

# *Echometer Model-M*

## *Digital Dual Channel Fluid Level Instrument*

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### *Introduction*

This operating manual contains information about the Echometer Model M Fluid Level Instrument including operating procedures, maintenance, shooting problem wells, chart interpretation and technical papers relating to the optimization of producing wells. Please read the first 25 pages and view the example of the strip chart output forms and charts on wells before operating the instrument. Additional technical papers can be accessed from the Echometer Web page, [www.echometer.com](http://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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# 1 - Safety Considerations

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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 casing pressure normally increases during a build-up test, caution should be exercised that the well pressure does not exceed equipment pressure ratings.

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

***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.

## *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.

## *2-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 in the appendix. The acoustic wellhead attachment consists of an acoustic pulse generator, a microphone and optionally a pressure gage. 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 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<sub>2</sub> or N<sub>2</sub> 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 electrically, 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 records the enhanced signals on a strip chart. Modern instruments use analog to digital converters and microprocessors to improve the signal quality and print the chart. 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 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 the 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 M records the signal on the dual channels. One channel is tuned to higher frequencies from the collars while the second channel is tuned to low frequencies from the liquid level. Single channel instruments can be operated in any of these modes and it is possible to switch from one frequency response to another while the instrument is recording. Initially, the single channel instrument is operated in the collar mode (high or medium frequency), which is then switched to the liquid level mode (low frequency) when the collar signal fades. Switching may be manual or automatic.

## *Depth Calculation*

In most cases, once a strip chart record has been obtained and the liquid level signal has been identified, the operator must count 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 chart distance or elapsed time. When the lengths of tubing joints vary considerably, so that an average joint length is not representative, some operators placed an over-sized tubing collar (marker) 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 read directly from the strip chart, which displays timing marks. The round-trip travel time 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 gun 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 not 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.

## *3 - General Description - Model M*

The Echometer Model M is a dual channel, microprocessor controlled amplifier/recorder. It permits better interpretation of reflections from downhole anomalies since two different filters are used to improve the signal. Processing and simultaneously recording reflected signal using two separate amplifiers having different frequency response, improve the ability of the operator to distinguish downhole obstructions from enlargements. The response from the liquid level (or reduction in annulus area) is opposite to the response from an enlargement such as a hole in the casing. The Model M uses modern electronics, integrated circuits, chart drive system and a thermal printhead, which result in a very compact and lightweight system.

The dual channel Model M accents and records collars on one channel, and the liquid level response on a second channel. The collar channel can be set to record sharp upper collars or deep collars. Selecting the proper collar filter will result in more accurate determination of the number of tubing collar reflections from the surface to the liquid level. The lower trace accents the signals from the liquid level, tubing anchor, gas-lift mandrels, casing perforations and other major anomalies.

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 programmed to evaluate the signal level and increase or decrease the collar amplifier gain as necessary to optimize the quality of the recording. The collar and other signals will be recorded at a width of approximately 0.6-inch (12-mm), which simplifies the manual counting of the collars since the amplitude of the collar signal is maintained automatically. The automatic control of the recording level is called automatic gain control.

The microprocessor is used in conjunction with a timer. Since these instruments are used throughout the world, the universal coordinated time and date are printed on the strip chart. Also, the timing capabilities of the microprocessor, clock and timing circuit are used to place labeled markers at one-second intervals beginning from the instant the acoustic pulse is generated. This allows the operator to determine the round trip travel time very accurately. The travel time and the distance to the liquid level are used to compute the 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 for Windows to compute the gas gravity and the pressure distribution in the well, including the pump intake pressure and the pressure at the perforations.

In addition to recording both collar and liquid level signals simultaneously, the digital printhead generates a header, an analysis form, and prints the values of background noise, battery voltage and special instructions on the strip chart.

The entire instrument is contained in a waterproof, dustproof plastic housing having dimensions of 11 by 10 by 5 inches and weighs 11 pounds (5 kg). The following section describes the instrument panel and the function of the various controls.

# Instrument Panel

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The instrument panel is shown schematically in Figure 2 in the appendix. The following controls are used for operating the instrument and for checking that it is operating correctly:

- **Power Switch:**

Momentarily placing the switch in the ON position energizes the amplifier, activates a red light that indicates that the battery is powering the electronics and records a header on the strip chart. The microprocessor performs a system test and checks the battery voltage. If the battery voltage is low, a message is printed to charge the battery. If the system is OK, the chart drive stops after printing the battery voltage and test signals on the collar and liquid level channels, and the message " TURN ON CHART DRIVE TO TEST WELL". The power can be turned off manually, or the power will automatically turn off after approximately 15 minutes of non-use.
- **Upper Collars/Lower Collars Switch:**

This two-position switch selects whether the collar channel is connected to the high frequency (Upper Collars) or medium frequency (Lower Collars) filter circuits.
- **Collars Gain**

This knob controls the gain of the collar channel. The most counter-clockwise position (AUTO) activates automatic gain setting and should be used first always. In the AUTO mode, the gain is set automatically. Having the gain indicator on a value greater than 1 when the chart drive is turned on allows the operator to control the amplifier gain by setting the gain control knob as desired before the "shot" is detected. After the "shot" is detected, the instrument uses the gain setting when the shot is detected and the operator cannot adjust the gain.
- **Liquid Level Gain**

This knob controls the gain of the liquid level channel. The most counter-clockwise position (AUTO) activates automatic gain setting and should be used first always. In the AUTO mode, the gain is set automatically. Having the gain indicator on a value greater than 1 when the chart drive is turned on allows the operator to control the amplifier gain by setting the gain control knob as desired before the "shot" is detected. After the "shot" is detected, the instrument uses the gain setting when the shot is detected and the operator cannot adjust the knob.
- **Chart Drive Switch**

This switch is used to turn on and off the chart drive. Turning the switch to ON begins the data acquisition sequence. This consists of printing the data forms followed by the gain settings and the noise level on both channels, followed by the statement GENERATE PULSE and the recording of the two channels. The chart drive continues on until the switch is turned OFF.
- **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.
- **Remote Fire Connector**

Connects the instrument to the solenoid valve of a remote fire gas gun if a remote fire gun is utilized.
- **Remote Fire Switch**

**Depressing** this switch operates the solenoid valve on a remote fired gas gun by applying 12 volts to the solenoid coil. Depress the switch for 1 second to fully release gas from the chamber.



- **Battery Charger Connector**  
Attaching the 110 VAC or the 220 VAC battery charger or the 12V-car battery power cable to this connector charges the built-in battery.
- **Test Connector and Test Switch (on units serial number 4999 and below only.)**  
This TEST connector should be attached to the INPUT connector using the coaxial cable in order to check that the instrument and the coaxial cable are operating correctly. Depressing the test switch applies a test signal to the input of the amplifier via the TEST connector and the coaxial cable.
- **Chart Paper Drive**  
Pushing the spring-loaded aluminum plate cover towards the right and lifting it from the left side accesses the chart paper. The paper is dropped into the cavity so that it unrolls counter-clockwise. After inserting the paper roll, the aluminum cover is replaced. The printed Echometer logo on the paper should face up since only this side of the paper is heat sensitive. The heat sensitive paper supplied by Echometer Company operates over a wide temperature range and is made for the Echometer Chart drive system. The chart drive has a paper sensor to determine when paper exists in the drive. If the sensor detects that paper is not present, power is not supplied to the printhead. If paper is not present in the drive system and power is supplied to the printhead, the printhead will be damaged because the small heating elements in the printhead will be overheated. Using paper that is not of the proper width may result in printhead failure. Use only Echometer paper to insure proper operation of the printhead and chart drive system.

## *Wellhead Attachments*

### *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 pulse is generated. If the pressure is greater in the casing annulus than in the volume chamber, a rarefaction 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 (refer to drawing)

## 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 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 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

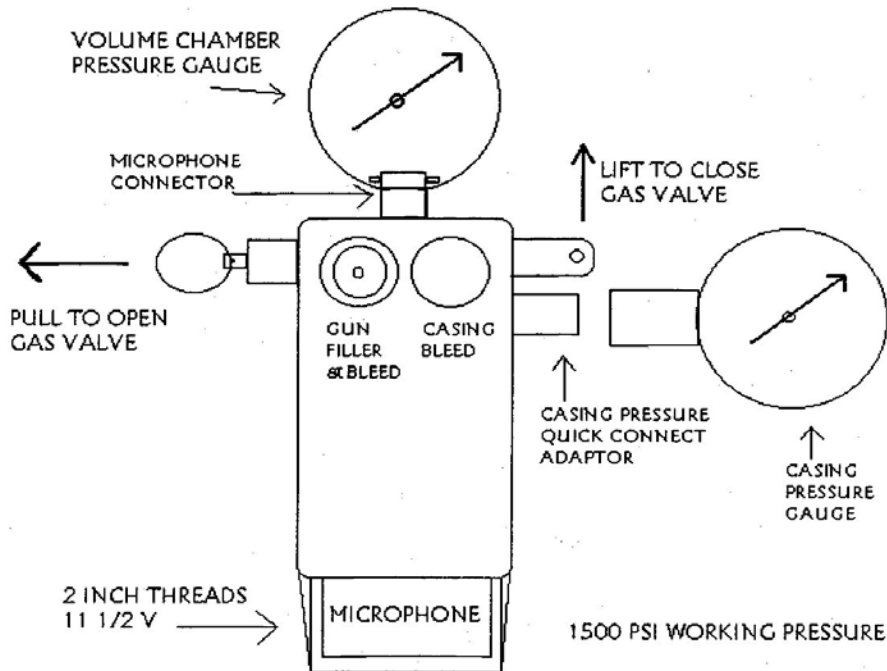
The filler-bleed valve is used to pressurize the gas gun volume chamber or to remove gas from the gas gun volume chamber. Gas is added to the chamber from a pressurized external gas source by insertion of mating quick connector, into the filler & bleed valve. Gas is bled from the chamber by rotating 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.

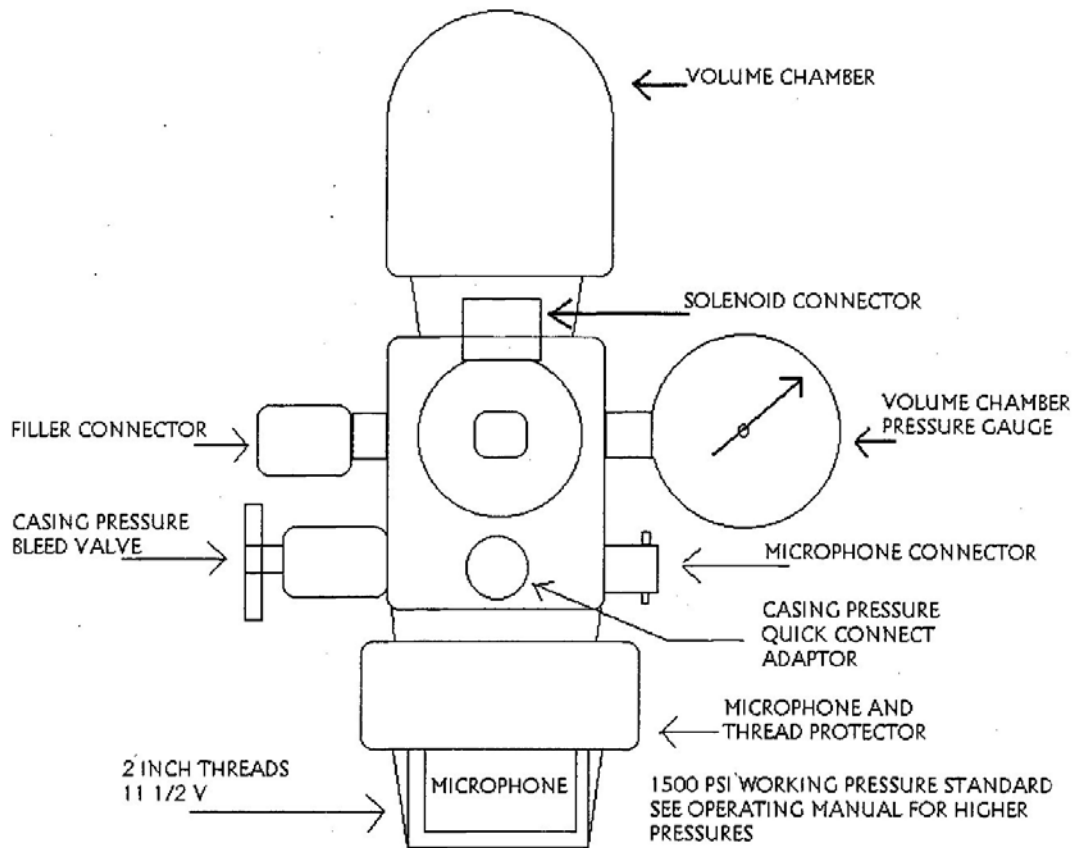
## Microphone

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



## Remote Fire Gas Gun

The remotely fired gas gun generates an acoustic pulse and detects the downhole reflections. The gas gun contains a volume chamber, which is filled with compressed gas to deliver the acoustic pulse to the well. A microphone housed in the gas gun detects the shot, collars and other wellbore reflections, and liquid level. The standard unit has a working pressure of 1500 PSI.



