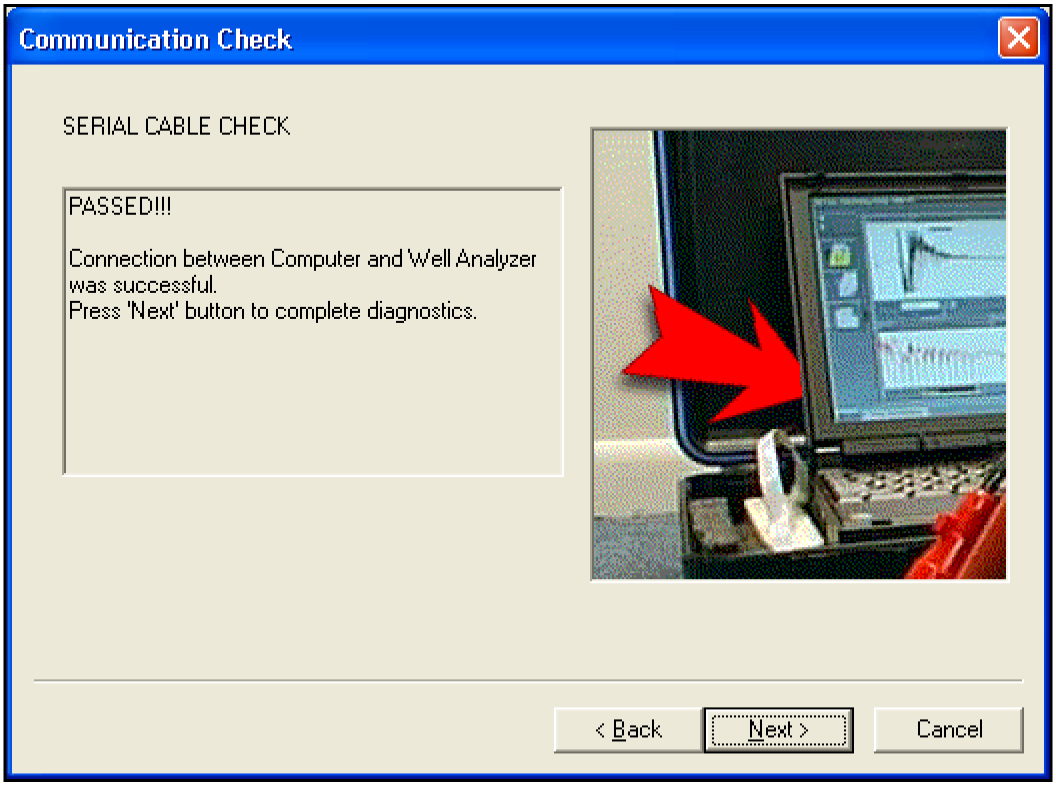
This is the most frequent cause of problems. Make sure that the **Master Switch** is reset any time that the program is terminated abnormally (blows-up!) and wait until the power light changes from yellow to green before starting the TWM software.

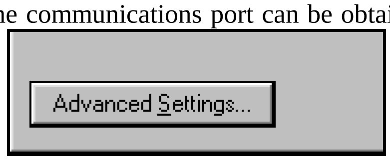
12.4.3 - Serial Cable Check

After resetting the power switch, continue by selecting **Next**:

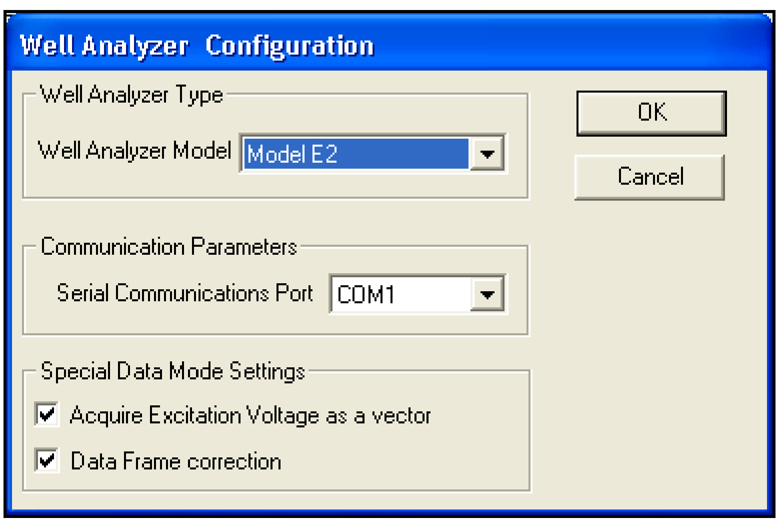






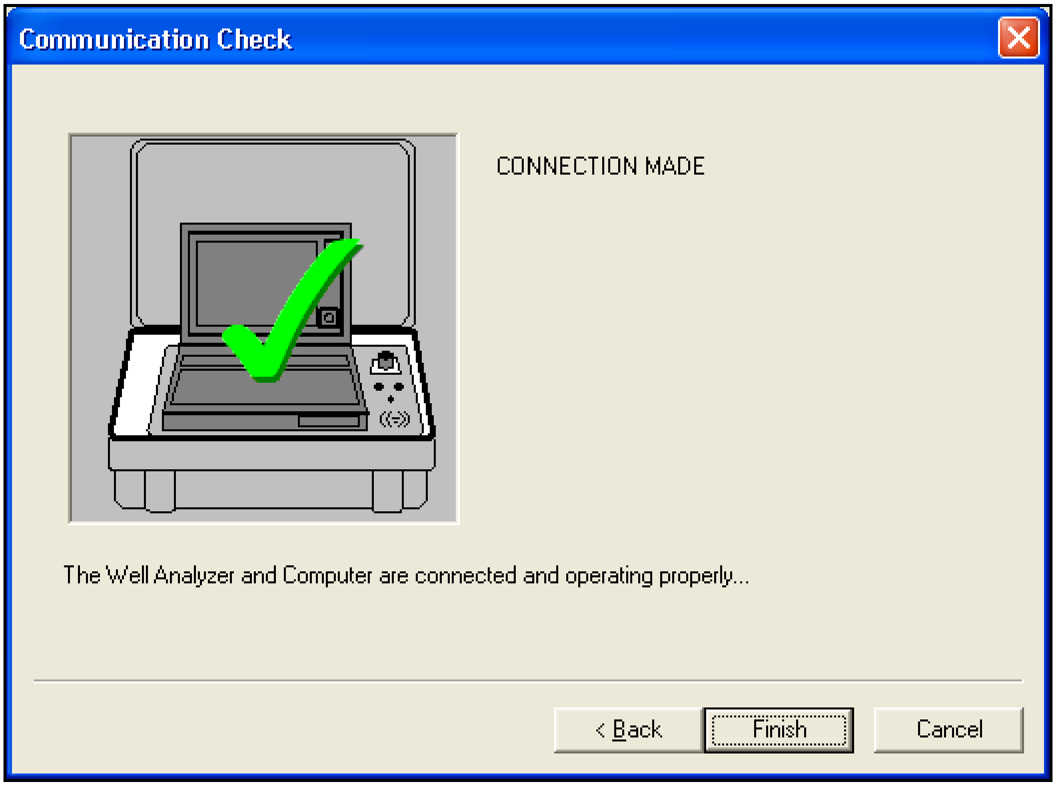
Detailed information about the communications port can be obtained selecting the **Show Advanced Analysis** mode in the **User Help Level** and selecting the 

and displaying the Communication Parameters.



These parameters need to be compatible with the communication parameters for the corresponding port as set in the **Windows Settings** for the **Control Panel's System** folder.

When communications have been re-established the following screen will be displayed.

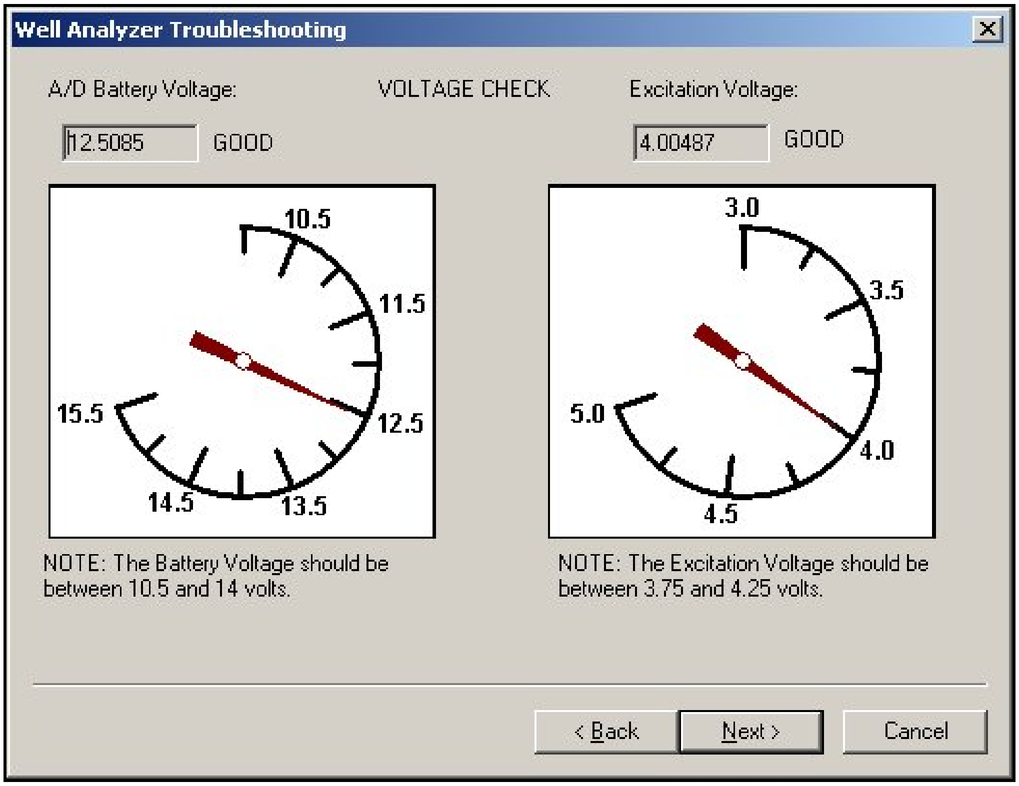

Communication Check
CONNECTION MADE
The Well Analyzer and Computer are connected and operating properly...
< Back
Finish
Cancel

12.5 - Trouble Shoot Wizard (E1 and E2)

When communication between the Well Analyzer and the Computer is operating properly, the data acquisition functions are tested using the **Troubleshoot Wizard**

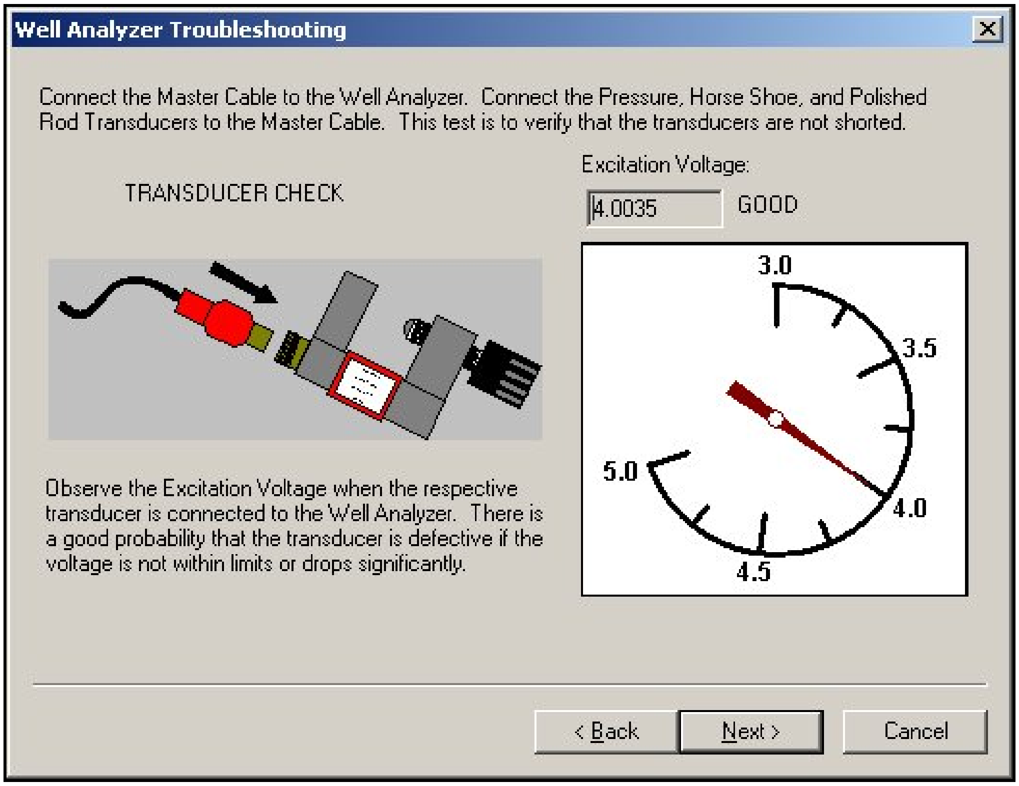
12.5.1 - Voltage Check

The screen displays the existing Well Analyzer battery voltage and the voltage used to power the transducers. If the values were not within the accepted limits, the battery should be recharged and the test repeated later.



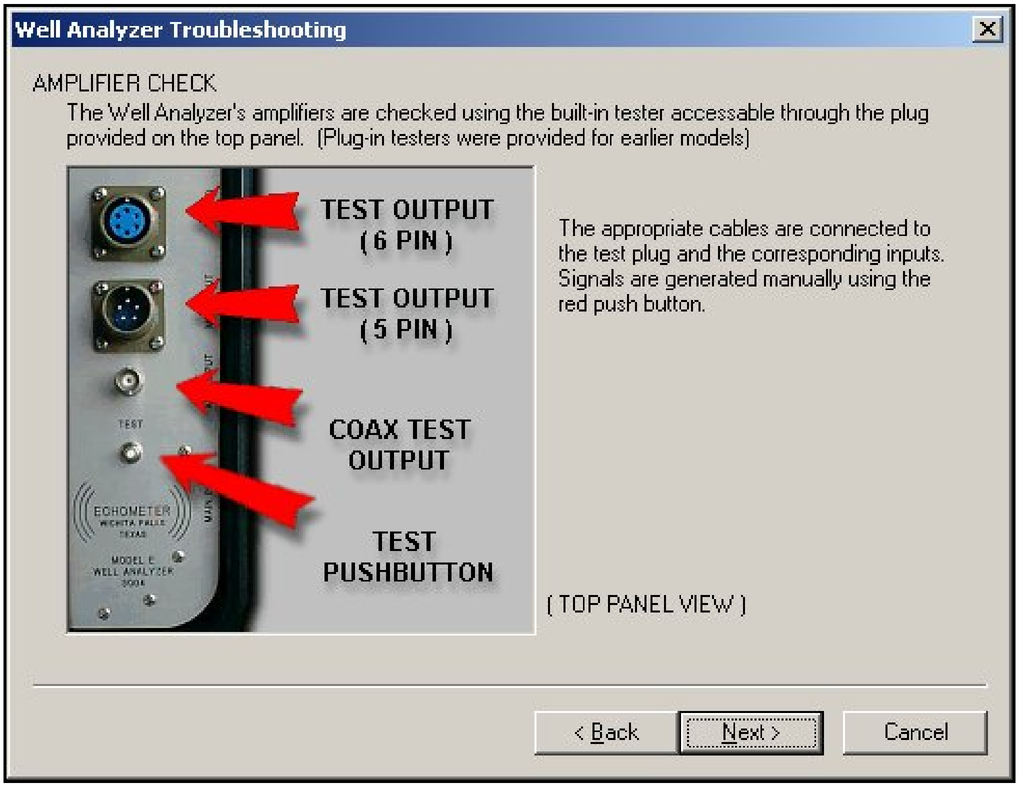
12.5.2 - Transducer Check

If the battery voltage is within limits but the excitation voltage is not within limits or it drops significantly when the respective transducer is connected to the Well Analyzer (using the master cable) there is a good probability that the transducer is defective. In this case the user should proceed with the troubleshooting procedure described in the next section.

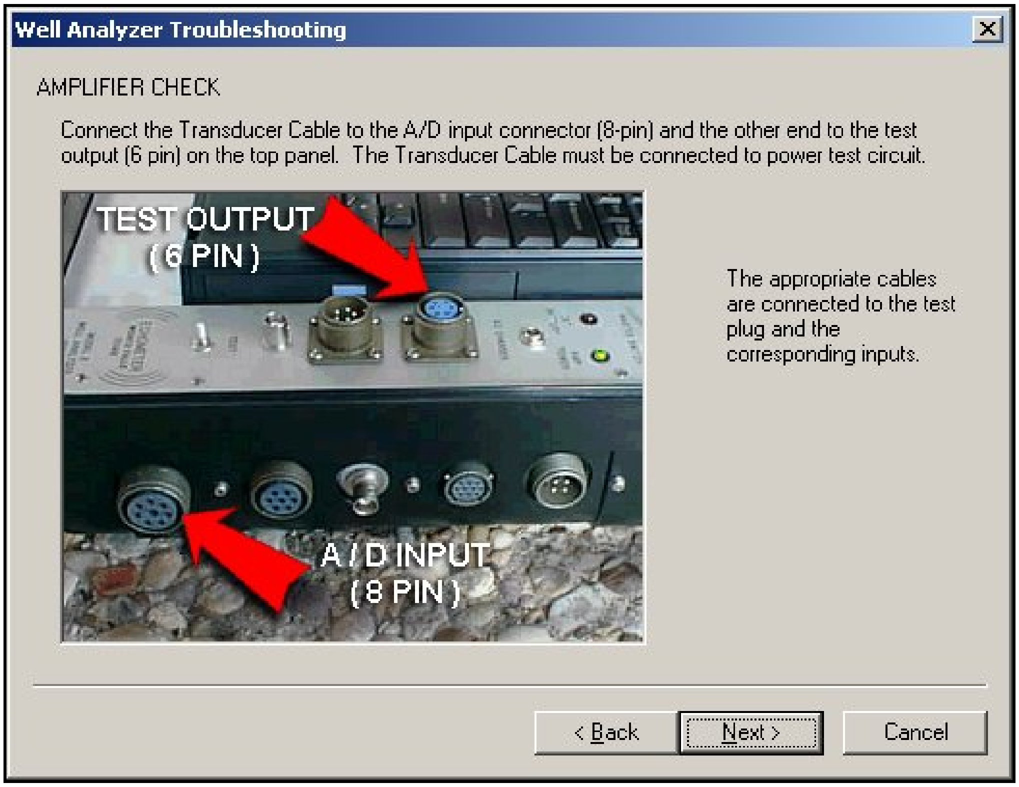


12.5.3 - Amplifier Checks

The Well Analyzer's amplifiers are checked using the built-in tester (plug-in testers were provided for earlier models) accessible through the plug provided on the top panel. The appropriate cables are connected to the test plug and to the corresponding inputs. Signals are generated manually using the red push button. When the appropriate response is not obtained it is important to check that the failure is not due to a faulty cable or connector. Either a spare cable should be used or continuity and ground checks using an Ohm-meter should be made on the questionable cable before concluding that the amplifiers are not operating properly. The instructions presented in the following screens should be followed in order to check both the cables and the amplifiers.

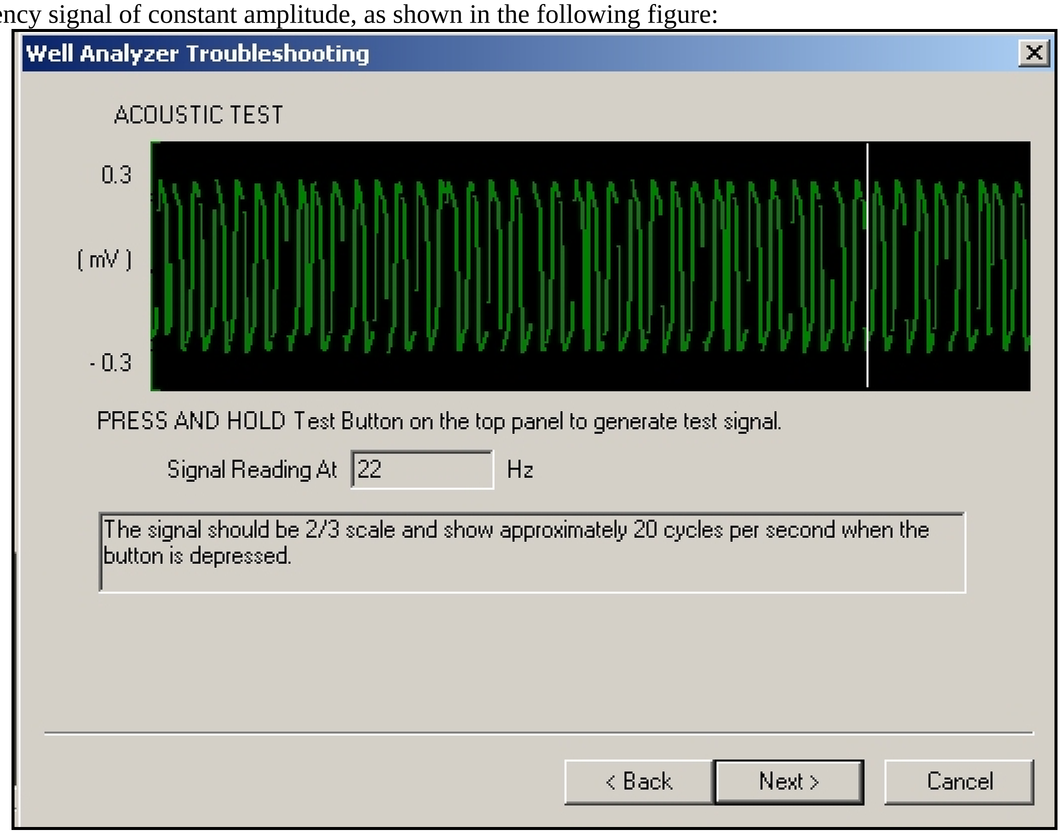

Well Analyzer Troubleshooting
AMPLIFIER CHECK
The Well Analyzer's amplifiers are checked using the built-in tester accessable through the plug provided on the top panel. (Plug-in testers were provided for earlier models)
TEST OUTPUT (6 PIN)
TEST OUTPUT (5 PIN)
COAX TEST OUTPUT
TEST PUSHBUTTON
The appropriate cables are connected to the test plug and the corresponding inputs. Signals are generated manually using the red push button.
(TOP PANEL VIEW)
< Back
Next >
Cancel


Well Analyzer Troubleshooting
AMPLIFIER CHECK
Connect the COAX Microphone cable to the A/D input connector and the other end to the COAX Test Output on the top panel.
COAX TEST OUTPUT
COAX A / D INPUT
The appropriate cables are connected to the test plug and the corresponding inputs.
< Back
Next >
Cancel



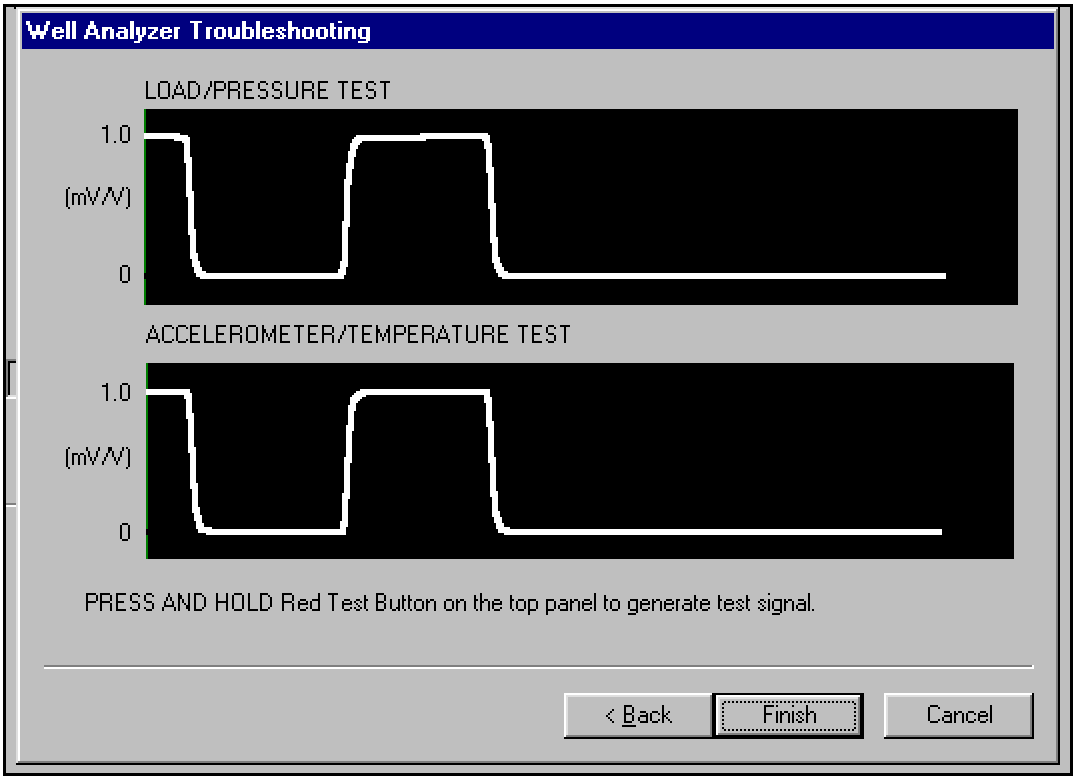
12.5.4 - Acoustic channel Test Output

This tests both the coaxial cable and the Acoustic channel amplifier. Depressing the test button should display a 20 Hz frequency signal of constant amplitude, as shown in the following figure:



12.5.5 - Cables, amplifiers and A/D converter check.

