# Intrinsically Safe Fluid Level Instrument for Hazardous Environments

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## ABSTRACT

Stringent safety requirements imposed by major operators when fluid level measurements are performed offshore or in enclosed wellhead spaces such as in Alaska's North Slope create procedural complications, such as the requirement for hot permits, when performing fluid level measurements in producing wells. This need has been eliminated by the development of a small, self contained, fully digital, battery powered instrument that is approved for use in hazardous areas. The Echometer Model H electronics has been tested at various locations on the North Slope. It facilitates the acquisition and interpretation of the data through an advanced software package that virtually automates the analysis even in acoustically noisy environments. Results are observed immediately on the instrument screen then saved in the data base for eventual transfer to corporate records. This paper presents detailed information about the new system and reviews data acquired in gas lift wells, flowing gas wells and ESP installations.

## INTRODUCTION

Echometer Company has always strived to provide the safest possible equipment for data acquisition and analysis of well systems performance. For over forty years, standard fluid level measuring equipment has been used worldwide without any instances of malfunctions that could have resulted in a hazardous situation. Continuing this tradition and in response to the recent development of international safety guidelines and requirements, a line of instruments have been developed [(1)] that, when properly installed and used as directed, are certified to be safe for undertaking measurements in areas where explosive atmospheres are present. Following that development, the availability of advanced electronics and powerful integrated circuits have made possible developing a very compact digital instrument that meets all the requirements for operation in hazardous areas. This paper describes this new instrument and its applications for fluid level measurements in oil and gas wells.

## HAZARDOUS LOCATIONS IN THE OILFIELD

High pressure, high temperature and combustible gases are associated with oil and gas production operations. This implies that extreme care must be exercised whenever working in a hydrocarbon production area and especially whenever connecting or installing measurement equipment to wells. Certain concentrations of combustible gases in air constitute explosive mixtures that can be ignited by electrical sparks or the development of high temperatures.
Electrical and electronic instruments that are used in these areas must meet strict guidelines if they are to be operated without the additional use of combustible gas detectors and the filing of papers detailing the procedures to be followed in order to obtain what is known as a "hot permit". The American Petroleum Institute (API) publishes documents that describe the conditions for hazardous location classification of the hazardous areas found in oil and gas facilities.

### API Classification of Drilling and Production Facilities

The purpose of the API RP 500 recommended practice[(2)] is to provide guidelines for classifying locations Class I, Division l and Class I, Division 2 at petroleum facilities for the selection and installation of electrical equipment following basic definitions given in the 1996 edition of NFPA 70, the National Electrical Code (NEC)

Section 10 of RP 500 defines the area classification for locations surrounding oil and gas drilling and workover rigs and production facilities on land and on marine fixed (bottom-supported) platforms where flammable petroleum gas and volatile liquids are produced, processed, stored, transferred, or otherwise handled prior to entering the transportation facilities.

Production facilities considered for classification by this section that impact measurements using Acoustic fluid Level equipment include the following:

Producing oil and gas wells

1. Flowing wells
2. Artificially lifted wells
   a. Beam pumping wells
   b. Mechanically driven, rotating, subsurface pumps
   c. Electric submersible pumping wells
   d. Hydraulic subsurface pumping wells
   e. Gas lift wells
   f. Plunger lift wells

Figure 1 is an example of API classification of the area surrounding producing wells. The figure shows the areas for a rod pumping well, note that there are two zones indicated: a Division 1 zone in the sump, where hydrocarbon gases heavier than air may accumulate and a Division 2 zone surrounding the tree, stuffing box and a portion of the flow line. The lower part of this zone extends up to about 15 feet from the centerline of the polished rod. If measuring instruments are not approved for use in the hazardous area they must be located away from the Division 2 zone. This requires using long cables between the recording instrument and the sensors (only sensors that meet the requirements for operation in hazardous environments may be used) that are located at the wellhead and to follow strict guidelines regarding installation and operation.

On the other hand, when using an instrument that is approved for operation in the hazardous area it can be located in the vicinity of the wellhead and its use does not require filing for special permits. One such instrument is the Echometer Model H, which is shown in Figure 2.

Intrinsically safe products and systems are certified or approved as safe by various agencies. These same agencies also approve explosion-proof devices, enclosures and accessories. The approval agency does all the safety analysis for the end user. The certification agencies in the U.S.A. are Underwriters Laboratory (UL) and Factory Mutual Research Corporation (FM or FMRC). Typically, FM does most of the intrinsically safe approvals. The design standard, which both FM and UL design their approval processes to meet, is ANSI/UL 913 (formerly NFPA 493). The installation standard is ANSI/ISA RP 12.6, "Installation of Intrinsically Safe Instrumentation Systems in Class I Hazardous Locations." This documentation should be used for guidance on intrinsically safe installations.

In Canada, Intrinsically Safe product approvals are obtained through the Canadian Standard Association (CSA). This group develops the standard and also certifies devices to the standard. CSA certification is accepted and recognized in the US and in most foreign countries.

The European Union (EU) has developed certification standards in response to the European Parliament directive-: "DIRECTIVE 94/9/EC OF THE EUROPEAN PARLIAMENT AND THE COUNCIL OF 23 MARCH 1994 ON THE APPROXIMATION OF THE LAWS OF THE MEMBER STATES CONCERNING EQUIPMENT AND PROTECTIVE SYSTEMS INTENDED FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES".

