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ACOUSTIC WATER LEAK ANALYZER. OPERATOR'S MANUAL.(U)
JAN 80 P M MOORE, R C TATE, J W DICKEY
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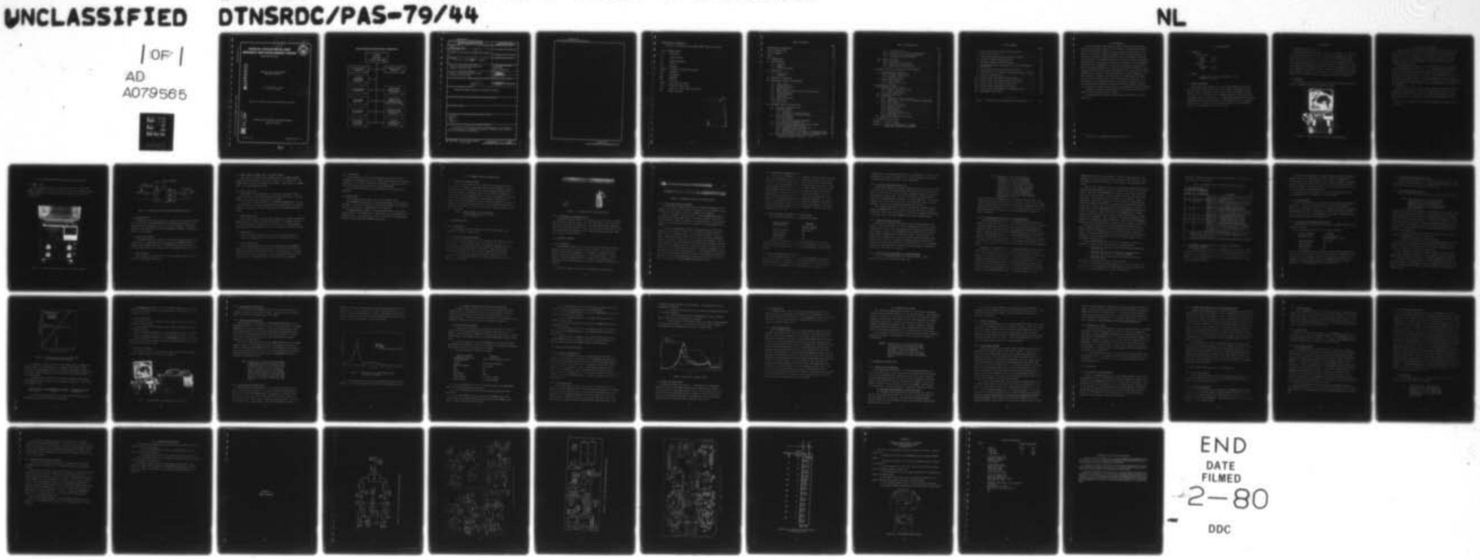

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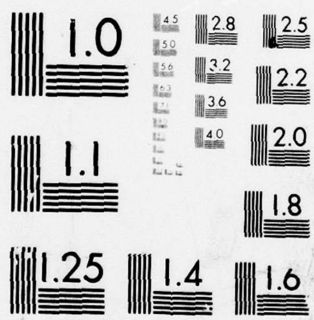

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ACOUSTIC WATER LEAK ANALYZER OPERATOR'S MANUAL

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

ACOUSTIC WATER LEAK ANALYZER OPERATOR'S MANUAL

by

P. M. Moore, R. C. Tate,
and J. W. Dickey

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PROPULSION AND AUXILIARY SYSTEMS DEPARTMENT

OPERATOR'S MANUAL

January 1980

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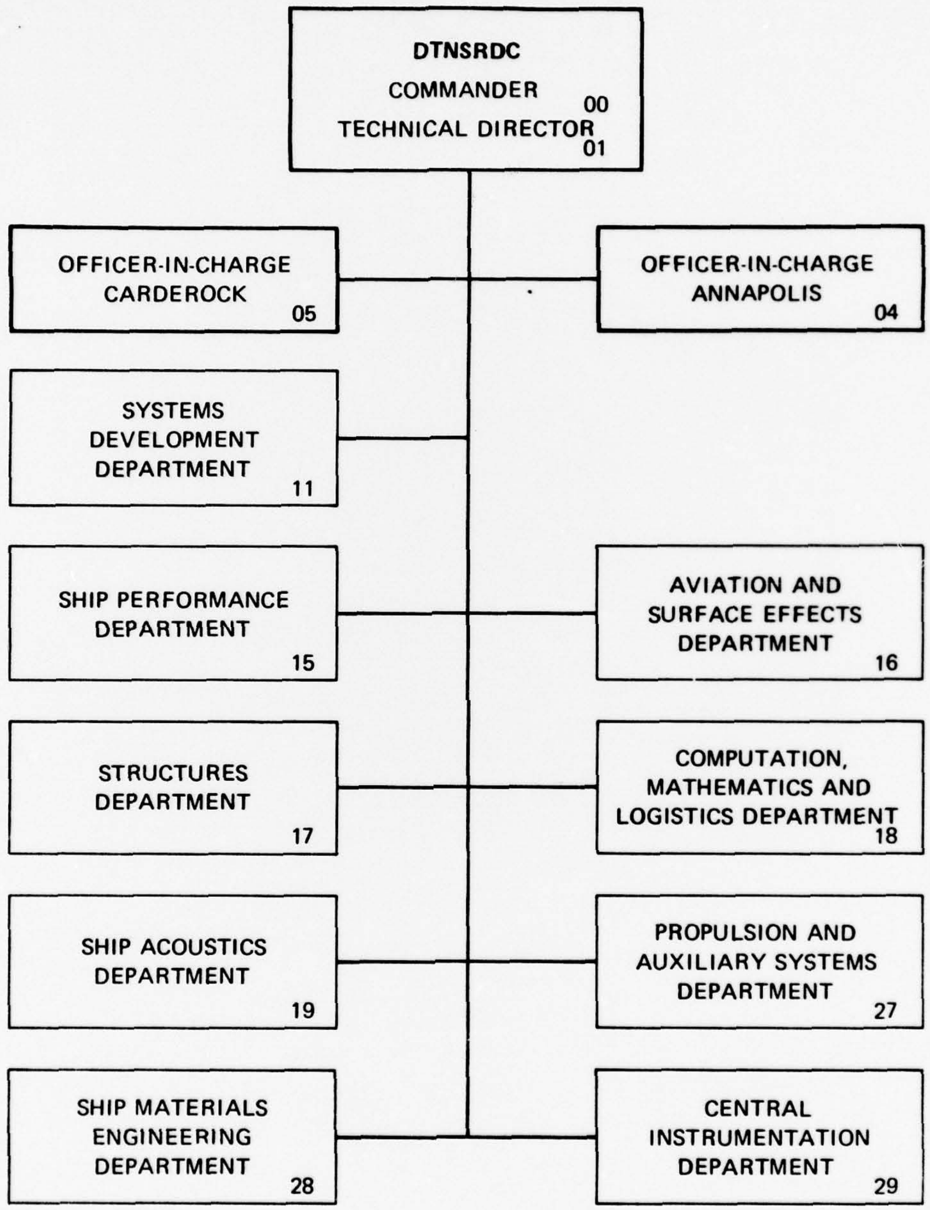

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This manual describes the operation and maintenance of the Acoustic Water Leak Analyzer. Principles of operation, controls, setup, operation, and troubleshooting are described.

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LIST OF ABBREVIATIONS

cm	Centimeter
$^{\circ}$C	Degree Celsius
$^{\circ}$F	Degree Fahrenheit
dB	Decibel
kg	Kilogram
kg/cm^2	Kilogram per centimeter squared
kHz	Kilohertz
mA	Milliampere
MHz	Megahertz
mV	Millivolt
ml/min	Milliliter per minute
psi	Pounds per square inch
psid	Pounds per square inch differential
RF	Radio frequency

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1.0 INTRODUCTION

The Acoustic Water Leak Analyzer monitors leak-associated acoustic energy in the frequency range of 10 to 100 kHz.* This frequency range was chosen because there is significant energy emitted by leaky valves, and energy in this range is rapidly attenuated with increasing distance from the source; therefore, background noises can be electronically separated from the signal. The analyzer permits the operator to observe the acoustic energy density as an analog meter reading or to listen to it on headphones. The audio output (headphones) is achieved by beating the incoming signal with a reference oscillator set at the center frequency of interest. The reference oscillator may be swept automatically, or a fixed center frequency (25 kHz) may be selected. The meter reading at a center frequency of 25 kHz provides an estimate of the leak rate. Two outputs are provided so that the acoustic energy spectra can be presented on an X-Y plot. The Y-axis output is a voltage proportional to the acoustic energy input in a 3.2 kHz band centered about the reference oscillator frequency, and the X-axis output is a voltage proportional to the reference oscillator frequency.

Appendix A includes a block diagram of the analyzer as well as diagrams of the electronic circuits involved.

The transducers and other accessories are stored within the instrument's case.

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*Definitions of abbreviations appear on page iii.

2.0 SPECIFICATIONS

2.1 DIMENSIONS

Detector Unit

Height:	17 cm
Width:	23.5 cm
Length:	24 cm

Transducer

Diameter:	1.4 cm
Length:	2.0 cm

2.2 WEIGHT

Analyzer Unit, with all accessories: 5 kg
Transducer: 35 grams

2.3 POWER REQUIREMENTS

The analyzer unit operates on a 4-cell battery pack, each cell a 6-volt "Gell Cell" (lead-acid storage) type, sealed, rechargeable battery. The unit draws 60 mA and will operate for 8 hours continuously or longer with on-off use. The battery will recharge overnight by using the built-in charging circuit. This is done by connecting the power cord and turning the POWER switch to the OFF position. Normal operation of the instrument should be with the power cord disconnected in order to provide maximum sensitivity and freedom from electrical noise.