### Gas Valve and Solenoid

The solenoid serves as a trigger mechanism to initiate the acoustic pulse. When energized, the solenoid lifts a small plunger and allows gas pressure to bleed off the top of the gas valve. Gas pressure then forces the gas valve open, causing an acoustic pulse to be delivered to the well as the gas flows from the volume chamber into the well, (see the remote fire gun diagram.) The gas valve does not hold pressure from the well. Therefore, gas pressure must be applied to the volume chamber inlet port in order to close it. Whenever the valve is left open, well fluids will flow backwards through the gun and into the volume chamber. This flow may entrain sand and other debris. These deposits may prevent the gas gun from operating properly. To minimize this potential problem, it is advisable to charge the volume chamber with clean gas before the casing valve is opened and as soon as the strip chart from any shot has been recorded. This will prevent the well fluids and debris from entering the solenoid gas valve mechanism and causing a malfunction of the firing mechanism.

### Volume Chamber Pressure Gauge

The volume chamber pressure gauge measures the pressure in the gas gun volume chamber. It should be used to determine if the chamber pressure is sufficiently high (explosion mode) to generate the acoustic pulse. The volume chamber pressure should be approximately 100-psi in excess of casing pressure unless additional pressure is required to obtain desired results.

## **Casing Pressure Gauge or Optional Transducer**

The casing pressure and casing pressure buildup during the acoustic test must be measured with an accurate and sensitive pressure gauge or sensor. The Remote Fire Gas Gun supplied with the Echometer Model M is equipped with a quick connect gauge that covers the range 0-200 psig. The user should consider the option of obtaining several gauges covering different pressure ranges.

## **Charging the Gas Volume Chamber**

To charge the volume chamber, first connect the filler adapter to a 7.5 oz. CO<sub>2</sub> bottle. Then, press the adapter against the filler fitting on the gun. When these two fittings are pressed together, a valve core in the bottle is depressed and gas will flow from the bottle into the volume chamber. Charge the chamber to at least 100 PSI above casing pressure before attaching the gas gun to the casing annulus valve to prevent debris from entering the gas gun internal valve parts. The volume chamber pressure can be read on the gun-mounted gauge. A 5-LB, CO<sub>2</sub> bottle and hose with connector can be used to change the gun, if desired.

## *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- AC) or (220 V - AC if requested)

Automobile Battery Cable

Automobile Cigarette Lighter Cable

Casing Pressure Gauges

    Precision Test Gauge

    Precision Digital Gauge

Gas Cylinders

    2-1/2 LB CO<sub>2</sub>

    5 LB CO<sub>2</sub>

    Nitrogen Cylinder

## *Model M Modifications and Enhancements*

The following changes have been made to improve the Model M performance and versatility starting with serial number 5100. 1) The year, date and local time can be printed on each chart. 2) A chart operation delay switch “ARM” has been added to allow the operator to “ARM” the Recorder and then walk over to the gas gun and fire the shot before the chart drive starts to record data. The chart will record one second of acoustic data before the shot, then record the shot and then the reflected acoustic data. 3) The well performance analysis header can be printed or not printed on the strip chart. Other internal electronic features have been added in addition to these operating features. The new panel, the information header and the well analysis header are shown below.

- 1. Year, Date and Time Setting** The Enhanced Model M has provisions for setting year, date and local time in the field. Previous units were set at Echometer Company factory for Universal Coordinated Time at Greenwich, England. Thus, each operator had to determine from the universal time setting what time that the chart was obtained at his particular location if he was outside of the Universal Coordinated Time Zone in England. The date and time on the enhanced Model M are set as follows. There are two small holes located in the lower panel to the left of the input connector. See picture on the next page. A small probe such as a straightened paper clip is inserted into either hole to depress either of two switches below the panel. To set the year, month, date and time, depress and hold down the switch below the left hole and turn the amplifier POWER switch ON. The instrument will enter the Date/Time setting mode and will print instrument information including the current year, month, date, and time. Pressing the switch below the left hole with the paper clip will decrement the year and pressing the switch below the right hole will increment the year. The number of times that the switch is depressed controls the amount of change. Turning the chart switch from OFF to ON to OFF will reprint the selected year. Again, the year can be changed by depressing the switches below the left or right holes. Turning the chart switch from OFF to ON to OFF without depressing either the left or right switches will advance the settings mode to the next unit (year, month, day, hour, minute). Turning the Amplifier switch “Off” will exit the setting mode.
- 2. “ARM” Delay Start Function** The Enhanced Model M has a new mode of operation that has been added to facilitate operation in normal or hazardous environments with a one-person crew. The Model M chart drive will not be actuated until the gas gun initial pulse is generated and the electronics senses the gas gun initial pulse. When the “ARM” button is depressed and held down while the chart drive is turned on, and the chart drive will not run until the electronics senses the large initial gas gun pressure pulse. The chart drive will not activate when the chart drive switch is turned on. A data delay memory system is present in the Model M electronics that saves data for later printing. When the shot is detected by the electronics, the chart will be started and the header will be printed followed by the delayed acoustic data beginning with the last second of acoustic background noise before the shot was detected. Then, the Model M prints acoustic data of the initial pulse and the reflected acoustic signal until the chart drive is switched “Off” or 30 seconds maximum. Auto and manual gains are operational but response is delayed by the memory system. **IMPORTANT:** wait at least 5 seconds after the “ARM” button is depressed while the chart drive is switched on for the system to measure background noise before actuating the gas gun pulse. When using CSA and ATEX certified equipment, the Model M is to be 25’ from the well in a “safe” area and connected by a single coaxial cable to the Certified Compact Gas Gun or Certified 5000 Psi Gas Gun.
- 3. Chart Header** The chart header is supplied from the Echometer factory with the following information showing instrument identification and also the second insert below showing well analysis. A switch on the processor circuit board permits selection of just the first header if desired. This header shows the ID, Version of software in the unit, Serial Number and other information. The header also shows the POWER ON/SELF TEST and immediately below, indicates whether the unit did PASS or FAIL the self test. Thus, the external test connector and the test pushbutton on earlier units have been eliminated. Please refer to the sample chart shown below for an example of a PASS test. Immediately below the self test, the Battery voltage is displayed. The unit can be charged every night without damaging the battery using the supplied Echometer AC charger; or, the unit can be charged when the battery voltage drops to 11.5 volts.

ECHOMETER MODEL M V2.0.1  
 SERIAL NO: 5115  
 ECHOMETER COMPANY  
 5001 DITTO LANE  
 WICHITA FALLS, TEXAS 76302  
 PHONE 940 - 767 - 4334  
 FAX 940 - 723 - 7507  
 E-MAIL INFO@ECHOMETER.COM

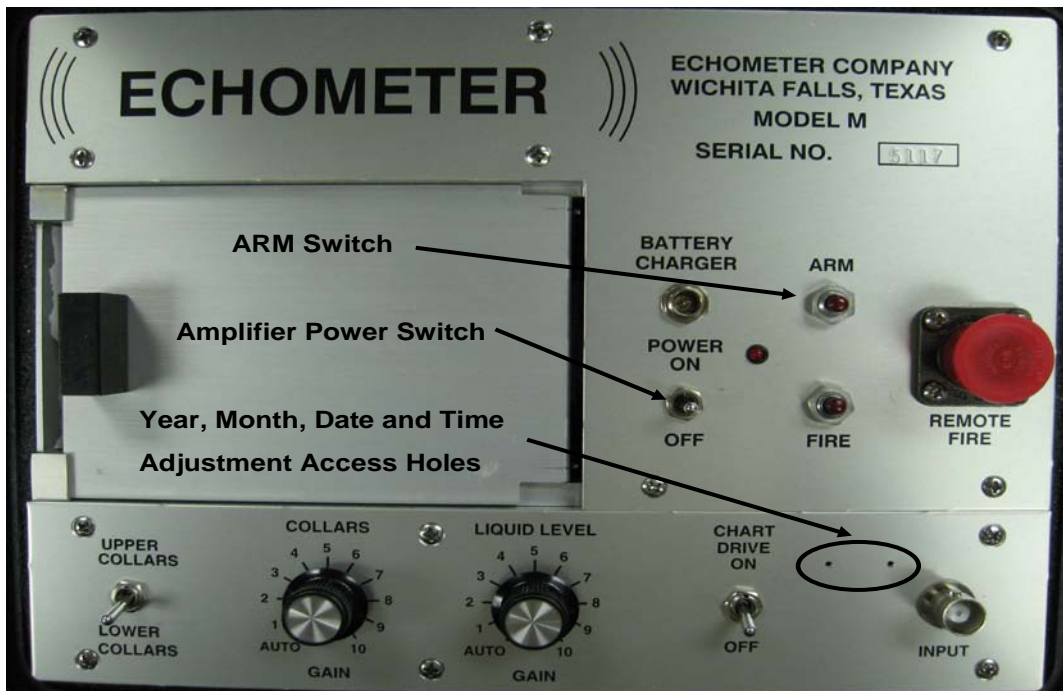
POWER ON  
 SELF TEST  
 PASS  
 REF 1.183 V  
 BATTERY  
 12.3 VOLTS

TURN  
 ON  
 CHART  
 DRIVE  
 TO  
 TEST  
 WELL

The special chart insert that follows the initial heading above allows the operator to indicate the producing rate efficiency and maximum production rate by hand input of the casing pressure and casing pressure build up rate along with other information to perform a well analysis that is hand written onto the chart itself. The software program "Analyzing Well Performance 2000" (for calculating the production rate efficiency and maximum production rate) can be downloaded from [www.echometer.com](http://www.echometer.com). Contact John Ryan at 940-767-4334 Ext 22 or email [John@echometer.com](mailto:John@echometer.com) for written instructions if you desire to delete the following from the chart header.

WELL .....	JOINTS TO LIQUID.....
CASING PRESSURE.....	DISTANCE TO LIQUID.....
$\Delta P$ .....	PBHP .....
$\Delta T$ .....	SBHP .....
PRODUCTION RATE.....	PROD RATE EFF, % .....
	MAX PRODUCTION .....

**Remote Fire Gas Gun** When both collar and liquid level gain controls are set to the "AUTO" position, the Model M will automatically provide a fire signal to the Remote Fire Gas Gun after the chart drive is turned ON. When manual gain settings are used, the FIRE pushbutton is used to provide a fire signal to the Remote Fire Gas Gun. The recorder must be connected to the Remote Fire Gas Gun solenoid by the proper Echometer cable.



# 4 - Operation

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Operation of the instrument is simple. First the acoustic wellhead should be attached to the casing annulus valve, and the cable connected between the microphone and the instrument. The valve between the casing annulus and the flow line should be closed to prevent the casing annulus gas from venting into the flow line causing excessive noise.