The EU standards are more stringent than the US or Canadian standards and are commonly referred to as the ATEX standards. Certification is issued by special organizations defined as "notified bodies". EU certification includes the requirement that the manufacturer shall operate an approved quality system for production, final equipment inspection and testing and shall be subject to monitoring by a quality inspector.

## INSTRUMENT DESCRIPTION

The Echometer Model H is a stand alone, battery powered and microprocessor controlled digital acoustic signal processor and recorder. When installed and used in accordance with the instructions X57H it is approved for operation in hazardous environments.

The Echometer Model H permits better interpretation of reflections from downhole anomalies through application of digital filtering and processing that improve the ability of the operator to distinguish downhole obstructions from enlargements. The response from the liquid level (or a reduction in annulus area) is opposite to the response from an enlargement such as a hole in the casing or perforations.

Selecting the proper digital filter will result in more accurate determination of the number of tubing collar reflections from the surface to the liquid level.

A microprocessor is used with an analog to digital converter, memory chip, amplifiers, clock, timing circuit and other electronic components to improve the performance and utility of the instrument. When an acoustic pulse is generated in the well, the signals reflected from the collars at the top of the well are large but rapidly attenuate.

The microprocessor is used in conjunction with a real time clock. The timing capabilities of the microprocessor, clock and timing circuit are used to determine the round trip travel time with a resolution of +/- 0.001 seconds. In the automatic mode of analysis, the travel time and the distance to the liquid level obtained by the software by counting the collar echoes are used to compute the average acoustic velocity of the gas in the annulus. The acoustic velocity the casing pressure and average temperature can be input to the utility program AWP 2000 (download at no cost from www.echometer.com) to compute the gas gravity and the pressure distribution in the well, including the pump or tubing intake pressure and the pressure at the perforations.

The entire instrument is contained in a waterproof, dustproof plastic housing having dimensions of 11 by 10 by 5 inches and weighs 11 pounds (5 kg).

## GENERAL OPERATION PROCEDURES

Upon powering up, the software is loaded and a self test is performed automatically. The labels at the bottom of the opening screen, shown in Figure 3, instruct the user to the actions that will be performed when the buttons at the bottom of the panel are pressed. (The instrument is designed to be operated wearing work gloves).

Operation of the instrument is simple. First the acoustic wellhead (gas gun) should be attached to the casing annulus or tubing-head valve, and the cable connected between the microphone and the instrument.

Typically a Compact Gas Gun, shown in Figure 4, which has been approved for use in hazardous environments, is used for acquisition of the record. The valve between the casing annulus and the flow line or between the tree wing valve and the flow line should be closed to prevent the well gas from venting into the flow line causing excessive noise.

The user selects the mode of acquisition from the main menu, shown in Figure 5, which also allows setting up the instrument according to the user's main activities and recalling previously acquired records for review and analysis. If the user has set up the instrument for the "Quick Shot" acquisition mode the next step is to prepare the gas gun for firing, generate the acoustic pulse, stop data acquisition, review the data and save the record to the instrument memory for transfer to the laptop's data base at a later time if desired.

When acquisition of data at the well is complete, the microphone cable is disconnected from the gas gun, wellhead valves are returned to their original position, pressure is relieved and the gas gun removed from the well.

In this mode, acquisition of the acoustic record can be completed in a minimum of time with a minimum of intervention from the user.

The following sections illustrate in detail a mode of operation of the instrument and software.

### Operation of the Model H with the Compact Gas Gun

The compact gas gun is operated either in the COMPRESSION (Explosion) mode or the RAREFACTION (Implosion) mode. The operator should use the Compression (explosion) technique when the casing pressure is less than approximately 100 psig. The Rarefaction (implosion) technique may be used whenever the casing pressure is sufficient to obtain a good record.

### Compression (Explosion) Mode

Expansion of gas from the Echometer gas gun is used to generate a pressure pulse. The pressure pulse is positive since the gas chamber is charged to a pressure that exceeds the well pressure by at least 100-psi.

- Securely attach the Echometer Gas Gun to the Casing or Tubing Valve.

- Close the Well Pressure Bleed Valve and Filler Bleed Chamber Valve.
- Lift the Cocking Arm to close the internal gas valve. This prevents debris from entering the volume chamber.
- Open the Well Valve to the Echometer Gas Gun slowly and close the casing or wing valve to the flow line.
- Measure the Well Pressure using the precision pressure gauge.
- Record Time and Well pressure.
- Fill the volume chamber with gas (CO2 or N2) to at least 100-psi (or more when a high background noise level is present) in excess of the Well Pressure.
- Connect the coaxial cable from the microphone to the Input of the Model H.
- Power up Instrument
- Navigate to the acquisition screen following the Explosion Pulse path as described in the following section.
- Generate pressure pulse by pulling Trigger Ring, after the message "Waiting for Shot to be Fired"" is displayed.
- Inspect the record and repeat the shot if the signal quality is not satisfactory.
- Record Time and Well Pressure.
- Close the Valve between Echometer Gas Gun and the well.
- Open the Well Pressure Bleed Valve and release the pressure.
- Open the Casing Valve or Wing Valve to the flow line.
- Remove the Echometer Gas Gun from the Casing or Tubing Valve.