3.0 DESCRIPTION

3.1 ANALYZER UNIT (See Figure 1)

This unit opens from the front and hinges in the back. The case is of watertight fiber glass construction. The operating controls are located in the lower half of the case. The accessories are stored in the upper half of the case (in the cover). The transducers are mechanically held on the control panel when they are not being used. The accessories consist of a headset, two transducers, two transducer holder assemblies, two transducer standoffs, two transducer cables, a package of mounting disks (to be epoxy bonded to the valves), a power cord, and a tube of silicone compound (applied as an interface between the mounting disk and the transducer).

3.2 TRANSDUCER

The transducer is a commercially produced model which may be used with either a transducer holder or a transducer standoff.

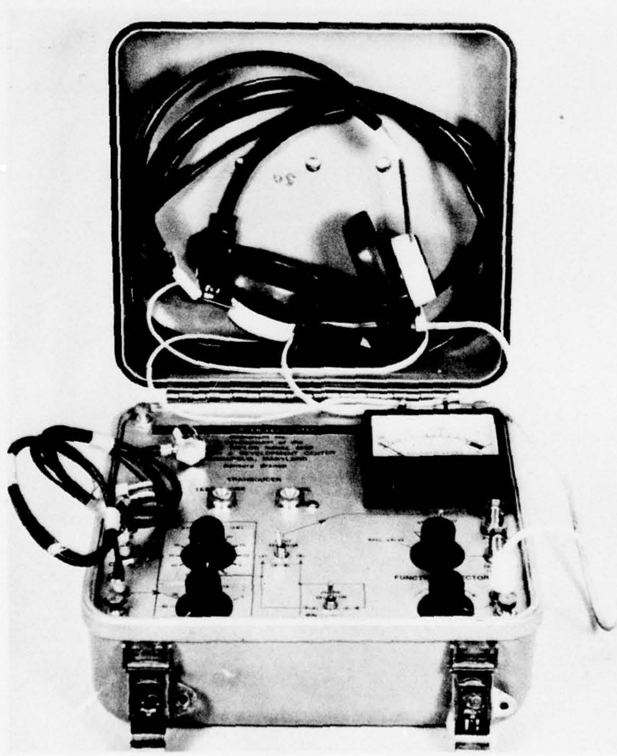

Figure 1 - Acoustic Water Leak Analyzer and Accessories

4.0 PRINCIPLE OF OPERATION

Sound is generated by water leaking through the ball-seat and/or seat-valve body interface. From measuring the sound in 3- to 5-inch-diameter seawater ball valves at ultrasonic frequencies up to 1 MHz, it has been found that most of the sound characteristically generated in leaky ball valves is in the 10- to 40-kHz frequency range. The unit detects this leakage-associated sound.

Two transducers are employed in this detection; one is placed either upstream or downstream of the valve to pick up background structureborne noise, and the other is located on the valve body or adjacent pipe to monitor the leakage-associated sound added to the background noise. It has been found that higher frequency sounds are attenuated to such an extent along the piping system that when electrical signals from the two transducers are subtracted, the leakage-associated electrical signal is separated from the background.

Signals from a local oscillator source and from one of the transducers are applied to an RF mixer. The difference between the oscillator and transducer signal is in the audio range. This can be listened to directly with earphones, and its amplitude is displayed on the Acoustic Amplitude meter.

A plot of the spectrum in the frequency range may be obtained with an X-Y Plotter.

5.0 FRONT PANEL CONTROLS AND FUNCTIONS (See Figure 2)

5.1 INPUT JACKS

The two transducers are to be connected to the "A" and "B" INPUT jacks. Transducer "A" should be the one attached to the downstream valve flange, transducer "B" attached upstream or downstream, on the pipe (see Figure 3).

Figure 2 - Acoustic Water Leak Analyzer Front Panel Controls

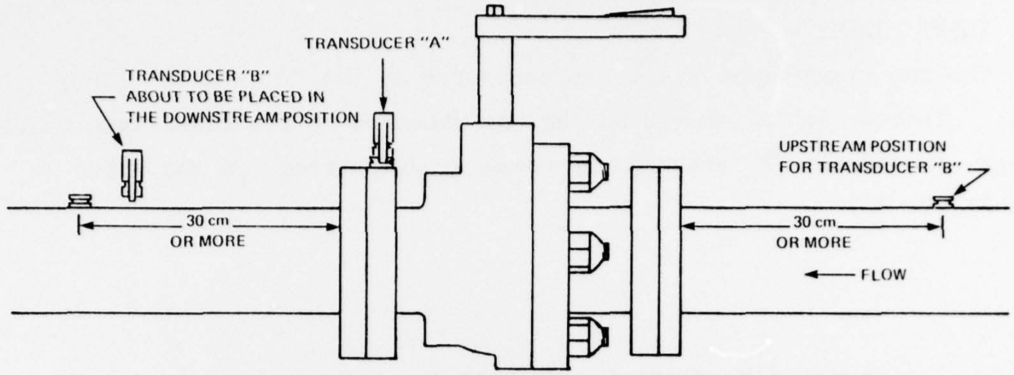

Figure 3 - Typical Valve Setup Showing Transducer Location

5.2 ATTENUATION DIAL

Attenuation of the input signal over a range of 0 to 55 dB is possible. A setting of "55" on the ATTENUATION dial gives maximum attenuation with the attenuation decreasing as the dial is turned clockwise. Each mark around the dial indicates 5 dB less attenuation as the dial is turned from higher to lower numbers.

5.3 ACOUSTIC LEVEL METER

The ACOUSTIC LEVEL meter indicates the acoustic energy density of the signal input in a frequency range determined by the FUNCTION SELECTOR. Combining the ACOUSTIC LEVEL with the ATTENUATION dial setting results in a single number known as the "sound level", as described in Section 6.7.2.

5.4 INPUT SELECTOR

Either channel "A", channel "B", or the difference "A-B" may be displayed on the ACOUSTIC LEVEL meter.

5.5 PHONE SELECTOR, PHONES JACK, AND VOLUME CONTROL

The headset is plugged into the PHONES jack. The PHONE SELECTOR switch allows the operator to listen to channel "A" or channel "B". The VOLUME control adjusts the volume in the headset. This control is independent of the INPUT SELECTOR setting.

5.6 FUNCTION SELECTOR

SWEEP/RESET - In this position, the frequency range may be swept automatically from 10 to 100 kHz, which takes about 30 seconds. The bandwidth of the acoustic spectra observed is 3.2 kHz.

BALL VALVE - In this position of the FUNCTION SELECTOR knob, a fixed center frequency of 25 kHz is maintained and the bandwidth of the spectrum observed is broadened to 7 kHz to include most of the leakage-associated sound.

5.7 SWEEP/RESET SWITCH

In the RESET position a fixed center frequency of 10 kHz is maintained. When the switch is turned from the RESET position to the SWEEP position, the center frequency is swept from 10 to 100 kHz. The center frequency then remains at 100 kHz until the switch is returned to the RESET position.

5.8 POWER SWITCH

Placing the POWER switch in the ON position turns the unit on.

Placing the POWER switch in the OFF position turns the unit off.

5.9 BATTER TEST SWITCH

When the BATTER TEST switch is in the TEST position, the ACOUSTIC LEVEL meter indicates the battery voltage. Full-scale meter deflection indicates a total of 28 volts across all of the battery cells. The unit may be operated whenever the meter reads within the green region during a battery check. Below this level, the battery must be recharged.

5.10 TEST SWITCH

When the TEST switch is in the ON position, the noise source is turned on, which provides a reference "white" noise signal for testing the transducers. The "white" noise signal is applied to a reference transducer located under the mounting disk labeled TEST/STORE.

When the TEST switch is in the OFF position, the noise source is turned off.

5.11 OUTPUT JACKS

The X-Y Plotter may be connected to the two Output jacks.

The FREQUENCY jack provides a voltage proportional to the operating frequency. It is to be connected to the plotter's X-axis. The output is from 1.0 to 10.0 volts, corresponding to 10 to 100 kHz.

The AMPLITUDE jack provides a voltage proportional to the acoustic energy density of the signal input. This signal is to be connected to the plotter's Y-axis. The output is from 0 to 7 volts and is simultaneously displayed on the analyzer's ACOUSTIC LEVEL meter.

6.0 INSTRUMENT SETUP AND LEAKAGE TEST

6.1 ATTACHING THE MOUNTING DISKS

A mounting disk should be epoxy bonded to the downstream flange of the valve to be checked. Additional disks should be mounted, one each, approximately 30 cm upstream of the upstream flange and downstream of the downstream flange, as necessary when noise is present (see Figure 3). A clean surface, free of lagging, dirt, or grease, is important. Apply the epoxy evenly and smoothly enough to ensure that no air gaps will be present in the bond. However, the epoxy should be squeezed out as thin as possible to assure metal-to-metal contact at the center of the disk for a good acoustical bond. Do not allow the epoxy to enter the groove on the side of the disk.

NOTE: When possible, it is desirable to mount the disks on top of the pipe in a horizontal plane.

6.2 TRANSDUCER HOLDER

6.2.1 Description

The transducer holder is designed to hold the transducer on the mounting disk during a leakage test.

6.2.2 Assembly of Transducer Holder

Place the tightly coiled end of the spring over the top of the transducer, using a twisting motion. Place the cylinder, ears end up, on a flat surface. Put the spring/transducer combination through the base of the housing from one side as shown in Figure 4. Push the transducer down into the cylinder until it is axially aligned with the cylinder.

Do not spread the ears when installing the transducer into the cylinder. If the ears are spread too far apart, they will not mate with the groove on the disk.