## *General Recording Procedure*

When the power switch is turned on, a red LED light indicates that the battery is powering the electronics. The chart drive turns on and a header is printed as shown in Figure 3 in the appendix. Next, a system test is performed which also displays the battery voltage. If the battery voltage is low, a message to charge the battery is displayed. Then, the message is printed to "Turn on the chart drive to test well" and the chart drive stops until the chart drive switch is turned to the ON position. At this point the operator selects the type of collar response (filter) desired. Sharp upper collars can be selected for special applications such as shallow wells, irregular tubing length, dual tubing strings and other special applications. The lower collar position is selected for most deep wells especially with low casing pressure. Normally, both gain controls are set to the AUTO position and only changes from these settings are necessary for those cases when satisfactory recordings are not obtained in the automatic position. When the chart drive is activated, the form shown in Figure 4 is printed on the strip chart. This form is designed to insure that the operator will write all the pertinent information about the well and the test. This includes the well designation, the casing pressure, the casing pressure buildup rate and the latest well production test results. The universal coordinated time stamp is beneficial for tracking the sequence of shots and calculating the exact time interval between shots. The time interval is necessary when calculating rate of change in liquid level from which can be computed the well influx (or injectivity) rates or to compute pressure buildup rates. Next, the acoustic analysis form is printed on the strip chart. During the time that the forms are being recorded on the strip chart, the instrument measures the background noise on both channels and then analyzes the noise in terms of peak to peak amplitude and records the AUTO position when the chart drive is turned on, later adjustment of the gain control does not affect amplifier gain. Then, a message to generate the pulse is printed on the strip chart. When the shot is generated, the instrument detects the large signal and prints a vertical dotted line to mark zero time on the chart. Each second thereafter another mark is recorded and labeled with the corresponding elapsed time in seconds. If the "shot" is not detected by the electronics (which is indicated by the zero time mark), a larger pulse must be generated so that the electronics will detect the initial pulse. After the zero time mark is printed on the chart, operator adjustments of the gain control do not affect amplifier gain. This prevents the operator from increasing the gain, which might result in noise being mistaken for a liquid level kick. The operator turns off the chart drive after the liquid level response and other desired information is observed on the chart. The acoustic liquid level test can be repeated by reloading the gas chamber, turning on the chart drive, and generating another acoustic pulse. If the operator desires to manually select the amplifier gain, the gain control knob must be set at a value greater than one before the chart drive is turned on. The collar channel gain should be set so that the response is approximately 1/8 inch (3 mm) before the shot. The liquid level channel gain should be set so that the response is 1/16 inch (1 mm) before the shot. Operator adjustment of the gain control after the "shot" is detected and the zero time mark is recorded does not affect amplifier gain. If the recording level is excessive from downhole anomalies such as a tubing anchor or perforations, a lower gain setting should be used. Both channels may be set in AUTO gain setting mode or both in manual gain mode or one channel may operate in manual while the other is set to AUTO. Figure 5 shows two records. The upper record is with the filter setting on upper collars and the lower record shows the response when the filter setting is lower collars.

## *Operation of the Model M with the Compact Gas Gun*

The compact gas gun is to be operated in the COMPRESSION (Explosion) or 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.

1. Securely attach the Echometer Gas Gun to the **Casing Valve**.
2. Close the **Casing Pressure Bleed Valve** and **Filler Bleed Chamber Valve**.
3. Lift the **Cocking Arm** to close the internal gas valve. This prevents debris from entering the volume chamber.
4. Open the **Casing Valve** to the Echometer Gas Gun slowly and **Close** the casing valve to the flow line.
5. Measure the Casing Pressure using the precision pressure gauge.
6. Record **Time** and **Casing pressure**.
7. Fill the volume chamber with gas (CO<sub>2</sub> or N<sub>2</sub>) to at least **100-psi in excess** of the **Casing Pressure**.
8. Connect the coaxial cable from the microphone to the **Input** of the Model M.
9. Turn **Power Switch** to **ON**.
10. Select the type of collar response desired and set the gain controls to **AUTO**.
11. Turn **chart drive ON**.
12. Generate pressure pulse by pulling **Trigger Ring**, after “**Generate Pulse**” is displayed on chart.
13. Turn chart drive **OFF** after detecting the liquid level signal.
14. Inspect the record and repeat the shot if the signal quality is not satisfactory.
15. Turn power switch to **OFF** after operation.
16. Record **Time** and **Casing Pressure**.
17. **Close** the Casing Valve between Echometer Gas Gun and the well.
18. Open the **Casing Pressure Bleed Valve** and release the pressure.
19. Open the Casing Valve to the flow line.
20. Remove the Echometer Gas Gun from the casing 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.

1. Securely **attach** the Echometer Gas Gun to the **Casing Valve**.
2. Close the **Casing Pressure Bleed Valve** and **Filler Bleed Chamber Valve**.
3. Open the **Casing Valve** to the Echometer Gas Gun slowly and **Close** the casing valve to the flow line.
4. Pull **Trigger Ring**.
5. Lift the **Cocking Arm** to close the internal gas valve.
6. Measure the Casing Pressure using the precision pressure gauge.
7. Record **Time** and **Casing Pressure**.
8. **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 casing pressure reading. Use greater or less differential pressure depending on the quality of the recording.
9. Connect the coaxial cable from the microphone to the INPUT of the Model M.
10. Turn **Power Switch** to **ON**.
11. Select the type of collar response desired and set the gain controls to **AUTO**.
12. Turn **chart drive ON**.
13. Generate pressure pulse by pulling **Trigger Ring**, after “**Generate Pulse**” is displayed on chart.
14. Turn chart drive **OFF** after detecting the liquid level signal.
15. Inspect the record and repeat the shot if the signal quality is not satisfactory.



16. Turn power switch to **OFF** after operation.
17. Record **Time** and **Casing Pressure**.
18. **Close** the Casing Valve between Echometer Gas Gun and the well.
19. Open the **Casing Pressure Bleed Valve** and release the pressure.
20. **Open** the Casing Valve to the flow line.
21. Remove the Echometer Gas Gun from the casing valve.

## *Operation of the Model M with the Remote Fired Gas Gun*

The main differences in operating procedure are that the Remote Fired Gas Gun initial pulse is generated by depressing the Remote Fire Button on the control panel, and that this gun can only be used in the Compression (Explosion) Mode.

1. Securely attach the Echometer **Remote Fire Gas Gun** to the **Casing Valve**.
2. Charge the gas **chamber** to at least 100-psi in excess of the estimated well pressure to prevent debris from entering the volume chamber and the solenoid dart valve assembly.
3. Close the gas gun's **Casing Pressure Bleed Valve**.
4. Open the **Casing Valve** to the Remote Fire Gas Gun slowly.
5. **Close** the casing valve to the flow line.
6. Measure the casing pressure using the precision pressure gauge.
7. Record **Time** and **Casing Pressure**
8. Verify that the volume chamber pressure is at least **100-psi in excess** of the **Casing Pressure**.
9. Connect the coaxial cable from the microphone to the **Input** of the Model M.
10. Connect the remote fire cable from the gun to the REMOTE FIRE connector.
11. Turn **Power Switch** to **ON**.
12. Select the collar **FILTER** and set the gain controls to **AUTO**.
13. Turn **chart drive ON**.
14. **Generate pressure pulse** by depressing the Remote Fire **button** for approximately one second to insure full opening of the solenoid valve.
15. Turn chart drive **OFF** after detecting the liquid level signal.
16. **Inspect** the record and repeat the shot if the signal quality is not satisfactory
17. Turn power switch to **OFF** after operation.
18. Record **Time** and **Casing Pressure**.
19. **Close Casing Valve** to the Remote Fire Gas Gun.
20. Open the **Casing Pressure Bleed Valve** and release the pressure.
21. Open the Casing Valve to the flow line.
22. **Disconnect** cables and remove the Echometer Gas Gun from the casing valve.

### NOTES

1. On deep, low pressure wells; first select the lower collar position.
2. If the initial pulse is not detected which is indicated by the zero timing mark, use a larger initial pulse.
3. If the liquid level is not detected (especially in deep wells with low casing pressure), the volume chamber pressure should be increased in increments of 300-psi up to the limit of the available gas supply.
4. Do not use a larger volume chamber pressure than needed. Operating the gas gun at 300-psi requires twice as much gas as when operating at 150-psi. Only one half as many shots will be obtained from a gas cylinder.
5. When using CO<sub>2</sub> gas above 300-psi (at normal temperatures), liquid may form in the gas gun, which will result in considerably more gas being used per shot.
6. When using nitrogen gas, use a regulator so that the pressure will not exceed the working pressure rating of 1500-psi.

## *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° 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.

Proper sensitivity setting is very important. Select the AUTO gain setting for the first shot. The background noise level is indicated on the chart. Surface vibrations, leaking gas connections, gas “popping” out of the gas/liquid interface and other unstable conditions, cause this noise. This background noise is not a part of the signals when the pressure wave is generated. The instrument will automatically record the background noise at a low level and larger collar and liquid level signals will be recorded at larger amplitudes, which simplifies the interpretation of the chart. When operating in the AUTO mode, adjusting the sensitivity after the chart drive is tuned ON does not change the automatic gain selection made by the electronics and software.

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 down-hole 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 down-hole 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.

## *Automatic Gain Setting (AGS) Mode Characteristics*

The Echometer Model M uses a microprocessor, which is programmed to evaluate the signal level before the shot and set the amplifier gain as necessary to optimize the quality of the recording. The AGS mode on either or both channels is activated by selecting the AUTO position before the chart drive is turned ON. Both channels are normally operated in the AUTO mode. Changing the gain control setting from AUTO after the chart drive is turned ON will not affect the amplifier gain. In both channels, the AUTO mode detects the noise level in the well and adjusts the GAIN SETTING of both amplifiers so that the noise signal is recorded at a width of  $\frac{1}{8}$  inch on the collar channel and  $\frac{1}{16}$  inch on the liquid level channel. The noise level in mV peak-to-peak and the gain settings (such as A: 7.1) is printed on the header just before the legend "GENERATE PULSE" is printed. The "A:" signifies the system was in the AUTO gain setting mode and the "7.1" indicates the gain setting.

## *Manual Gain Setting (MGS) Mode Characteristics*

MANUAL gain setting mode is selected by locating the gain control knob to a value greater than 1 before the chart drive is turned ON. When the acoustic traces are displayed, adjust the gain on the collar channel until  $\frac{1}{8}$  inch response is obtained. Adjust the liquid level channel gain control until  $\frac{1}{16}$  inch response is obtained. Lower gain settings may be beneficial when the traces are over-driven. Higher settings on the liquid level channel, so that the background noise is  $\frac{1}{8}$  inch, may be beneficial if the liquid level response is weak. The gain controls should not be adjusted after the initial pulse is generated. Both channels can be set to manual mode, or either channel can operate in manual mode while the other channel is in AUTO mode, or both channels can be set to AUTO mode.

## *Collar Channel Automatic Gain Control (AGC)*

The **gain** of the COLLAR channel amplifier is **automatically controlled** so that the signal level is maintained at 0.6 inch peak to peak until the amplifier gain is increased to the setting that results in the background noise being recorded at an amplitude of 1/8-inch. This results in a record showing collars at an amplitude of 0.6 inch when strong collar signals are received. When the collar signal level fades to the background noise level or less, the collar trace and noise will be recorded at 1/8-inch, which indicates to the operator that collars are no longer distinguishable on the trace.

## *Liquid Level Channel Gain Control*

When operating in the AGS mode, that is, the liquid level gain control is in the AUTO position before the chart drive is turned ON, the LIQUID LEVEL channel amplifier gain **is kept fixed at the setting** that is established automatically by measurement of background noise prior to the shot. AGC is not used. For large, reflected signals after the shot, the liquid level channel recording will show that these peaks and valleys are clipped. This method will insure that even low amplitude reflections caused by minor changes in cross section of the annulus (or tubing) as well as the liquid level signal from deep low-pressure wells will be detected as long as their amplitude exceeds the noise level. Adjusting the liquid level gain control after the chart drive is turned ON will not affect the amplifier gain in the AUTO mode.

When operating in the MGS mode, that is, the liquid level gain is set greater than 1 before the chart drive is turned ON, the liquid level gain control should be manually set so that the noise response is  $\frac{1}{16}$  inch before the shot. The gain control knob controls the gain. AGC is not used. On deep low-pressure wells, the manual gain control can be set so that the background noise is recorded at  $\frac{1}{8}$  inch before the shot is desired. If reflections from downhole anomalies are excessive, use a lower gain setting. In manual gain mode, the proper gain should be set before the initial pulse is detected by the electronics, which is indicated by the zero timing mark. When the initial pulse is detected, the electronics maintains the gain setting selected by the operator at the time of the pulse detection, and does not permit an increase in gain by the operator, which could result in the background noise being amplified and mistaken for the liquid level.

