# *Echometer Model-H*

The Acoustic Liquid Level Instrument for Hazardous Environments

## *Introduction*

This operating manual contains information about the Echometer Model H Fluid Level Instrument including installation instructions, operating procedures, requirements for intrinsically safe application, maintenance, shooting problem wells, record interpretation and technical references relating to the optimization of producing wells. Please read the manual and view the example screens before operating the instrument. Additional technical papers can be accessed from the Echometer Web page, www.echometer.com; these articles offer additional information on the use of acoustic fluid level instruments to optimize production. Please read these papers at your convenience.

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## *Safety Considerations*

Read this manual before operating the equipment.

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 wellhead 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.

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.

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.

The user must read, understand and accept the conditions for using the Echometer Model H in a hazardous environment. Please refer to the section in this manual that describes the requirements to use the instrument in a safe manner in or near a hazardous area where explosive mixtures of gases may be present.

### Operation in Hazardous Environments

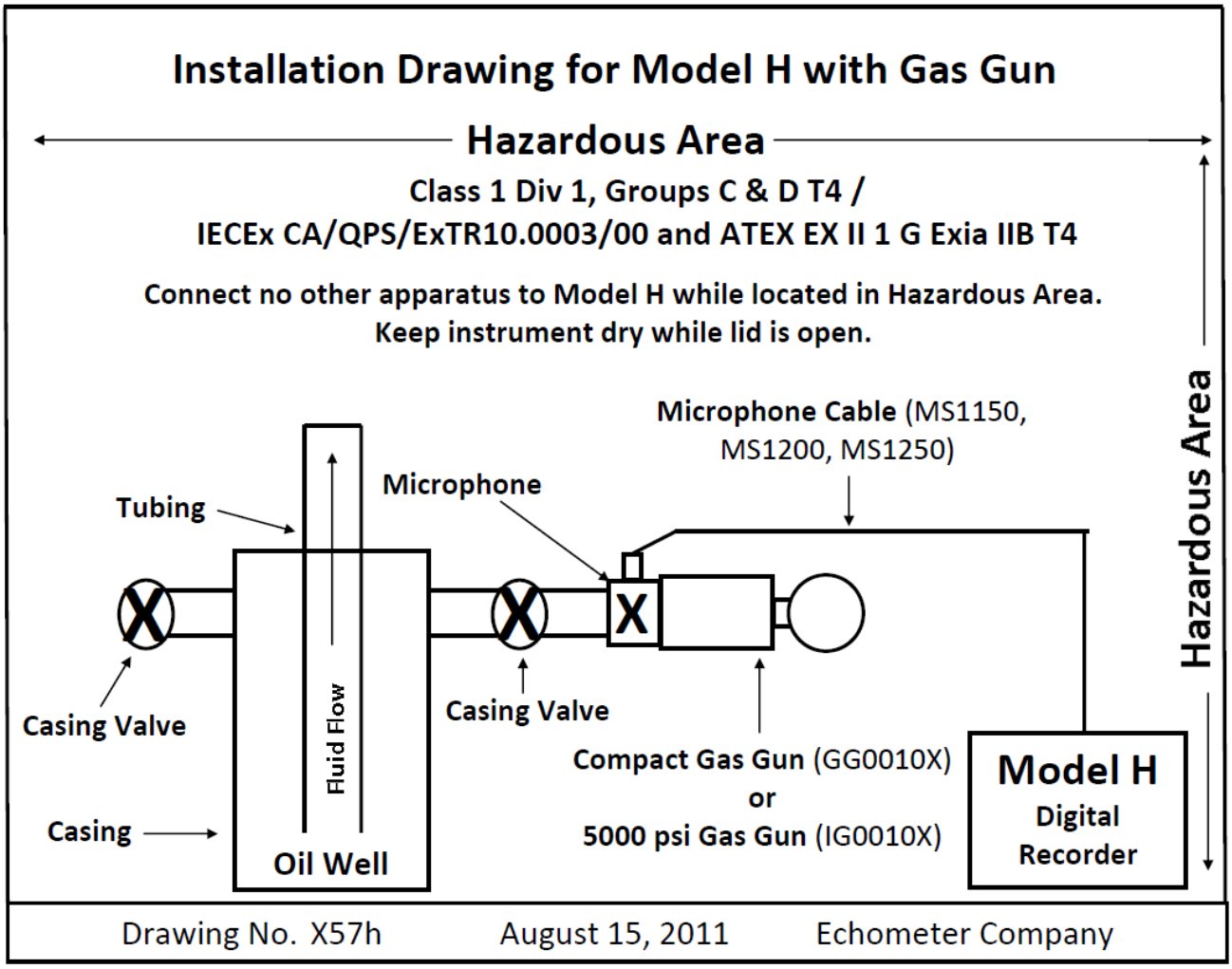
The Echometer Model H is approved for operation in hazardous environments that are classified as Class I Division 1 Groups C & D T4 and

 II 1 G Ex ia IIB T4 ,when installed and used in accordance with the instructions X57H, found on the following page.

Note: To maintain Intrinsically Safe certification, the unit must be charged in a safe area and can only be charged using Echometer P/N MS1610.

As part of the instrument set-up procedure and to be able to use the instrument, the user is expected to read, understand and ACCEPT the following conditions of operation:

- The user agrees to follow the instructions related to using the Echometer Model H in a hazardous environment with regard to connecting to the well, connecting to the acoustic hardware and operating the instrument to acquire, recall and analyze data.
- The user agrees that connecting the Echometer Model H to the battery charger will occur only in a NON hazardous area.
- The user agrees that downloading or uploading data or software via the USB port will be done only in a NON hazardous area and only by connecting to a Battery Powered laptop or notebook computer and NEVER connecting the instrument to the USB port of a computer connected to an AC power source.
- The user understands that the Echometer Model H is not waterproof when the lid is opened and must be kept dry while the case is opened.
- The user agrees that he is aware and understands that if any ONE of these requirements is not fulfilled the Echometer Model H instrument will no longer meet the specifications of intrinsic safety.


Installation Drawing for Model H with Gas Gun
Hazardous Area
Class 1 Div 1, Groups C & D T4 /
IECEx CA/QPS/ExTR10.0003/00 and ATEX EX II 1 G Exia IIB T4
Connect no other apparatus to Model H while located in Hazardous Area.
Keep instrument dry while lid is open.
Hazardous Area
Microphone Cable (MS1150, MS1200, MS1250)
Tubing
Microphone
Casing Valve
Casing Valve
Fluid Flow
Casing
Oil Well
Compact Gas Gun (GG0010X)
or
5000 psi Gas Gun (IG0010X)
Model H
Digital
Recorder
Drawing No. X57h
August 15, 2011
Echometer Company

## Echometer Schools

Echometer Company offers schools on the use and applications of this equipment. You are invited to attend free of charge. A list of the schools, which are taught throughout the United States and Canada, will be sent upon request or can be viewed at http://www.echometer.com

Additional Information

Please contact Echometer Company to obtain additional information or to clarify any questions that you may have in regard to the use of this instrument. The street and mailing address, phone number, fax number and e-mail address are given on the first page.

# *Instrument Description – Model H*

The Echometer Model H is a stand alone, battery powered, microprocessor controlled digital acoustic signal processor. When installed and used in accordance with instructions X57H it is approved for operation in Class I Division 1 Groups C & D and Ex II 1 G Ex ia IIB T4.

The Echometer Model H permits better interpretation of reflections from down hole anomalies through application of digital filtering and processing that improve the ability of the operator to distinguish down hole 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 x 10 x 5 inches and weighs 11 pounds (5 kg). The following section describes the instrument panel and the function of the various controls.

## Instrument Panel

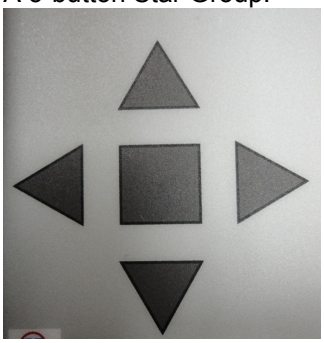
The instrument panel is shown in the following Figure.


The panel incorporates both soft keys and a navigational 5-button star input keypad. A row of “soft key” buttons below the LCD are used to execute the actions described in the labels at the bottom of the screen.

- Power Button:

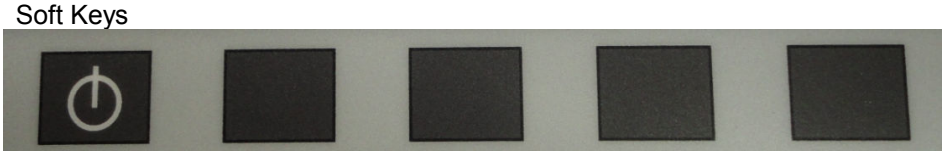
Momentarily pressing the power button energizes the instrument fully and initiates the booting of the software. The microprocessor performs a system test and displays the battery charge status. The instrument can be turned off manually by pressing the power button.

- A 5-button Star Group:



The up, down, right, left, and enter are used to navigate through the menus and also to enter or edit program parameters and well information.

- Soft Keys



The function of each soft key change depending on the screen that is currently active. Their function is described by the labels displayed at the bottom of the LCD display.

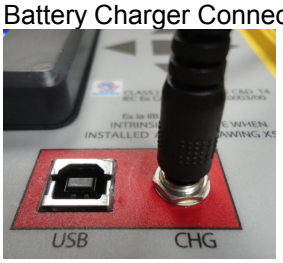
- Input Connector


This BNC INPUT connector is the input to the amplifiers. When acquiring data, this INPUT connector must be connected to the microphone connector on the acoustic wellhead using a good coaxial cable with clean connectors.

- USB Connector (left side)


This input/output connector is used to transfer well information records, acquired shot data records and analysis results between the Model H and an external computer running the Model H Laptop Manager Software.

- Battery Charger Connector (right side)




Connection to a battery charger should be made only when the instrument is outside the hazardous area. Attaching the 110 VAC or the 220 VAC Echometer battery charger having an input of 110/220 VAC and an output of 14.8 volts DC and 2Amps.

Note: To maintain Intrinsically Safe certification, the unit must be charged in a safe area and can only be charged using Echometer P/N MS1610.

- Battery Reset Button (Pin-Hole)


In the event of a necessary hard power down or battery reset, the pin-hole reset button can be accessed with a paper clip. Depressing the pin-hole button will cut the power from the battery to the instrument causing a hard reset of the battery. Pressing the power button will restore power to the unit and initiates booting of the software.

**Caution should be used when utilizing the hard reset. It is recommended that the pin-hole reset button is only pressed when the instrument is completely powered down.**

# *General Operation Procedures*

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 should be connected between the microphone and the instrument. 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. Then the instrument is powered up and the user selects the mode of acquisition, prepares the gas gun for firing, generates the acoustic pulse, stops data acquisition, reviews the data and saves the record to the instrument memory. 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. 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 ($CO_2$ or $N_2$) 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 by pressing the left soft key.
- 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 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 by pressing left soft key.
- 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.

# *Acquisition of Acoustic Records – Model H Quick Reference*

***1 - Power up instrument by pressing the ON/OFF button on the instrument panel.***

***2 - Press the soft key corresponding to "Continue" and select "Accept" at the Conditions of Operation.***

***3-To continue with Acquisition press the soft key below the Acquire Data label.***

***4- Use the Star Keys Up and Down buttons to select the group that contains the information for the well being tested.***

***5- Use the Star Keys Right Arrow to select the Well option to display the list of wells included in the chosen Group.***

***6- Use the Star Keys Up and Down arrows to select the desired well from the list.***

***7- Press the "Acquire Shot" button on the instrument panel after the well has been selected from the list (either pressing the button below the "Select Well" label or the "Enter" button of the 5 button Star Keys)***

***8- Select the method of acquisition, "Implosion" or "Explosion," and review the check list displayed for connection and preparation of the hardware to perform the acoustic test.***

***9 – When ready press the button under the "Continue" label and monitor the noise signal strength to determine the level of differential pressure that should be used.***

***10 – Press the "Start" button after adjusting the gas gun pressure if necessary.***

***11 – Actuate the gas gun control (trigger) to generate the pulse.***

***12 – Press the button under the Stop label to terminate acquisition after observing the liquid level response and a repeat if desired.***

***13- Save or Discard the acquired shot.***

***14- Return to Main Menu or Retest the same well.***

## *Acquisition of Acoustic Records*

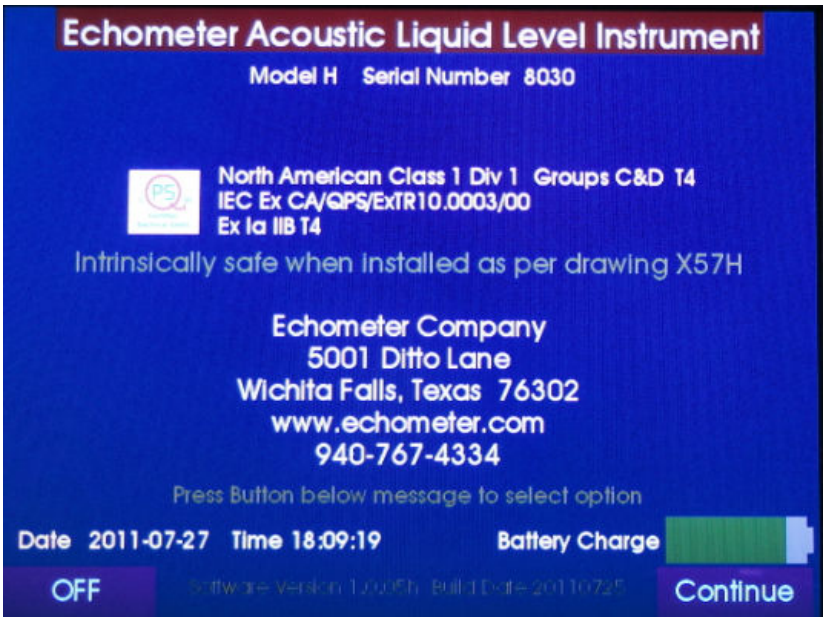
Following are illustrated the steps normally followed when acquiring fluid level acoustic record.

***1 - Power up instrument by pressing the ON/OFF button on the instrument panel.***

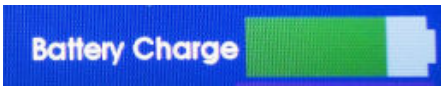
The following Self Test Screen is displayed for about 45 seconds:


The following **Title** screen is displayed after powering up the instrument:

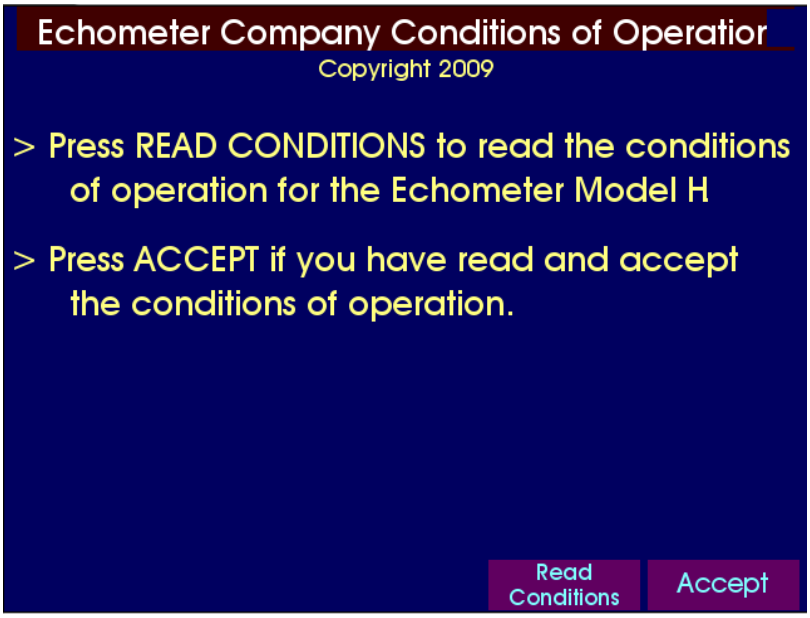
Title Screen



Check that the battery is adequately charged to successfully undertake the proposed testing sequence. The color of the battery level indicator will turn from green to yellow when charging is required immediately. Regular charging increases battery life.

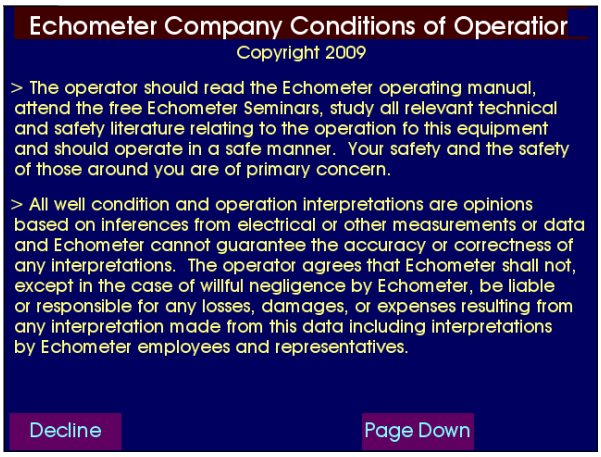


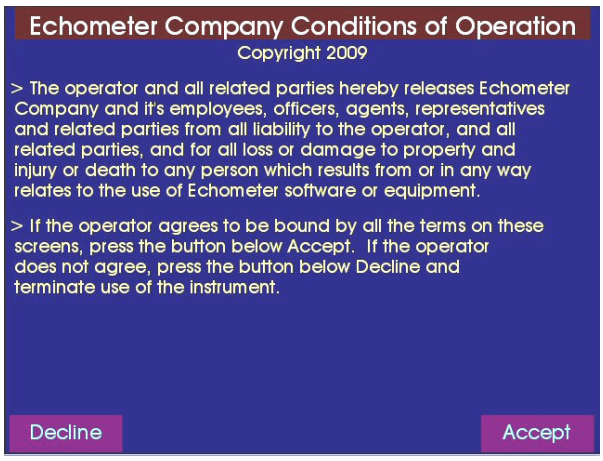

***2 - Press the soft key corresponding to Continue to display the following screen:***




Selecting the ***Read Conditions*** options opens the following screens. Selecting the ***Accept*** option proceeds to the ***Main Menu*** screen.

## Conditions of Operation



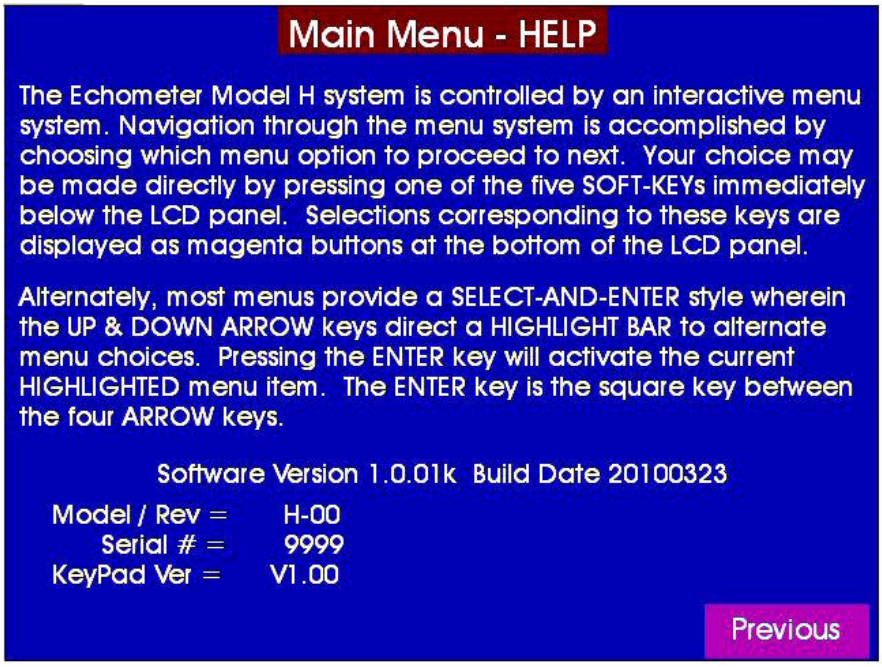




If the user **Declines** to accept the conditions the program **shuts OFF** the instrument. **Page Down** displays the continuation of the text detailing the conditions of operation.

When the user **Accepts** the **Conditions**, the **Main Menu** is displayed as shown in the following figure:

Main Menu


The Main Menu **Help Screen** gives general instructions for user input and control as well as information regarding the software version and instrument serial number:



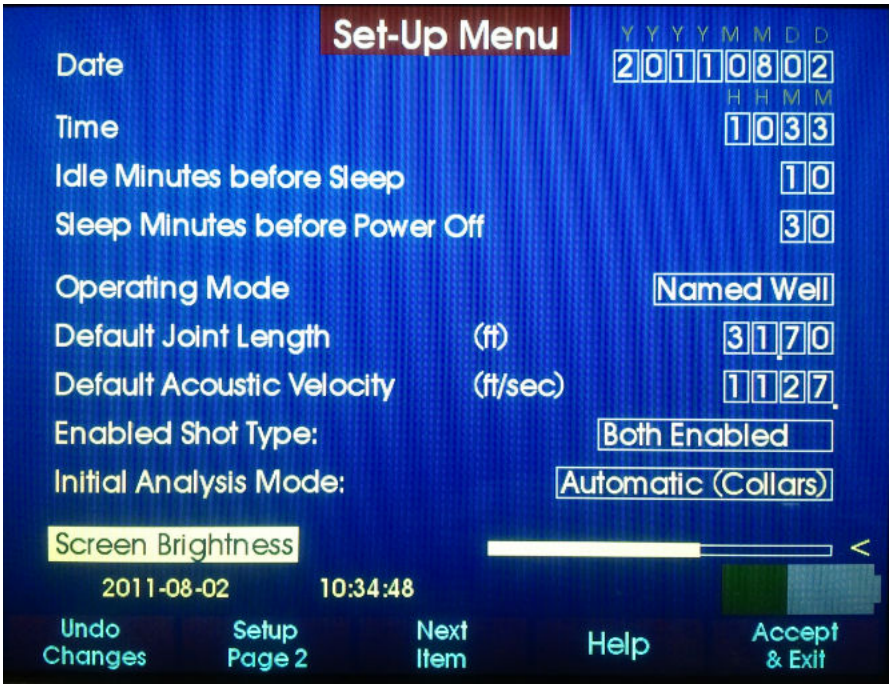
In the following description, the acquisition procedure assumes that the default mode of acquisition is the "***Named Well Mode***" where the user first selects from the instrument's data base the specific well information where the acoustic test is being performed and then acquires the acoustic record. Upon completion, the data set is added to the records for that specific well.

An alternate "***Quick Shot***" mode of acquisition can be preselected in the ***Setup*** menu as the default method where the user is automatically directed to the acquisition screen without having to select a well from the data base. The acquired record is then added to the previously acquired data sets in the "***Quick Shot***" group as a record labeled with date and time of acquisition but no direct reference to the specific well that was tested. The intent of the quick shot mode of acquisition is to obtain the fluid level data in a minimum of time for routine monitoring of well operation.

Instrument Set-Up

The instrument is shipped with standard default options and quantities as displayed in the **Set-Up Menu** that is accessed by pressing the button below the **Setup** label in the **Main** screen as discussed on page 25 of this manual.

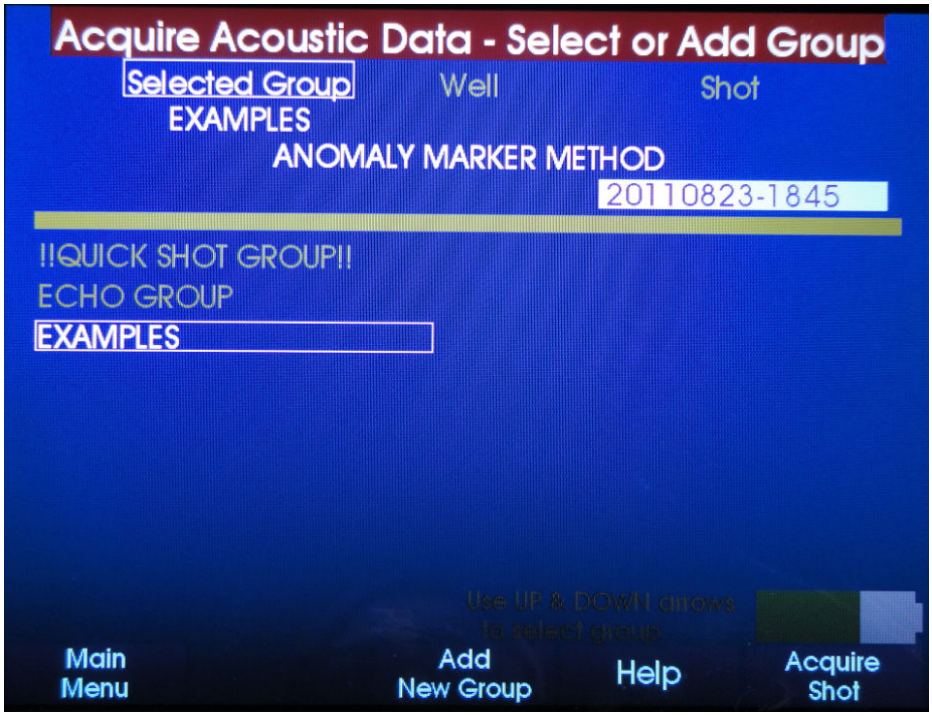
Any acquired data will be named according to the date and time the shot was taken. Make sure the date and time are correct for your time zone so that your shot record will be accurate.

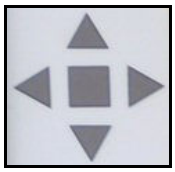


***3-To continue with Acquisition press the soft key below the Acquire Data label.***

The following screen is displayed showing the available well groups with the name of the most recently selected group highlighted. If the Selected Group column title is not displayed with a list of Groups displayed below it, use the left arrow key to highlight the Selected Group column.

Well and Group Selection



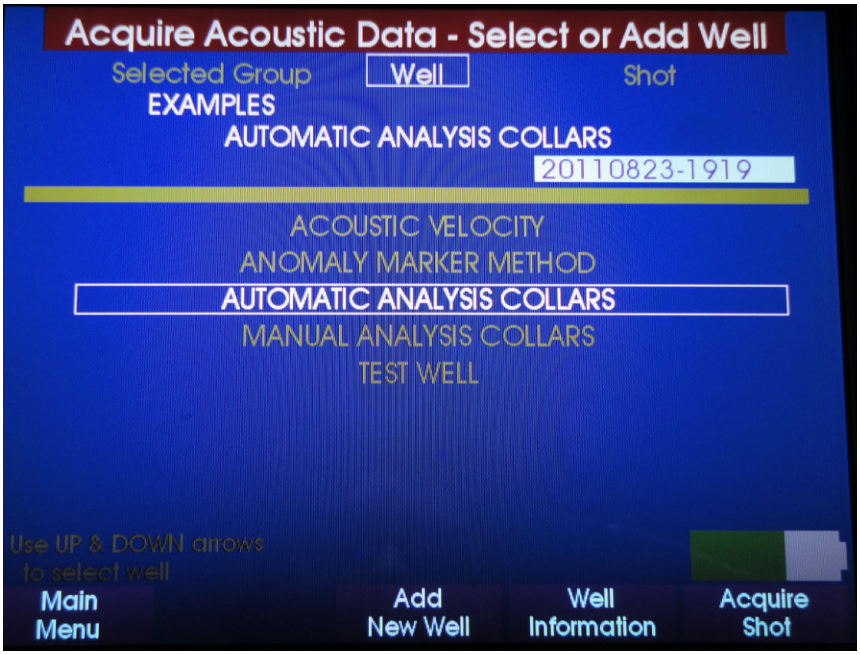



***4- Use the Star Keys Up and Down buttons to select the group that contains the information for the well being tested.***

In the above figure the "Examples" group has been selected. If the desired Group is not in the list pressing the button under the "Add New Group" label will display the screen that allows adding new groups to the list as described later in this manual.