This test verifies that the main transducer cable and the A/D converter are performing properly. The test should be repeated using all the cables individually and connected in series so as to check the connectors as well as the cable. Whenever the test button is depressed the signal should increase from zero to 1 mV/v as shown below.



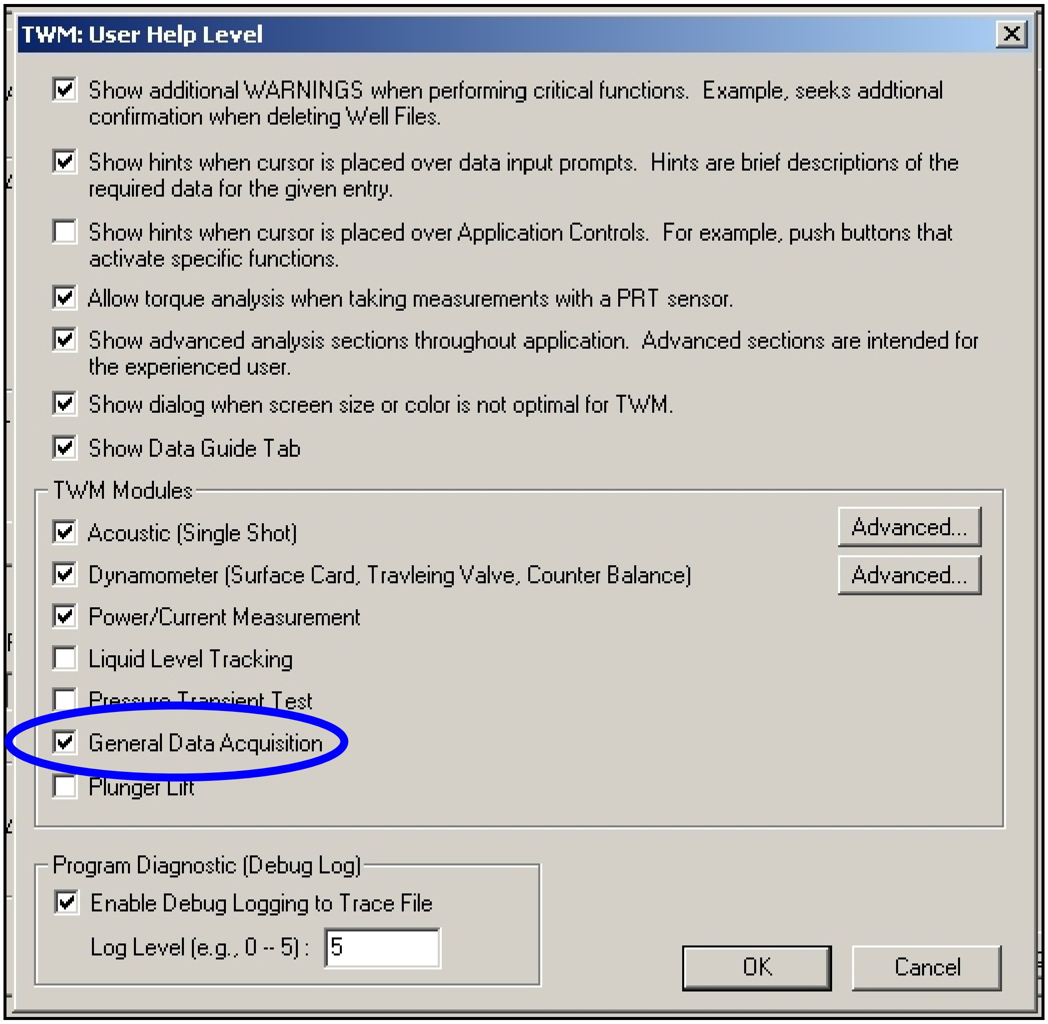
This completes the testing sequence.

13.0 - GENERAL DATA ACQUISITION

The general data acquisition module of the TWM program is a very useful utility for detailed analysis of the data acquired by the Analog to Digital converter. One or more channels may be sampled at rates ranging from 30 to 3840 samples per second. The data is then saved as a file that may be recalled and analyzed in detail or exported to a spreadsheet.

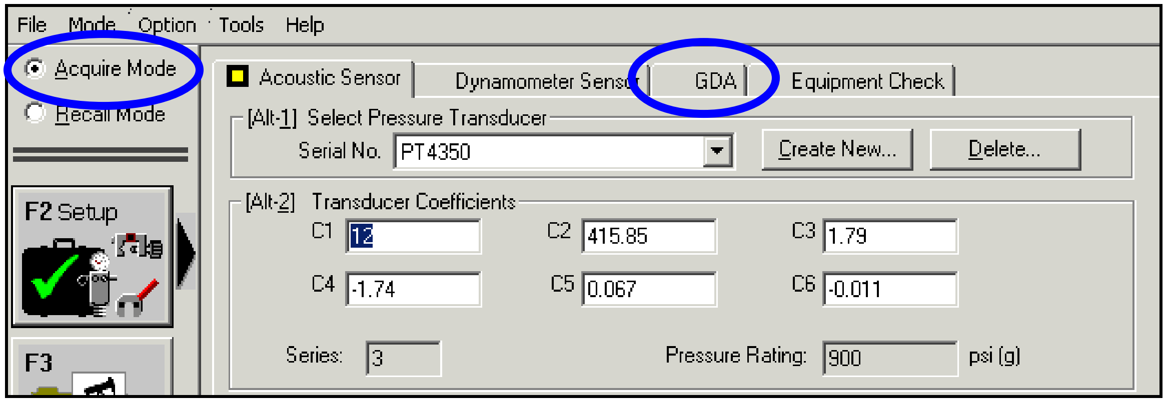
13.1 - Set Up of the General Data Acquisition (GDA) Mode

To use the GDA module it must be selected as an active module in the **User Help Level** pull down menu as shown below:

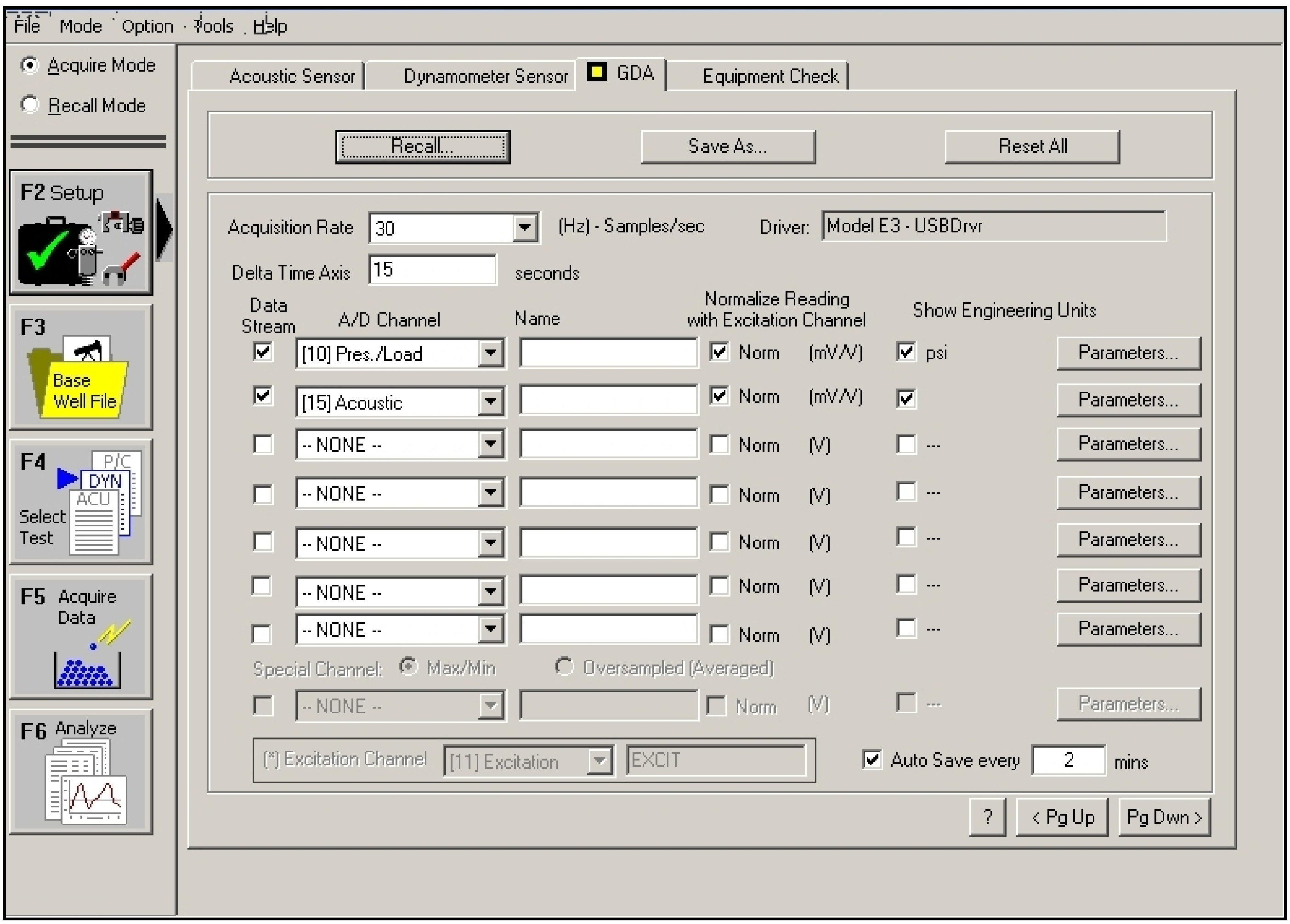


This choice will display the GDA tab when starting the TWM program and selecting the

Acquire Mode as seen in the following figure:



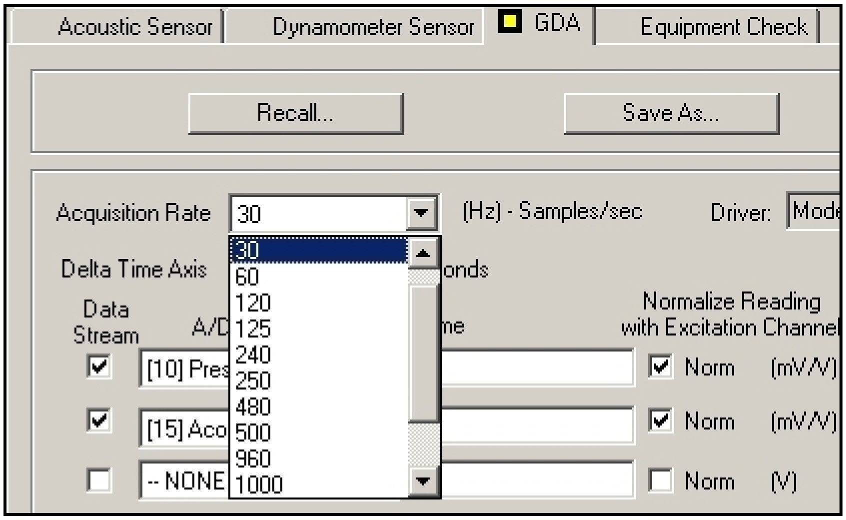
Selecting the **GDA** tab opens the form to set up the GDA acquisition parameters. In this form the user selects the channels to be monitored, the sampling rate, the graphics characteristics and other variables. The form also displays the Analyzer model number and the driver (Model E3 – USBDrvr)



The user has to select the **Acquisition Rate**, the span of the time axis (**Delta Time Axis**) and the channels to be acquired.

13.1.1 - Acquisition Rate

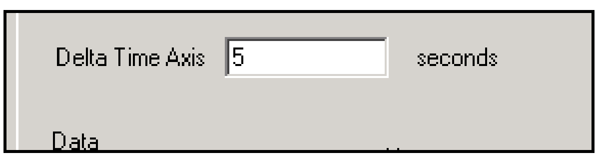
The rate at which channels will be sampled is selected from the pull down menu as shown in the following figure:



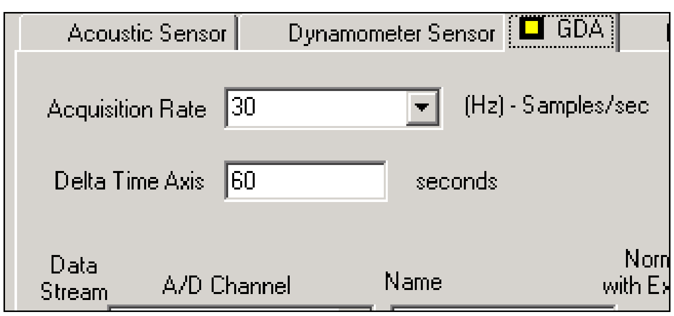
The default value is 30 samples per second and the maximum rate is 3048 samples per second.

13.1.2 - Time Span of Graphic Display

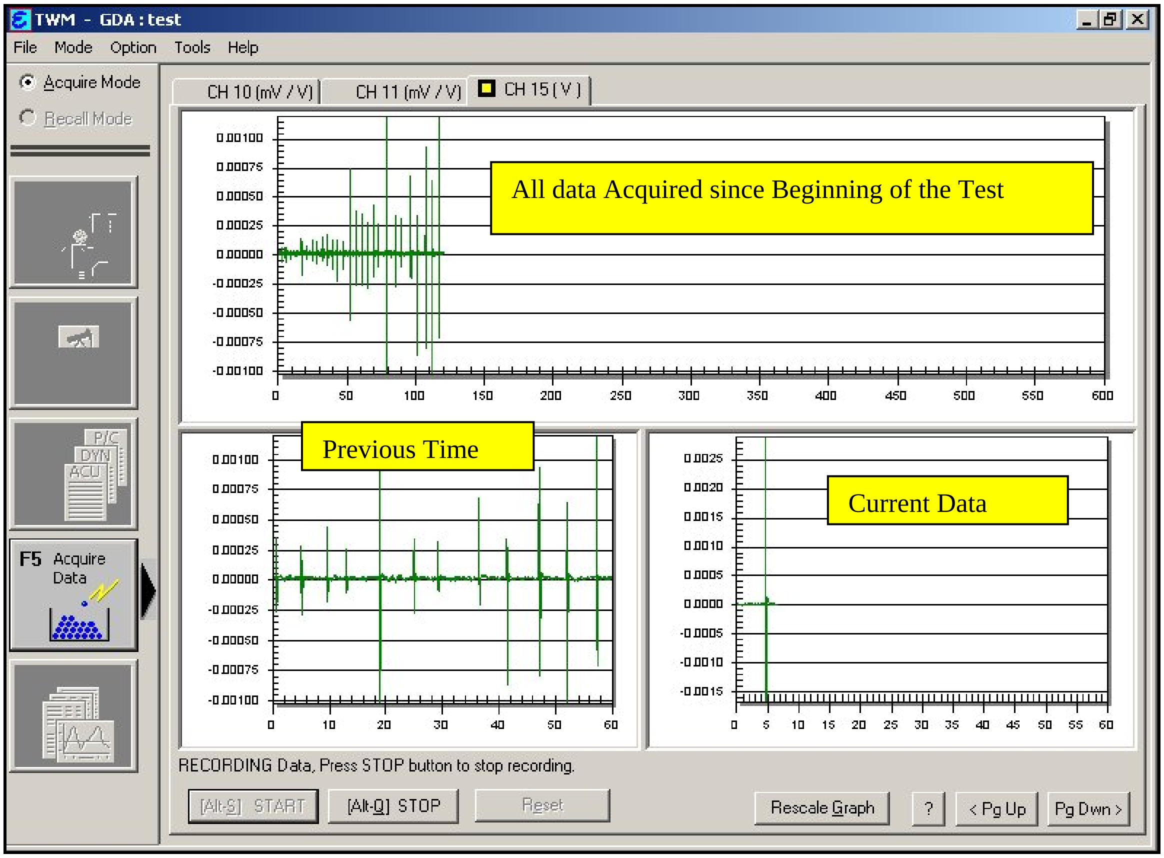
During acquisition the values for each channel will be displayed on a graph as a function of time. The user should select the time span for the graph where the current data is being displayed. The span should be a reasonable number of seconds depending on the sampling rate which has been selected. The default value is 5 seconds as shown below:



Generally a span of 60 seconds is a convenient value when recording data from dynamometer transducers such as load cells, accelerometer and power probes.



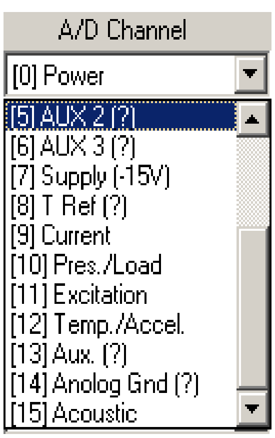
During acquisition the display is divided into three windows. The lower two windows display the data for the current time span and the immediately previous time span. The upper window displays all the data acquired since the beginning of the test. The upper window scale will be reset to a larger value when the elapsed time exceeds the maximum scale value. This will result in compression of the graph but all the data points will be preserved in the data file.



There are two acquisition modes in GDA. The first mode is where the acquired data is **scrolling by** and is not saved to a file. The second mode is where the user pressed **START** and the **data is captured** until the **STOP** button is pressed.

13.1.3 - Channel Selection

The name of the channel(s) to be acquired and recorded is selected from the drop down list. A total of 15 channels are allowed by the software but in the current E3 version only channels 0,1,2,3,7,9,10,11,12, and 15 are active



Some channels have dual functions depending on the transducer that is being used. For example channel 10 corresponds to either load or pressure depending on whether a load cell or a pressure transducer is connected to the master cable.

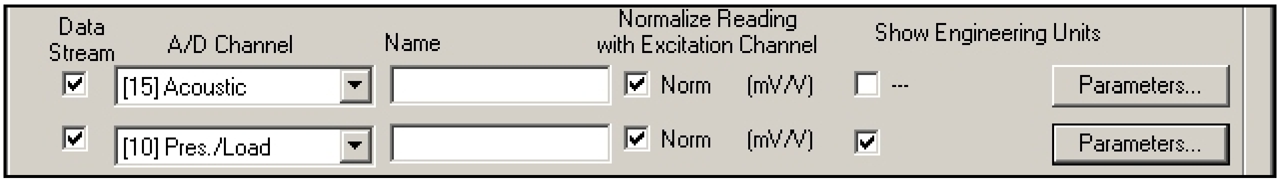
Acquisition is activated by checking the **Data Stream** box to the left of the channel. The data from a specific channel can be recorded in terms of actual voltage or normalized with respect to the transducer excitation voltage (mV/V) by checking the

Norm box at the left of the channel name. The data may be displayed in engineering units when the calibration coefficients of the sensor are input.

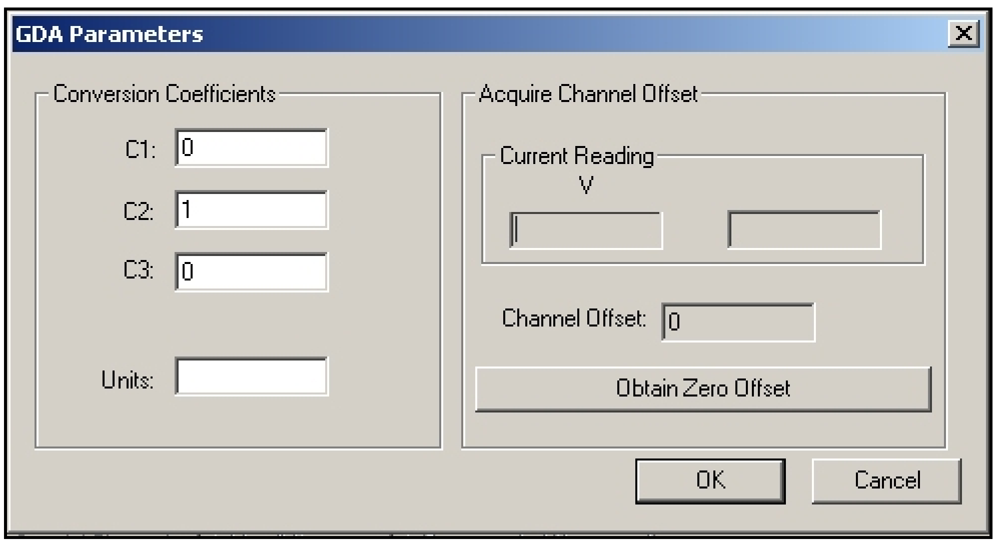
13.1.4 - Show Engineering Units

For certain measurements such as pressure or load it is convenient to convert the acquired sensor output voltage to the corresponding physical quantity. This requires knowing the calibration coefficients of the specific transducer.