## 5 - Interpretation

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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 chart 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 charts the collars can be distinguished from the beginning of the chart to the liquid level signal and all the collars can be counted. The most accurate procedure is to use the eleven point dividers and to mark off groups of ten collars directly on the chart. On other charts 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 extrapolate the count to the liquid level, using the eleven point dividers set on the last collar spacing. 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.

On both channels, the direction of kick indicates enlargements and reductions in the cross sectional area of the annulus (or internal diameter of pipe if shooting down tubing). For an explosion signal, objects which reduce the cross sectional area of the annulus result in compression reflections and are recorded as downward kicks when the top of the chart is at the left of the operator. 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. If an implosion pulse is used, then the responses will be reversed from those of an explosion pulse.

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

For the explosion pulse 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 recorder is still running. 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.

## 6 - Problem Wells

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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. The gain controls permit an actual measure of extraneous noise as described in Section 4.

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 chart 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 chart. 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.

# 7 - Battery and External Power Information

The Echometer Model M instrument will operate from the self-contained rechargeable battery or from a power cord, which is plugged into an automobile cigar lighter or is connected to an external 12-volt battery.

A sealed, rechargeable, lead cell, 2.5 amp/hour internal battery is used in the Echometer Model M instrument. The battery is similar to a 12 volt sealed automobile battery. The battery charger provided with the unit permits charging the battery from an AC power outlet. Either a 110 VAC or a 220 VAC unit can be specified at the time of ordering. The battery charger will charge the battery at a rate of 500 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 is OFF. Approximately 7 hours are required to charge a fully discharged battery. Continuous charging does not damage the battery.

When operating with the cigar lighter power cord, a low battery will be partially charged by an operating automobile system in 5 to 10 minutes and will be completely charged if the car is driven for four hours.

The battery should be charged when the operating voltage printed on the header of the strip chart drops to about 11.3 volts. 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.

Temperature °F	Temperature °C	Battery Life, Hours
104	40	4
77	24	3.5
32	0	3
-4	-20	2

The battery should be charged when the operating voltage printed on the strip chart drops to about 11.3 volts. Charging more often will improve battery life. A message to charge the battery is printed on the strip chart when the voltage drops to 11 volts. The amplifier current drain is 330 ma. The amplifier, chart drive, and print head current drain is approximately 800 ma. A fully charged battery in good condition should perform more than 200 tests before the battery will require recharging. The battery is rated at 2.5 amps/hour.

Long storage periods without charging will severely reduce service life. An unused, fully charged battery will discharge in 6 months at 113°F, in 15 months at 77°F (20°C) and in 50 months at 23°F (-5°C). A discharged battery deteriorates rapidly. Experience has indicated that the battery should be recharged at least monthly using the AC charger. Charging the battery before it is fully discharged will result in longer battery life.

## Battery Sulfonation

A very deeply discharged battery may not accept a charge normally. The red light on the AC charger does not come on when the AC charger is attached. After a period of time, up to 6 hours, the red light will come on indicating that charging has started. After 7 hours the red light will go out indicating the battery is charged. In some cases a battery will not accept a charge and will require replacement.

## *Important Notes and Instructions for Rechargeable Batteries*

The battery is rated at 2.5 Amp-Hour. The Model M current drain with the chart drive on is 1 Amp. Thus the battery operating ON-time is approximately 2.5 hours and the unit would use about five rolls of paper.

- 1 - Charge battery before using. Use ONLY the CHARGER that is provided with the Echometer Model - M.
- 2 - When not in use for extended periods of time, remove battery from the instrument and store in a cool dry place or leave the AC charger connected continuously.
- 3 - Do not short-circuit the battery terminals.
- 4 - Keep away from fire and do not incinerate when disposing of battery ... it may explode.
- 5 - Under no circumstance should you attempt to open the battery case.
- 6 - Do not expose battery to moisture or rain.
- 7 - Do not drop, hit or abuse the battery, because it will break and may release electrolyte as well as expose cell contents, which are corrosive.
- 8 - It is perfectly normal for the battery 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 1000 charge-discharge cycles.
- 11 - New batteries may require four or five charge-discharge cycles before achieving their designated capacities.
- 12 - Sealed lead-acid batteries may be stored as long as 12 to 18 months in a cool dry place. They should be recharged every 6 months.
- 13 - Always fully charge the battery before using it after it has been stored for over one week.

# 8 - Testing/Troubleshooting

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The Echometer Model - M has an internal test circuit, which is used to verify that the electronics and the acoustic cable 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 strip chart. (See Appendix Example).

In addition a test switch and connector allows testing the microphone cable in addition to the electronic circuits. Connecting the microphone cable from the TEST connector and to INPUT connector will verify that the cable is not open or shorted out.

After checking the operation of the electronic circuits the microphone sensitivity should be checked.

## *Amplifiers Check*

This test verifies the proper response and gain of the liquid level and collars amplifiers. See Appendix.

## *Filters Check*

This test verifies the proper response of the Upper collars and Lower collars filters. See Appendix.

## *Microphone Cable check*

This test verifies the integrity of the microphone cable. See Appendix.

## *Microphone Check*

Proper operation and sensitivity of the microphone can be verified with this test. See Appendix.



# 9 - Maintenance

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The Echometer Model –M 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 Remote Fire Gas Gun in the EXPLOSION mode (the preferred mode of operation) 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<sub>2</sub>S) 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 exist. 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 derated 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. Derate 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 times, 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<sub>2</sub> or N<sub>2</sub>) 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.

## *Remote Fire Gas Gun Pressure Rating*

The pressure rating of a NEW Remote Fire gas gun is 1500-psi. After the gun has been used, its pressure rating should be derated by the operator depending on the condition of the gun. The Remote Fire Gas Gun may have internal and external corrosion, deep external wrench marks, 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. Derate 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 Remote Fired Gas Gun cannot be used in the implosion mode. In order to protect the internal parts, the gas chamber should be charged to a pressure of at least 200-psi or a pressure greater than the well pressure (if known) before installing the gas gun onto the casing valve. This will insure that debris will not be admitted into the solenoid/dart valve mechanism. This will greatly reduce the need for maintenance.

## *Remote Fire Gas Gun Disassembly and Assembly Special Precautions*

When disassembling DO NOT REMOVE the MICROPHONE unless results of the troubleshooting tests have shown that it is not operational.

All internal parts can be accessed from the end where the volume chamber is attached.

Removing the volume chamber will expose the retaining nut that gives access to the gas valve. Remove with a socket wrench. Use the threaded rod (provided with the repair kit) to pull the gas valve from the housing. Inspect and replace if needed. Replace the "O" rings as needed.

All other connectors, ports, and the solenoid valve can be serviced without need to remove the volume chamber.

# 10 – Calculation of Bottomhole Pressures

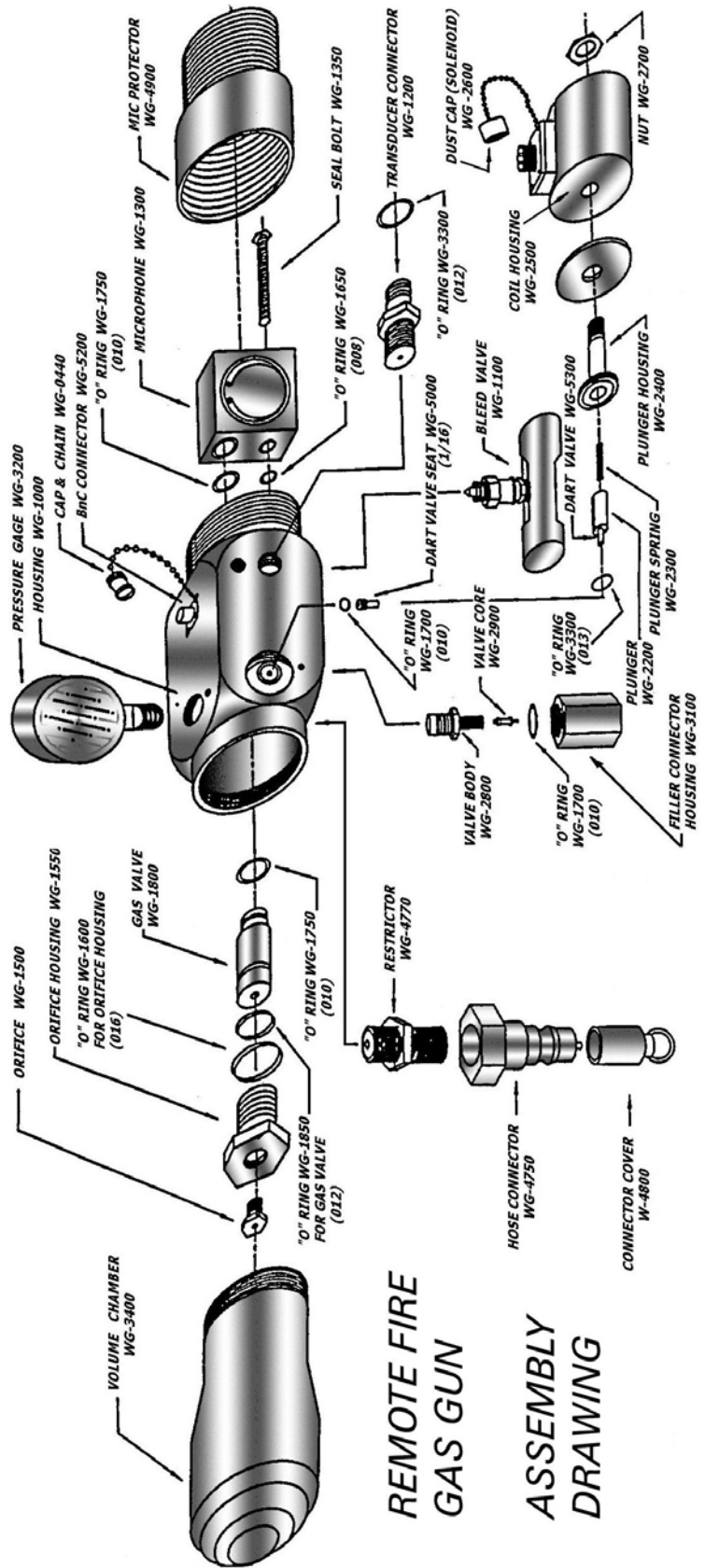
Bottomhole pressure calculation in static and producing wells is described in technical papers and is facilitated by the use of software, which is supplied with the Echometer Model M. Details of the calculation methods used by the software are found in technical papers on the internet at [www.echometer.com](http://www.echometer.com). Various versions of the programs are available for use in conjunction with DOS and Windows based computers. The available programs include:

BHP and AWP in DOS for calculation of static and producing BHP  
AWP2000 for Windows 9x, ME, NT, 2000 and XP for calculation of static and producing BHP can be downloaded for free from the Echometer Web page, [www.echometer.com](http://www.echometer.com).

The programs have been designed to be easy to use and they require a minimum of data. The user should however remember 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.



**FIGURE 1b - REMOTE FIRE GAS GUN  
ASSEMBLY DRAWING**



Panel shown is serial number 4999 and below.