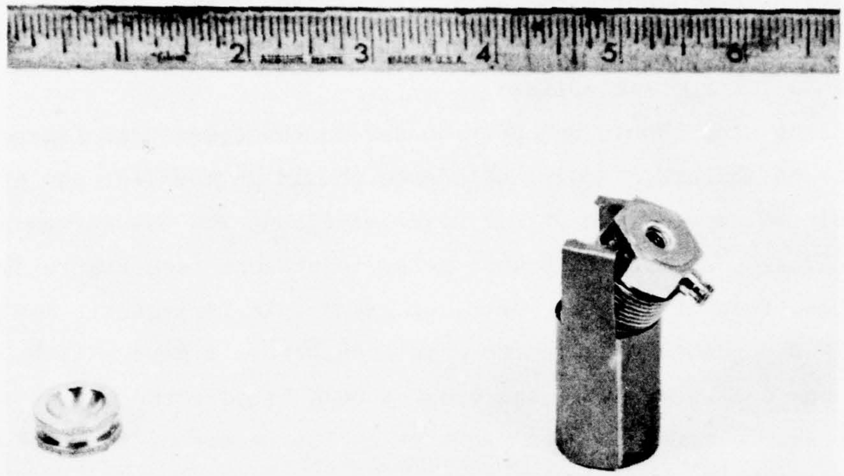

Figure 4 - Transducer Holder and Mounting Disk

6.2.3 Disassembly of Transducer Holder

Place the transducer holder, ears-side up, on a flat surface. Holding the cylinder with the left hand, place the index finger of the right hand on the connector and push down gently. The transducer/spring combination will tilt to the side toward the connector, away from the ears, and can then be removed without spreading the ears. Remove the spring from the transducer, using a twisting motion.

6.3 TRANSDUCER STANDOFF

6.3.1 Description

The transducer standoff (see Figure 5) is an 8-inch long by 3/8-inch diameter steel rod with a 1/2-inch diameter ball end. The other end is threaded, allowing the transducer to be attached. The ball end mates with the spherically-shaped indentation in the mounting disk. A small amount of silicone compound* should be applied at the transducer-rod interface and the ball-disk interface in order to assure a good acoustical contact.

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*e.g., Dow Corning, Type 340, Heat Sink Compound or Equivalent.

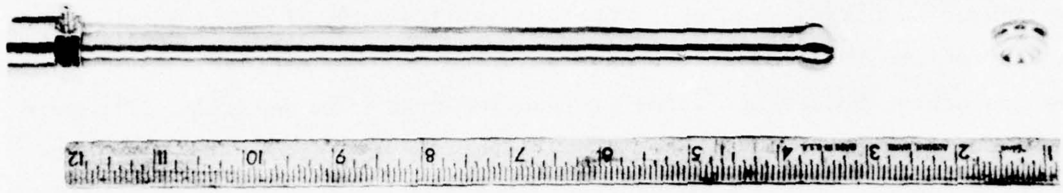

Figure 5 - Transducer Standoff and Mounting Disk

6.3.2 Use of the Transducer Standoff

The transducer standoff may be used as a hand-held probing tool to quickly move from one valve location to another or as an insulator to keep the heat of a hot valve or pipe from damaging the transducer.

When the standoff is used as a probe, turn the FUNCTION SELECTOR to the BALL VALVE position and listen to the audio signal at each valve or pipe location to compare the sounds and the meter levels. This procedure can help the operator to identify the source of the leakage-associated noise.

If acoustic measurements on steam valves and piping or other high-temperature structures are desired, the transducer standoff should be used to keep the transducer cool. The transducer must not be allowed to reach a temperature above 177° C (350° F) or it will become permanently damaged or destroyed. Start with a cool standoff and transducer. Using a small amount of silicone compound on the ball of the standoff, place the ball onto the hot mounting disk. No excessive pressure is required if the surfaces are free of dirt and mated properly. Hold the transducer end of the standoff while making the measurement. If the standoff becomes mildly hot near the transducer, remove the standoff from the valve and plunge the ball-half of the standoff in water for several seconds until the standoff is cool to the touch. The measurement may then be resumed.

6.4 ATTACHING THE TRANSDUCER HOLDER

First, turn the ATTENUATION dials completely counterclockwise (to SAT). This avoids saturating the mixer which would give erroneous results which may appear as normal readings. Apply a small amount of silicone compound to the face of the transducer, thus assuring good acoustical contact. Take the transducer holder and slide it onto the disk from one side. The ears on the cylinder portion of the holder mate with the groove of the disk. Do not attempt to push the holder onto the disk from above as this will damage the ears. Rotate the transducer back and forth slightly to allow the silicone compound to spread evenly across the transducer face. Once it is in place (centered) and any excess silicone compound is squeezed out, connect the transducer cable to the "A" input on the analyzer. The same procedure should be followed for the "B" transducer. In this case, connect the cable to the "B" input.

6.5 SETTING CONTROLS TO MEASURE THE ACOUSTIC SIGNAL

Set the following switches to the positions indicated:

Switch or Control	Position
ATTENUATION dial	Both "A" and "B" Counterclockwise
FUNCTION SELECTOR	BALL VALVE
INPUT SELECTOR	"A"
PHONE SELECTOR	"A"
POWER Switch	ON

The analyzer is now set to "listen" to the acoustic energy in the portion of the spectrum which has been found to contain most of the energy characteristically generated in leaky 3- to 5-inch-diameter, seawater ball valves.

6.6 BALL VALVE LEAKAGE TEST PROCEDURE

The test procedure begins with a check of the transducer sensitivity. This is followed by a determination of the background noise level at the valve when there is no differential pressure across it. If the background noise level is not significant, (see Section 6.6.2 for a definition of "significant"), a procedure requiring only one transducer is used. If the background noise level is significant, it may be necessary to follow the procedure which requires the use of both transducers.

6.6.1 Transducer and Meter Offset Test

Apply a small amount of silicone compound to the face of the "A" transducer and slide it onto the TEST/STORE disk located on the detector front panel. Be sure that all excess silicone compound is squeezed from between the transducer and the disk. Turn the TEST switch to the ON position. Turn the "A" ATTENUATION dial clockwise to the 0-db position. If the meter deflection is not at least 16 (on the 0 to 30 dB scale), there is a malfunction. Turn to the troubleshooting guide (Section 8.0).

For the meter offset test, turn the TEST switch to the OFF position. Turn the ATTENUATION dial fully clockwise and note and record the meter deflection. This is the meter offset, and it will be compared with readings to be taken later. Turn the ATTENUATION dial fully counterclockwise.

6.6.2 Background Noise Level Test

Ensure that no pressure differential exists across the valve to be tested. Apply a small amount of silicone compound to the face of the "A" transducer and slide it onto the mounting disk located on the downstream valve flange. Rotate the "A" ATTENUATION dial clockwise until a midscale meter reading (between 20 and 30 decibels) occurs. If the control is rotated fully clockwise and no meter deflection (beyond the offset noted above) occurs, there is no significant background noise present and the leakage test can be made as detailed under Section 6.6.3. If meter deflection occurs, background noise is present and the leakage test detailed in Section 6.6.4 may need to be followed.

6.6.3 Leak Detection in the Absence of Background Noise

Turn the "A" ATTENUATION dial fully counterclockwise. Apply a differential pressure to the valve under test.

NOTE: The Acoustic Water Leak Analyzer was designed to operate with a minimum differential pressure of 0.5 kg/cm^2 (7 psi) (i.e., with static water pressure at an approximate depth of 5 meters (16 feet) on the input side of the valve). A differential pressure less than about 0.5 kg/cm^2 (7 psi) will significantly decrease the instrument's capability to detect leakage, whereas increasing differential pressure above this range increases leakage detectability.

Slowly rotate the "A" ATTENUATION dial clockwise until the meter reads midscale and record the level setting of the dial. If the dial is rotated fully clockwise and no meter deflection beyond the background noise level reading (noted in Section 6.6.2) is noticed, the valve does not leak. If the meter deflection is above the background noise level reading, the valve is leaking.

6.6.4 Leak Detection in the Presence of Background Noise

When the background noise level is excessive and the procedure outlined in Section 6.6.3 fails to give conclusive results, it will be necessary to use two transducers in the "A-B" mode. This requires attaching two additional disks: one each upstream and downstream, as additional test points. Turn both the "A" and "B" ATTENUATION dials fully counterclockwise. Turn the INPUT SELECTOR switch and the PHONE SELECTOR switch to the "B" position. Connect the "B" transducer cable to the "B" input on the analyzer. Test transducer "B" in the same manner as described for transducer "A" in Section 6.6.1, using the "B" ATTENUATION dial rather than the "A" ATTENUATION dial.

Transducer "A" should still be on the downstream valve flange from the "Background Noise Level Test". Set the controls as detailed in Section 6.5. Slowly rotate the "A" ATTENUATION dial clockwise until the meter reads midscale or the dial is fully clockwise. Note the meter deflection. Without changing any of the controls, move the "A" transducer to the disk mounted on the upstream pipe, using an additional amount of silicone compound on the face of the transducer. Note the meter deflection, comparing it to the deflection previously noted. Move the "A" transducer to the disk mounted on the downstream pipe, using an additional amount of silicone compound on the face of the transducer. Note the meter deflection, comparing it to the two deflections noted previously. The location at which the highest deflection occurred is the disk nearest the background noise source.

Move the "A" transducer to the disk nearest the background noise source using an additional amount of silicone compound on the face of the transducer. Adjust the "A" ATTENUATION dial until the meter reads midscale or the dial is fully clockwise. Remove transducer "A" from the valve flange and store it temporarily on one of the disks on the detector. Apply a small amount of silicone compound to the face of the "B" transducer and slide the transducer holder onto the mounting disk nearest the background noise source. This is the same position that transducer "A" occupied a moment ago. Turn the INPUT SELECTOR switch and the PHONE SELECTOR switch to the "B" position. Slowly rotate the "B" ATTENUATION dial clockwise until the meter deflection is the same as that which previously occurred using the "A" transducer. This "matching" of the meter deflections compensates for transducer response differences. The "A" and "B" ATTENUATION dials are now set and should not be changed for the remainder of the test.

Move the "B" transducer to the disk mounted on the upstream pipe, using an additional amount of silicone compound on the face of the transducer. Move the "A" transducer to the disk mounted on the downstream flange, using an additional amount of silicone compound on the face of the transducer. Apply a differential pressure to the valve under test (see the "NOTE" in Section 6.6.3).

Turn the INPUT SELECTOR switch to the "A-B" position. The meter deflection should fall into one of the three categories below:

- \+ indicates that the average meter deflection is higher than the meter zero.
- \- indicates that the meter deflection is pegged below the meter zero with little or no positive movement.
- 0 indicates that the average meter deflection is near the meter zero mark.

Record into which category the meter deflection falls.

Without changing any of the instrument control settings, place transducer "B" on the disk mounted on the downstream pipe, using an additional amount of silicone compound on the face of the transducer.