To activate this option the show Engineering units box at the right of each channel should be checked as shown below for the Press/Load channel:

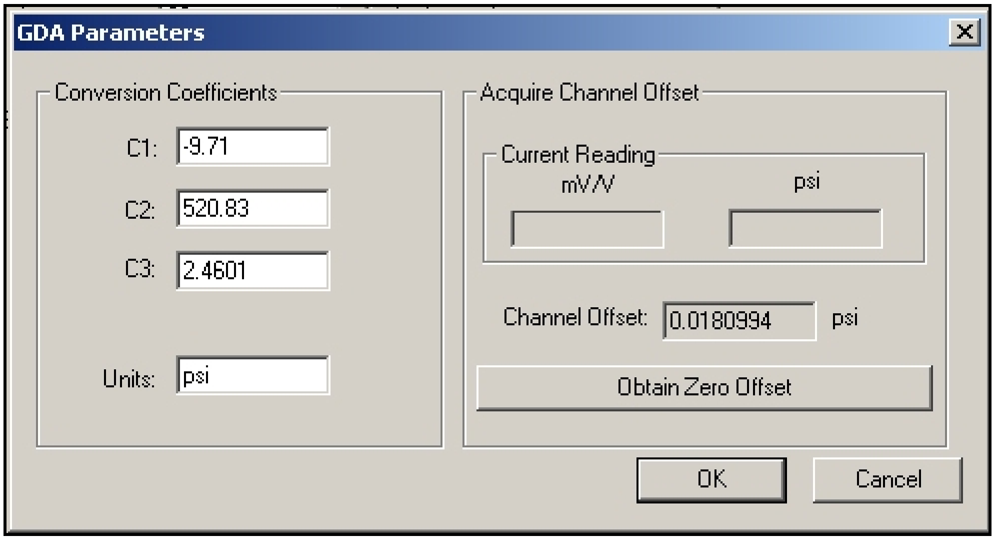


Then the Parameters button is clicked to display the form for entering the transducer coefficients. If no parameters have been entered earlier, the form displays the default values as shown below:



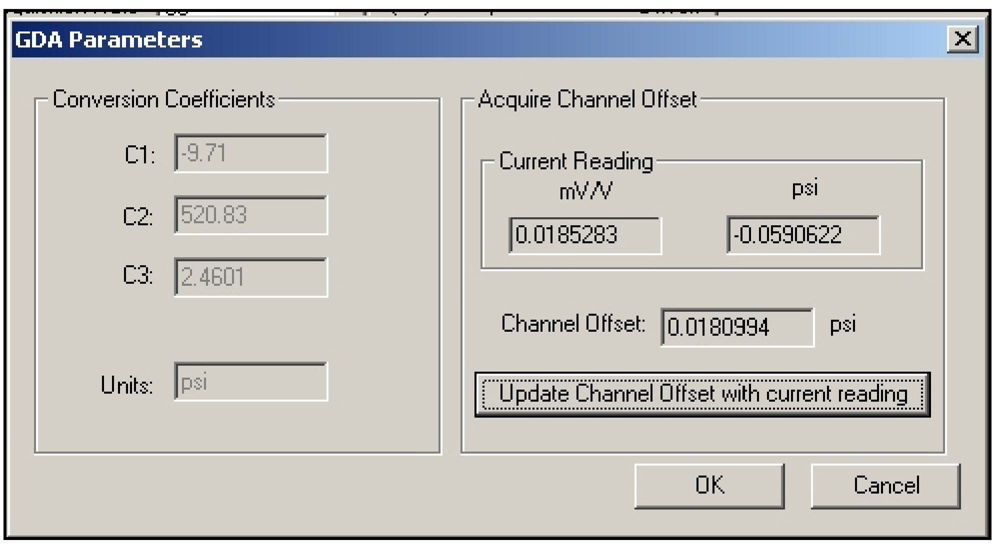
The default values for C1, C2 and C3 need to be replaced by the corresponding coefficients for the transducer to be used. The name of the corresponding engineering units should be typed in the Units field.

The following figure shows this form after entering the pressure transducer coefficients and units:

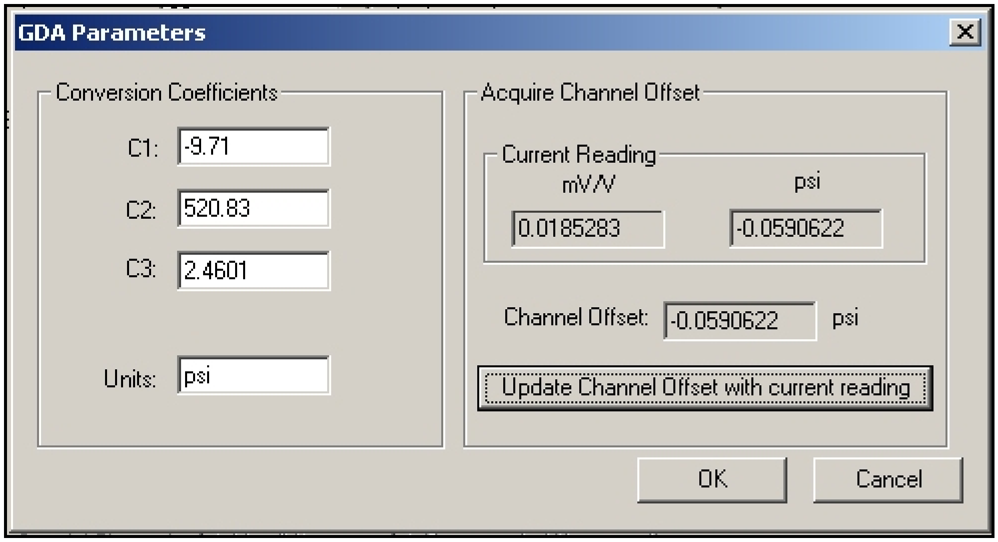


Accurate measurements require determining the transducer's Zero Offset. In this case the transducer is first exposed to atmospheric pressure, and then the Obtain Zero Offset button is clicked.

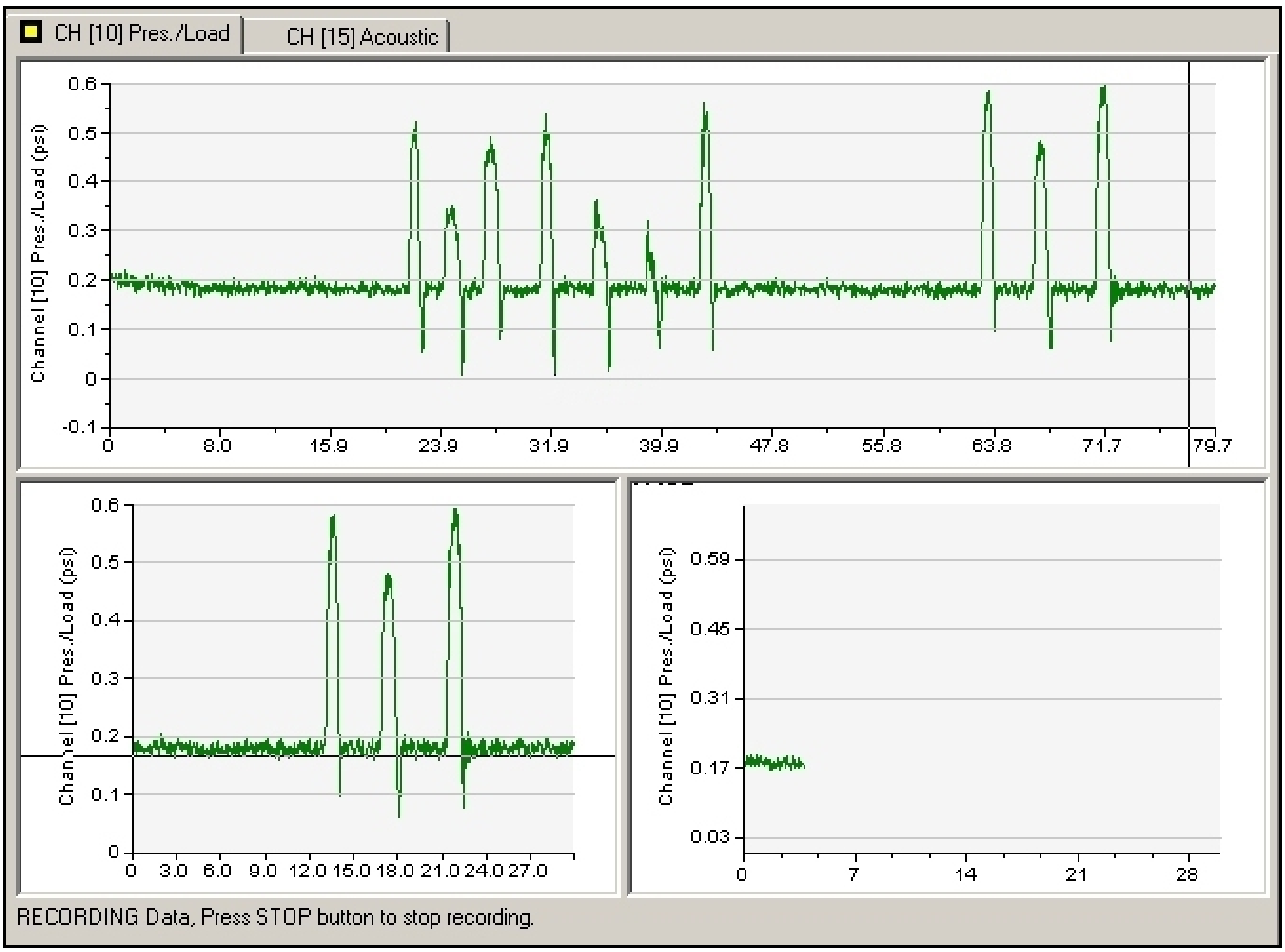
After clicking on Obtain Zero Offset the following is displayed:



The measured zero offset is stored and becomes active only after by clicking on the Update Channel Offset with current reading button. After updating the C1, C2



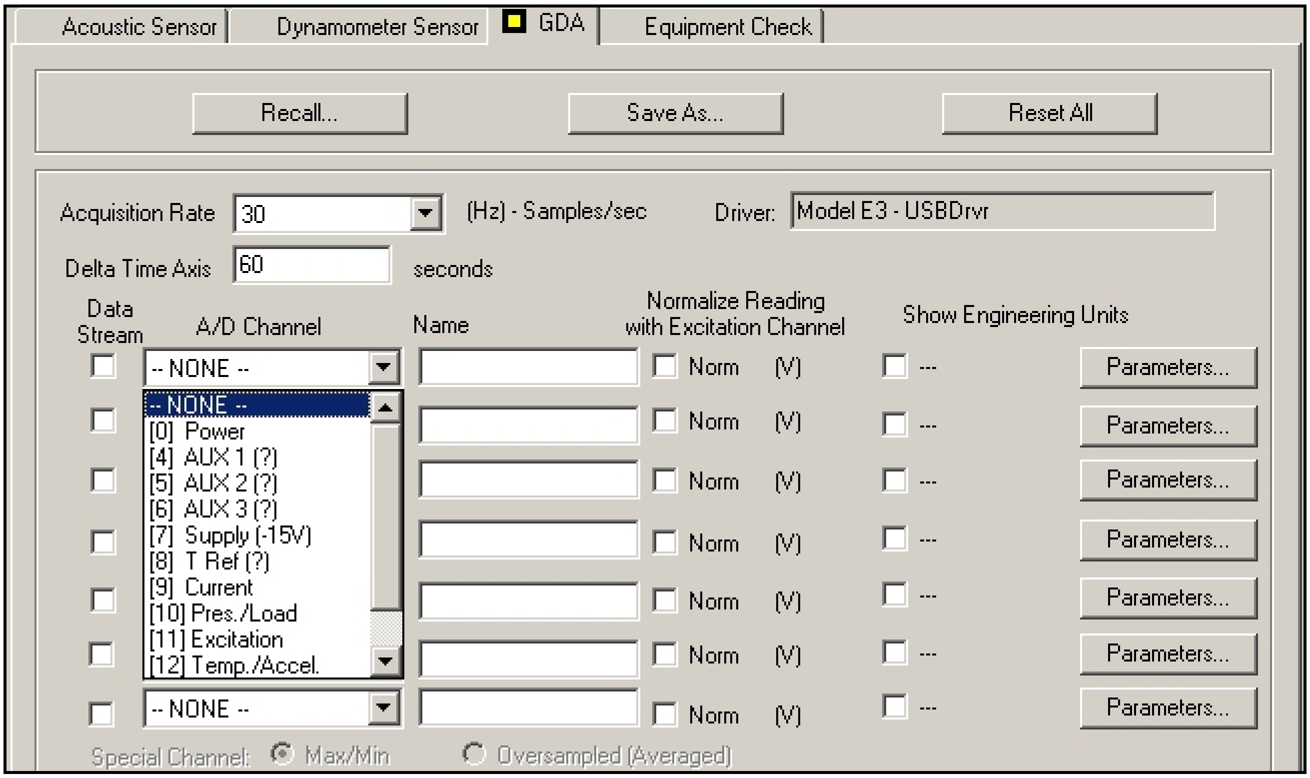
The following figure shows the acquisition screen with the vertical axes calibrated in the corresponding pressure units:



13.2 - Example Acquisition Using the GDA Module

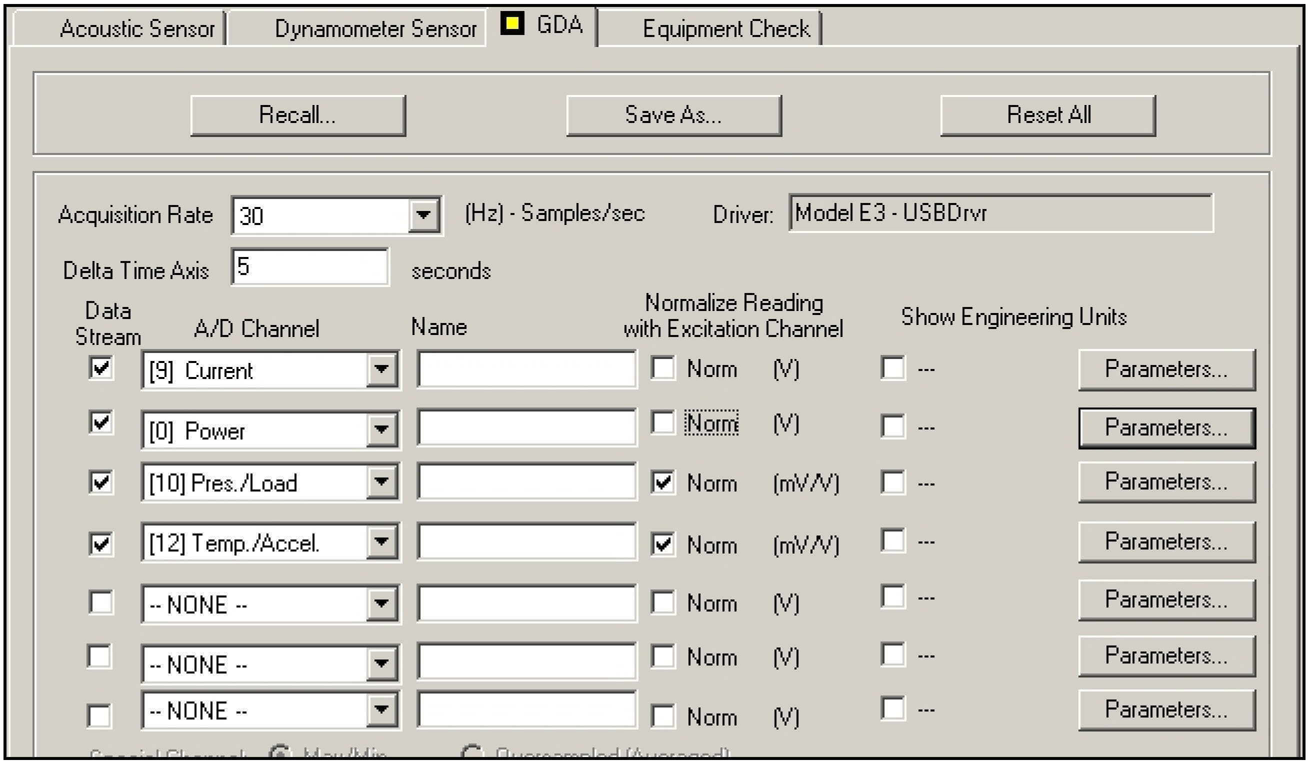
The following sequence of screens illustrates setting up the GDA program to monitor Dynamometer and Power data for an extended period of time. Data from the load, acceleration, current and power transducers are monitored and recorded.

Step 1 – Select GDA Tab from the Set Up Screen. Select acquisition rate at 30 samples per second and set the Delta Time Axis to 60 seconds so as to monitor one minute of current data.

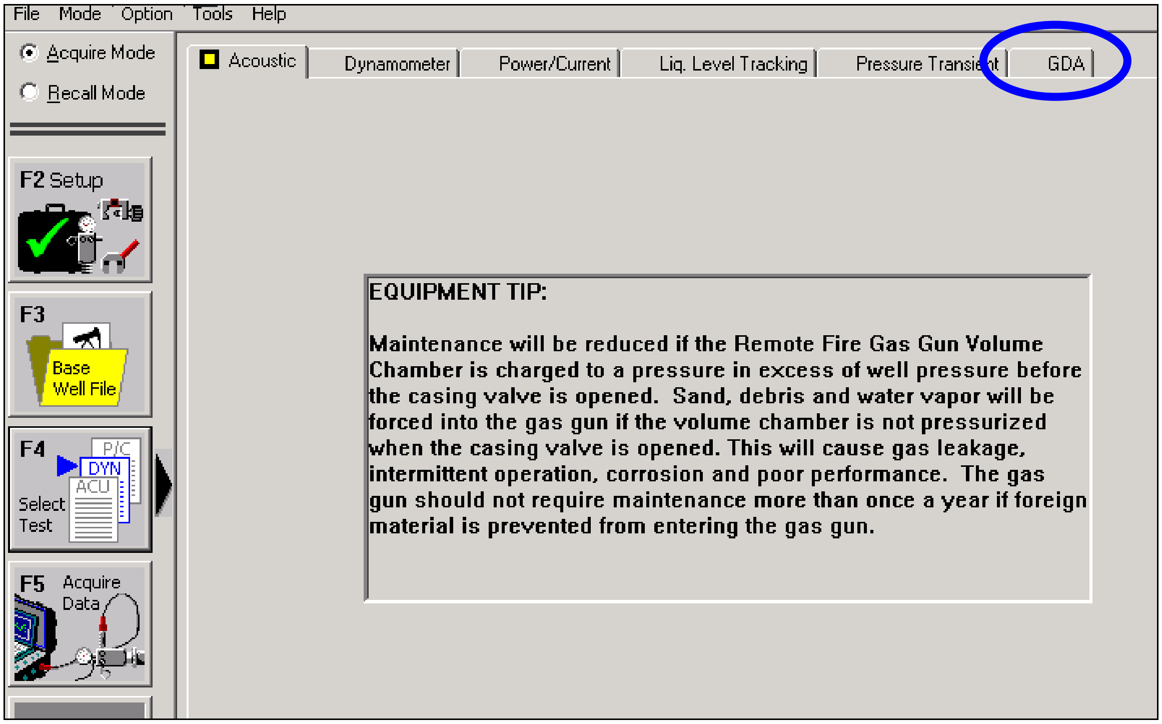


Step 2 – Select and enable acquisition for the channels to be monitored. The polished rod load is monitored on channel 10 and the acceleration on channel 12 and both signals are normalized with respect to the excitation voltage so they are recorded as millivolt/volt.

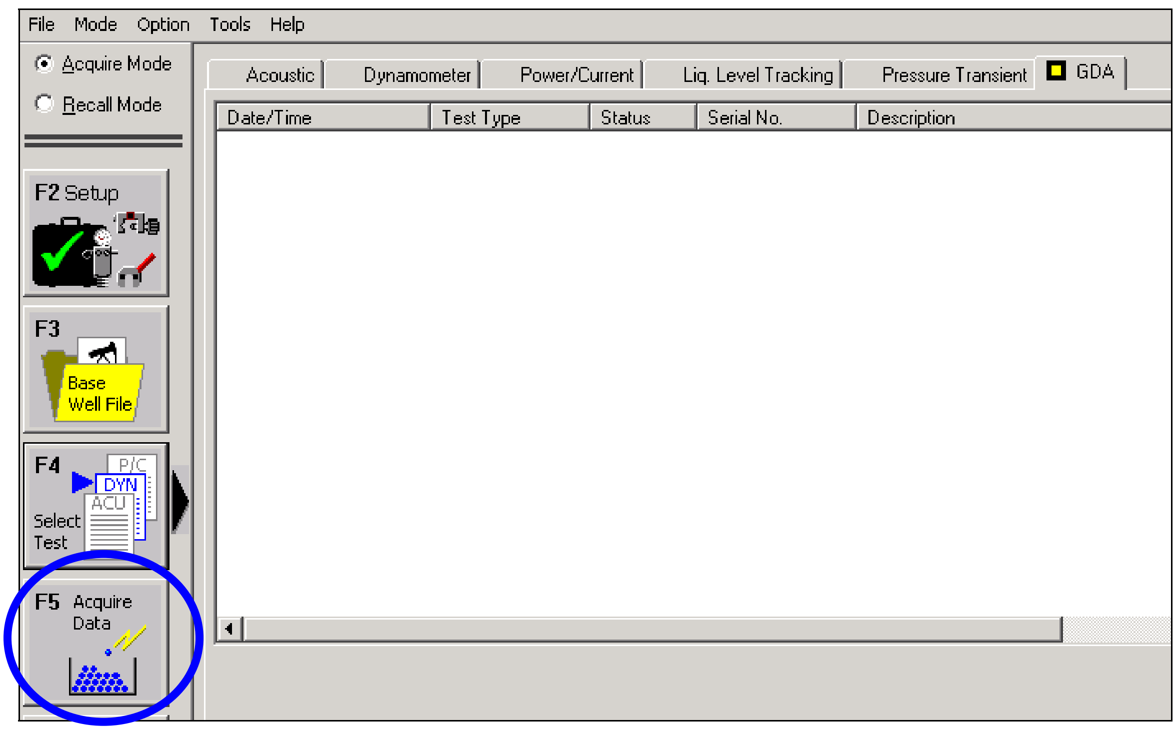
The motor power is monitored on channel 0 and the current on channel 9 and both signals are recorded as volts since the transducer output is a voltage proportional to the instantaneous power and current. NOTE: If a pressure transducer were connected to the master cable then channels 10 and 12 would monitor the pressure and the transducer temperature.



Step 3 – Select Test and click on the **GDA** Tab:

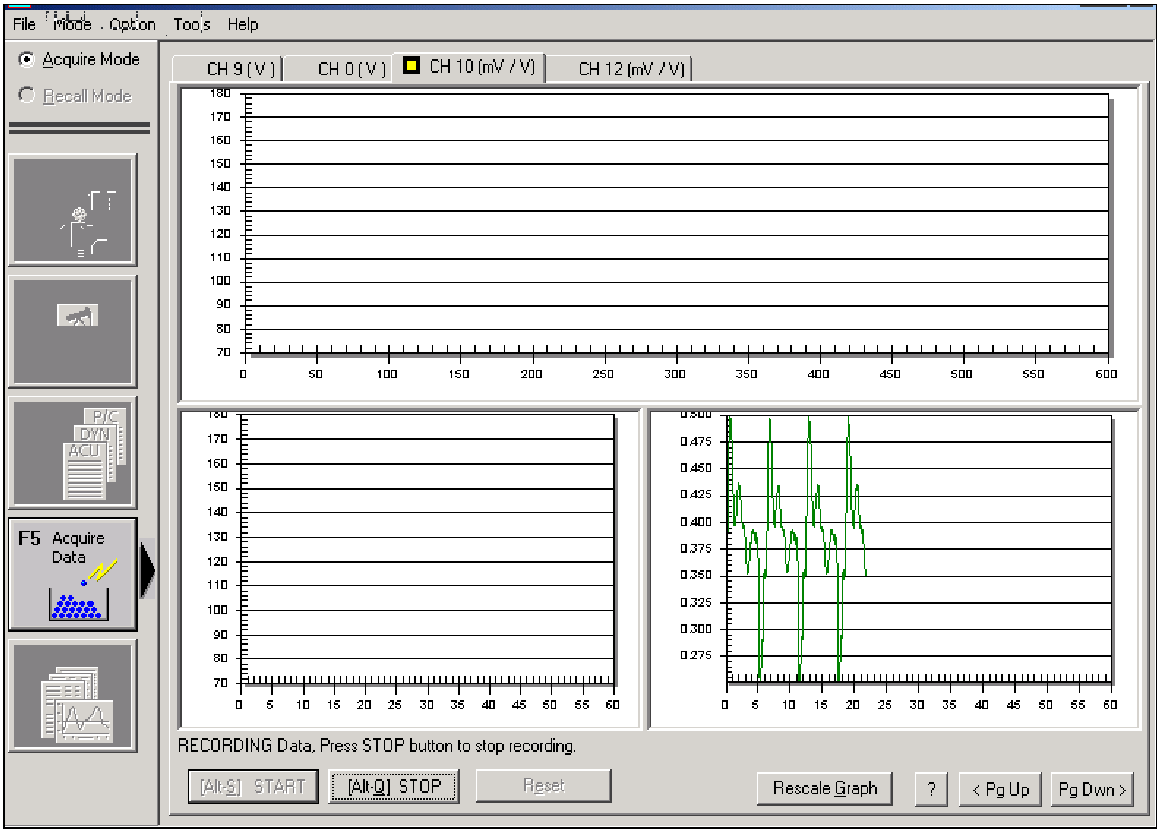


Step 4 – From the GDA Tab, click on the Acquire Data button or use the F5 key.

