With limited space available, some menu items are abbreviated. None-the-less, abbreviations and acronyms represent terms familiar to qualified ultrasonic NDT personnel. Quantum TE is based upon a powerful microcomputer, combining the absolute latest in high-speed digital electronics technology and high capability ultrasonic instrument features. Quantum TE software has been designed with the needs of NDT personnel foremost in mind; complex, computer-like terminology and operations have been purposely avoided. The following is a description of each Menu item(s) and its associated sub-functions.

One key point to keep in mind is that HELP is always just a keystroke away. No matter the menu item you are on or have question with, just Hi-Light the menu item then press and hold the select key. A menu item description and use will pop up for review. It's almost like having a mini-manual built in.

2.2 MENUS

Four Menu items are arranged vertically along the left-hand margin of the display as shown in Figure 2.1. Whenever a Menu is displayed, an active A-trace is also displayed. The highlighted menu item can either be selected (to reveal related sub-functions) or changed by appropriate keying of the arrow keys. In some highlighted Menu items, variables can be changed without having to select sub-functions.

2.2.1 MAIN MENU

The functions grouped in the **MAIN** menu are used to select Quantum TE basic setup parameters. These items are logically among the first to be addressed during a new setup. Last setup/factory default values are automatically displayed. Even though the defaults permit many kinds of ultrasonic tests using many kinds of transducers to be successfully performed, highly precise flaw detection tests may require refinements to the default variables to better match transducer/instrument characteristics.

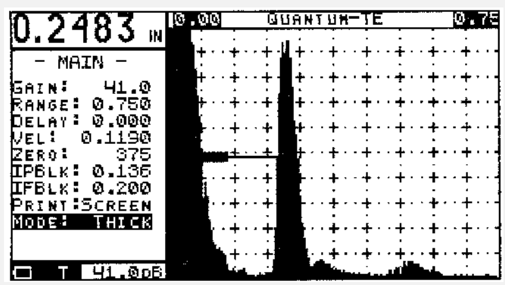


Figure 4

GAIN

Used to adjust the amplitude of the A-trace display. Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

RANGE

Used to determine how much time (distance) is represented on the horizontal axis of the A-trace display. Increasing or Decreasing the RANGE will cause the A-trace display to expand or contract.

DELAY

Used to adjust the start of the A-trace display along the horizontal axis. Gates that are synchronized with the A-trace will also delay accordingly.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity when ANGLE MODE is selected.

ZERO ADJUST (Zero)

A fine delay function which allows for compensation of transducer wearsurfaces, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

IP BLOCKING GATE (IPBlk)

Used to Increase or Decrease the length of the gate that is used to block out any unwanted signals after the Main Bang (Initial Pulse) . Adjustment of the IP **BLOCKING GATE** will allow proper setup for IP to first back echo measurement in the thickness mode.

IF BLOCKING GATE (IFBlk)

Used to Increase or Decrease the length of the gate that is used to block out any unwanted signals between the first back echo (IF) and the second back echo. Proper adjustment of the IF BLOCKING GATE will allow measurement of the first back echo to the second back echo in the thickness mode.

PRINT

There are two options available when printing**:**

SCREEN when selected, causes the contents of the display to be printed to a serial printer through the RS-232C port. Note: Serial port parameters are: 9600 Baud, 8 Data Bits, 1 Stop Bit and None Parity.

SETUP when selected, prints the current instrument setup to a serial printer through the RS-232C port. Note: Serial port parameters are: 9600 Baud, 8 Data Bits, 1 Stop Bit and None Parity.

BOTH When selected will print the screen with it's associated setup at the same time.

Printing is started by placing the cursor in print, then using the left or right arrow keys to select SCREEN, SETUP or BOTH, then pressing the SEL key. A message will occur at the top of the screen reminding the operator to press and hold the MENU button to start printing. You may then cursor around to other menus and print any screen by pressing and holding the menu key. Short taps on the menu key will move you through the menu selections as normal. To cancel the print mode, place the cursor over the print field again and press the SEL key. A message will appear stating the print mode is canceled

MODE - MEASUREMENT MODE

Used to select the type of inspection to be performed.
THICKNESS mode enables the Thickness Measurement Gate and Thick Menu which is used to set all thickness parameters.
FLAW mode enables the use of Flaw Gates and the GATE1/GATE2 menus.
ANGLE sets the gage for Angle Beam inspection. The Thickness measurement mode and one flaw gate are available for use in Angle Beam inspection. FLAW TRIANGULATION data is also displayed in **ANGLE** mode.

A status icon in the top right corner of the display shows the current mode selected. When the cursor is placed over the MODE position the user can select desired mode and press SEL to jump to that menu. I.E. if the MODE is set to ANGLE pressing SEL will jump to the ANGLE menu. You can also get to the ANGLE menu by cycling through the menus using the MENU key.

The relative battery pack charge status icon is also displayed. When the is battery icon is empty approximately one-half to three-quarters of an hour of use remains. This is a warning to the Operator that a freshly charged battery pack should soon be installed.

2.2.2 SETUP MENU

The functions grouped in the **SETUP** menu are used to select memory, screen and keypad, and print out functions.

SAVE SETUP (SAVE)
Stores, into the QFT's memory, the Ultrasonic setup currently in use. 1 - 50 and User definable setups can be stored.

RECALL SETUP (RCALL)
Recalls any ultrasonic setup stored in QFT's memory. This includes User setup, Factory Default setup or any of the other 50 instrument setups. Note: If the gage is powered ON with the SEL/Help button depressed, the Factory Default setup will be loaded.

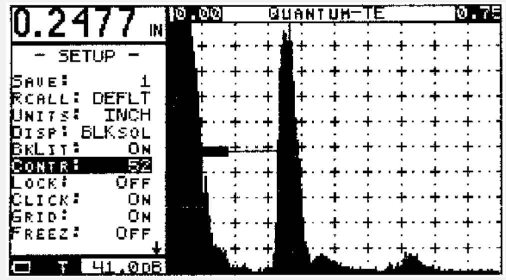


Figure 5

UNITS
Allows selection of the basic unit of measurement for the gage. Select between INCHES or MILLIMETERS.

<u>**DISPLAY**</u> (DISP) - There are four selectable screen displays:

BLACK LINES (BLKLin) - When selected, displays a black lined, hollow A-trace waveform against a light background.

BLACK SOLID (BLKSol) - When selected, displays a black filled A-trace waveform against a light background.

WHITE LINE (WHTLin) - When selected, displays a white lined hollow A-trace waveform against a black background.

WHITE SOLID (WHTSol) - When selected, displays a white filled A-trace display against a black background.

BACK LIGHT
(BKlit) allows On or Off selection of the Back light. Turn the Back light On to operate in low ambient lighting conditions. The Back light can be switched Off during bright ambient lighting conditions to save power.

CONTRAST (CONTR)
Adjusts the contrast of the LCD display for best possible viewing. Continually adjustable from full white to full dark.

LOCK
When selected, will lock out key pad functions from inadvertently being activated.

CLICK
When On, causes an audible annunciator to sound when a key is pressed.

GRID
Turns the display graticule on or off. If the display is "busy".

FREEZE (FREEZ)
When activated stops any screen activity and "holds" whatever was on the screen at the time the freeze option was selected. Activate the function by using the left & right arrow keys.

PEAK ECHO HOLD (Phold)

When Peak Echo Hold is selected two things happen. 10 the display (A-Trace) remains active and dynamic. 2) An outline of the peak echos will be retained on the screen for reference. Refer to the figure which indicates the instrument in the PHold mode as well as the Freez mode on. To activate PHold, cursor to the menu item and use the left or right arrow keys. When the display indicates on the mode is active. You may clear the PHold line at any time by pressing the SEL key while in the PHold mode.

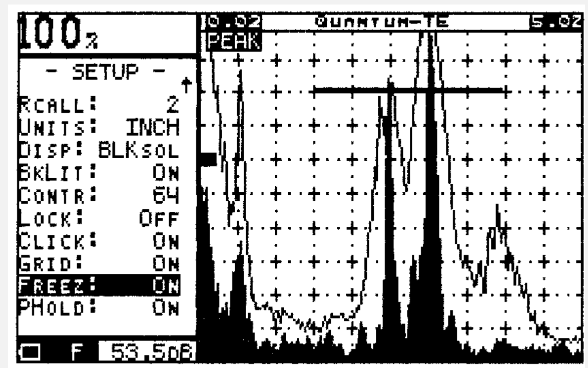


Figure 6 Peak Echo Hold

2.2.3 THICKNESS MODE

The **THICKNESS MODE** contains items specific to thickness gaging. These items are :

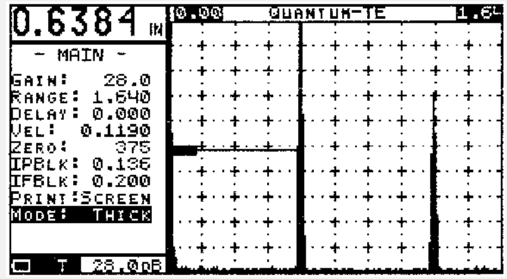


Figure 7 Thickness Gate

THICKNESS GATE THRESHOLD (TThrs)

Allows Increase or Decrease the Measurement Threshold level. Any echo or echo half cycle with amplitude equal to or greater than the Thickness Gate Threshold will be measured. The threshold gate is the bar on the left of the A-Trace frame extending to the first echo in the figure.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity when ANGLE MODE is selected.

ZERO ADJUST

A fine delay function which allows for compensation of transducer wear, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

ECHO

Allows the selection of a multiple echo from which the thickness measurement will begin. For instance, 1^{st} to 2^{nd}, 2^{nd} to 3^{rd} and so on. Up to the fifth multiple echo can be selected.

ECHO BLOCKING GATE (EBlk)

Allows Increase or Decrease the length of the echo blocking gate that is used to block out any unwanted signals between multiple echos in the thickness mode.

THICKNESS RESOLUTION (RESOL)

Selects the thickness measurement resolution on LCD display . **NORMAL** resolution is 0.001 inch or 0.01 mm. However, when high frequency delay line transducers are used, stable and reproducible resolution of 0.0001 inch is achievable in **HIGH** resolution.

THICKNESS HOLD (Thold)

When the transducer is removed from the part under test the Quantum will by default display the LAST thickness value read just before the probe was removed. Other choices are MIN value or MAX value, where the thickness display will hold the lowest or the highest value respectively. The thickness reading will once again become “live” when the probe is coupled to the part under test.

THICKNESS ALARM (TALRM)

Used to turn on pre-set HI-LO limit monitoring. If on and limits are set, any reading above or below the limits will trigger the alarm speaker and light.

HI LIMIT ALARM (HiAlm)

Use the left and right arrow keys to set the desired Hi-Limit alarm. For instance, if you wanted to be notified of any reading over 0.500", set the Hi-Alarm to 0.501". Once this thickness value is reached the alarm will sound.

LO LIMIT ALARM (LoAlm)

Similar to Hi-Limit except used for setting a low alarm limits.

AUTOMATIC GAIN CONTROL (AGC)

A unique feature of the Quantum TE is the Automatic Gain Control. Actually this control is semi-automatic. The usefulness of this feature would be evident on material with varied attenuation properties such as painted and non painted surfaces or corroded back surfaces. AGC may also help overall reading accuracies due to the fact that the thickness gate will be reading to the same height on the echo “flank” (first rising edge). There are four ranges in which the AGC will operate. 55dB, 71dB, 87dB and 103dB.

2.2.4 FLAW MODE

The **FLAW MODE** (selected from the main menu or front panel direct access keys) contains items specific to flaw detection. When this mode is selected GATE1 & GATE2 will be displayed in sequence after the setup menu with repeated presses of the menu button. These menu items are :

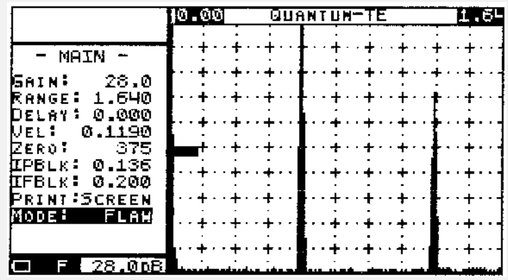


Figure 8 Flaw Mode

GATE1 or GATE2 Menu

Enables or disables either the flaw gate, GATE 1 or GATE 2, independently. Highest echo amplitude in gated area is expressed as a percent (%) of screen height on the digital LCD display.

ALARM1 or ALARM2

Enables or disables GATE 1 or GATE 2 alarms independently. POSITIVE gate enable means alarm activates when signal exceeds threshold in gate. NEGATIVE gate enable means alarm activates when signal drops below gate threshold.

GATE1 or GATE2 START (STRT1 or STRT2)

Allows adjustment of the horizontal position of the leading edge (start) of the gate. Continuously adjustable from 0.000 to 200.0 inches (500mm).

GATE1 or GATE2 WIDTH (WID1)

Allows adjustment of the horizontal position of the trailing edge (width) of the gate. Continuously adjustable from 0.000 to 200.0 inches (500mm).

GATE THRESHOLD THRS1 or THRS2

Allows adjustment of the threshold level of the gate. Adjustable from 10% to 90%of full screen height in 1% increment.

2.2.5 ANGLE MODE

The **ANGLE MODE** contains items specific to angle beam flaw detection. The ANGLE mode functions in a manner which requires the THICKNESS and FLAW facilities of the Quantum TE. The end result of a proper calibration will net proper readings for Sound Path, Flaw Depth and Surface Path distances. Calibration procedures for the ANGLE MODE are discussed in chapter 4.4.3. The items on the menu are :

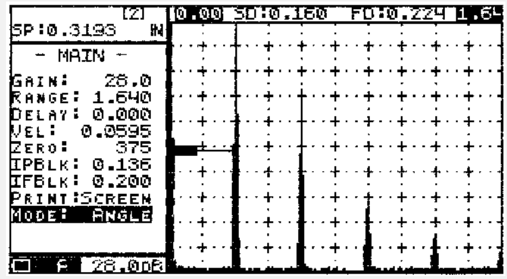


Figure 9 Angle Mode Selected

GAIN

Used to adjust the amplitude of the A-trace display.
Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

Ref dB

Used to set the Reference Gain. When Ref dB is adjusted it will force the Gain parameter to the same value as Ref dB. When the field cursor is positioned over the Ref dB field, the instrument gain will become the Ref dB value. When the field cursor is not on the Ref dB field, the instrument gain becomes the value of the Gain field. Pressing the SEL button on the Ref dB field will cause the Gain field to become the same value as Ref dB.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity while in the **ANGLE MODE**.

ZERO ADJUST (ZERO)

Fine delay function which allows for compensation of transducer wear, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

DELAY

Used to adjust the start of the A-trace display along the horizontal axis. Gates that are synchronized with the A-trace will also delay accordingly.

SHEAR ANGLE (Angle)

Allows user entry of the refracted beam angle (for flaw triangulation measurements) of the transducer being used. Adjustable from 0 to 90 degrees in 0.1 degree increments.

NOMINAL THICKNESS (Thick)

Allows entry of the nominal thickness of the material being tested (used for flaw triangulation measurements). Adjustable from 0.01. To 50.00 inches.

SURFACE DISTANCE OFFSET (Sdoff)

Permits the user to enter the sound path offset in order to compensate for wedge or shoe distance. This offset is subtracted from the actual Surface Distance to allow for more accurate flaw location.

2.2.6 PULSER/RECEIVER MENU

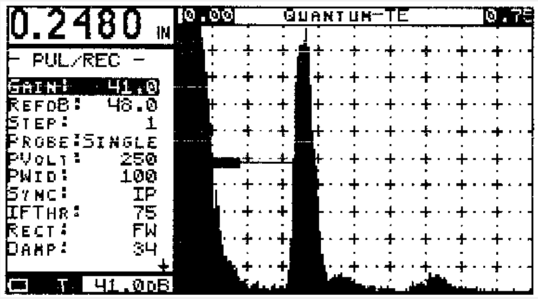


Figure 10 Top of PUL/REC Menu (Note Arrow)

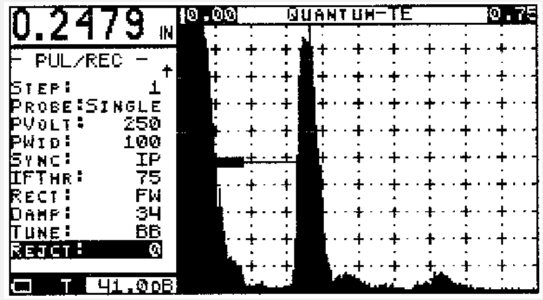


Figure 11 Bottom Of Menu (Note up arrow)

PULSER / RECEIVER MENU

Contains items that are initially adjusted when different transducers (probes) are used. The obvious first consideration is to what type of transducer is being used: single element or dual element (or two separate transducers). Each requires some special start-up considerations. For single element transducers, regardless of whether delay line, protected element or contact varieties, the instrument pulser and receiver configuration is necessarily different from the case where two separate or dual element transducers are being used.

GAIN

Used to adjust the amplitude of the A-trace display. Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

Ref dB

Used to set the Reference Gain. When Ref dB is adjusted it will force the Gain parameter to the same value as Ref dB. When the field cursor is positioned over the Ref dB field, the instrument gain will become the Ref dB value. When the field cursor is not on the Ref dB field, the instrument gain becomes the value of the Gain field. Pressing the SEL button on the Ref dB field will cause the Gain field to become the same value as Ref dB.

GAIN STEP SIZE (Step)

Used to select the incremental value for **GAIN** adjustment. Selectable values are: 0.1dB, 1.0dB, 2.0dB and 6.0dB.

PROBE TYPE (PROBE)

Used to select transducer type. Options are single or dual element. Dual can also be used for thru transmission applications

PULSER VOLTAGE (PVolt)

Used to Increase or Decrease the amplitude voltage of the square wave pulser and is selectable from 50 to 400 volts in 5 volt increments. Adjustment of Pulser Voltage allows visual optimization of the A-trace for the transducer being used.

PULSE WIDTH (PWID)

Used to Increase or Decrease the width of the square wave pulse and is selectable from 30 to 250 nanoseconds in 5 nanosecond increments. Adjustment of Pulse Width allows visual optimization of the A-trace for the transducer being used.

SYNC

(IP) INITIAL PULSE SYNC

Causes the gage to synchronize the presentation of the A-trace to the Initial Pulse or Main Bang echo. The Initial Pulse will appear at the left edge of the display.

(IF) INTERFACE SYNC
Causes the gage to synchronize the presentation of the A-trace to the first resolvable echo signal past the initial pulse which is greater or equal to the Interface Threshold. The Interface Pulse will appear at the left edge of the display.

A little preface in the use and setup of IF Sync…. There are two ranges to be thinking about.

One is the MAIN range. This is adjusted in the IP mode. Both the menu selectable range and keypad range change values.

The other is IF range which must fit fully into the MAIN range. Best way to set this up is to put instrument into IP range and be sure that the flaw or back wall echo will always stay on screen. This means that the water path to the IF will be seen as well as the IF to destination target/back wall. Be sure this rule stays in place throughout the water path change probability.