***5- Use the Star Keys Right Arrow to select the Well option to display the list of wells included in the "Examples" group:***

The selected well is highlighted: "Automatic Analysis Collars"



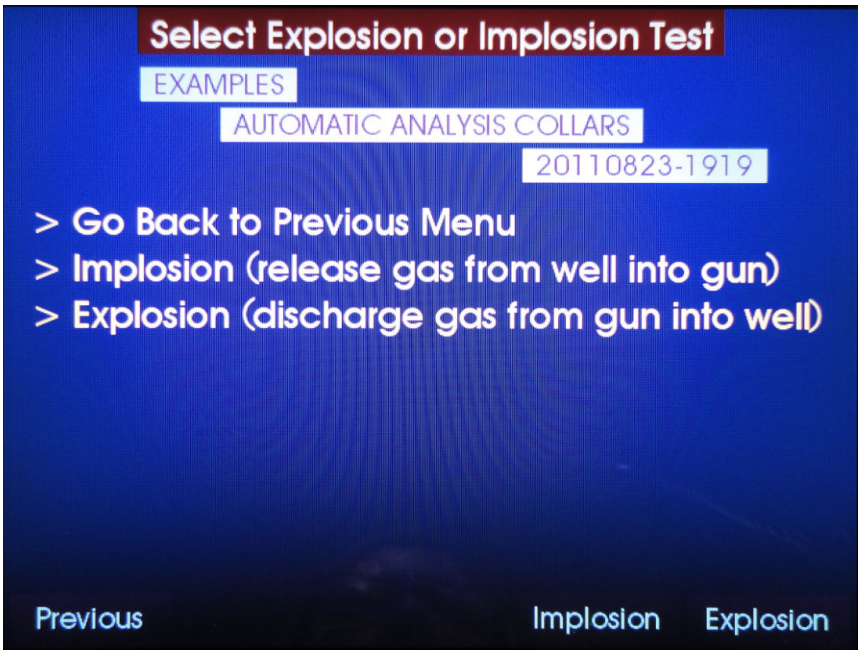

***6-Use the Star Keys Up and Down arrows to select the desired well from the list.***

If the well to be tested is not in the list pressing the button under the "**Add New Well**" label will display the screens that allow adding new wells to the list as described later in this manual.

***Acoustic Record Acquisition***

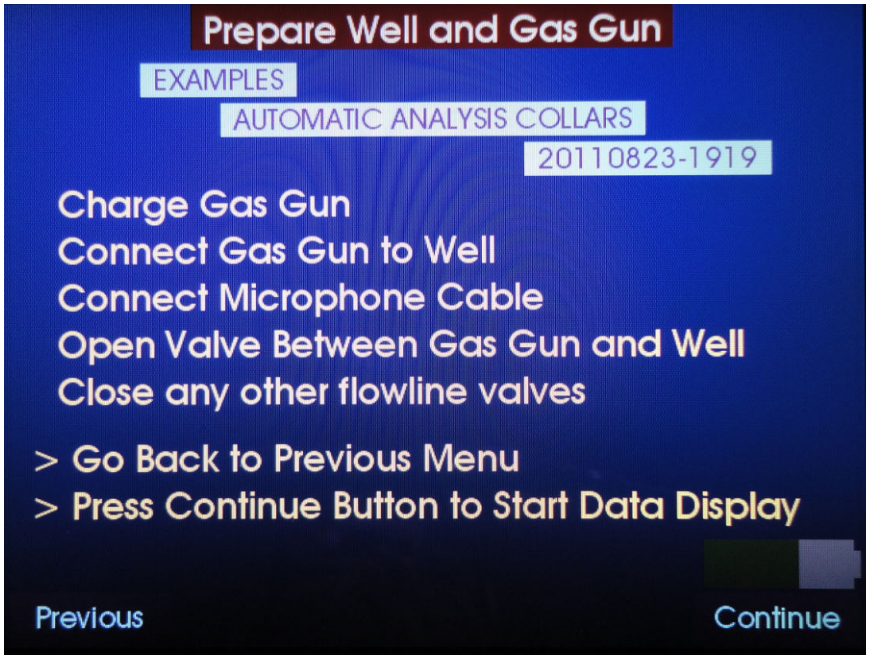
***7- Press the "Acquire Shot" button on the instrument panel after the well in question has been selected from the list (either pressing the button below the "Select Well" label or the "Enter" button of the 5 button Star Keys)***

The Select Test screen is displayed so that the user may select the type of pulse: “Implosion” or Explosion”



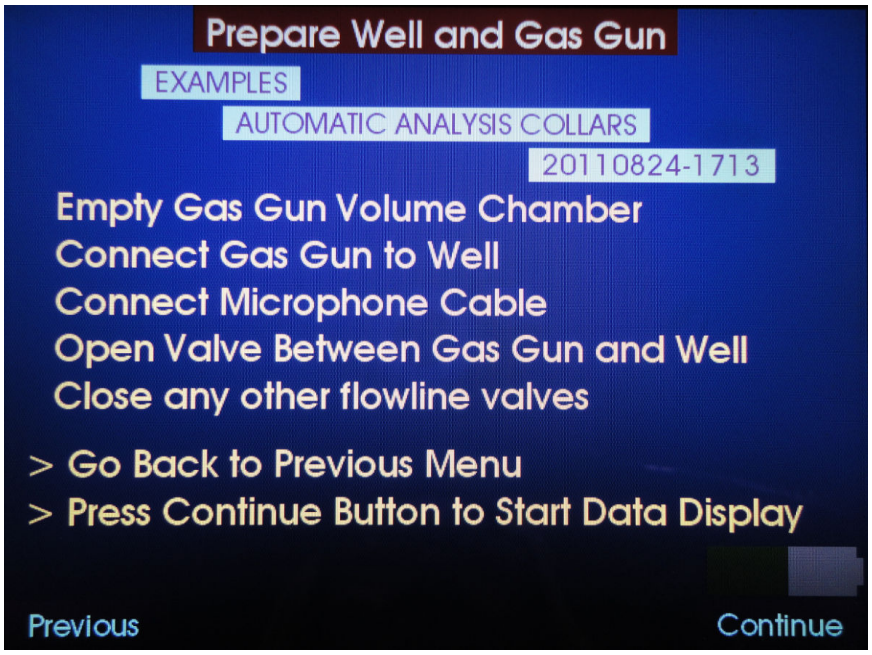

***8a-Pressing the button below “Explosion” label displays the check list for connection and preparation of the hardware to perform the acoustic test.***

Prepare Well and Gas Gun for Explosion Shot



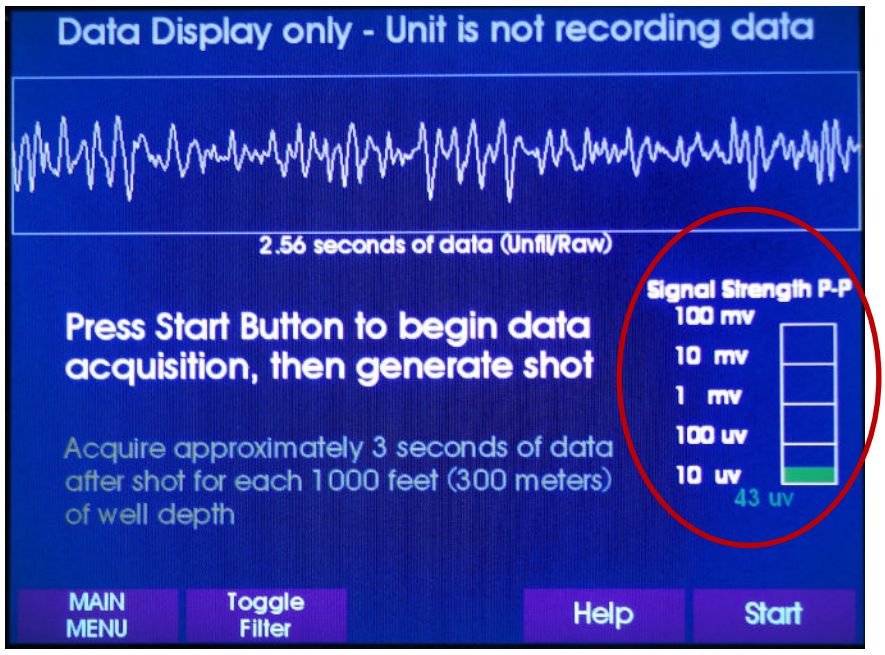
***8b-Pressing the button below "Implosion" label displays the check list for connection and preparation of the hardware to perform the acoustic test.***

Prepare Well and Gas Gun for Implosion Shot




***9 – When ready press the button under the "Continue" label***

Background Noise Display

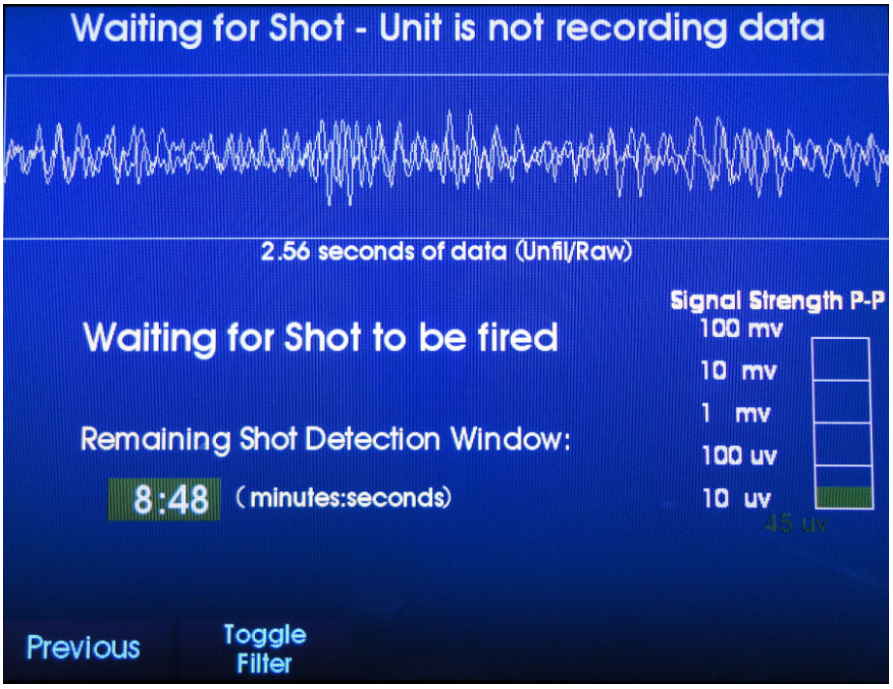


The signal strength indicator will change from **green** to **yellow** when the background noise in the well exceeds 1mV and from **yellow** to **red** when the noise exceeds 10 mV.

A **red** indicator suggests that a higher level of differential pressure should be used to generate the shot.

***10 – Press the "Start" button after adjusting the gas gun pressure if necessary.***

Waiting for Shot to be Fired



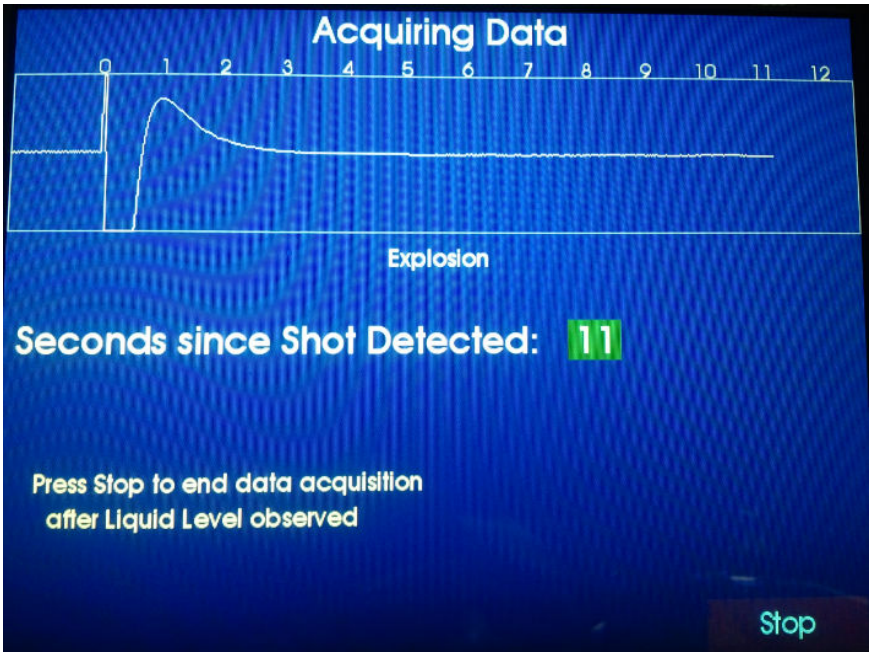

The display indicates that the software is monitoring the microphone signal and is ready to detect the shot when it is fired. Shot detection occurs when the microphone voltage exceeds the preset threshold voltage. The user has 10 minutes to generate the acoustic pulse by actuating the gas gun trigger or control valve. When the allotted time expires the screen will change automatically to the previous screen (Background Noise Display).

In noisy wells it may be advantageous to Toggle ON/OFF a Low Pass filter to enhance the displayed data and help the user observe the echo from the liquid level and/or other anomalies present in the well.

***11 – Actuate the gas gun control (trigger) to generate the pulse.***

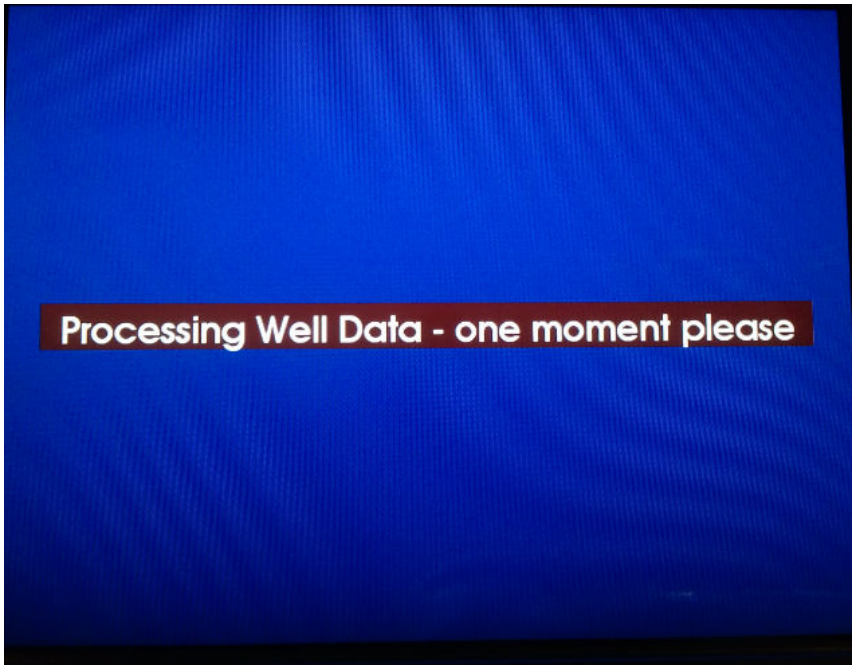
Upon detection of the shot the following screen is displayed:

Acquiring Data Screen



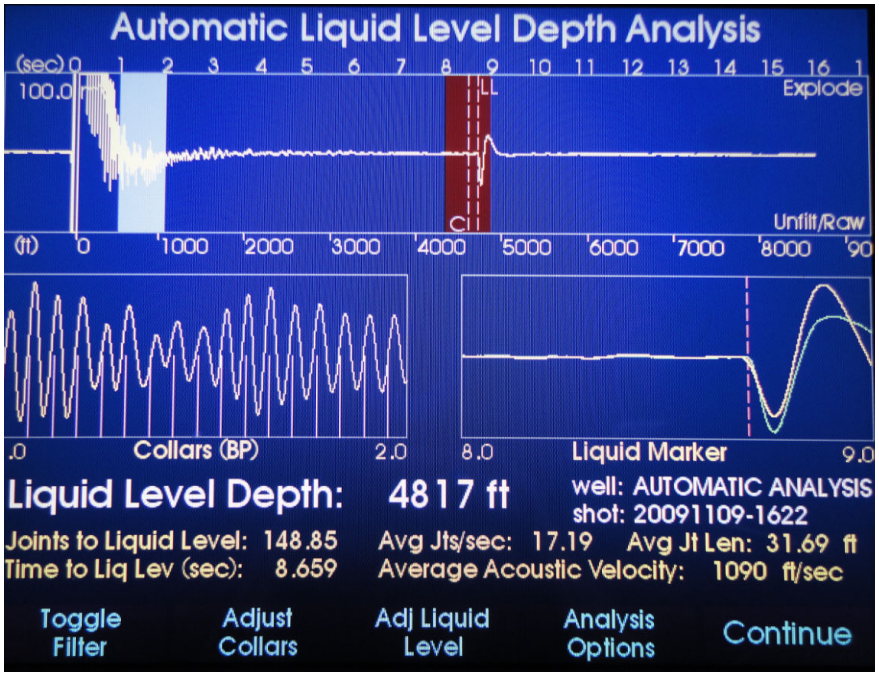

***12 – Press the button under the Stop label to terminate acquisition after observing the liquid level response and a repeat if desired.***

Following the Stop command, or the expiration of the 30 second maximum recording interval, the program will process the acoustic data and display the following screen:



When processing is finished the following screen is displayed:

## *Automatic Fluid Level Analysis*




The software scans the acoustic record to identify all the signals that are similar to echoes from the liquid level and displays a vertical dashed line labeled “LL” on the signal that has the greatest probability of corresponding to the liquid level.

The program then builds a low pass filter designed to enhance the echoes from the tubing collars and attempts to count as many tubing joints as possible before the signal attenuates to a level similar to the background noise level. The point in time where the collar count stops is indicated on the acoustic trace by the vertical dashed line labeled “C”. This filtered shot data is displayed in the Liquid Marker window as a green shot trace. The Unfiltered/Raw shot trace is displayed as the brighter yellow.

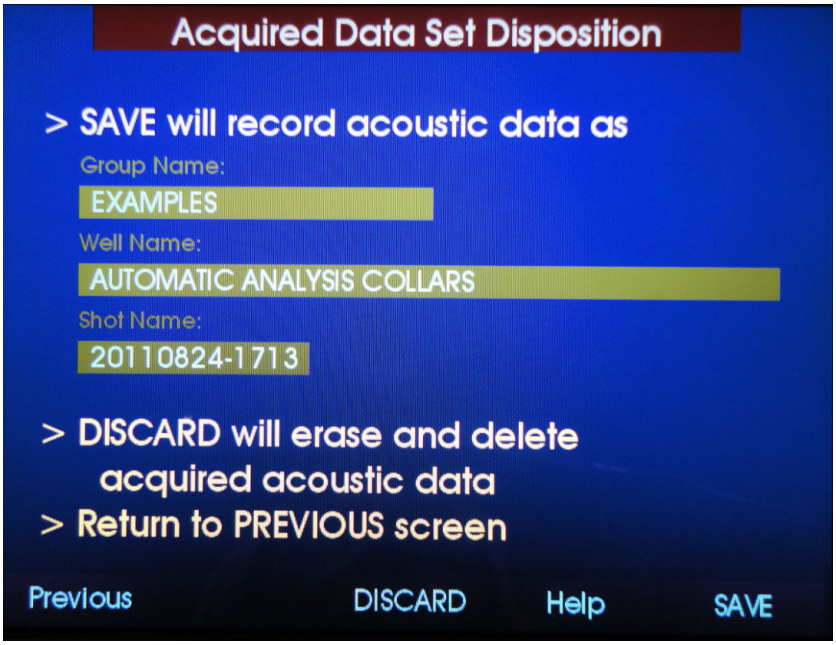
The user should verify that the software has correctly identified the echo from the liquid level and that the collar count marker is located near the liquid level echo for maximum accuracy.

If the user determines that the automatic analysis is not accurate, the user has the option of manually adjusting the marker identifying the liquid level or modifying the collar count by pressing the corresponding “**Adjust**” buttons. When the user is satisfied that the software has correctly identified the liquid level echo and generated an accurate collar count then the analysis can be saved by pressing the button below the **Continue** label and the screen will display the **Data Set Disposition** screen.

Manual Adjustments

The functions: ***Toggle Filters, Adjust Collars, Adjust Liquid Level and Analysis Options*** are discussed in detail in the next chapter of this manual.

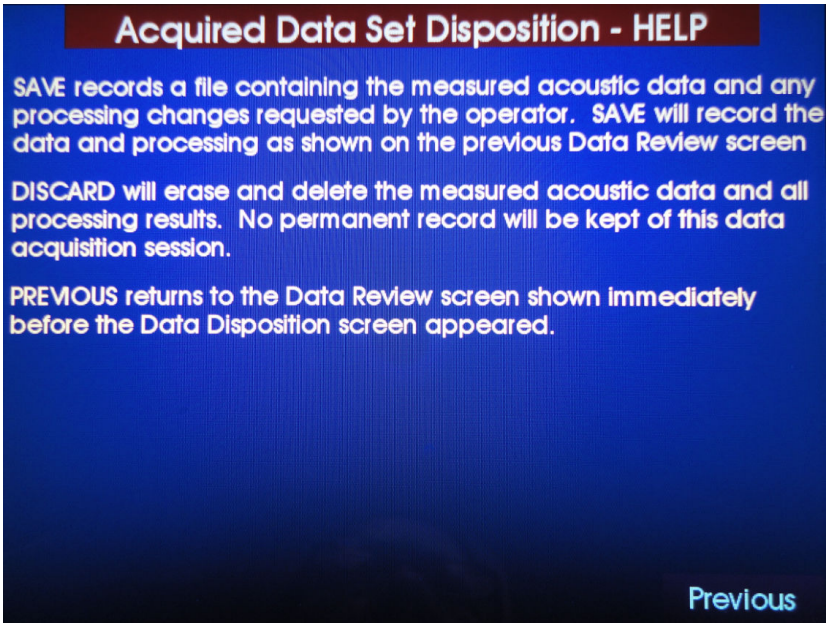
### *Data Set Disposition*



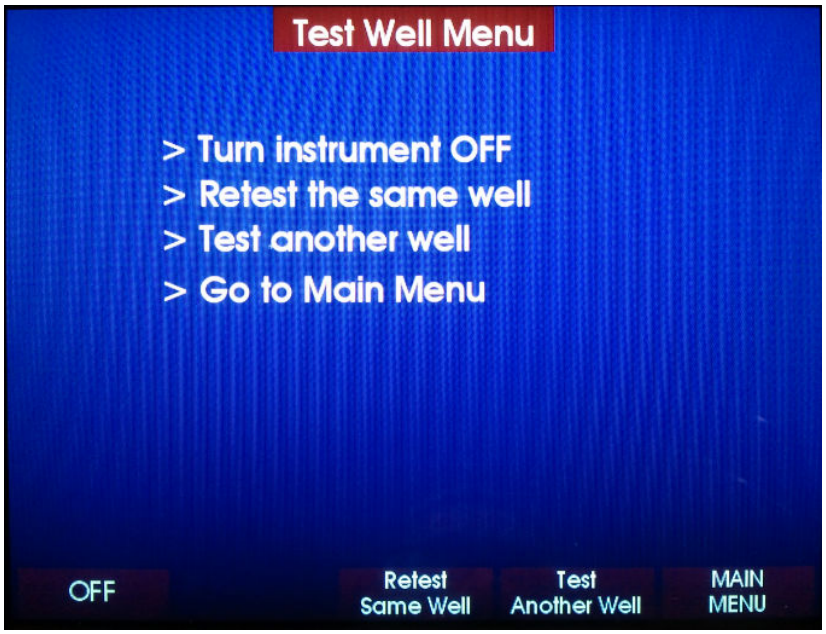

Pressing the button below the **"Save"** label will store in the memory of the instrument the current analysis and interpretation of the acoustic data then the **Test Well** screen will be displayed.

Pressing the button below the **"Discard"** label will delete the acquired data and display the **Test Well Menu** screen.

Pressing the button below the "Help" label will display the following **Acquired Data Set Disposition – HELP** screen reviewing the above information.



## Repeat Acquisition




The user has the option of repeating the acquisition of acoustic data at the same well by pressing the button below the "**Retest Same Well**" label.

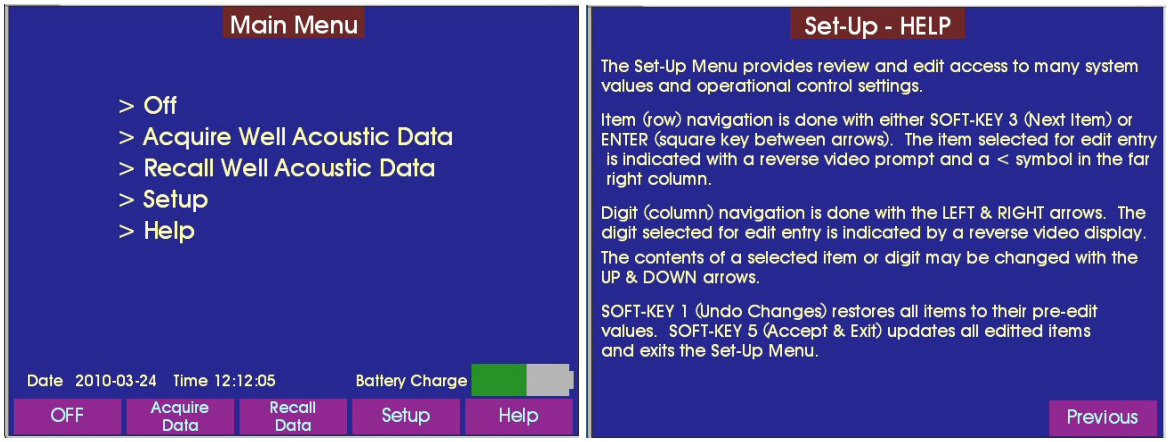
Other options are:

Go to **Main Menu**
Prepare instrument to **Test Another Well**
Turn **OFF** the instrument

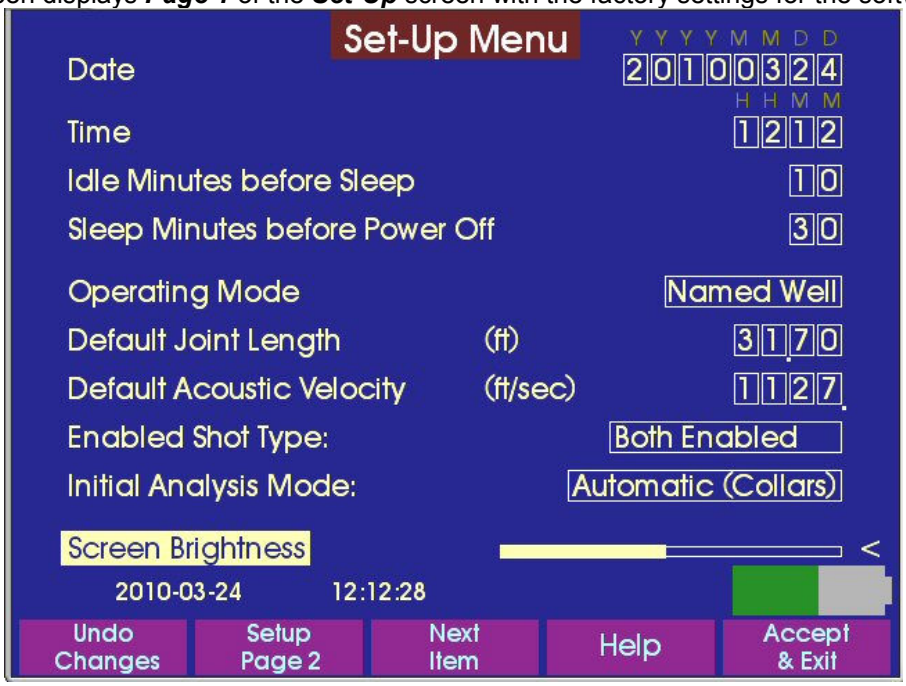
Those are activated by pressing the corresponding buttons on the instrument panel.

## *Set-Up Menu*

The instrument is shipped with standard default options and quantities as displayed in the **Set-Up** Menu that is accessed by pressing the ***Setup*** button below the **Setup** label in the ***Main Menu*** screen. Pressing the ***Help*** button displays the corresponding instructions:




The following screen displays ***Page 1*** of the ***Set-Up*** screen with the factory settings for the software:




Date and Time: The instrument's real time clock should be set to the correct values. This is important since the acquired data files are stored in the database using a date-time stamp.
Idle Minutes Before Sleep: Number of minutes (set to 10) of inactivity before the instrument automatically dims the screen and shuts down unnecessary circuits to save battery power. Pressing any button will wake up the instrument.

Sleep Minutes before Power Off: Number of minutes after sleep time before instrument is powered OFF. Pressing the ON/OFF button will restart the Model H after power OFF.

## Operating Mode:

The Echometer Model H offers two options for acquisition of acoustic data; **Named Well** and **Quick Shot.**

**Named Well**

This option requires that an existing well file be selected before acquiring data. Upon acquisition the time-stamped acoustic record will be added to the records for that well.

**Quick Shot:**

This option automatically sets up the Quick Shot Group and Well to proceed directly to firing of the shot, after powering up the instrument and accepting the Conditions of Operation. The acoustic record will be added to the "**Quick Shot**" data base with the corresponding date-time stamp.

Default Joint Length (ft) 31.7 is the average joint length that the software uses when the value for a specific well has not been updated by the user or when acquiring data in the Quick Shot mode

Default Acoustic Velocity (ft/sec) **1127** is the average acoustic velocity that the software uses when the value for a specific well has not been updated by the user.