### Rarefaction (Implosion) Mode

Gas is released from the well into the gas gun volume chamber to generate the initial pulse. Debris, moisture, corrosive liquids and chemicals, and other foreign material may be imploded into the gas gun volume chamber, which will increase maintenance requirements and may cause corrosion on the inside of the 316 stainless steel volume chamber.

- Securely attach the Echometer Gas Gun to the Casing or Tubing Valve.
- Close the Well Pressure Bleed Valve and Filler Bleed Chamber Valve.
- Open the Well Valve to the Echometer Gas Gun slowly and close the casing valve or the wing valve to the flow line.
- Pull Trigger Ring.
- Lift the Cocking Arm to close the internal gas valve.
- Measure the Well Pressure using the precision pressure gauge.
- Record Time and Well Pressure.
- Bleed the gas chamber pressure through the Filler-Bleeder Chamber Valve by rotating the knob clockwise until the gas gun pressure has decreased to approximately 200-psi below the well pressure reading. Use greater or less differential pressure depending on the background noise level.
- Connect the coaxial cable from the microphone to the INPUT of the Model H.
- Power up Instrument
- Navigate to the Acoustic Record Acquisition screen following the Implosion Pulse path as described in the following section.
- Generate pressure pulse by pulling Trigger Ring, after the message "Waiting for Shot to be Fired" is displayed.
- Inspect the record and repeat the shot if the signal quality is not satisfactory.
- Record Time and Well Pressure.
- Close the Casing Valve or Tubing Valve between Echometer Gas Gun and the well.
- Open the Well Pressure Bleed Valve and release the pressure.
- Open the Casing Valve or Wing Valve to the flow line.
- Remove the Echometer Gas Gun from the Casing or Tubing valve.

## USER INTERACTION WITH SOFTWARE

The instrument has been designed to facilitate and speed up acquisition of data by minimizing the number of steps to obtain a liquid level depth. This is achieved by setting up the program for the "Quick Shot" mode so that once the instrument is powered up it takes only three "clicks" to display the signal acquisition screen in Figure 6. When the user presses the "Start "button the instrument shifts to the listening mode and waits until it detects the firing of the

acoustic pulse as shown in Figure 7. The user then observes the screen looking for signals that correspond to echoes from the liquid level and manually stops the recording after the first (or the repeat) echo is observed as shown in Figure 8. The program automatically analyzes the record, selects the liquid level echo, filters the record, detects and counts the echoes from the tubing collars and displays the depth to the liquid level as shown in Figure 9.

The user manages the acquired data and controls the flow of the program from the Main Menu shown in Figure 5. Wells can be organized in logical groups to facilitate access to the well files and specific acoustic shots as shown in Figure 10.

## MANAGING WELL DATA AND INFORMATION

Acoustic records and well information are stored in the memory of the Echometer Model H in a data base organized into Groups that contain Wells that contain Shots. The user navigates through the data base using the 5 button star keypad after having selected either Acquire or Recall acoustic Data in the Main screen. Figure 10 shows the form that is used to manage the groups of wells, the well information and the acquired data.

Using the Model H Laptop Manager software is a more efficient tool for entry of well data and management of the acoustic records.

## EXAMPLE FLUID LEVEL RECORDS

Following are some examples of acoustic records for various well types and conditions.

Figure 11 shows that before acquisition of the record the software monitors the background acoustic noise in the well, displays a color bar indicating the sound level and warns the user to increase the pressure differential between the chamber and the wellbore when the noise exceeds the preset threshold level.

Automatic Analysis of the fluid level record in a deep well is shown in Figure 12. The software analyzes the record to identify the most likely signals that could correspond to the echo from the liquid level and highlights the most probable signal with a vertical dashed indicator within the dark band. This signal is also displayed with an expanded time scale (from 14.5 to 15.5 seconds) in the window at the lower right. The time scale is converted to a distance scale using the average acoustic velocity computed from a count of the collar echoes from time zero to the time indicated by the vertical dashed line labeled "C". This line indicates the point in the record where the amplitude of the collar echoes is equal to the amplitude of the background noise. Past this point in time the collar echoes cannot be identified with certainty.

When an acoustic record is acquired in a gas lift well the program will perform the automatic analysis using the collar count procedure to determine the liquid level, as shown in Figure 13. Note that the collar count marker is very close to the liquid level echo and also that this acoustic record was acquired for a time sufficient to observe the repeat of the liquid level echo at about 22 seconds.

Note also that preceding the liquid level echo there are signals that correspond to the echoes from the gas lift mandrels. The user can input in the well file the depth of each mandrel and then use this information to refine the calculated liquid level depth using the analysis option "Anomaly Method" as shown in Figure 14. For this method the software initially places tick marks on the depth axis (labeled 1,2,3,4, O and P) that correspond to the depth of the known features as listed on the left of the figure. The user then manually relocates the markers, starting with the topmost signal, at the exact point in time of the signal arrival. The software computes the acoustic velocity for that time interval knowing the depth to the marker. The procedure is repeated until the deepest marker has been located and then the depth to the liquid level is computed using the acoustic velocity that corresponds to the deepest interval in conjunction with the depth of the lowest tagged anomaly. This procedure yields a more accurate calculation of the liquid level depth especially in those wellbores where there are significant temperature variations, such as in offshore platforms, or when the gas column is stratified.