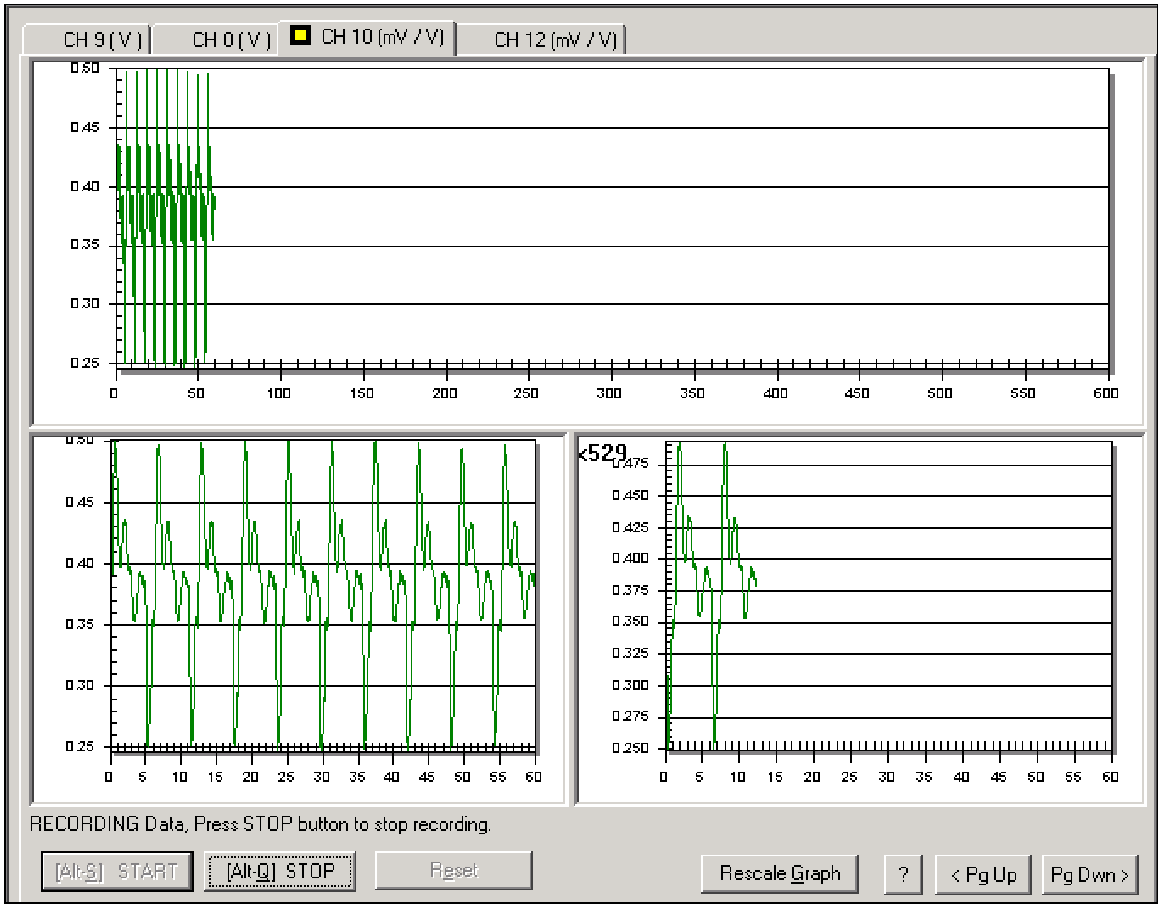


The GDA monitoring screen is displayed with the four tabs corresponding to the channels previously selected. In the screen below Channel 10, that corresponds to the polished rod load, is being **displayed** and the data is also **being recorded** since the user pressed the **START** button. Recording will continue until the **STOP** button is depressed.

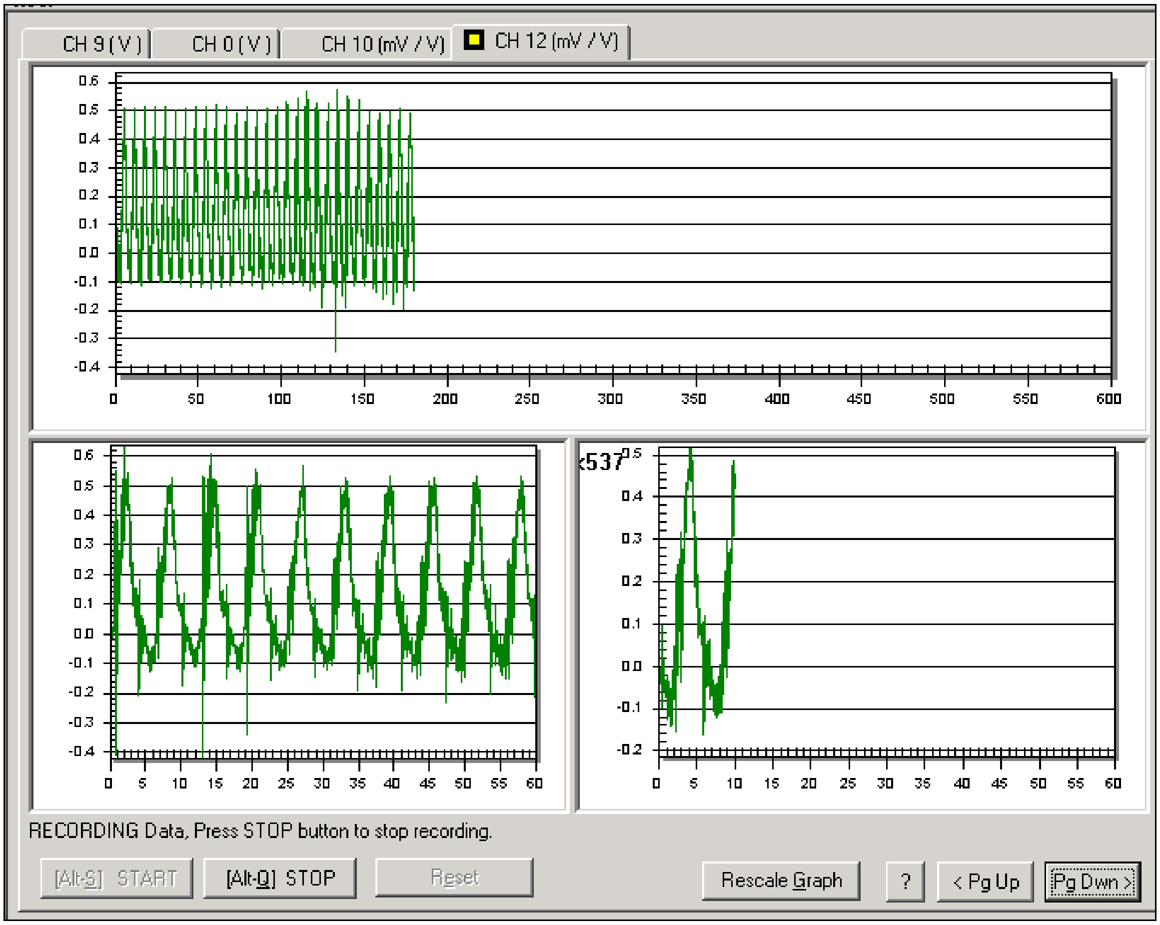
At this point only 24 seconds have elapsed from the start of acquisition, thus data is displayed only in the lower right screen:



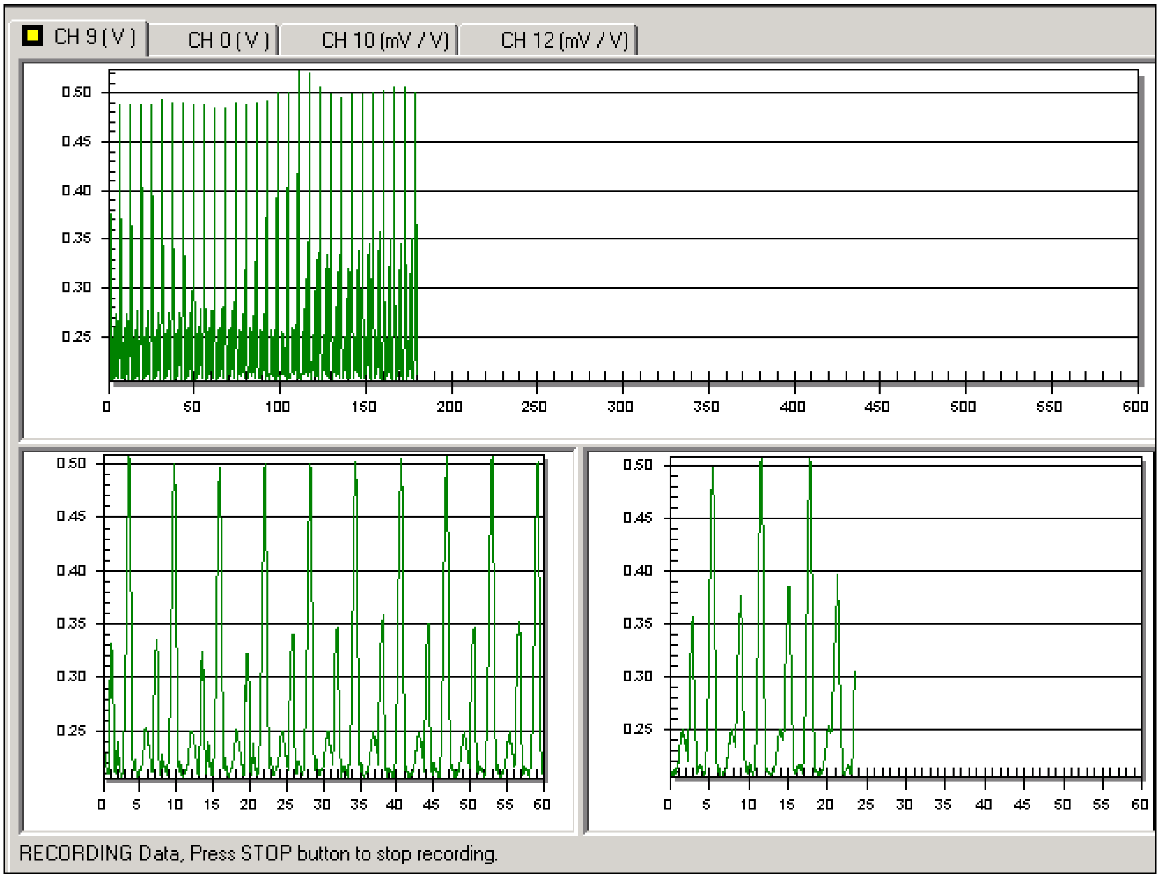
After one minute and 14 seconds the display shows the current data in the lower right screen, the last 60 seconds of data in the lower left screen and all the recorded data in the upper screen. This screen has a time span of 600 seconds and thus the data appears compressed:



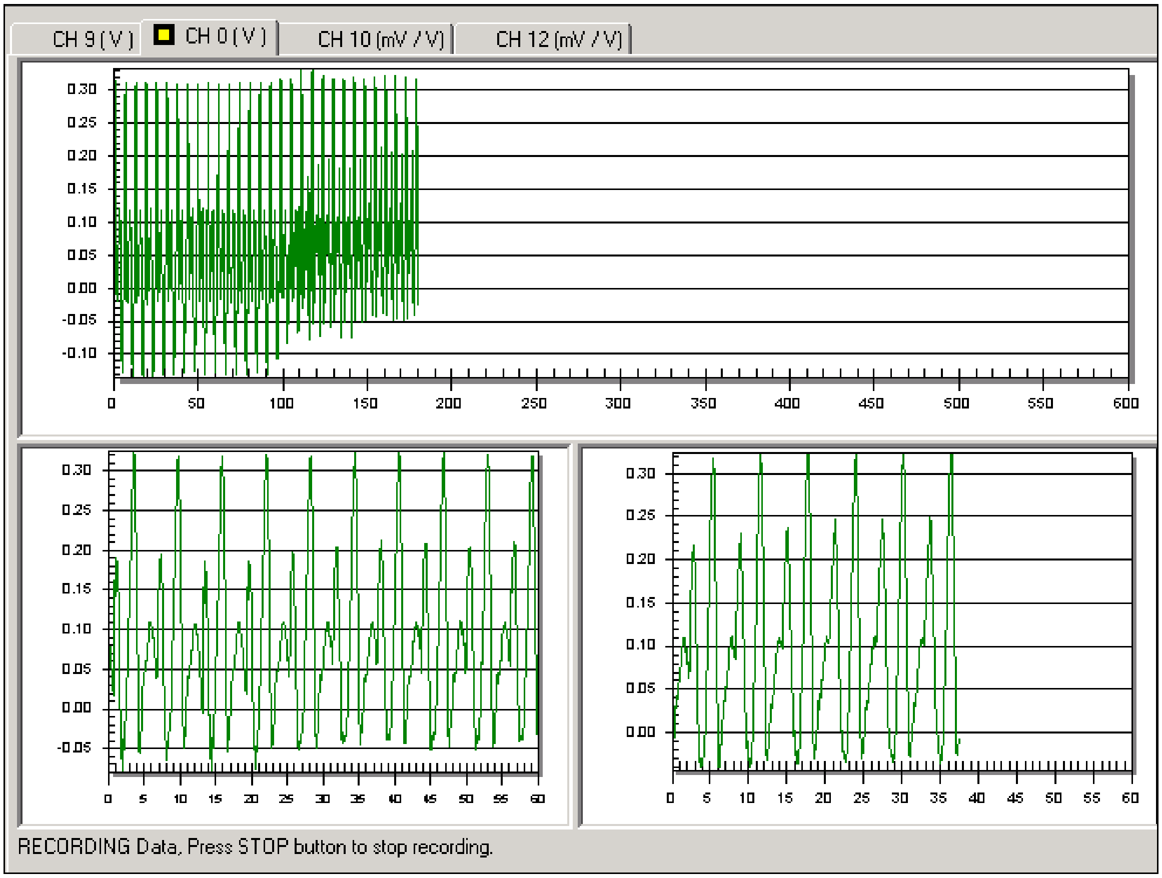
The acceleration signal is monitored by selecting the **Channel 12 Tab**:



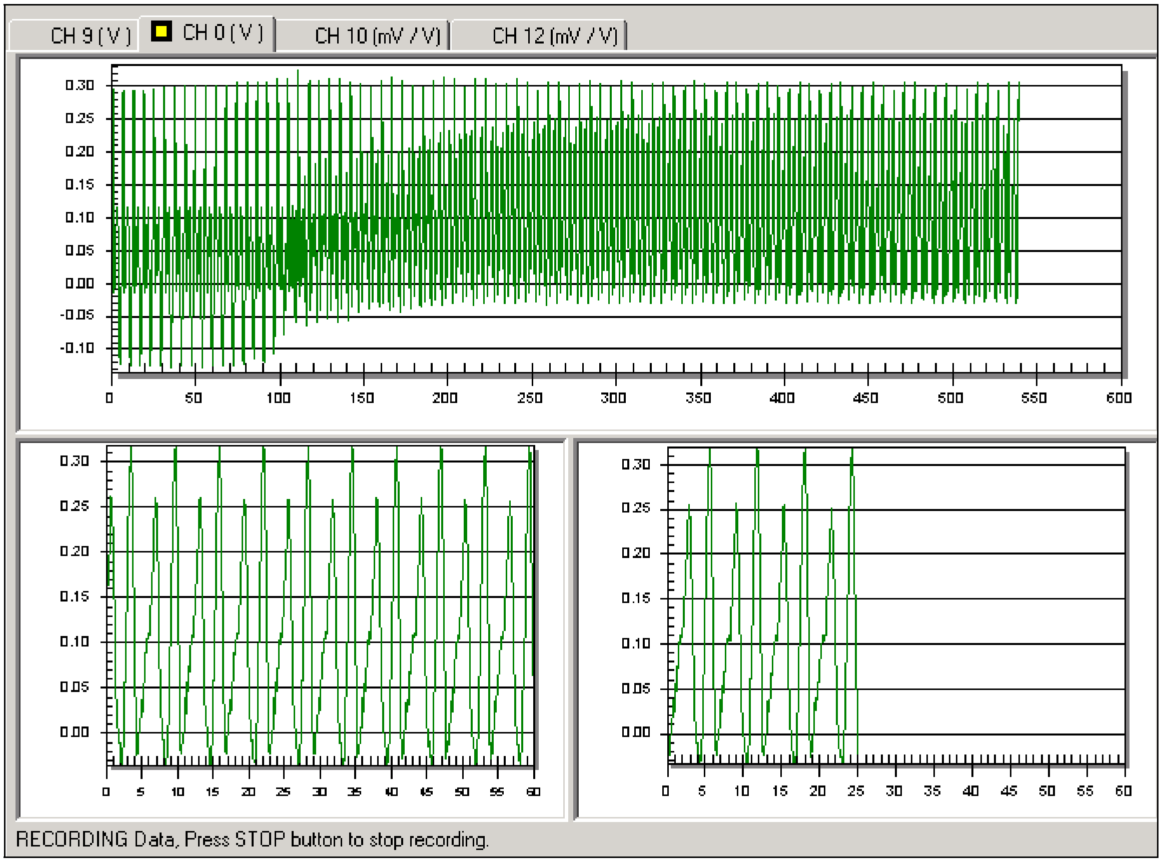
The electrical current signal is monitored by selecting the **Channel 9 Tab**.



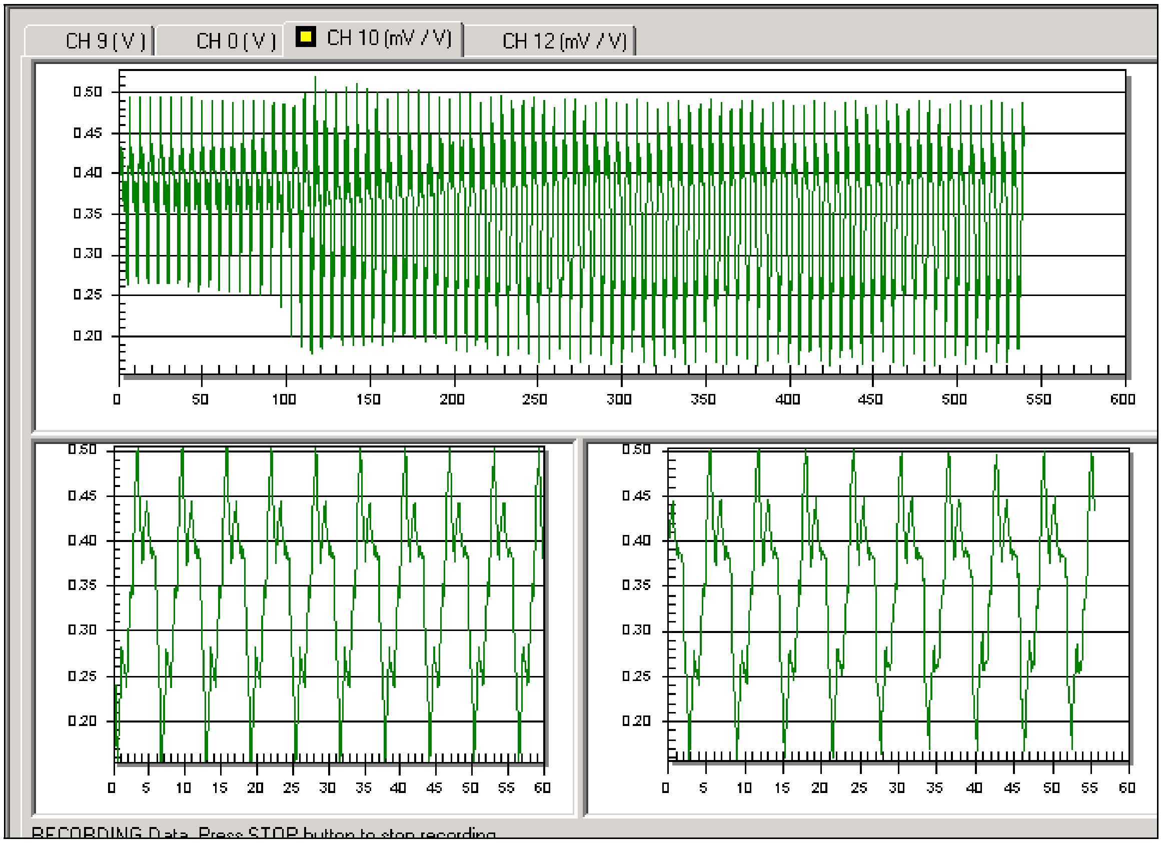
The instantaneous power signal is monitored by selecting the **Channel 0 Tab**. Note that this signal shows both positive and negative values which correspond to the motor switching from the motoring to the generating mode during the pump stroke.