Enabled Shot Type: defines the most commonly used pulse generation method:

- ***Both Enabled***: Both explosion and Implosion may be selected by user at time of acquisition
- ***Implosion Only***: Acquisition screen will display Implosion procedure checklist
- ***Explosion Only***: Acquisition screen will display Explosion procedure checklist

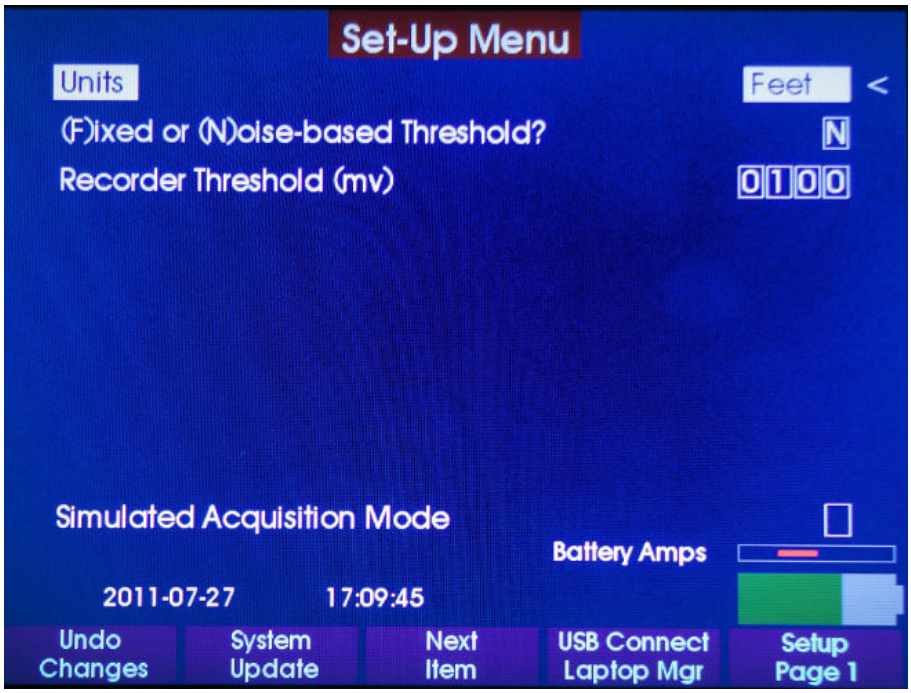
Note that Implosion Mode causes the trace data to be inverted to compensate for the pressure wave direction reversal.

Initial Analysis Mode: defines the default method for calculation of the distance to the liquid level:

- ***Automatic (collars):*** software performs automatic collar count and selects the liquid level.
- ***Anomaly Markers***: user flags the echoes from known wellbore anomalies defined in well file.
- ***Acoustic Velocity:*** a constant value of acoustic velocity is used to convert time to liquid level echo to distance to liquid level.

Screen Brightness: Manually adjust screen brightness using ***Left/Right*** arrows. **Brighter screen drains the battery faster.**

The following screen displays **Page 2** of the Set Up screen




Units: Selection of the system of units to display values of distance; ***Feet*** or ***Meters***

The Model H can operate with Depth Units of Feet or Meters. The Units specified in the SetUp configuration are used automatically for display of newly acquired shot data and analysis results. For Recall access the current SetUp units are compared to the depth units used when the shot was last saved, and if they are different the operator is asked to select the desired Depth Units for Recall viewing and processing.

## (F)ixed or (N)oise-based Threshold:

A Fixed Threshold (F) allows the operator to enter a recorder threshold value that the instrument will use to detect when a shot is fired. Setting the threshold too high or too low may inhibit the Model H from “hearing” the shot fired, or may increase the sensitivity to a level that would not allow it to discern a fired shot from low level noise in the well.

A Noise-based Threshold (N) will automatically adjust the instrument sensitivity to respond to a noise introduced to the well that is approximately four times the stabilized noise level. The instrument would automatically respond to the shot fired as long as the noise level from the shot introduction is within this range.

The instrument is defaulted to use the Noise-based threshold.

## Recorder Threshold (mv):

When using the Fixed Threshold for shot detection, the recorder threshold is entered by the operator. The default fixed-based threshold is 100mV. Setting the threshold too high or too low may inhibit the Model H from “hearing” the shot fired, or may increase the sensitivity to a level that would not allow it to discern a fired shot from low level noise in the well.

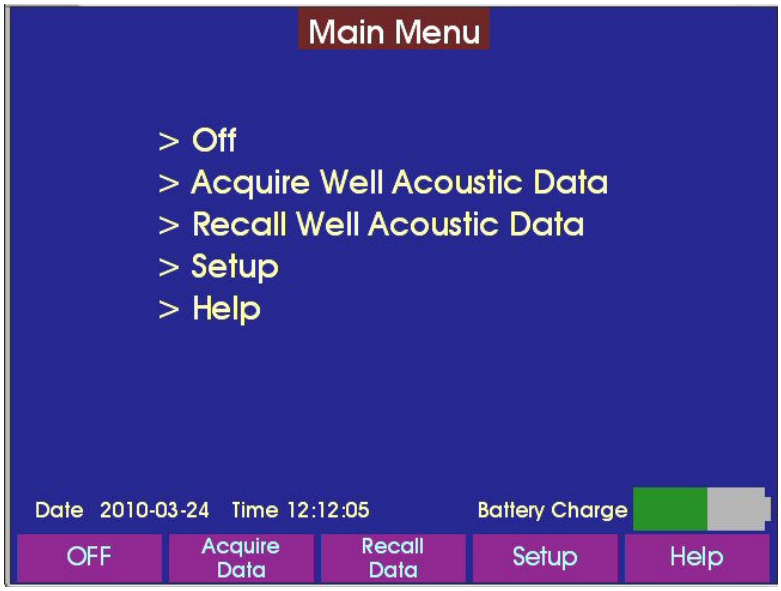
# *Recalling, Analyzing and Uploading Acoustic Records*

Acoustic records that have been saved in the data base can be reprocessed and analyzed using the instrument software or may be uploaded to a laptop computer for storage or further processing with the Model H Laptop Manager Software.

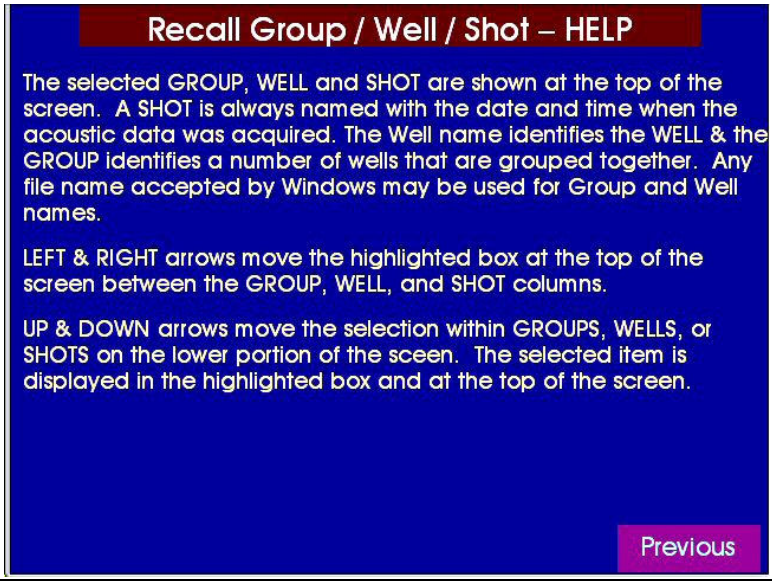
The following section illustrates how to recall and analyze acoustic records using the stand alone Echometer Model H.

## Recalling and Analyzing Acoustic Records

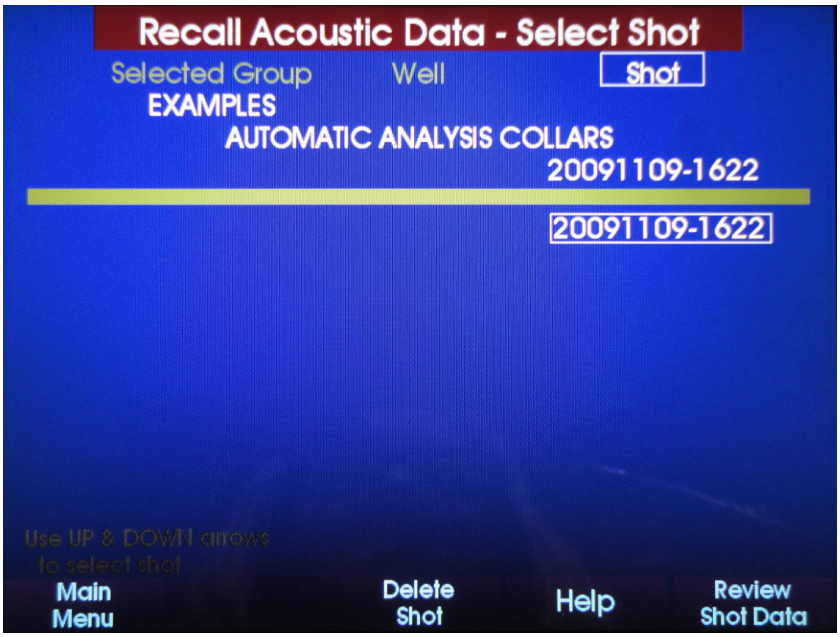
Starting at the ***Main*** menu press the button below the "**Recall Data**" label.




The following instructions are displayed by selecting **Help:**



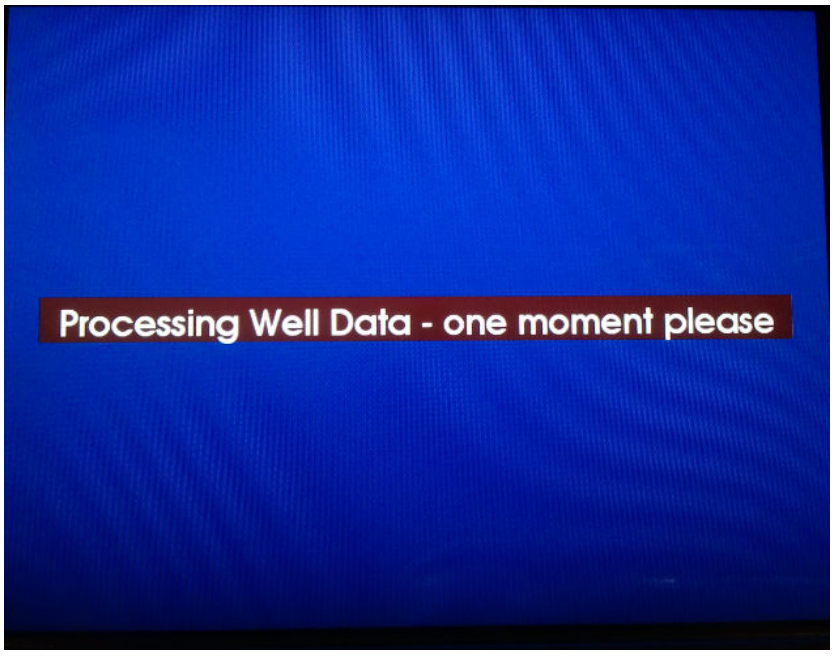
Use the arrow controls to select the group (Examples), the well (Automatic Analysis Collars) and the shot (20091109-1622) that contains the acquired data in question as shown in the following figure:



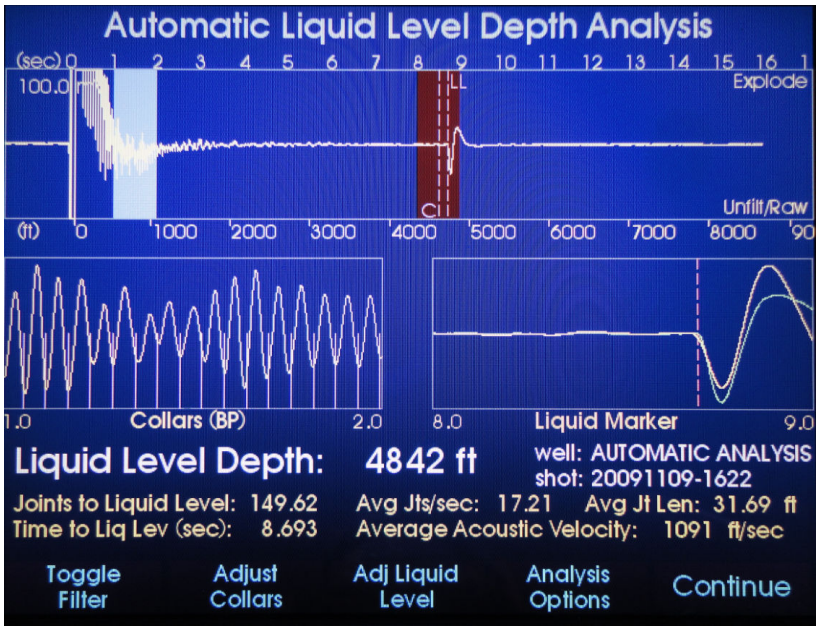

When multiple wells are listed, use the **UP** and **Down Arrow** buttons of the 5 star keypad to select the desired well.

The currently selected data set (20091109-1622) is displayed in the "**Shot**" column. Highlight the "**Shot**" column using the **Right Arrow** to display the list of all available shots. When various shots are displayed select the shot to be reviewed using the **Up & Down** arrows.

Press the button below the "**Review Shot Data**" label when the desired shot is selected. This will initiate the processing of the data as seen in the following screen:



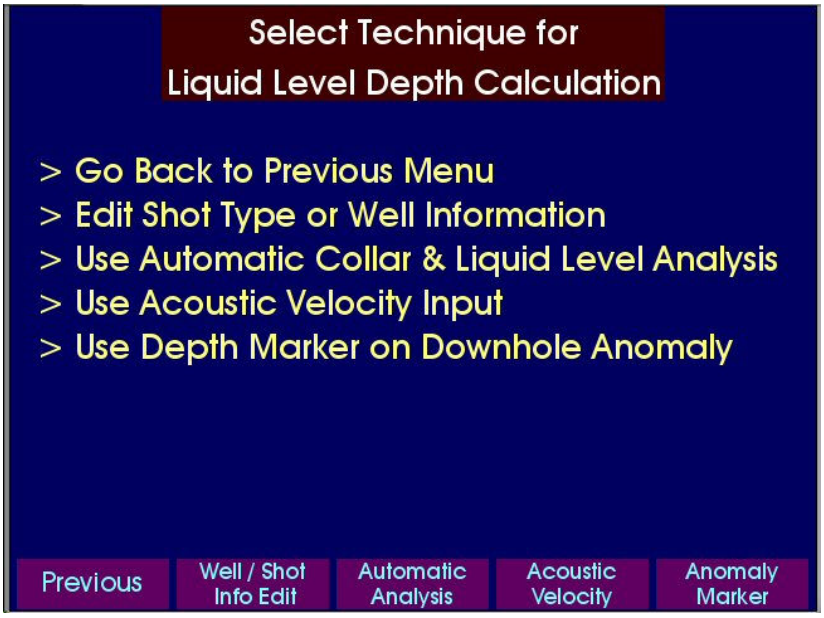
When processing is completed the following screen is displayed showing the distance to the liquid level computed by the method that was selected at the time when the data was previously saved which in this example is the Automatic (Collar Count) method.




When the user wishes to apply a different method of analysis he can do so by pressing the Analysis Options button to open the following screen:

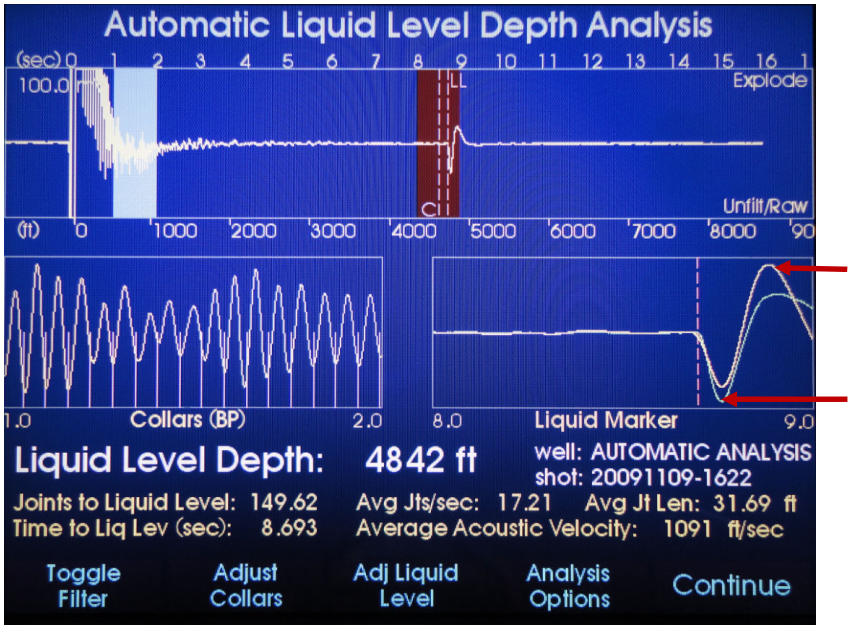
## *Analysis Options*:

This screen presents the user with a list of alternative liquid level depth calculation methods.




The following section discusses the Automatic Collar and Liquid Level Analysis which is the method that is used most commonly.

## Automatic Collar and Liquid Level Analysis

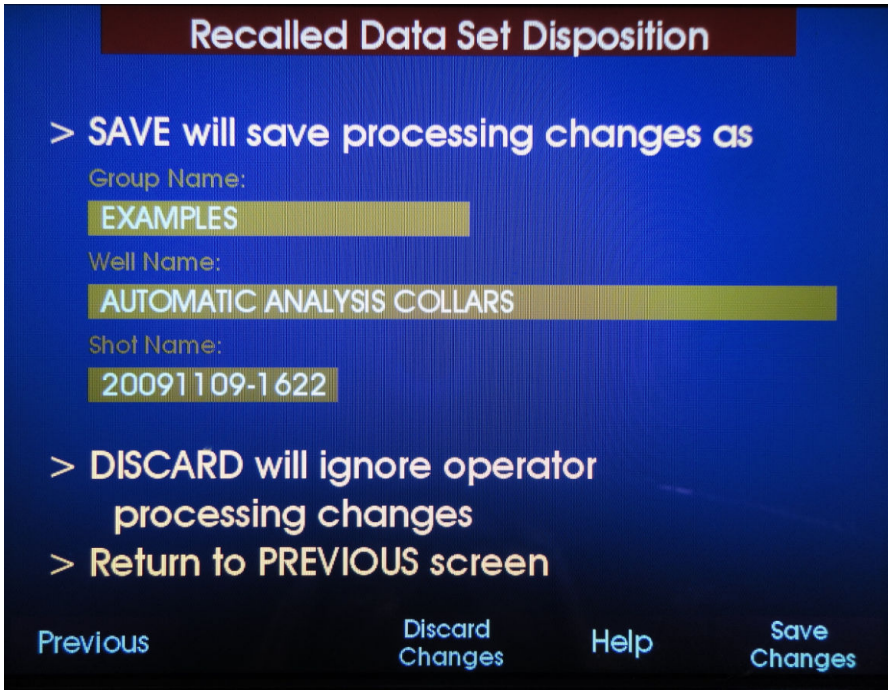



The user may accept the current calculations or has the option of making adjustments and modifications as follows:

**Continue:** Accepts the analysis and offers the option to save the record
**Toggle Filters:** This option toggles ON and OFF a low pass filter to the acoustic data display. The filtered data appears in the Liquid Marker window as a green trace.
**Adjust Collars:** this option opens a screen that allows the user to modify the collar count.
**Adjust Liquid Level:** this option opens a screen that allows the user to relocate the liquid level marker.
**Analysis Options:** this presents the user with a list of alternative liquid level depth calculation methods.

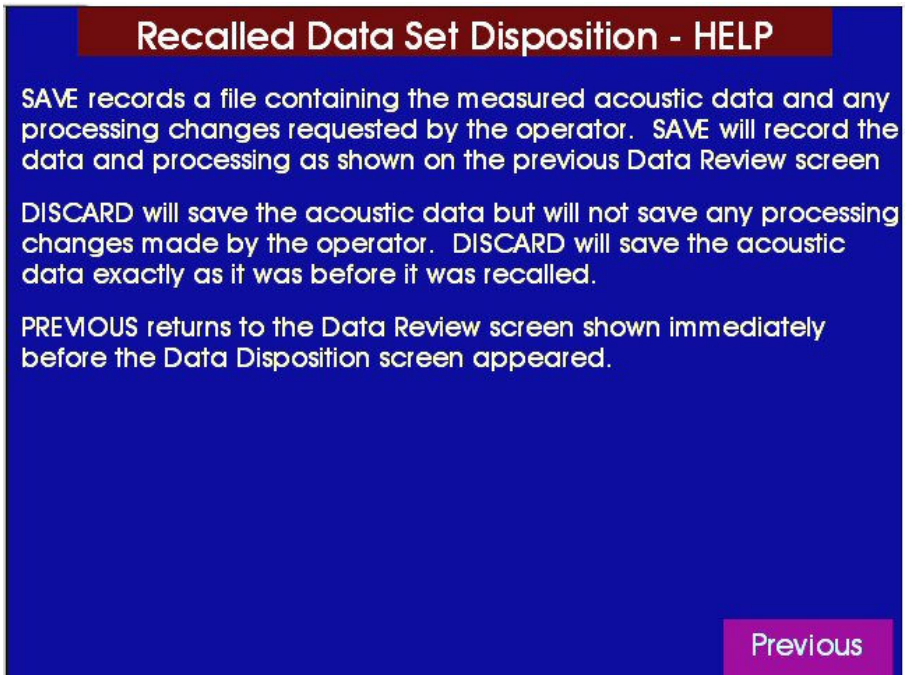
Each of these tools are discussed in the following sections.

Pressing the button under ***Continue*** presents the following screen:

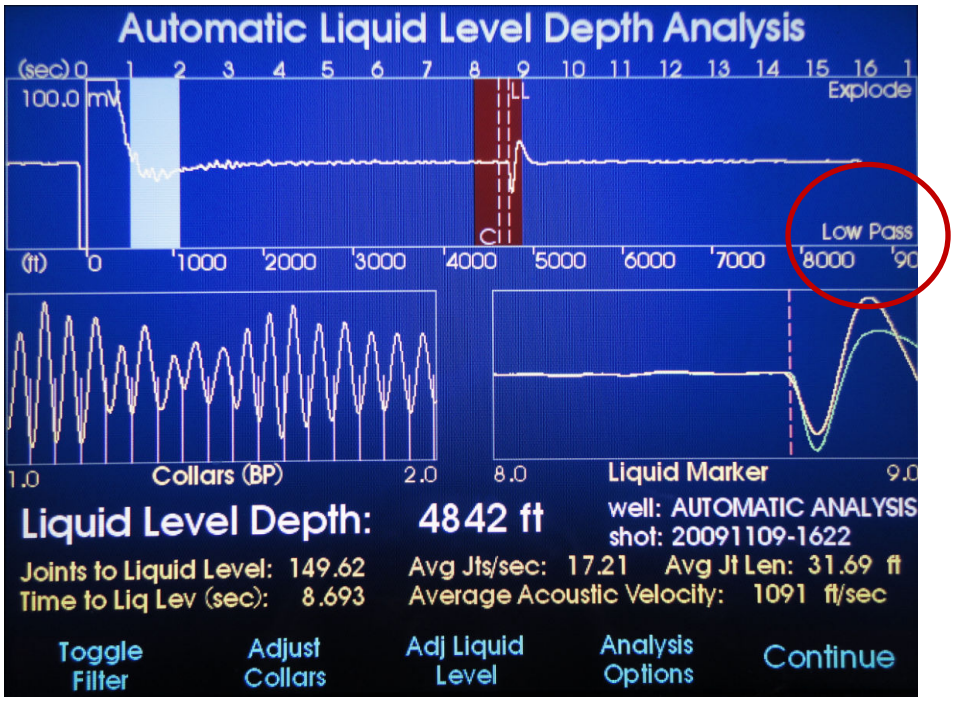



Pressing the button below the "**Save Changes**" label will store in the memory of the instrument the current analysis and interpretation of the acoustic data.

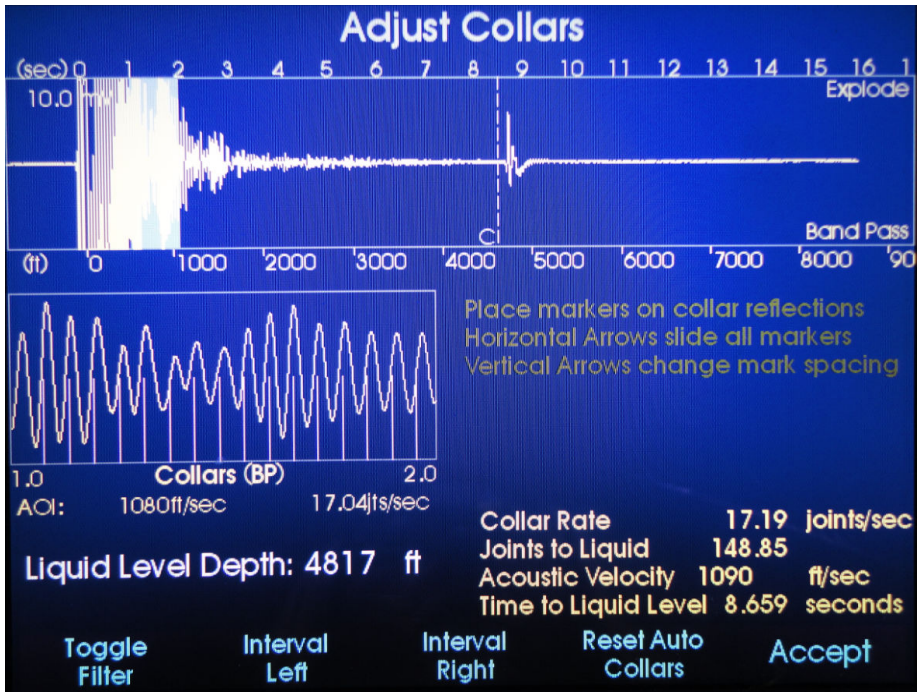
Pressing the button below the "**Discard Changes**" label will leave unchanged the previously stored analysis and interpretation of the acoustic data.



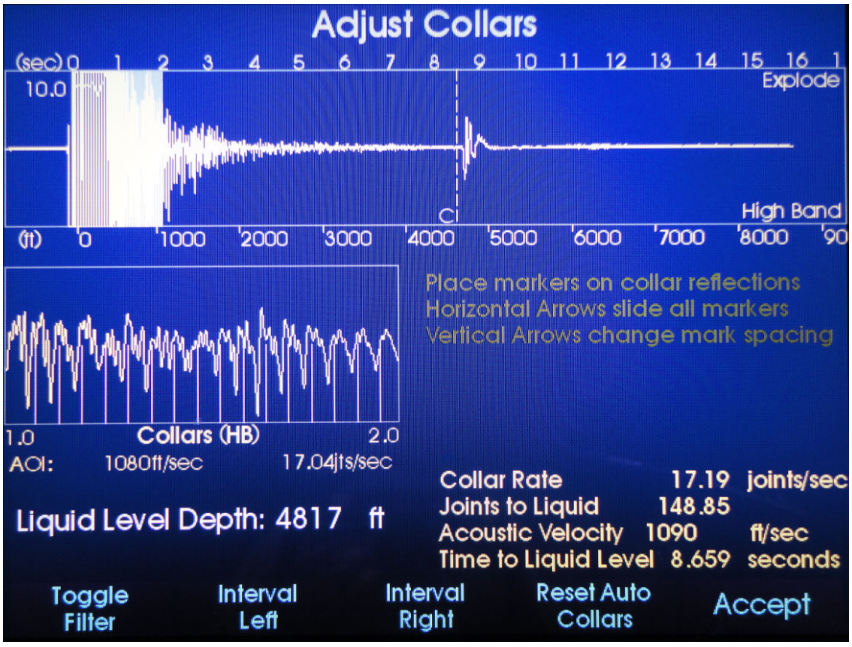
**Toggle Filter*:***
This option toggles ON and OFF a low pass filter to the acoustic data display.