## SUMMARY

The development of enhanced instrumentation that is certified for use entirely in hazardous environments was made possible by the availability of advanced electronics. The Echometer Model H was developed as a user friendly instrument to acquire and analyze acoustic liquid level data in a hazardous environment. The Model H instrument

provides enhanced capabilities for managing and analyzing acoustic liquid level measurements that are not available in other instruments.

## AKNOWLEDGEMENTS

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## REFERENCES

1-Jim McCoy, Bill Drake, and A. L. Podio: “Intrinsically Safe Well Analysis Instruments” SWPSC, 2007.

2- API RECOMMENDED PRACTICE 500, Recommended Practice for
Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2
SECOND EDITION, NOVEMBER 1997, Reaffirmed 11, 2002

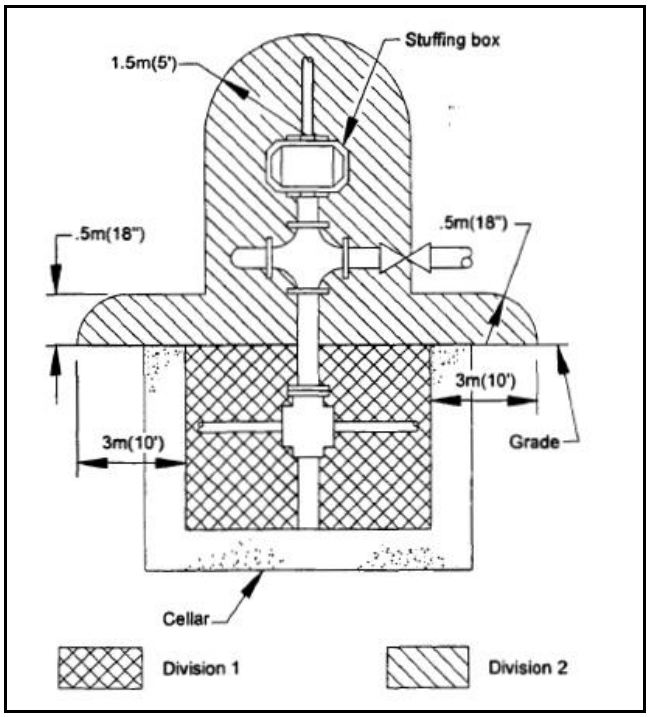


Figure 1 – Classification of Hazardous Zones for A Rod Pumped Well According to API-RP500

Figure 2 – The Echometer Model H Installed at the Wellhead with an Intrinsically Safe Acoustic Pulse Generator


Figure 3 – Model H Control Panel and Screen


Figure 4 - Compact Gas Gun Modified (as shown by the engraving) with Special Microphone for use in Hazardous Areas