It is OK to select a long MAIN range and a short IP. For instance, I even set 20 inches as a MAIN range and then used a IF range of 2". The IF range can never be longer than the MAIN range!!! We think we rang this all out but.. if a limit we didn't check gets through the gage would likely lock up.

1. Setup transducer/pulser parameters to optimize test as usual.
2. Be sure to start with IP mode (currently in the P/R menu)
3. You can adjust these parameters in RF (Could never gate in RF before), FW, HW- or HW+
4. On the MAIN menu be sure to set an IP block outside the IP noise/ringdown at test sensitivity. This should not approach the lower limit of the lowest potential IF position or the IF could get blocked, i.e., If the IP block is set to 2 inches the IF can not be below that limit or the next echo over the threshold will be the IF start.
5. In the P/R menu, set an IF threshold level. Your call but 40-75% depending on noise is a reasonable zone.
6. Set IF Polarity. Best seen in RF mode. This would be the half of the IF echo waveform with the cleanest, sharpest edge. Usually one side will have a lower level half cycle that would sync IF sporadically and one half that is pretty clean from the base line up to the 1st half cycle peak.
7. Set rectification HW+, HW-, RF or FW. I like FW. This does not have to be the same as the IF Polarity.
8. Then set IF on the P/R menu and you should be in business. If you get no IF echo you should see a dotted bar at the level you set the IF threshold with the IP blocking gate shown. Once an IF signal over threshold is detected the instrument will Sync on the IF.

NOTE… when in the IF mode the range across the top of the instruments A-Trace will be that of your original IFRange setting, rather than the full range set in the MAIN menu, IP Mode. You can adjust the IF range while in the IF mode using the MAIN menu IFRange menu selection only… not the front panel keyboard. This will only adjust the MAIN Range for the moment.
Alarms will function quite fast as before. One thing to keep in mind is that if the gate start is set at 2", it will show at 2" from IP or if in the IF mode, 2" from the IF.

INTERFACE THRESHOLD (IFThr)
Used to Increase or Decrease of the threshold level (where on a given half cycle) to which an Interface Sync is detected. Once the interface sync is detected, the Interface signal is positioned to the left edge of the display.

RECTIFICATION (Rect)
Sets the rectification mode for the echo signal on the A-trace display. Four selectable waveform types scan be displayed :

+HW *- Positive half-wave rectified*

+HW when selected, displays only the positive portion of the RF signal on the A-trace display.

- HW *- Negative half-wave rectified*

- HW when selected, displays only the negative portion of the RF signal on the A-trace display.

FW *- Fullwave rectified*

FW when selected, displays a superimposed -HW signal on a +HW signal on the A-trace display.

RF *- Non rectified radio-frequency*

RF when selected, displays both the +HW and -HW signals, non-rectified, at 50% screen height.

Thickness measurements are not allowed if **RF RECTIFICATION** is selected.

DAMPING

Changes receiver damping through these values : 16, 18, 20, 21, 25, 26, 31, 32, 34, 36, 44, 50, 77, 100, 200, 500 ohms. As each new value is switched in, the effect on the waveform in the A-trace display can be observed. Use Damping to visually optimize the receiver / transducer performance.

After damping you will notice a little arrow pointing downward in the lower right corner of the menu box. This indicates there are more choices below the last line of the menu. Continue to cursor down to view the other options. As you do so you will note the arrow moves up to the upper right corner of the menu box.

TUNE FREQUENCY (TUNE)

Selects of the frequency range of the receiver to match the transducer. A broadband frequency range(BB) of 0.5 to 25MHz, tuned channels of 0.5, 1.0, 2,25, 5.0, 10.0 MHZ (nominal) are selectable.

REJECT

Allows suppression of unwanted low amplitude signals, such as electrical or material noise. Reject is adjustable from 0 to 90% in 1% increments of screen height of the A-trace display.

2.2.7 CURVE Menu - It would be a good idea to read through this entire section before attempting to use the features. There are several menu items interlinked to each other. They may or may not have an effect depending on the mode you are using.

Curve Type - Ctype

Off - Turns activation of curves on and off

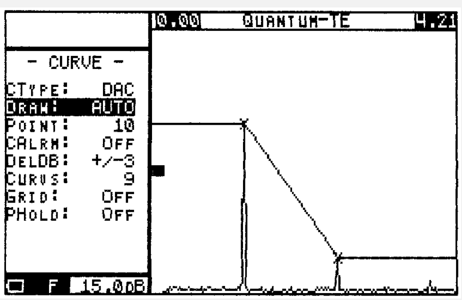
DAC - Turns on electronic Distance Amplitude Correction. DAC is an electronic means for the user to vary the instrument gain with time to minimize the sound attenuation effects with increased distance. The user has access for up to 10 points to define the area of the signal with which DAC will operate. This menu item selects DAC and functions to turn DAC on or off through the use of the SEL/HELP key once the DAC curve has been defined. This step will be covered under the POINT menu selection.

DAG - Turns on Distance Amplitude Gating. With this feature the user enters a curve which represents the sound attenuated echo pattern. When DAG is turned on any echo which exceeds the gate threshold will trigger the alarm. This function acts much like a standard gate except the user can contour it.

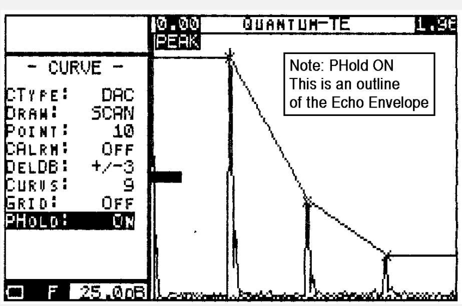
Weld - This function is similar to the DAG function in that it displays a curve on the screen which is representative of the echo decay pattern but allows the user to “switch” on other reference lines at defined amplitude (dB) levels with reference to the defined curve. The user can specify reference lines at $\pm$3dB or $\pm$6dB. You also have the ability to define up to 9 curves total on screen (hence the ability to turn the GRID off).

Draw

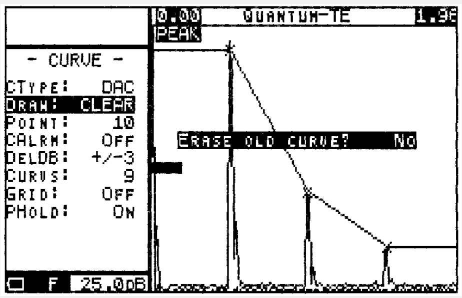
Manual - Allows the user to define the DAC, DAG or Weld curves manually using up to 10 points. This is accomplished through the use of the cursor keys to move the cursor to each point and cinch or set that point.



Auto - AUTO will automatically draw a curve using a set of up to 10 multiple echos displayed on the screen. This function will automatically select the peak values of each echo and then draw the curve across those peaks.



Scan - SCAN DAC works in conjunction with PEAK ECHO HOLD (PHOLD). When Peak Echo Hold is active and the user scans across a test or setup block(s) the echo envelope or outline will be displayed. When you are satisfied that each echo has been optimized press SEL/HELP key while the cursor highlights the SCAN item. The Quantum TE will then analyze the display and draw” a curve across the peaks of the echo envelope. If a mistake has been made in the making the curve pressing the SEL/HELP will solicit a response from the Quantum asking if you want to Erase The Old Curve. Pressing the left or right arrow and then SEL/HELP will draw a new curve. If an error was made in the Peak Echo Envelope acquisition you must go to PHold and press SEL/HELP to erase the old outline and start new.



Clear - Will clear a previously established curve. The user will be asked if they really want to erase the curve displayed.

Points

In the MANUAL mode the user defines how many points to use in the definition of the DAC / DAG / Or Weld curve. In the AUTO and SCAN mode the Quantum will automatically pick as many points as needed up to 10 and between 15% & 90% FS.

Curve Alarm (CAlrm)

The Curve Alarm is used in conjunction with the DAG feature. Allowable options are OFF, POS & NEG. POSitive will trigger both the audible and visual alarm when an echo exceeds the DAG threshold. NEGative will trigger the alarms whenever there is no echo at or above the threshold.

Delta dB (DelDB)

This feature as well as the CURVS is used in conjunction with the WELD curve feature. Options are ±3dB and ±6dB. These added lines are just reference indicators.

Curves (Curvs)

Defines the total number of curves displayed on the screen. The total number is 9 including the first defined curve used as the central reference curve. Options are 3, 5, 7 & 9

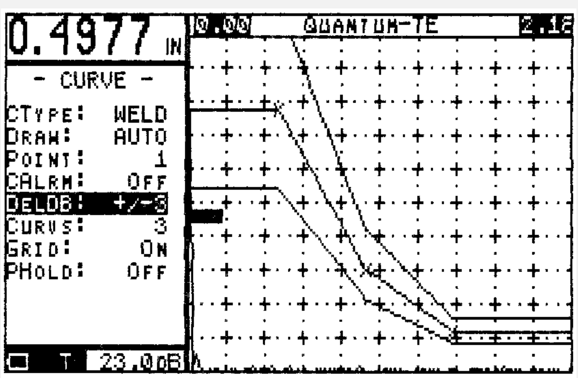


Figure 15 3 Curves defined

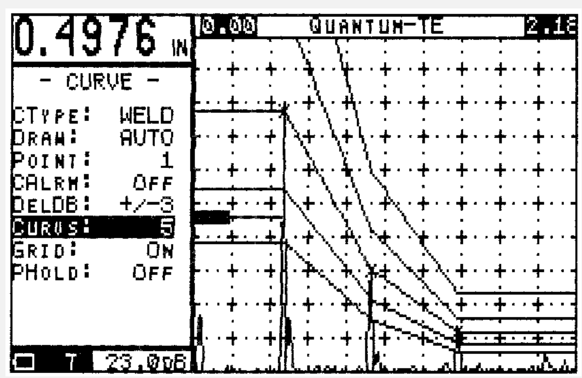


Figure 16 5 Curves defined @ +/- 3dB

GRID

Turns the display graticule on or off. If the display is “busy”, as can be the case if several curves along with peak echo hold and the dynamic display are all present.

PEAK ECHO HOLD (PHold)

When Peak Echo Hold is selected two things happen. 10 the display (A-Trace) remains active and dynamic. 2) An outline of the peak echos will be retained on the screen for reference. Refer to the figure which indicates the instrument in the PHOLD mode as well as the Freez mode on. To activate PHOLD, cursor to the menu item and use the left or right arrow keys. When the display indicates on the mode is active. You may clear the PHOLD line at any time by pressing the SEL key while in the PHOLD mode.

2.2.8 ZOOM Menu

Zoom permits the user to view an entire screen and then expand just a section of it for easier viewing at the press of a button. This is most useful when longer ranges are being used. To define the limits of ZOOM use the cursor keys to move the left & right vertical limit bar to the desired position while the Zoom menu item is OFF.

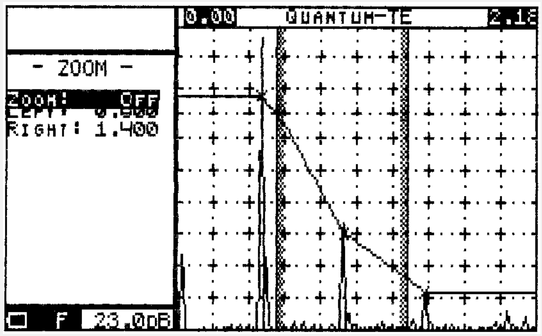


Figure 17 ZOOM OFF - Note Vertical Bars

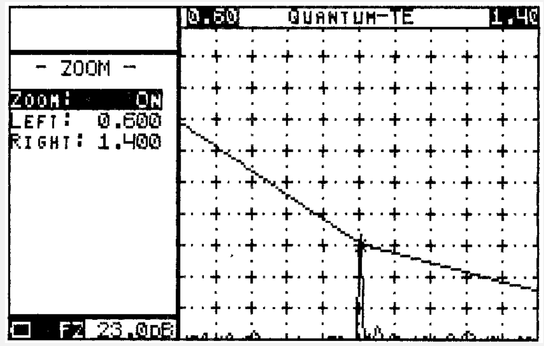


Figure 18 ZOOM ON - Everything between bars

2.3 HELP SCREENS

Every menu function has a help screen to allow you to quickly review the functionality of that item without the need the refer to this manual. Cursor to any item, press and hold the SEL/HELP button and the LCD screen will display information about that function. The following images are just a couple of examples.

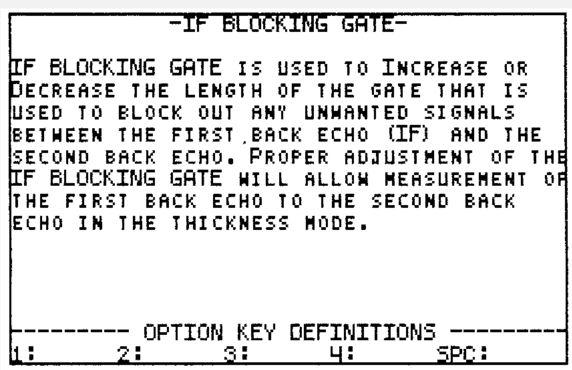


Figure 19 Help Screen Example

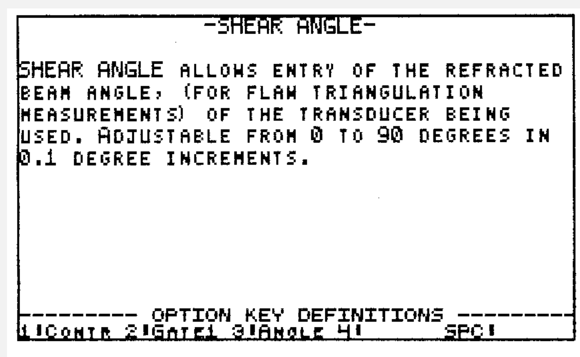


Figure 20 Help Example w/assigned OPT keys

With limited space available, some menu items are abbreviated. None-the-less, abbreviations and acronyms represent terms familiar to qualified ultrasonic NDT personnel. Quantum TE is based upon a powerful microcomputer, combining the absolute latest in high-speed digital electronics technology and high capability ultrasonic instrument features. Quantum TE software has been designed with the needs of NDT personnel foremost in mind; complex, computer-like terminology and operations have been purposely avoided. The following is a description of each Menu item(s) and its associated sub-functions.

One key point to keep in mind is that HELP is always just a keystroke away. No matter the menu item you are on or have question with, just Hi-Light the menu item then press and hold the select key. A menu item description and use will pop up for review. It's almost like having a mini-manual built in.

2.2 MENUS

Four Menu items are arranged vertically along the left-hand margin of the display as shown in Figure 2.1. Whenever a Menu is displayed, an active A-trace is also displayed. The highlighted menu item can either be selected (to reveal related sub-functions) or changed by appropriate keying of the arrow keys. In some highlighted Menu items, variables can be changed without having to select sub-functions.

2.2.1 MAIN MENU

The functions grouped in the **MAIN** menu are used to select Quantum TE basic setup parameters. These items are logically among the first to be addressed during a new setup. Last setup/factory default values are automatically displayed. Even though the defaults permit many kinds of ultrasonic tests using many kinds of transducers to be successfully performed, highly precise flaw detection tests may require refinements to the default variables to better match transducer/instrument characteristics.

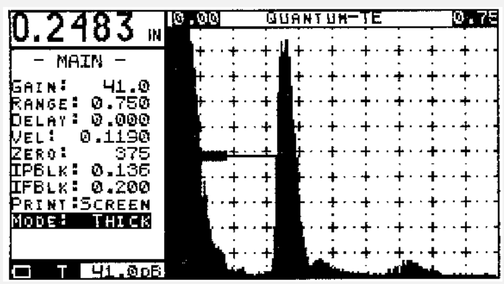


Figure 21

GAIN

Used to adjust the amplitude of the A-trace display. Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

RANGE

Used to determine how much time (distance) is represented on the horizontal axis of the A-trace display. Increasing or Decreasing the RANGE will cause the A-trace display to expand or contract.

DELAY

Used to adjust the start of the A-trace display along the horizontal axis. Gates that are synchronized with the A-trace will also delay accordingly.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity when ANGLE MODE is selected.

ZERO ADJUST (Zero)

A fine delay function which allows for compensation of transducer wearsurfaces, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

IP BLOCKING GATE (IPBlk)

Used to Increase or Decrease the length of the gate that is used to block out any unwanted signals after the Main Bang (Initial Pulse) . Adjustment of the IP **BLOCKING GATE** will allow proper setup for IP to first back echo measurement in the thickness mode.

IF BLOCKING GATE (IFBlk)

Used to Increase or Decrease the length of the gate that is used to block out any unwanted signals between the first back echo (IF) and the second back echo. Proper adjustment of the IF BLOCKING GATE will allow measurement of the first back echo to the second back echo in the thickness mode.

PRINT

There are two options available when printing**:**

SCREEN when selected, causes the contents of the display to be printed to a serial printer through the RS-232C port. Note: Serial port parameters are: 9600 Baud, 8 Data Bits, 1 Stop Bit and None Parity.

SETUP when selected, prints the current instrument setup to a serial printer through the RS-232C port. Note: Serial port parameters are: 9600 Baud, 8 Data Bits, 1 Stop Bit and None Parity.

BOTH When selected will print the screen with it’s associated setup at the same time.

Printing is started by placing the cursor in print, then using the left or right arrow keys to select SCREEN, SETUP or BOTH, then pressing the SEL key. A message will occur at the top of the screen reminding the operator to press and hold the MENU button to start printing. You may then cursor around to other menus and print any screen by pressing and holding the menu key. Short taps on the menu key will move you through the menu selections as normal. To cancel the print mode, place the cursor over the print field again and press the SEL key. A message will appear stating the print mode is canceled

MODE - MEASUREMENT MODE

Used to select the type of inspection to be performed.

THICKNESS mode enables the Thickness Measurement Gate and Thick Menu which is used to set all thickness parameters.

FLAW mode enables the use of Flaw Gates and the GATE1/GATE2 menus.

ANGLE sets the gage for Angle Beam inspection. The Thickness measurement mode and one flaw gate are available for use in Angle Beam inspection. FLAW TRIANGULATION data is also displayed in **ANGLE** mode.

A status icon in the top right corner of the display shows the current mode selected. When the cursor is placed over the MODE position the user can select desired mode and press SEL to jump to that menu. I.E. if the MODE is set to ANGLE pressing SEL will jump to the ANGLE menu. You can also get to the ANGLE menu by cycling through the menus using the MENU key.

The relative battery pack charge status icon is also displayed. When the is battery icon is empty approximately one-half to three-quarters of an hour of use remains. This is a warning to the Operator that a freshly charged battery pack should soon be installed.

2.2.2 SETUP MENU

The functions grouped in the **SETUP** menu are used to select memory, screen and keypad, and print out functions.

SAVE SETUP (SAVE)

Stores, into the QFT's memory, the Ultrasonic setup currently in use. 1 - 50 and User definable setups can be stored.