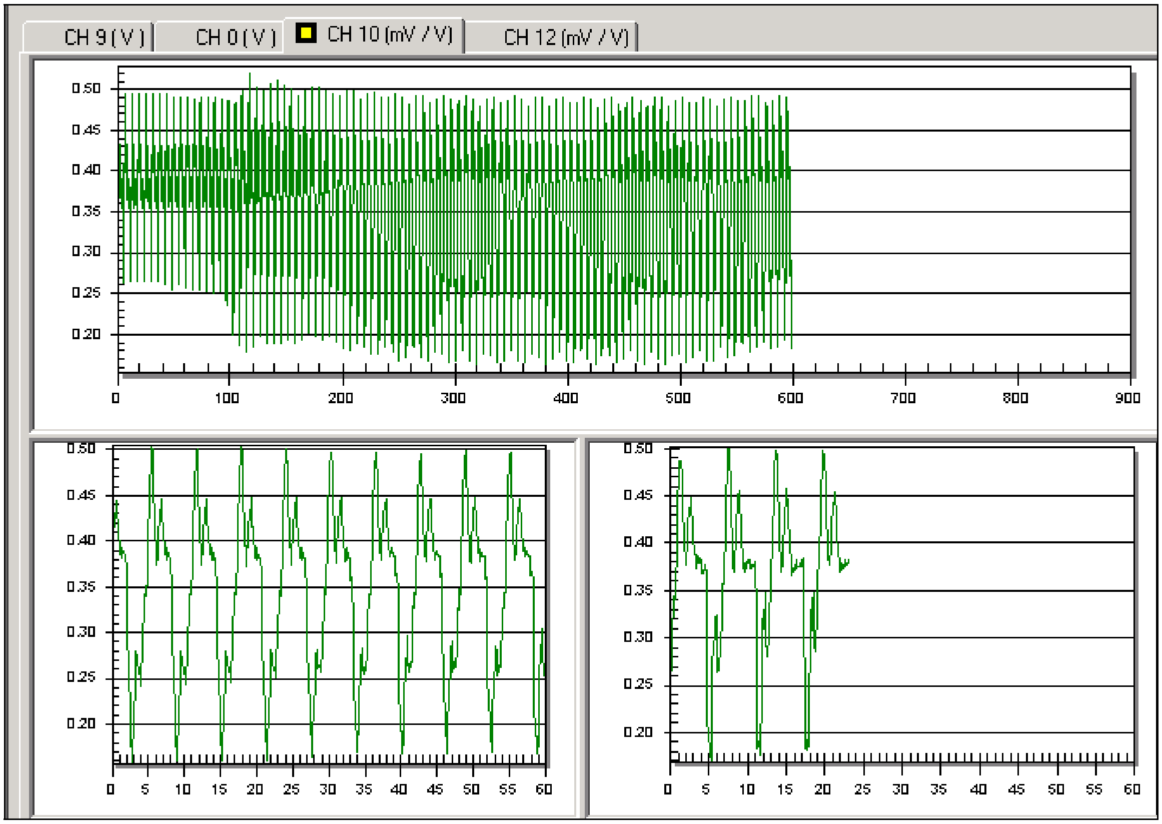
After nine minutes of recording the following screen shows the variation in motor power with a significant change occurring at about 130 seconds. This change corresponds to conditions at the pump changing from a full pump to partial fillage and eventually to pumped off:



A similar variation due to pumping off is observed in the data from the polished rod load as seen in the following figure:

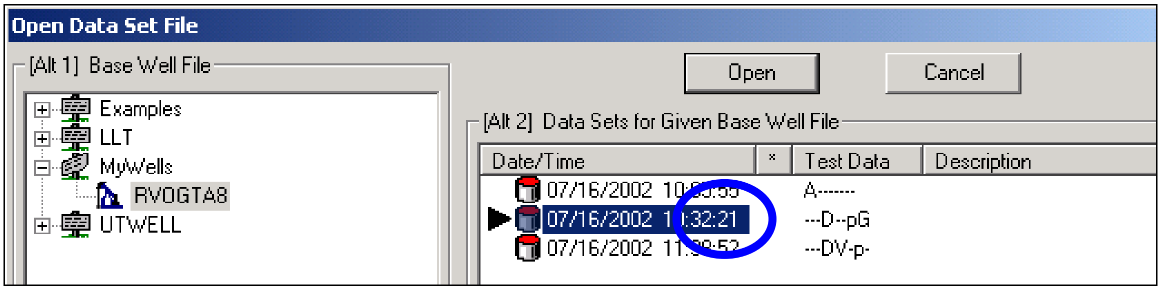


Automatic Rescaling of the time axis of the upper graph is done once the original time span is exceeded. Note the axis span increased to 900 seconds and the graph is compressed further in the following figure:



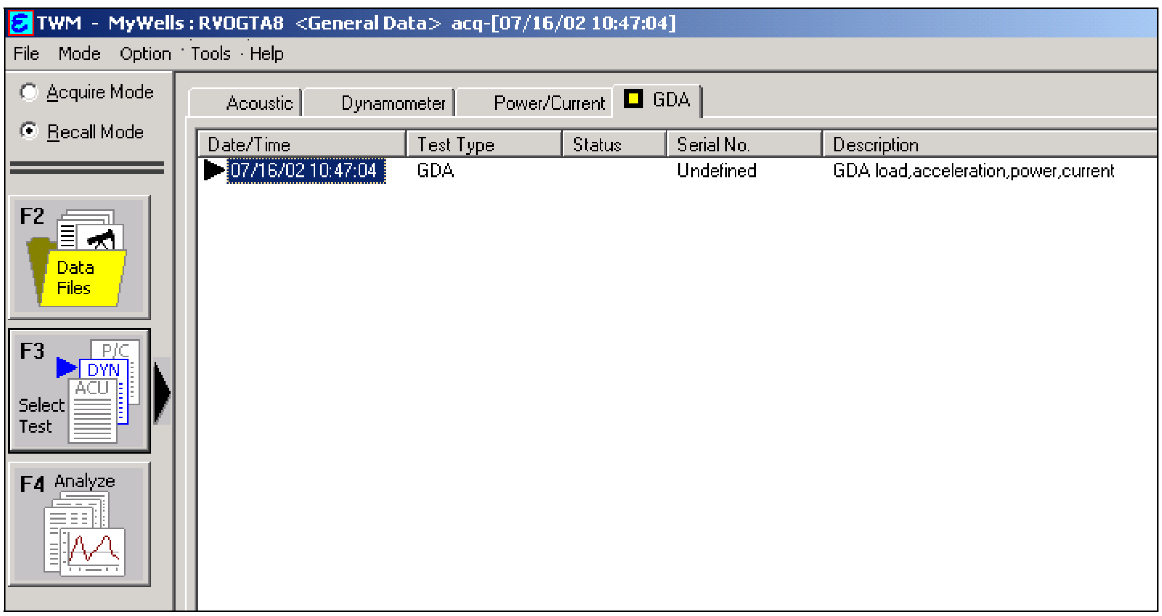
13.3 - Recalling GDA Data

GDA data is saved in the active group under the well file name in the same manner as other well analyzer files. Opening the TWM program in the Recall mode and selecting the corresponding group and well name gives a listing of the stored data as shown below:

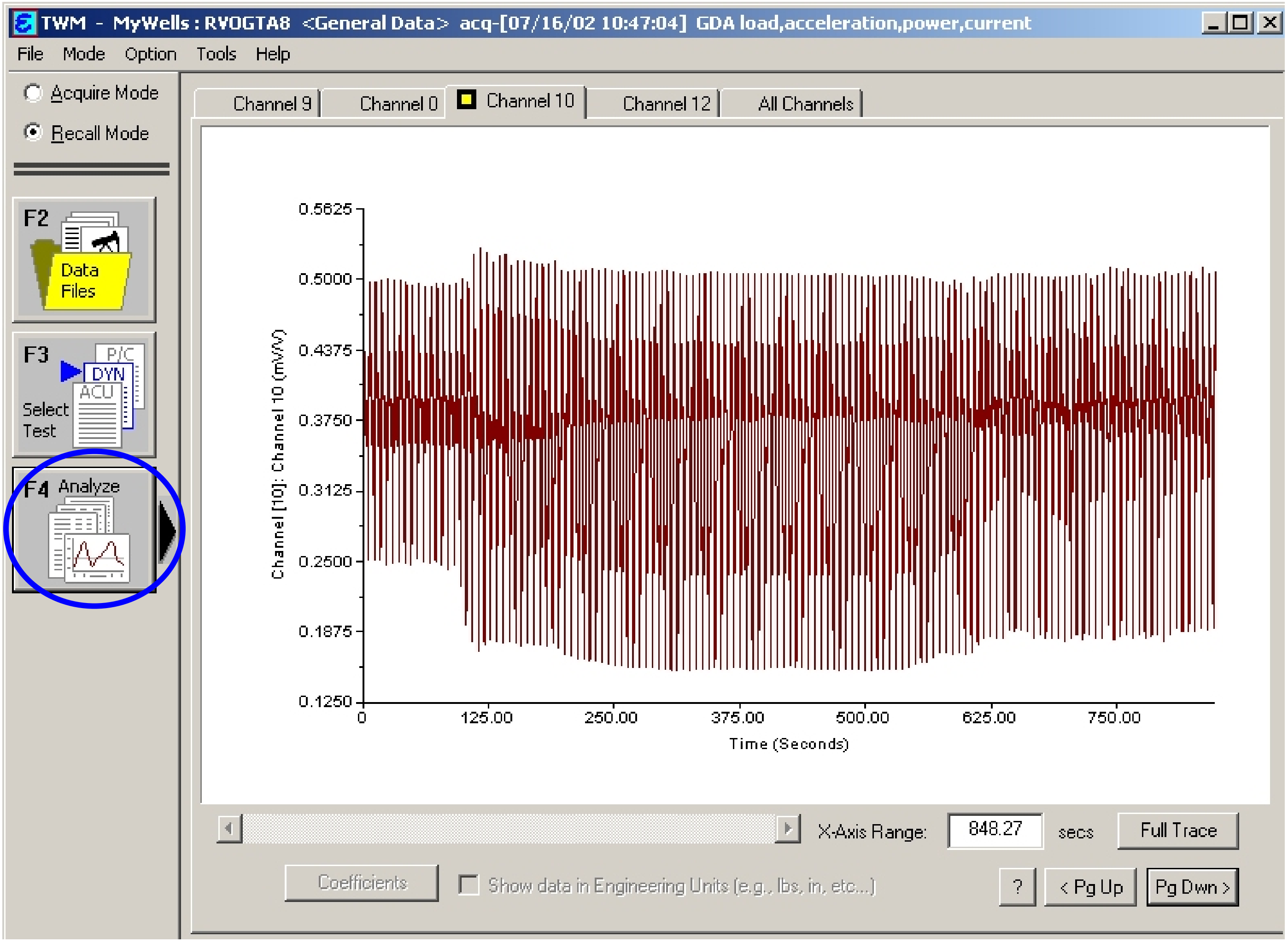


Note that the data set that contains the GDA data is indicated by a **G** in the Test Data field.

Clicking on the **Open** button gives the following screen, after selecting the GDA Tab, which lists the date and time of acquisition and the description of the data set as it was entered when it was saved:

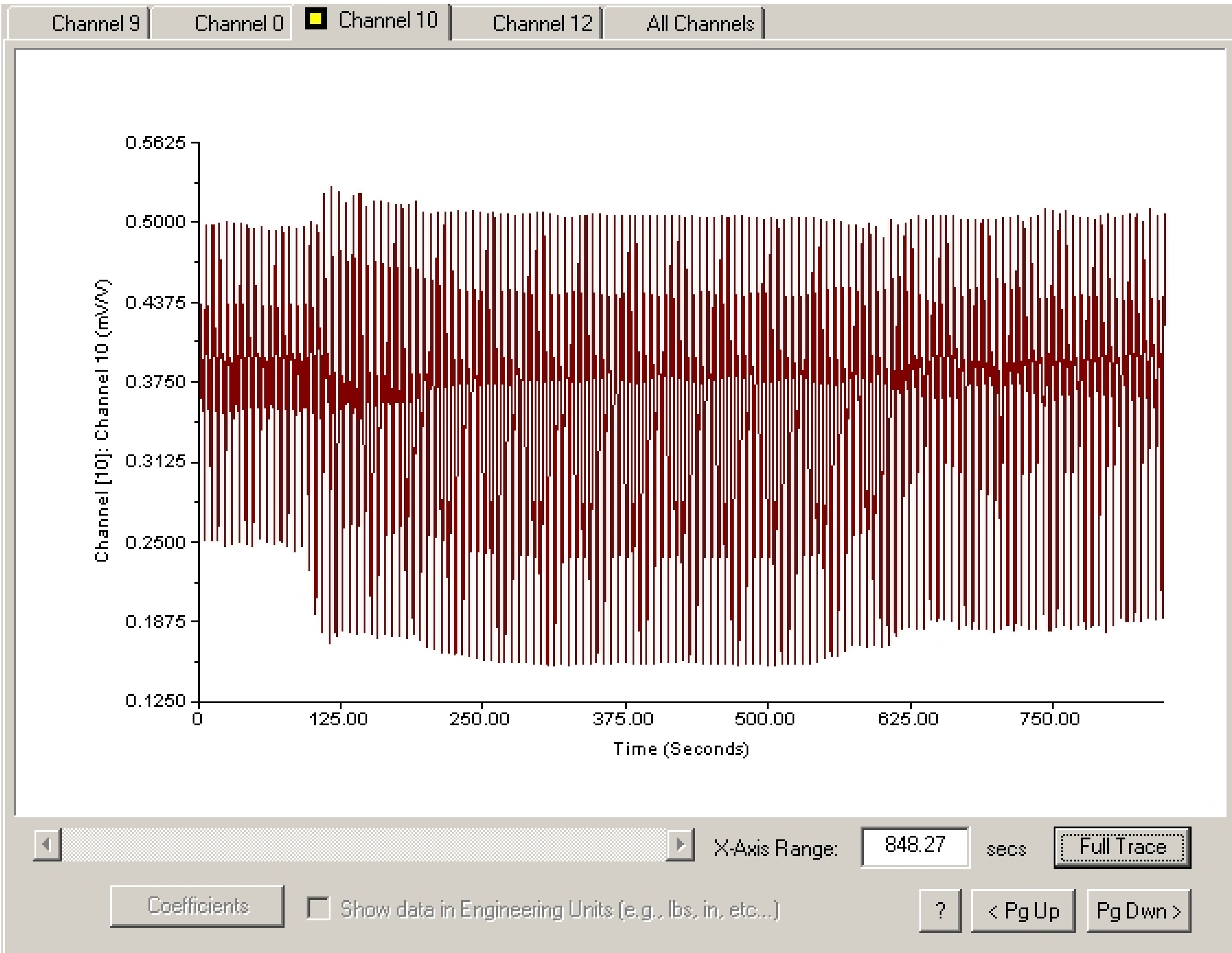


Clicking on the **Analyze** button, results in the display of the four tabs for the corresponding channels that were recorded, channel 10 is displayed below:



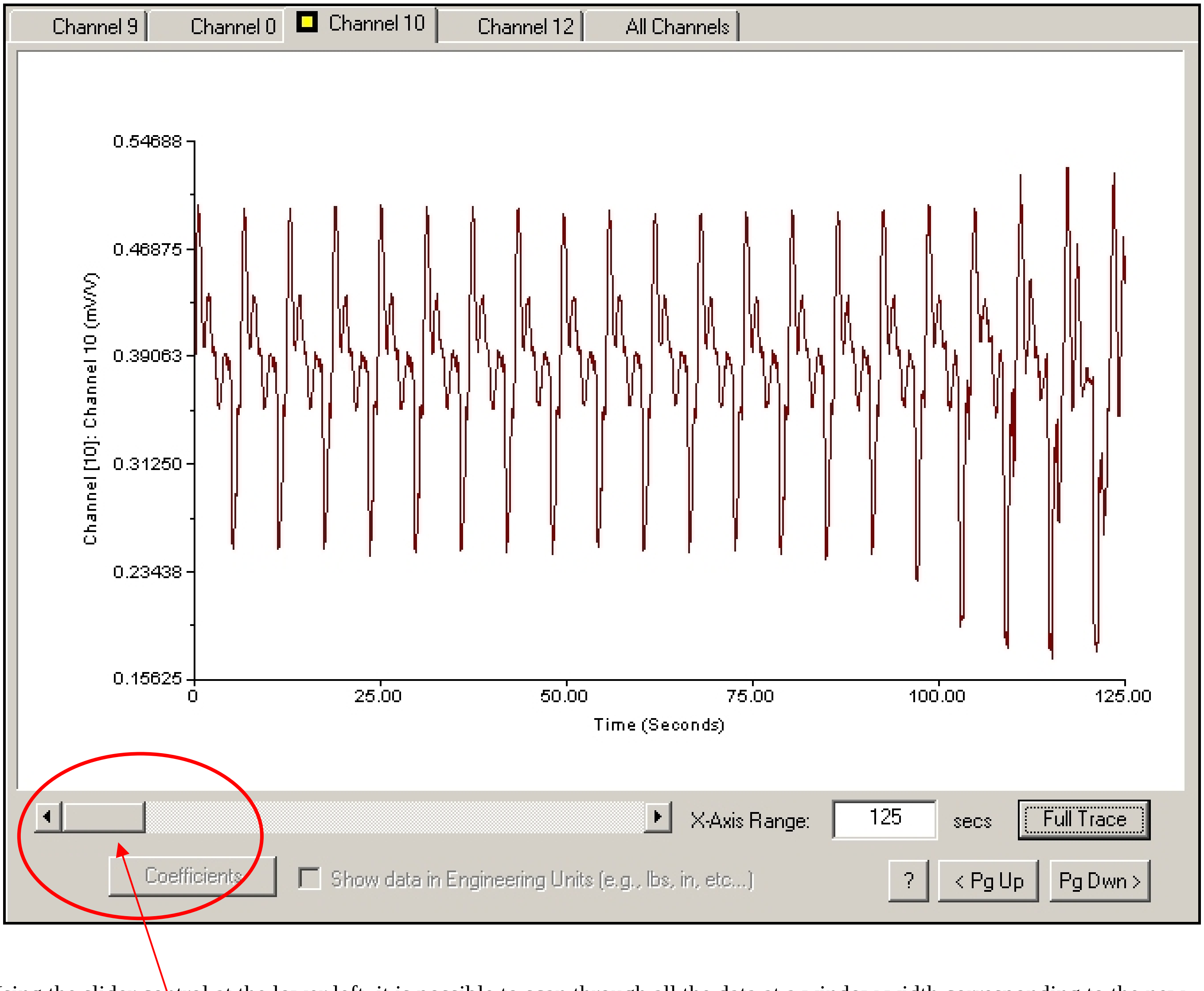
13.3.1 - Expanding the time axis

When an extended data series has been recorded it is possible to display selected portions and scroll through the data using the **X-Axis Range** to input a value that determines the range of the displayed time axis:

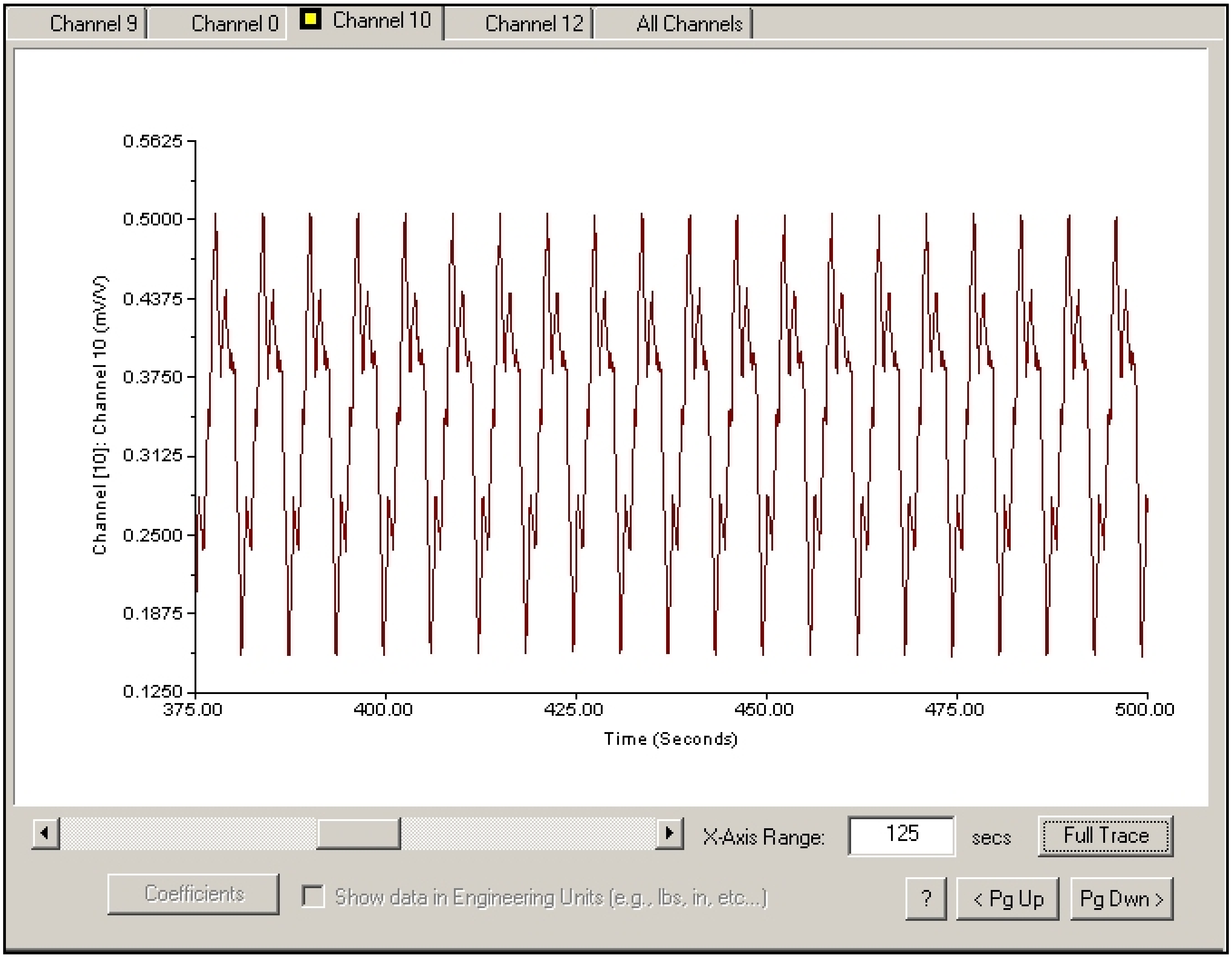


The full trace value of 848.27 is replaced with the range width, in seconds, that the user wants to display, for example 125 seconds.

After entering the new range value of 125 seconds, the following is displayed:



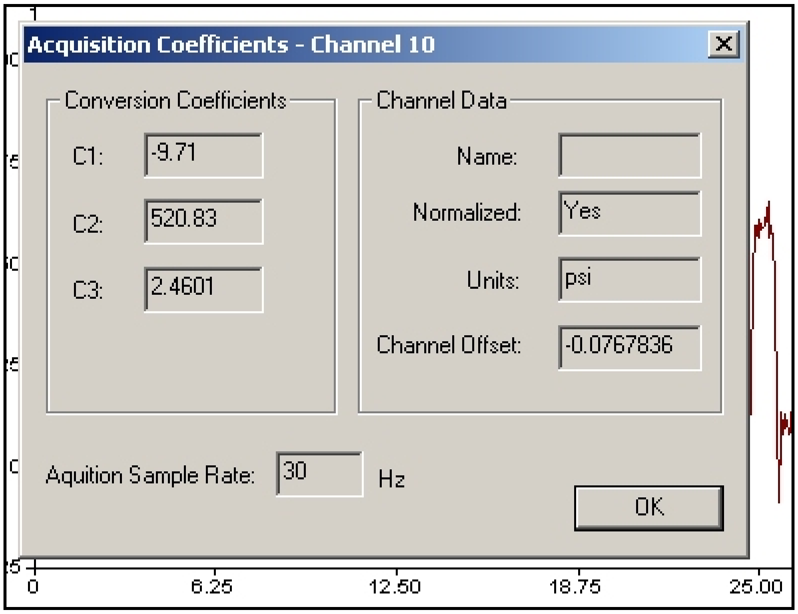
Using the slider control at the lower left, it is possible to scan through all the data at a window width corresponding to the new range as shown in the next figure:



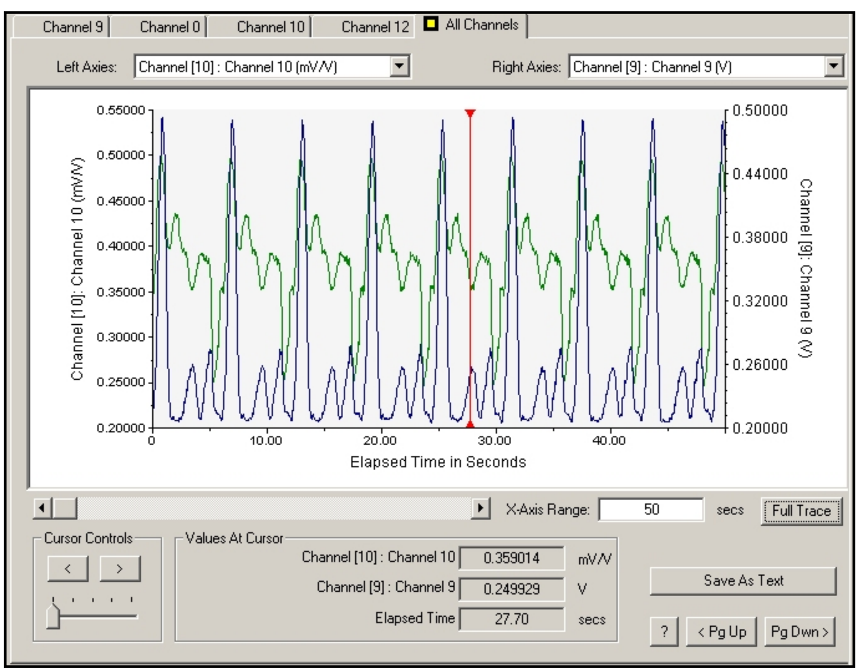
Clicking on the **Full Trace** button, returns the display to the original time scale.