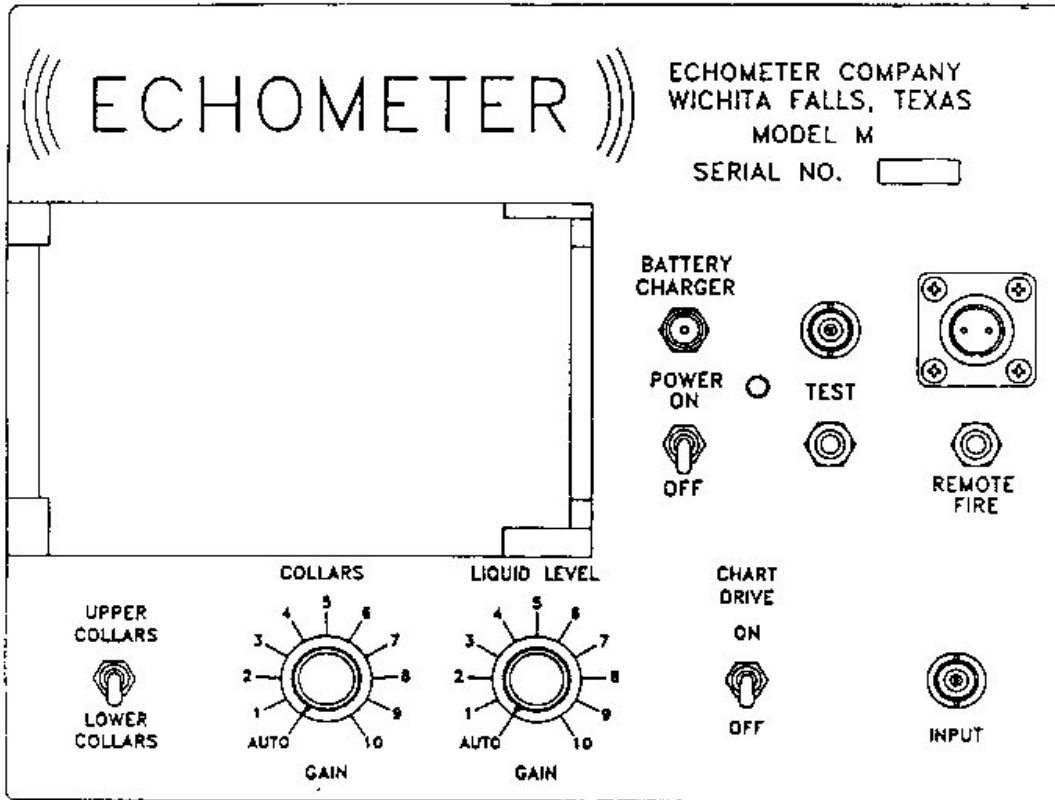
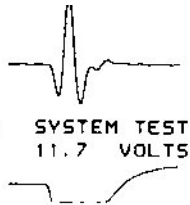


FIGURE 2 - ECHOMETER PANNEL

ECHOMETER MODEL M  
 SERIAL NO: 1457  
 ECHOMETER COMPANY  
 5001 DITTO LANE  
 WICHITA FALLS, TEXAS 76302  
 PHONE 940 - 767 - 4334  
 FAX 940 - 723 - 7507  
 E-MAIL INFO@ECHOMETER.COM



On units above serial number 5000, the test traces at left are replaced by notation of SELF TEST PASS or FAIL.

TURN ON CHART DRIVE TO TEST WELL

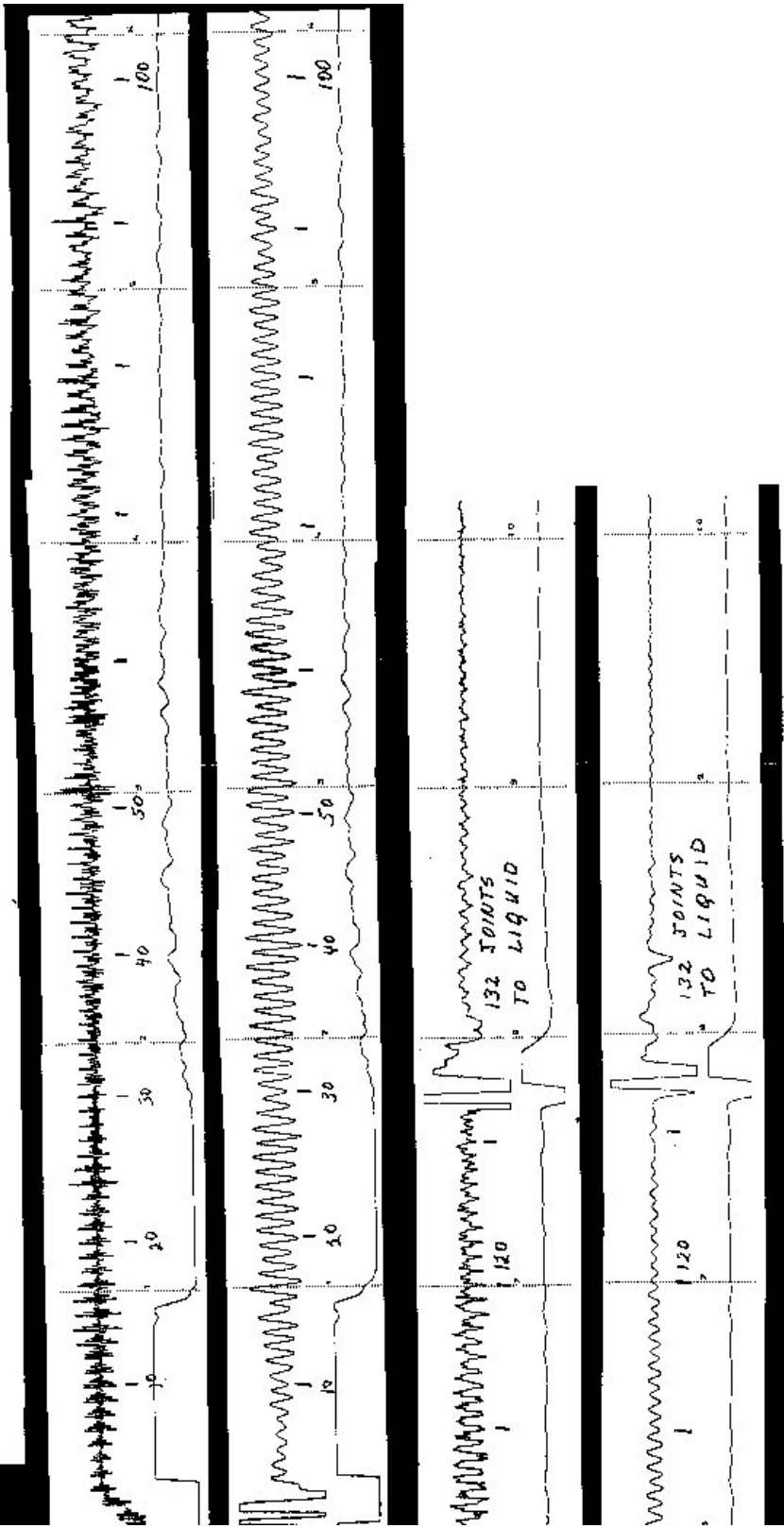
FIGURE 3 - INITIAL HEADER AND SYSTEM TEST (SHOWN 1/2 SCALE)

WELL .....	JOINTS TO LIQUID.....	COLLAR P-P mV.O. 188	GENERATE PULSE
CASING PRESSURE.....	DISTANCE TO LIQUID.....	LOWER	
ΔP .....	PBHP .....		
ΔT .....	SBHP .....		
PRODUCTION RATE.....	PRD RATE EFF. % .....		
20:09:34 UTC 07/28/1997	MAX PRODUCTION .....	LIQUID P-P mV.O. 273	11.6 VOLTS

FIGURE 4 - DATA INFORMATION FORM AND TIME STAMP

The top chart was obtained with the filter set to upper collar position. The collar spikes contain high frequency energy. The lower chart was obtained in lower collar position and the collar responses are filtered using a medium frequency filter.

WELL **UPPER COLLARS**  
 CRISING PRESSURE..... 7.0  
 ΔP..... 1.8  
 ΔT..... 3  
 PRODUCTION RATE..... 2.0  
 12:08:06 UTC 07/31/1997  
 JOINTS TO LIQUID..... 132  
 DISTANCE TO LIQUID..... 0.097  
 FBHP..... 1.46  
 SBHP..... 1.46  
 PROD RATE EFF. %..... 2.7  
 MAX PRODUCTION..... 2.7  
 COLLAR P-P mV 0.097  
 RI 9.5  
 UPPER  
 LIQUID P-P mV 0.194

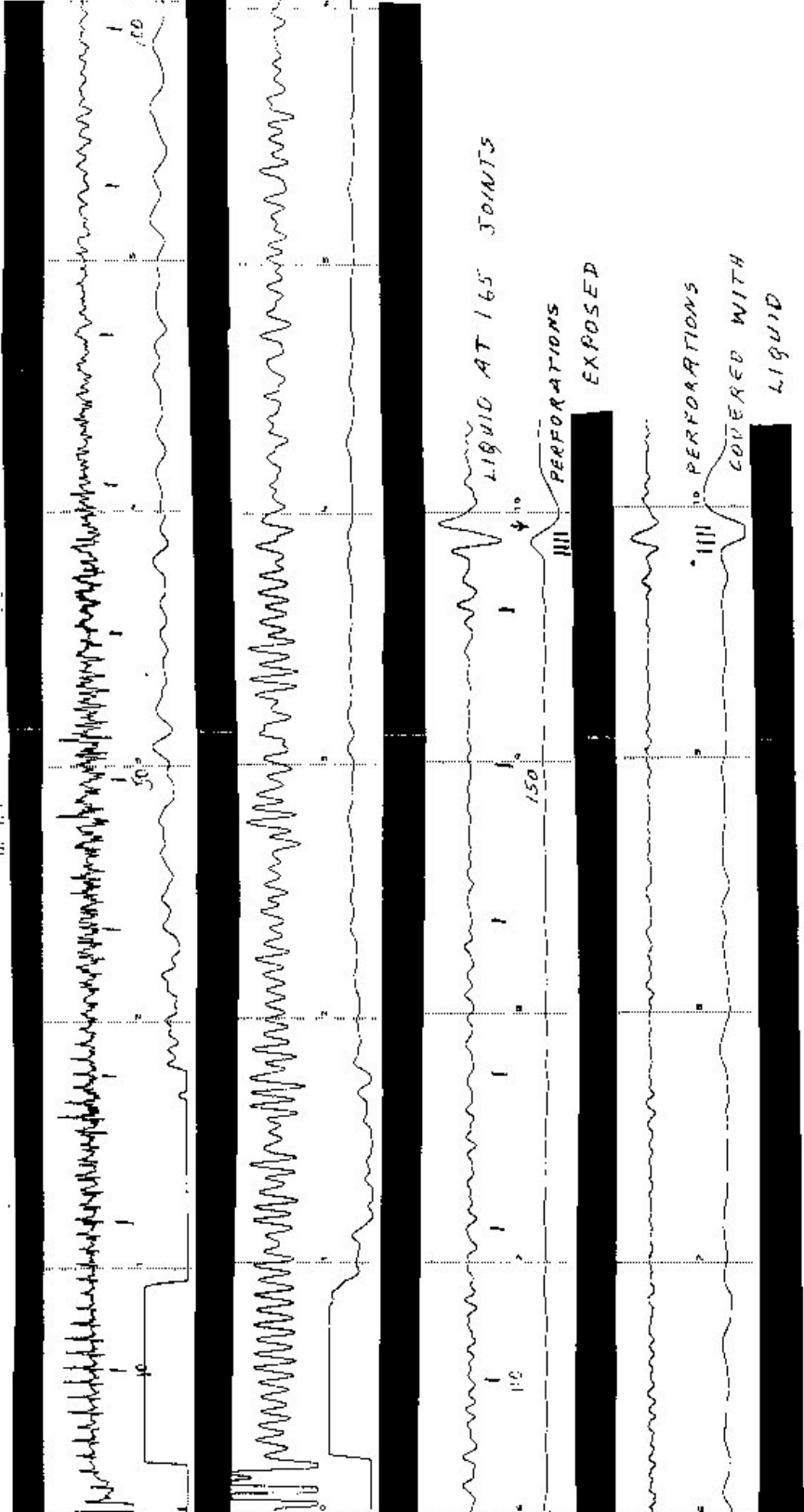


WELL **LOWER COLLARS**  
 CRISING PRESSURE..... 7.0  
 ΔP..... 1.8  
 ΔT..... 3  
 PRODUCTION RATE..... 2.0  
 12:12:21 UTC 07/31/1997  
 JOINTS TO LIQUID..... 132  
 DISTANCE TO LIQUID..... 0.184  
 FBHP..... 1.46  
 SBHP..... 1.46  
 PROD RATE EFF. %..... 2.7  
 MAX PRODUCTION..... 2.7  
 COLLAR P-P mV 0.184  
 RI 9.8  
 LOWER  
 LIQUID P-P mV 0.621  
 GENERATE PULSE  
 VOLTS 11.6

Figure 5 UPPER/LOWER COLLARS ACCENTED

The first shot was in upper collar filter position. The liquid level was below the casing perforations. The casing perforations are indicated by an upward kick. The liquid level is immediately below the perforations. The well was shut down for 53 minutes, and the liquid level rose above the perforations. The liquid level response is indicated by a downward kick. Please refer to the charts.