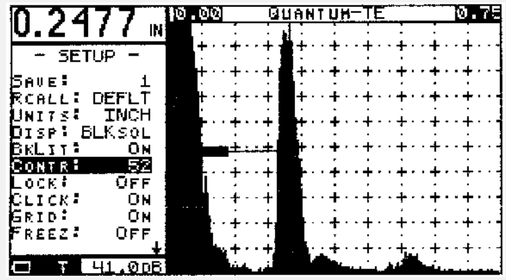


Figure 22

RECALL SETUP (RCALL)

Recalls any ultrasonic setup stored in QFT's memory. This includes User setup, Factory Default setup or any of the other 50 instrument setups. Note: If the gage is powered ON with the SEL/Help button depressed, the Factory Default setup will be loaded.

UNITS

Allows selection of the basic unit of measurement for the gage. Select between INCHES or MILLIMETERS.

DISPLAY (DISP) - There are four selectable screen displays:

BLACK LINES (BLKLin) - When selected, displays a black lined, hollow A-trace waveform against a light background.

BLACK SOLID (BLKSol) - When selected, displays a black filled A-trace waveform against a light background.

WHITE LINE (WHTLin) - When selected, displays a white lined hollow A-trace waveform against a black background.

WHITE SOLID (WHTSol) - When selected, displays a white filled A-trace display against a black background.

BACK LIGHT

(BKlit) allows On or Off selection of the Back light. Turn the Back light On to operate in low ambient lighting conditions. The Back light can be switched Off during bright ambient lighting conditions to save power.

CONTRAST (CONTR)

Adjusts the contrast of the LCD display for best possible viewing. Continually adjustable from full white to full dark.

LOCK

When selected, will lock out key pad functions from inadvertently being activated.

CLICK

When On, causes an audible annunciator to sound when a key is pressed.

GRID

Turns the display graticule on or off. If the display is "busy".

FREEZE (FREEZ)

When activated stops any screen activity and "holds" whatever was on the screen at the time the freeze option was selected. Activate the function by using the left & right arrow keys.

PEAK ECHO HOLD (Phold)

When Peak Echo Hold is selected two things happen. 10 the display (A-Trace) remains active and dynamic. 2) An outline of the peak echos will be retained on the screen for reference. Refer to the figure which indicates the instrument in the PHold mode as well as the Freez mode on. To activate PHold, cursor to the menu item and use the left or right arrow keys. When the display indicates on the mode is active. You may clear the PHold line at any time by pressing the SEL key while in the PHold mode.

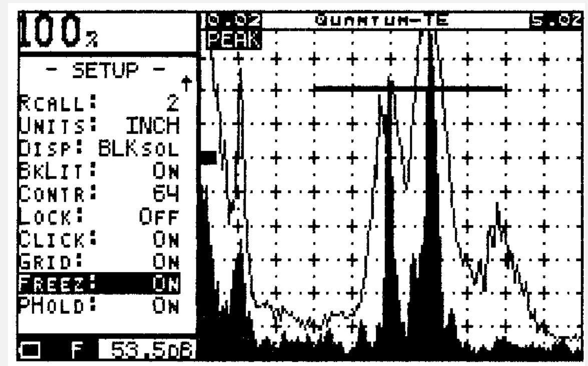


Figure 23 Peak Echo Hold

2.2.3 THICKNESS MODE

The **THICKNESS MODE** contains items specific to thickness gaging. These items are :

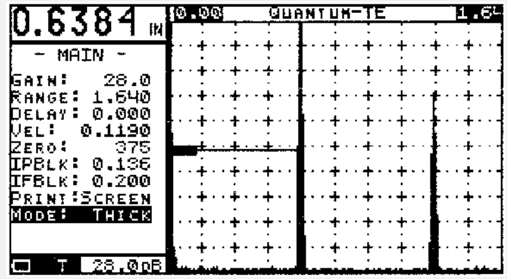


Figure 24 Thickness Gate

THICKNESS GATE THRESHOLD (TThrs)

Allows Increase or Decrease the Measurement Threshold level. Any echo or echo half cycle with amplitude equal to or greater than the Thickness Gate Threshold will be measured. The threshold gate is the bar on the left of the A-Trace frame extending to the first echo in the figure.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity when ANGLE MODE is selected.

ZERO ADJUST

A fine delay function which allows for compensation of transducer wear, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

ECHO

Allows the selection of a multiple echo from which the thickness measurement will begin. For instance, 1st to 2nd, 2nd to 3rd and so on. Up to the fifth multiple echo can be selected.

ECHO BLOCKING GATE (EBlk)

Allows Increase or Decrease the length of the echo blocking gate that is used to block out any unwanted signals between multiple echos in the thickness mode.

THICKNESS RESOLUTION (RESOL)

Selects the thickness measurement resolution on LCD display . **NORMAL** resolution is 0.001 inch or 0.01 mm. However, when high frequency delay line transducers are used, stable and reproducible resolution of 0.0001 inch is achievable in **HIGH** resolution.

THICKNESS HOLD (Thold)

When the transducer is removed from the part under test the Quantum will by default display the LAST thickness value read just before the probe was removed. Other choices are MIN value or MAX value, where the thickness display will hold the lowest or the highest value respectively. The thickness reading will once again become “live” when the probe is coupled to the part under test.

THICKNESS ALARM (TALRM)

Used to turn on pre-set HI-LO limit monitoring. If on and limits are set, any reading above or below the limits will trigger the alarm speaker and light.

HI LIMIT ALARM (HiAlm)

Use the left and right arrow keys to set the desired Hi-Limit alarm. For instance, if you wanted to be notified of any reading over 0.500", set the Hi-Alarm to 0.501". Once this thickness value is reached the alarm will sound.

LO LIMIT ALARM (LoAlm)

Similar to Hi-Limit except used for setting a low alarm limits.

AUTOMATIC GAIN CONTROL (AGC)

A unique feature of the Quantum TE is the Automatic Gain Control. Actually this control is semi-automatic. The usefulness of this feature would be evident on material with varied attenuation properties such as painted and non painted surfaces or corroded back surfaces. AGC may also help overall reading accuracies due to the fact that the thickness gate will be reading to the same height on the echo “flank” (first rising edge). There are four ranges in which the AGC will operate. 55dB, 71dB, 87dB and 103dB.

2.2.4 FLAW MODE

The **FLAW MODE** (selected from the main menu or front panel direct access keys) contains items specific to flaw detection. When this mode is selected GATE1 & GATE2 will be displayed in sequence after the setup menu with repeated presses of the menu button. These menu items are :

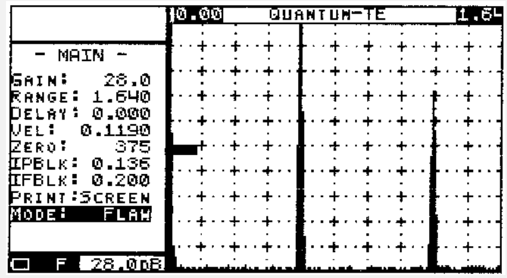


Figure 25 Flaw Mode

GATE1 or GATE2 Menu

Enables or disables either the flaw gate, GATE 1 or GATE 2, independently. Highest echo amplitude in gated area is expressed as a percent (%) of screen height on the digital LCD display.

ALARM1 or ALARM2

Enables or disables GATE 1 or GATE 2 alarms independently. POSITIVE gate enable means alarm activates when signal exceeds threshold in gate. NEGATIVE gate enable means alarm activates when signal drops below gate threshold.

GATE1 or GATE2 START (STRT1 or STRT2)

Allows adjustment of the horizontal position of the leading edge (start) of the gate. Continuously adjustable from 0.000 to 200.0 inches (500mm).

GATE1 or GATE2 WIDTH (WID1)

Allows adjustment of the horizontal position of the trailing edge (width) of the gate. Continuously adjustable from 0.000 to 200.0 inches (500mm).

GATE THRESHOLD THRS1 or THRS2

Allows adjustment of the threshold level of the gate. Adjustable from 10% to 90%of full screen height in 1% increment.

2.2.5 ANGLE MODE

The **ANGLE MODE** contains items specific to angle beam flaw detection. The ANGLE mode functions in a manner which requires the THICKNESS and FLAW facilities of the Quantum TE. The end result of a proper calibration will net proper readings for Sound Path, Flaw Depth and Surface Path distances. Calibration procedures for the ANGLE MODE are discussed in chapter 4.4.3. The items on the menu are :

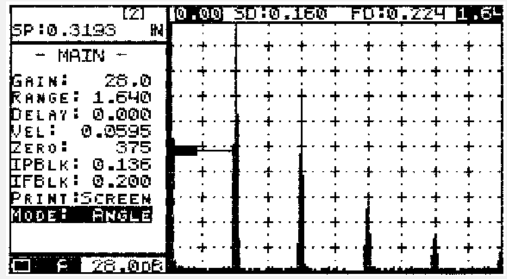


Figure 26 Angle Mode Selected

GAIN

Used to adjust the amplitude of the A-trace display.
Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

Ref dB

Used to set the Reference Gain. When Ref dB is adjusted it will force the Gain parameter to the same value as Ref dB. When the field cursor is positioned over the Ref dB field, the instrument gain will become the Ref dB value. When the field cursor is not on the Ref dB field, the instrument gain becomes the value of the Gain field. Pressing the SEL button on the Ref dB field will cause the Gain field to become the same value as Ref dB.

VELOCITY (VEL)

Sets the material velocity (inches/microsecond or mm/microsecond) used in calculations of thickness. NOTE: The VELOCITY value will be decreased by approximately one-half from reference velocity while in the **ANGLE MODE**.

ZERO ADJUST (ZERO)

Fine delay function which allows for compensation of transducer wear, coupling membranes and angle beam wedge. Adjustment is continuous from 0 to 20,000 nanoseconds.

DELAY

Used to adjust the start of the A-trace display along the horizontal axis. Gates that are synchronized with the A-trace will also delay accordingly.

SHEAR ANGLE (Angle)

Allows user entry of the refracted beam angle (for flaw triangulation measurements) of the transducer being used. Adjustable from 0 to 90 degrees in 0.1 degree increments.

NOMINAL THICKNESS (Thick)

Allows entry of the nominal thickness of the material being tested (used for flaw triangulation measurements). Adjustable from 0.01. To 50.00 inches.

SURFACE DISTANCE OFFSET (Sdoff)

Permits the user to enter the sound path offset in order to compensate for wedge or shoe distance. This offset is subtracted from the actual Surface Distance to allow for more accurate flaw location.

2.2.6 PULSER/RECEIVER MENU

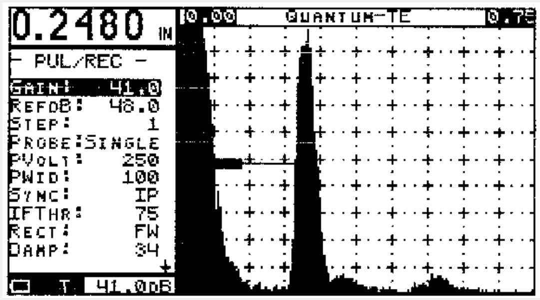


Figure 27 Top of PUL/REC Menu (Note Arrow)

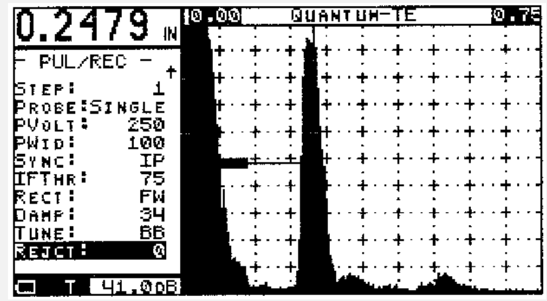


Figure 28 Bottom Of Menu (Note up arrow)

PULSER / RECEIVER MENU

Contains items that are initially adjusted when different transducers (probes) are used. The obvious first consideration is to what type of transducer is being used: single element or dual element (or two separate transducers). Each requires some special start-up considerations. For single element transducers, regardless of whether delay line, protected element or contact varieties, the instrument pulser and receiver configuration is necessarily different from the case where two separate or dual element transducers are being used.

GAIN

Used to adjust the amplitude of the A-trace display. Increasing or Decreasing the GAIN will cause the A-trace signal to increase or decrease in amplitude.

Ref dB

Used to set the Reference Gain. When Ref dB is adjusted it will force the Gain parameter to the same value as Ref dB. When the field cursor is positioned over the Ref dB field, the instrument gain will become the Ref dB value. When the field cursor is not on the Ref dB field, the instrument gain becomes the value of the Gain field. Pressing the SEL button on the Ref dB field will cause the Gain field to become the same value as Ref dB.

GAIN STEP SIZE (Step)

Used to select the incremental value for **GAIN** adjustment. Selectable values are: 0.1dB, 1.0dB, 2.0dB and 6.0dB.

PROBE TYPE (PROBE)

Used to select transducer type. Options are single or dual element. Dual can also be used for thru transmission applications

PULSER VOLTAGE (PVolt)

Used to Increase or Decrease the amplitude voltage of the square wave pulser and is selectable from 50 to 400 volts in 5 volt increments. Adjustment of Pulser Voltage allows visual optimization of the A-trace for the transducer being used.

PULSE WIDTH (PWID)

Used to Increase or Decrease the width of the square wave pulse and is selectable from 30 to 250 nanoseconds in 5 nanosecond increments. Adjustment of Pulse Width allows visual optimization of the A-trace for the transducer being used.

SYNC

(IP) INITIAL PULSE SYNC

Causes the gage to synchronize the presentation of the A-trace to the Initial Pulse or Main Bang echo. The Initial Pulse will appear at the left edge of the display.

(IF) INTERFACE SYNC
Causes the gage to synchronize the presentation of the A-trace to the first resolvable echo signal past the initial pulse which is greater or equal to the Interface Threshold. The Interface Pulse will appear at the left edge of the display.

INTERFACE THRESHOLD (IFThr)
Used to Increase or Decrease of the threshold level (where on a given half cycle) to which an Interface Sync is detected. Once the interface sync is detected, the Interface signal is positioned to the left edge of the display.

RECTIFICATION (Rect)
Sets the rectification mode for the echo signal on the A-trace display. Four selectable waveform types scan be displayed :

***+HW** - Positive half-wave rectified*
+HW when selected, displays only the positive portion of the RF signal on the A-trace display.

***- HW** - Negative half-wave rectified*
- HW when selected, displays only the negative portion of the RF signal on the A-trace display.

***FW** - Fullwave rectified*
FW when selected, displays a superimposed -HW signal on a +HW signal on the A-trace display.

***RF** - Non rectified radio-frequency*
RF when selected, displays both the +HW and -HW signals, non-rectified, at 50% screen height.

Thickness measurements are not allowed if **RF RECTIFICATION** is selected.

DAMPING
Changes receiver damping through these values : 16, 18, 20, 21, 25, 26, 31, 32, 34, 36, 44, 50, 77, 100, 200, 500 ohms. As each new value is switched in, the effect on the waveform in the A-trace display can be observed. Use Damping to visually optimize the receiver / transducer performance.

After damping you will notice a little arrow pointing downward in the lower right corner of the menu box. This indicates there are more choices below the last line of the menu. Continue to cursor down to view the other options. As you do so you will note the arrow moves up to the upper right corner of the menu box.

TUNE FREQUENCY (TUNE)
Selects of the frequency range of the receiver to match the transducer. A broadband frequency range(BB) of 0.5 to 25MHz, tuned channels of 0.5, 1.0, 2,25, 5.0, 10.0 MHZ (nominal) are selectable.

REJECT
Allows suppression of unwanted low amplitude signals, such as electrical or material noise. Reject is adjustable from 0 to 90% in 1% increments of screen height of the A-trace display.

2.2.7 CURVE Menu - It would be a good idea to read through this entire section before attempting to use the features. There are several menu items interlinked to each other. They may or may not have an effect depending on the mode you are using.

Curve Type - Ctype

Off - Turns activation of curves on and off

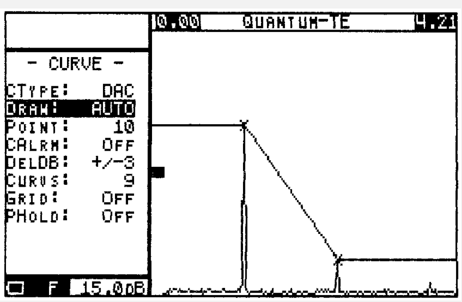
DAC - Turns on electronic Distance Amplitude Correction. DAC is an electronic means for the user to vary the instrument gain with time to minimize the sound attenuation effects with increased distance. The user has access for up to 10 points to define the area of the signal with which DAC will operate. This menu item selects DAC and functions to turn DAC on or off through the use of the SEL/HELP key once the DAC curve has been defined. This step will be covered under the POINT menu selection.

DAG - Turns on Distance Amplitude Gating. With this feature the user enters a curve which represents the sound attenuated echo pattern. When DAG is turned on any echo which exceeds the gate threshold will trigger the alarm. This function acts much like a standard gate except the user can contour it.

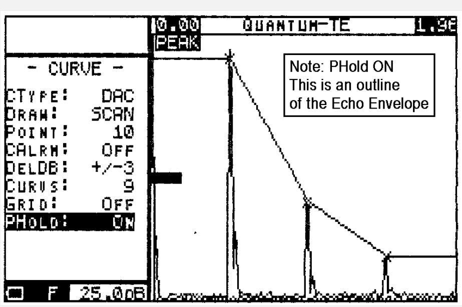
Weld - This function is similar to the DAG function in that it displays a curve on the screen which is representative of the echo decay pattern but allows the user to “switch” on other reference lines at defined amplitude (dB) levels with reference to the defined curve. The user can specify reference lines at ±3dB or ±6dB. You also have the ability to define up to 9 curves total on screen (hence the ability to turn the GRID off).

Draw

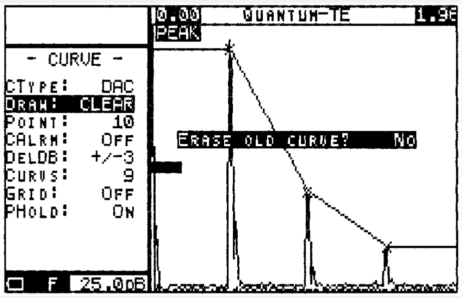
Manual - Allows the user to define the DAC, DAG or Weld curves manually using up to 10 points. This is accomplished through the use of the cursor keys to move the cursor to each point and cinch or set that point.



Auto - AUTO will automatically draw a curve using a set of up to 10 multiple echos displayed on the screen. This function will automatically select the peak values of each echo and then draw the curve across those peaks.