Note which category the meter deflection now falls into. See Table 1 for interpretation of the results.

TABLE 1 - INTERPRETATION OF THE RESULTS OF THE "A-B" TEST

Meter Deflection "A" at Downstream Flange		
"B" Upstream	"B" Downstream	Conclusions
+	+	Valve leaks. Leakage signal is substantial relative to the background noise.
0	0	Valve does not leak.
-	+ or 0	There is a dominant upstream noise source whose signal level is much higher than any noise that may be created by a possible leak. Make a spectral plot as described in Section 6.9.
+ or 0	-	There is a dominant downstream noise source whose signal level is much higher than any noise that may be created by a possible leak. Make a spectral plot as described in Section 6.9.
0	+	Valve leaks. Leakage signal is at a level similar to an upstream noise source level.
+	0	Valve leaks. Leakage signal is at a level similar to a dcwnstream noise source level.
-	-	There is a dominant level of background noise both upstream and downstream of the valve which is higher than any noise that may be created by a possible leak. Make a spectral plot as described in Section 6.9.

\+ Indicates that the average meter deflection is higher than zero.
\- Indicates that the meter deflection is pegged below zero with little or no positive movement.
0 Indicates that the average meter deflection is near the zero mark.

6.7 MEASUREMENT OF SEAWATER BALL VALVE LEAKAGE AT AN ELEVATED DIFFERENTIAL PRESSURE

The following method of leak rate measurement is to be used only when a differential pressure of 50 psid can be produced across the valve. The higher pressure is applied to the side of the valve which is normally upstream so that the measurement conditions will closely approximate normal system operating conditions.

The procedure is designed to estimate the leak rate from the acoustic emission level. The application of this procedure to the detection of system leakage and to the isolation of all sources of leakage in a piping system is beyond the scope of this manual. A part of the test; however, does check whether the measured sound is from the valve in question or from other sound sources in the piping system.

The sum of the decibel reading on the meter and the setting of the "A" ATTENUATION dial is referred to as the sound level.

6.7.1 Instrument Setup

Attach a mounting disk to the downstream valve flange as described in Section 6.1. Attach a transducer holder to the disk as described in Section 6.4, connecting the cable to the "A" input on the detector whenever this transducer is used. The transducer standoff, described in Section 6.3, will be used with a second transducer as a probe to compare the sound levels at several points in the piping system.

6.7.2 Procedure for Obtaining the Sound Level

This procedure is to be used with either the transducer holder or the transducer standoff.

Set the following switches to the positions indicated:

Switch or Control	Position
ATTENUATION dial	Both "A" and "B" Counterclockwise (55 dB)
FUNCTION SELECTOR	BALL VALVE
INPUT SELECTOR	"A"
PHONE SELECTOR	"A"
POWER Switch	ON

Turn the "A" ATTENUATION switch clockwise until the meter reads between 20 and 30 decibels. Record the meter reading and the "A" ATTENUATION switch setting; sum the two numbers. Record the sound level as the sum of the ACOUSTIC LEVEL meter reading and the "A" ATTENUATION switch setting. Return the "A" ATTENUATION switch to the 55-dB position.

6.7.3 Obtaining the Background Sound Level

Ensure that no pressure differential exists across the valve. Using the transducer holder attached to the downstream valve flange, obtain and record the sound level as described in Section 6.7.2.

6.7.4 Leak Detection and Estimation

Apply a 50 psi ±10 psi differential pressure to the valve under test.

> NOTE: Record the actual differential pressure across the valve at the time of the test. Although the most precise estimate of leak rate is obtained with 50 psid, differential pressures of 40 to 60 psid may be used if necessary.

Using the transducer holder attached to the downstream valve flange, obtain and record the sound level as described in Section 6.7.2. If the sound level obtained with 50 psid exceeds the background sound level by 5 dB or more, the valve is probably leaking. To verify this conclusion, use the transducer standoff as a probe. Connect the transducer standoff cable to the "A" input on the analyzer. Obtain the sound level, as described in Section 6.7.2, at the downstream valve flange and at nearby points in the piping system including:

- Adjacent piping, approximately 1 meter (3 feet) and further upstream or downstream of the valve under test.
- Nearby valves along the adjacent piping.

If the sound level becomes higher as the transducer standoff is moved to points away from the valve, then background noise originating from sources other than the valve under test is too high to determine whether the valve is leaking or to estimate the leak rate.

If the sound level, using the transducer standoff, at the downstream valve flange exceeds the sound level on the adjacent piping and adjacent valves, then the valve is leaking and a leak rate estimate may be made.

The leak rate may now be estimated from the sound level by using the graph in Figure 6. The solid line is used to estimate the leak rate. The dashed line represents the single standard deviation error range based on laboratory data.

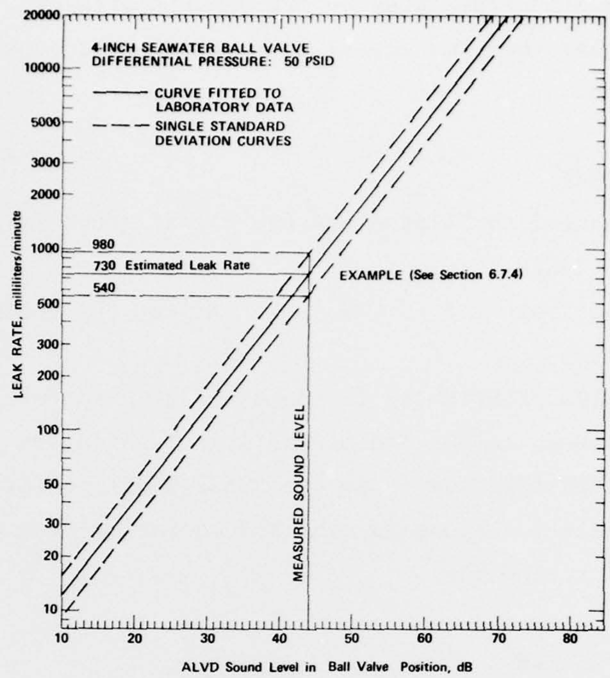

Figure 6 - Estimating Leak Rate from Sound Level for 4-Inch Seawater Ball Valves

As an example, suppose the sound level obtained with the transducer holder attached to the downstream valve flange is 44 decibels. From Figure 6, the corresponding leak rate estimate is 730 ml/min. Allowing for the single standard deviation error yields a leak rate estimate range of 540 to 980 ml/min.

A correction must be made to this leak rate estimate if the differential pressure was not equal to 50 psid during the leak test. The following formula is used:

$$\text{Adjusted Leak Rate Estimate} = \frac{\text{Actual Differential Pressure}}{\text{50 psid}} \times \text{Estimated Leak Rate from Figure 6}$$

It must be noted again that this correction is valid only where the differential pressure is in the 40-60 psid range.

For downstream pressures close to atmospheric pressure, the leak rate estimate may be higher than the actual leak rate if the leakage is due to a cracked valve seat.

6.8 USING THE HEADSET

The headset is used to "listen" to the signal after it has been converted to the audio range.

Plug the headset into the PHONES jack. Adjust the VOLUME control to a comfortable level.

When the FUNCTION SELECTOR is in the BALL VALVE position, the operator can "hear" the frequency components of the signal which are near 25 kHz.

When the FUNCTION SELECTOR is in the SWEEP/RESET position, the operator can "hear" the frequency components near the operating frequency, which is being swept from 10 to 100 kHz.

6.9 USING AN X-Y PLOTTER

An X-Y Plotter may be used to obtain a plot of the signal's spectrum for the frequency range 10 to 100 kHz (see Figure 7).

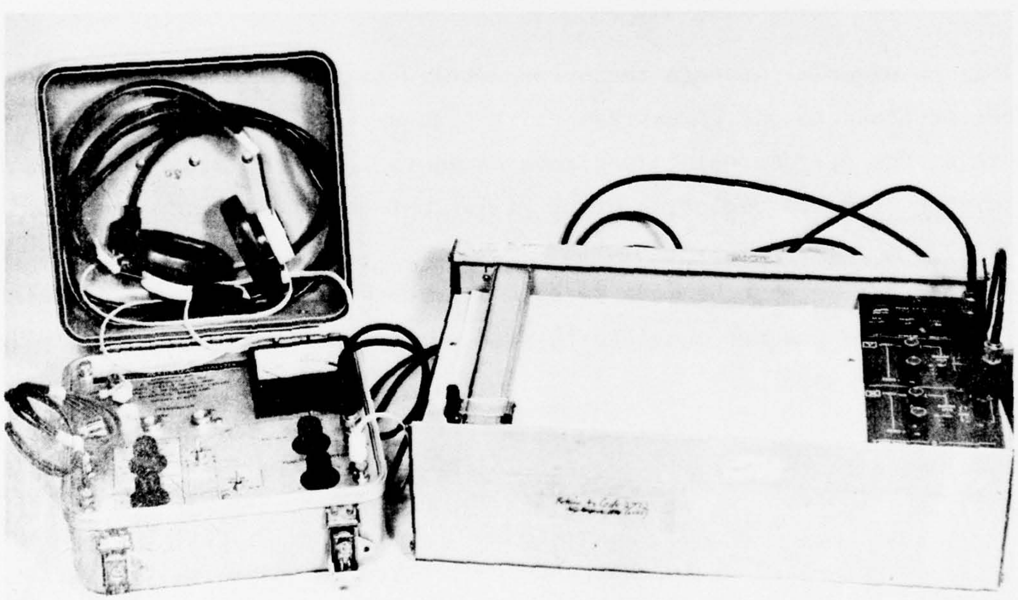

Figure 7 - Acoustic Water Leak Analyzer and X-Y Plotter

6.9.1 Calibration of X-Y Plotter

Set the vertical and horizontal gain to 1.0 volts per inch (or 0.5 volt per centimeter for a metric recorder). Adjust the zero volt input level for the lower left-hand corner of the graph.