WELL: *PHAMEL* 100111  
 COLLAR P-P: 165  
 Casing Pressure: 60  
 DISTANCE TO LIQUID: 250  
 R: 9.5  
 P-RP: 11  
 S-RP: 12.5  
 PROD RATE EFF. %: 30  
 MAX PRODUCTION: 200  
 11:39:28 UTC 07/31/1997



WELL: *PHAMEL* 100111  
 COLLAR P-P: 165  
 Casing Pressure: 60  
 DISTANCE TO LIQUID: 250  
 R: 9.5  
 P-RP: 11  
 S-RP: 12.5  
 PROD RATE EFF. %: 30  
 MAX PRODUCTION: 200  
 12:32:07 UTC 07/31/1997

Figure 6 Prove liquid Level



Refer to the INTERPRETATION section of the OPERATOR'S MANUAL for an analysis of this chart. The liner can serve as a marker if the operator knows that the liner is in the well.

WELL: .....  
 CRISING PRESSURE: .....  
 AP: .....  
 AT: .....  
 PRODUCTION RATE: .....  
 17:56:10 UTC 07/11/1997

JOINTS TO LIQUID: .....  
 DISTANCE TO LIQUID: .....  
 FBHP: .....  
 SBHP: .....  
 PROD RATE EFF, %: .....  
 MAX PRODUCTION: .....

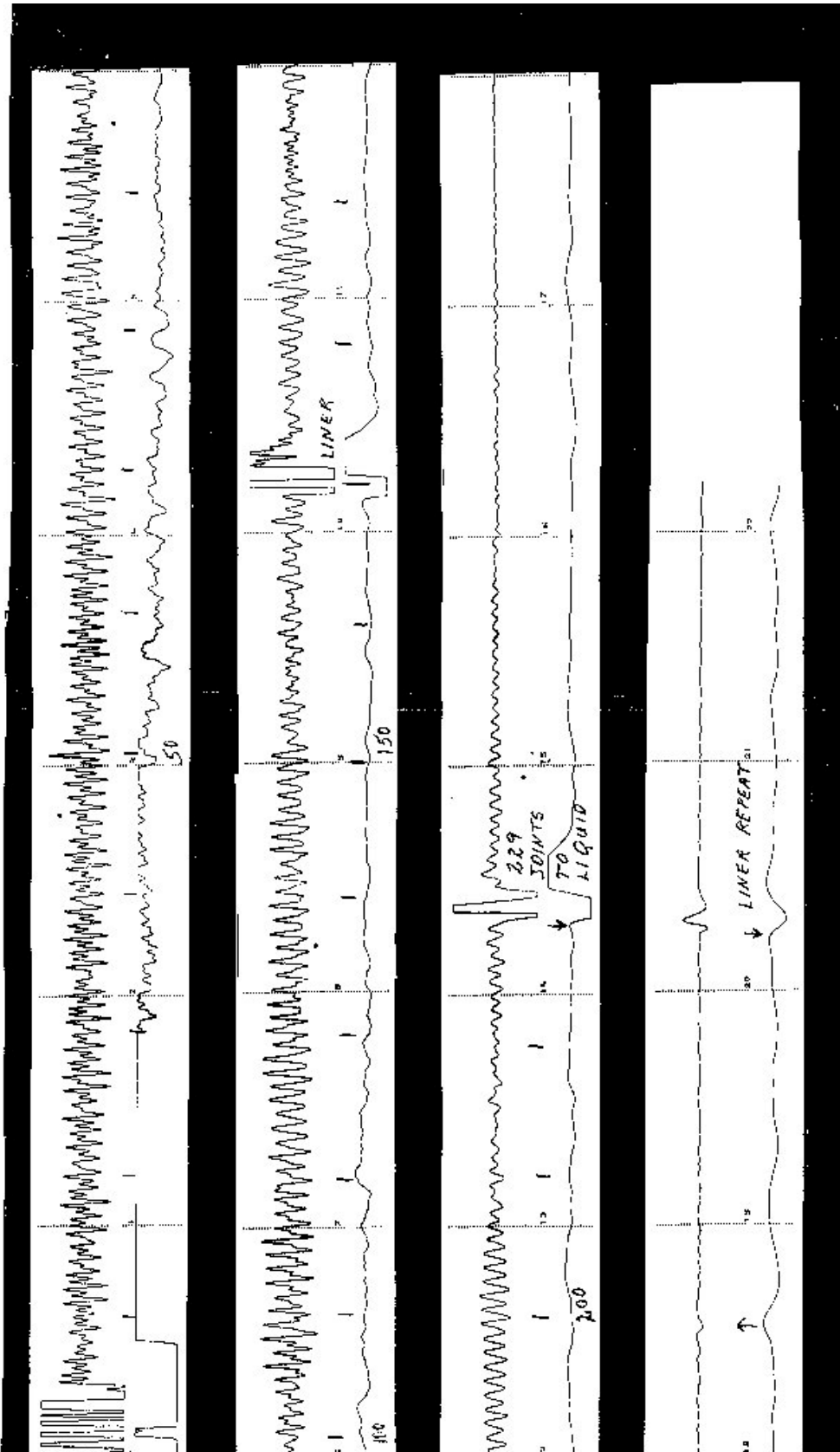
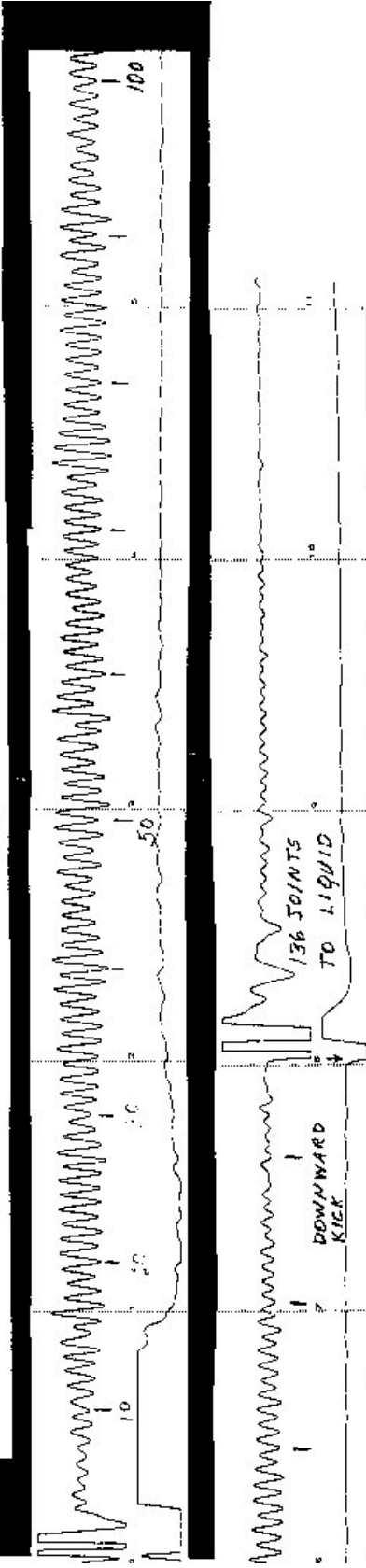


Fig. 7 - WELL WITH LINER

Figure 7 Well With Liner

WELLS COMPRESSION PULSE  
 CRASING PRESSURE..... 120  
 AT..... 10  
 PRODUCTION RATE..... 100 L/SO  
 12:53:52 UTC 07/31/1997  
 JOINTS TO LIQUID..... 136  
 DISTANCE TO LIQUID..... 316  
 P8HP..... 9.5  
 S8HP..... 3.0  
 AT..... 3.0  
 PROD RATE EFF. %..... 2.3  
 MAX PRODUCTION..... 330  
 COLLAR P-P mV 0.092  
 RI 9.5  
 LIQUID P-P mV 2.316  
 RI 5.3  
 GENERATE PULSE 11.5 VOLTS



WELLS RAREFACTION PULSE  
 CRASING PRESSURE..... 120  
 AT..... 10  
 PRODUCTION RATE..... 100 L/SO  
 12:53:15 UTC 07/31/1997  
 JOINTS TO LIQUID..... 136  
 DISTANCE TO LIQUID..... 316  
 P8HP..... 9.5  
 S8HP..... 3.0  
 AT..... 3.0  
 PROD RATE EFF. %..... 2.3  
 MAX PRODUCTION..... 330  
 COLLAR P-P mV 0.091  
 RI 9.5  
 LIQUID P-P mV 2.966  
 RI 5.8  
 GENERATE PULSE 11.4 VOLTS

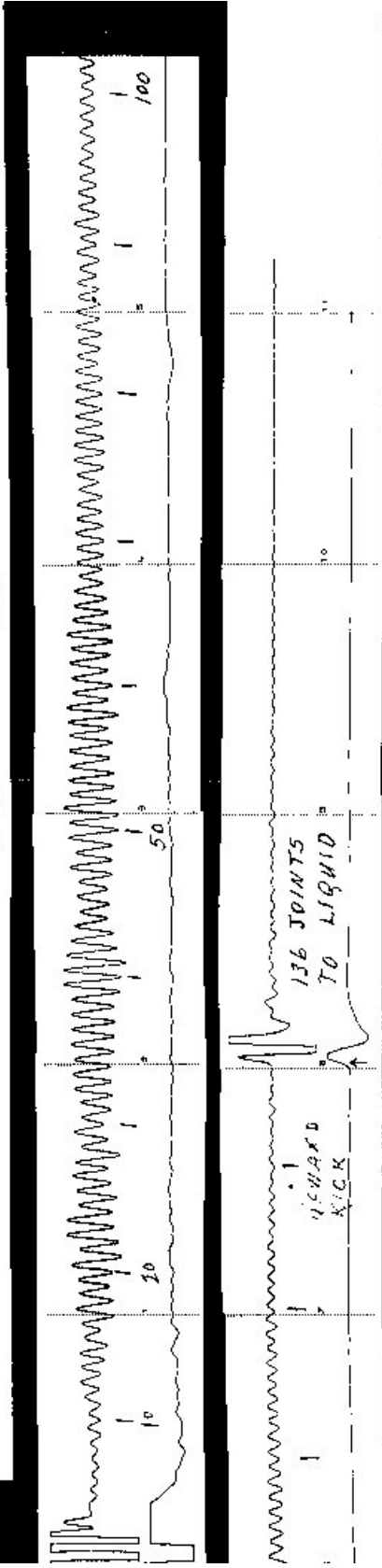


Figure 8 Records of Compression/Rarefaction Initial Pulse

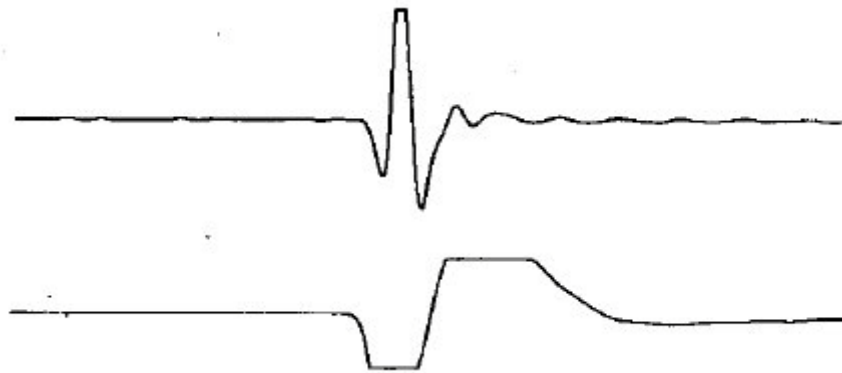
## ***ACOUSTIC RESPONSES FROM DOWNHOLE ANOMALIES***

Following are examples of the responses obtained from restrictions such as the liquid level and from enlargements such as perforations. The initial pulse generated by the gun is a compression (explosion) pulse; that is, the pressure in the gas gun volume chamber is in excess of well pressure. If the initial pulse were a rarefaction (implosion) pulse, the responses would be reversed.