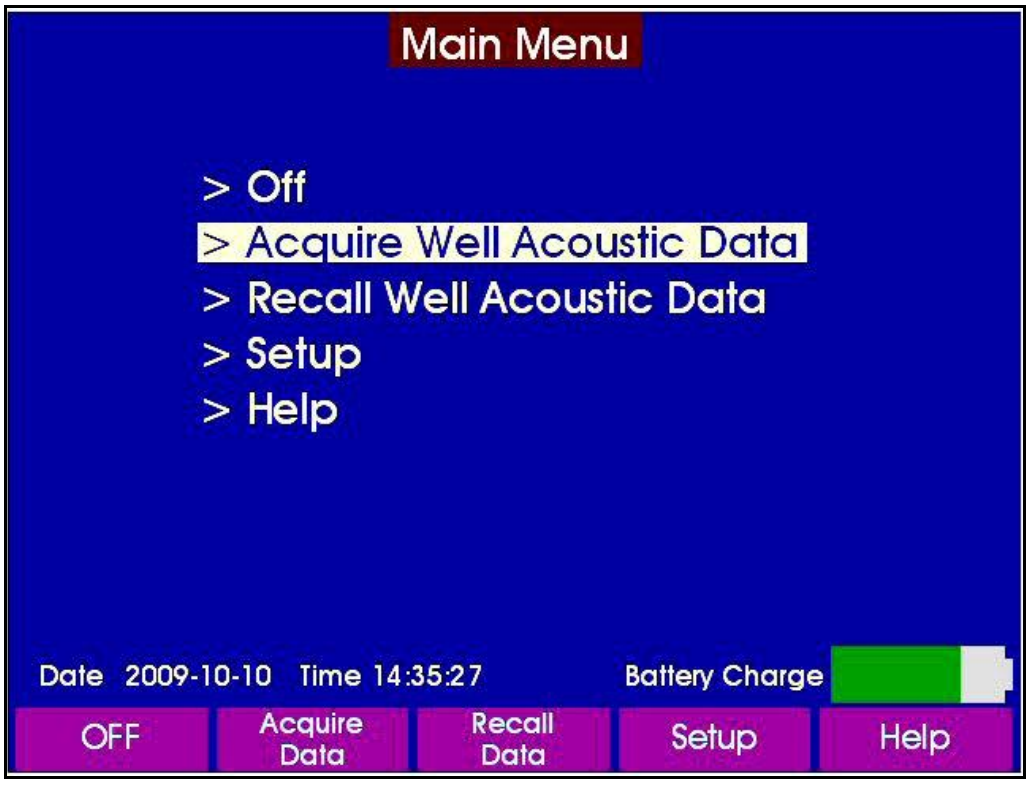


Figure 5 – Model H Main Menu

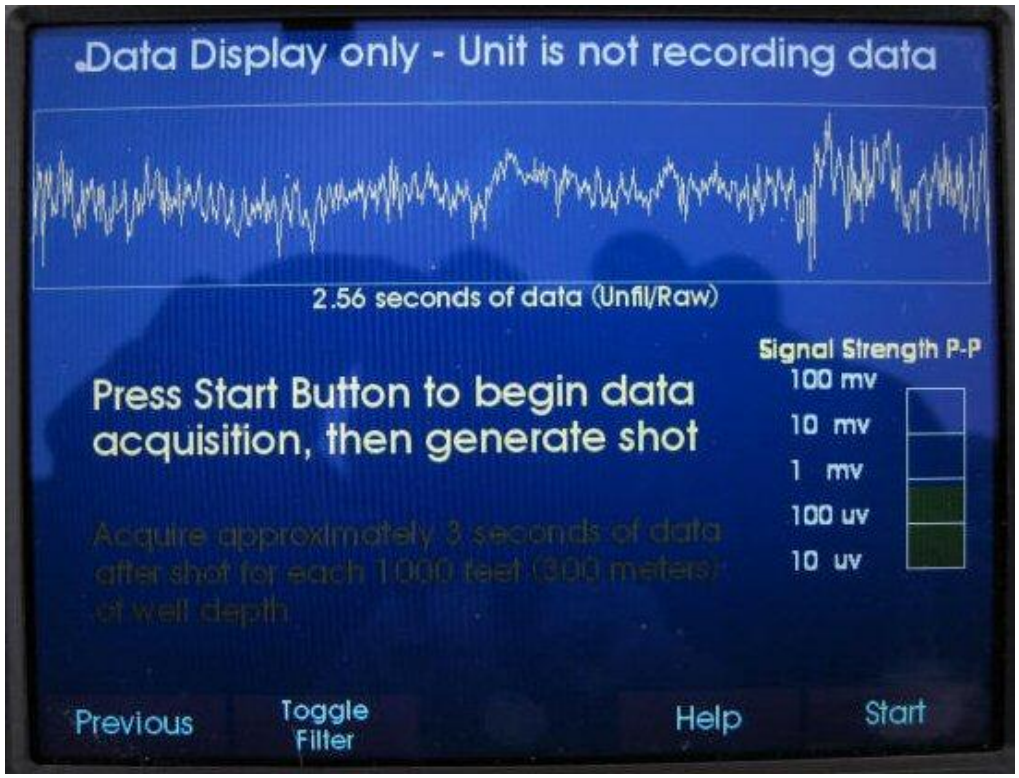


Figure 6 – Acoustic Data Acquisition Screen


Figure 7 – Shot Detection screen