Scan - SCAN DAC works in conjunction with PEAK ECHO HOLD (PHOLD). When Peak Echo Hold is active and the user scans across a test or setup block(s) the echo envelope or outline will be displayed. When you are satisfied that each echo has been optimized press SEL/HELP key while the cursor highlights the SCAN item. The Quantum TE will then analyze the display and draw” a curve across the peaks of the echo envelope. If a mistake has been made in the making the curve pressing the SEL/HELP will solicit a response from the Quantum asking if you want to Erase The Old Curve. Pressing the left or right arrow and then SEL/HELP will draw a new curve. If an error was made in the Peak Echo Envelope acquisition you must go to PHold and press SEL/HELP to erase the old outline and start new.



Clear - Will clear a previously established curve. The user will be asked if they really want to erase the curve displayed.

Points

In the MANUAL mode the user defines how many points to use in the definition of the DAC / DAG / Or Weld curve. In the AUTO and SCAN mode the Quantum will automatically pick as many points as needed up to 10 and between 15% & 90% FS.

Curve Alarm (CAlrm)

The Curve Alarm is used in conjunction with the DAG feature. Allowable options are OFF, POS & NEG. POSitive will trigger both the audible and visual alarm when an echo exceeds the DAG threshold. NEGative will trigger the alarms whenever there is no echo at or above the threshold.

Delta dB (DelDB)

This feature as well as the CURVS is used in conjunction with the WELD curve feature. Options are ±3dB and ±6dB. These added lines are just reference indicators.

Curves (Curvs)

Defines the total number of curves displayed on the screen. The total number is 9 including the first defined curve used as the central reference curve. Options are 3, 5, 7 & 9

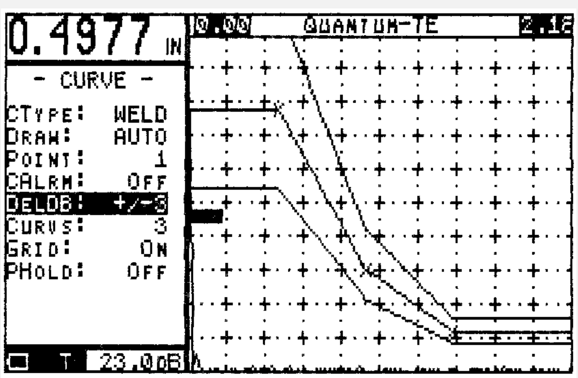


Figure 32 3 Curves defined

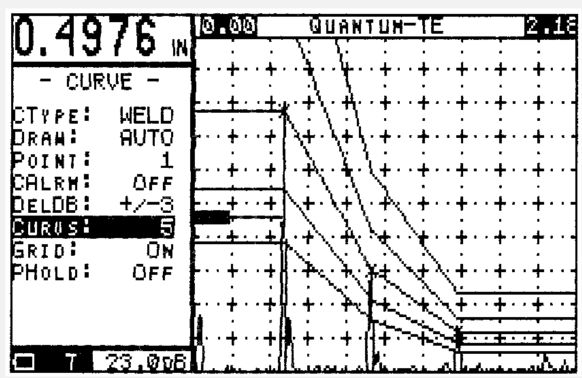


Figure 33 5 Curves defined @ +/- 3dB

GRID

Turns the display graticule on or off. If the display is "busy", as can be the case if several curves along with peak echo hold and the dynamic display are all present.

PEAK ECHO HOLD (PHold)

When Peak Echo Hold is selected two things happen. 10 the display (A-Trace) remains active and dynamic. 2) An outline of the peak echos will be retained on the screen for reference. Refer to the figure which indicates the instrument in the PHOLD mode as well as the Freez mode on. To activate PHOLD, cursor to the menu item and use the left or right arrow keys. When the display indicates on the mode is active. You may clear the PHOLD line at any time by pressing the SEL key while in the PHOLD mode.

2.2.8 ZOOM Menu

Zoom permits the user to view an entire screen and then expand just a section of it for easier viewing at the press of a button. This is most useful when longer ranges are being used. To define the limits of ZOOM use the cursor keys to move the left & right vertical limit bar to the desired position while the Zoom menu item is OFF.

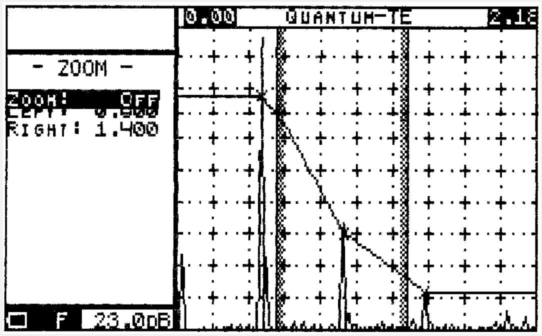


Figure 34 ZOOM OFF - Note Vertical Bars

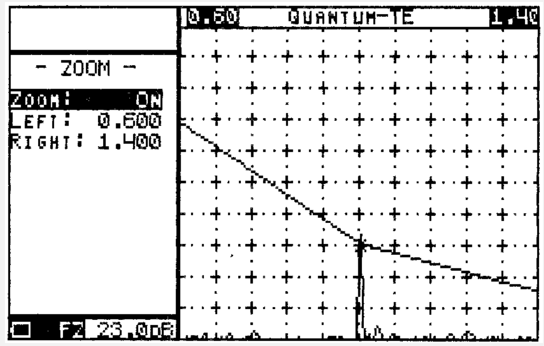


Figure 35 ZOOM ON - Everything between bars

2.3 HELP SCREENS

Every menu function has a help screen to allow you to quickly review the functionality of that item without the need the refer to this manual. Cursor to any item, press and hold the SEL/HELP button and the LCD screen will display information about that function. The following images are just a couple of examples.

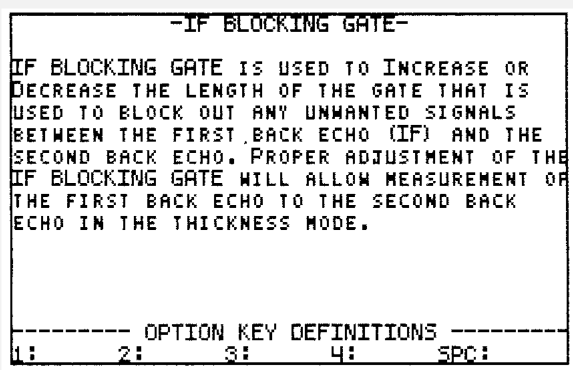


Figure 36 Help Screen Example

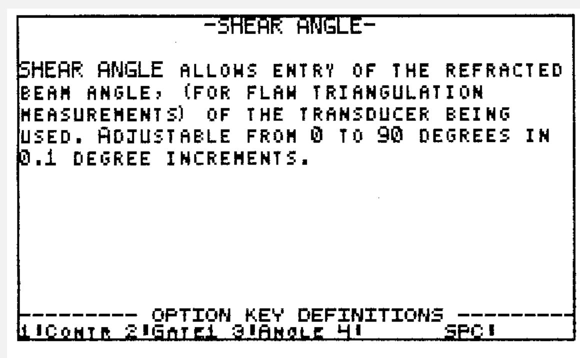


Figure 37 Help Example w/assigned OPT keys

3.0 TRANSDUCER SELECTION

The Quantum TE is also a capable precision thickness gage. Virtually any broad band or general purpose transducer (application dependant) used with the Quantum TE, as can equivalent transducers manufactured by other producers.

While the commentary below pertains to applications in metals, there are numerous applications to a wide variety of engineering materials. For plastics, glasses and other more or less isotropic materials, the procedures are similar to those for metals. Major differences in testing nonmetals are in the velocity of sound and different impedance characteristics. Fiber-reinforced composite materials are characteristically anisotropic, having different acoustical properties in different directions, and often require specialized transducers and procedures for satisfactory ultrasonic testing results.

In general, however, many of the transducer selection criteria factors outlined below apply for nonmetals, but additional experimentation may be required. NDT Systems, Inc. engineers have extensive experience in ultrasonic testing of many materials and can provide assistance when called upon.

The following suggestions are by no means fully comprehensive or mandatory. Alternative approaches may produce essentially the same results. The operator should experiment to determine the best transducer for given applications or contact NDT Systems, Inc. for advice.

3.1 Thickness Gaging Applications.

3.1.1 Thickness Ranges

Metals with Thicknesses Ranging from 0.008 inch to Approximately 0.750 inch (0.2 to 20.0 millimeters). In this range, there are overlapping considerations that will dictate which type of transducer will produce the desired results. Foremost is the limitation of the minimum thickness that can be resolved by different types of transducers.

3.1.1.1 Single Element, Delay Line Transducers.
Some highly damped, high frequency transducers of this type are capable of producing fully resolved multiple back echos equivalent to as little as 0.005 inch (0.13mm) in steel having smooth surfaces. However, such transducers will be relatively expensive and not readily attainable.

Standard inexpensive delay line transducers, highly damped, in the frequency range of 10 to 20 MHZ, will ordinarily produce good results down to approximately 0.008 inch (0.20mm). Given smooth surfaces in metals having relatively low attenuation, like wrought steel or aluminum, such transducers can be used to gage up to 0.75 inch (20mm), more or less, depending upon the length of the delay line.

To determine the practical minimum thickness resolution of a delay line transducer, it is necessary to have an array of thin shims ranging in thickness around the desired minimum to be measured. Inexpensive sets of steel shims, used as feeler gages, can be obtained from well equipped hardware stores, automotive parts houses or specialty tool suppliers. The nominal thickness is typically imprinted onto each shim, often in inches and millimeters. Available sets contain as many as 15 or 20 shims, ranging from 0.005 to 0.025 inch (0.13 to 0.64mm) thick. While we have found that the stated thickness is nominal, subject to variation up to ±0.0004 inch (0.01mm), these shims can be used to readily determine the minimum thickness that can be expected from a given transducer.

Under ideal conditions, parts having very smooth, parallel surfaces can be measured to an accuracy approaching ±0.0001 (±0.003mm). To achieve such accuracy, not only is it necessary to have an appropriate transducer, the thickness gaging instrument must have extremely stable, high speed electronic circuitry. Quantum TE fulfills this requirement admirably. For a procedure to demonstrate this capability, see Section 4.3.2.3, below.

3.1.1.2 Single Element, Focused Immersion Transducers.
Some transducers of this type have been designed specifically for precision thickness gaging of metals 0.010 inch (0.25mm) thick and greater. Small diameter, high frequency, short-focused immersion transducers also can be used to measure the distance to quite small internal reflectors. This is useful, for example, in gaging remaining thickness over internal passages in turbine blades. Procedures for using immersion transducers are outlined in Section 4.3.2.4, below.

3.1.2 Metals with Thicknesses Ranging from 0.030 inch (0.76mm) Upward.

3.1.2.1 Single Element Contact Transducers Hard-Faced Wear Plates.
Depending upon active element size and frequency, highly damped (broadband) transducers of this type can seldom be used on steel or aluminum much below 0.030 inch (0.8mm). The ultimate minimum thickness limitation must be determined experimentally.

The advantage of using this type of transducer is that much thicker sections can be gaged, and on materials that have less than smooth surfaces or are relatively attenuative. Again, some experimentation will indicate the limitations and advantages among transducers of the same type, but having different sizes, frequencies and spectral characteristics.

When trying to achieve best results on relatively thin materials, the most important considerations are frequency and spectral characteristics. Foremost is the need to use a transducer having the greatest bandwidth, all other things being equal. Such transducers have relatively large, high density masses bonded to the internal face of the active element. This mass minimizes the amount of "ringing" of the active element following excitation by a short duration, high voltage electrical pulse. This kind of high mechanical damping minimizes the length of the ultrasonic wavetrain associated with the high energy initial pulse as well as the subsequent back-wall echos.

Also necessary to achieve best thickness resolution is the need to use the highest frequency consistent with external factors that affect coupling efficiency, and to take material attenuation into consideration. IF a transducer is expected to produce minimum thickness resolution and be used over a broad range of thicknesses, test material attenuation may dictate a compromise. While higher frequencies produce thinner thickness resolution, attenuation is more pronounced at higher frequencies.

For relatively flat, smooth-surfaced steel or aluminum test objects, highly damped contact transducers in the frequency range from 5 to 10 MHZ generally will produce acceptable results in the thickness range from 0.040 inch (1.0mm) up to 5 inches (125mm) more or less. With QFT-100, and under ideal external conditions, transducers of 5, 7.5 or 10 MHZ having active elements of 0.25 to 0.50 inch (6.4 to 12.7mm) diameter will cover the range from 0.030 to 10 inches (0.76 to 250mm) or more.

For procedures outlining the use of broad banded contact transducers, see Section 4.3.2.1.

3.1.2.2 Single Element Contact Transducers with Membrane and Other Protective Devices.
So-called protected element transducers are used in relatively rugged applications involving rough, abrasive test object surfaces or surfaces at elevated temperatures. Usual designs of protected element transducers include reduced internal damping, lower frequencies and larger diameters. As a result, their application typically ranges from a few tenths of an inch (10mm plus or minus) upwards.

Often used on castings, forgings and mill-finished piping, protected element transducers are infrequently used for thickness gaging -- more often used for flaw detection. However, if the protective element is a relatively thin elastomer or flexible polymer, the procedures for thickness gaging are similar to those for single element contact-type transducers. For thicker wear-caps or temperature-protective delay lines, procedures are more like those for delay line transducers.

3.1.2.3 Dual Element Contact-Type Transducers.
This category of transducers is frequently used in thickness gaging applications, combining some of the advantages of both single element contact and delay line models. They have two elements, each with a separate delay line, mounted side-by-side in a single fixed housing. The elements are isolated acoustically from one another by a sound-absorbing barrier between them. They are electrically isolated as well; one serves as a transmitter, the other as a receiver. The ultrasonic instrument must provide the capability of isolating the pulser and receiver, as does the Quantum TE.

Practical minimum thickness resolution from a dual element transducer optimized for thickness gaging is approximately 0.040 inch (1.0mm). Typical frequencies for thickness gaging applications range from 2.25 to 10 MHZ, and the elements can be semi-circular or rectangular. While again it is only possible to generalize the applications, dual elements provide a good balance among resolution, penetration and sensitivity.

Procedures for using dual element transducers are outlined in Section 4.3.2.5.

3.2 Flaw Detection Applications.

3.2.1 Straight Beam Longitudinal Wave Tests**.**
All the various types of transducers used for thickness gaging are also used for flaw detection. However, flaw detection focuses on characterizing the amplitude of echos from small internal reflectors (flaws) as opposed to accurate measurement of the time-of-flight interval between front-wall and back-wall echos.

In a sense, both flaw detection and thickness gaging procedures combine in most tests governed by flaw detection criteria. In most instances, once a flaw has been detected and judged to be significant, it is also required to describe its geometry, position and location within the test object, at least to the extent possible.

Usual flaw detection procedures depend upon the capabilities of the instrument/transducer combination to detect small reflectors. Occasionally, this feature of high sensitivity requires that both the transducer and instrument receiver amplifier be narrow-banded and frequency-matched to one another. To produce a narrow-banded transducer, little or no mechanical damping is applied to the back face of the active element. This results in a more highly energetic transducer, hut one that vibrates or "rings down" for a short time after the excitation pulse shuts off. This continuing oscillation produces a long duration wave-train that effectively "blinds" the transducer from differentiating echos from reflectors (flaws or hack-wall) within the ring-down period. While sensitive to the detection of echos from small, deep-lying reflectors, narrow-banded transducers are limited in their ability to resolve echos from near-surface flaws or from the surfaces of thin-walled test objects.

Transducer frequency also has significant effects on the sensitivity to detection of small flaw echos. As the frequency of a narrow-hand transducer is increased (assuming narrow-band frequency matching in the instrument receiver), the ability of the sound beam to react to small reflectors is enhanced. However, hl polycrystalline metals and multi constituent composites, internal reflections from grain boundaries or other interfaces greatly increases at high ultrasonic frequencies.

The effect is to scatter the sound beam, both reducing its ability to penetrate and decreasing the signal-to-noise ratio in reflected echos that return to the transducer.

A further consideration in transducer .selection for flaw detection is in the effects of frequency and active element size on the directivity and coherence of the sound beam. The shape of the sound beam often must be taken into account Both near-field effects and beam-spreading relate to sensitivity; unfortunately the relationships between element frequency and size are sometimes at odds, forcing compromises with respect to sensitivity, penetration and near-surface flaw detection.

Without delving into the mathematics of beam geometry, the facts are:

1. For a given element size, higher frequencies produce less divergent beams, but increase the length of the near-field.

2. For a given frequency, smaller element sizes produce shorter near-fields, but increase beam divergence.

Since the sensitivity requirements are dictated by the particular code, standard or procedure governing specific tests, it is not possible to he very specific in recommending flaw detection transducers. However, since a large number (if not a majority) of straight beam flaw detection ultrasonic tests are performed on metals less than 2 to 3 inches (50 to 75mm) thick, a few general statements apply:

1. Using broadband transducers will greatly enhance near-surface flaw detection capabilities and most frequently will produce adequate penetration and sensitivity - generally a better compromise in many tests than using narrow band transducers.

2. If penetration of the soundbeam is a problem, use the lowest frequency transducer that produces desired sensitivity if near-surface resolution is not required, use a low frequency narrowband transducer.

3. If signal-to-noise sensitivity is a problem, use narrow-band transducers sensitive to small flaws yet not overly sensitive to other internal reflectors such as grain boundaries in metals.

4. When a combination of problems exists, experiment with different spectral characteristics (bandwidth) at the theoretical size and frequency otherwise indicated.

The foregoing discussion applies for immersion transducer selection as well as for the various types of contact transducers. However, with immersion transducers, another significant factor emerges; the sound beam can be focused. Within some limits, focusing can produce several advantages

A. The irregular effects of the near-field can he eliminated.

B. Beam divergence can he controlled; beam energy can be concentrated within a small cross-section of the beam. Sensitivity to detection of small flaws can he increased.

C. On parts having convex curved surfaces, focusing can be used to improve soundbeam coupling: spherical focusing is best for compound curvature; cylindrical focusing can be used on conic and cylindrical shapes

Focusing is only effective within certain limits depending upon transducer size and frequency. For a complete discussion on the focus ranges of immersion transducers, see OPTIMA transducer catalog in the Transducer Selection section of Part 4, Immersion 'transducers.

3.2.2 Angle-Beam Shear Wave Tests**.**
Transducer selection for angle-beam tests is relatively simple. Except for a few isolated applications, there is little need for the transducer to be broad banded. Medium-to-low damping is ordinary; some angle-beam transducers are basically undamped. However, such transducers generally perform well with broad banded instrument receivers.

AWS transducers, specified for use when the AWS Structural Welding Code is invoked, are supplied in three element sizes, 5/8 x 5/8 inch, 5/8 x 3/4 inch, and 3/4 x 3/4 inch (15.9 x 15.9mm, 15.9 x 19.1mm, and 19.1 x 19.1mm). All are available with a nominal frequency of 2.25 MHZ, as specified by the code. Acrylic plastic wedges are supplied to convert the longitudinal wave to refracted shear waves at incident angles of 45ـه, 60ـه, and 70ـه, again as required by the Code.

Similar, general purpose, or so-called "standard" models are available in a greater variety of sizes and with standard angle-beam wedges additionally available for 30ـه and 90ـه refracted angles. Virtually any angle can he specified for special applications.