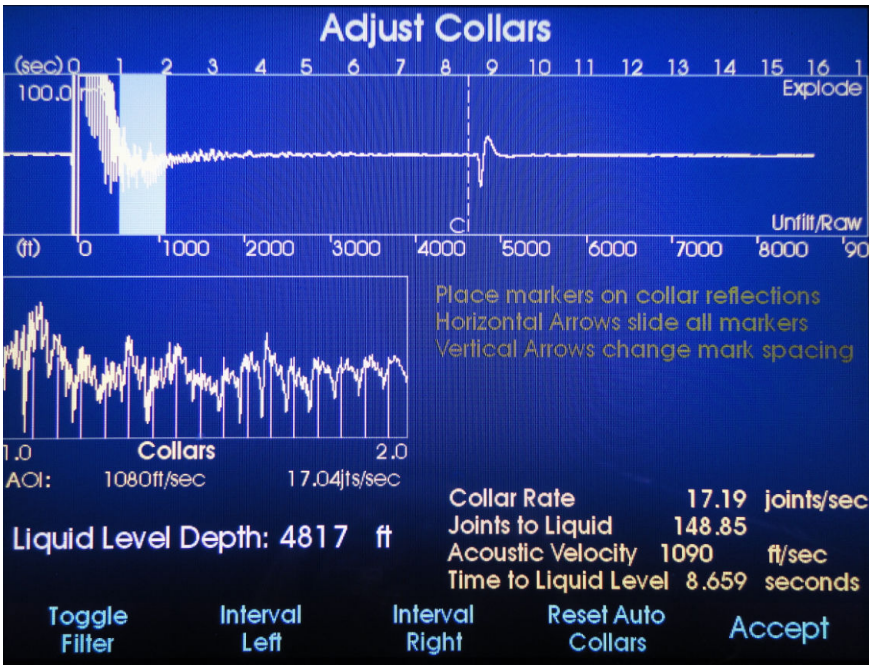

**Adjust Collars*:***
Adjust Collars option opens a screen that allows the user to modify the collar count.



Identification of the collars may be facilitated by observing the signal after toggling different filters. The user can decide which filtered collar display is more appropriate for aligning the markers to the collar echoes. The previous display corresponds to the ***Band Pass*** filter.



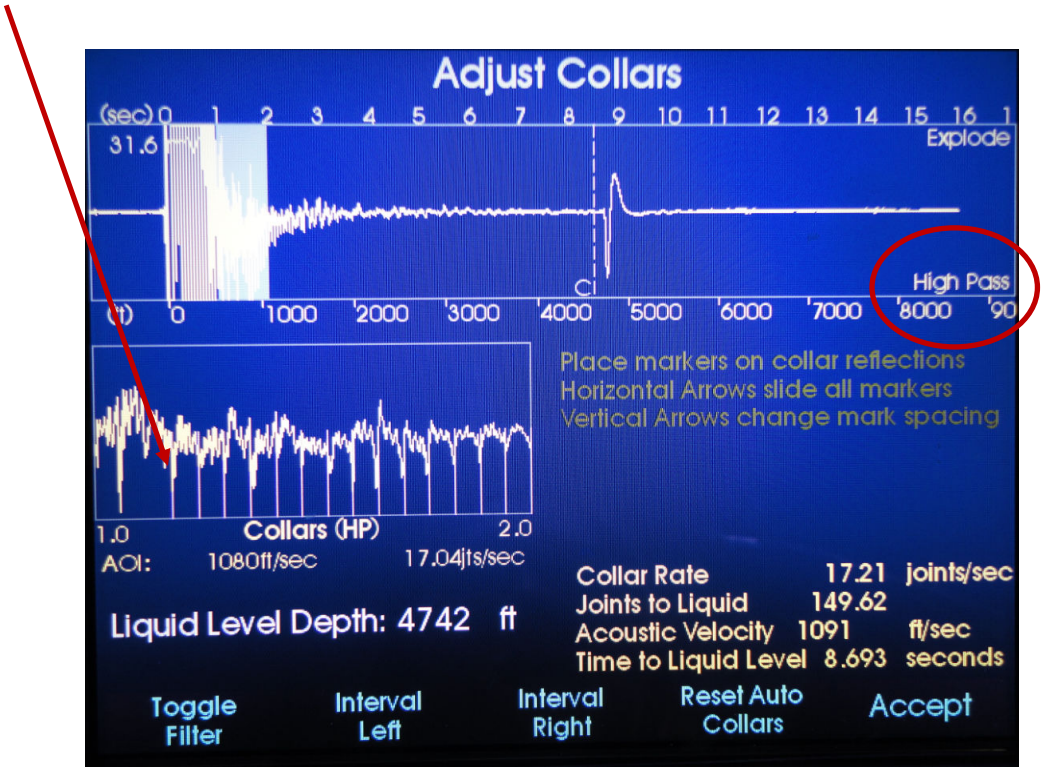

The previous display corresponds to the ***High Band*** filter.




The previous display corresponds to the ***Unfiltered/Raw*** data

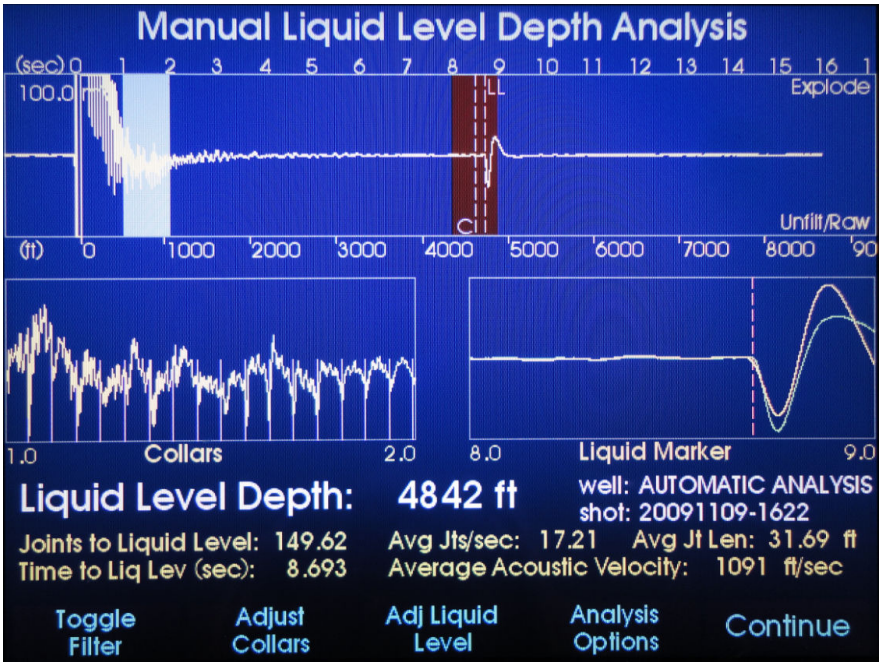
The ***High Pass*** filter usually yields the best presentation of the collar echoes.

After selecting the appropriate filter, the markers are displaced horizontally using the **left/right** arrows until the leftmost marker is aligned with the first identifiable collar echo:




Then the spacing of the collars is adjusted (by pressing the UP and DOWN buttons) until the majority of the markers are aligned with collar echoes. This yields a joint count of 17.21 joints per second in the specific interval between 1 and 2 seconds.

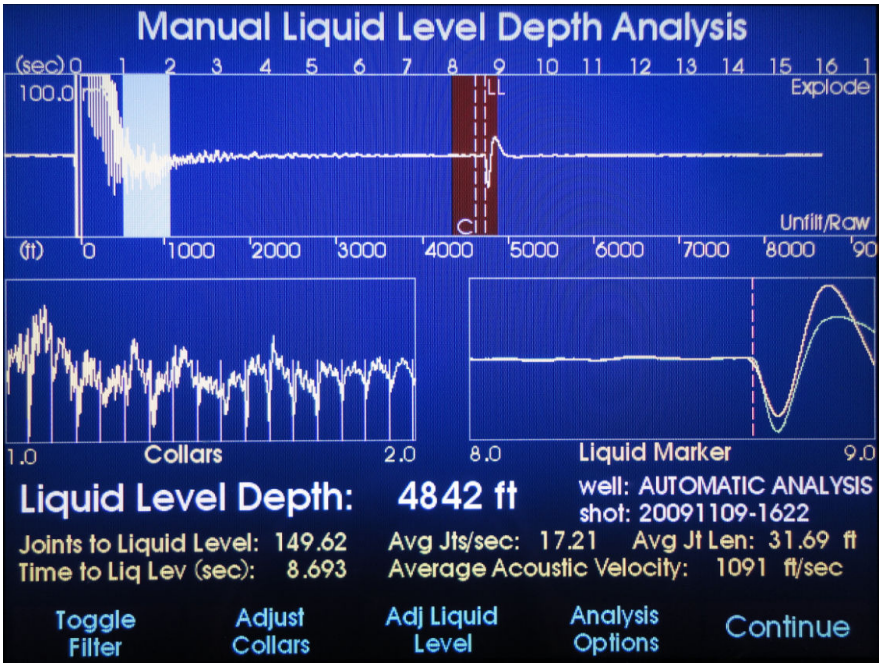
Having completed the adjustment of collar frequency, pressing the ***Accept*** button yields the following figure:




In the above figure the tubing joint count to liquid level 149.62 is the most accurate value for the depth to the liquid level. The accuracy of the indicated depth of 4842 ft is dependent on the accuracy of the Average Joint length that the user has entered in the well information. Note that in this case the operator input value of 31.69 feet/joint is being used in the depth calculation.

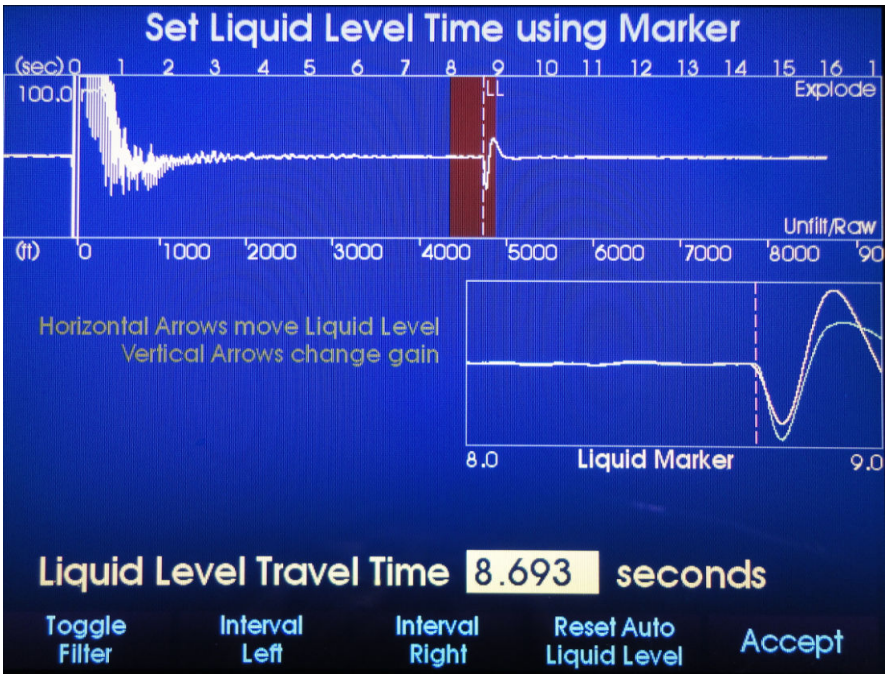
Once a change has been made to an Automatic Analysis, notice the screen title changes to reflect **Manual Liquid Level Depth Analysis**.

***Adjust Liquid Level*:**
This option opens a screen that allows the user to relocate the liquid level marker using the LEFT and RIGHT buttons to a time position where the user considers the arrival of the liquid level echo is observed.




## Set Liquid Level Time Using Marker

Pressing the button corresponding to the "**Adj Liquid Level**" takes the user to the following **Set Liquid Level Time using Marker** screen. The user considers that the software located the marker slightly past the actual "first break" corresponding to the liquid level echo. The marker has been moved forward in the figure below.

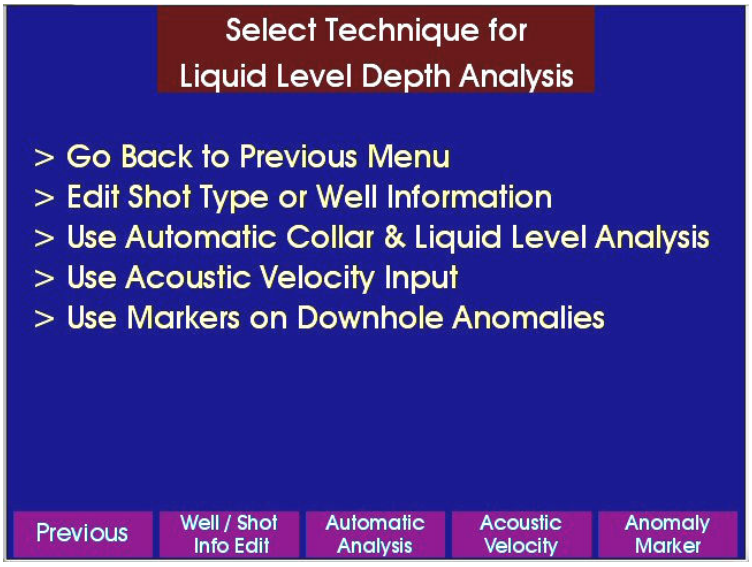


## Anomaly Marker Method

The purpose of this method is to accurately calculate the distance to the liquid level echo using the known distance to one or more specific echoes that are generated by wellbore changes in diameter (hereafter defined as "anomalies") that exist in the wellbore at known distances from the wellhead. This method accounts for the variation of acoustic velocity that is commonly observed in most wellbores due to the variation of temperature, pressure and gas composition as a function of depth.

**General Description of Procedure**
Given a list of anomalies and their corresponding distances the software initially places labeled tick marks along the depth axis of the acoustic record at approximate locations based on a previously defined acoustic velocity at distances that would correspond to the location of the echoes from each anomaly.
Subsequently, the user scans the acoustic record and relocates each tick mark to match exactly the first break of the echo for that specific anomaly. This fixes the anomaly on the distance axis and defines the average acoustic velocity for the time interval from the start of the shot to the first anomaly, then from the first anomaly to the second anomaly and so on until the echo from the last anomaly that can be identified.
The distance to the liquid level is then computed by adding to the distance to the deepest anomaly the distance that corresponds to the product of the acoustic velocity for the last interval between anomalies and the one half of difference in round trip travel time between the liquid level and the last anomaly.

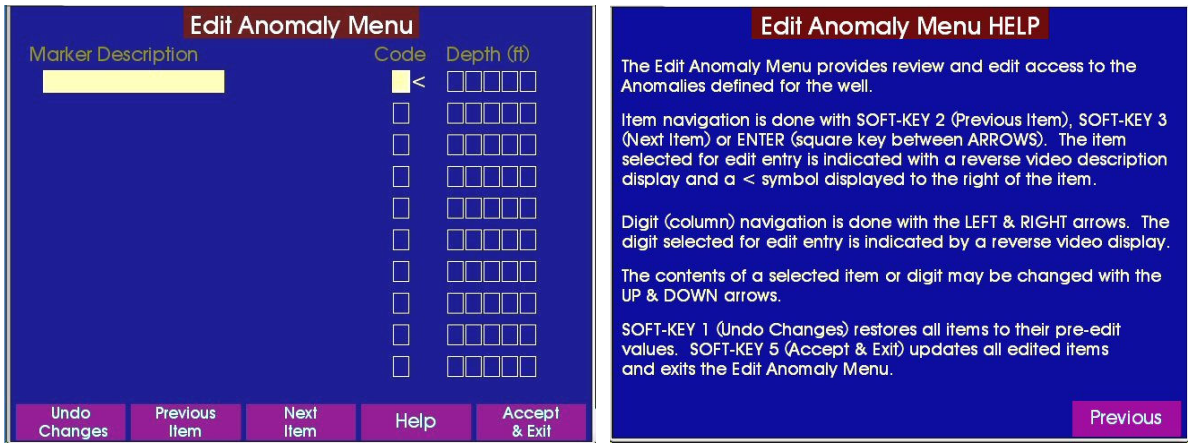
The ***Markers on Downhole Anomalies*** option is selected by pressing the ***Analysis Options*** button to display the following screen:




The process is similar whether the acoustic record has just been acquired or is being recalled from the data base. The following example assumes the record is being recalled:

If the anomalies data was entered previously in the well file then the user is still presented with the ***Edit Marker Menu*** with the objective of verifying the accuracy of the identity and distance to each anomaly.
Selecting the ***Anomaly Marker*** option opens the following form that in this case is blank since information about the distances to the known downhole markers had not been previously entered in the well file:

**Edit Anomaly Menu**

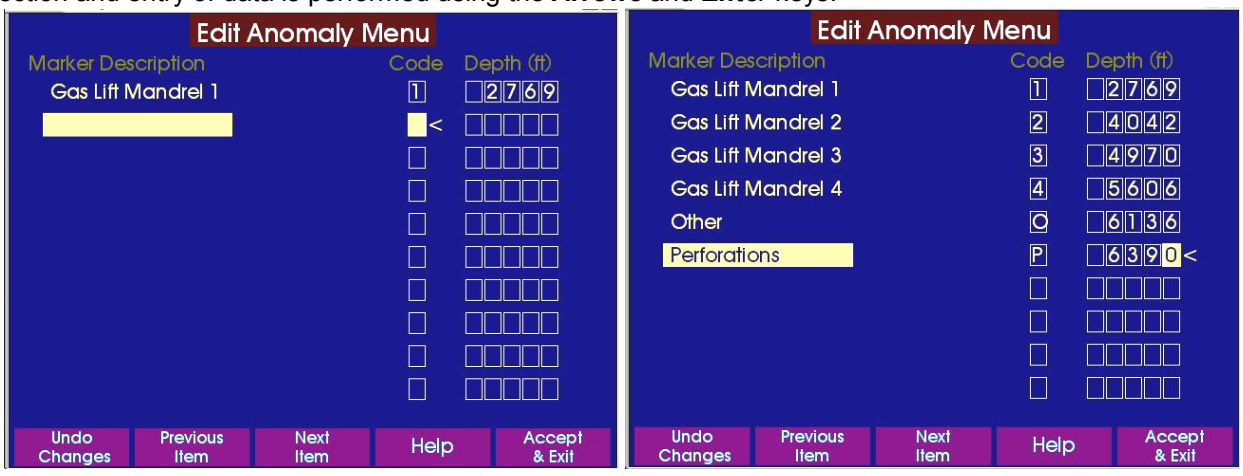



Using the ***Up/Down*** arrows allows selecting a description of each anomaly from the following list:

| | |
|---|---|
| Gas Lift Mandrel No 1 (shallowest) | Code 1 |
| Gas Lift Mandrel No 2 | Code 2 |
| Gas Lift Mandrel No 3 | Code 3 |
| Gas Lift Mandrel No 4 | Code 4 |
| Gas Lift Mandrel No 5 | Code 5 |
| Gas Lift Mandrel No 6 | Code 6 |
| Gas Lift Mandrel No 7 | Code 7 |
| Gas Lift Mandrel No 8 | Code 8 |
| Gas Lift Mandrel No 9 | Code 9 |
| Enlargement | Code E |
| Liner | Code L |
| Other | Code O |
| Perforations | Code P |
| Total Depth | Code T |
| Packer | Code R |
| SSSV | Code S |

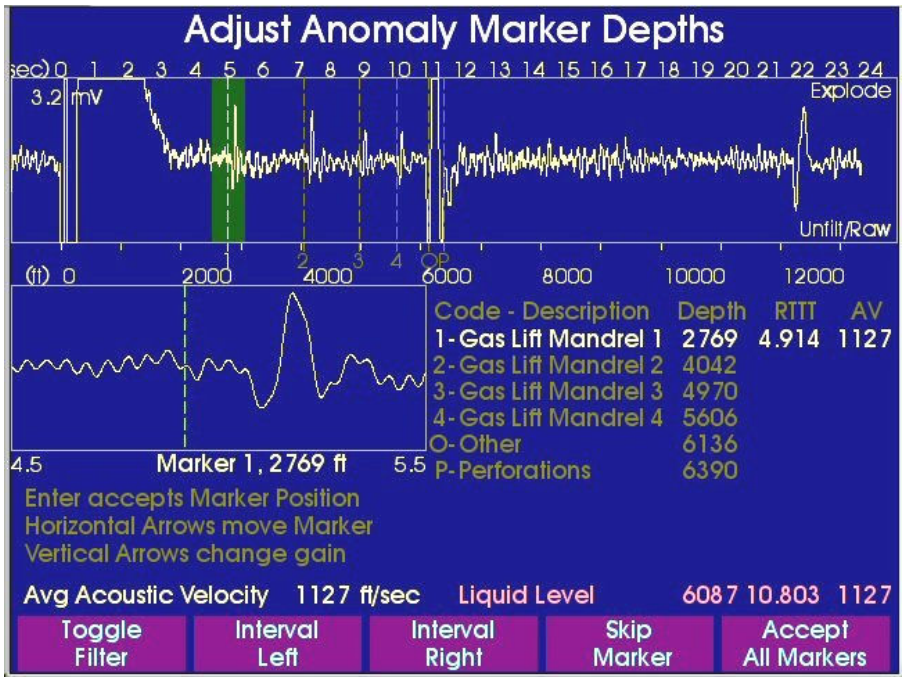
The user then should refer to the wellbore description for the particular well and enter the measured depth to each downhole marker. The depth values entered here should take into account the Model H automatic depth correction applied for any Depth Reference Offset entered into the Well Information record.

Selection and entry of data is performed using the ***Arrows*** and ***Enter*** keys:



The table is navigated using the **Next Item** and **Previous Item** keys and also the **Tab** key. **Undo Changes** will reset the table to all blanks.

Having completed the entry or review of the marker data, selecting the ***Accept & Exit*** option presents the user with the Adjust Anomaly Marker Depths screen, where the program has automatically indicated with a vertical dashed line and green highlighted band, the general location of the echo generated from the first anomaly in the table.




The marker location (at 4.914 seconds) is based on the default acoustic velocity currently active in the program. This default velocity is obtained from the ***Well Information*** record if one has been entered, otherwise the **SetUp Default Acoustic Velocity** is used.

Note also that the program displays additional vertical dashed lines at the **approximate** distance for all the other anomalies that have been entered in the table, whether their echoes are visible or not.

The user now must manually process the record, from the top down, beginning at the anomaly highlighted with the green band and should align correctly each individual marker with the corresponding visible echo. In this process the program calculates the average acoustic velocity for the wellbore interval between the marker currently being adjusted and the previous marker or the wellhead in case there is only one marker such as a liner top.

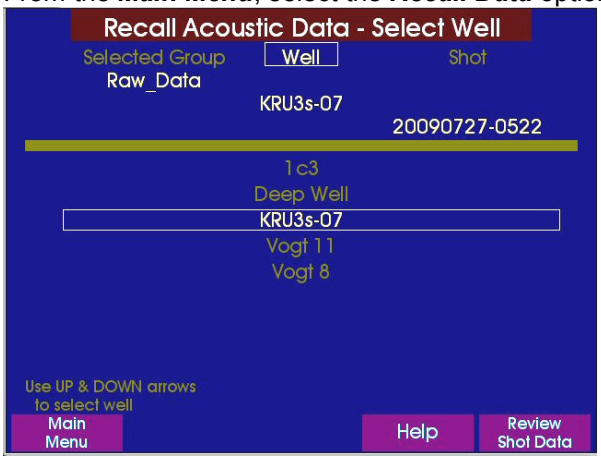
The highlighted portion of the record is displayed in the zoom window at the center left of the screen. In this example the window spans the time between 4.5 and 5.5 seconds. Note that the location of the vertical dashed line does not coincide with the first break of the echo from the known anomaly. The difference is due to the use of the default acoustic velocity (1127 ft/sec which is an estimate of the actual velocity) to locate the marker in time.

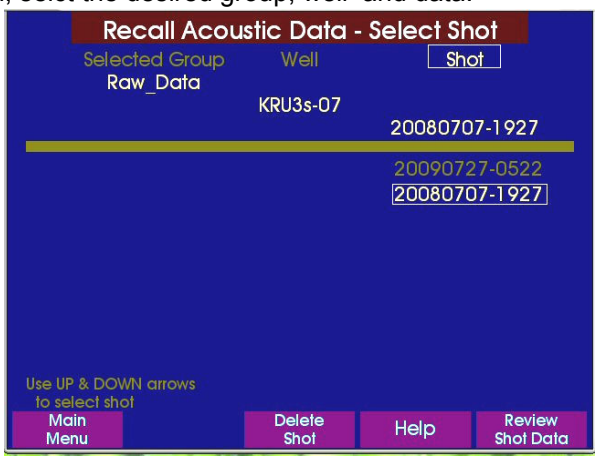
The horizontal arrows, ***Left/Right*** are used to move the marker. The vertical ***Up/Down*** arrows are used to change the vertical scale of the window. The ***Enter*** button is used to accept the marker position.

## Example of Data Processing by the Anomaly Markers Method

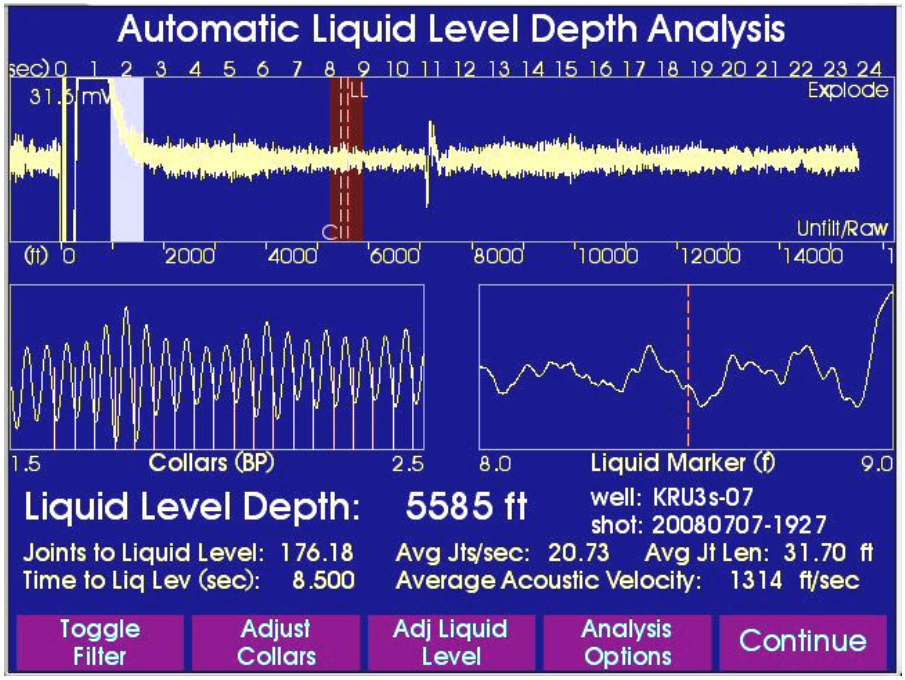
In the following example we assume that the user knows that this record corresponds to a well operating in gas lift and that any echoes that are visible before the liquid level echo correspond to the echoes from the gaslift valve mandrels. However at the time of acquisition the record was analyzed with the Automatic Analysis Method because at that time the exact depth to the markers (mandrels) was not known. Before reprocessing the data the user entered the depth to the anomalies into the well information and now wants to repeat the analysis of the record using the "Markers on Downhole Anomalies" method to get a more accurate liquid level depth.