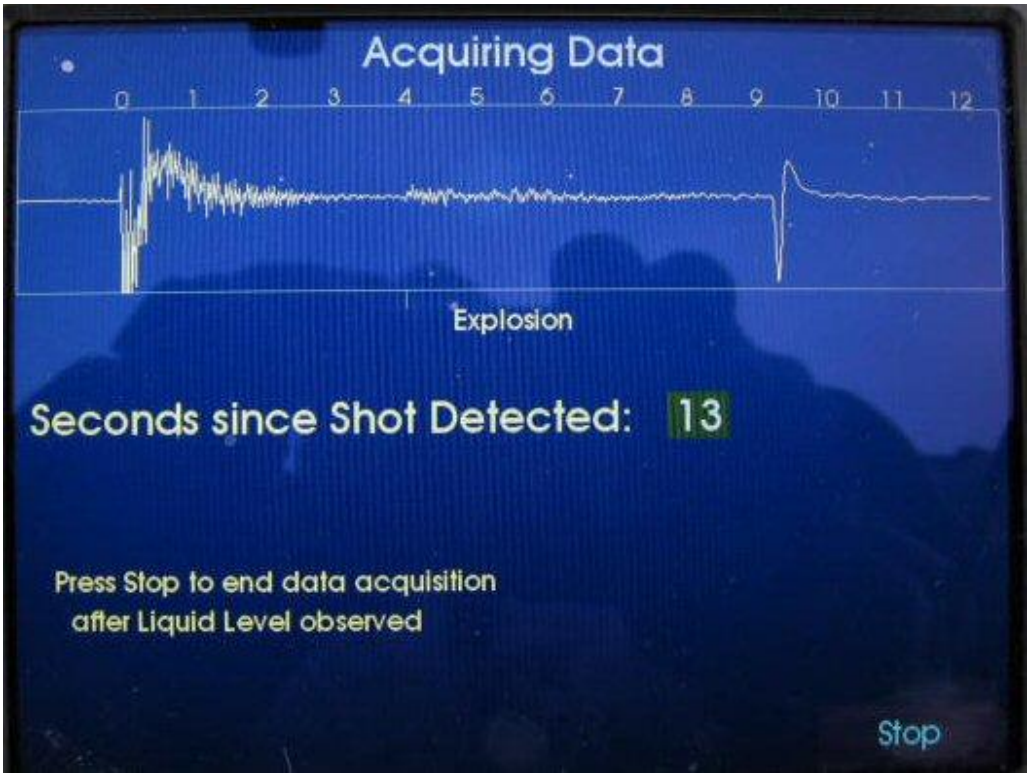


Figure 8 – Echo Monitoring Screen

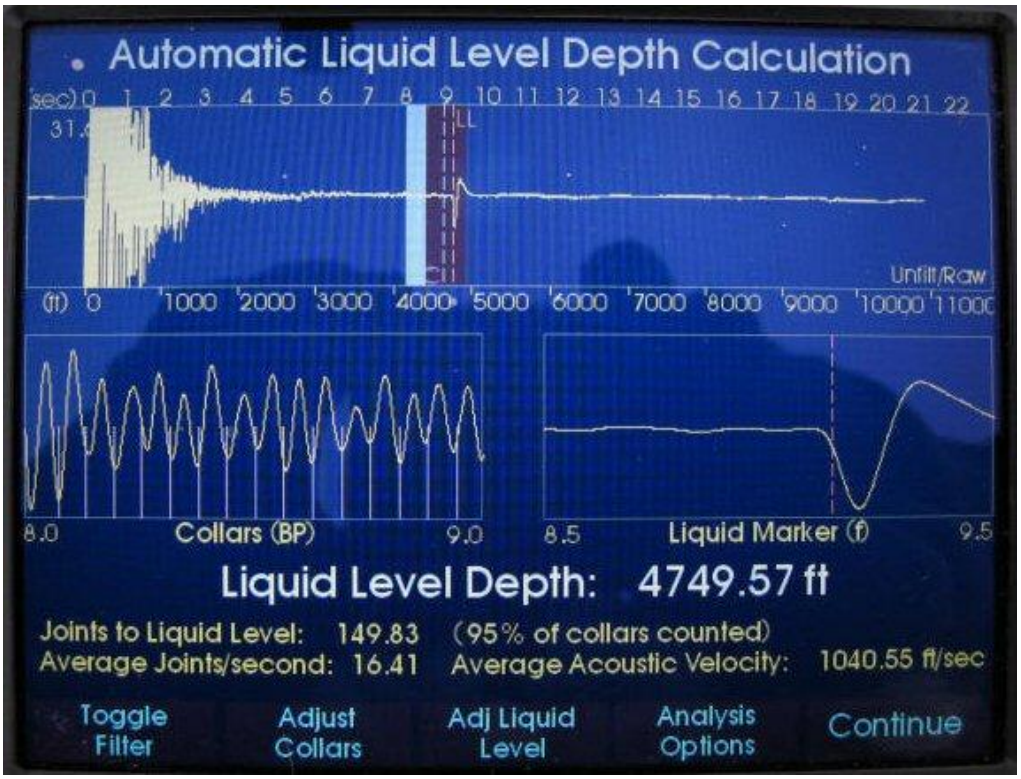


Figure 9 – Automatic Analysis of Acoustic Record

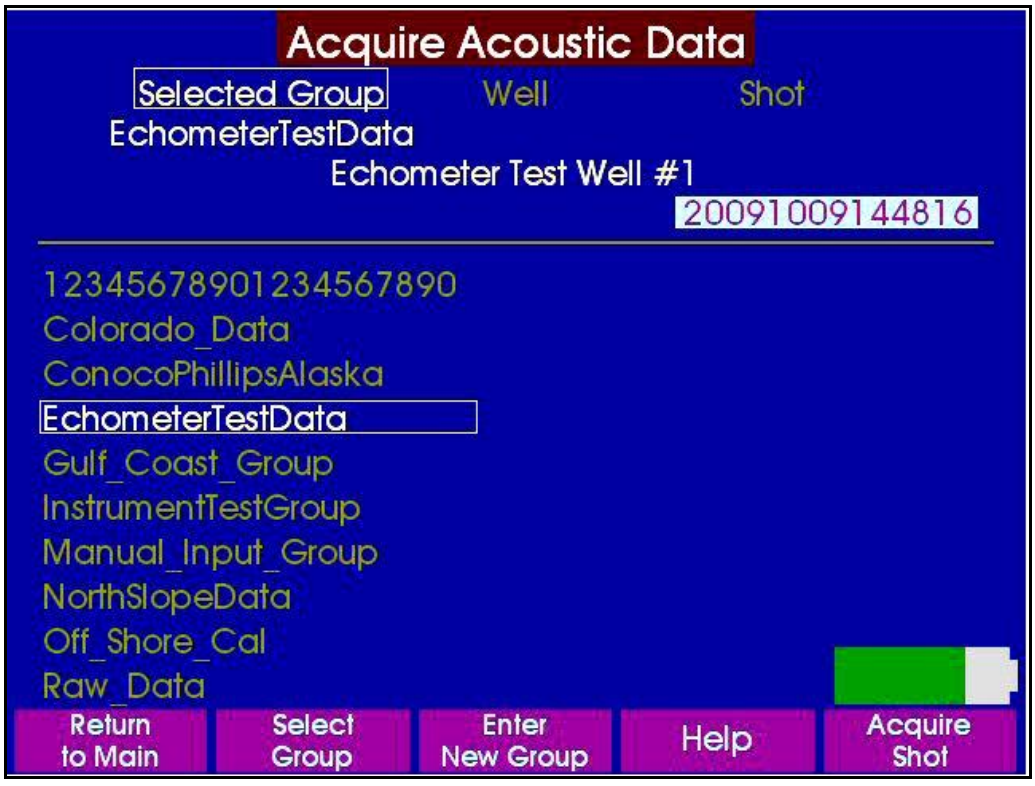