Other types of angle-beam transducers include Quick Change and Mini models. The Quick Change models have circular element sizes of 1/4, 3/8 and ½ inch (6.4, 9.5 and 12.7mm) diameter and are threaded to accommodate replaceable wedges that screw onto the transducer element. No tools are required and worn wedges are discarded. Standard and AWS models also have replaceable wedges, hut a .small screwdriver is required to remove and replace the wedges. Mini Angle-Beam models are compact, designed for use in confined spaces, for small parts, and to permit access between closely-spaced fasteners.

For any angle-beam application it must be kept in mind that the stated refracted angle provided by the plastic wedges pertains only for a specific material. Wedges designed for use on common alloy steels will not produce the same refracted angle in aluminum, most super-alloys, many stainless steels, titanium alloys coppers etc. When purchasing wedges, the test material must he specified or a sample furnished to the supplier in order to obtain specific refracted shear-wave incident angles.

Another precaution should he observed: replaceable wedges must be acoustically coupled to the face of the transducer element. Glycerin is most often recommended although other couplants of similar consistency can be used. During use of transducers with replaceable wedges, the interface between element and wedge should be checked frequently for proper coupling. Bubbles and incompletely wetted mating surfaces will significantly affect transducer performance; usually incomplete coupling can he seen by looking through the transparent wedge material.

3.2.3 Through-Transmission Tests**.**
QUANTUM can he used for through transmission testing on test objects where access permits placement of transducers on opposing sides of the test object, with two transducers aligned in opposition. One serves as transmitter and is connected by a separate cable to the pulser output connector marked with a red dot. The other is connected to the adjacent connector When DUAL is selected in the PRB (probe) menu, QUANTUM's pulser and receiver are electrically isolated. With the transducers coupled to the test object and in opposition with each other, the sound beam will pass from one to the other, unless there is an intervening acoustic discontinuity in the path of the sound beam. This technique is often used On highly attenuative test materials and is particularly suited for detection of laminar-type flaws, or regions of varying composition due to porosity or other inhomogeneous variations.

Many such tests are conducted through immersion Or squirter techniques. Although specialized mechanical systems may he required to maintain transducer alignment and to provide scanning or other manipulations, more-or-less standard types of immersion transducers are used.

While some experimentation may he required in order to determine optimum combinations of transmitter/receiver transducers, these are generally available from the extensive line of NDT Systems OPTIMA transducers.

Likewise, for contact transducer through-transmission tests, experimentation will most probably require specific combinations of transducers, generally available from the OPTIMA selections.

3.2.4 Immersion Tests**.**
In addition to the through-transmission or squirter techniques mentioned just above, QUANTUM can he used for single transducer, pulse-echo tests. Interface synchronization (IF SYNC, found in the PULSER/RECEIVER menu) provides for synchronizing the A-Trace beginning from the entry echo that occurs between the liquid couplant column and the test object surface. Even if the couplant path length varies, the start of the A-trace and thickness gate are synchronized from the interface (IF) echo.

A complete assortment of imrnersion transducer types, sizes, frequencies, and spectral characteristics can he found in the OPTIMA transducer catalog. Accompanying each different type of transducer shown is a brief guide to the applications appropriate for that type.

3.3 Transducers for Non-Metallic Test Materials.

Virtually all the techniques and applications described above can be applied to a host of non-metallic and composite materials. It is not possible to cover the numerous applications in this manual. Transducer selection for non-metals often is much more involved. However, QUANTUM's unique design can accommodate a huge variety of transducer types. For advice, contact our Transducer Applications Specialists. Often a transducer can he recommended on the basis of a description of the application. If not, it may he necessary to submit samples of the test material.

3.4 Transducers for Specialized Applications.

Ultrasonic testing techniques have applications beyond those traditionally though of regarding flaw detection and thickness gaging. There are applications in material characterization, flaw analysis, extensometry, bondtesting, liquid level sensing, velocity measurement, and others in more or less limited usage. In some cases, because the application is specialized, so must be the transducers. QFT-100 can be used as the basic instrument for many unusual applications, and NDT Systems can usually match either a standard OPTIMA transducer or a custom design to the requirements of the application. QFT-100 user are invited to contact a NDT Systems Transducer Applications Specialist for recommendations.

3.0 TRANSDUCER SELECTION

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While the commentary below pertains to applications in metals, there are numerous applications to a wide variety of engineering materials. For plastics, glasses and other more or less isotropic materials, the procedures are similar to those for metals. Major differences in testing nonmetals are in the velocity of sound and different impedance characteristics. Fiber-reinforced composite materials are characteristically anisotropic, having different acoustical properties in different directions, and often require specialized transducers and procedures for satisfactory ultrasonic testing results.

In general, however, many of the transducer selection criteria factors outlined below apply for nonmetals, but additional experimentation may be required. NDT Systems, Inc. engineers have extensive experience in ultrasonic testing of many materials and can provide assistance when called upon.

The following suggestions are by no means fully comprehensive or mandatory. Alternative approaches may produce essentially the same results. The operator should experiment to determine the best transducer for given applications or contact NDT Systems, Inc. for advice.

3.1 Thickness Gaging Applications.

3.1.1 Thickness Ranges

Metals with Thicknesses Ranging from 0.008 inch to Approximately 0.750 inch (0.2 to 20.0 millimeters). In this range, there are overlapping considerations that will dictate which type of transducer will produce the desired results. Foremost is the limitation of the minimum thickness that can be resolved by different types of transducers.

3.1.1.1 Single Element, Delay Line Transducers.

Some highly damped, high frequency transducers of this type are capable of producing fully resolved multiple back echos equivalent to as little as 0.005 inch (0.13mm) in steel having smooth surfaces. However, such transducers will be relatively expensive and not readily attainable.

Standard inexpensive delay line transducers, highly damped, in the frequency range of 10 to 20 MHZ, will ordinarily produce good results down to approximately 0.008 inch (0.20mm). Given smooth surfaces in metals having relatively low attenuation, like wrought steel or aluminum, such transducers can be used to gage up to 0.75 inch (20mm), more or less, depending upon the length of the delay line.

To determine the practical minimum thickness resolution of a delay line transducer, it is necessary to have an array of thin shims ranging in thickness around the desired minimum to be measured. Inexpensive sets of steel shims, used as feeler gages, can be obtained from well equipped hardware stores, automotive parts houses or specialty tool suppliers. The nominal thickness is typically imprinted onto each shim, often in inches and millimeters. Available sets contain as many as 15 or 20 shims, ranging from 0.005 to 0.025 inch (0.13 to 0.64mm) thick. While we have found that the stated thickness is nominal, subject to variation up to ±0.0004 inch (0.01mm), these shims can be used to readily determine the minimum thickness that can be expected from a given transducer.

Under ideal conditions, parts having very smooth, parallel surfaces can be measured to an accuracy approaching ±0.0001 (±0.003mm). To achieve such accuracy, not only is it necessary to have an appropriate transducer, the thickness gaging instrument must have extremely stable, high speed electronic circuitry. Quantum TE fulfills this requirement admirably. For a procedure to demonstrate this capability, see Section 4.3.2.3, below.

3.1.1.2 Single Element, Focused Immersion Transducers.
Some transducers of this type have been designed specifically for precision thickness gaging of metals 0.010 inch (0.25mm) thick and greater. Small diameter, high frequency, short-focused immersion transducers also can be used to measure the distance to quite small internal reflectors. This is useful, for example, in gaging remaining thickness over internal passages in turbine blades. Procedures for using immersion transducers are outlined in Section 4.3.2.4, below.

3.1.2 Metals with Thicknesses Ranging from 0.030 inch (0.76mm) Upward.

3.1.2.1 Single Element Contact Transducers Hard-Faced Wear Plates.
Depending upon active element size and frequency, highly damped (broadband) transducers of this type can seldom be used on steel or aluminum much below 0.030 inch (0.8mm). The ultimate minimum thickness limitation must be determined experimentally.

The advantage of using this type of transducer is that much thicker sections can be gaged, and on materials that have less than smooth surfaces or are relatively attenuative. Again, some experimentation will indicate the limitations and advantages among transducers of the same type, but having different sizes, frequencies and spectral characteristics.

When trying to achieve best results on relatively thin materials, the most important considerations are frequency and spectral characteristics. Foremost is the need to use a transducer having the greatest bandwidth, all other things being equal. Such transducers have relatively large, high density masses bonded to the internal face of the active element. This mass minimizes the amount of "ringing" of the active element following excitation by a short duration, high voltage electrical pulse. This kind of high mechanical damping minimizes the length of the ultrasonic wavetrain associated with the high energy initial pulse as well as the subsequent back-wall echos.

Also necessary to achieve best thickness resolution is the need to use the highest frequency consistent with external factors that affect coupling efficiency, and to take material attenuation into consideration. IF a transducer is expected to produce minimum thickness resolution and be used over a broad range of thicknesses, test material attenuation may dictate a compromise. While higher frequencies produce thinner thickness resolution, attenuation is more pronounced at higher frequencies.

For relatively flat, smooth-surfaced steel or aluminum test objects, highly damped contact transducers in the frequency range from 5 to 10 MHZ generally will produce acceptable results in the thickness range from 0.040 inch (1.0mm) up to 5 inches (125mm) more or less. With QFT-100, and under ideal external conditions, transducers of 5, 7.5 or 10 MHZ having active elements of 0.25 to 0.50 inch (6.4 to 12.7mm) diameter will cover the range from 0.030 to 10 inches (0.76 to 250mm) or more.

For procedures outlining the use of broad banded contact transducers, see Section 4.3.2.1.

3.1.2.2 Single Element Contact Transducers with Membrane and Other Protective Devices. So-called protected element transducers are used in relatively rugged applications involving rough, abrasive test object surfaces or surfaces at elevated temperatures. Usual designs of protected element transducers include reduced internal damping, lower frequencies and larger diameters. As a result, their application typically ranges from a few tenths of an inch (10mm plus or minus) upwards.

Often used on castings, forgings and mill-finished piping, protected element transducers are infrequently used for thickness gaging -- more often used for flaw detection. However, if the protective element is a relatively thin elastomer or flexible polymer, the procedures for thickness gaging are similar to those for single element contact-type transducers. For thicker wear-caps or temperature-protective delay lines, procedures are more like those for delay line transducers.

3.1.2.3 Dual Element Contact-Type Transducers.
This category of transducers is frequently used in thickness gaging applications, combining some of the advantages of both single element contact and delay line models. They have two elements, each with a separate delay line, mounted side-by-side in a single fixed housing. The elements are isolated acoustically from one another by a sound-absorbing barrier between them. They are electrically isolated as well; one serves as a transmitter, the other as a receiver. The ultrasonic instrument must provide the capability of isolating the pulser and receiver, as does the Quantum TE.

Practical minimum thickness resolution from a dual element transducer optimized for thickness gaging is approximately 0.040 inch (1.0mm). Typical frequencies for thickness gaging applications range from 2.25 to 10 MHZ, and the elements can be semi-circular or rectangular. While again it is only possible to generalize the applications, dual elements provide a good balance among resolution, penetration and sensitivity.

Procedures for using dual element transducers are outlined in Section 4.3.2.5.

3.2 Flaw Detection Applications.

3.2.1 Straight Beam Longitudinal Wave Tests**.**
All the various types of transducers used for thickness gaging are also used for flaw detection. However, flaw detection focuses on characterizing the amplitude of echos from small internal reflectors (flaws) as opposed to accurate measurement of the time-of-flight interval between front-wall and back-wall echos.

In a sense, both flaw detection and thickness gaging procedures combine in most tests governed by flaw detection criteria. In most instances, once a flaw has been detected and judged to be significant, it is also required to describe its geometry, position and location within the test object, at least to the extent possible.

Usual flaw detection procedures depend upon the capabilities of the instrument/transducer combination to detect small reflectors. Occasionally, this feature of high sensitivity requires that both the transducer and instrument receiver amplifier be narrow-banded and frequency-matched to one another. To produce a narrow-banded transducer, little or no mechanical damping is applied to the back face of the active element. This results in a more highly energetic transducer, hut one that vibrates or "rings down" for a short time after the excitation pulse shuts off. This continuing oscillation produces a long duration wave-train that effectively "blinds" the transducer from differentiating echos from reflectors (flaws or hack-wall) within the ring-down period. While sensitive to the detection of echos from small, deep-lying reflectors, narrow-banded transducers are limited in their ability to resolve echos from near-surface flaws or from the surfaces of thin-walled test objects.

Transducer frequency also has significant effects on the sensitivity to detection of small flaw echos. As the frequency of a narrow-hand transducer is increased (assuming narrow-band frequency matching in the instrument receiver), the ability of the sound beam to react to small reflectors is enhanced. However, hl polycrystalline metals and multi constituent composites, internal reflections from grain boundaries or other interfaces greatly increases at high ultrasonic frequencies.

The effect is to scatter the sound beam, both reducing its ability to penetrate and decreasing the signal-to-noise ratio in reflected echos that return to the transducer.

A further consideration in transducer .selection for flaw detection is in the effects of frequency and active element size on the directivity and coherence of the sound beam. The shape of the sound beam often must be taken into account Both near-field effects and beam-spreading relate to sensitivity; unfortunately the relationships between element frequency and size are sometimes at odds, forcing compromises with respect to sensitivity, penetration and near-surface flaw detection.

Without delving into the mathematics of beam geometry, the facts are:

1. For a given element size, higher frequencies produce less divergent beams, but increase the length of the near-field.

2. For a given frequency, smaller element sizes produce shorter near-fields, but increase beam divergence.

Since the sensitivity requirements are dictated by the particular code, standard or procedure governing specific tests, it is not possible to he very specific in recommending flaw detection transducers. However, since a large number (if not a majority) of straight beam flaw detection ultrasonic tests are performed on metals less than 2 to 3 inches (50 to 75mm) thick, a few general statements apply:

1. Using broadband transducers will greatly enhance near-surface flaw detection capabilities and most frequently will produce adequate penetration and sensitivity - generally a better compromise in many tests than using narrow band transducers.

2. If penetration of the soundbeam is a problem, use the lowest frequency transducer that produces desired sensitivity if near-surface resolution is not required, use a low frequency narrowband transducer.

3. If signal-to-noise sensitivity is a problem, use narrow-band transducers sensitive to small flaws yet not overly sensitive to other internal reflectors such as grain boundaries in metals.

4. When a combination of problems exists, experiment with different spectral characteristics (bandwidth) at the theoretical size and frequency otherwise indicated.

The foregoing discussion applies for immersion transducer selection as well as for the various types of contact transducers. However, with immersion transducers, another significant factor emerges; the sound beam can be focused. Within some limits, focusing can produce several advantages

D. The irregular effects of the near-field can he eliminated.

B. Beam divergence can he controlled; beam energy can be concentrated within a small cross-section of the beam. Sensitivity to detection of small flaws can he increased.

C. On parts having convex curved surfaces, focusing can be used to improve soundbeam coupling: spherical focusing is best for compound curvature; cylindrical focusing can be used on conic and cylindrical shapes

Focusing is only effective within certain limits depending upon transducer size and frequency. For a complete discussion on the focus ranges of immersion transducers, see OPTIMA transducer catalog in the Transducer Selection section of Part 4, Immersion 'transducers.

3.2.2 Angle-Beam Shear Wave Tests**.**
Transducer selection for angle-beam tests is relatively simple. Except for a few isolated applications, there is little need for the transducer to be broad banded. Medium-to-low damping is ordinary; some angle-beam transducers are basically undamped. However, such transducers generally perform well with broad banded instrument receivers.

AWS transducers, specified for use when the AWS Structural Welding Code is invoked, are supplied in three element sizes, 5/8 x 5/8 inch, 5/8 x 3/4 inch, and 3/4 x 3/4 inch (15.9 x 15.9mm, 15.9 x 19.1mm, and 19.1 x 19.1mm). All are available with a nominal frequency of 2.25 MHZ, as specified by the code. Acrylic plastic wedges are supplied to convert the longitudinal wave to refracted shear waves at incident angles of 45ـه, 60ـه, and 70ـه, again as required by the Code.

Similar, general purpose, or so-called "standard" models are available in a greater variety of sizes and with standard angle-beam wedges additionally available for 30ـه and 90ـه refracted angles. Virtually any angle can he specified for special applications.

Other types of angle-beam transducers include Quick Change and Mini models. The Quick Change models have circular element sizes of 1/4, 3/8 and ½ inch (6.4, 9.5 and 12.7mm) diameter and are threaded to accommodate replaceable wedges that screw onto the transducer element. No tools are required and worn wedges are discarded. Standard and AWS models also have replaceable wedges, hut a .small screwdriver is required to remove and replace the wedges. Mini Angle-Beam models are compact, designed for use in confined spaces, for small parts, and to permit access between closely-spaced fasteners.

For any angle-beam application it must be kept in mind that the stated refracted angle provided by the plastic wedges pertains only for a specific material. Wedges designed for use on common alloy steels will not produce the same refracted angle in aluminum, most super-alloys, many stainless steels, titanium alloys coppers etc. When purchasing wedges, the test material must he specified or a sample furnished to the supplier in order to obtain specific refracted shear-wave incident angles.

Another precaution should he observed: replaceable wedges must be acoustically coupled to the face of the transducer element. Glycerin is most often recommended although other couplants of similar consistency can be used. During use of transducers with replaceable wedges, the interface between element and wedge should be checked frequently for proper coupling. Bubbles and incompletely wetted mating surfaces will significantly affect transducer performance; usually incomplete coupling can he seen by looking through the transparent wedge material.

3.2.3 Through-Transmission Tests**.**
QUANTUM can he used for through transmission testing on test objects where access permits placement of transducers on opposing sides of the test object, with two transducers aligned in opposition. One serves as transmitter and is connected by a separate cable to the pulser output connector marked with a red dot. The other is connected to the adjacent connector When DUAL is

selected in the PRB (probe) menu, QUANTUM's pulser and receiver are electrically isolated. With the transducers coupled to the test object and in opposition with each other, the sound beam will pass from one to the other, unless there is an intervening acoustic discontinuity in the path of the sound beam. This technique is often used On highly attenuative test materials and is particularly suited for detection of laminar-type flaws, or regions of varying composition due to porosity or other inhomogeneous variations.

Many such tests are conducted through immersion Or squirter techniques. Although specialized mechanical systems may he required to maintain transducer alignment and to provide scanning or other manipulations, more-or-less standard types of immersion transducers are used.

While some experimentation may he required in order to determine optimum combinations of transmitter/receiver transducers, these are generally available from the extensive line of NDT Systems OPTIMA transducers.

Likewise, for contact transducer through-transmission tests, experimentation will most probably require specific combinations of transducers, generally available from the OPTIMA selections.

3.2.4 Immersion Tests**.**
In addition to the through-transmission or squirter techniques mentioned just above, QUANTUM can he used for single transducer, pulse-echo tests. Interface synchronization (IF SYNC, found in the PULSER/RECEIVER menu) provides for synchronizing the A-Trace beginning from the entry echo that occurs between the liquid couplant column and the test object surface. Even if the couplant path length varies, the start of the A-trace and thickness gate are synchronized from the interface (IF) echo.