If the check box “**Show data in Engineering Units**” is selected:

then the **Coefficients** button may be used to input the calibration coefficients of the respective transducer when they were not input before data acquisition:



The **All Channels** Tab is used to view one or more traces on the same graph and to scan through the values using a movable cursor

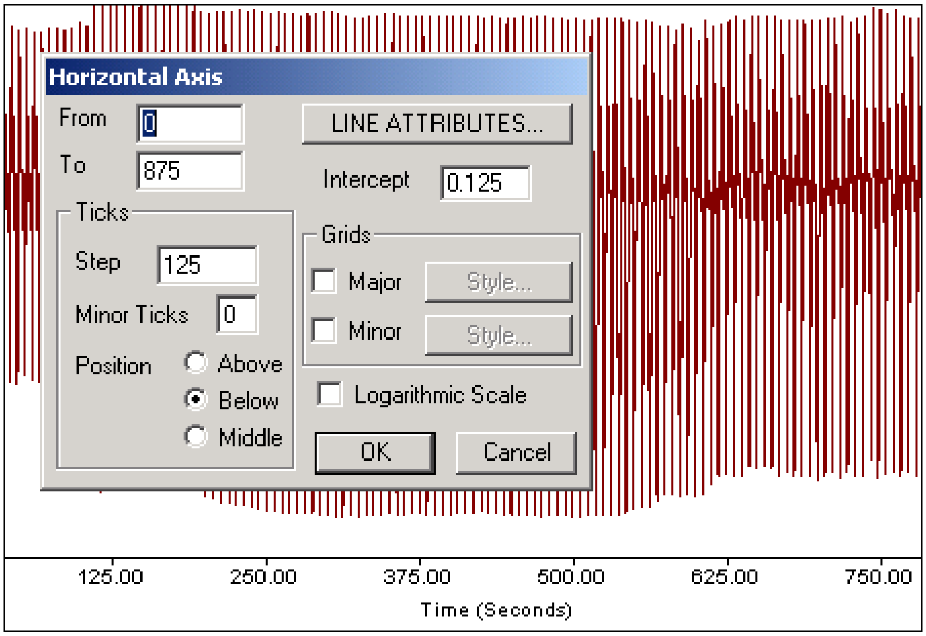


The cursor may be displaced with the Cursor Controls buttons, or it may be located on the trace by pointing and clicking with the mouse buttons.

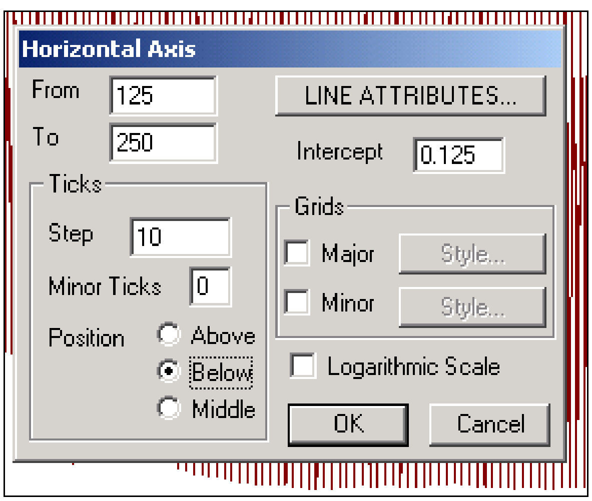
The channels to be displayed are selected from the pull down menus for each axis.

13.3.1.1 - Alternate Method of Time Axis Control

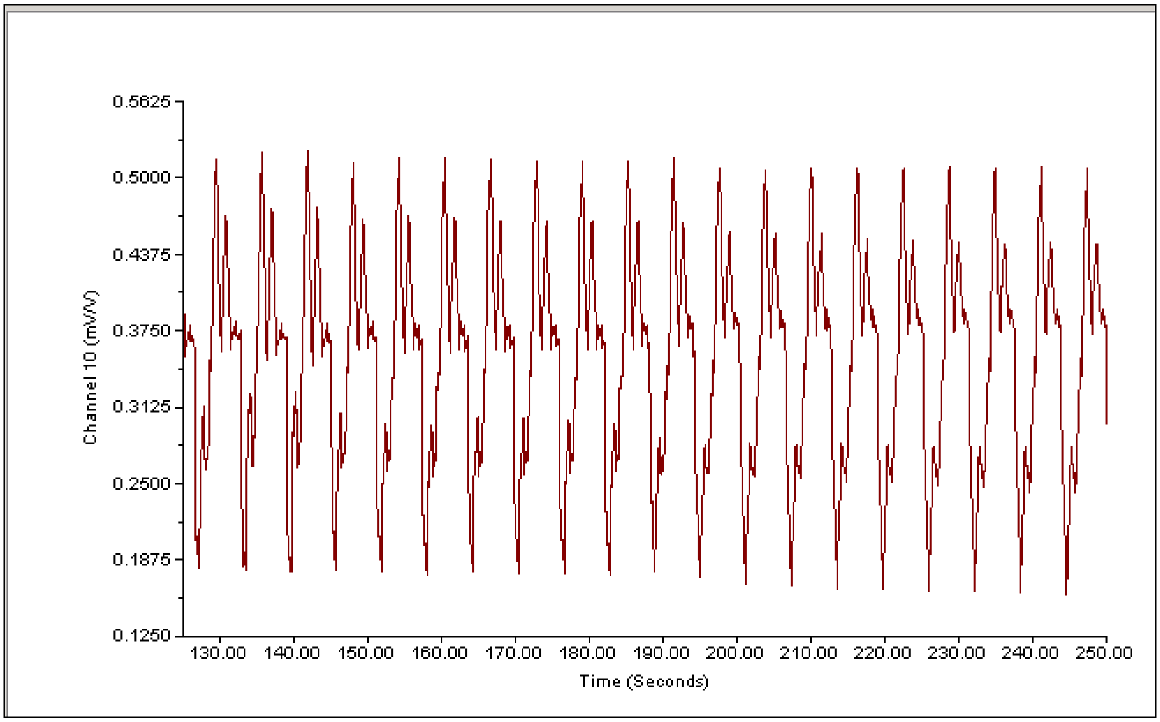
When large data sets have been recorded the displayed data will be compressed to the point that features will not be recognizable. The graphics software provides means to change the scale parameters t view the data in more detail. This is done by placing the mouse or pad cursor on the horizontal axis and double clicking (left button) will present the following form to change the axis characteristics:



The values From 125 to 250 and Step 10, will display the data from 120 to 250 seconds with tick marks every 10 seconds, as entered in the screen below:

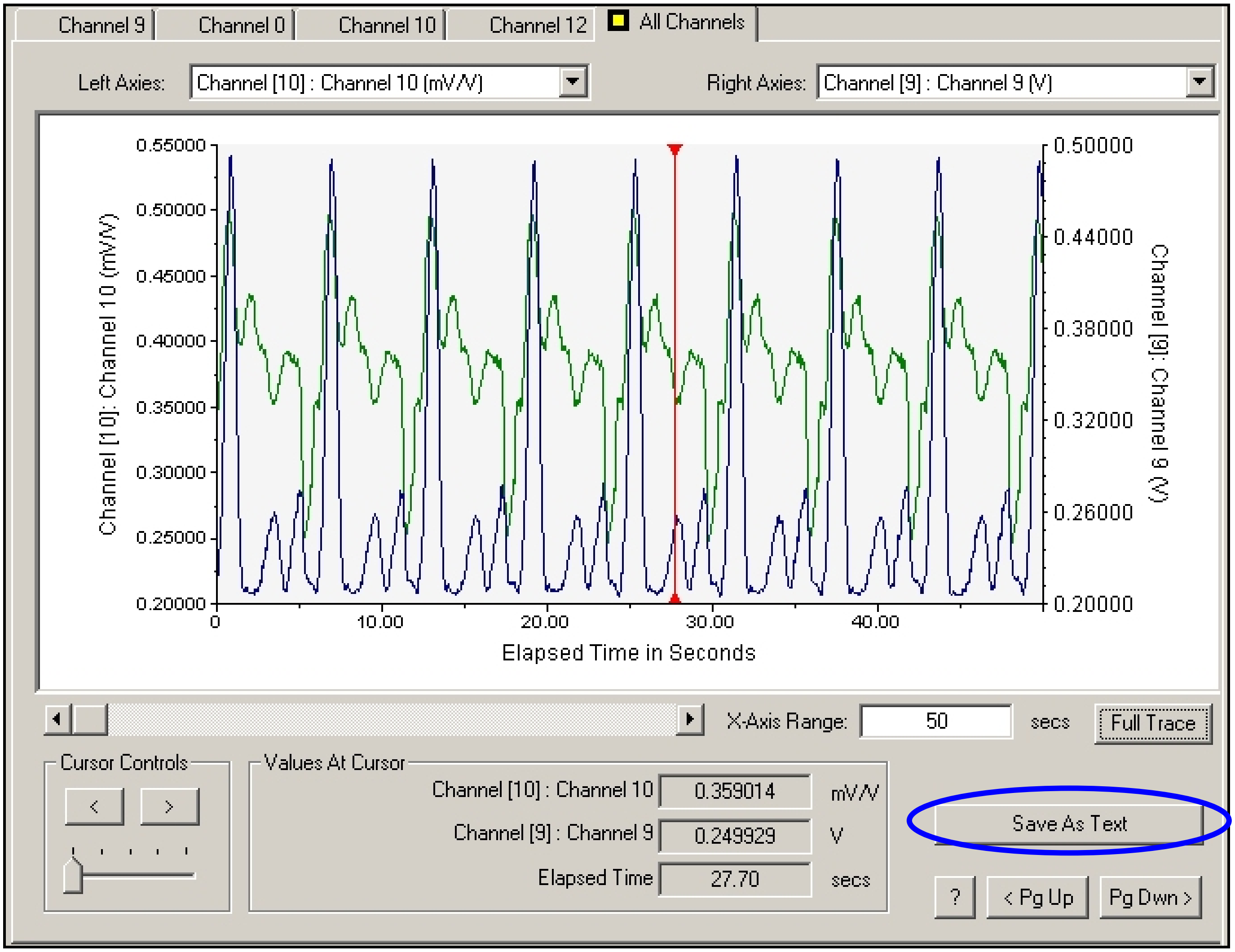


The following screen shows the new presentation of the data. This process may be repeated as many times as necessary to view the data in greater detail.

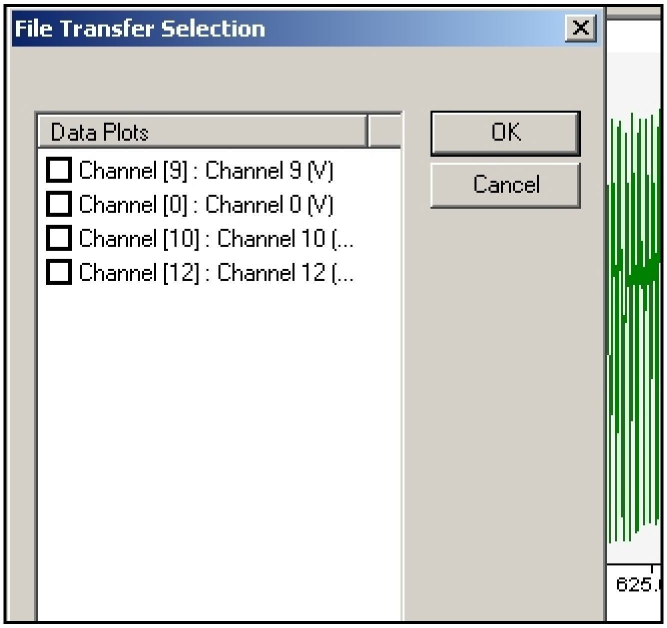


13.4 - Exporting Data as a Text File

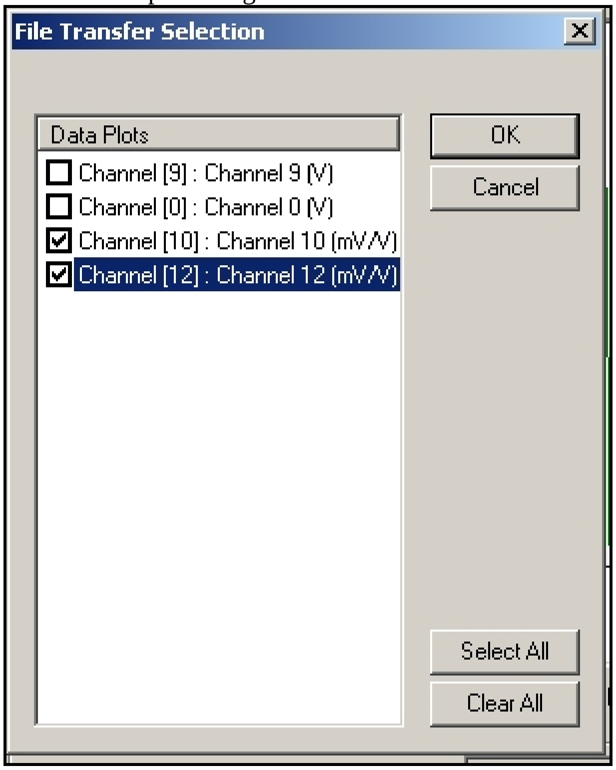
The GDA data may be exported as a text file which then may be imported into a spreadsheet or word processing software. This is done by clicking on the Save as Text button at the bottom of the **All Channels** Tab:



The following dialog box is displayed for the user to select the data channels to be exported to the text file:

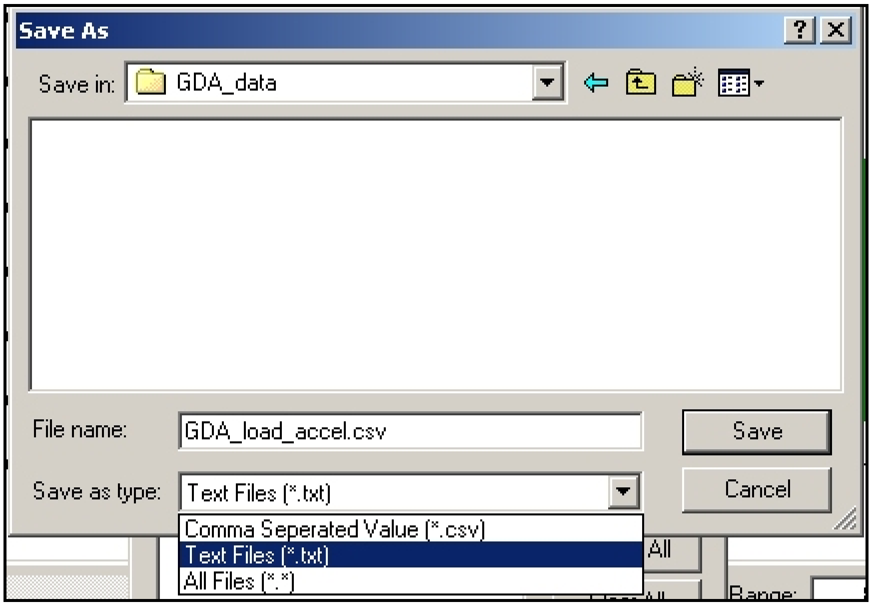


Channels are added or removed from the list to export using the **check boxes** as indicated below:

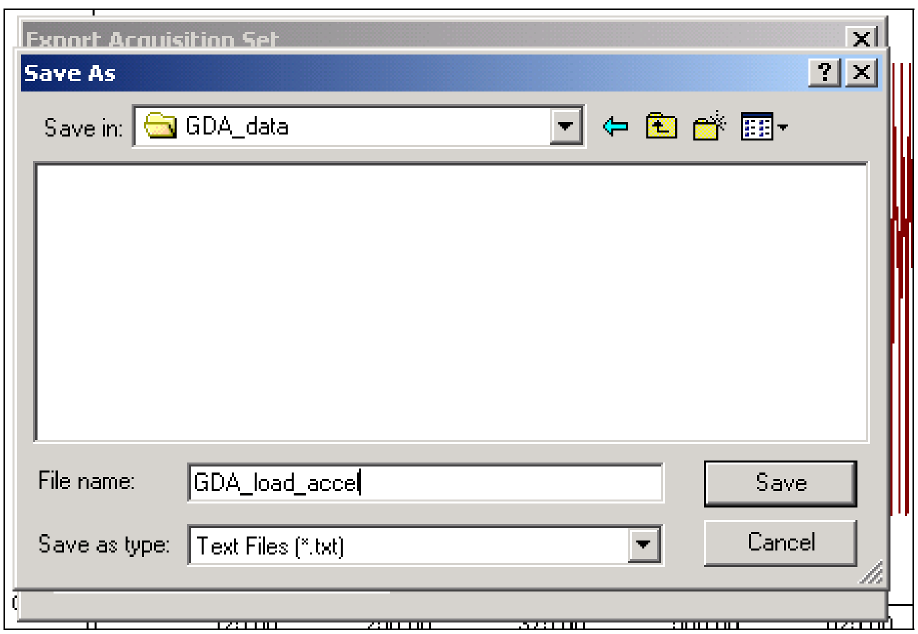


When all the selections have been completed, the **OK** button is clicked

The following screen is presented for the user to select a folder and assign a file name for saving the selected data. In the example below the data will be saved in the **GDA_data** folder (which was created previously) and will be given the name **GDA_load_accel.csv** by default:

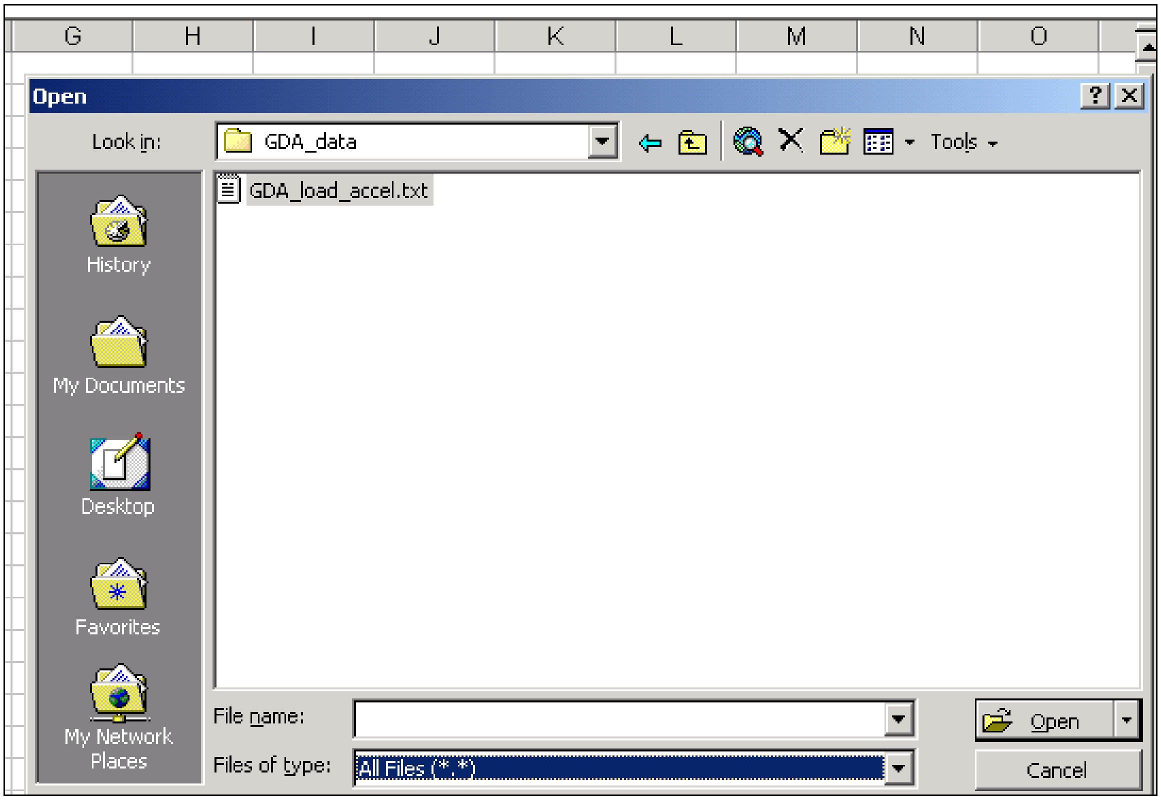


or if preferred the text format may be selected by the user from the **type** pull down menu:



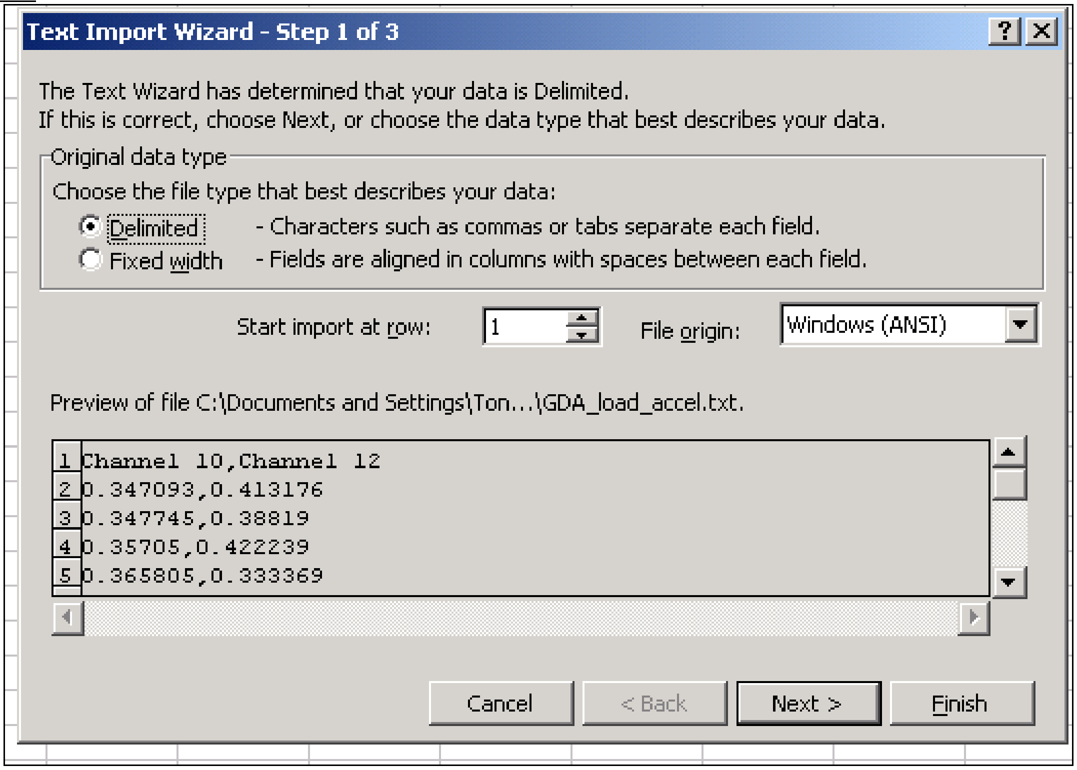
13.5 - Importing Data Into Spreadsheet

After starting the spreadsheet program, select the File Open command and navigate to the corresponding folder and file name, as shown below (note that the file type has been selected as “All Files”):

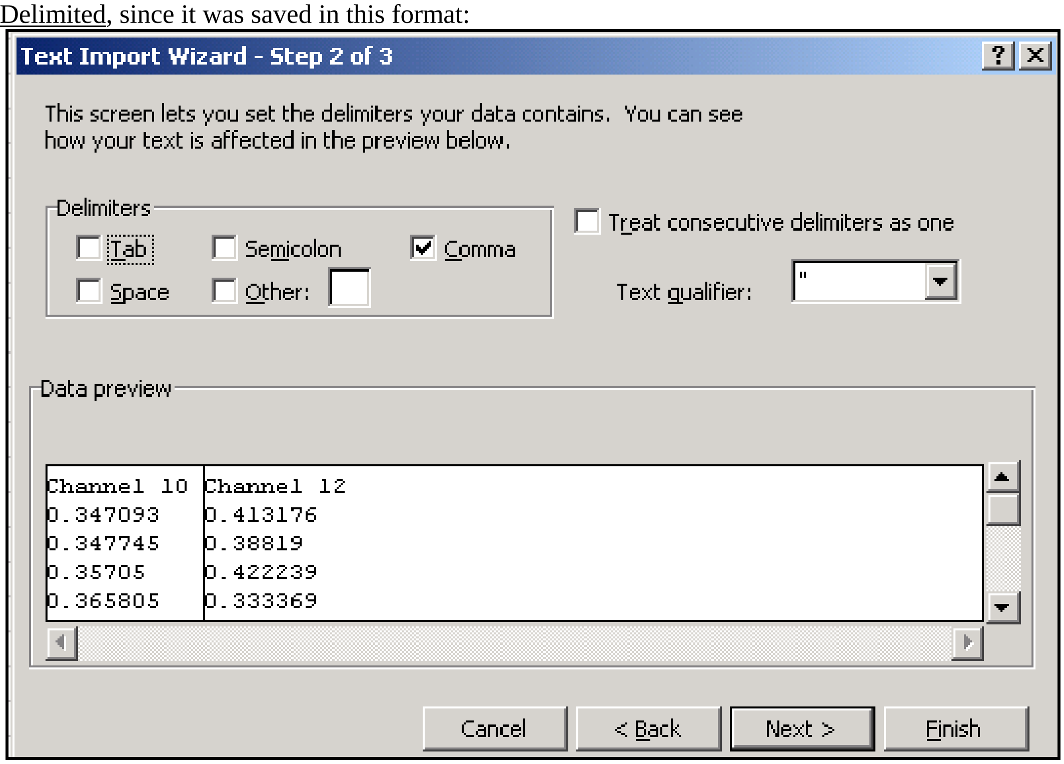


After clicking the Open button follow the instructions of the **Text Import Wizard** as shown in the following figures:

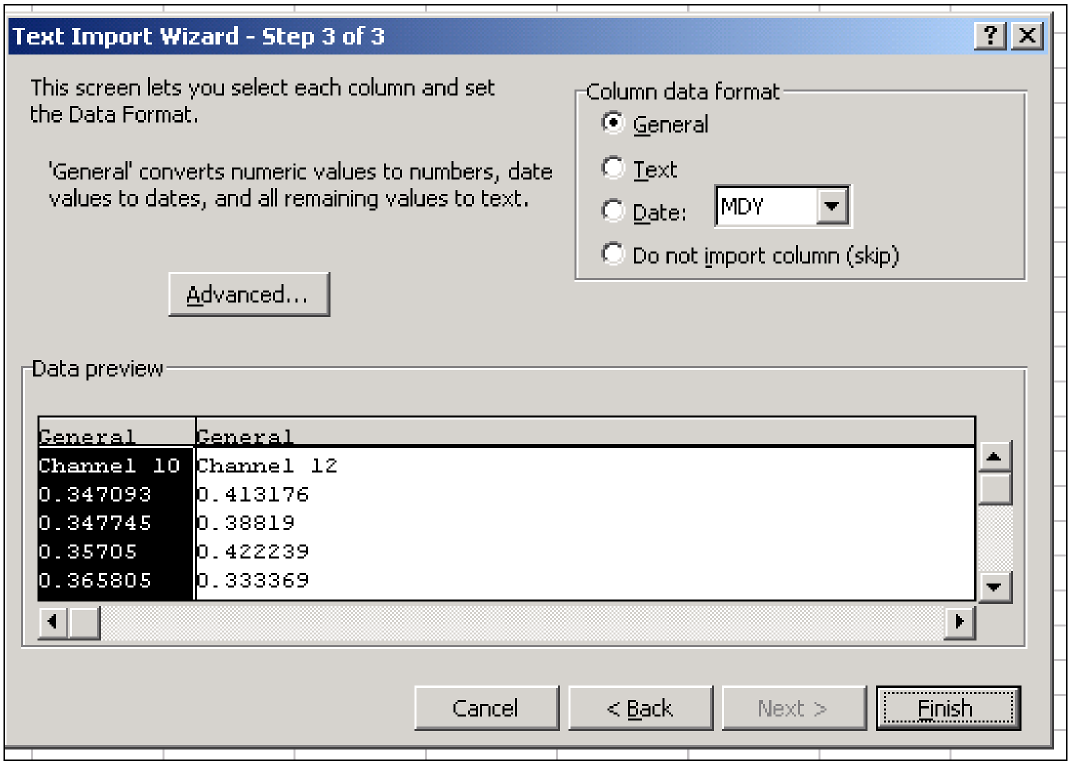
Choose Delimited:



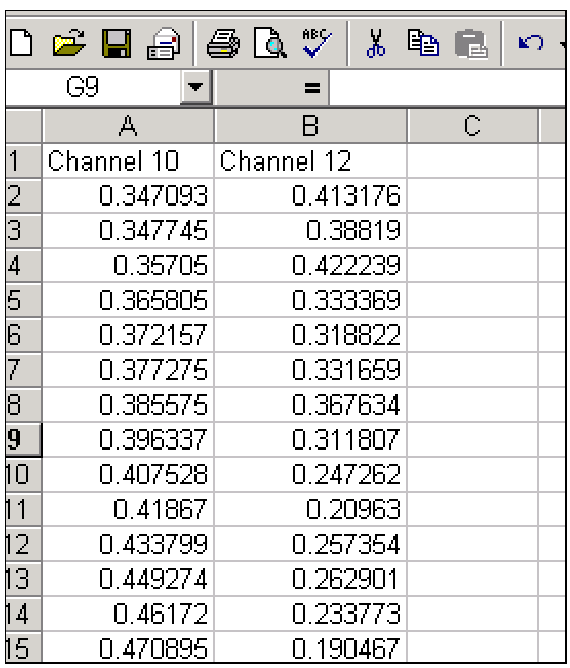
Select Comma Delimited, since it was saved in this format:



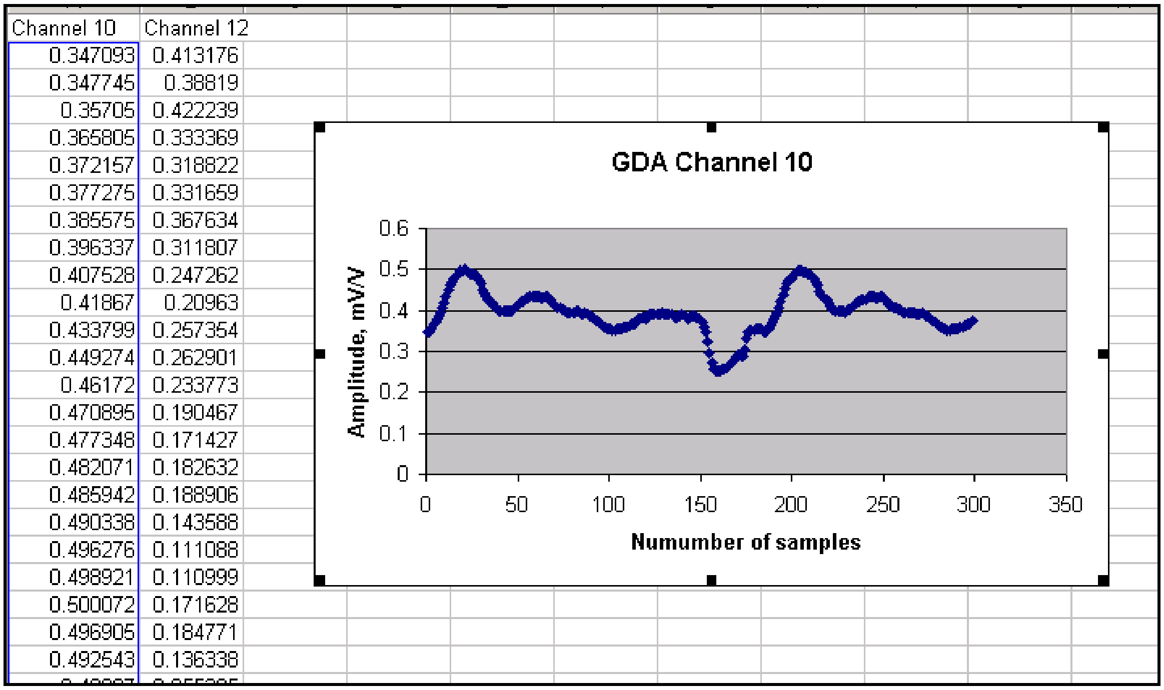
Choose General data format:



Clicking **Finish** will import the data into the spreadsheet:



Once the data is in the spreadsheet it can be manipulated or plotted at will. The figure below shows a graph of the Channel 10 data (Polished Rod Load) plotted as a function of number of points from zero to 300.



Channel 10	Channel 12
0.347093	0.413176
0.347745	0.38819
0.35705	0.422239
0.365805	0.333369
0.372157	0.318822
0.377275	0.331659
0.385575	0.367634
0.396337	0.311807
0.407528	0.247262
0.41867	0.20963
0.433799	0.257354
0.449274	0.262901
0.46172	0.233773
0.470895	0.190467
0.477348	0.171427
0.482071	0.182632
0.485942	0.188906
0.490338	0.143588
0.496276	0.111088
0.498921	0.110999
0.500072	0.171628
0.496905	0.184771
0.492543	0.136338

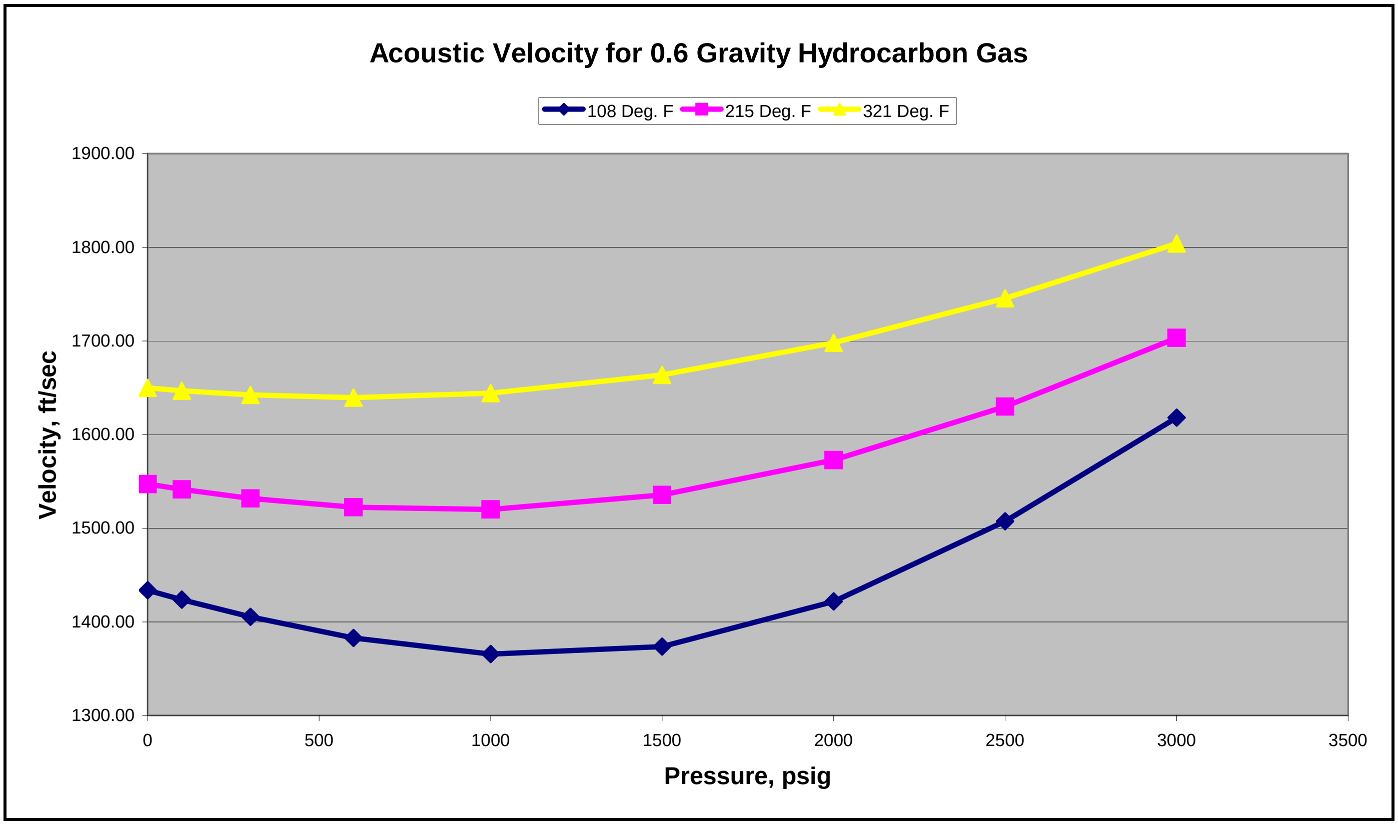
APPENDICES

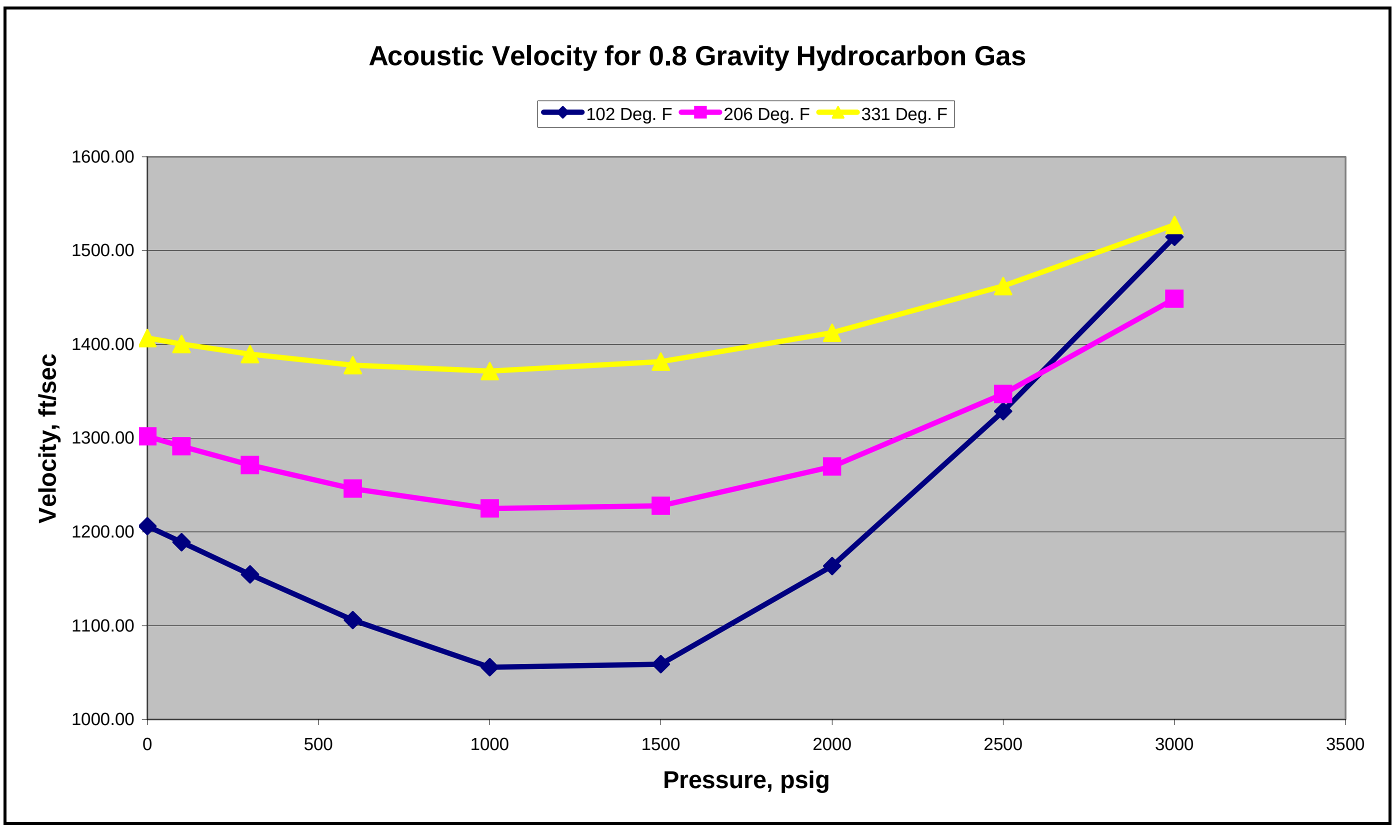
APPENDIX I – TYPICAL ACOUSTIC VELOCITY IN HYDROCARBON GAS AS A FUNCTION OF PRESSURE AND TEMPERATURE

The acoustic velocity of air at 82^{o} F is 1140 ft./sec. The velocity of 0.8 SG hydrocarbon gas at 50 PSI and 90^{o} F is 1175 ft./sec. The velocity of hydrocarbon gas varies from a practical minimum of 600 ft./sec. to 2000 ft / sec. (at 5000 PSI) to 3500 ft/sec (at 15000 PSI). More detailed information about acoustic velocity of hydrocarbon gases at various pressures and temperatures can be obtained from Echometer's web page www.echometer.com or by contacting the company. The following Table and figures correspond to hydrocarbon gases of 0.6 and 0.8 specific gravity. They are reproduced here to serve as a quick reference.

Specific gravity 0.6				Specific Gravity 0.8		
Temp, degF	Pressure, psi	Velocity, ft/sec		Temp, degF	Pressure psi	Velocity ft/sec
108	0	1433.72		102	0	1206.15
108	100	1423.75		102	100	1188.92
108	300	1405.37		102	300	1154.73
108	600	1382.77		102	600	1105.94
108	1000	1365.57		102	1000	1055.77
108	1500	1373.49		102	1500	1059.01
108	2000	1421.77		102	2000	1163.66
108	2500	1507.29		102	2500	1328.60
108	3000	1618.15		102	3000	1514.72
215	0	1547.00		206	0	1301.89
215	100	1541.40		206	100	1291.22
215	300	1531.91		206	300	1271.31
215	600	1522.44		206	600	1246.15
215	1000	1520.07		206	1000	1225.11
215	1500	1535.68		206	1500	1227.71
215	2000	1572.83		206	2000	1269.59
215	2500	1629.92		206	2500	1347.04
215	3000	1703.15		206	3000	1448.49
321	0	1649.76		331	0	1406.71
321	100	1646.72		331	100	1400.49
321	300	1642.21		331	300	1389.62
321	600	1639.57		331	600	1377.75
321	1000	1644.27		331	1000	1371.59
321	1500	1663.81		331	1500	1381.63
321	2000	1698.10		331	2000	1412.36
321	2500	1745.64		331	2500	1462.18
321	3000	1804.19		331	3000	1527.39

The general behavior of the acoustic velocity is illustrated in the following figures.


Acoustic Velocity for 0.6 Gravity Hydrocarbon Gas
108 Deg. F
215 Deg. F
321 Deg. F
Velocity, ft/sec
1900.00
1800.00
1700.00
1600.00
1500.00
1400.00
1300.00
0
500
1000
1500
2000
2500
3000
3500
Pressure, psig


Acoustic Velocity for 0.8 Gravity Hydrocarbon Gas
102 Deg. F
206 Deg. F
331 Deg. F
Velocity, ft/sec
1600.00
1500.00
1400.00
1300.00
1200.00
1100.00
1000.00
0
500
1000
1500
2000
2500
3000
3500
Pressure, psig

APPENDIX II - 5000 PSI GAS GUN, IMPLOSION/EXPLOSION OPERATING MANUAL SUPPLEMENT

NOTE - The following covers both the new and the old models of the 5000 psi gas gun.

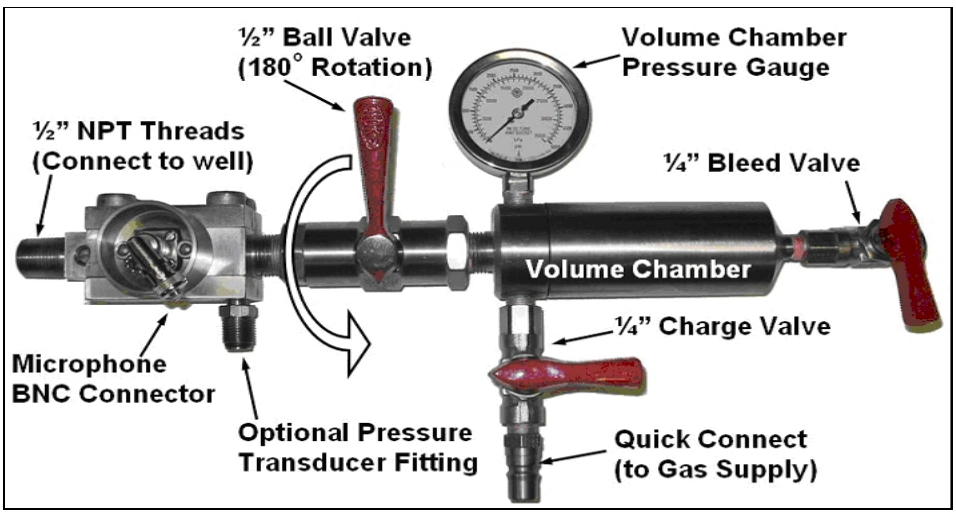
A - SAFETY

Read the operating manual and all pertinent safety information before using this equipment. Always use good safety practices. Contact Echometer Co. (info@echometer.com) if you have any questions about this equipment. Do not exceed 5000 PSI or safe working pressure at any time.

B - GENERAL - GUN OPERATION IN IMPLOSION MODE

The 5000 PSI gas gun is a general purpose gas gun which can be used below the working pressure of 5000 PSI. The gas gun is attached to a valve which opens into the casing annulus or tubing depending upon which is to be tested. The pressure pulse is generated by releasing gas from the well through the (new 180 degree rotation) 1/2" ball valve into the volume chamber.

Figure 1 – New model of 5000 psi gas gun including 180 degree rotation valve, ¼ " charge valve and optional pressure transducer fitting



Depending upon the well, from 100 to 500 PSI well pressure is required for satisfactory operation. The amplitude of the initial pulse can be controlled by the differential pressure between the well and the volume chamber. Generally, a differential pressure of 100 PSI should be sufficient. However, use enough differential pressure so that collars are counted all -the way-to the liquid level and the liquid level signal is distinct if possible.

B1-OPERATING TECHNIQUE -IMPLOSION MODE

1. Verify that the well pressure is less than 5000 PSI. Open the valve to the well and bleed a small amount of gas from the well if possible. Check that liquid is not present at the surface valve. This also removes foreign particles and grease from the valve so that these foreign materials will not be released into the gas gun.

2. Attach the gas gun securely to the valve or fitting on the well. Attach the pressure transducer to the gas gun when the optional pressure transducer is used with the Well Analyzer.

3. Open the 1/2" ball valve (see figure below), and close the 1/4" bleed valve and the 1/4" charge valve.

4. Open the well valve slowly and fully. For best results, the opening between the gas gun and the well should be ½ inch or larger. Needle valves and/or small openings will reduce the accuracy of acoustic liquid level depth measurements. The pressure gauge on the volume chamber indicates well pressure. Do not exceed 5000-PSI WP.

5. Connect the Well Analyzer or Model M amplifier/recorder to the gas gun microphone BNC connector using the Echometer coaxial microphone cable. Follow the directions in the operating manuals concerning operation of the Well Analyzer or Model M amplifier/recorder. Connect the pressure transducer cable if the Well Analyzer and pressure transducer are used.

6. Close the 1/2" ball valve. Open the 1/4" bleed valve and bleed the volume chamber pressure so that the differential pressure between the volume chamber and the well is at least 100 PSI. A larger differential pressure will result in larger reflections from collars, anomalies and the liquid level. Close the 1/4" bleed valve. The pressure pulse is generated by rapidly opening the 1/2" ball valve when a differential pressure exists across the 1/2" ball valve. The valve should be rapidly opened and closed by rotating the valve 180o from the closed position to the open position to the closed position.

7. The well can easily be re-tested by following the steps in (6). If collars are not obtained all the way to the liquid level, use a larger differential pressure. Bleed the volume chamber pressure to 0 PSI if necessary.

8. When finished obtaining acoustic tests, close the valve to the well. Open both the 1/2" ball valve and the 1/4" bleed valve. Then, the Echometer gas gun can be removed from the well.

C - GENERAL - GUN OPERATION IN EXPLOSION MODE

The 5000-PSI gas gun can be used in the explosion mode when the well pressure is low and does not permit satisfactory operation in the implosion mode. In the explosion mode, an external gas source is used to pressurize the volume chamber to at least 200 PSI in excess of well pressure. Then, this gas is rapidly released into the well to generate the acoustic pulse. The volume chamber can be pressurized using C02 gas or nitrogen gas. To pressurize the volume chamber, connect the high-pressure hose Quick-Connector Fitting from the CO2 or N2 supply bottle to the Quick-Connect Fitting located on the gas gun volume chamber (see figure below). With the 1/2" ball valve and the 1/4" bleed valve in the closed position, slowly open the 1/4" charge valve and pressure the gas gun volume chamber to at least 200 psi above the well pressure. Close the 1/4" charge valve on the gas gun before firing the shot. The acoustic pulse is generated by rapidly rotating the 1/2" ball valve handle 180o and allowing gas to discharge from the volume chamber into the well.