6.9.2 Obtaining a Spectral Plot

Once the Plotter is calibrated and the FUNCTION SELECTOR is in the SWEEP/RESET position, the Plotter is ready to plot the spectrum. The INPUT SELECTOR switch allows the operator to plot the signal generated at the valve flange (position "A"), the signal upstream or downstream (position "B") or the difference between these signals (position "A-B"). In the "A-B" mode, the background noise may be subtracted from the acoustic emission of the leaking valve.

To plot the signal spectrum, turn the SWEEP/ RESET switch to the RESET position and set the X-Y Plotter pen down. The frequency is now set at 10 kHz. Turning the SWEEP/RESET switch to the SWEEP position initiates the sweep of the frequency from 10 to 100 kHz. Upon completion of the sweep, the frequency will remain at 100 kHz until the SWEEP/RESET switch is returned to the RESET position.

> NOTE: As each plot is being made, the operator should write on the plot the value of the ATTENUATION dial setting and which signal is being observed; that is, "A", "B", or "A-B". A typical data plot is shown in Figure 8 where two curves are presented. The top curve represents a valve leaking. The lower curve represents the same valve when it is not leaking. Notice the large peak in the top curve, which occurs near 30 kHz.

6.9.3 Valve Setup for Spectral Plot

With controls and transducers set up as detailed in Section 6.6.4, apply a differential pressure to the valve. Run a plot as described in Section 6.8.2. Without changing any of the analyzer's controls, either shut all drains and vents to the system so that pressure is built up on the downstream side of the valve, or open the system upstream of the valve so that pressure is relieved there. When the differential pressure is overcome in this way, run another spectral plot on the same sheet as the previous plot. If the second plot is lower in amplitude than the first, it may be taken as an indication of leakage. The indication should be further confirmed by once again opening a downstream drain and observing that the spectral plot returns to its initial value.

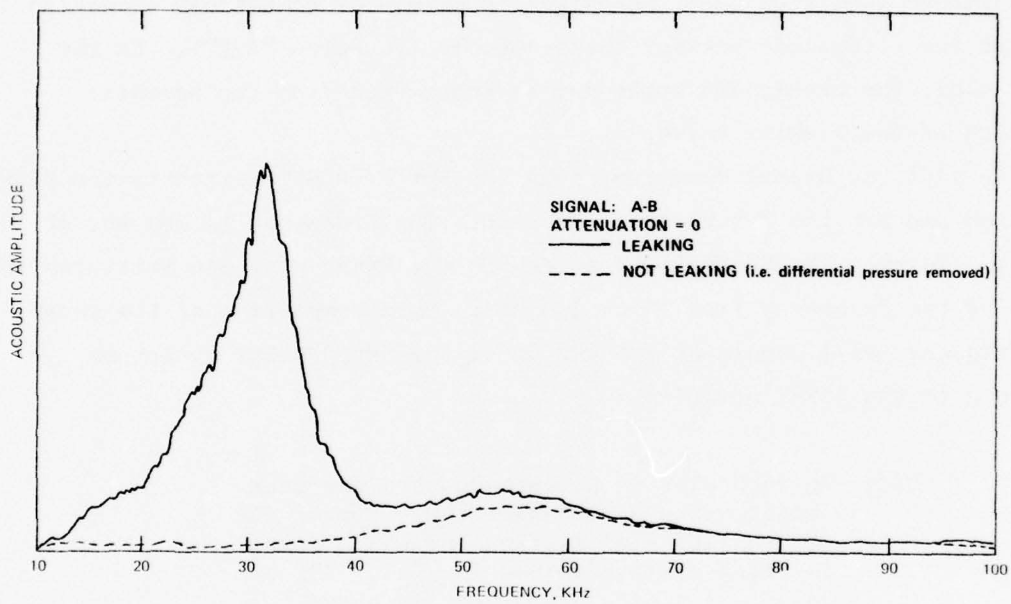

Figure 8 - "A-B" Curves for a Valve When Leaking and When not Leaking

This same technique may be applied for spectral plots with a single transducer on the valve flange in the absence of high background noise.

7.0 ACOUSTIC WATER LEAK ANALYZER SELF-TEST FUNCTION

A complete system self-test is built into the Acoustic Water Leak Analyzer and it is recommended that this self-test function be used to confirm proper operation of the instrument before beginning a day's testing schedule. The self-test verifies operation of the electronics and transducers and can be used to isolate any defective components.

7.1 SYSTEM SELF-TEST PROCEDURE

A. Calibrate the X-Y Plotter as detailed in Section 6.8.1 (Calibration of X-Y Plotter) and connect the horizontal plotter input to the Acoustic Water Leak Analyzer FREQUENCY (X-Axis) Output jack and the vertical plotter input to the Acoustic Water Leak Analyzer AMPLITUDE (Y-Axis) output jack.

B. Attach a transducer to the TEST/STORE disk on the Acoustic Water Leak Analyzer front panel, as detailed in Section 6.4 (Attaching Transducer), and connect the cable to the desired input channel.

C. Set the front panel controls as follows:

Switch or Control	Position
ATTENUATION Channel "A" and Channel "B"	Fully counterclockwise (55 dB)
VOLUME	Fully counterclockwise
FUNCTION SELECTOR	BALL VALVE
TEST	OFF
POWER	OFF
SWEEP/RESET	RESET
PHONE SELECTOR	To desired channel
INPUT SELECTOR	To desired channel

D. Turn the POWER switch to the ON position and set the ATTENUATION dial of the desired channel to 20 decibels.

E. Turn the TEST switch to the ON position and observe the meter deflection.

F. Put the headphones on, plug them into the PHONES jack on the Acoustic Water Leak Analyzer front panel and increase the VOLUME control until a hissing sound can be clearly heard.

G. Turn the TEST switch to the OFF position and observe the meter drop to zero and the hissing sound leave the headphones.

H. Set the FUNCTION SELECTOR switch to the SWEEP/RESET position and lower the pen onto the X-Y Plotter.

I. Set the SWEEP/RESET switch to the SWEEP position and obtain a background noise plot.

J. Lift the X-Y Plotter pen and then set the SWEEP/RESET switch to the RESET position.

K. Turn the TEST switch to the ON position, lower the X-Y Plotter pen, and set the SWEEP/RESET switch to the SWEEP position to obtain a spectral plot.

L. When the plot is completed, raise the X-Y Plotter pen and set the SWEEP/RESET switch to the RESET position. Turn the TEST switch to the OFF position and turn the POWER switch to the OFF position.

7.2 SYSTEM SELF-TEST APPLICATIONS

7.2.1 Transducer Response Test

The X-Y plot resulting from the self-test procedure detailed in Section 7.1 is a graph of the response of the transducer and electronics to a "white" noise source and can be used to verify the proper operation of the transducer and electronics over the entire spectral range of the Acoustic Water Leak Analyzer. Figure 9 shows typical response curves for a pair of transducers. It is recommended that a response plot be made for each new transducer when it is received and that this respnse plot be kept on file for comparison purposes to detect transducer or instrument deterioration.

7.2.2 Comparison Tests

The self-test response curves can be used on a comparison basis to check (a) the performance of the channel "A" electronics against the channel "B" electronics by using the same transducer on both channels and (b) the response of two transducers against each other by using the same channel of electronics. The self-test feature can also be used to provide a constant signal to compare the meter reading with the amplitude output level or with the volume present in the headphones. This latter test is best performed as follows:

- Setup for the system self-test procedure as detailed in Section 7.1, steps A through F.
- Turn the desired channel ATTENUATION dial slowly clockwise until a full-scale meter deflection is obtained.
- The signal at the AMPLITUDE output jack should be approximately 7.0 volts direct current. As the VOLUME control is rotated clockwise, the hissing in the headphones should become extremely loud.

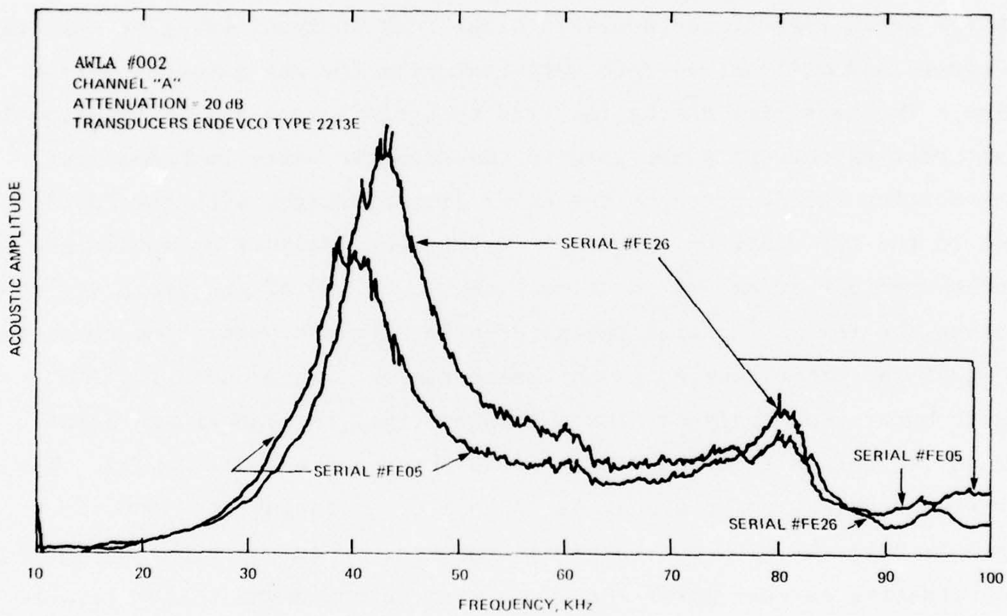

Figure 9 - Transducer Comparison Test

7.3 BATTERY AND POWER SUPPLY

The Acoustic Water Leak Analyzer is equipped with a rechargeable battery pack and an alternating current power supply and is capable of 8 or more hours of continuous operation from a fully charged battery pack. The alternating current power supply is capable of fully recharging the battery pack overnight (16 hours) or operating the Acoustic Water Leak Analyzer from the power line with the battery pack removed.

7.3.1 Battery Test

The BATTER TEST switch is spring loaded and must be held in the TEST position to allow momentary monitoring of the rechargeable battery pack condition and/or the condition of the alternating current power supply. This switch places the Acoustic Water Leak Analyzer front panel meter directly across the battery leads.