### **COMPRESSION RESPONSE**

(Downward kick)

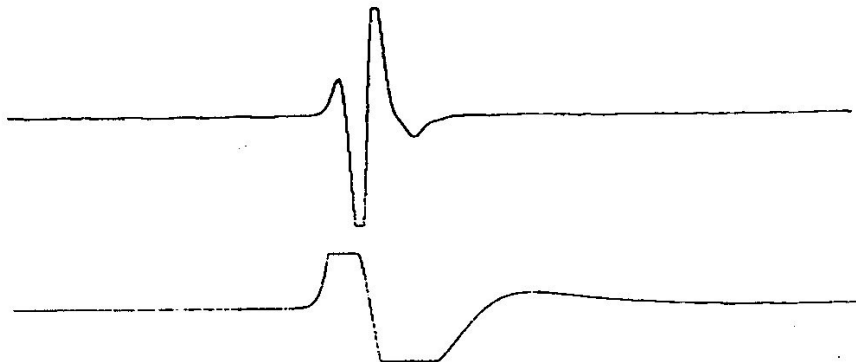
The liquid level, liners, gas mandrels and other anomalies causing a reduction in casing annulus area will cause a reflected signal back to the surface that will be of the same type as the initial pulse, which was a compression wave. The direction of the initial pulse is downward when the top of the chart is to the operator's left.



### **RAREFRACTION RESPONSE**

(Upward kick)

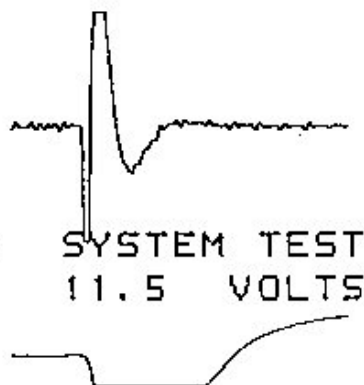
Perforations, "shot" holes, a reduction in tubing size and other anomalies causing an increase in casing annulus area will cause a reflected signal back to the surface that will be of the opposite polarity as the initial pulse. Thus, the response from these anomalies will be upward when the top of the chart is to the operator's left.



## Amplifiers And Filters Test

On Model M Recorders having serial numbers above 5100, the amplifiers and filters are checked automatically. After the power switch is turned on and the test has been performed, the message PASS or FAIL is recorded onto the strip chart. On units below serial number 5100, the amplifiers and filters are checked each time that the POWER switch is turned ON. The UPPER COLLARS filter is checked if the filter switch is in the UPPER COLLARS position. The LOWER COLLARS filter is checked if the filter switch is in the LOWER COLLARS position. Internally, an electrical pulse is applied to the input of the electronics so that the amplifiers, filters, microprocessor, battery, printhead and chart drive are tested. The test patterns displayed below are recorded if the battery and electronics are operating properly. The positions of the gain controls do not affect the recorded test patterns. The battery voltage is also displayed. Refer to Section 7 for information on proper battery voltage. The battery must be charged sufficiently to power the red LED light beside the power switch, the electronics and the chart drive motor. If the red LED does not light, the battery must be recharged or the 12-volt external power cord must be used before a proper test can be performed on the electronics system.

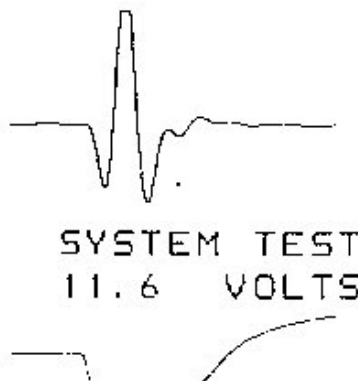
ECHOMETER MODEL M  
SERIAL NO: 1457  
ECHOMETER COMPANY  
5001 DITTO LANE  
WICHITA FALLS, TEXAS 76302  
PHONE 940 - 767 - 4334  
FAX 940 - 723 - 7507  
E-MAIL INFO@ECHOMETER.COM



UPPER  
COLLARS  
FILTER  
TEST

LIQUID  
LEVEL  
FILTER  
TEST

ECHOMETER MODEL M  
SERIAL NO: 1457  
ECHOMETER COMPANY  
5001 DITTO LANE  
WICHITA FALLS, TEXAS 76302  
PHONE 940 - 767 - 4334  
FAX 940 - 723 - 7507  
E-MAIL INFO@ECHOMETER.COM



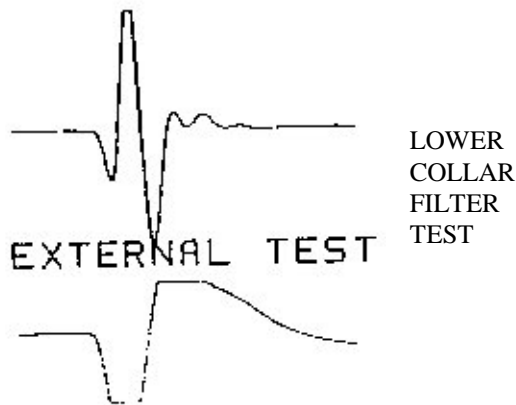
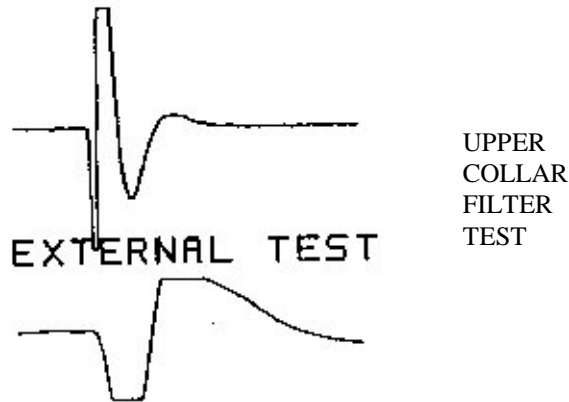
LOWER  
COLLAR  
FILTER  
TEST

LIQUID  
LEVEL  
FILTER  
TEST

## MICROPHONE CABLE TEST

On Model M Recorders having serial numbers above 5100, the microphone cable is tested in conjunction with the microphone test as described on the next page. On Model M Recorders having a serial number below 5100, the microphone cable can be tested using a special TEST circuit and TEST connector on the panel of the instrument. First, the Amplifier and Filter Check should be performed to insure that the electronics, chart drive and printhead are performing properly. Then, attach the microphone cable to the TEST connector and also to the INPUT connector. Turn the POWER switch ON. Verify that the SYSTEM TEST is as shown on the Amplifier and Filters Check in the Appendix. Wait for the chart drive to stop. Set the filter switch to UPPER COLLARS. Then, press the TEST button below the TEST connector. Next, set the filter switch to LOWER COLLARS. Then, press the TEST button again. The following records should be obtained depending upon the position of the filter selector switch. The chart drive is turned ON automatically; therefore, the operator should not turn ON the chart drive switch during this test. The positions of the gain control knobs do not affect this test. Always keep the connectors clean and the cable in good condition. The microphone cable and connectors can be a source of noise and cause faulty operation of the instrument.

Model M instruments having serial number greater than 5100 do not offer the microphone cable test.

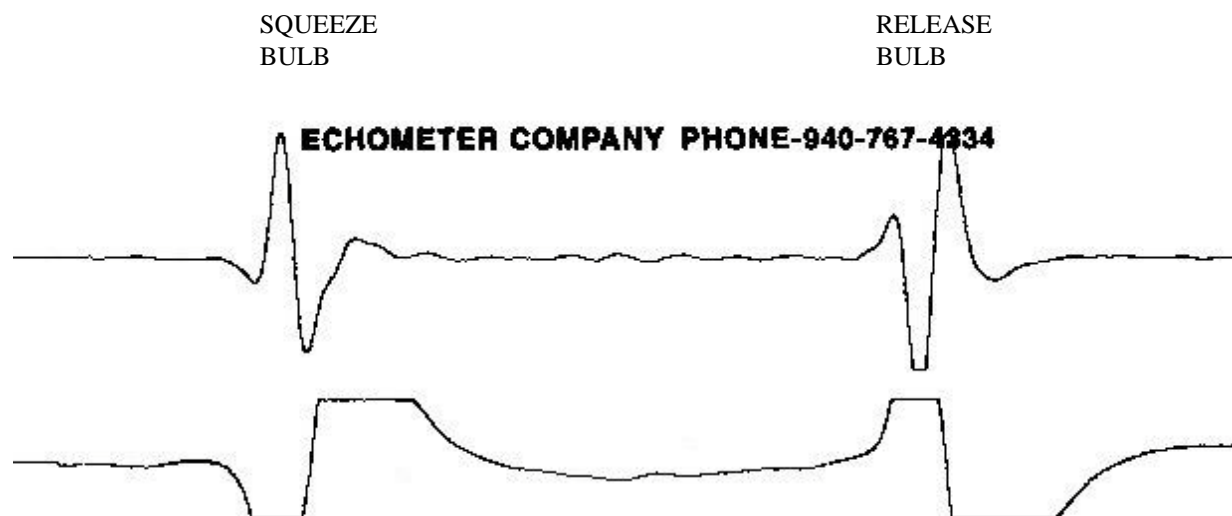


## *Microphone Test*

A microphone test can be performed after the Amplifiers and Filters Test has shown that the battery and electronics are performing properly, and the Microphone Cable Test indicates that the cable is operating 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, 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. When testing the Remote Fire Gun, close the gas valve by charging the volume chamber. 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. When testing the 15000-psi gun, rotate the gas valve control knob until the internal gas valve is shut. Then, close the casing bleed valve.

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. Set the sensitivity controls as shown below depending on which gas gun is to be tested. Turn the Power Switch ON. Set the filter switch to LOWER COLLARS. After the chart drive stops, turn the Chart Drive Switch ON. Squeeze the test bulb. Hold for approximately 1 second, and then release the test bulb. The response should be similar to the examples below.

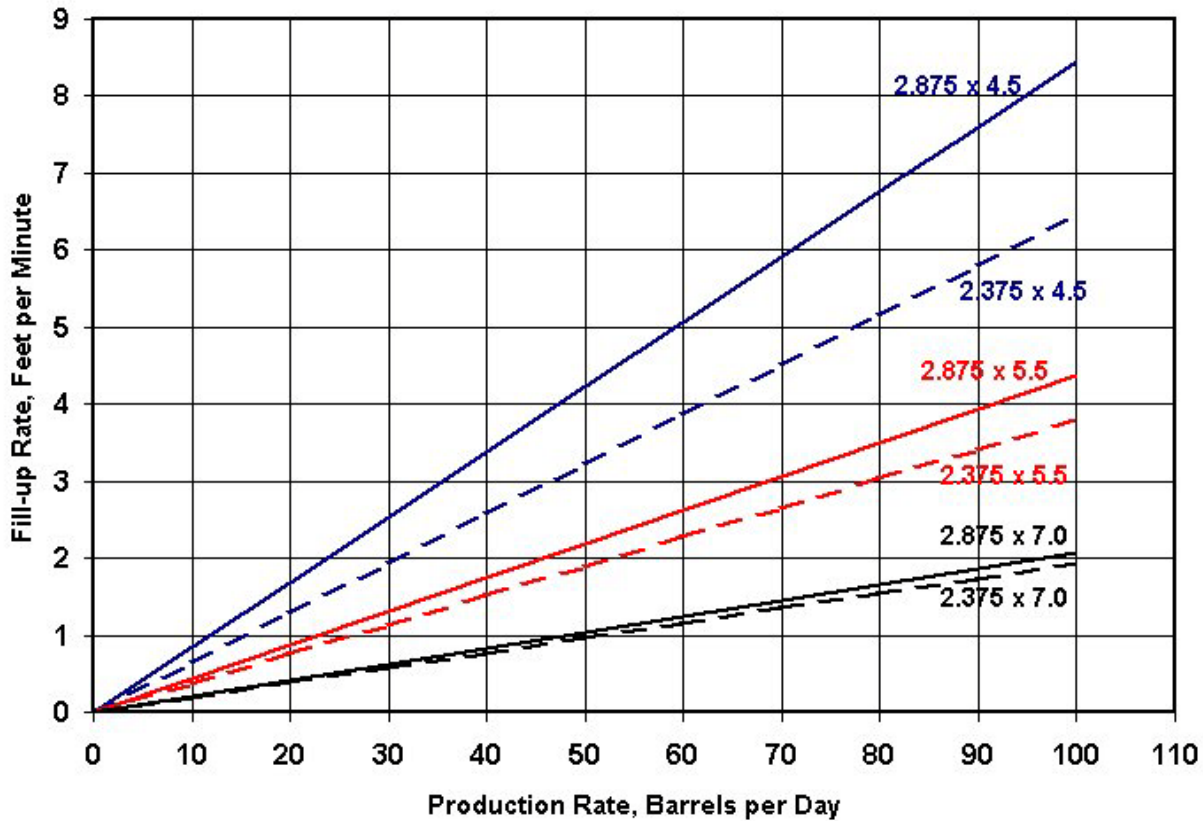
MODEL M SERIAL NO.	<u>BELOW 5100</u>		<u>ABOVE 5100</u>	
	COLLAR	LIQUID	COLLAR	LIQUID
	GAIN	LEVEL	GAIN	LEVEL
	SETTING	GAIN	SETTING	GAIN
		SETTING		SETTING
Compact Gas Gun	4	2	5 ½	5
Remote Fire Gas Gun	3 ½	1 ½	5	5
5000-psi Gas Gun	3	1 ½	5	6
15000-psi Gas Gun	3	1 ½	6	6