From the ***Main Menu***, select the ***Recall Data*** option, selct the desired group, well and data:



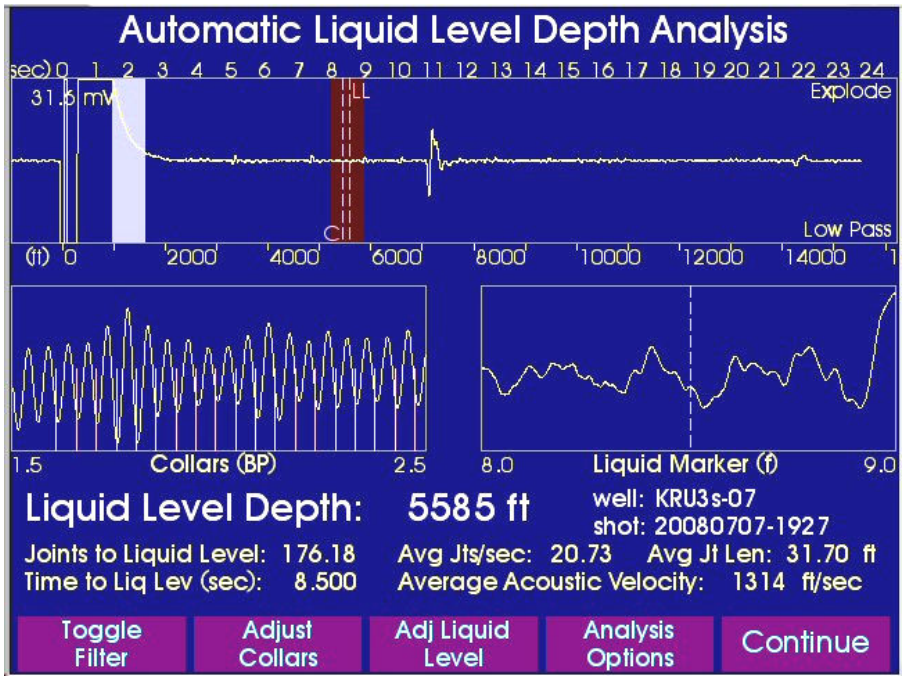

The screen that is presented next, depends on the analysis method that was used when the shot was last **SAVED** into the data base. In this example we know that when the shot was acquired and was saved it had been analyzed by the ***Automatic Analysis Method*** by the operator, thus upon recalling the shot the following screen is displayed:



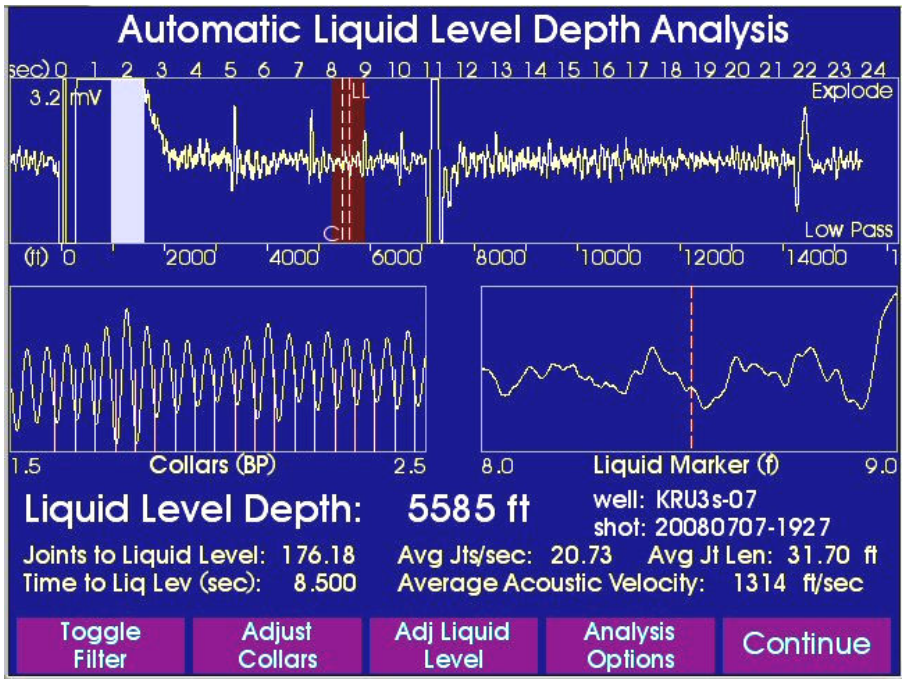

This particular acoustic record was acquired in a gas lift well while gas was flowing into the casing. This caused the high frequency noise that is observed throughout the record and that obscures the echoes from the liquid

level and gas lift mandrels. The noise also interferes with the automatic identification of the liquid level echo as discussed later.

The ***Toggle Filter*** option allows digital filtering of the record with a ***Low Pass*** filter to eliminate the noise as shown in the following figure:

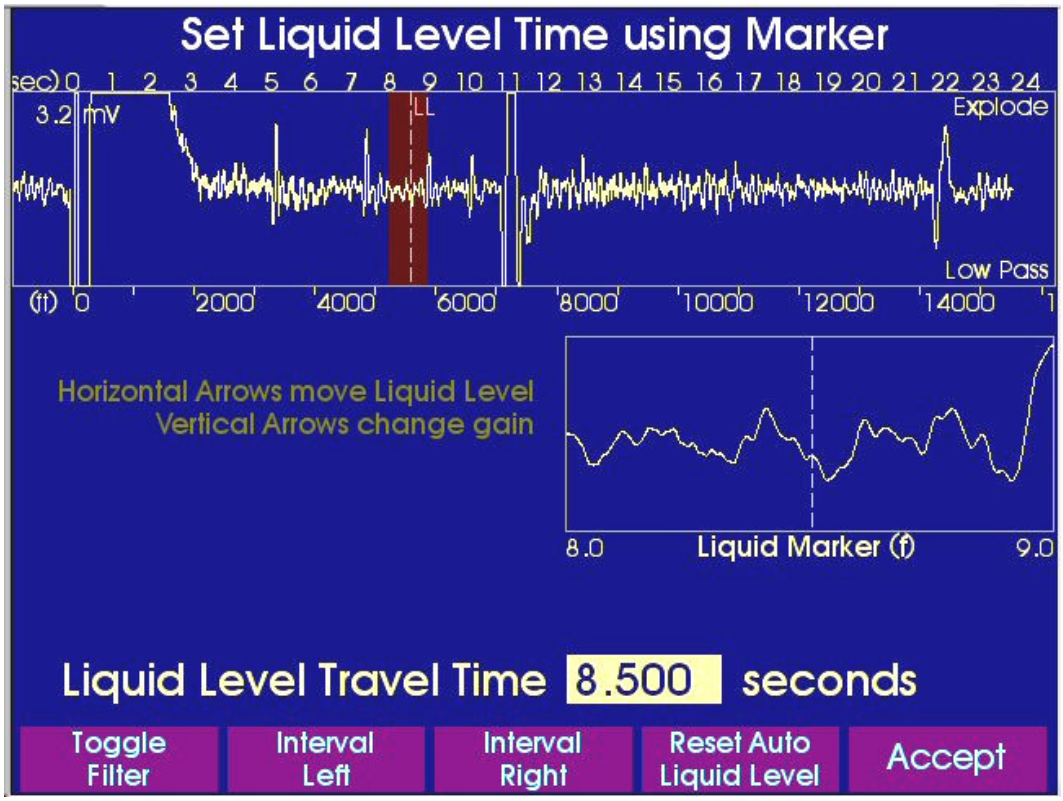



After filtering, the vertical scale ( now set at 31.6 mV) should be readjusted using the ***Up/Down*** arrow keys to better observe the details of the record as shown in the following figure where the vertical scale is set at 3.2 mV:



Visible in the acoustic record previously displayed are several distinct echoes that precede the large echo that is the most likely echo from the liquid level. These are the echoes from the gas lift mandrels.

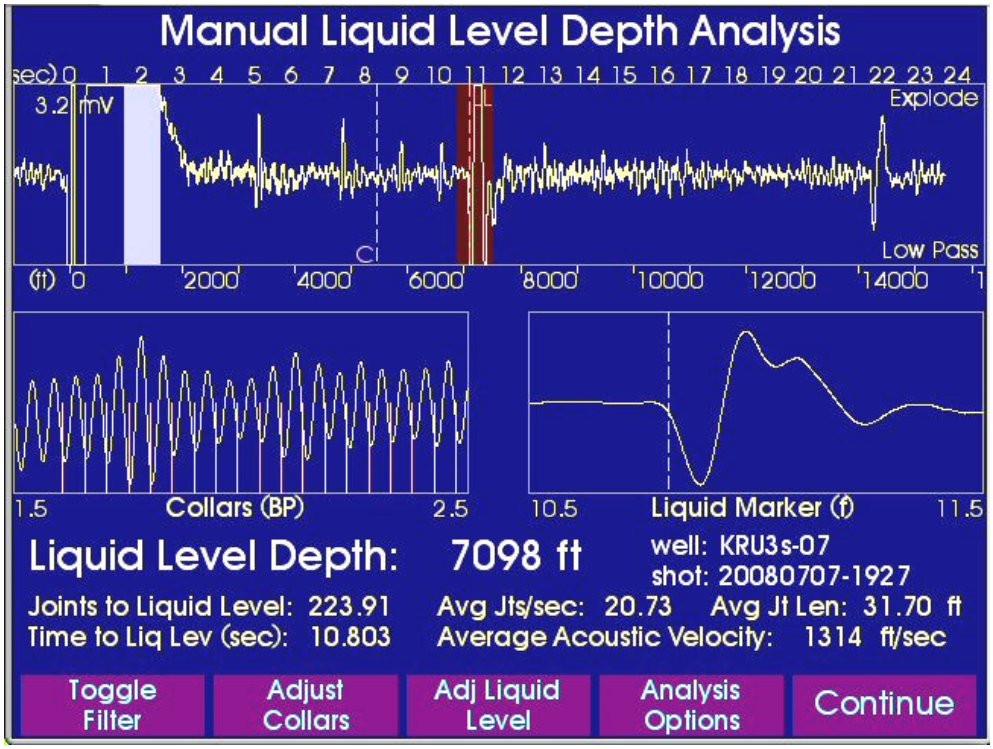
In this example note that the software is not flagging the liquid level echo correctly with the vertical dashed marker (**LL**) locating it to some feature at 8.500 seconds. This is probably due to interference from the high frequency noise. So it is also necessary for the user to adjust the liquid level marker by selecting the ***Adjust Liquid Level*** option that displays the following screen:




Using the ***Interval Right*** button and the ***Left/Right*** arrow keys the liquid level marker is repositioned at the first break of the liquid level echo (at 10.803 seconds) and then the ***Accept*** button is used to return to the manual fluid level analysis screen.

It is important to note that when using the Toggle Filter feature, the **Liquid Level Marker must be picked using the Unfiltered/Raw data NOT the Low Pass filtered data**. Manipulating the Liquid Level while the Low Pass filter is on will position the Liquid Level Marker incorrectly. This will be apparent if the Liquid Level Marker is chosen and the Low Pass filter is turned off. Similarly, once the Liquid Level has been selected in the Unfiltered/Raw shot trace, Toggling the filter to Low Pass may make it seem as though the Liquid Level has been incorrectly chosen. Do not readjust the Liquid Level marker when the Low Pass filter is turned on.

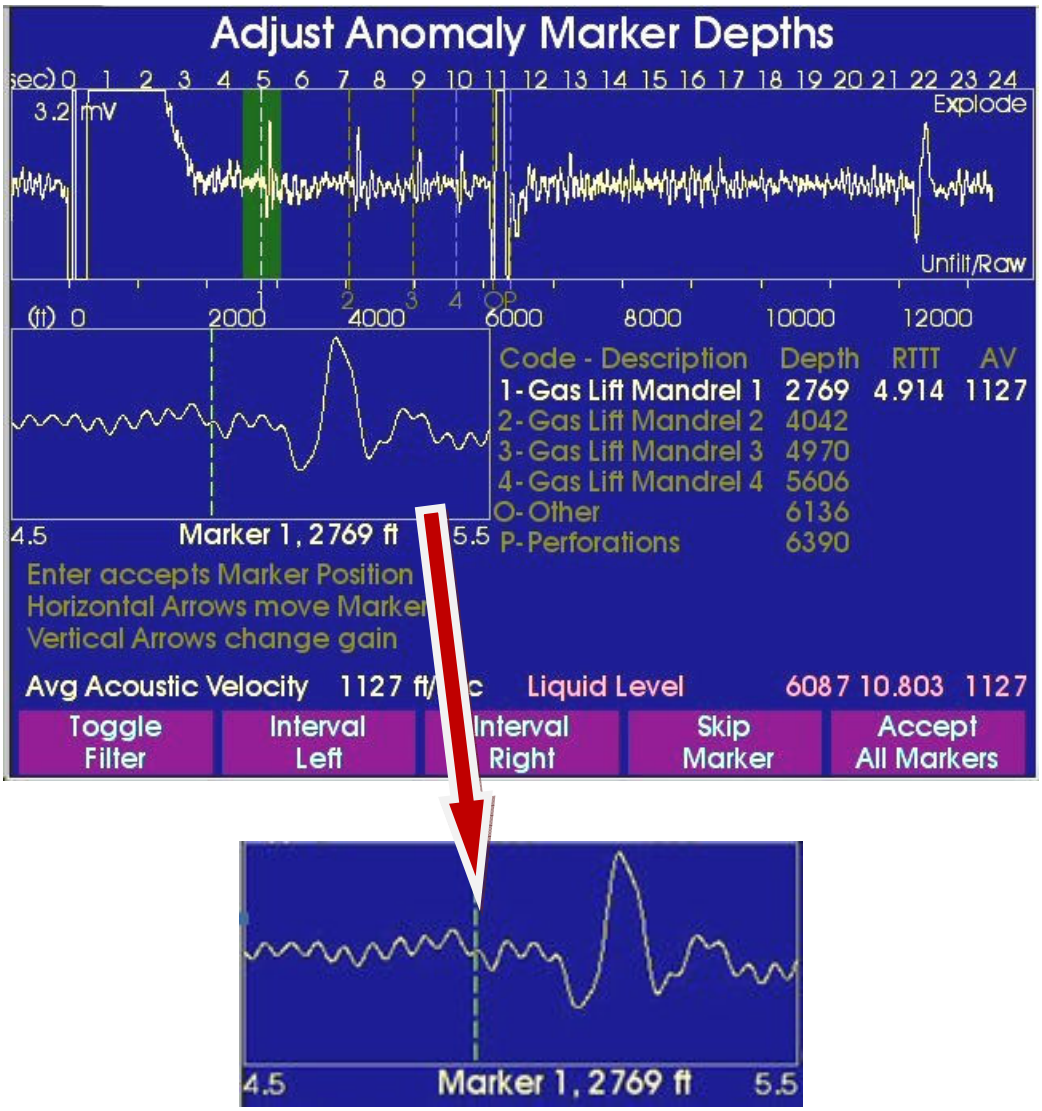
Once the Liquid Level has been selected, the Manual Liquid Level Depth Analysis screen is displayed:




Note that the collar count dashed marker labeled "**C**" indicates that the collar count stops about 3 seconds before the liquid level echo instead of continuing to near the liquid level. This means that the indicated number of joints to the liquid level (223.91) may not be as accurate as if the collar count had continued to a time closer to the liquid level echo. Also, the displayed liquid level depth of **7098** feet is computed using the **Average Jt Length** that was entered in the well description screen and in this case the value of 31.7 is the default value and does not necessarily represent the actual average joint length for this well. The conclusion is that the indicated liquid level depth of 7098 feet is not as accurate as we normally expect.

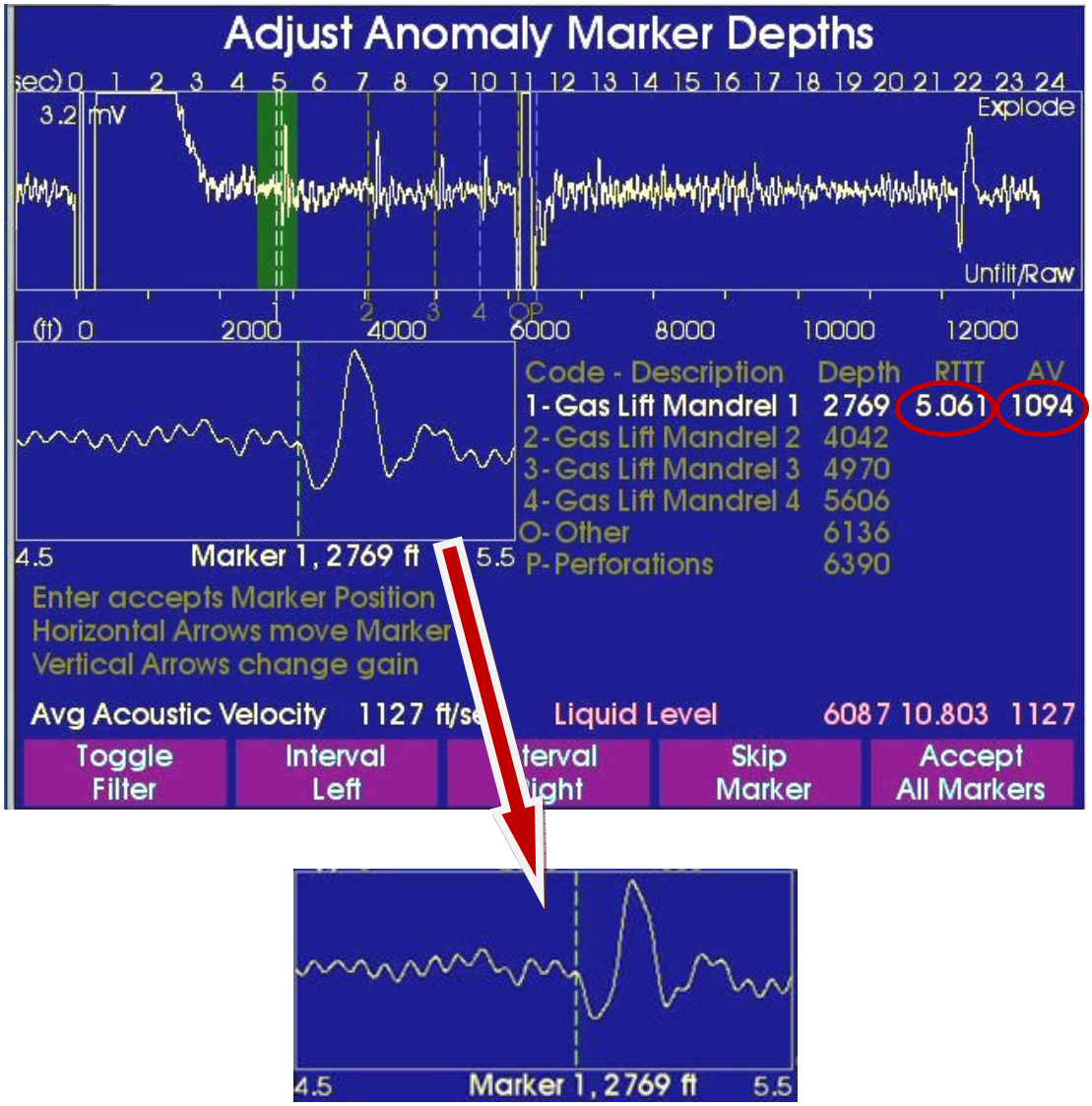
Since the user now recognizes the echoes from the mandrels and has entered the depths to all the known downhole anomalies, he can improve the accuracy of the calculated liquid level depth by pressing the ***Analysis Options*** button and then the ***Anomaly Markers*** button which displays the following screen as discussed in the previous section:

## Adjust Anomaly Marker Depths Procedure




The user manually adjusts the first marker position using the ***Left/Right*** arrows to fine tune the movement. The ***Interval Left*** and ***Interval Right*** feature softkeys will move the highlighted left and right along the shot trace in .5 second intervals.

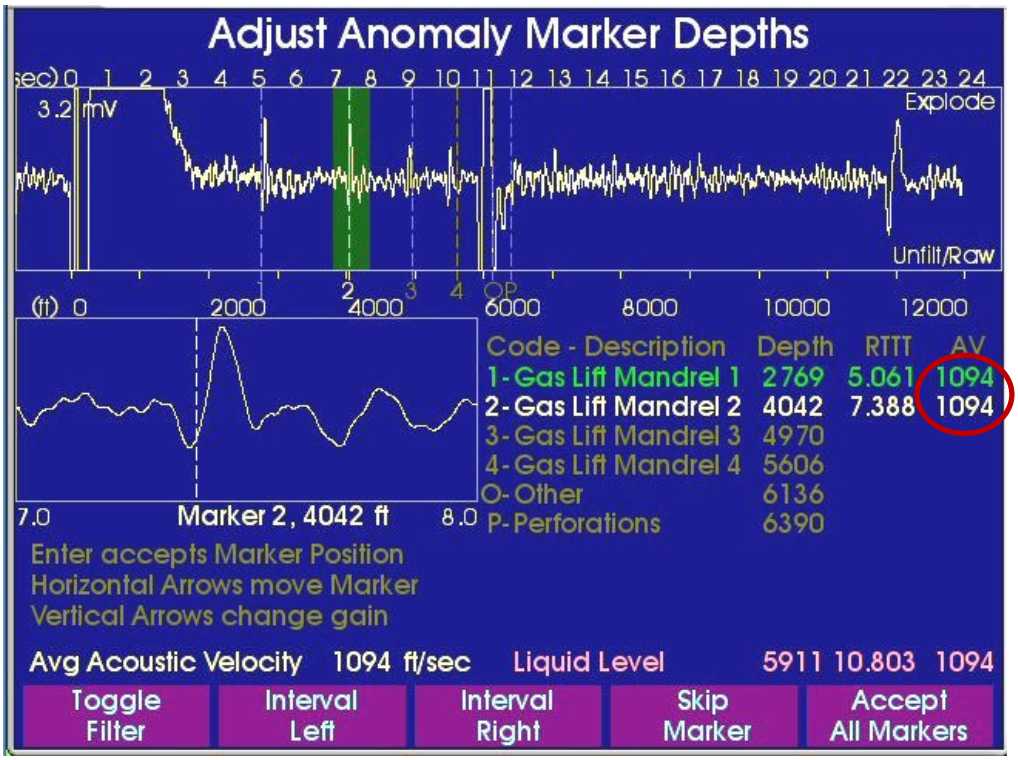
The marker is manually adjusted by the user until it is aligned with the first break of the echo at a time of 5.061 seconds as shown in the following figure:



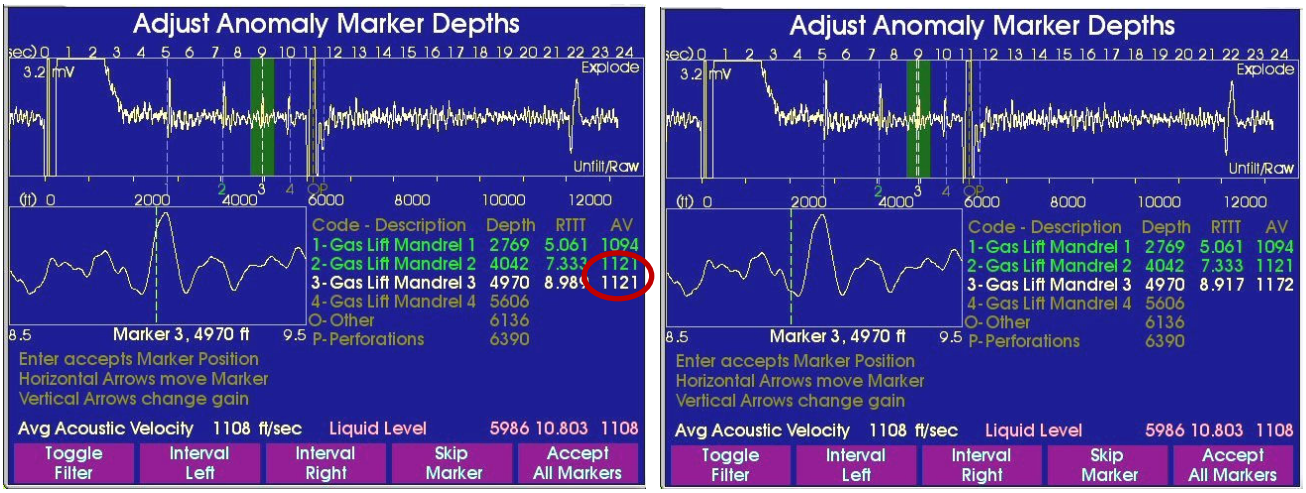

Pressing the ***Enter*** key accepts the location of the marker on the first anomaly and proceeds to the next anomaly marker listed. Automatically, the program displays the dashed marker in the vicinity of the location of the second anomaly echo which is now highlight in green.

The ***Skip Marker*** button is used to pass over any downhole anomaly listed in the table but that is presently below the liquid level or that does not generate a clear echo signal, such as plugged perforations. Any changes made must be saved using the ***Enter*** key. ***Skip Marker*** will ***ignore*** any changes made and proceed to the next marker. If a marker is accidentally skipped, the operator must press the ***Skip Marker*** key through each selected marker until the highlighted selection comes back around to the marker in question.

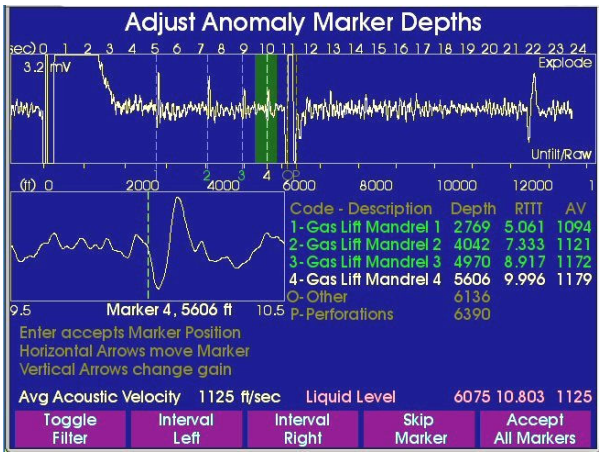
Note that the Acoustic Velocity (**AV**) is now recomputed based on the new Round Trip Travel Time (**RTTT**) of 5.061 seconds yielding a value of 1094 feet per seconds for the average **AV** between the wellhead and the first gas lift mandrel.

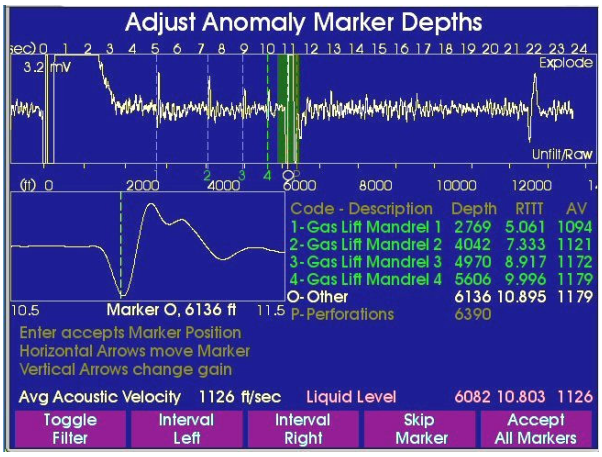



Adjustment is again made using the **left arrow** key until the marker is positioned at the first break and the ***Enter*** key is pressed to accept the new location. The procedure is repeated for the echoes from the deeper anomalies until all have been processed.



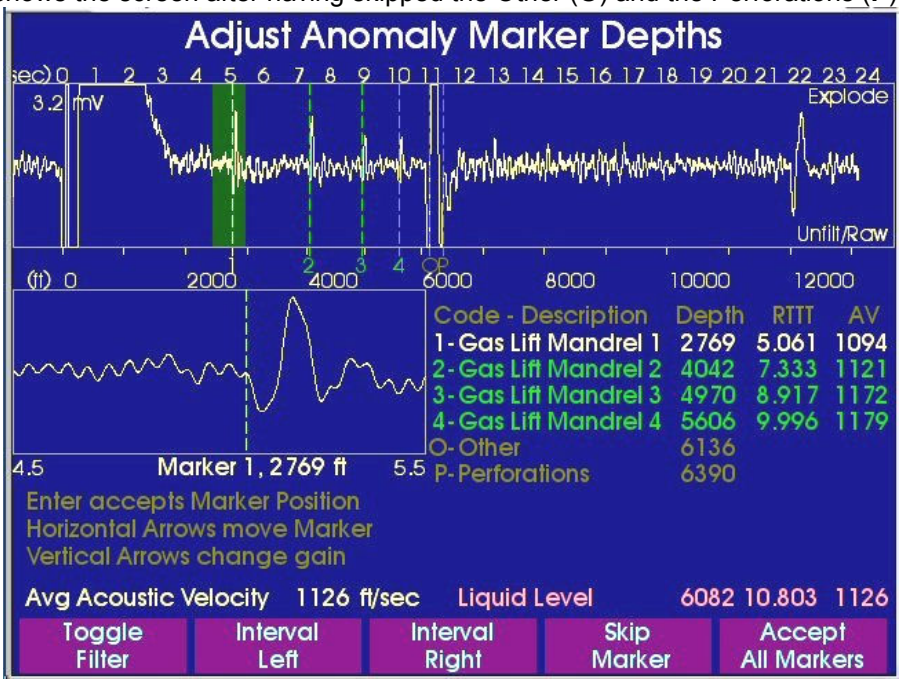

The newly calculated Acoustic Velocity for each line populates the ***AV*** field of the marker following the manually adjusted marker until that next marker has also been positioned and the ***Enter*** key has been pressed, saving the marker's position and moving to the next marker.