A complete assortment of imrnersion transducer types, sizes, frequencies, and spectral characteristics can he found in the OPTIMA transducer catalog. Accompanying each different type of transducer shown is a brief guide to the applications appropriate for that type.

3.3 Transducers for Non-Metallic Test Materials.

Virtually all the techniques and applications described above can be applied to a host of non-metallic and composite materials. It is not possible to cover the numerous applications in this manual. Transducer selection for non-metals often is much more involved. However, QUANTUM's unique design can accommodate a huge variety of transducer types. For advice, contact our Transducer Applications Specialists. Often a transducer can he recommended on the basis of a description of the application. If not, it may he necessary to submit samples of the test material.

3.4 Transducers for Specialized Applications.

Ultrasonic testing techniques have applications beyond those traditionally though of regarding flaw detection and thickness gaging. There are applications in material characterization, flaw analysis, extensometry, bondtesting, liquid level sensing, velocity measurement, and others in more or less limited usage. In some cases, because the application is specialized, so must be the transducers. QFT-100 can be used as the basic instrument for many unusual applications, and NDT Systems can usually match either a standard OPTIMA transducer or a custom design to the requirements of the application. QFT-100 user are invited to contact a NDT Systems Transducer Applications Specialist for recommendations.

4.0 Quantum TE SETUP AND OPERATING PROCEDURES.

For experienced Level I or Level II ultrasonic inspectors, setting up and operating the Quantum TE will be little different from analog-type ultrasonic instruments. Instead of using knobs and switches for control adjustments, the appropriate menu item must be found, then selected, then controlled by using one or more of the keys.

For persons unfamiliar with fully micro computerized instruments, perhaps the most frustrating part of learning is in the finding the item they wish to control. The Quantum TE is just about the only instrument on the market today in which the operator con perform a simple "screen" calibration without the use of ANY menus! :-) In designing the menus for the Quantum TE, particular attention has been paid to simplifying the process of locating items, then prompting the operator to do something intuitive in order to change control settings. To some extent, once the operator is familiar with the operation, digitally controlled instruments are easier, more intuitive to operate than analog types.

4.1 Quantum TE Display Characteristics.

A difference noticed by experienced operators of analog-type instruments is in the "stair-step" appearance of the display on instruments having digitally derived pixel-type displays, especially at relatively short ranges of the time base. There are two aspects of this type of display that should be considered:

1. The effect on determining vertical linearity, and
2. The effect on the appearance of horizontal linearity.

Horizontally, the Quantum TE display is 170 pixels wide. However, because of the way a smoothly curved analog waveform is sampled by analog-to-digital circuitry, "stair-stepping" can produce the appearance of being less smoothly shaped. This effect is visual only, being more pronounced when the time-base is at short range. However, the determining factor regarding horizontal linearity is in the digital sampling rate, not in the actual visible appearance. Because distance/thickness readouts in Quantum TE are determined from a Hi-Speed sampling or "digitizing" rate, the digital readout has inherent accuracy and resolution far superior to that which can be measured visually from a conventional CRT. Even at modestly short ranges, measurements made visually from Quantum TE's display are essentially equivalent to those made from CRTs. Quantum TE's thickness readouts are precise, regardless of the range or stair-stepped appearance of the A-trace display.

Within a short time of familiarization with Quantum TE's display and alarm systems, the operator will adapt to the display and will especially appreciate the large area and visibility of the A-trace. Most experienced operators of analog-type instruments can effectively operate the Quantum TE without reference to the Operator's Manual. However, some of the procedures outlined below will guide the operator in quickly setting up and using the many features incorporated in Quantum TE that are not found in many "standard" ultrasonic instruments. The versatility of Quantum TE will be readily evident by following the procedures described below.

4.2 FACTORY Setup Variables.

When the Quantum TE is turned on by pressing the ON/OFF control, the LOGO screen is displayed automatically. When the gage is operated for the first time, or if FACTORY DEFAULT is selected from memory, all the control variables "default" to specific values (After that they will display the last previous setup parameters). For many common thickness gaging applications, it is only necessary to "fine tune" a few variables. Some applications can be started without <u>any</u> adjustments. The FACTORY setup variables have values that match or nearly match a variety of the most commonly used transducers for thickness gaging. By pressing any key to continue, then by depressing and holding the MENU key the FACTORY setup default variables are displayed as listed below.

With Quantum TE's broadband receiver and powerful square-wave type pulser, it is possible to achieve high resolution, penetration, and sensitivity by using relatively highly damped, broadband transducers for thickness gaging. Of course, there will be instances where reduced bandwidth transducers will be preferred, but a surprising number of applications can be satisfied with broadband transducers.

QUANTUM-TE Setup

Range: 2.000	Freez: Off	Thrs1: 55
Delay: 0.000	PHold: Off	Gate2: Off
Vel: 0.2330	TThrs: 46	Alrm2: Off
IPBlk: 0.200	Zero: 350	Strt2: 0.500
IFBlk: 0.200	Echo: 1	Wid2: 0.100
Print: Setup	EBlk: 0.200	Thrs2: 45
Mode: Thick	Resol: High	Angle: 30.0
Save: DEFLT	THold: last	Thick: 0.250
Rcall: DEFLT	TAlrm: Off	SDoff: 0.000
Units: INCH	HiAlm:10.000	Gain: 48.0
Disp: BLKlin	LoAlm: 0.000	RefdB: 48.0
BkLit: On	AGC: Off	Step: 1
Contr: 50	Gate1: Off	Probe:Single
Lock: Off	Alrm1: Off	PVolt: 250
Click: On	Strt1: 0.200	PWid: 50
Grid: On	Wid1: 0.100	Sync: IP
Freez: Off	Thrs1: 55	IFThr: 75
PHold: Off	Gate2: Off	Rect: +HW
TThrs: 46	Alrm2: Off	Damp: 50
Zero: 350	Strt2: 0.500	Tune: BB
Echo: 1	Wid2: 0.100	Rejct: 0
EBlk: 0.200	Thrs2: 45	CType: Off
Resol: High	Angle: 30.0	Draw: CLEAR
THold: last	Thick: 0.250	Point: 1
TAlrm: Off	SDoff: 0.000	CAlrm: Off
HiAlm:10.000	Gain: 48.0	DelDB: +/-3
LoAlm: 0.000	RefdB: 48.0	Curvs: 1
AGC: Off	Step: 1	Zoom: Off
Gate1: Off	Probe:Single	Left: 0.600
Alrm1: Off	PVolt: 250	Right: 1.400

Figure 38

4.3 <u>Thickness Gaging Procedures</u>

4.3.1 Sample Setup procedures (A Walk Through).

4.3.1.1 3/8" 5.0 MHZ Contact Transducers

Once the effects of variables affecting thickness gaging precision are understood, the operator can quickly diagnose which variables should be adjusted. A good way of observing these effects, and to become quickly familiar with Quantum TE's controls is to perform the following procedure:

1. Attach a highly damped, broadband transducer such as the OPTIMA CHG053 or NOVA C11 (5 MHZ, 3/8 inch element diameter) to the micro-dot connector on the ML-01 transducer cable supplied with Quantum TE. Insert the Lemo connector in the receptacle marked with a red dot on the top closure of Quantum TE.

2. Obtain a steel stepped wedge with several known thickness steps. An excellent choice, and the one upon which this procedure is based, is the OPTIMA Model TBS114. This wedge, made from 4340 vacuum-melted steel alloy and nickel plated, has five steps precision machined to thicknesses of 0.100, 0.200, 0.300, 0.400, 0.500 inch (2.54, 5.08, 7.62, 10.16, 12.70mm).

3. Couple the transducer to the 0.400 inch (10.16mm) step using a drop of glycerin, light machine oil, mineral oil, or low viscosity gel-type couplant. For this familiarization exercise, it will be

convenient to use a rubber band or a small weighted object that will hold the transducer in place. This procedure will relieve you from having to hold the transducer in place for an extended period during familiarization.

4. Press the ON/OFF control. Quantum TE's screen will briefly be back-lit and a series of horizontal bars will be seen. During this very brief period, Quantum TE undergoes a host of internal diagnostic checks. Once these checks are complete, the LOGO screen automatically appears.

5. The darkened, reversed text area reads "PRESS ANY KEY TO CONTINUE". Depress any key and the MAIN MENU will be displayed .

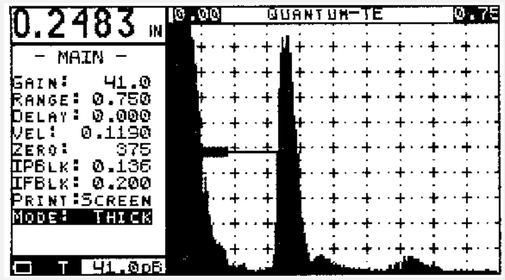


Figure 39 Main Screen

An A-trace will appear, along with the Main Menu items and a thickness readout, the large numbers in the upper left-hand corner of the A-trace. Note that immediately above the A-Trace is a highlighted STATUS field which displays "UNITS NOW : INCHES" (or MM, if metric units have been selected. See Section 2.1.4, SETUP Menu). This is the FACTORY setup default full-scale range of 2.00 inches (50mm). Also note the large back echo at the second major horizontal scale division and the thin horizontal bar at 46% full-scale (FS) amplitude. Observe that this horizontal line extends from the extreme left edge of the A-trace and terminates on the leading edge of the back echo. This line, or bar, represents the thickness gate (T-gate) and shows which echo stops the gate. In this example, since the 0.400 inch (10.16mm) step is the one being measured and the horizontal FS range is 2.00 inches, the T-gate terminates on the first echo above 46% FS amplitude, the back echo from the 0.400 inch (10.16mm) step. Along the left-hand vertical axis, a signal will also be seen. Since the FACTORY setup defaults to initial pulse synchronization (IP SYNC), this signal is the initial pulse (IP) with its leading edge coincident with the left-hand vertical axis.

One other feature that should be noted is the presence of a dark bar extending horizontally along the thickness gate on the A-trace from the left-hand axis. This bar represents the blocking gate (BLK gate) which serves to "block" out the string of high amplitude echos typically accompanying the IP. In its FACTORY setup default position, the IPBlk gate is at 0.200" to block out the IP echos and thus prevent the T-gate from terminating within the IP. Control of the IPBLK gate is explained in Section 2.1.7 and will be further examined later in this procedure. (If an undamped or lightly damped transducer other than those recommended for this exercise is being used, it may be necessary to make an immediate adjustment of the IPBLK gate in order to proceed. If so, go to Step 15, below, and perform the necessary adjustment.)

9. For the transducers and stepped wedge recommended, the thickness readout (T-readout) should be within a few thousandths of an inch (a few hundredths of a millimeter) from 0.400 inch (10.16mm) plus or minus. Position of the cursor in the Main Menu is at GAIN.

10 With the cursor at GAIN, right and left arrow keys increase/decrease effective gain accordingly. The increment/decrement values of gain change is 1.0 dB (FACTORY default). The increment/decrement values of gain change is selectable in 0.1 dB, 1.0 dB, 2.0 dB, 6.0 dB (go to step ? to adjust values). Use the down arrow to place cursor on REF dB.

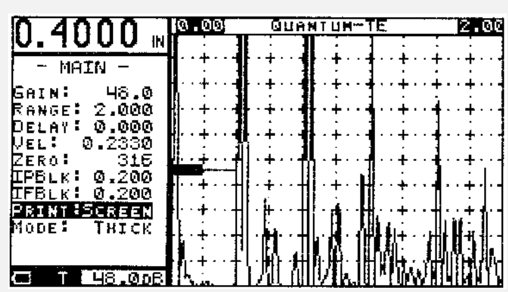


Figure 40

11. Reference gain (REF dB) is a function that facilitates compliance with several common specifications regarding establishment of the gain level used for evaluating flaw echos. Specifications usually require that scanning be done at higher gain than the acceptance level gain. With REF dB, at any time REF gain is greater than GAIN , GAIN resets to the same level as REF dB. REF dB is the operative gain and increase or decrease adjustments are made to satisfy the specification accept/reject gain level. GAIN when cursored to, “freezes REF dB gain and permits adding the amount of gain required by the specification for scanning. This procedure increases the likelihood that small flaw echos will be detected. Once a flaw is detected, REF dB is again selected and the flaw echo amplitude compared against the accept / reject criteria. To quickly adjust GAIN value to REF dB value, place cursor on REF dB and quickly press SEL.

12. To become familiar with the RANGE function, position the cursor at RANGE The left arrow key will move echos on the A-trace to the left, that is, except for the initial pulse. IF multiple back echos are present, they will move toward the left <u>and</u> approach each other more closely. In our 0.400 inch (10.16mm) steel block example, depress the right arrow key until the first back echo, originally at the second vertical division of the electronic graticule moves to the fourth full vertical division.

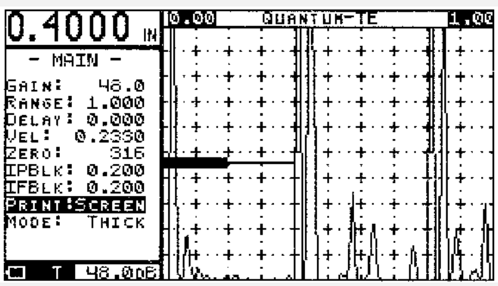


Figure 41 - Range

The second back echo will be aligned (or nearly so) at the 8th full division. The readout value under RANGE should be close to 1.00 inch (25.4mm). <u>**However, note that T-readout did not change unless the gain was substantially in creased. With Quantum TE’s digital elec tronics, it is not necessary to use the graticule or other precise settings of range in order to calibrate for, and to readout precise thicknesses.**</u>

13. The DELAY function also has pronounced effects on the location of signals on the A-trace. Set the full-scale range at 1.00 inch (25.4mm), and position the cursor at DELAY. Depress the RIGHT arrow key and observe the effect. Signals move toward the left, including that of the initial pulse, which moves off-screen to the left. Note that the distance between multiple back echos <u>does not change</u> as it did when range was increased. Continued depression of the RIGHT arrow key moves echos toward the left until they are completely delayed off-screen. If calibration has been performed for the material under test, the readout under DELAY indicates how far the display has been delayed.

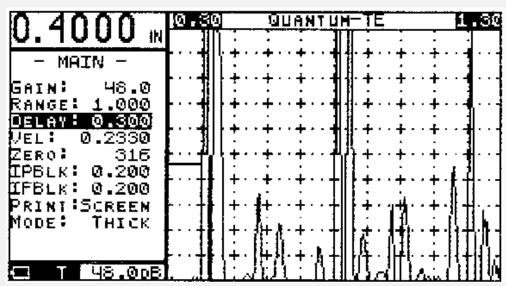


Figure 42 - Delay

14. Move cursor past VEL (VELOCITY). <u>**NOTE**</u>: <u>VELOCITY adjustment will be covered in step 21 below.</u>

15. With the RANGE at 1.00 inch (25.4mm), cursor to IPBLK. The right/left arrow keys control the length of the blocking gate, referred to as "IPBLK gate", and represented by the dark bar extending horizontally along the thickness gate on the A-trace from the left-hand axis. Its purpose is to "block" the trailing edge echos associated with the initial pulse. This group of echos contains ring-down echos from the transducer and "noise" accompanying stray reflections resulting from coupling. The "noise" figure is minimal when both the front surface of the transducer and the surface of the test object are smooth. This is the usual case with new,

unworn transducers and with many finely-machined test blocks or reference standards. However, actual test objects seldom have clean, smooth surfaces. They often have rough machined or mill-finished surfaces (as-cast surfaces on castings), sometimes corroded and sometimes painted surfaces. In these cases, the extent of coupling noise will be greater than that returned from test blocks.

At default, the length of the blocking gate (IPBLK gate) is 0.200 inch (5.08mm) equivalent in steel. With medium to broadband transducers of 2.25 MHZ or greater, that distance is usually sufficient to block IP echos and coupling noise from standard test blocks. Note, however, that it would not be possible to thickness gage steel less than the width of the IPBLK gate, less than 0.200 inch (5.08mm) at FACTORY defaults. If the total IP is greater, and the blocking gate must be further extended, any significant echos within the blocking gate, back echos or otherwise, will be blocked and will dictate the minimum thickness that can be gaged with the correct digital thickness readout. In such cases, it may be necessary to use a different transducer or a different technique (such as visual isolation of the back echo and non-digital measurement, or gating between multiple back echos). With highly damped, broadband transducers of 5 or 10 MHZ, it should be possible to shorten the IPBLK gate to permit IP to first back echo digital readout of 0.030 inch (0.8mm) steel or equivalent. Even with some transducers of 2.25 or 3.5 MHZ, the blocking gate can be reduced to permit gaging from between 0.030 inch (0.8mm) to 0.040 inch (1.0mm) on smooth surfaces.

15a. At this point, use the right/left arrow keys to change the length of the IPBLK gate in order to observe the effects of the control.

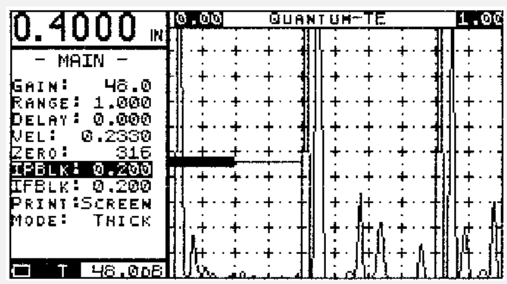


Figure 43 - IP Block

16. IFBLK functions in a similar fashion as the IPBLK but when Interface Synchronization (IF) is selected. IF Sync automatically starts the T-gate at the leading edge of the interface echo (the echo between the delay line and the test object surface. The delay line could be a plastic tip or a water path). Whenever practical, if delay lines are used, interface synchronization (IF Sync) should be selected. A complete description of IF Sync is discussed in step 25e.

17. When the cursor is on MODE, the right or left arrow keys allow you to select the inspection method as described in para. 2.1.2. THICK is the current mode the Quantum TE is displaying. FLAW and ANGLE will be discussed in para 4.4.1 and 4.4.3

18. Before examining the function of THICKNESS THRESHOLD (TTHRS),press MENU to display the THICKNESS (THICK) Menu. At TTHRS, note that the horizontal T-gate bar is at 46%. Right / left arrow key controls change the threshold level of the T-gate accordingly, and the actual level of the T-gate is readout in % full-scale amplitude, variable from 10% minimum to 90% maximum. The FACTORY default amplitude of 46% is a good compromise and generally effective when the first back echo amplitude is maintained between approximately 70% full-scale and to somewhat greater than saturation amplitude (greater than 100% full-scale).