7.3.2 Battery Charge Level

Hold the BATTER TEST switch in the TEST position and note the meter reading. When the meter is in the green region, the Acoustic Water Leak Analyzer may be safely operated for 4 to 8 hours. When the meter falls below the green region, the Acoustic Water Leak Analyzer may give calibration errors and will not operate satisfactorily for any extended period of time. The batteries may be restored to satisfactory levels by attaching the alternating current power cord to the Acoustic Water Leak Analyzer and connecting the detector to the power line overnight with the POWER switch in the OFF position. Acoustic Water Leak Analyzer operation may be extended when batteries are in or near the lower end of the green region by operating the instrument with the alternating current power line connected, as long as the meter remains in the green region. When operating the Acoustic Water Leak Analyzer from the power line, the background noise level may be raised by signals coupled in through the power supply. The alternating current power supply is capable of operating the Acoustic Water Leak Analyzer with the batteries removed. When charging the batteries, the alternating current power supply current output drops to the trickle charge level when the batteries reach full charge.

8.0 TROUBLESHOOTING GUIDE

The following troubleshooting procedure is intended as a supplement to the self-test procedure detailed in the previous section. This procedure should be carried out in a laboratory equipped with a good quality digital voltmeter, oscilloscope, and frequency meter, and performed by a skilled electronics technician. The guide is written as a series of tests which should be performed sequentially. Once a specific problem is detected, that problem should be corrected and the remaining tests not performed unless it has been determined that an operating difficulty still exists.

If the operator finds that the operating difficulty cannot be corrected using this procedure, the instrument should be returned for repair and recalibration.

WARNING: Disconnect the alternating current line cord any time the front panel is opened as potentially lethal voltage will otherwise exist. When reinstalling the electronics package into the case, care should be taken not to pinch the alternating current power lead wires or the battery wires.

8.1 BATTERIES AND POWER SUPPLY

8.1.1 Battery Test and Charging

After being charged overnight, the batteries should register well up in the green region. Fully charged batteries should show little change in the meter reading when the alternating current line cord is removed. If, after overnight charging, the batteries fail to register in the green region, a weak battery or a loose connection is indicated. If the meter fails to register at all, the fault may be in the BATTER TEST switch or the meter wiring. To check the battery connections, proceed as follows:

- Disconnect the alternating current line cord.
- Disengage the panel fasteners located at the four corners of the front panel and carefully lift the electronics package (attached to the front panel) out of the case. Note that the electronics package remains connected to the alternating current power connector and batteries which remain in the case.

If any of the wires leading to the battery pack are disconnected, reconnect them by pushing the lugs firmly onto the battery terminals. Check the voltage level with the BATTER TEST switch and front panel meter. Recharge if necessary.

8.1.2 Battery Voltages

The battery pack consists of four 6-volt "GELL CELL" (lead-acid storage) type sealed, rechargeable batteries connected in series. Check the voltage across the entire battery pack and then across each individual battery. If all the batteries appear to be low in charge, after a normal charging procedure has been used with properly connected batteries, the power supply (charging circuit) may be at fault. If one of the four batteries appears to be far weaker than the others, it must be replaced.

8.1.3 Power Supply Voltage

Disconnect the three wires leading to the batteries and wrap the connectors with electrical tape to avoid a short circuit. Carefully place the electronics package back into the case. Connect the alternating current line cord. Hold the BATTER TEST switch in the TEST position. If the meter now reads in or above the green region, test the current output of the power supply by turning ON the POWER switch with the BATTER TEST switch still held in the TEST position. If the meter remains in the green region, the alternating current power supply is good and the Acoustic Water Leak Analyzer may be operated with the batteries disconnected. The batteries need to be replaced if they will not charge when connected to a working power supply. If the meter deflects below the green region or not at all, the power supply is not working properly.

As a final check on the power supply, check the voltages produced at the three leads that go to the battery while they are disconnected. This can only be done when the electronics package has been lifted out of the case. The alternating current line cord is then connected. To perform this check, the previous WARNING must be violated; therefore, use extreme care not to touch the main power line wires or the transformer to which they are connected. The voltage between the red (positive) and black (negative) battery leads should be 28 volts direct current with the POWER switch in the OFF position (corresponding to full-scale meter deflection) and at least 24 volts direct current with the Acoustic Water Leak Analyzer POWER switch turned to the ON position. If the power supply voltage is correct and the meter still reads low, check the meter wiring and adjust meter calibration potentiometer R3 on the power supply board. (See Figure A-3 of Appendix A). Disconnect the alternating current power cord.

8.2 TRANSDUCERS AND CABLES

If the batteries are adequately charged and connected and the instrument still does not work properly, the next step is to test the transducers and cables. Switch the FUNCTION SELECTOR to the BALL VALVE position, rotate the appropriate ATTENUATION dial to "0" dB and turn the phones VOLUME con trol fully clockwise. Scratch the front panel near the transducer with your fingernail. This should cause a deflection of the meter and a sound in the headphones. If no deflection or sound occurs, replace the cable and the transducer. If there is still no deflection of the meter and sound is not heard, turn to Section 8.4.

If a meter deflection is seen and sound is heard, proceed with a test of the noise source. If a sound is not heard, but the meter deflects, turn to Section 8.4.7. If a sound is heard, but no meter deflection occurs, turn to Section 8.4.6.

8.3 NOISE SOURCE

8.3.1 Operation of the Noise Source

Switch the FUNCTION SELECTOR to the BALL VALVE position. With a working transducer placed on the TEST/STORE disk and connected to Channel "A", rotate the "A" ATTENUATION dial to the "0" dB mark (fully clockwise). Turn the TEST switch to the ON position, wait 10 seconds and then turn it back to the OFF position. The meter should deflect approximately to midscale (24 dB) when the TEST switch is in the ON position, and return below 10 dB when the TEST switch is in the OFF position. If the meter does not deflect, the noise source is not working properly.

8.3.2 Random Noise Signal and the Ceramic Mounting Disk

Disconnect the line cord and remove the electronics package carefully, keeping the battery leads connected. With the POWER switch turned to the OFF position, connect an oscilloscope probe to capacitor C49 or resistor R87 on the end nearest the edge of the main circuit board (see Figure A-4 of Appendix A). Turn the POWER switch and the TEST switch to the ON position. A 100-mV rms (10 Hz to 1 mHz) random noise signal should appear on the oscilloscope. If no signal appears, the noise source electronics are faulty. Try replacing zener diode Z2 to remedy the situation and then adjust the 1000-ohm trim potentiometer R120 to yield a 100-mV rms random noise output. If random noise does exist, but cannot be adjusted as high as 100 mV, replace the zener diode again as necessary until the 100-mV level is attainable.

If the correct level random noise signal appears at the connector and the cable running to the ceramic disk is connected, but there is still no noise produced at the TEST/STORE disk, the ceramic disk has become detached from the front panel and must be cleaned and reattached, using a cyanoacrylate adhesive (e.g., Eastman 910). The ceramic disk must be precisely located, centered 2¼ inches in from the left edge of the front panel and 3 7/8 inches down from the top of the front panel, or erroneous transducer plots will result.

8.4 MAIN CIRCUIT BOARD (see Figure A-4 of Appendix A)

8.4.1 Use of This Section

The main circuit board test procedure should only be tried after it has been determined that the batteries are properly charged and the preceding tests have already been tried.

8.4.2 Connectors and Cables

Turn the POWER switch to the OFF position. Disconnect the line cord and remove the electronics package carefully, keeping the battery leads connected. Check all connectors and cables that go to the main circuit board to ensure a proper connection. Make sure that none of the integrated circuits have left their sockets.

8.4.3 Supply Voltages

Turn the POWER switch to the ON position. Check the voltages between ground, available at any connector jack, and pins 14 and 15 of the 16-pin ribbon cable connector, J16. The voltage between ground and pin 14, available at the jumper wire between resistor R92 and jack J16, should be +12 volts; the voltage between ground and pin 15, available at the jumper wire at the inside end of J16, should -12 volts.

8.4.4 Ramp Circuit

Connect a direct current voltmeter to the FREQUENCY output jack on the front panel. Rotate the FUNCTION SELECTOR to the SWEEP/RESET position. As the SWEEP/RESET switch is operated, the voltage at the FREQUENCY output jack should range from 1 to 10 volts in about 30 seconds.

8.4.5 Oscillator Waveform

Turn the POWER switch to the OFF position. Connect an oscilloscope probe to the test point (labeled TP), located near the center of the main circuit board. This point is also accessible at resistors R60A or R60B and is connected to pin 2 of integrated circuit IC8. Rotate the FUNCTION SELECTOR to the BALL VALVE position. Turn the POWER switch to the ON position. A 25-kHz, 0.25-volt rms sinusoidal waveform should appear on the oscilloscope. The voltage appearing at the FREQUENCY output jack should be 2.5 volts, corresponding to 25 kHz. If the proper voltage appears at the FREQUENCY output jack and no waveform appears at the test point, the integrated circuit (IC8) may be faulty and should be replaced. If the proper voltage appears at the FREQUENCY output jack and a highly distorted or low amplitude waveform appears at the test point, the circuitry associated with integrated circuit IC8 is likely at fault.

If the waveform appears to be good, rotate the FUNCTION SELECTOR to the SWEEP/RESET position. As the frequency voltage runs from 1 to 10 volts, the frequency of the waveform at the test point should range from 10 to 100 kHz.

8.4.6 Amplitude Output and Meter

Connect a direct current voltmeter to the AMPLITUDE output jack. Rotate the FUNCTION SELECTOR to the BALL VALVE position. Connect a working transducer to the channel "A" input jack and place the transducer on the TEST/STORE disk. Turn the TEST switch to the ON position. Rotate the "A" ATTENUATION dial until a direct current voltage level between 1 and 7 volts appears on the direct current voltmeter and/or on the ACOUSTIC LEVEL meter. (A full deflection on the front panel meter corresponds to 7 volts at the AMPLITUDE output jack.) Turning the TEST switch to the OFF position and back to the ON position should cause the direct current level to drop nearly to zero volts (or the "meter zero" mark) and return again. If the direct current level does not appear, scratch the front panel with your fingernail. If the direct current level still does not appear, the main circuit board electronics may be faulty. If the direct current level appears at the AMPLITUDE output jack, but does not cause a front panel meter deflection, the front panel meter and/or associated wiring, including trim potentiometer R101 on the main circuit board, may be faulty. Check the connections to the BATTER TEST switch. Once the connections are correct, operation of the BATTER TEST switch should produce a meter deflection in the green region. If the meter does not deflect, isolate and test the meter, which has a 1 mA movement. If the BATTER TEST switch produces a meter deflection, but the direct current level at the AMPLITUDE output jack still does not register on the meter, replace potentiometer R101.