Figure 10 – Model H – Well and Data Information Management Screen

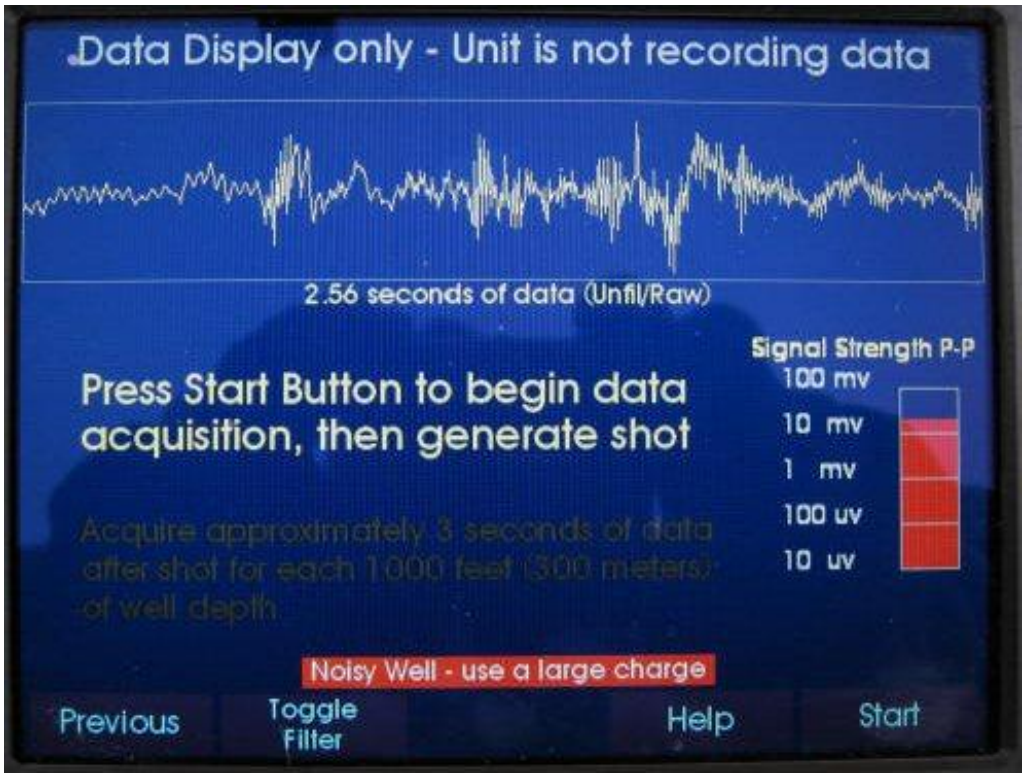

Figure 11 – Noisy Well Warning

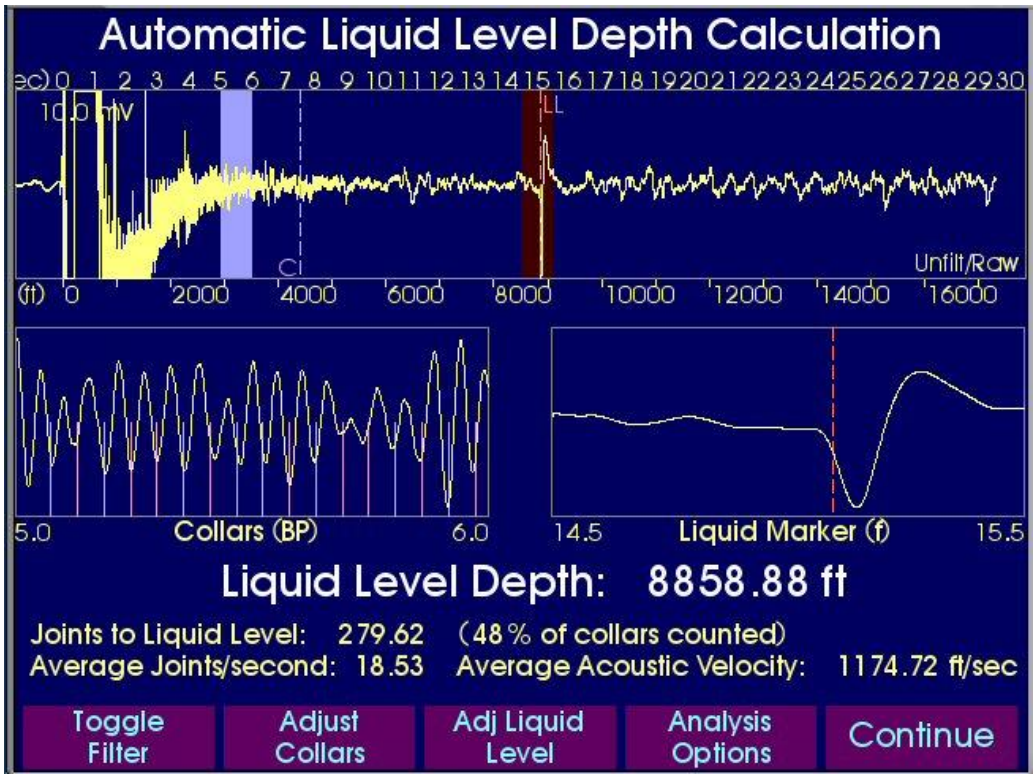