19. Move the cursor to TALRM. Using the left or right arrow will turn on or off THICKNESS ALARM

20. Both LO ALR and HI ALR function in the same manner. These selections represent low thickness alarm and high thickness alarm, respectively. They can be used to alert the operator (through the visual and audible alarms) when pre-set thickness levels, low, high or both low and high, have been exceeded. The level sets are scrolled when the right /left arrow keys are depressed. With the cursor at the TALRM position, arrow keys toggle the alarm system (audible

tone and visual LED) on and off. In gaining familiarization with these features, note that it is not possible to "cross" these levels. That is, the high alarm setting cannot be set lower than the low alarm setting and vice-versa.

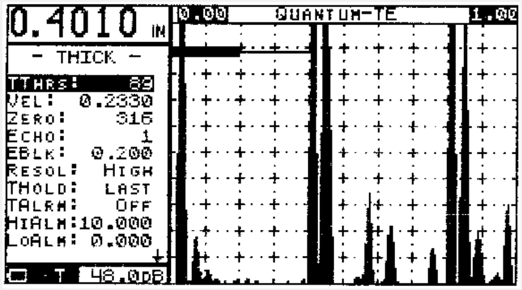


Figure 44a Thickness Threshold @ 89dB

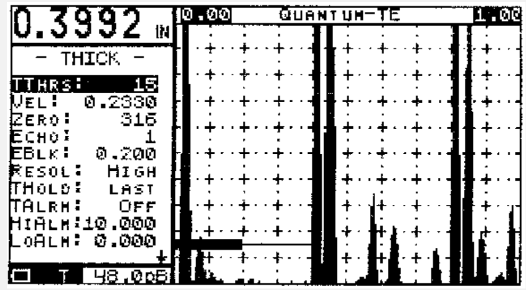


Figure 45 - Thickness Threshold @ 15dB

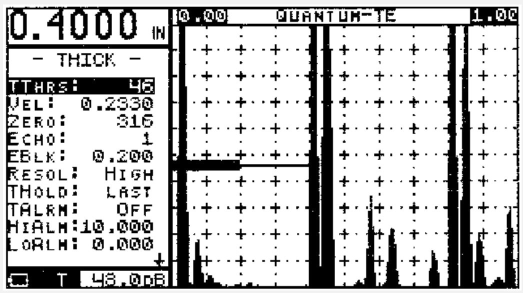


Figure 46 - Thickness Threshold @ 46dB

The next two functions, VEL and ZEROA are adjustments necessary to "calibrate" all the timing functions, since all timing functions have effects on the horizontal aspects of the A-trace

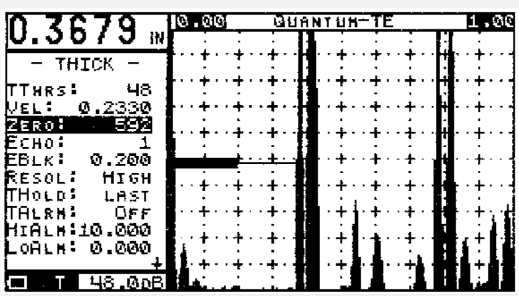


Figure 47

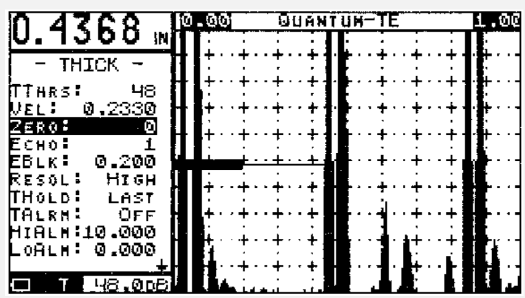


Figure 48

In our example, using a 0.400 inch (10.16mm) thickness step, we have yet to perform any operations to "calibrate" the T-readout. Most probably the reading is close to 0.400 inch (10.16mm), since the FACTORY setup defaults are deliberately designed to produce nearly correct calibration for a contact transducer being used on steel having longitudinal sound velocity of 0.2330 inches/microsecond (5.92mm / microsecond).

21. As a first step in becoming familiar with the VEL and ZEROA functions, let us complete the calibration for thickness measurement using the stepped wedge in our example. The cursor will be at VEL. Using the down arrow, reposition it at ZEROA, the probe zero control position. Note the reading next to ZEROA on the horizontal menu line. The default setting of 350 ns (nanoseconds) will increase or decrease when the right or left arrow keys are activated. Depress the right arrow key and hold it. The value at ZEROA will increase continuously as long as the key is depressed. Repeated or continued depression of the left arrow key has two effects:

A. If held for continuous "scrolling" of the ZEROA value, the position of echos on the A-trace will move slowly left.
B. The T-readout will decrease.

The opposite effect takes place when the left arrow key is depressed. When 0.400 inch (10.16mm) [or whatever the known actual thickness of the step] is achieved in T-readout, the upper range calibration is complete. Note that zero may change through up to 10 ns before the indicated thickness changes. Choosing zero roughly at the mid-point of the range needed to move from 0.399 inch to 0.401 inch (10.13mm to 10.19mm). This procedure can improve thickness gaging precision.

21a. Remove the transducer from the 0.400 inch (10.16mm) step and couple it sequentially to the other steps. If the test block has been accurately measured and the material is steel with a VELOCITY (VEL) of 0.2330 inch/microsecond (5.22mm/micro-second), the other measurements should be exact within ±0.001 inch (±0.02mm) and reproducible. **NOTE : to measure to thinnest step on the block it will be necessary to adjust IPBLK as per step 15 above**

21b. IF some metal other than steel is used, a somewhat different procedure will be required. For a transducer of similar type as recommended for these procedures, reset the ZEROA to approximately that of the default (350 ns). Depress the up arrow key to position the cursor at VEL (velocity). With the transducer coupled to the thickest step, use the right and left arrow keys to decrease/increase velocity until the known thickness is at T-readout.

Now couple the transducer to the thinnest step. If T-readout does not agree with the known thickness, reposition the cursor at Z (ZEROA) and use the right and left arrow keys to produce the known thickness in T-readout.

Again check the thickest step. If T-readout still does not agree with known thickness, reposition the cursor at VEL (velocity) and use the right/left arrow keys to obtain the known thickness.

Continued adjustments between ZEROA and VELOCITY will soon produce correct T-readout on both the thickest and thinnest steps. At this point, the steps in between will read correctly [within the resolution, ±0.001 inch (±0.02mm)]. The velocity value below VEL is the velocity of the material of the test block.

A short-cut in the calibration routine for metals other than steel is to scroll the value at VEL to the nominal velocity for that material. Velocity values are tabulated in a variety of publications, including NDT Systems, Inc.' OPTIMA transducer catalog. **NOTE: Tabulated velocity values have been obtained from a variety of sources that do not always agree. It is strongly recommended that accurately known thicknesses of the same material as the test object be used to calibrate for accurate thickness measurement**

22. To examine ECHO function, place the transducer on the 0.400 inch (10.16mm) thickness step. Scroll back to MAIN MENU using the MENU key. Cursor to and set RANGE to 2.00 inch (50.80mm). Scroll back to THICKNESS MENU. Cursor to ECHO. Use right arrow key to select “2". ECHO allows the selection of a multiple echo from which the thickness measurement (T-gate) will begin. Up to the fifth multiple echo can be selected using the left / right arrow keys. This function is useful when using single element transducers with thin-elastomeric membranes or on coated test objects.

23. Cursor to ECHO BLOCKING GATE (EBLK). Note the thick horizontal bar on the T-gate. Use the right arrow key to select the length of the echo blocking gate that is used to block out any unwanted signals between multiple echos in the thickness mode. The FACTORY default value is .200 inch (5.08mm). EBLK is actively displayed when ECHO is set at 2 to 5

24. Cursor to THICKNESS RESOLUTION (RESOL).use the right /left arrow keys the selection either NORMAL or HIGH thickness measurement resolution on LCD display. NORMAL resolution is 0.001 inch or 0.01 mm. However, when high frequency delay line transducers are used, stable and reproducible resolution of 0.0001 inch is achievable in HIGH resolution. This display is set to Lo resolution.

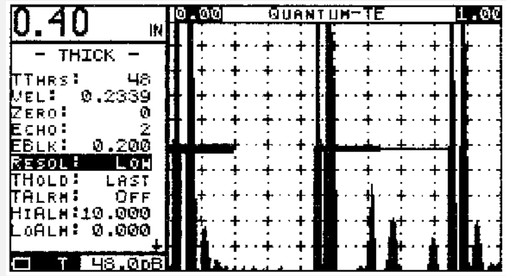


Figure 49 - RESOL

25. The PULSER / RECEIVER menu contains the variables that have to do with optimizing the damping and pulse characteristics with the transducer (probe) being used It is worth while to experiment with these variables as the over all quality of the received echo envelope can be effected greatly. In many higher frequency tests, these variables can “make-or-break” an inspection. Pay particular attention to Pulse Width!

25a. The functions of GAIN and REFdB have already been examined (please refer to steps 10 and 11 above).

25b. Move cursor past REFdB to STEP. The right / left arrow keys change the increment / decrement values of gain changes through 0.1, 1.0, 2.0, and 6.0 dB.

25c. Move cursor to highlight PULSE VOLTAGE (PVOLT). This refers to the Amplitude of the square-wave type pulse available from Quantum TE’s variable pulser. By switching back and forth between dB and PVOLT and continuously increasing/decreasing the pulse voltages between its extremes of 50 to 400 volts, the effect of pulse voltage on back echo (and IP) amplitude can be observed. For most transducers used in precision thickness gaging, pulse voltages between 150 and 250 volts are usually optimum; pulse voltage increases beyond 200 to 250 volts produce little effect on signal amplitude.

25d. Perform the same exercise with the cursor on PULSE WIDTH (PWIDTH). Note the units of the variable are ns (nanoseconds). By observing the unsaturated amplitude of the back echo, the effect of continuous increases and decreases in pulse width tend to cause the back echo amplitude to pass through an optimum high amplitude. However, somewhat lesser values of pulse width (less than maximum amplitude) do not degrade the performance of broadband transducers. In fact, using low pulse widths can result in best minimum thickness resolution performance from undamped transducers. NOTE: Unnecessarily high pulse voltage or pulse width can reduce the life of high frequency, undamped, broadband transducers. In addition, since the product of pulse voltage and pulse width are the measure of pulse energy, unnecessarily high values of either will drain the battery pack more rapidly than at lower values.

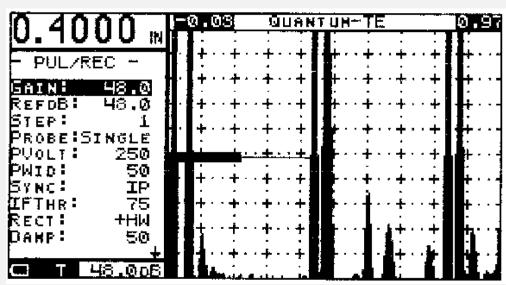


Figure 50 - PUL/REC Menu

25e. Yet another important selection in the PUL/REC menu is that of SYNC. Note that IP SYNC is the default setting. IP SYNC (initial pulse synchronization), synchronizes the start of the A-trace and the various gates (blocking gate, thickness gate) from the time the pulser "fires". With contact transducers having thin wearplates, this time is nearly coincident with the leading edge of the initial pulse signal. Most thickness gaging inspections using contact transducers will be done with IP SYNC.

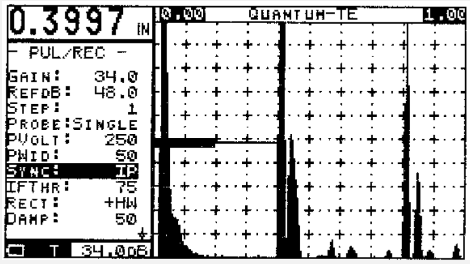


Figure 51 - IP Sync

Interface synchronization (IF SYNC) is most often selected when delay line, dual element, or immersion transducers are being used. The common factor in using any of these transducer types is that the transducer element is removed by some distance from being in contact with the test object surface. Delay lines and dual elements have a stand-off material coupled to the transducer element. The stand-off is usually plastic, but could be other materials. Quartz, ceramics and, occasionally, metals are sometimes used as the stand-off (or delay) materials. In immersion testing, the delay material is a liquid, usually water. Whatever the case, it is usually desirable to start the A-trace and synchronize the gates from the entry surface echo of the test object. When IF SYNC is selected, Quantum TE does just that. Whenever IF SYNC is selected, the mode icon in the top left corner of the display flashes. This is a reminder that IF SYNC is in effect.

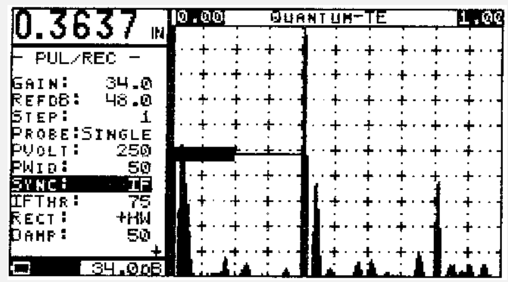


Figure 52 - IF Sync

25f. Before we examine INTERFACE THRESHOLD (IFTHR), one precaution should be kept in mind when IF SYNC is selected. The A-trace will synchronize on the <u>first echo</u> that exceeds the threshold set. In immersion testing, if there is dirt or other particulate matter in the immersion bath, or if squirter parts or other obstacles intervene, the IF SYNC circuitry attempts to resynchronize on the echo(s) from the obstructions. This can produce "jitter" in the A-trace display. Further, if there is no interface echo (as when a dual element transducer is not coupled to the test object), there is no signal upon which the IF SYNC can synchronize. The A-trace is essentially blank. If, IF SYNC is active and, for any reason, the operator is unaware of that fact, the impression could be that the instrument is malfunctioning. For that reason, INTERFACE THRESHOLD (IFTHR) allows Increase or Decrease of the threshold level to which an Interface Sync is detected. Once the interface sync is detected, the Interface signal is positioned to the left edge of the display.

<u>NOTE: Cursor back to SYNC and select IP before next step.</u>

For precision thickness gaging, the type of waveform used for setups has a significant effect on gaging results. Note that the RECT default is +HW, meaning that the current display is of signals that are positive half-wave rectified.

25g. To better illustrate the effects produced by the various waveform displays, press MENU to return to the Main Menu. Cursor down to RANGE. Use the left arrow key to change the RANGE readout to 1.00 inch (25.4mm). Press MENU key to return to **PUL/REC** menu. With the cursor positioned on RECT, use right / left arrow keys to select RF. For this example, the display will be similar to that shown below:

Note that the back echos are now displayed on a centered horizontal baseline and have both positive and negative components. This mode of display, RF (radio frequency), reveals all the details of the signal. IF necessary to more faithfully reproduce the waveform in the figure above, it may be necessary to key to dB

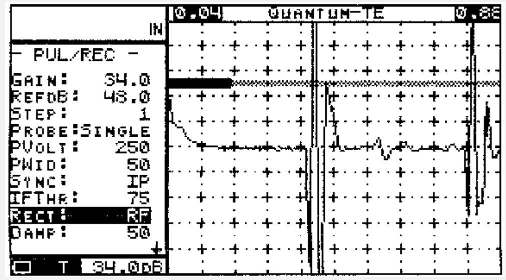


Figure 53 - RF Display

and change the gain. Now examine the details of the back echo. The first half-cycle is negative-going, but has less relative Amplitude than the next half-cycle, which is positive-going. This being the case, imagine what the back echo would look like if everything below (on the negative side of) the base line were removed from the display. Vertically enlarged, that is what actually happens when +HW is selected. Selection of -HW results in the converse -- only the negative-going components of the back echo signal are displayed. On the A-trace, the negative-going parts of the signal are "flipped" upright (rectified). FW represents full-wave rectification; that is, both the positive half-cycles and the flipped over negative half-cycles are displayed simultaneously.

25h. Look at each of the responses and make a mental note of the differences. These are important differences in thickness gaging. For example, under the current test setup conditions, if FW (full-wave rectification) is selected, the lower Amplitude negative cycle appears as the first, or leading edge of the back echo. By manipulating the gain to cause the T-gate to terminate on the negative component, then on the positive part, a significant difference in T-readout occurs.

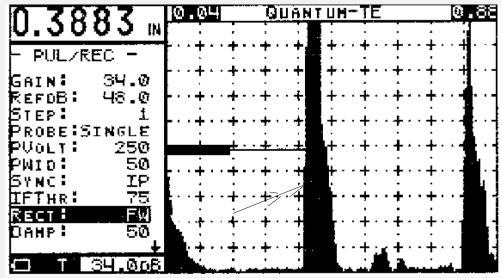


Figure 54 - FW Display

Referring back to Figure 4.3.7 which shows the RF display, a good reason to select +HW over -HW or FW is because the first positive-going component of the signal has greater Amplitude than does the first negative, produces a "cleaner" display than FW and is less sensitive to producing T-readout changes as a function of gain.

There are other good reasons for offering this variety of display modes. There are instances where the more prominent half-cycle is not positive-going. In cases where the back wall is lined with another material (e.g. some elastomers), the first negative-going half-cycle is more prominent. This phenomenon has to do with the relative acoustical impedance characteristics of the two materials that make up an interface. Many liquids, elastomers and polymers forming an intimate interface with metals produce echos whose phase is reversed from that of the metal/air interface.

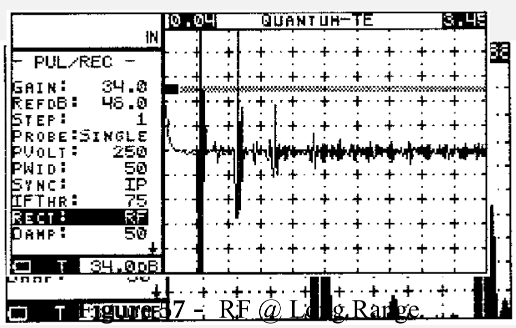


Figure 55 (-HW)

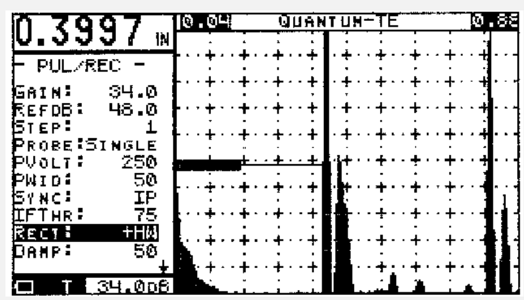


Figure 56 (+HW)

The RF display can be referred to if there is any question about which waveform should be se lected. For thickness gaging metals much beyond one inch (25mm) thick, it will be necessary to "expand" the RF display. If, for example, for a 2 inch thick test specimen, the full-scale range of the Quantum TE has been set to a long range, and the RF display is selected, there will be poor detail in the presentation of the RF.

In order to expand the RF display of the back echo under such condition, delay can be used to reposition the back echo very near the left side of the A-trace. Then, reducing full-scale range to 0.50 (12.7mm) reproduces the RF of the back echo similar to that of a much thinner test object.