8.4.7 Audio Output

If the instrument appears to be operating properly except for the headphones, try another pair of headphones.

NOTE: The Acoustic Water Leak Analyzer is supplied with high impedance headphones, but will drive standard 8-ohm headphones at a reduced signal level with no damage to the Acoustic Water Leak Analyzer.

If no signal is audible, connect an oscilloscope to the PHONES output jack and observe the waveform. If there is still no signal, inspect main circuit board jacks J13 and J14 to be sure they are properly inserted. Inspect the connections at the PHONE SELECTOR switch, the VOLUME control potentiometer and the PHONES jack, and observe the signal at these points with an oscilloscope.

8.5 BANDWIDTH AND AMPLITUDE CALIBRATION

A test of the instrument's bandwidth discrimination and amplitude calibration can be performed if it is suspected that they have changed greatly.

Install the electronics package back into the case. Check the battery level and charge the battery if necessary. Connect a plotter to the Acoustic Water Leak Analyzer. Apply a 10-mV rms, 25-kHz sinusoidal signal to the INPUTS jack for the channel to be tested. Be sure that the signal is not of a greater amplitude, since this may damage the preamplifier circuit. Place the FUNCTION SELECTOR in the BALL VALVE position and rotate the appropriate ATTENUATION dial to "10" dB. Tune the input oscillator frequency for a peak displacement of the meter. Rotate the ATTENUATION dial to "0" dB. This should cause a full-scale meter deflection and 7 volts at the AMPLITUDE output jack.

Rotate the FUNCTION SELECTOR to the SWEEP/RESET position and plot a spectrum. The spectrum should contain only one large peak with a 3.2 kHz bandwidth.

9.0 INSTRUMENT MODIFICATIONS

The Acoustic Water Leak Analyzer differs from the Acoustic Valve Leak Detector Model C in two ways:

- The "A" ATTENUATION dial uses a 12-position switch rather than a variable potentiometer.
- A decibel scale replaces the linear scale on the meter face.

These two changes enable the instrument to be used for leak rate estimation as described in Section 6.7.

The document, "Draft Military Specification, Acoustic Valve Leak Detector, October 1977," includes the ATTENUATION dial change but not the meter face change. The details of the meter face change are given in Appendix B.