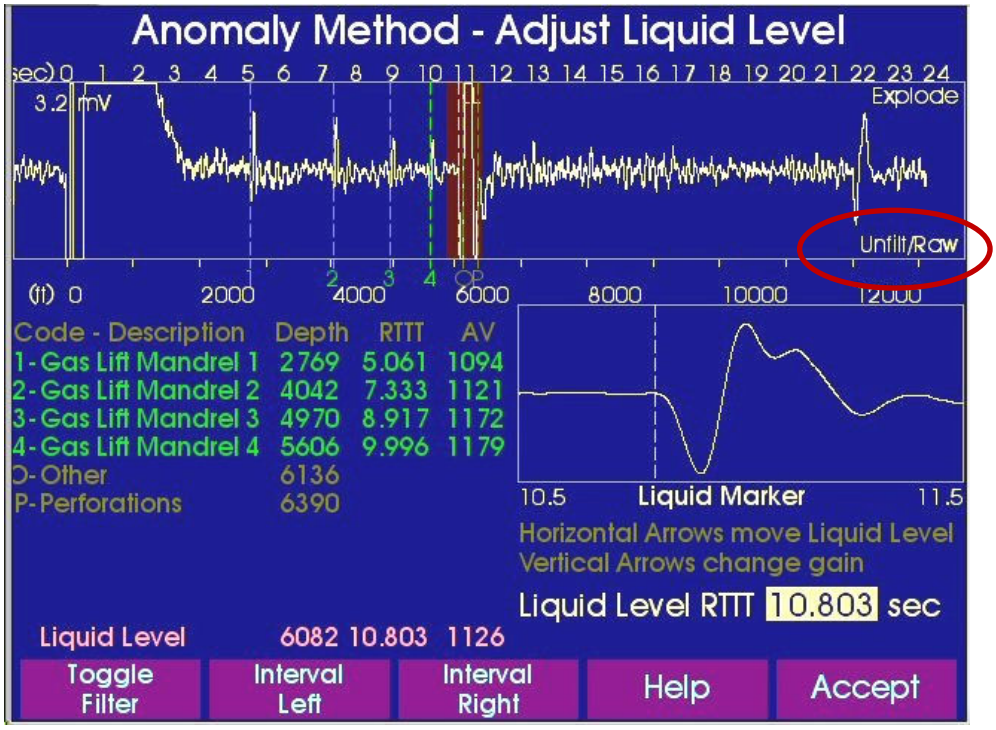

In the previous figures a total of four markers were identified that correspond to the top four gaslift mandrels. The ***Skip Marker*** button is used to pass over any downhole anomaly listed in the table but that is presently below the liquid level or that does not generate a clear echo signal, such as plugged perforations.

The figure below shows the screen after having skipped the Other (**O**) and the Perforations (**P**) markers.



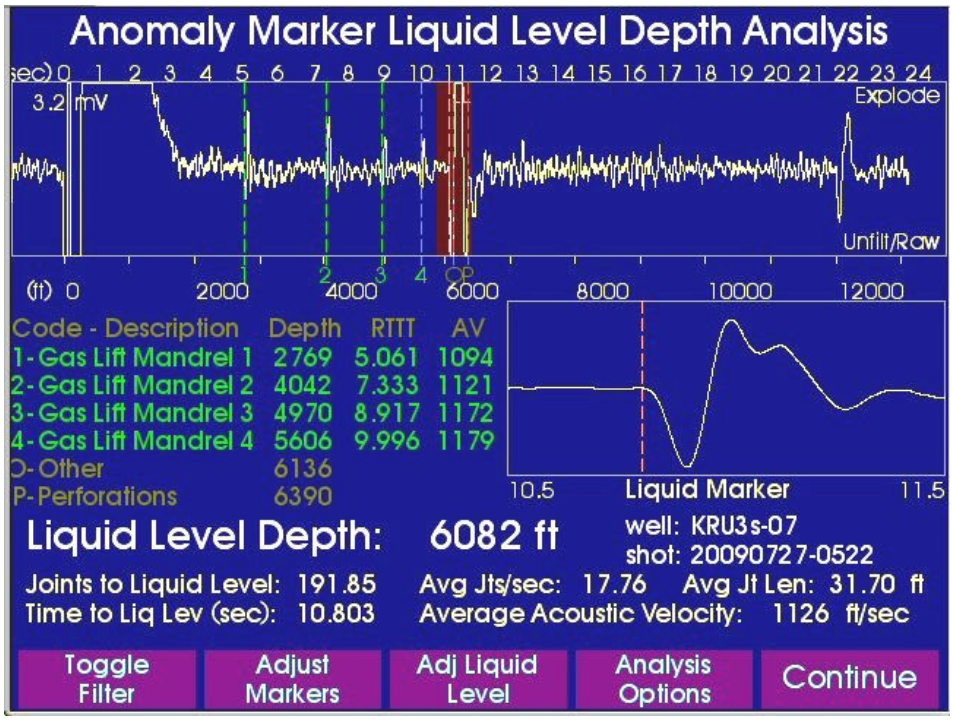

Pressing the button ***Accept All Markers***, finalizes the analysis and displays the following screen that allows adjusting, if necessary, of the marker corresponding to the liquid level echo:

## Anomaly Method – Adjust Liquid Level




The Liquid Level should be adjusted using the Unfiltered/Raw data NOT the Low Pass filtered data.

Pressing the ***Accept*** button displays the final Liquid Level Depth Analysis for the Anomaly Marker option:



The following table compares the result from the anomaly marker analysis with the initial analysis that was performed using the ***Automatic Analysis*** option:

| Variable | Automatic Liquid Level Depth Method | Anomaly Marker Liquid Level Depth Analysis |
|---|---|---|
| Liquid Level depth | 7098 | 6082 |
| Joints to Liquid Level | 223.91 | 191.85 |
| Average jts/sec | 20.73 | 17.76 |
| Average jt length (ft) | 31.70 | 31.70 |
| Time to Liquid, sec | 10.803 | 10.803 |
| Average Acoustic Velocity ft/sec | 1314 | 1126 |

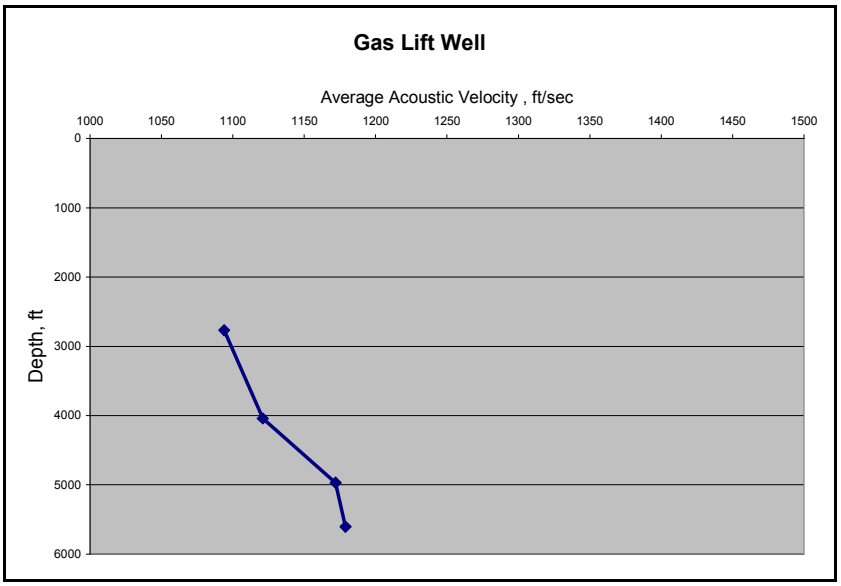
In this example there is a very large difference in the resulting number of joints to the liquid level, the liquid level depth, the average acoustic velocity and number of joints per second.

Assuming that the depths to the downhole markers were entered correctly in the well data, then the Anomaly Marker Analysis yields the most accurate calculation of the distance to the liquid level and shows that this new method is a major improvement over the existing automatic method for processing fluid level depth, and should always be used when echoes from downhole anomalies are visible in the acoustic trace.

Pressing the ***Continue*** button, the user is given the option of saving the acoustic record analysis or of discarding the changes.

## Acoustic Velocity Variation in Wellbore

Having computed the acoustic velocity for each interval between the markers, it is possible to graph the variation of velocity with depth as shown in the following plot:

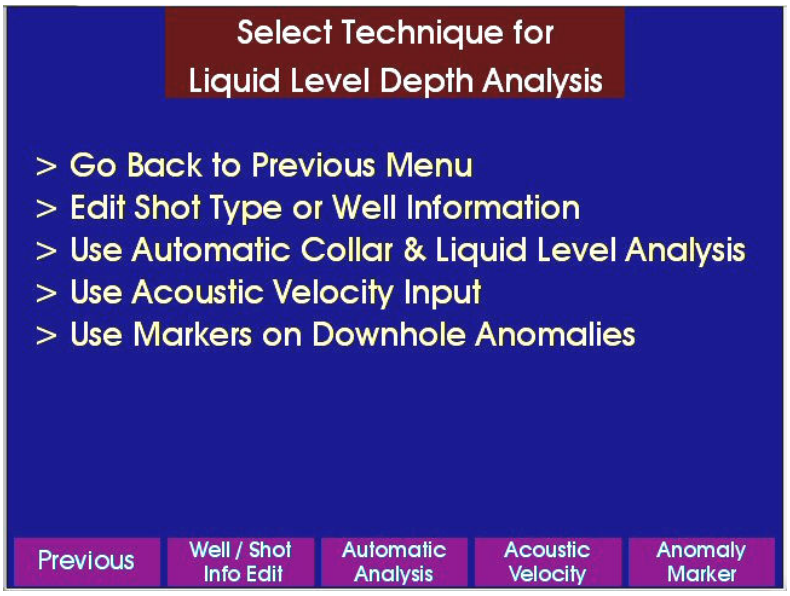



The graph shows that in this wellbore there is about 10% variation of acoustic velocity as a function of depth.

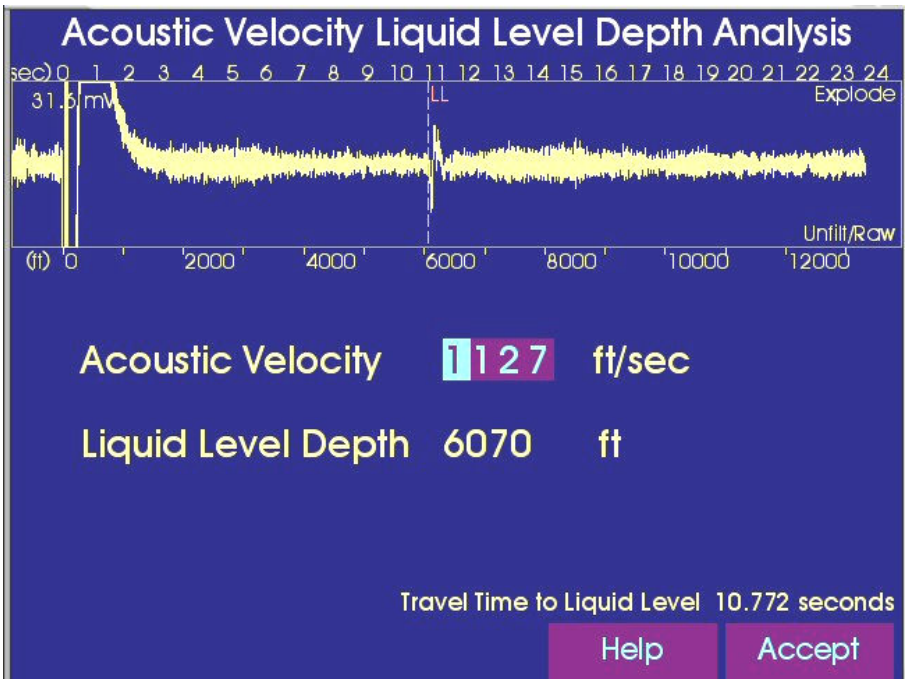
## Acoustic Velocity Input Analysis

The conversion from round trip travel time to distance to the liquid in wellbores where there are no tubing collars or other changes in cross sectional area, it is necessary for the user to input a value of the acoustic velocity.

After acquiring or recalling an acoustic record and after displaying the record on the screen, pressing the ***Analysis Options*** button opens the following menu:



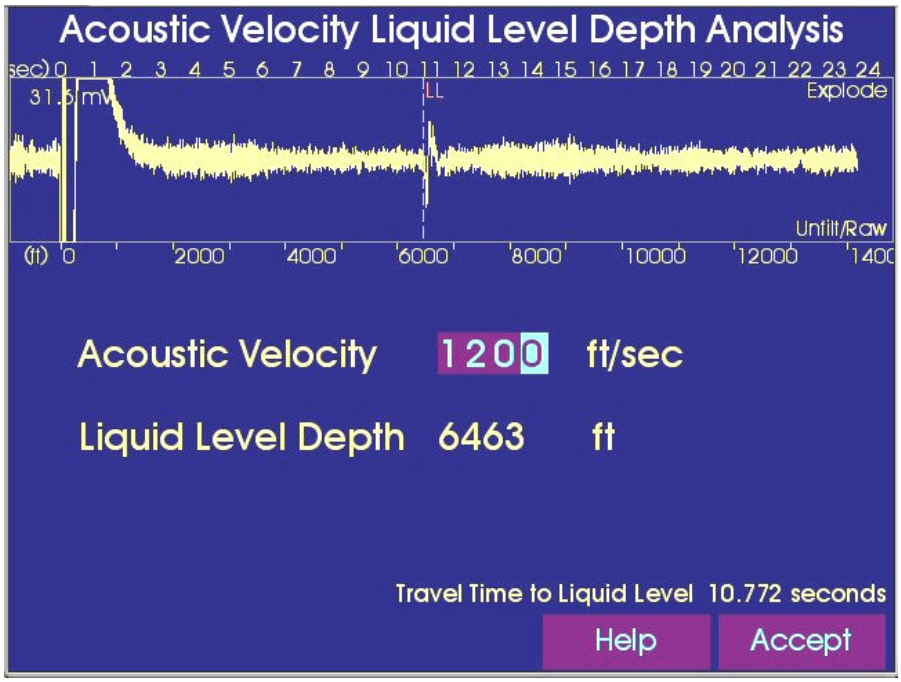
By pressing the ***Acousic Velocity*** button the liquid level depth analyis is performed using the default acoustic velocity, as shown in the following figure:



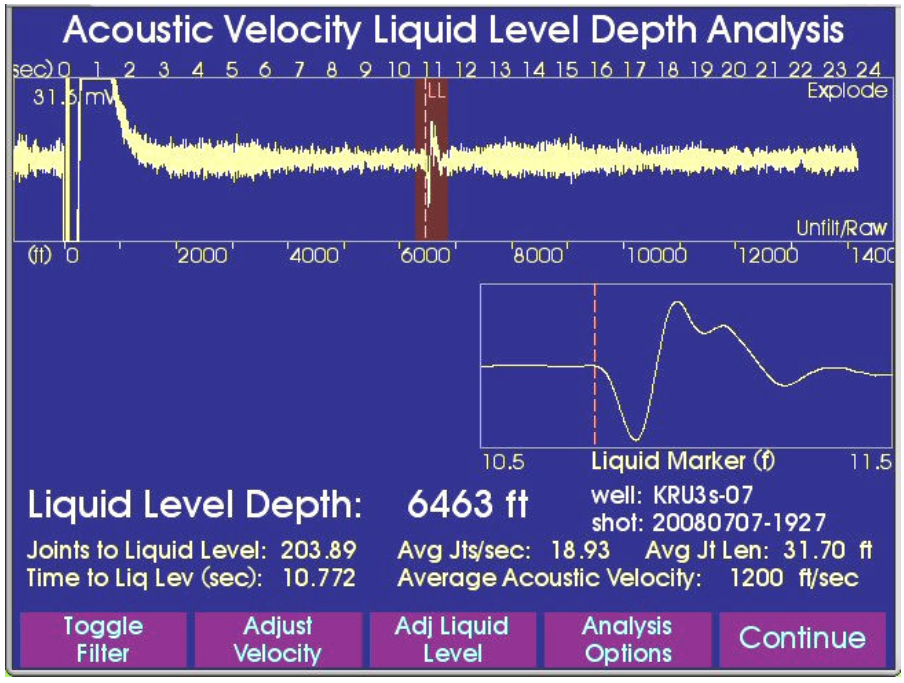

The acoustic velocity that is displayed is either the default value that is currently present in the setup screen or the default value for this specific well.

Note that the first digit is highlighted and can be changed by the user with the ***Up/Down*** arrows. The ***Left/Right*** arrows move left and right between the character fields.

The following screen shows that the user has entered a new acoustic velocity value of **1200 ft/sec.**




Pressing the ***Accept*** button shows the final liquid level analyis:




Pressing the ***Continue*** button gives the options of either saving or discarding the analyis.

## *Managing Well Data and Information*

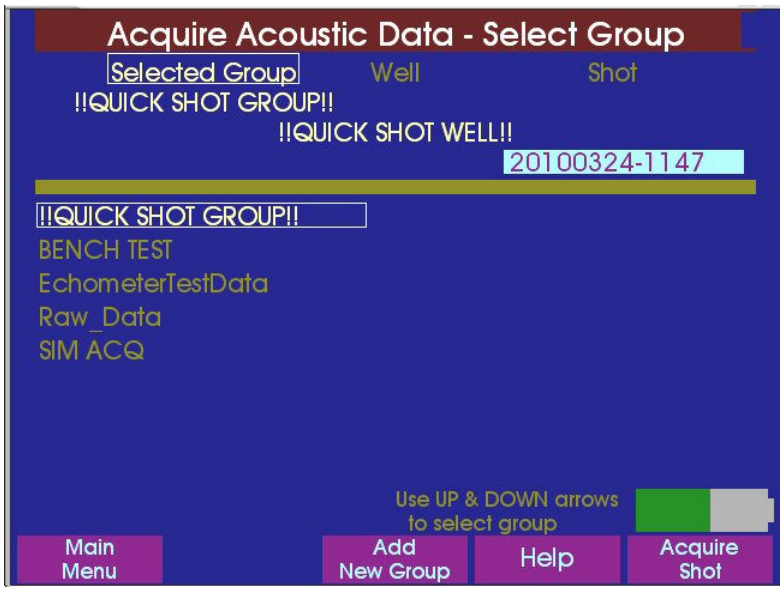
Acoustic records and well information are stored in the memory of the Echometer Model H in a data base organized into **Groups** that contain **Wells** that contain **Shots**. The user navigates through the data base using the 5 button star keypad after having selected either **Acquire** or **Recall** acoustic Data in the **Main** screen.

The following section illustrates how to enter new groups and well data using the stand alone instrument.

### Entering New Group of Wells

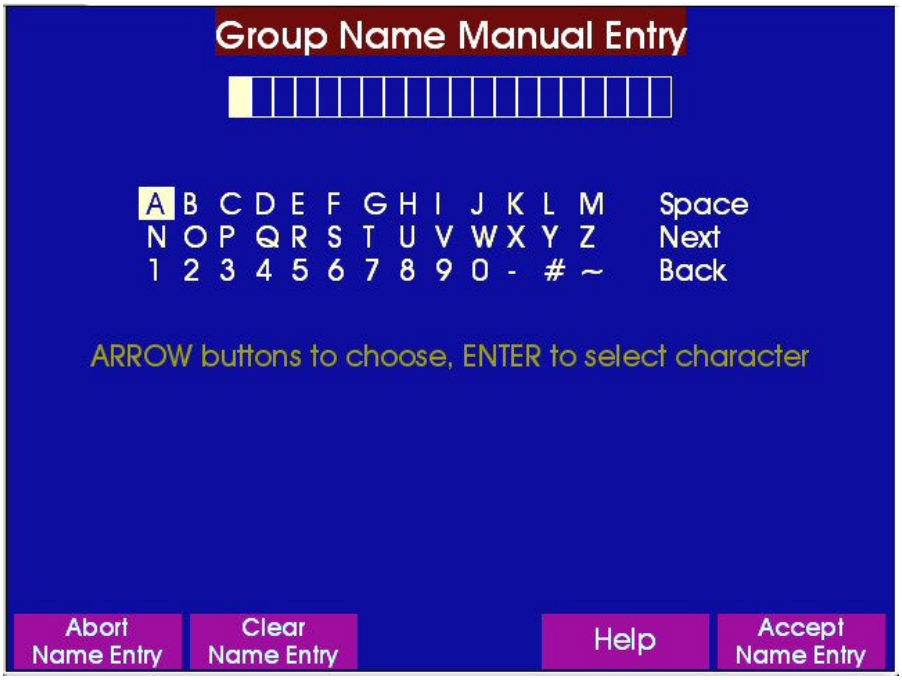
The user should decide how to organize the wells into some logical number of groups although it is possible to assign all the wells to a single group.

The name of a group may consist of up to 20 characters and include letters, numbers and spaces. The following figure illustrates various group names as they appear on the screen after selecting the option "**Acquire Data**" from the **Main** screen:

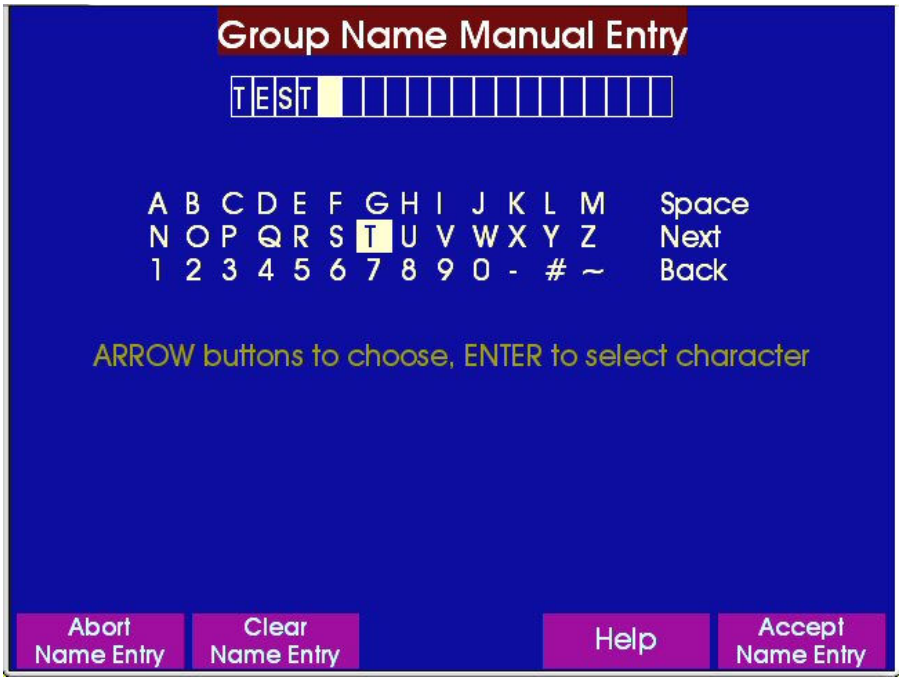



To create a new group of wells, press the button on the instrument panel below the label "**Add New Group**". The following screen is displayed for the user to enter the name of the new group by selecting individual characters via the 5-button Star keypad.

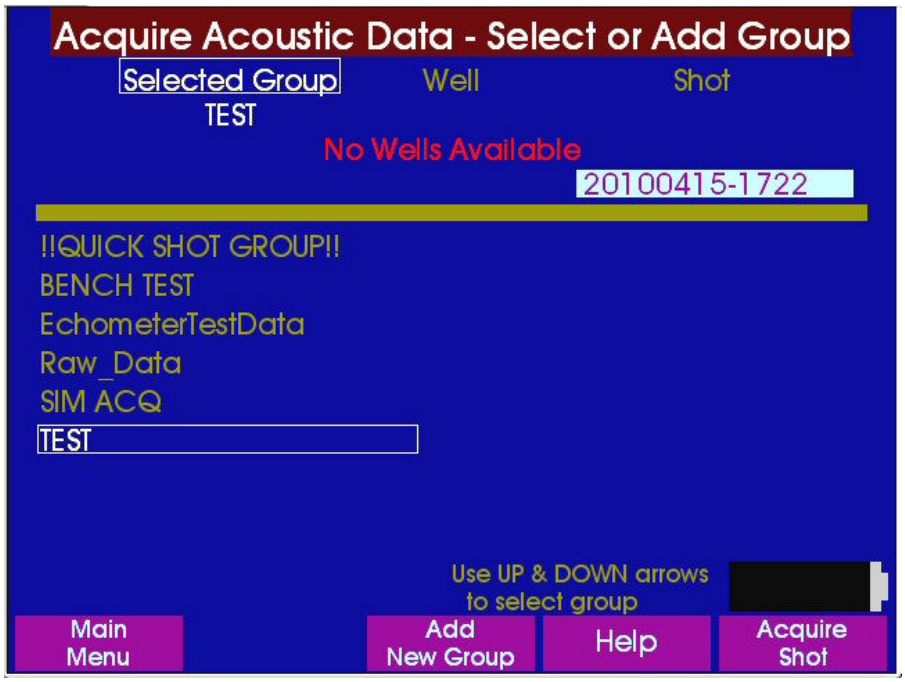
*Group Name Manual Entry*




The letters and numbers in the table are selected using the **Left/Right/Up/Down** arrow buttons. Pressing the **"Enter"** key moves the character into the name field and highlights the next place.

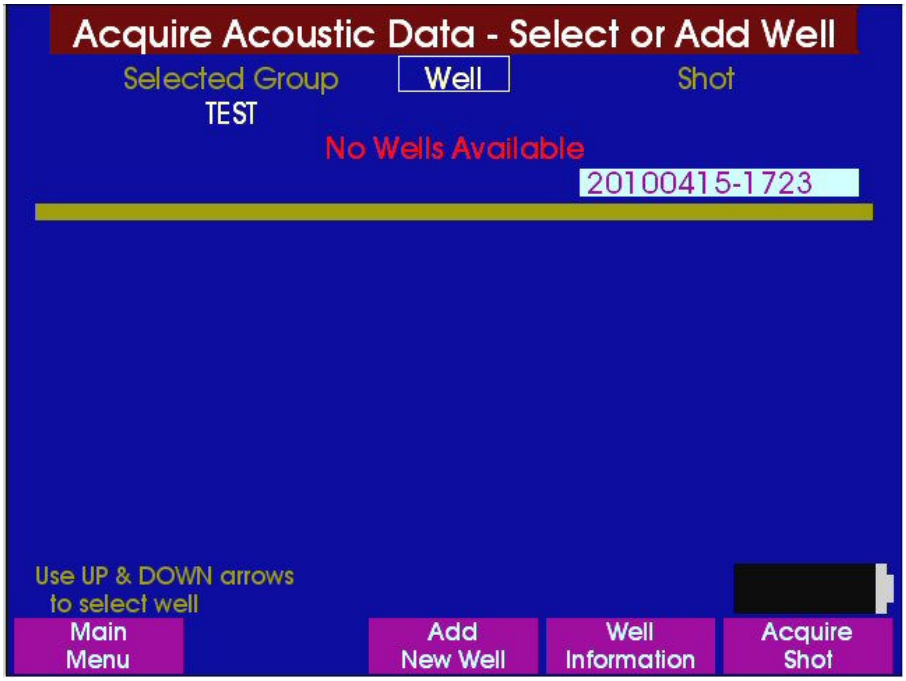



Once the full name has been entered, press the button under the label **"Accept Name Entry".** The screen with the list of all the existing groups will be displayed as shown below:



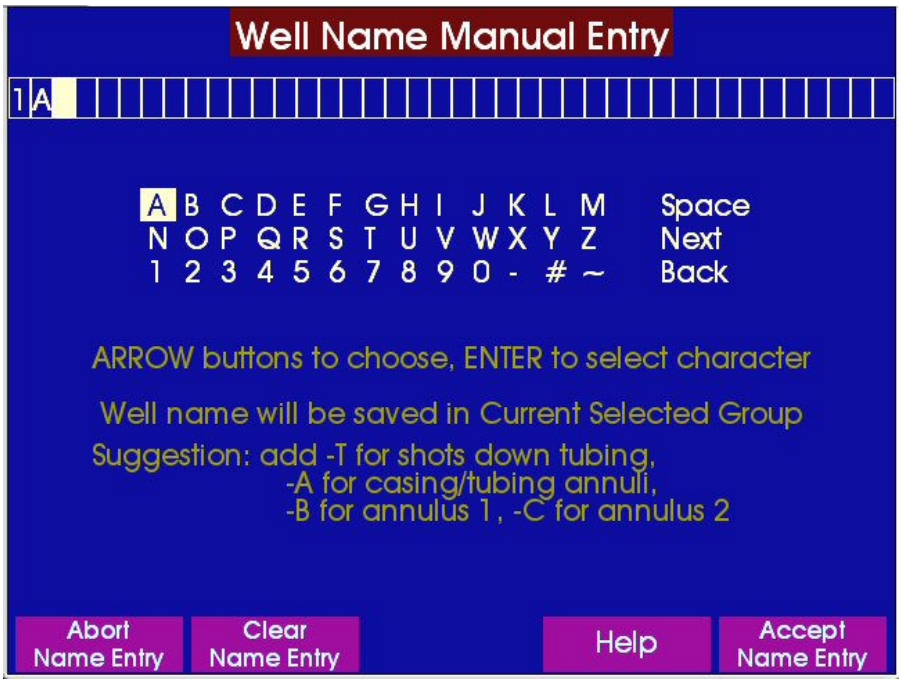

If necessary use the **Up/Down** arrow of the 5-star keypad to scroll to the newly created group as shown in the next figure:

The screen also indicates that NO Wells have been entered in the new group. Therefore the next step is to enter well names and their corresponding information.
The **Right Arrow** key is pressed to select the **"Well"** screen as shown in the next figure to display the **Well list** (that is empty at this point in the procedure). The next step is to start entering well names.