C1 -OPERATING TECHNIQUE- EXPLOSION MODE

1. Verify that the well pressure is less than 5000 PSI. Open the valve to the well and bleed some gas from the well if possible. Check to insure that liquid is not present. This also removes foreign particles and grease from the valve so that these foreign materials will not be released into the gas gun.

2. Attach the gas gun securely to the valve on the well. Attach the pressure transducer to the gas gun when the pressure transducer is used with the Well Analyzer.

3. Open the 1/2" ball valve and close the both 1/4" bleed valve and the 1/4" charge valve.

4. Open the well valve slowly and fully. For best results, the opening between the gas gun and the well should be ½ inch or larger. Needle valves and/or small openings will reduce the accuracy of acoustic liquid level depth measurement. The pressure gauge on the volume chamber indicates well pressure. Do not exceed 5000-PSI WP.

5. Attach the Well Analyzer or Amplifier/recorder to the gas gun microphone BNC connector using the Echometer microphone coaxial cable. Attach the pressure transducer cable if the Well Analyzer is used. Follow the directions in the operating manuals concerning operation of the Echometer Well Analyzer or Amplifier/recorder.

6. Note the pressure in the volume chamber that is the well pressure. Close the 1/2" ball valve. To pressurize the volume chamber, connect the high-pressure hose Quick Connect Fitting from the CO2 or N2 supply bottle to the Quick Connect Fitting located on the gas gun volume chamber. Open the gas supply container valve. Add gas using the 1/4" charge valve to charge the volume chamber pressure at least 200 psi above the well pressure. Close the 1/4" charge valve to the gas supply before firing the

shot. The pressure pulse is generated by rapidly rotating the 1/2" ball valve handle 180o when a positive differential pressure exists between the gas gun volume chamber and the well.

7. If satisfactory reflections are not obtained from the collars and the liquid level, try again with a higher pressure in the volume chamber. Do not exceed 5000 PSI.

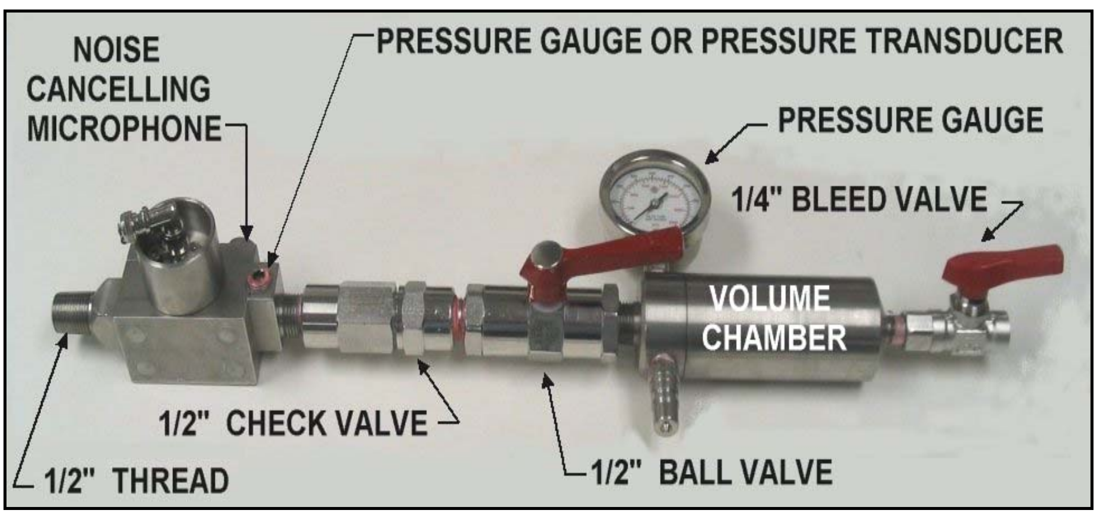
8. When finished obtaining acoustic tests, close the well valve between the gas gun and the well. Close the gas supply container valve. Open the 1/4" bleed valve, the 1/4" charge valve and the 1/2" ball valve to bleed gas from the gas gun, the volume chamber and the hose to atmosphere. Disconnect the gas supply by releasing the Quick Connect Fitting on the hose from the Quick Connect Fitting on the gas gun.

D - GENERAL - OLD MODEL OF THE 5000 PSI GAS GUN

Older models of the 5000 psi gas gun were assembled with a one way check valve designed to suppress internal reflections that cause excessive acoustic noise. The acoustic signal produced by the microphone in the 5000 psi gas gun is affected by pressure resonating in the gas gun volume chamber. When a high energy pressure pulse in the acoustic reflection is detected by the 5000 psi gas gun microphone, the pressure pulse continues into the volume chamber and the volume chamber begins to resonate at a frequency of between 45 and 75 hertz. The resonating frequency of the volume chamber depends on the acoustic velocity of the gas, the higher the acoustic velocity, then the higher the resonating frequency.

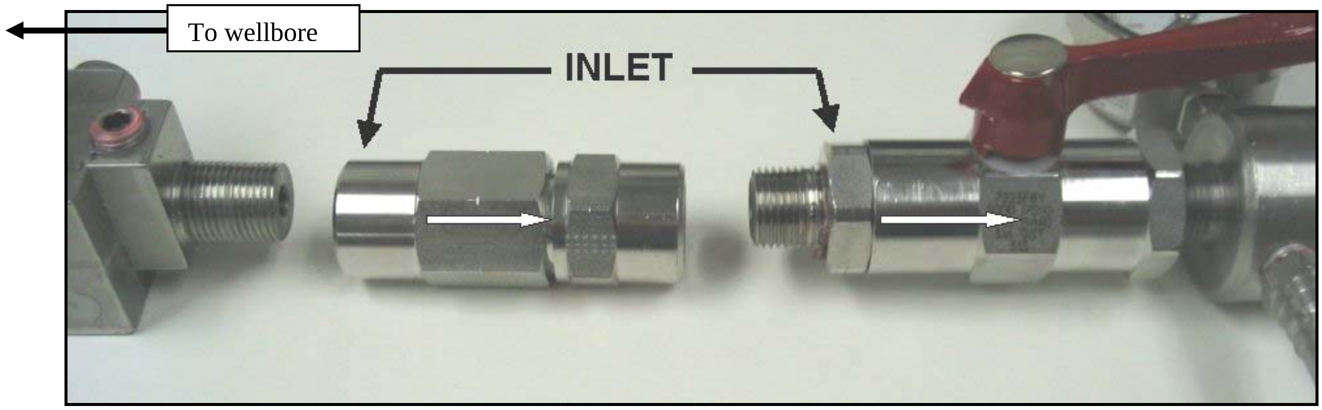
The resonating frequency from the volume chamber can interfere with collar reflections and make counting the tubing collars reflections more difficult. The resonating signal can make the determination of the exact location of liquid level kick more difficult. The purpose of the one-way gas flow check valve is to allow high pressure gas to implode into the volume chamber on the gas gun, but any resonating energy is not reflected back out of the volume chamber because the check is closed (isolating the volume chamber from the microphone). By removing the resonating effect of the volume chamber, the one-way gas flow check valve improves the quality of the acoustic trace from the 5000 psi gas gun and makes analysis of the acquired data easier and more accurate.

Figure 2 – Old model of 5000 psi gas gun with check valve installed



D1 - OPERATING TECHNIQUE -IMPLOSION MODE

The following picture shows how the one-way check valve and 7223F8Y ball valve are installed for implosion gun operation.



Check that the well pressure is less than 5000 PSI. Open the valve to the well and bleed a small amount of some gas from the well if possible. Check to insure that liquid is not present. This also removes foreign particles and grease from the valve so that these foreign materials will not be released into the gas gun.

Attach the gas gun securely to the valve on the well.

Open the 1/2" ball valve and close the 1/4" ball valve.

Open the well valve slowly. Open the well valve fully. Do not exceed 5000 PSI WP.
Attach the Well Analyzer or Model D amplifier/recorder to the gas gun using the Echometer cable. Follow the directions in the operating manuals concerning operation of the Well Analyzer or Model D amplifier/recorder.

Close the 1/2" ball valve. Open the 1/4" ball valve and bleed the volume chamber pressure so that the differential pressure between the volume chamber and the well is more than 100 PSI. A larger differential pressure will result in larger reflections from collars, anomalies and the liquid level. Close the 1/4" ball valve. The pressure pulse is generated by rapidly opening the 1/2" ball valve.

The well can easily be re-shot. Close the 1/2" ball valve. Bleed the volume chamber by opening the 1/4" valve. Then, close the 1/4" valve. Rapidly open the 2"ball valve to re-shoot. If collars are not obtained all the way to the liquid level, use a larger differential pressure. Bleed the volume chamber pressure to 0 PSI if necessary. However, a differential pressure of 100 PSI will be satisfactory on many wells.

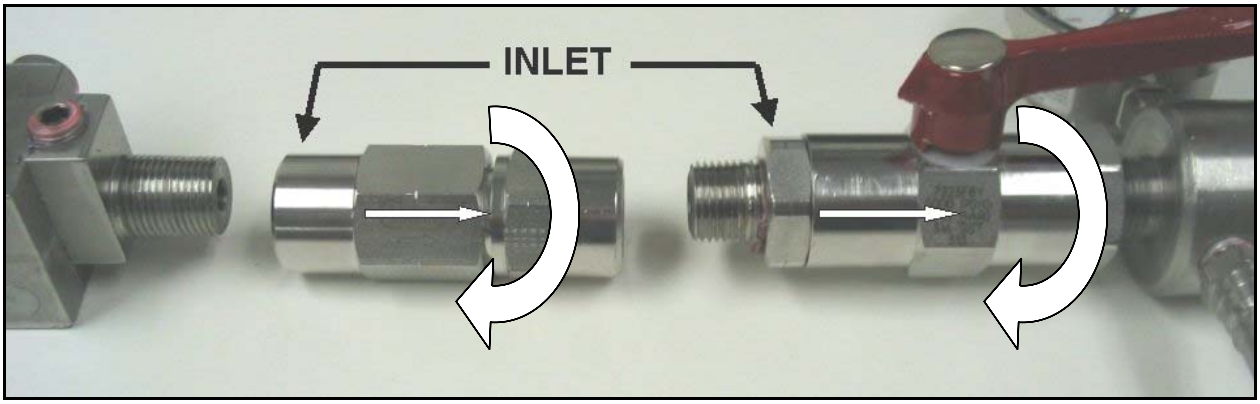
When finished obtaining acoustic records, close the valve to the well. Open both the 1/2" and the 1/4" valves. Then, the Echometer gas gun can be removed from the well.

D2 - OPERATING TECHNIQUE -EXPLOSION MODE

Although the 5000 PSI gas gun is generally used in the implosion mode it can also be used in the explosion mode when the well pressure is too low and does not permit satisfactory implosion operation. A modification of the valve connection needs to be made as detailed below. In the explosion mode, external gas is used to pressurize the volume chamber to a pressure at least 100 PSI in excess of well pressure. If satisfactory operation cannot be obtained by releasing gas from the well into the gas gun, the volume chamber on the gas gun can be pressurized using C02 gas or nitrogen gas. To fill the volume chamber, the 1/4" ball valve is connected to a gas supply. The 1/4" ball valve is opened and the 1/2" ball valve is closed. Open the valve on the gas supply and fill the volume chamber 100 PSI above well pressure or safe working pressure, whichever is lower. Then close the 1/4" ball valve. The acoustic pulse is generated by rapidly opening the 1/2" ball valve and allowing gas to discharge from the volume chamber into the well. The well can be re-shot by closing the 1/2" ball valve and refilling the volume chamber through the 1/4" ball valve utilizing the gas in the external supply bottle. Then close the 1/4" ball valve. The gas pulse will be generated when the 1/2" ball valve is rapidly opened.

E - VALVE CONNECTION MODIFICATION

The following picture shows how the one-way check valve and 7223F8Y ball valve are normally installed for implosion gun operation. IN ORDER TO FIRE THE 5000 PSI GAS GUN IN EXPLOSION MODE, THE VALVES NEED TO BE ROTATED 180 DEGREES AND INSTALLED IN THE GUN WITH THE INLET OF THE CHECK VALVE AND THE INLET OF BALL VALVE FACING TOWARD THE VOLUME CHAMBER OF THE GUN AND AWAY FROM THE MICROPHONE. Well debris tends to cause the ball valve to leak pressure, if the ball valve is not rotated 180 degrees when used in explosion mode.



Check that the well pressure is less than 5000 PSI. Open the valve to the well and bleed some gas from the well if possible. Check to insure that liquid is not present. This also removes foreign particles and grease from the valve so that these foreign materials will not be released into the gas gun.

Attach the gas gun securely to the valve on the well.

Open the 1/2" ball valve and close the 1/4" ball valve.

Open the well valve slowly. Open the well valve fully. Do not exceed the 5000 PSI WP.

Attach the Well Analyzer or amplifier/recorder to the gas gun using the Echometer cable. Follow the directions in the operating manuals concerning operation of the Echometer.

Note the pressure in the volume chamber which is the well pressure. Close the 1/2" ball valve and connect the 1/4" ball valve to a gas supply source. Open the gas supply source. Slowly open the 1/4" ball valve until the volume chamber pressure increases to approximately 500 PSI above well pressure. Then, close the 1/4" ball valve. The pressure pulse is generated by rapidly opening the 1/2" ball valve when a positive differential pressure exists between the gas gun volume chamber and the well.

The well can easily be re-shot. Simply close the 1/2" ball valve. Slowly open the 1/4" ball valve and fill the volume chamber pressure 10500 PSI above well pressure. If greater responses are desired from the collars and the liquid level reflections, increase the volume chamber pressure to 1000 PSI above well pressure. Close the 1/4" ball valve. To generate the pressure pulse, rapidly open the 1/2" ball valve. If satisfactory reflections are not obtained from the collars and the liquid level, try again with a higher pressure in the volume chamber. Do not exceed 5000 PSI.

When finished obtaining acoustic records on the gas gun, close the valve to the well between the gas gun and the well. Close the 1/4" ball valve and the 1/2" ball valve. Disconnect the gas supply. Slowly open the 1/4" and 1/2" ball valves to bleed gas from the gas gun and volume chamber to atmosphere. When not in use, leave both valves open.

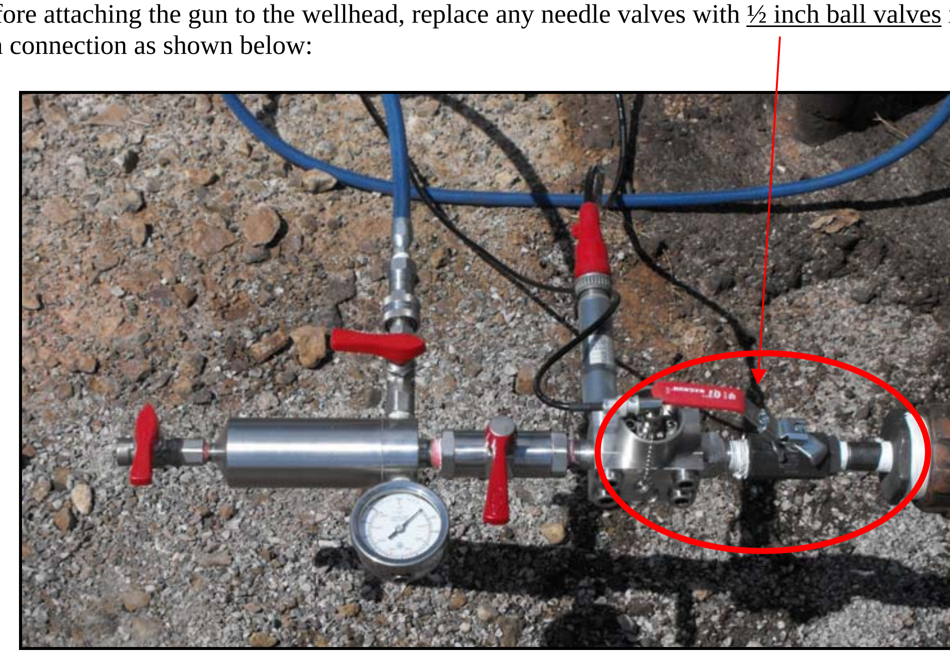
F - MAINTENANCE

Very little maintenance is required for this gas gun except for inspection to insure that the threads, parts and materials are in good condition and have not been subjected to excessive wear or corrosion.

G - INSTALLATION OF THE 5000 PSI GAS GUN TO ACQUIRE ACOUSTIC RECORD

Rig-up for shooting through Tubing: If possible, use a ½ inch NPT to 2 inch High Pressure nipple adaptor, as shown below.

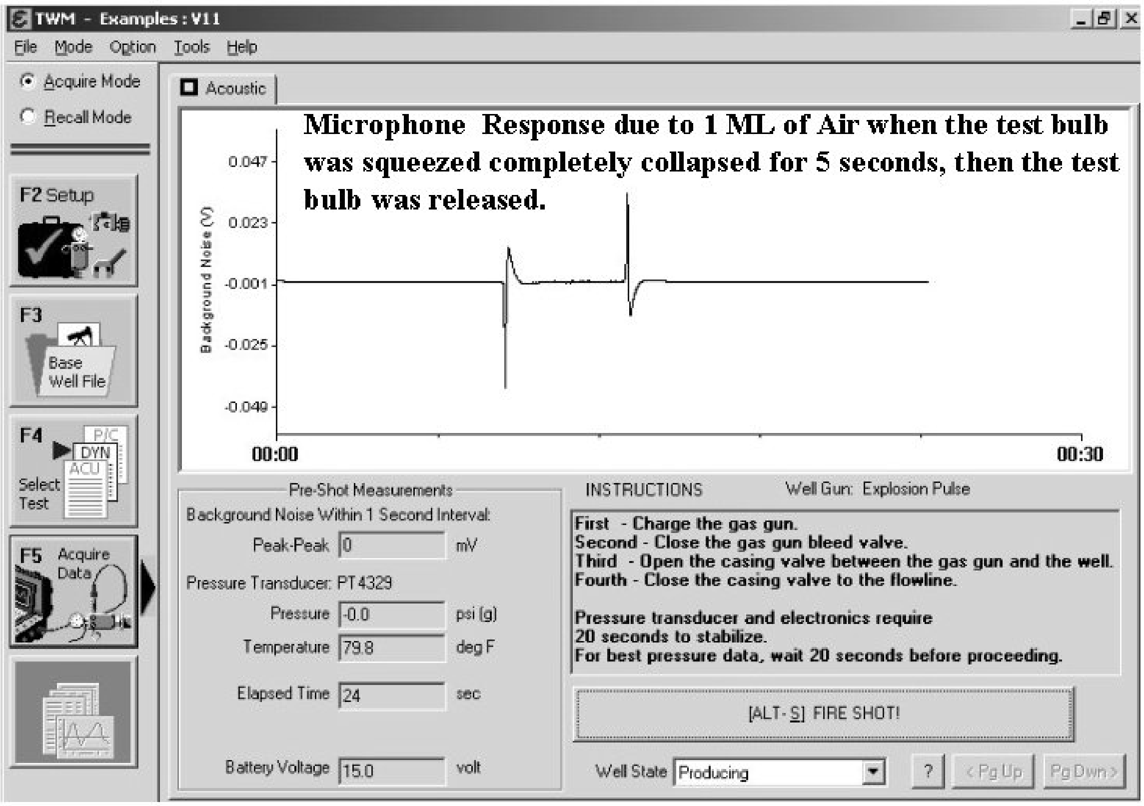
For best results, before attaching the gun to the wellhead, replace any needle valves with ½ inch ball valves in order to minimize energy loss through connection as shown below:



APPENDIX III - CHECKING MICROPHONE RESPONSE

The purpose of this test is to check the output of the microphone in either the Remote Fire or the Compact Gas Gun
The following figure shows the typical microphone response when using the 2 inch diameter, white PVC, test cap provided with the equipment.

Microphone Response from Squeezing Test Bulb Acquired with TWM Software and Well Analyzer



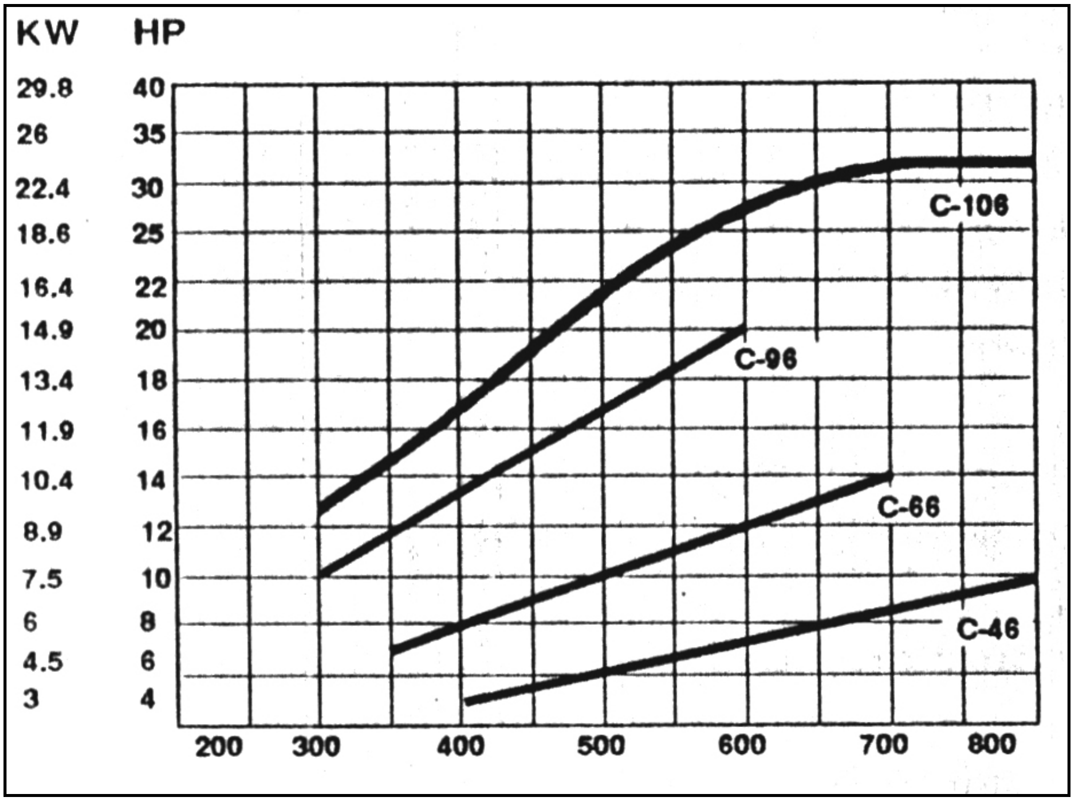
The test bulb is attached to the remote fire gun with the pressure transducer attached to the gun, the bleed valve closed and the volume chamber pressurized to close the gas discharge valve.

A similar response should be obtained when performing the test with a Compact Gas gun.

APPENDIX IV – TYPICAL PERFORMANCE CURVES FOR ARROW GAS ENGINES

The following curves are intended to illustrate the typical performance of gas engines as a function of RPM. It is recommended that the user refer to the actual performance curves supplied by the manufacturer of the engine installed on the beam pump.

The following figure shows the relationship between engine power at the shaft vs. RPM for different size Arrow Gas engines



During the pumping cycle the motor speed will vary over a significant range. It is recommended that the average RPM be determined using an indicating tachometer and this value used as input to the well file in the Surface Equipment tab.

The following figure shows the energy consumption (1000 BTU/hr) corresponding to the operating power for different size Arrow gas engines.

This value may be used in conjunction with the BTU content of the fuel gas to estimate the energy consumption of the engine.