APPENDIX A

CIRCUIT DRAWINGS

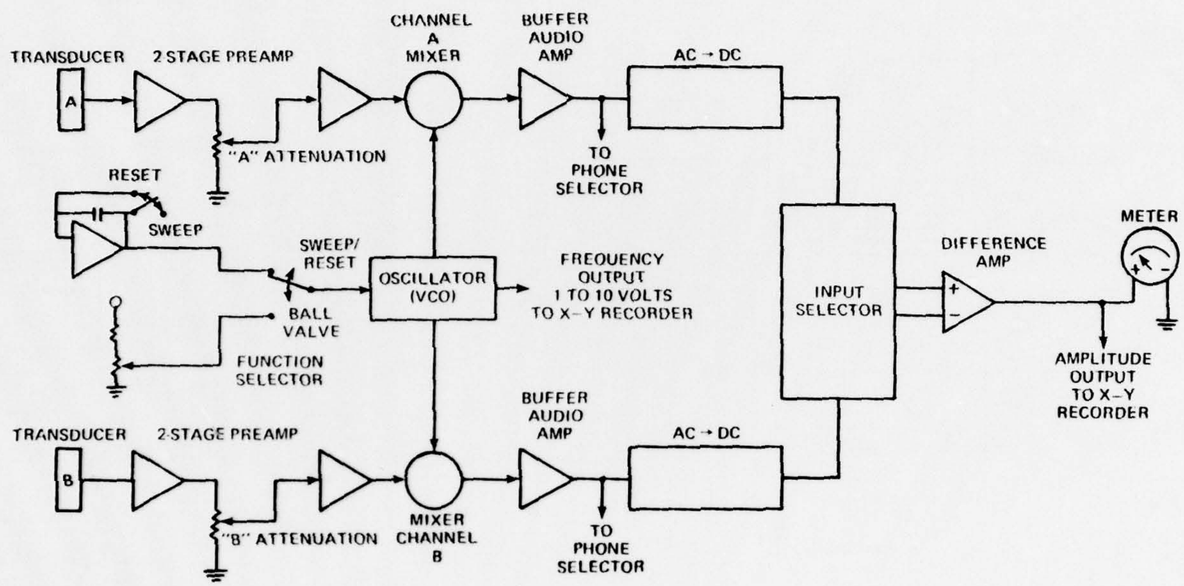

Figure A-1. Acoustic Water Leak Analyzer Block Diagram

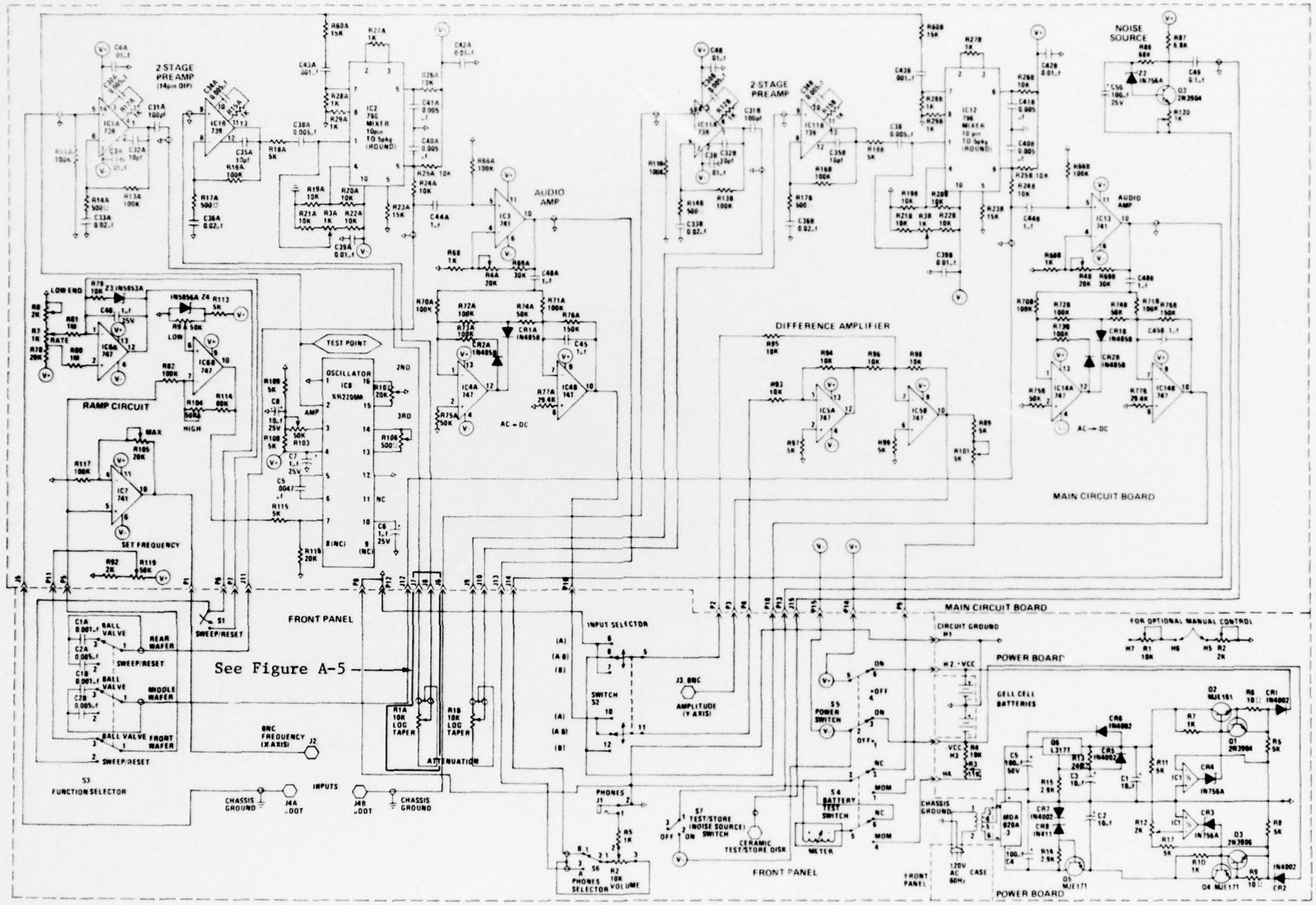

Figure A-2. Acoustic Water Leak Analyzer Schematic Diagram

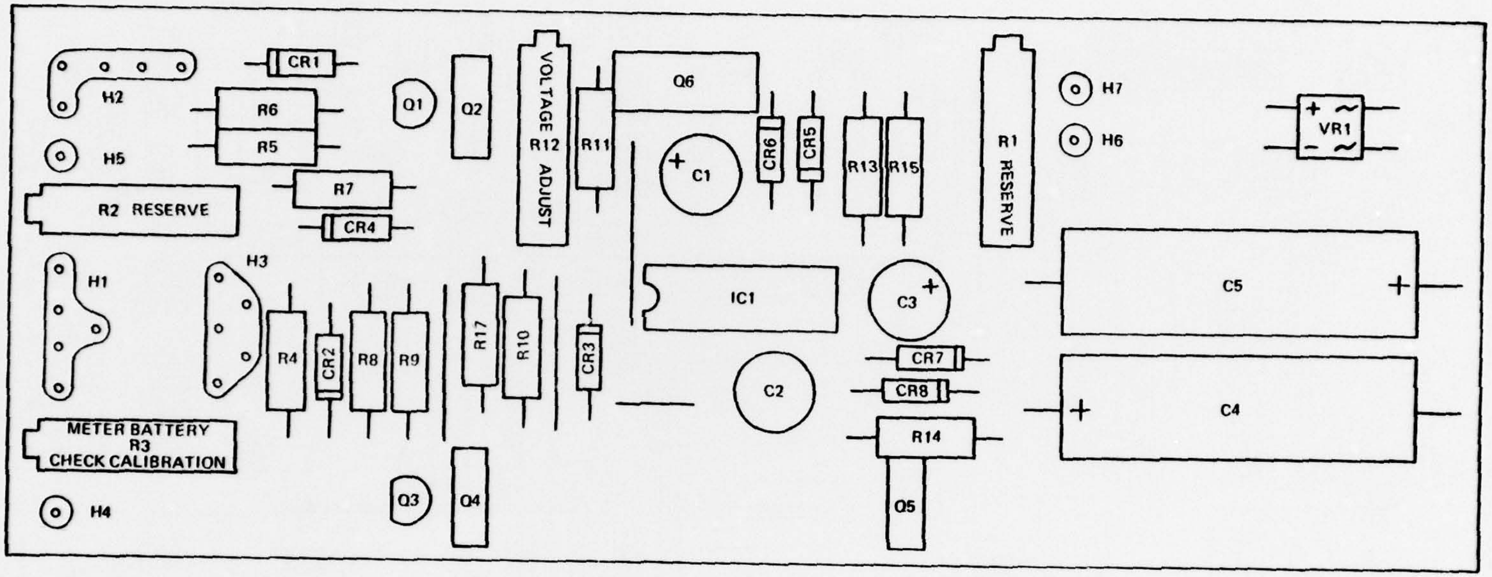

Figure A-3. Acoustic Water Leak Analyzer Power Board Layout

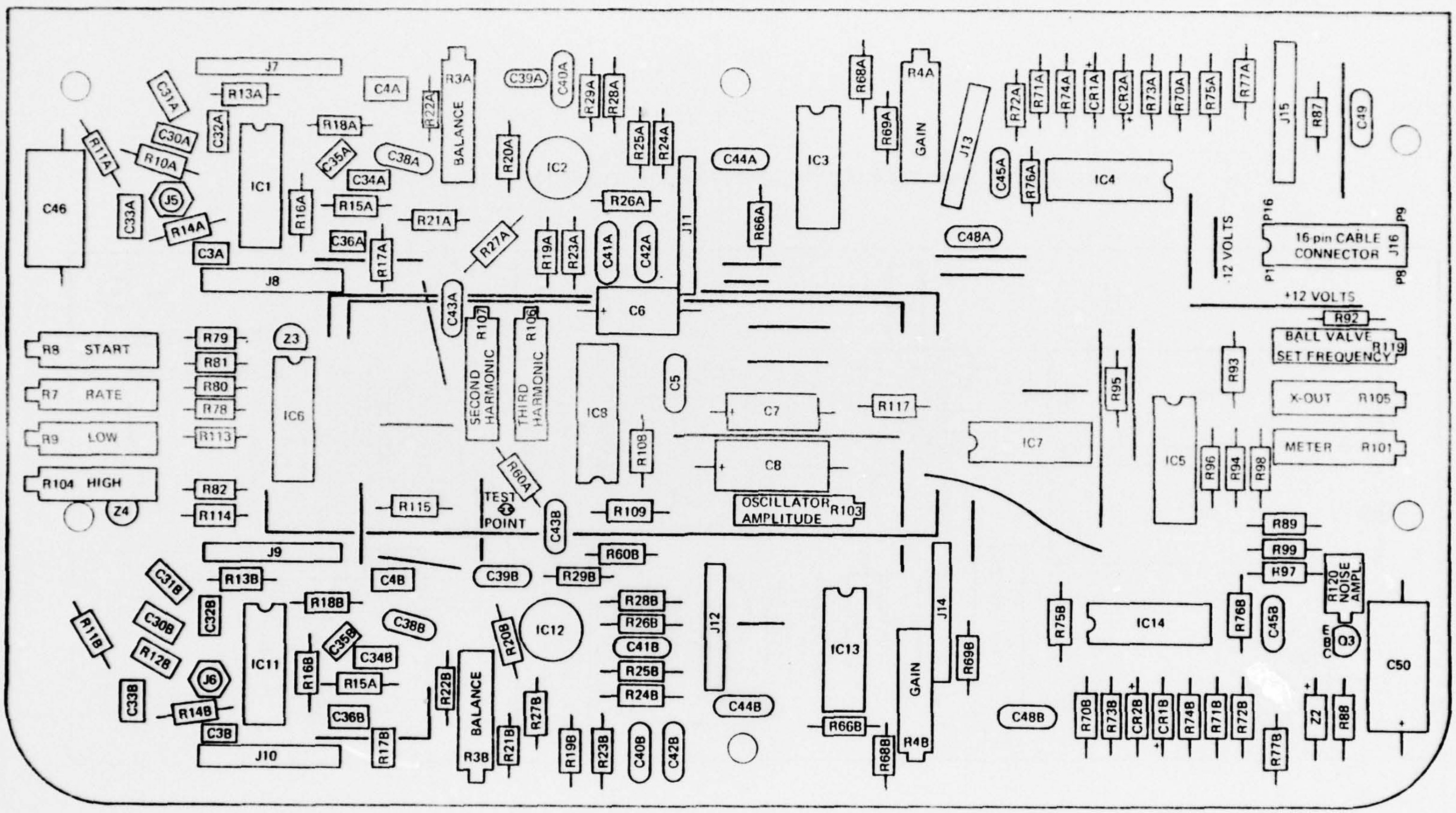

Figure A-4. Acoustic Water Leak Analyzer Main Board

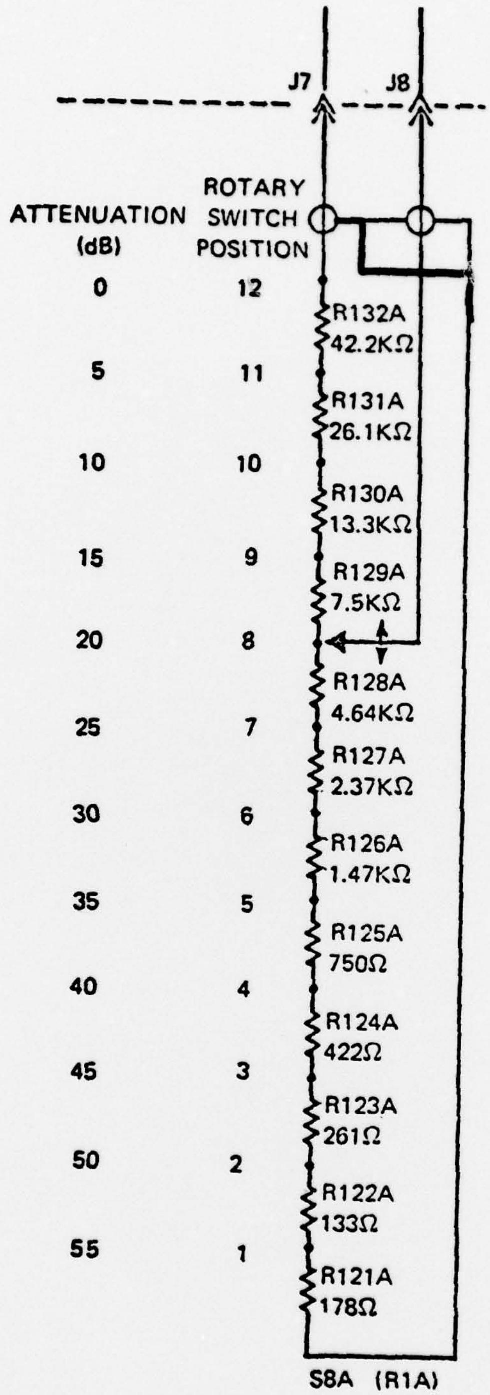

Figure A-5. Acoustic Water Leak Analyzer "A" Attenuation Dial

APPENDIX B

METER FACE MODIFICATION TO ACOUSTIC VALVE LEAK DETECTOR MODEL C SPECIFICATION

The face of the milliammeter shall be modified as follows: (refer to Figure B-1).

- Replace the words "DC MILLIAMPERES" with the words "ACOUSTIC LEVEL".
- Replace the linear scale with the logarithmic scale as shown in Figure B-1.
- The numerals "0", "10", "20", "25", and "30" shall be placed above the scale as shown in Figure B-1.
- The area between the 73.8 degree mark and the 77.4 degree mark shall be colored yellow.
- The area to the right of the yellow area, between the 77.4 degree mark and the 90 degree mark shall be colored green.
- The lettering "BATT" shall be placed within the green area.
- The words "METER ZERO" shall be placed below the 0 degree mark.

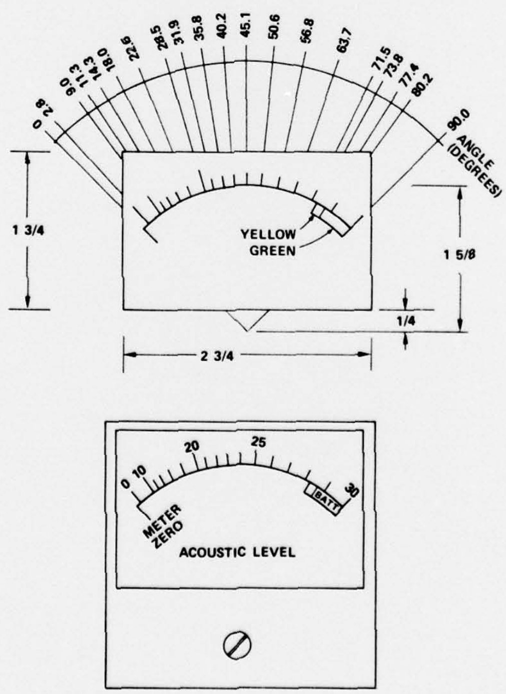

Figure B-1. Milliammeter Modification

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