## 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 5½" casing is producing 60 BPD, the initial fill-up rate is 2.2 feet per minute. A well with 2½" tubing and 4½" casing, producing at 700 BPD will have an initial fill-up rate of 59 feet per minute.

**Fill-up Rate for Various Production Rates in Different Sizes of Pipe**



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 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% 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 is 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.

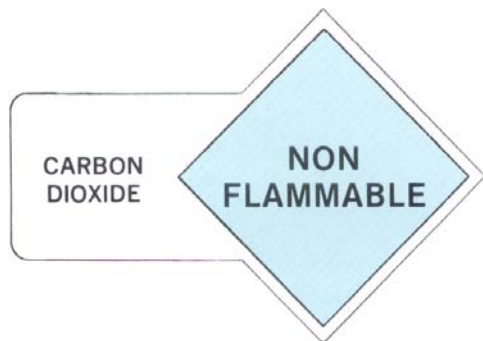


# CARBON DIOXIDE CYLINDER

Part No. GG0430 & GG0470

## CAUTION

- **DO NOT OVER FILL**, fill cylinder based on weight of CO<sub>2</sub>.
- 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°C). Keep out of reach of children.
- See details in operating manual.
- Have Cylinder pressure checked or replaced two years from date of purchase.



## CARBON DIOXIDE INFORMATION (CO<sub>2</sub>)

Carbon dioxide is a nonflammable, colorless, odorless, slightly acid gas. It is one and one-half times as heavy as air. CO<sub>2</sub> 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<sub>2</sub> liquid and gas are in equilibrium at a vapor pressure shown in the table below. For example, a Cylinder of CO<sub>2</sub> 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.

<u>Temperature</u>		<u>Pressure</u>	
°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<sub>2</sub> becomes a fluid. Liquid does not exist separate from gas. The pressure in the tank is an indication of the amount of CO<sub>2</sub> 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<sub>2</sub> in a cylinder is determined by weighing the cylinder containing the CO<sub>2</sub> and then subtracting the weight of the empty cylinder which is shown on the cylinder. Below 88°F, the amount of CO<sub>2</sub> 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<sub>2</sub> and very little CO<sub>2</sub> remains in the Cylinder.

CO<sub>2</sub> is heavier than air and may collect in confined, unventilated areas. Do not permit a leaking cylinder in a closed automobile. CO<sub>2</sub> is the regulator of the breathing function, and an increase in the CO<sub>2</sub> inhaled will cause an increased rate of breathing. In high concentrations, CO<sub>2</sub> can paralyze the respiratory system. Do not breathe air having excessive amounts of CO<sub>2</sub>.

Do not overfill a CO<sub>2</sub> Cylinder or dangerous pressures can result. Do not use CO<sub>2</sub> cylinders, which show any sign of wear, abuse, corrosion, worn threads or any mishandling.

### 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- <i>psia</i> (73- <i>atm</i> )
Specific Gravity	1.53
Specific Volume @ 70°F, 1- <i>atm</i>	8.76 cu ft/lb or 15,000 cu in/lb or 950 cu in/oz

## ***NITROGEN INFORMATION (N<sub>2</sub>)***

Nitrogen comprises approximately 79<sup>0</sup>/<sub>0</sub> 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<sub>2</sub> 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.

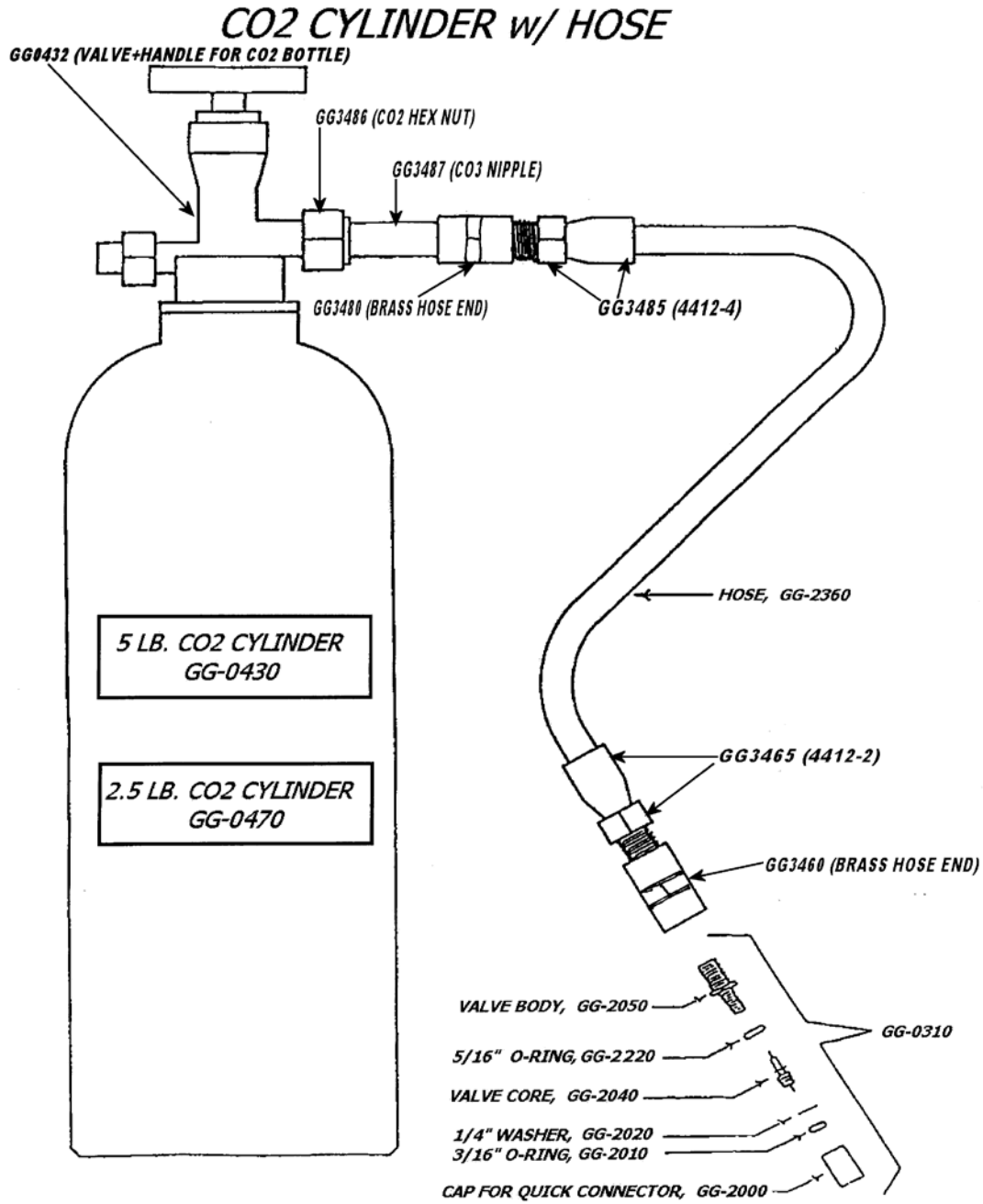
### **HANDLING PRECAUTIONS**

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.

### **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



**FIG. 9 – CO2 CYLINDER W/ HOSE**

# FILLER CONNECTOR, GG-0420

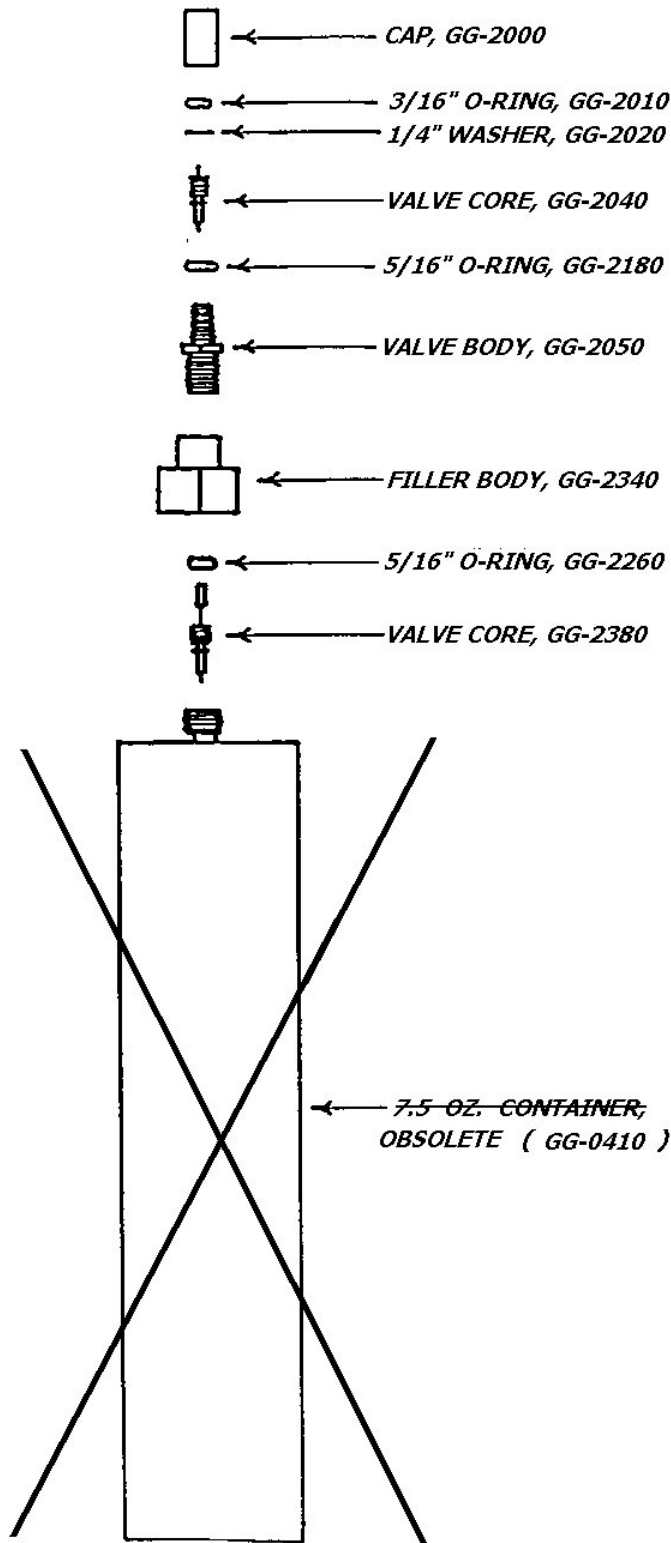


FIG. 10 - Filler Connector for 7.5 OZ. CO2 CYLINDER