Figure 12 – Deep Well Automatic Analysis

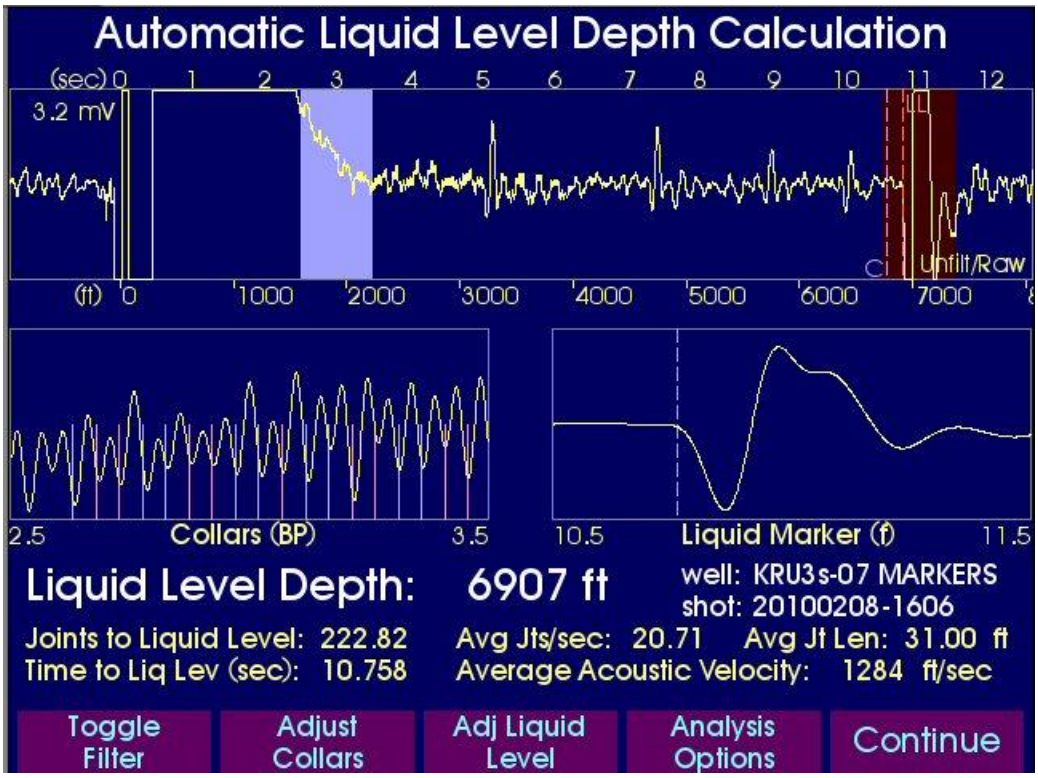


Figure 13 – Gas Lift Well Automatic Analysis

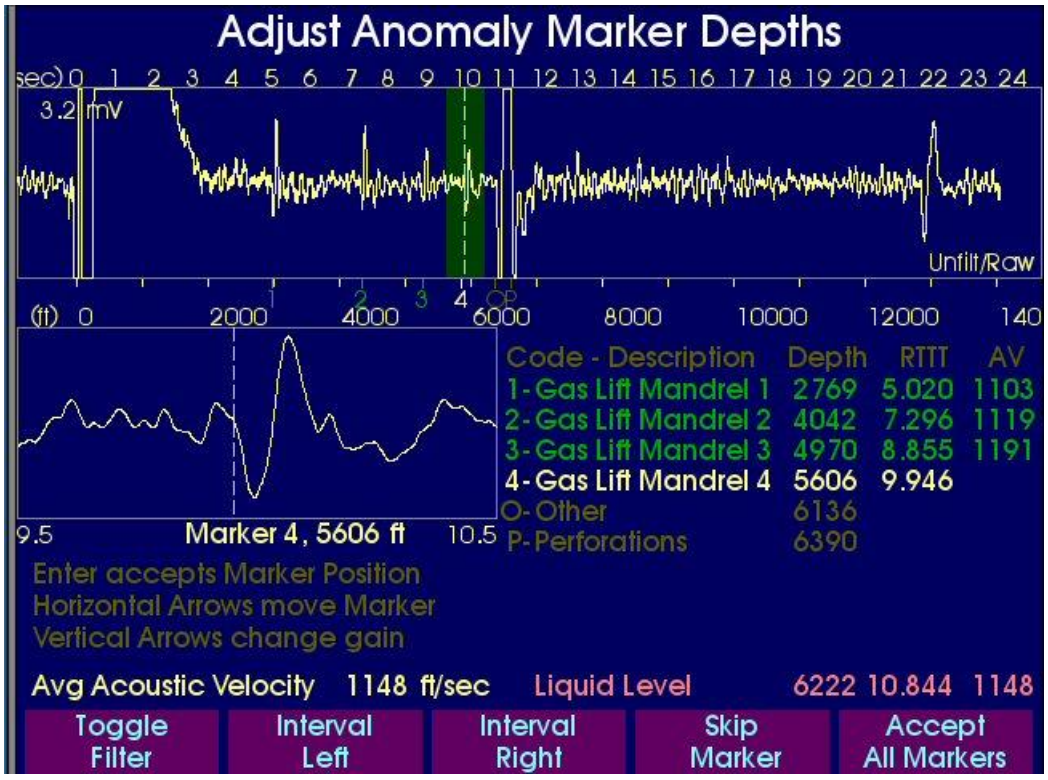


Figure 14– Gas Lift Well, Downhole Marker Analysis