Press the button under the label **"Enter New Well"** and then use the 5 button star key to select and enter the characters of the well name. Wells will be organized alphabetically in the list that is being created. Well names may consist of letters, numbers and spaces up to 40 characters.

## Well Name Manual Entry



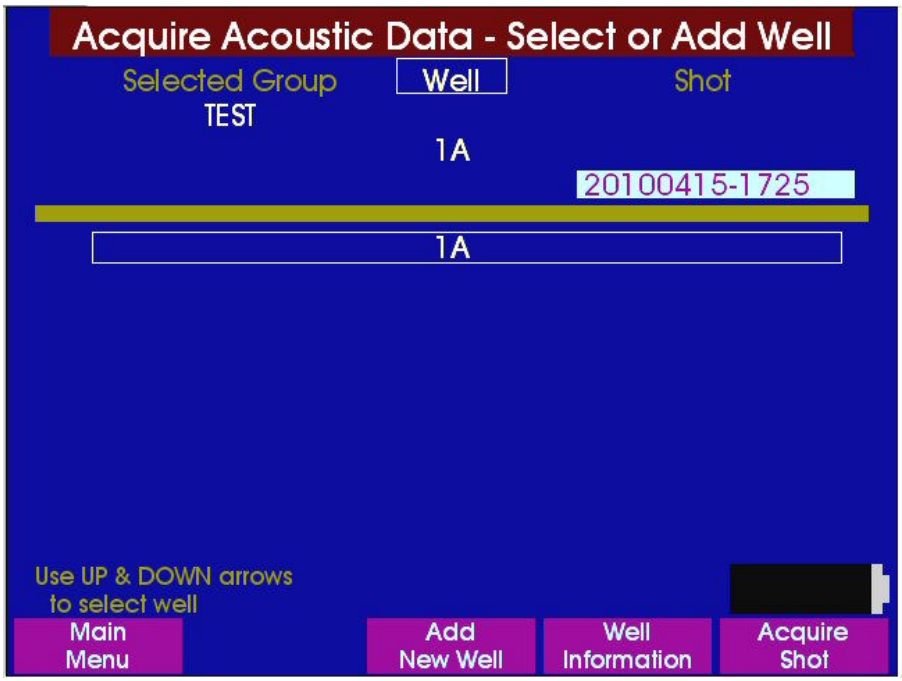

In wells where acoustic records may be taken in various tubulars or annuli it is suggested to add an extra character at the end of the name to identify the acoustic path.

Follows an example using the well name 1A:

| | |
|---|---|
| Shooting down tubing string: add a "T" | such as 1A-T |
| Shooting down casing/tubing annulus: add "A" | such as 1A-A |
| Shooting down production casing/intermediate casing annulus: add "B" | such as 1A-B |
| Shooting down surface casing/production casing annulus: add "C" | such as 1A-C |

Other methods may be used to identify the path of the acoustic record.

Once the full name has been entered pressing the button under the **"Accept Name Entry"** adds the Well to the list in the previously selected group.

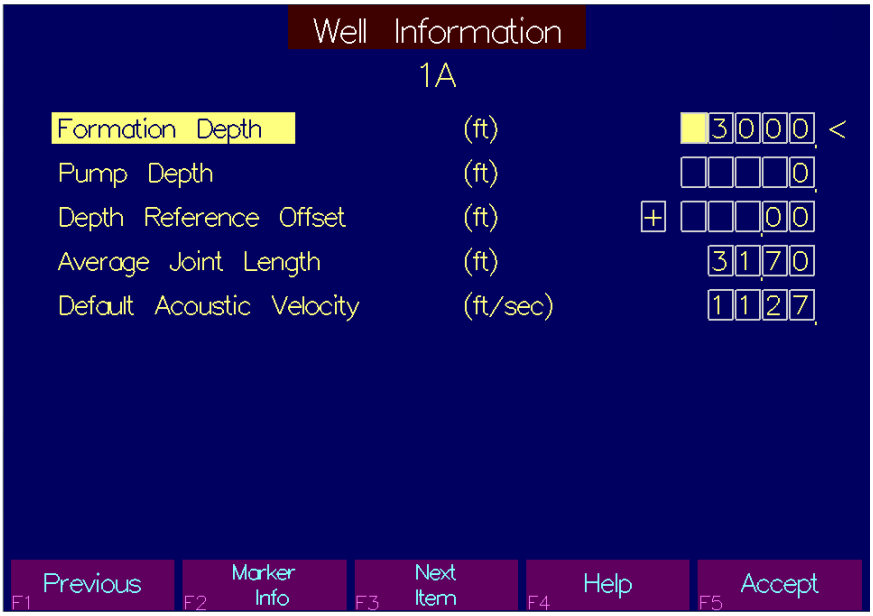



Wells are listed alphabetically.

Note that under the ”**Shot**” heading at the top of the figure is displayed the “date-time” name (20100415-1725) that would be used by the software to identify the next acoustic record for this well if the user were to press the button under the label “**Acquire Shot**”. In such case, since the user has not entered any well information, the software would use the “default” values of **Average Joint Length** and **Acoustic Velocity** to complete the liquid level calculations.

It is recommended that the values of these parameters for the well be entered in the data base, at this time, by pressing the button below the label **“Well Information”.**

*Well Information*




Select the Item to be updated by pressing the **Next Item** button.
Use the **Up/Down** arrows to increment or decrement the number in the space that is highlighted.
Move from character to character using the **Left/Right** arrows.

Press the button under the **"Next Item"** label when the edited quantity is correct.

The **Well Information** screen will be displayed with the updated information as shown above. If the well has wellbore anomalies the Marker Info button will open the screen for input of the corresponding depths as previously shown in the **Anomaly Marker Analysis** section. Press the button below the **Accept** label to return to the **Acquire Acoustic Data** screen.

## *Wellhead Attachments*

When operating the Echometer Model H instrument in a hazardous area the wellhead attachments must be certified intrinsically safe and approved for use in the classified area.

### Compact Gas Gun

The Compact Gas Gun consists of a microphone and a ten cubic inch volume chamber with a ¼" 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 (explosion) pulse is generated. If the pressure is greater in the casing annulus than in the volume chamber, a rarefaction (implosion) pulse is created. 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.

**Compression (Explosion) Pulse**

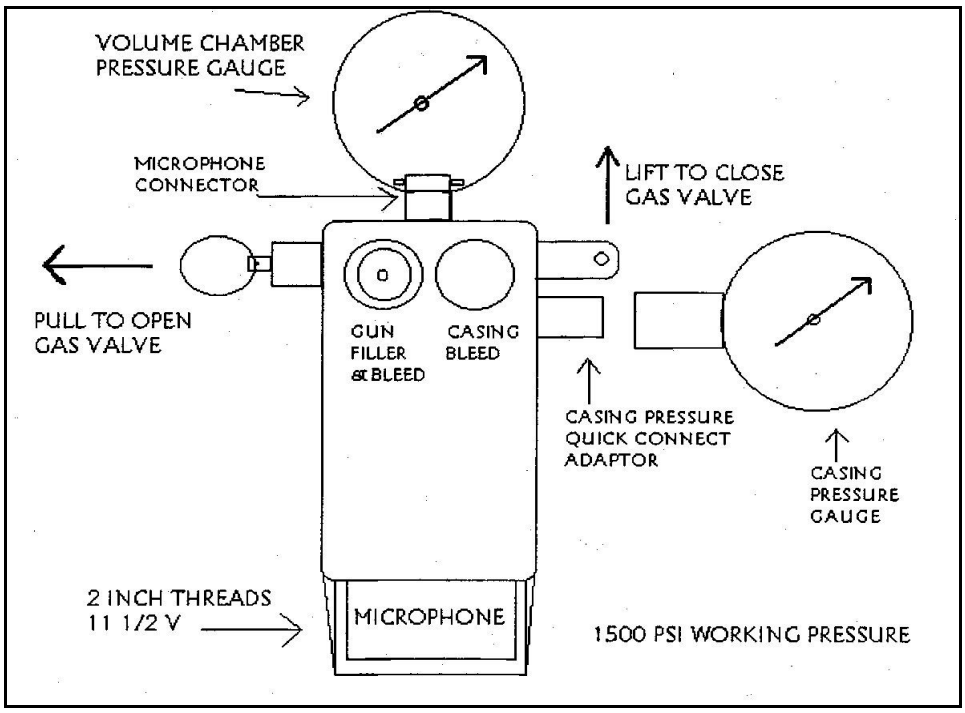
Explosion utilizes an external gas supply to generate an acoustic pulse in the well. In the explosion mode, the volume chamber is charged from an external gas supply to a pressure in excess of the well pressure. Operating in the explosion mode keeps the inside of the chamber cleaner and results in less maintenance.

**Rarefaction (Implosion) Pulse**

If the well's casing pressure is greater than 200 PSI, implosion can be used. This method uses the well's pressure to generate a pulse. Use the 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. Operation in this mode forces sand, moisture and other debris into the gas gun volume chamber and thus requires more maintenance including frequent replacement of "O" rings.

### Description of Compact Gas Gun Control Functions

The following drawing is a schematic diagram of the Compact Gas Gun



Volume Chamber Pressure Gauge
The volume chamber pressure gauge measures the pressure in the gas gun volume chamber. During normal operation, the volume chamber is charged to 100-psi more than the casing pressure. Use additional pressure if required for satisfactory results. If the internal gas valve is open, the gauge indicates the pressure between the gas gun and the casing annulus valve. If the casing annulus valve is open, the gauge indicates the casing pressure.

Casing (or Tubing) Pressure Gauge Quick Connector
The quick connector is located on the side of the housing. A precision pressure gage having a range close to the pressure being measured will fit into the quick connector to enable the operator to obtain the casing pressure and casing pressure change with sufficient accuracy to perform calculations of producing BHP and casing gas flow rate.

Cocking Arm
The cocking arm is lifted to depress and close the valve between the gas chamber and the casing.

Casing (or Tubing) Pressure Bleed Valve
This valve allows bleeding the pressure between the casing valve and the compact gas gun. Turn the knob counter clockwise to release the pressure. Verify that the casing valve is closed before opening the bleed valve.

Gun Filler-Bleed Valve
The filler-bleed valve is used to pressurize the gas gun volume chamber or to remove gas from the gas gun volume chamber. Gas is added to the chamber from a pressurized external gas source by insertion of mating quick connector, into the filler & bleed valve. Gas is bled from the chamber by rotating the knob clockwise. This action depresses the internal valve core and releases the gas from the volume chamber to the atmosphere.

Trigger Pawl
The Trigger Pawl is pulled to release the gas valve between the gas gun volume chamber and the casing. If sufficient pressure exists in the volume chamber or on the end of the gas valve, the gas valve will open.

Microphone
The microphone is a twin-disc pressure sensitive device that is vibration canceling.

## High Pressure Gas Guns

The 5000-psi gas gun is normally used in the implosion mode. It has an excellent noise-canceling microphone and generates a very good pulse when the $^1/_2$-inch ball valve is opened rapidly and the well pressure exceeds 200-psi. When the 5000-psi gas gun becomes dirty due to debris imploding from the wellbore, the volume chamber and the microphone assembly can be easily flushed with a solvent. The 5000-psi gas gun requires very little maintenance. It is excellent for gas lift, flowing and high-pressure shut-in wells. It can be used in the explosion mode by charging the gas gun volume chamber to a pressure in excess of the well pressure.

The 15000-psi High Pressure Gas Gun operates in the implosion mode only. Excellent results have been obtained at pressures above 1500-psi through needle valves with 1/8-inch orifices, which are standard in most high-pressure wells.

For more details please refer to the Gun-Microphone Assemblies brochure in the appendix.

Accessories

Battery Charger (110 V/220 V- AC)

Casing Pressure Gauges

- Precision Test Gauge
- Precision Digital Gauge

Gas Cylinders

- 2-1/2 LB $CO_2$
- 5 LB $CO_2$
- Nitrogen Cylinder

# *Principles of Acoustic Measurements*

Acoustic liquid level instruments were developed in the 1930's. An acoustic wellhead attachment is connected to an opening in the casing annulus at the surface of a well as shown in Figure 1. The acoustic wellhead attachment consists of an acoustic pulse generator, a microphone and optionally a pressure gauge. Throughout the years, acoustic pulse generators have included a dynamite cap, 45-caliber blank, 10 gauge black powder blank, a compression gas pulse and a rarefaction gas pulse. The explosive dynamite caps and blanks are a safety hazard and have resulted in damage to wells and to the environment. While these explosive sources should not create a problem if the casing annulus contains only hydrocarbon gas, major explosions have occurred when oxygen was allowed to enter the casing annulus during work-overs or when special conditions resulted in a vacuum in the casing annulus.

The versatility, economy and convenience of gas guns have resulted in widespread use of this type of acoustic pulse generator. The expansion of gas from a volume chamber into the well generates the acoustic pulse. In most cases, compressed $CO_2$ or $N_2$ gas is loaded into the volume chamber, which is charged to a pressure greater than the well pressure. A valve in the wellhead attachment is opened rapidly, either manually or through an actuator, resulting in a pressure pulse being generated in the casing annulus gas. The acoustic pulse travels through the gas in the casing annulus and is partially reflected by changes in cross sectional area such as tubing collars, tubing anchors, casing perforations, etc. The remaining pulse energy is then reflected by the gas/liquid interface at the depth of the liquid level. The reflected signals travel back to the surface of the well where they are detected by the microphone.

The microphone within the wellhead attachment converts the reflected acoustic signal into an electrical signal consisting of a series of pulses, which correspond to the sequence of reflections. The microphone must operate over a wide pressure range from a vacuum to the maximum pressure that exists in the wells being tested. The microphone should be designed to cancel the mechanical vibrations of the wellhead while remaining sensitive to the acoustic signal reflections.

## Recording and Interpretation of Signals

An amplifier/recorder filters and amplifies the electrical signal from the microphone and feeds the enhanced signals to an analog to digital converter and microprocessor to digitize, filter, display and store a record of the acoustic signal. The frequency content of the reflected acoustic signals varies depending on the characteristics of the initial pulse, the pressure in the gas, the distance traveled by the sound wave and the type of cross sectional area change. In general, as the pulse travels in a gas, the amplitude of the signal decays. The high frequency energy decays more rapidly than the low frequency energy. Thus, the acoustic response from tubing collars at the top of the well contains high frequency energy, the response from deep collars contains medium frequency and the signal from the liquid level is mostly low frequency energy. This is especially apparent in deep wells with low casing pressure. Fluid level instruments are designed to include various filters, which can be used to accent signals that correspond to these frequency ranges. The Model H records the signal with the highest possible resolution and frequency content so that signal analysis and interpretation is optimized using digital signal processing techniques.

## Depth Calculation

In most cases, once an acoustic record has been obtained the liquid level is identified automatically and the software determines the number of tubing collar reflections from the surface to the liquid level in order to calculate its depth. The corresponding number of tubing joints, multiplied by the average joint length yields the distance to the liquid level.

Other techniques are available for determining the liquid level depth. When other signals are identified on the chart, such as those generated by gas lift mandrels, liner tops, tubing anchors or perforations, the known depth of these anomalies can be used to calculate the depth to the deeper liquid level by the ratio of elapsed time. When the lengths of tubing joints vary considerably, so that an average joint length is not representative, some operators place an over-sized tubing collar (marker) at a known point in the tubing to serve as a depth reference.

When the specific gravity or the composition of the gas in the annulus is known with some accuracy, then the velocity of sound in the gas can be calculated. The acoustic wave round-trip travel time from the initial pulse to the liquid level reflection is divided by two and multiplied by the acoustic velocity to calculate the depth to the liquid level.

Still another technique involves measuring the acoustic velocity of the gas by sampling the casing gas into a tube of sufficient length to measure the velocity of sound in the gas by pulse testing. This technique is applicable only if the well continuously vents gas from the annulus so that a representative sample of the gas sample obtained at the top of the well will be representative of the gas in the well.

The most common application of an acoustic liquid level instrument is to measure the distance to the liquid level in the casing annulus of a well. However, it can also be applied to measurements inside tubing. Other applications include determination of the distance to the mud or kill liquid level during drilling and work-overs. The acoustic instruments can be used to measure the distance to any change in cross-sectional area inside pipe or in the annulus.

## Recommendations for Optimum Performance

The Echometer wellhead should be as near as possible to the casing annulus (or the tubing) preferably within 5 feet. Short (5-10 ft) lengths of pipe can mask the desired downhole signals. Longer (20-60 ft) lengths will generate multiple reflections, which are hard to distinguish from collar reflections. Use a minimum of $90^0$ ells and tees and direct the blast straight into the well if possible. Two-inch connections are recommended, but one inch connections are generally satisfactory if the length of 1 inch pipe is kept to a minimum.

The pressure pulse travels down the well and is reflected by tubing collars and the liquid level. The signals from upper collar reflections are strong, but the collar response becomes weaker as the pressure pulse travels long distances to the bottom of the well so that the reflections from the lower collars may be weaker than the background noise. The liquid level reflection varies from a strong signal in a shallow high pressure well to a very weak signal in a deep low pressure well. Only signals stronger than the background noise are meaningful in the recording. It is obvious that strong background noises must be reduced if the recording of lower collars and liquid level is to be obtained.

Background noise can be classified as surface mechanical vibration noise or acoustic noise. The source of noise can be determined easily by increasing the sensitivity until signal deflection is obtained. Closing the casing valve between the microphone and the annulus will cause a reduction in the noise level if its source is acoustic noise. If the signal level remains the same, then the noise is caused either by surface vibrations or by gas leakage from extraneous lines connected on the same side of the closed casing valve as the microphone. The microphone is shock mounted, but if the wellhead attachment vibrates excessively, unwanted signals are generated. Wellhead vibration result from running gas engines, chattering check valves and other reciprocating surface equipment. It may be necessary to eliminate wellhead vibrations to obtain better quality records in deep low-pressure wells. All other lines leading to the casing annulus should be closed.

The main source of down-hole acoustic noise is gas "popping" out of a gaseous annular liquid column or liquid falling into the wellbore. Downhole noise can also result from tubing and casing leaks. Generally, the downhole acoustic noise can be reduced in relation to the desired reflected signals by causing an increase in the casing pressure. In order to do this, continue to pump the well with the casing vent valve closed. At low pressures, an increase of 10-psi in the casing pressure almost always improves the record and it only depresses the liquid level by 30 feet.

If the signal from the liquid level is not detected due to excessive surface vibration noise or downhole acoustic noise, a larger signal from the liquid level can be obtained by generating a larger initial pressure pulse. Also, increasing the sensitivity so that the background noise level exceeds 1/8 inch generally will make interpretation much more difficult and is not recommended.

## Acoustic Record Interpretation

In an average well, the following events will be recorded on the chart: A kick will show the initial blast. A series of small kicks will indicate the tubing collars and then the liquid level kick will be recorded. If the chart is allowed to continue to run, another kick will often occur after the liquid level kick at twice the time of the first reflected liquid level kick. This is a signal that corresponds to the pulse traveling from the gun to the liquid level and then to the surface where it is reflected by the wellhead back down the well and is again reflected by the liquid interface back to the surface. In shallow and in high pressure wells there may be numerous other reflections from the liquid level. These are known as "multiples" of the pulse. Since all these signals have traveled the same distance at the same speed the distance (time) from the initial blast to the first liquid level reflection will be equal to the distance (time) between the first liquid level kick and the second reflected level kick. Multiple liquid level reflections on very shallow liquid levels, which are 20 to 60 ft from the surface, can be misinterpreted as collar reflections.

The normal acoustic record has a kick at the start of the trace which corresponds to the initial pressure pulse, a series of small evenly spaced kicks indicating the collar signals and a large kick indicating the liquid level. On some records the collars can be distinguished from the beginning of the shot to the liquid level signal and all the collars can be counted. On other records the collars cannot be distinguished clearly all the way from the beginning to the liquid level reflection. In these cases it may be convenient to repeat the test trying to improve the signal to noise ratio so as to be able to count a large percentage (better than 60%) of the collars in the well. In these cases it is necessary to count the collars to the last discernible collar reflection signal and then the software extrapolates the count to the liquid level. The total number of collars counted multiplied by the average tubing joint length results in the depth to the liquid level. This assumes that the range of tubing joints is similar for all tubing in the well. This procedure may not be used if there are significant differences in the lengths of tubing joints. Alternative methods to determine the depth to the fluid level are discussed in the following section.

The direction of kick of an echo signal, indicates enlargements and reductions in the cross sectional area of the annulus (or internal diameter of pipe if shooting down tubing). Objects which reduce the cross sectional area of the annulus result in compression reflections and are recorded as downward kicks. Such objects would be liners, tubing anchors, paraffin deposits or the liquid level. Conditions that increase the area of the annulus result in rarefaction reflected waves and are recorded as upward kicks. Such conditions include perforations, "shot" holes, parted casing, parted tubing and the end of the tubing casing annulus. It is important to select the correct mode of pulse generation (Implosion or Explosion) by pressing the corresponding soft key, so that the displayed polarity of the echoes will be consistent with the above description.

Please refer to the appendix where several examples of traces corresponding to various wells and different cases of signals are presented.

The liquid level is recorded as a downward kick. If the liquid level is 20 feet or so in a "shot" hole, then the signal would first deflect upwards, then down as the sound wave is reflected from the liquid level. Recording the liquid level below a liner will show a downward kick at the liner and a downward kick at the liquid level then an upward kick if the record time is sufficiently long. The upward kick corresponds to the signal generated at the liner by the wave which was reflected at the liquid level and which is returning to the surface. When the wave passes from the narrow liner to the larger casing, a portion of the wave is converted to a rarefaction pulse, which then travels down to the liquid level and then to the surface where it is recorded.

## Calculation of Bottomhole Pressures

Bottomhole pressure calculation in static and producing wells is described in technical papers and is facilitated by the use of software, which is supplied with the Echometer Model H. Details of the calculation methods used by the software are found in technical papers on the internet at www.echometer.com .

The BHP calculation program AWP2000 requires one of the following: Windows 9x, ME, NT, 2000 and XP, and can be downloaded for free from the Echometer Web page, www.echometer.com.

The program is designed to be easy to use and require a minimum of data. The user should remember, however, that the results from computer calculations are only as good as the data that is entered. Thus, make sure that the data input is accurate or the results will be meaningless.

## Fluid Level Acquisition in Problem Wells

Obtaining a good record is made more difficult by excessive surface vibrations, excessive down-hole noise from gaseous liquid columns, improper wellhead connections, dirty microphone and electrical connections, or low casing pressure.

Excessive surface vibrations and downhole noise should be reduced as much as possible.

Any well venting gas to the atmosphere, venting gas to the flow line or using casing gas to operate an engine, will have a gaseous liquid column if liquid exists above the pump or formation. The amount of liquid present in a gaseous liquid column can be determined by a casing pressure build-up test. Another technique is compression of the gaseous column with casing pressure to determine the gaseous column gradient. Additional information is presented in the papers "Producing Bottom Hole Pressures" and "Acoustic Foam Depression" in the appendix. Gaseous columns caused by gas bubbling through oil cause excessive down-hole noise and can be a problem in obtaining clear records of deep collars and liquid levels. Increasing the casing pressure by closing the flow line-casing valve will generally result in much improved signals. The pressure in the gas gun volume chamber may have to be increased to the maximum so as to increase the signal to noise ratio.

Whenever there are doubts that the correct liquid level signal has been identified the best way to differentiate it from other signals (such as signals from liners, paraffin rings, or liquid influx from perforations) is to cause the liquid level to move. The liquid level signal is the only signal that can move in a well and such movement identifies the liquid level. A high fluid level can be depressed by increasing the casing pressure. An increase of 10-psi in the casing pressure will depress a gas-free liquid level by approximately 30 feet. The liquid level will rise when a producing well is shut down. The rate of fill-up will vary with the productivity of the well and the annular volume. A Rate of Fill-up chart is presented in the appendix and may be used to estimate the amount of time required for liquid level rise. Note also that this chart may be used to estimate the production rate from a well by shutting in the well and measuring the change in fluid level as a function of time, then using the chart to estimate the production rate.

If a record shows numerous "kicks" which are difficult to interpret, the shot should be repeated and the new chart compared with the first recording. All "kicks" should be duplicated on each record. Signals that are not duplicated correspond to stray noises and other random signals. The source of these noises should be identified so as to eliminate them as described above.

The effect of casing pressure on signal quality is very important. Stronger signals are returned in high-pressure wells. It is especially difficult to obtain good recordings in deep wells with the casing pressure near or below atmospheric pressure.

On rare occasions, paraffin deposits, scaling, dirty tubing or other conditions can result in additional down-hole signals, which make it difficult to count collars or to determine the fluid level depth. In extreme cases it may be necessary to clean the tubing and casing to remove the foreign material.

## Battery Power Information

Note: To maintain Intrinsically Safe certification, the unit must be charged in a safe area and can only be charged using Echometer P/N MS1610.

The Echometer Model H instrument will operate from the self-contained rechargeable battery. Battery MUST NOT be recharged while instrument is located in a hazardous area.

The battery charger will charge the battery at a rate of 1800 ma until the battery is almost fully charged then it will trickle charge at a 25 ma rate. The red light on the charger is ON when the charger is charging at high rate. When the charger is in trickle charge mode the light changes to green. Approximately 12 hours are required to charge a fully discharged battery. Continuous charging does not damage the battery.

The battery should be charged when the operating voltage bar-meter displayed on the screen changes from green to yellow. The battery can be charged more often if desired. Best operating performance will be obtained with battery temperatures from 0 to 120 degrees F (-15 to +50 C). The battery has less capacity and voltage at lower temperatures. Battery life also varies with display brightness setting. The table below is for a typical mid level brightness setting and a fully charged battery. After 300 full charge / discharge cycles, battery capacity will drop to about half the initial capacity. There are three different states for the instrument, each with a different power requirement. Operating demand is .425 to .950 Amps depending on screen brightness. Standby, which provides for instant on, is .325 Amps. Off, which requires 45 seconds boot time is 0.035 Amp. In the off state, the battery will discharge in about 10 days.

| Temperature $^{O}$F | Temperature $^{O}$C | Battery Life, Hours |
|---|---|---|
| 104 | 40 | 8.5 |
| 77 | 24 | 8 |
| 32 | 0 | 6 |
| -4 | -20 | 3.5 |

Long storage periods without charging will severely reduce service life. Charging the battery before it is fully discharged will result in longer battery life.

## Important Notes and Instructions for Rechargeable Batteries

The battery is rated at 9 Amp-Hour. The Model H current drain is approximately .825 Amps operating and .325 Amps standby. Thus the battery operating ON-time is approximately 10.9 hours.

**NOTE: Due to the intrinsic safety of the Model H, the instrument has the required overvoltage protective circuitry on the charger input. If a voltage surge is detected, or if battery voltage is allowed to fall below critical levels, the protective circuitry will cut power to the battery and a recharge will not be possible until a hard reset has been performed via the pin-hole reset button on the front panel of the instrument.**

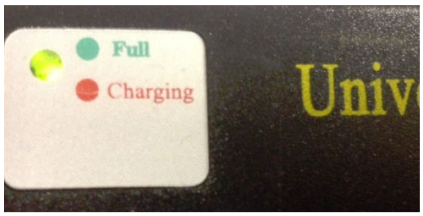
1 - Charge battery before using instrument. To maintain intrinsically safe certification, ONLY the CHARGER that is provided with the Echometer Model – H can be used (Echometer P/N MS1610).
2 - When not in use for extended periods of time leave the AC charger connected continuously.
5 - Under no circumstance should you attempt to open the instrument case.
6 - Do not expose instrument to moisture or rain.
7 - Do not drop, hit or abuse the instrument, because it will break.
8 - It is perfectly normal for the instrument to become warm to the touch during charging and discharging.
9 - Running time depends on the power demand and the operating temperature.
10 - The life of the battery under normal conditions may be as long as 300 full charge-discharge cycles.
11 - New batteries may require four or five charge-discharge cycles before achieving their designated capacities.
12 - Always fully charge the battery no less than once every four weeks.

Steps to Reset Model H Battery to Begin Taking a Charge

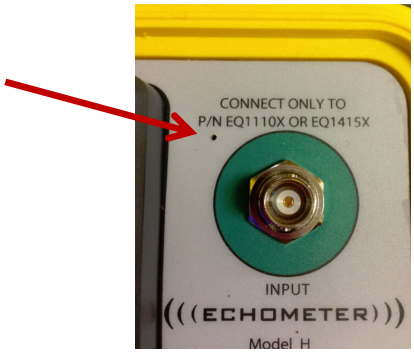
There are a number of safety features associated with the battery in the Model H assembly. Certain requirements are necessary in order to achieve certification as an intrinsically safe instrument. One of these safety features is an automatic “kill switch” that will shut off power to the instrument due to a detected voltage surge, or if the voltage capacity on the battery drops below 10%. When the shut off occurs, the battery will not begin taking a charge unless the battery is reset.

Please take the following steps to reset the battery:

1) With the instrument completely powered down, plug the wall charger into the instrument and the outlet. The light on the charger will show "green" due to the fact that the charge is not reaching the battery.




2) The pin-hole reset button is located in the upper right hand corner of the Model H front panel. The end of a paper clip should be inserted the button inside the pin hole depressed for three full seconds.




3) Upon removal of the paper clip, the light on the charger should turn red if the battery was able to reset.


4) After the charger turns red, allow the Model H to charge for several hours before you turn it back on or try to remove it from the power source.

Steps to Reset and Charge a “Critically Low Battery”

In the event a Model H instrument has been without charge for a period exceeding four weeks, it may drop to a “critically low” voltage range. When this range is reached, attempts to charge the battery may be unsuccessful.

Please completely read through and follow these instructions carefully to insure the battery is brought back above the critically low voltage point and will begin taking a charge.

**Step 1 – Plug the Model H charger into the instrument front panel.**

If the battery voltage is critically low, the light on the Model H charger will remain green.


**Step 2 - In the upper right hand side of the Model H front panel, locate the pin hole next to the microphone cable connector. Take the end of a paper clip and depress the button inside the pin hole for three seconds.**


When the paper clip is released the pinhole button, the charger indicator light will briefly (for about one second) turn from green to red and then back to green. When the battery falls to the critically low voltage point, the cells will trickle charge up to a point that they are able to begin taking a charge normally. Until this point is reached, the charger light will display green.

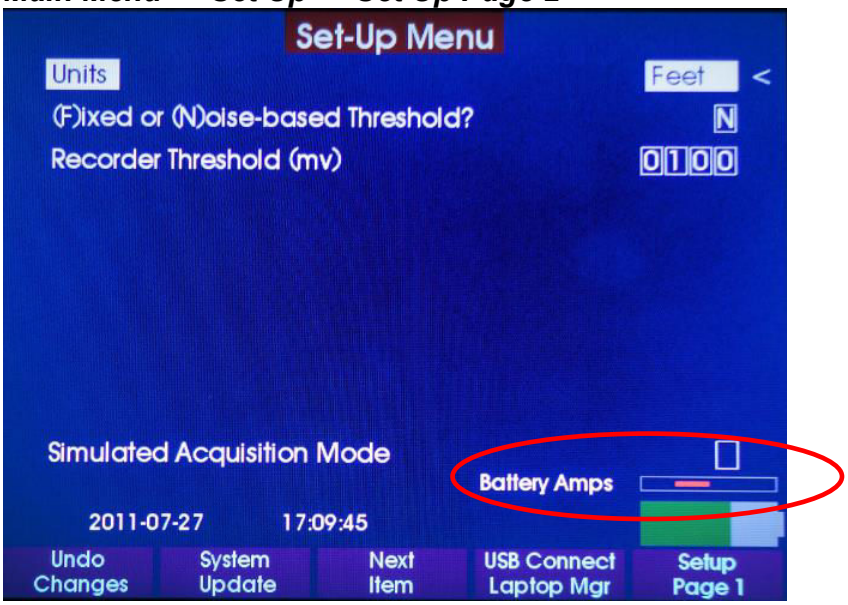
**Step 3 – Allow the instrument to sit on charge for a period of not less than 5 hours.**

This gives the battery cells ample time to trickle charge up to a point of normal operation.

**Step 4 – With the charger still plugged into the instrument, press the Power button on the panel.**

After the initial boot up, continue to the Main Menu and perform the following navigation to the Set-Up screen to see a visual display of the battery charge.

***Main Menu → Set Up → Set Up Page 2***




Above the visual battery charge display is a bar labeled “Battery Amps”. If the battery is taking a charge, the colored bar will turn from a red bar to a green bar. This color scheme is opposite to the light indicator on the charger.

**Step 5 – With the charger still plugged into the instrument, depress the pin hole reset button for three seconds.**

When the paper clip is removed, the indicator light on the charger should turn from green to red and should remain red as the battery continues its normal charging sequence.

**Step 6 – Allow the instrument to remain on charge until the visual battery charge display on Set Up Screen 2 indicates a full battery and the Model H charger indicator light turns from red to green, indicating a full charge.**

**THE MODEL H SHOULD BE PLACED ON CHARGE WHEN NOT IN USE, OR IF IT HAS BEEN SITTING WITHOUT CHARGE FOR A PERIOD OF MORE THAN FOUR WEEKS.**

## Instrument Testing/Troubleshooting

The Echometer Model - H has an internal test circuit, which is used to verify that the electronics and the acoustic amplifier are operating correctly. The test circuit is activated automatically when the power is turned ON. A system test and battery voltage is displayed on the screen.

## Maintenance

The Echometer Model –H instrument should be kept clean. The battery should be kept charged as described by the instructions in Section 7. Do not subject the unit to shock loads.

Using the Compact Gas Gun or the High Pressure Guns in the EXPLOSION or IMPLOSION mode will require minimum maintenance. Clean and inspect threads of the Microphone Protector (2 inch threads). Replace this collar if it is worn or damaged.

The microphone cavity should be rinsed with a solvent (kerosene) periodically to remove any oil, grease or any foreign materials that may have accumulated. DO NOT REMOVE the microphone.

When using in wells that produce sour gas or oil ($H_2S$) it is recommended that the microphone cavity be coated with a fine layer of grease or corrosion resistant primer. This will retard the formation of corrosion pits.

If the gas gun does not operate properly it probably needs replacement of “O" rings and it should be disassembled. Be sure to check all threads, the moving gas valve and all other pieces thoroughly. If any signs of wear or deterioration exist replace the parts before reassembling. Replace the "O" rings when any sign of deterioration exists. Lubricate the gas valve and all "O" rings with light oil before assembly.

### Compact Gas Gun Pressure Rating

The pressure rating of a NEW compact gas gun is 1500-psi. After the gun has been used, its pressure rating should be de-rated by the operator depending on the condition of the gun. The compact gas gun may have internal and external corrosion, deep external wrench marks, improperly tightened cap bolts or worn threads. Corrosion causes pitting and reduction in the strength of the remaining metal. Any corrosion should be examined visually and depending on its severity the maximum working pressure of the gas gun should be reduced. Marks and notches caused by pipe wrenches, any type of bending or denting of the metal will cause a reduction in strength. De-rate the gas gun for any noticeable physical damage to the gas gun.

The stainless steel 2-inch line pipe thread on the housing will become worn after unprotected use. For this reason a knurled microphone protector has been added to the gun to protect the threads on the gas gun. This protector should be replaced whenever excessive corrosion or wear has occurred.

The compact gas gun can be operated in an implosion mode. That is, gas from the casing can be released into the compact gas gun to create the pressure pulse. Often, the gas in the well contains sand, water vapor and corrosive gases. Thus, operating in the implosion mode will result in additional maintenance requirements.

The preferred mode of operation when an external gas source ($CO_2$ or $N_2$) is available is in the EXPLOSION mode. The gas gun chamber should be charged to a pressure in excess of the well pressure before the gas gun is exposed to well pressure (follow operating instructions in section 4). This will isolate the internal parts from the well fluids and they will have longer life and require less maintenance.

Compact Gas Gun Disassembly and Assembly Special Precautions

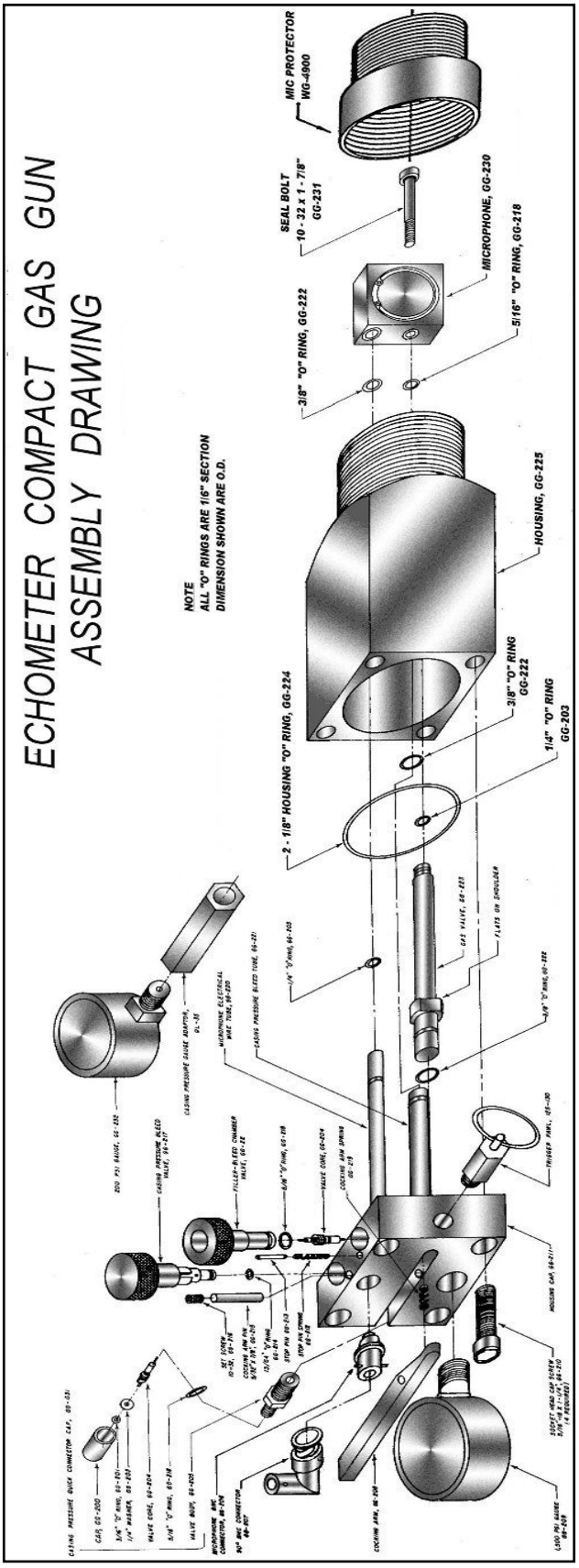
When the gas gun is disassembled, always REMOVE the MICROPHONE FIRST. The microphone is located at the lower end of the gas gun. It is removed by unscrewing a 10-32 x 1-1/4 cap screw. Then remove the Housing Cap by unscrewing the four Allen-head cap bolts.

When reassembling the gas gun, always FIRST attach the Housing Cap to the housing with the 4 bolts then INSTALL the MICROPHONE LAST. Do not over torque bolts.

The four cap bolts, Part No. GG-210, which hold the housing cap to the main gas gun housing should be properly tightened and periodically replaced. The proper torque for the bolts is approximately 50 inch-pounds. The "O" ring seal between the housing cap and the housing does not require excessive tightening of the bolts to properly seal. Do not over tighten bolts. If the bolts are excessively tightened, the bolts would be pre-tensioned to a stress such that when internal pressure is applied, the additional force on the housing cap generated by the internal pressure could cause the bolts to fail.

# *APPENDIX*

FIGURE A1- COMPACT GAS GUN ASSEMBLY DRAWING



## Microphone/Cable Test

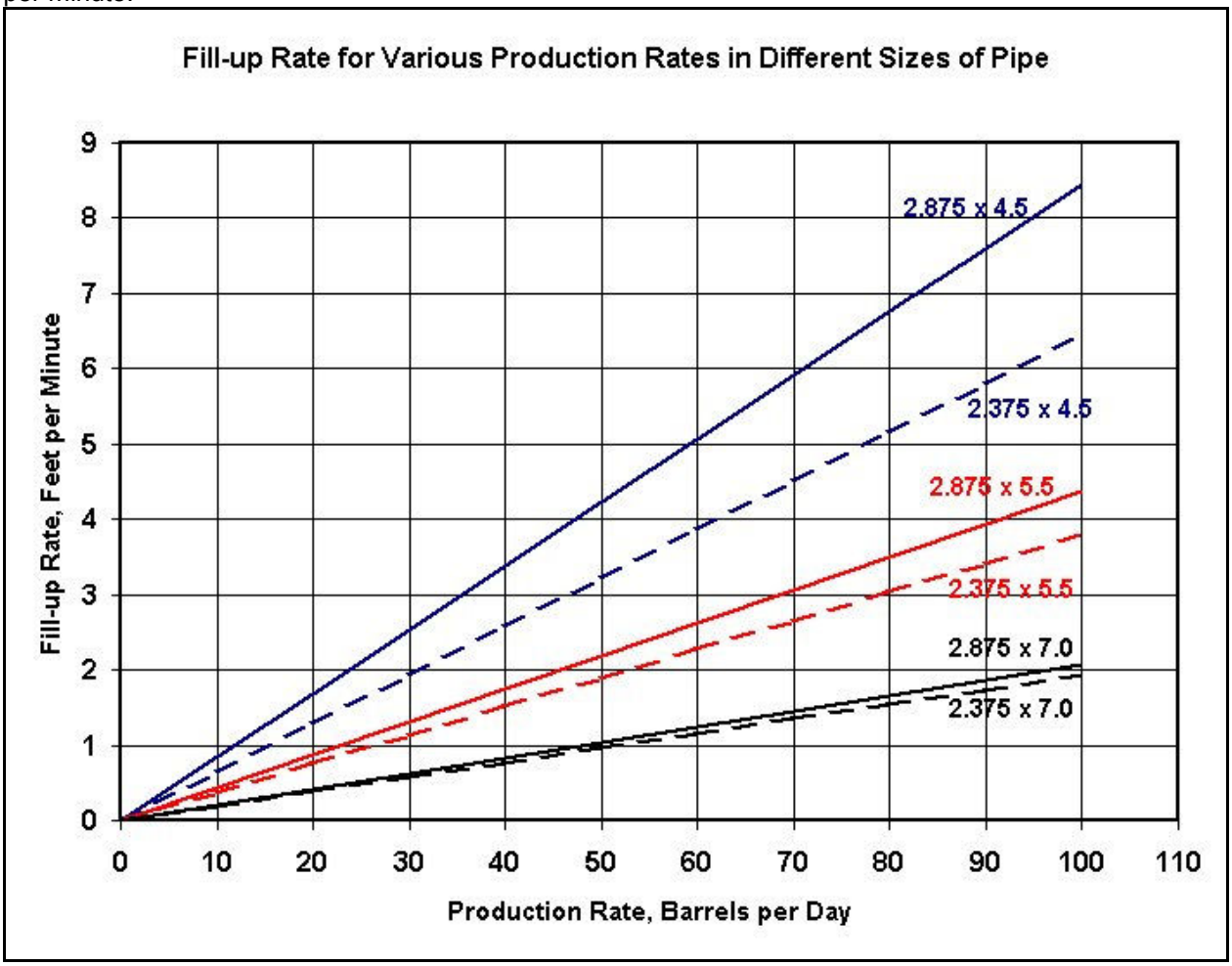
The microphone/cable test can be performed after the instrument self test has shown that the battery and electronics are performing properly.

The microphone test is used to measure the output of the microphone when a pre-determined pressure pulse is applied to the microphone. A rubber squeeze bulb attached to a plastic threaded cap is supplied with the gas gun so that the gas gun microphone can be tested whenever desired. The rubber squeeze bulb applies a compression pressure pulse to the microphone when the bulb is squeezed. Continue to squeeze the bulb for approximately 5 seconds, and then release the bulb. When the bulb is released, a rarefaction pressure pulse is generated which is opposite in polarity. When testing the Compact Gas Gun, the internal gas valve and the casing bleed valve must be closed. Lifting the cocking arm closes the internal gas valve. Be sure that the casing bleed valve is closed. When testing the 5000-psi gun, close the valve between the microphone and the volume chamber

Attach the rubber test bulb to the end of the gas gun securely. Attach the microphone cable to the microphone outlet BNC connector and to the instrument INPUT.

## Rate of Fill-up Graph

The accompanying graph is very useful in liquid level work. The graph indicates the initial rate of fill-up between casing and tubing in a well for a certain producing rate after the well is shut-in. The chart is read as follows: If the well produces less than 100 BPD, find the point on the bottom scales corresponding to the producing rate, read straight up until intersecting the line indicating the pipe sizes, then read to the left to find fill-up rate. For over 100 BPD, find the point on the bottom scale corresponding to 1/10 of the producing rate, read up until intersecting the line indicating the pipe sizes, then read to the left to find fill-up rate and multiply by 10. For example, if a well which has 2" tubing and $5^1/_2$" casing is producing 60 BPD, the initial fill-up rate is 2.2 feet per minute. A well with $2^1/_2$" tubing and $4^1/_2$" casing, producing at 700 BPD will have an initial fill-up rate of 59 feet per minute.




| Pipe Size (In) | Casing Weight (Lbs/Ft) | Casing ID (In) | Annular Capacity (BBLS/1000 Ft) | Annular Area (Sq In) |
|---|---|---|---|---|
| 2.375 x 4.5 | 9.5 | 4.090 | 10.77 | 8.71 |
| 2.875 x 4.5 | 9.5 | 4.090 | 8.22 | 6.65 |
| 2.375 x 5.5 | 15.5 | 4.950 | 18.32 | 14.81 |
| 2.875 x 5.5 | 15.5 | 4.960 | 15.87 | 12.83 |
| 2.375 x 7.0 | 17.0 | 6.538 | 36.04 | 29.14 |
| 2.875 x 7.0 | 17.0 | 6.538 | 33.49 | 27.08 |

## Use of Rate of Fill-up Information

If a pumping well is shut down for ten minutes for surface connection work prior to a liquid level shot and the initial fill-up rate is only 1.3 feet per minute, then the maximum error would be only 13 feet due to the shut-in time. However, if the fill-up rate is 35 feet per minute, the maximum error could be as high as 350 feet.

The fill-up rate found in the chart is the initial rate at which liquid will fill the casing annulus. This rate decreases as the pressure in the well bore approaches the static reservoir pressure. For example, if the static reservoir pressure is 1000 PSI, the reservoir pressure will support approximately 2500 feet of liquid (assuming low casing pressure), so the fill-up rate found on the chart would be within $10^{o}/_{o}$ for the first 600 feet or so. However, if the static reservoir pressure would support only 900 feet of liquid, then the fill-up rate would be reduced to one-half by the time the well had filled with 600 feet of liquid.

The rate of fill-up graph can be used to estimate the production rate of a well. A first fluid level depth measurement is performed while the well is at normal producing conditions. Then, the well is shut down and the liquid level in the casing annulus is allowed to rise. The height that the liquid rose and the amount of shut-in time are recorded. This data is used in conjunction with the casing and tubing sizes to determine the production rate of a well. This procedure is more accurate in wells that produce small amounts of gas up the casing annulus.

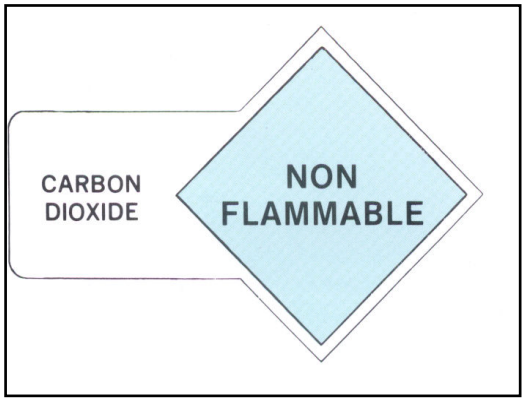
If the well is producing gas up the casing annulus, the rate of fill-up is not as predictable. Also, using the rate of fill-up to estimate the production rate is not as accurate. A casing pressure build-up rate in excess of 1 PSI in three minutes indicates that the casing annulus liquid contains a substantial amount of free gas and the fill-up data should be used with caution.

## CARBON DIOXIDE CYLINDER

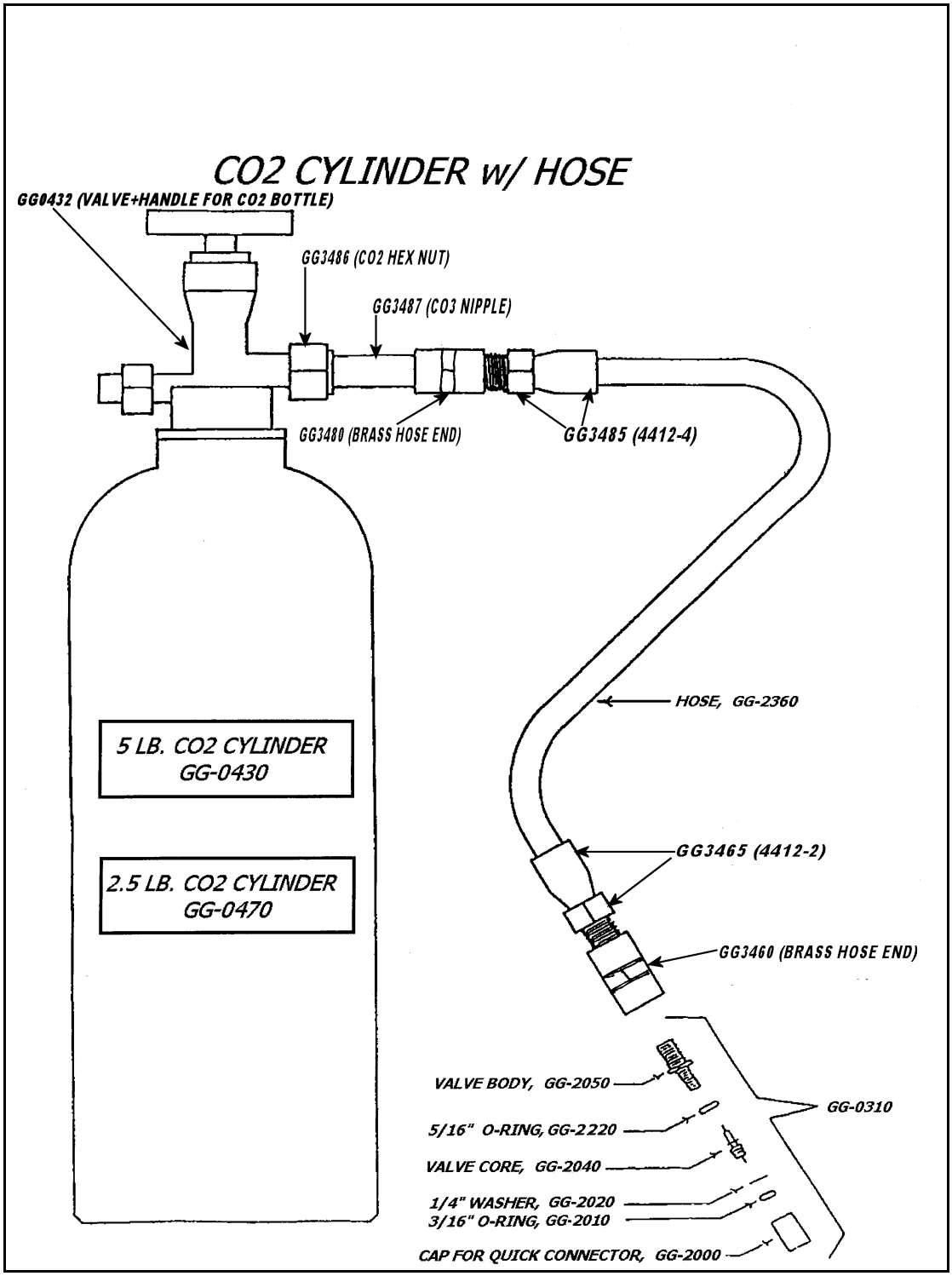
Echometer Part No. GG0430 & GG0470

# CAUTION

DO NOT OVER FILL, fill cylinder based on weight of CO2.
Contents under pressure.
Do not inhale gas or allow gas to touch skin. Gas becomes cold during use and can cause frostbite or other personal injury.
Metal parts of Cylinder can become extremely cold during use. Protect hands and other parts of body from direct contact with metal parts of Cylinder during use.
Contains carbon dioxide gas under pressure. Do not puncture or incinerate Cylinder. Do not expose to heat or store at temperature above 170 degrees F (76$^{o}$C). Keep out of reach of children.
See details in operating manual.
Have Cylinder pressure checked or replaced two years from date of purchase.



CO2 Cylinder  Schematic With Part Numbers



CARBON DIOXIDE GAS INFORMATION ($CO_2$)

Carbon dioxide is a nonflammable, colorless, odorless, slightly acid gas. It is one and one-half times as heavy as air. $CO_2$ is used in the carbonation of soda pop, as an inert agent in fire extinguishers, in canned food products, and many other applications.

Below 88°F, confined $CO_2$ liquid and gas are in equilibrium at a vapor pressure shown in the table below. For example, a Cylinder of $CO_2$ liquid and gas at 59°F has a pressure of 723-psia. As gas is removed from the cylinder, the liquid vaporizes into a gas, which maintains the vapor pressure shown. When all of the liquid has been vaporized, the gas pressure will reduce as gas is withdrawn. Following is a table of the vapor pressure as a function of temperature.

| Temperature | | Pressure | |
|---|---|---|---|
| °F | °C | PSI | Bar |
| 88 | 31 | 1053 | 73 |
| 59 | 15 | 723 | 50 |
| 32 | 0 | 490 | 34 |
| 5 | -15 | 317 | 22 |
| -22 | -30 | 192 | 13 |

Above 88°F, $CO_2$ becomes a fluid. Liquid does not exist separate from gas. The pressure in the tank is an indication of the amount of $CO_2$ present in the tank. As the gas is used, the pressure will decline. At 90°F, the pressure in a full cylinder will be approximately 1100-psi.

The amount of $CO_2$ in a cylinder is determined by weighing the cylinder containing the $CO_2$ and then subtracting the weight of the empty cylinder which is shown on the cylinder. Below 88°F, the amount of $CO_2$ in the cylinder cannot be estimated by measuring the pressure unless the pressure is less than the vapor pressure shown on the graph. If the pressure is less than the vapor pressure, the Cylinder does not contain any liquid $CO_2$ and very little $CO_2$ remains in the Cylinder.

$CO_2$ is heavier than air and may collect in confined, unventilated areas. Do not permit a leaking cylinder in a closed automobile. $CO_2$ is the regulator of the breathing function, and an increase in the $CO_2$ inhaled will cause an increased rate of breathing. In high concentrations, $CO_2$ can paralyze the respiratory system. Do not breathe air having excessive amounts of $CO_2$.

Do not overfill a $CO_2$ Cylinder or dangerous pressures can result. Do not use $CO_2$ cylinders, which show any sign of wear, abuse, corrosion, worn threads or any mishandling.

CO2 - PHYSICAL CONSTANTS

| | |
|---|---|
| Density, Gas @ 70°F, 1atm | 0.1146 lb/cu ft |
| Critical Temperature | 87.8°F (31°C) |
| Critical Density | 0.468 g/ml |
| Critical Pressure | 1072-psia (73-atm) |
| Specific Gravity | 1.53 |
| Specific Volume @ 70°F, 1-atm | 8.76 cu ft/lb<br>or 15,000 cu in/lb<br>or 950 cu in/oz |

## NITROGEN GAS INFORMATION ($N_2$)

Nitrogen comprises approximately 79% by volume of the air. It is found chemically combined in many forms in nature. Nitrogen will not burn and will not support combustion. Nitrogen is normally available in cylinders compressed to 2200-psi.

Nitrogen is used as an inert gas in electrical systems, the chemical industry, and in the food packaging industry. Nitrogen, also finds extensive use as an inert atmosphere and in the filling of some incandescent lamps.

Nitrogen is nontoxic but can asphyxiate human beings and animal life by displacing the necessary amount of oxygen in the air to sustain life.

### ACOUSTIC LIQUID LEVEL DEPTH MEASUREMENT CONSIDERATIONS

Generally, a pressure regulator should be used with $N_2$ since the initial cylinder pressure is 2200-psi, which is normally in excess of the wellhead pressure rating or the maximum rating of some of the pressure gauges.

During pressure buildup testing, the pressure regulator should be set so that the pressure in the volume chamber will exceed the pressure on the casing annulus when the operator returns to check the equipment. Less gas will be used if the pressure regulator is set to a lower value.

### HANDLING PRECAUTIONS

Never drop cylinders or permit them to strike each other violently.

Never tamper with safety devices in valves or cylinders. See your local gas supply dealer for other precautions.

### N2 - PHYSICAL CONSTANTS

| | |
|---|---|
| Molecular Weight | 28.016 |
| Density @ 70°F, 1-atm | 0.17247 lb/cu ft |
| Critical Temperature | -232.87°F (-147.15°C) |
| Critical Pressure | 492.45-psia (33.5-atm) |
| Specific Volume @ 70°F, 1-atm | 13.8 cu ft/lb or 31,000 cu in/lb |