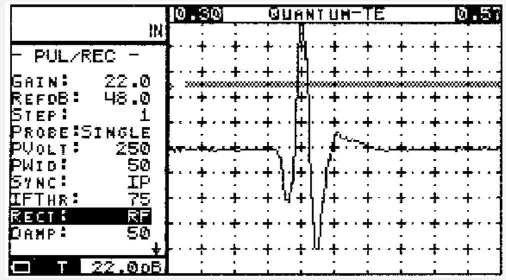


Figure 58 - RF Expanded

25g Cursor down until DAMPING is highlighted. The default value is 50 ohms, a usually good match for the type of transducer being used in this example. To observe the effect of damping changes, depress the right arrow key and note a new, higher damping resistance value displayed. Also note that the IP echos tend to extend farther at higher damping resistance. Damping changes likewise increase both the Amplitude and shape of the back echo. To observe the effect of damping on the back echo, cursor up to highlight GAIN. Now, press the left arrow and keep it depressed. You are controlling the gain (dB) in this selection without having to go to the dB selection in the Main menu. With down and up arrow key adjustments as required, establish the Amplitude of the first back echo at approximately 50% FS (the precise location is unimportant). Then, return the cursor to DAMPING and use the right arrow key to once again increase the damping resistance. Observe the Amplitude of the back echo increase, perhaps substantially, with increased damping resistance. While this effect can be used to advantage under some conditions, for precision, high resolution thickness gaging, it is usually desirable to select relatively low damping resistance. With experience, through careful observation of the changing shapes of the IP and back echo, it is possible to optimize the damping for the job at hand. For now, return the damping resistance value to 50 ohms, the default value.

25h. TUNE FREQUENCY (TUNE) allows you to select the frequency range of the receiver to match the transducer. A broadband frequency range(BB) of 0.5 to 25MHz, tuned channels of 0.5, 1.0, 2,25, 5.0, 10.0 MHZ (nominal) are selectable.

25i. <u>Procedure for Using Linear Reject</u>. Quantum TE's linear reject feature performs in the same manner as in any other high-capability flaw detector. When the PULSER/ RECEIVER menu is displayed, advance the cursor to REJECT. With the cursor at REJECT, pressing the right arrow key scrolls the reject level from 0% upward. Any signals in the A-trace having amplitude equal to or less than the reject level will be "clipped off" or rejected. Signals having amplitude greater than the reject level will be unaffected above the reject level. While establishing the desired level of reject, it may be necessary to also adjust gain.

Most inspection documents either forbid the use of or require that, if reject is used, that fact is signaled by a unique annunciator. For that reason , whenever the reject level is increased above 0%, a reject icon (R) flashes intermittently in the display status bar above the A-scan display.

25j. First note that SGL is highlighted in a column of another selection, DUAL. Press the right / left arrow key once to select DUAL and note that the A-trace essentially blanks out. This selection is for using a dual element transducer and will be discussed later. Press the left / right arrow key to return to SINGLE.

4.3.1.2 Procedures for Using Dual Element Transducers with Delay Lines.

Dual element transducers combine the advantages of single element delay line transducers with the addition of one more: the sound beam can be directed into the test object at a small angle. This effect offsets, to some extent, the natural tendency of the sound beam from a single element transducer to diverge. Beam divergence "wastes" a large portion of beam energy. The dual element transducer has two active elements mounted side-by-side with a barrier strip of sound-absorbing material between them. One element is connected to the instrument pulser and the other to the receiver. Otherwise, they are electrically isolated from one another. The elements are mounted at slight angles with respect to the barrier strip, thus forming the shape of a shallow angle roof. The transmitted longitudinal beam centerline enters the test object at the "roof angle". The beam continues into and through the test object, reflects from the back wall and returns at the same angle toward the receiving transducer. The time it takes to traverse this path includes the sum of times through the transmission delay line, through the test object thickness to the back wall, from the back wall through the test object again, and through the receiving element delay line.

By "ZEROING" out the constant distance paths taken by the sound beam in traversing the dual delay lines, a measurement can be made of the travel distance in the test object only.

Since the sound beam travels at a slight angle into and out of the test object, the path taken is slightly longer than in the case where the sound beam enters and exits perpendicular to the test object surface. Calibration at a specific thickness applies only for that thickness, plus or minus. While the error at other thicknesses is small, for high precision measurements, it should be taken into account. While the error can be calculated, it is usually more convenient to determine it experimentally, or to recalibrate for different ranges of expected test object thickness. This point will be illustrated in the following setups. The error is referred to as "V-Path Error", so-called because of the V-shaped path the soundbeam takes in traveling from the transmitting element to the receiving element of the transducer.

There are several approaches to dual element transducer setups:

1. If the temperatures of the test object and transducer are essentially the same and the setup is made at basically ambient conditions, the delay line ZEROA procedure is relatively easy.

2. If the test object is at a substantially different temperature than the transducer, setting up for multiple echo interval measurement will be more precise. This technique is also applicable if the test object is coated or painted.

3. Less precise measurements can be made by using the A-trace screen graticule points. By "calibrating" convenient thickness values to the graticule divisions, thickness can be estimated reasonably well.

4. Quantum TE's delay is "calibrated" with readout in units of distance ("mils" -- milli-inches). A procedure utilizing this feature will be outlined.

4.3.1.2.1 Dual Element Delay Line ZEROING Procedure.

Most dual element transducers are either undamped or lightly damped. As a consequence, and particularly with the square-wave pulser in Quantum TE, the setup must be carefully optimized. The first step is to decide upon which form of display rectification will best serve. In the following procedure, a 5 MHZ, 3/8 inch (9.5mm) diameter transducer (NOVA Model DV506) was used to produce measurements in the range from 0.200 to 0.500 inch (5.08 to 12.70mm).

1. In the PUL/REC Menu, select DUAL. Then, in the MAIN Menu, change RANGE to 1.00 inch (25mm) and use ZEROA to delay the first back echo to approximately mid-screen. In the PUL/REC Menu, select RF. Adjust gain to produce and maintain an echo pattern with less-than-saturation elements. In the PUL/REC Menu, set DAMPING at 500 ohms and adjust pulse WIDTH and PVOLT to produce the sharpest, or "cleanest" echo pattern.

2. Study this echo pattern carefully. Notice that there is a low amplitude negative-going half-cycle, then larger amplitude positive and negative half-cycles. During the optimization step above, observe that the amplitude of the first small negative-going half-cycle changes very little as a consequence of varying pulse width and amplitude. In the PUL/REC Menu, alternately observe the effects of +HW and -HW rectification. While -HW (shown on the right, below) could be used, the echo half-cycle on which the T-Gate terminates varies considerable with changes in echo amplitude. At +HW, the first positive-going

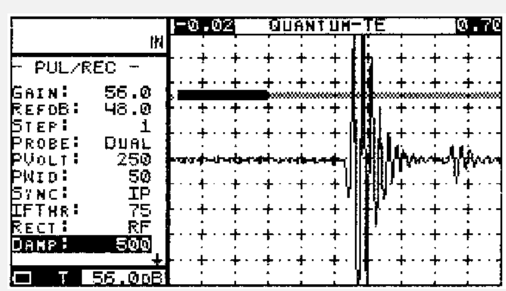


Figure 59 RF with small Neg. Half Wave

half-cycle is at full-scale amplitude (shown in the left-hand example). Since both displays were produced at the same level of gain, +HW rectification should be chosen.

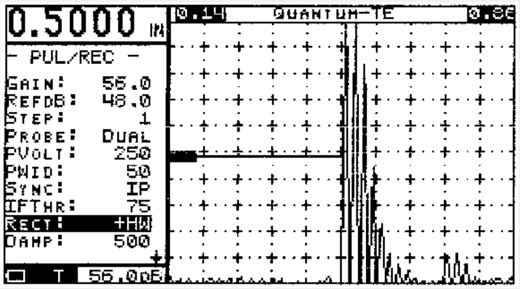


Figure 60 (+HW) selected

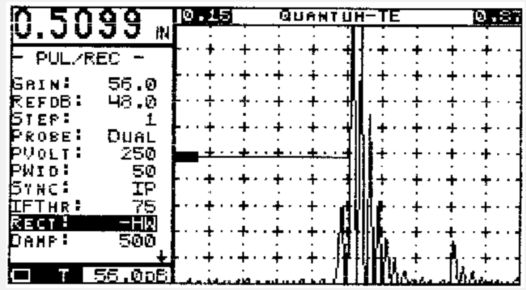


Figure 61 (-HW) Selected

3. The next step is to complete the calibration. In the THICK menu, adjust ZEROA to produce the thickness readout corresponding to a known thickness (in this case, 0.500 inch). Measurement of the 0.200 inch step produces 0.205 inch. This error is due to "V-Path Error", mentioned above.

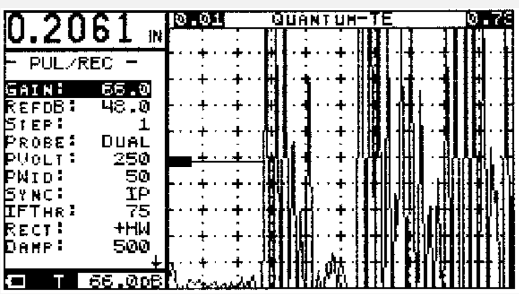


Figure 62

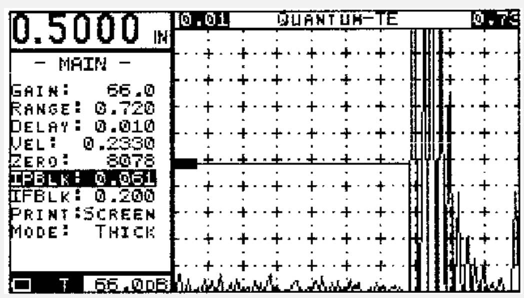


Figure 63

4. With the error having been determined to be 0.005 inch in the range from 0.200 to 0.500 inch, the "safer" way to calibrate is to establish the known thickness at the lower extreme of the measurement range. Thus, ZEROING at 0.200 inch produces the "conservative" error of 0.006 inch at the 0.500 inch step. Note the ZEROA difference of 8249 ns, above, to 8288 ns, below.

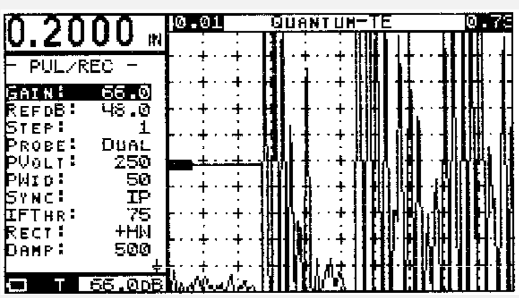


Figure 64

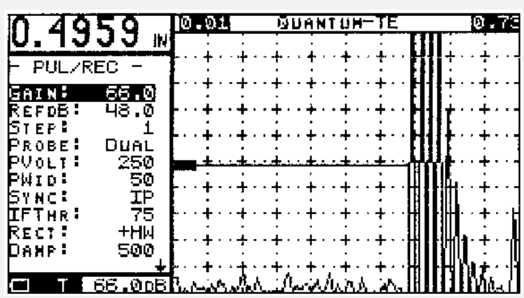


Figure 65

4.3.1.2.2 Dual Element Multiple Echo Interval Measurement Procedure.

With careful optimization and setup, multiple back echo intervals can be used for thickness measurement using dual element transducers. In the example shown below, multiple back echo intervals as far as the fifth back echo could be selected in the THK Menu. In this case, the first back echo was ZEROED to the left-hand start of the A-trace.

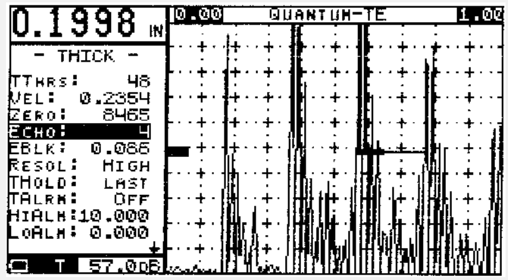


Figure 66 - Dual Element Multi-Echo

This technique can be used with many dual element transducers to measure objects at elevated temperatures. With the ZEROING technique described in the preceding procedure, when the transducer delay lines contact a hot surface, they rapidly expand. Expansion changes the V-path significantly, and consequently produces sizeable errors. IF the temperature of the test object is known, the temperature coefficient of expansion can be applied to the measurement obtained, while the calibration can be performed at ambient temperature.

4.3.1.2.3 Dual Element Measurements Using The Display Graticule.

In all the sequences illustrated above, Range was set at either 1.00 or 0.50 inch full-scale. Echos can be seen to align with graticule points accordingly. For quick checks, this technique produces reasonably accurate results. However, with Quantum TE's precise thickness measurement capabilities, very few additional steps are needed to achieve accuracy, by using the procedure in 4.3.2.5.1.

4.3.1.2.4 Dual Element Measurement Using Calibrated Delay.

As with the technique using visual estimates from the screen graticule, this technique requires visual alignment of echos; hence, it will be less than precise.

1. Prior to selecting the dual mode in PUL/REC, note the thickness readout; it corresponds closely with the steel equivalent of the delay line length.

2. Use delay to enter the T-readout and record it for later reference. This positions the delay line/steel surface interface at the left or starting edge of the display, even though there is no visible interface echo when DUAL is selected in PUL/REC.

3. For a reasonably accurate thickness measurement, use added delay to position the first back echo at the left vertical axis, read the FACTORY delay and subtract the original ZEROA interface reading from it. The result is thickness. IF multiple echos are present, the delay readout difference between them is also thickness.

4. For enhanced precision in using delay readout, use an expanded range, say 0.50 inch (12.7mm) full scale. The leading edge of the echo can be more precisely aligned with the vertical axis.

4.3.3 Thickness Gaging Procedures for Non-Metallic and Composite Materials.

To some extent, all of the previously described procedures can be applied to thickness gaging of engineering materials other than metals. Because there are so many such materials, there will be no attempt in this manual to detail them. Materials other than metals have their own unique properties with respect to the transmission and propagation of ultrasonic energy. In general, the velocity of ultrasound is lower and attenuation greater. Characteristics such as the presence of scattering reflectors, impedance, an isotropy, Modula, and other physical and mechanical properties all interact with ultrasonic sound beams somewhat differently than in metals.

Despite the differences, most polymers and glasses, some ceramics and composite materials can be tested with the same transducers and procedures as for metals, except for the obvious adjustments that may be required in calibration. Once the procedures for thickness gaging metals are understood, experimentation with other materials is generally straightforward. Feel free to consult with NDT Systems, Inc.' factory engineering personnel or technical field sales representatives on special techniques/procedures.

4.4 Flaw Detection Procedures.

Preliminary to flaw detection, most of the foregoing procedures incident to thickness gaging are required to be followed, at least to some extent. The major differences result when narrow-beam transducers are used. In the large majority of field inspection flaw detection applications, it is unnecessary to use transducers having narrow-beam spectral characteristics. Broadband transducers most often produce excellent results for flaw detection. If there is difficulty in penetrating some of the more highly attenuative materials, simply choosing a broadband transducer of lower frequency may suffice. However, there is a marked tendency for broadband transducers to produce a frequency spectrum that is more reactive to scattering and reflection from grain structure in metals. This tendency is less pronounced for corresponding frequency narrow band transducers By selecting a tuned receiver frequency to match the narrow band transducer frequency will yield good results.

For the flaw detection procedures to be outlined below, assume the use of the lowest frequency broadband transducer that will produce the flaw detection sensitivity called for by the Code, Standard or Specification in effect. If sensitivity or signal-to-noise requirements cannot be satisfied, assume the use of the lowest frequency medium- or narrow-bandwidth transducer that produces the required response.

4.4.1 Straight Beam Longitudinal Wave Flaw Detection Procedure.

While it may not be required to perform the detailed calibration routine necessary for precision digital thickness gaging, no harm is done by following the procedures of Section 4.3.1. on the Effect of Adjusting Variables. The combination of transducer/reference standard/test object variables are external; adjustments of QFT-100 to compensate for these variables are essentially the same, whether for flaw detection or thickness gaging. The only major extension of the thickness gaging procedures for flaw detection is to establish the flaw gate (F-gate) and echo amplitudes properly. FLAW is a special menu that contains all the features necessary to accomplish those needs.

1. Position the cursor in the Main menu to MODE. Use the left arrow key to select FLAW, and press MENU key. The following is displayed, as in Fig 31:

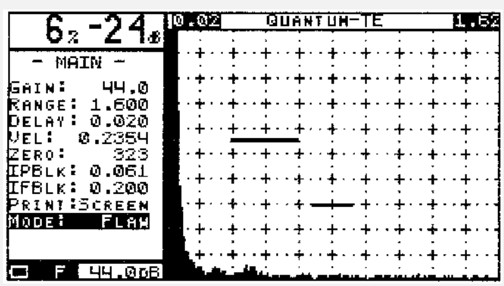


Figure 67 - Flaw Mode

Use the left/right arrow keys turn GATE1: ON. Note the small, short horizontal line located at 55% FS amplitude at the first major division on the active A-trace . This is the default position of the flaw gate (F-gate).

2. To adjust START GATE 1 (STRT1), position cursor to STRT1. Use the left/right arrow keys to position the start of the F-gate. Note that the F-gate width is constant as the F-gate is positioned at 0.200 inch (10.16mm).

3. Place the cursor on WIDTH GATE 1(WID1), press and hold the right arrow key. The left-hand side of the F-gate will remain stationary and the right-hand side will extend towards the first back echo. If the time-base has been calibrated visually by the usual procedures for flaw detection tests and those of QFT-100's digital thickness gaging procedures of Section 4.3.1, the digital starting position of the F-gate is 0.200(5.08mm) inch displayed under STRT1. WID1 is set at 0.400 inch (10.16mm)

4. Now move the cursor THRESHOLD LEVEL 1 (THRS1). Use right / left arrow keys to position the F-gate threshold level between 10% and 90% FS.

5. The default position of ALARM 1 (ALRM1) is OFF. Use right / left arrow keys to select POSITIVE (POS). This signifies that the flaw alarms will activate whenever any signal within the F-gate exceeds the level set in threshold. When NEGATIVE (NEG) is selected, the opposite alarm condition can occurs. Signals within the F-gate below the level set in THRS1, will activate the alarms. feature permits monitoring the loss or reduction in amplitude of back-wall echo, a requirement of some Codes and Specifications.

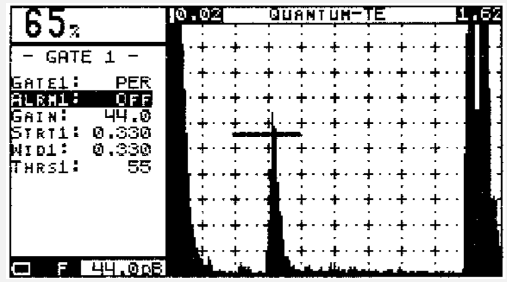


Figure 68

6. With the positive gate configuration (+GATE), note that there is a digital percentage displayed on the large LCD display above the menu. This number represents the peak amplitude, in % to FS, whenever an echo signal within the F-gate exceeds the level set amplitude. The opposite condition exists for -GATE selection. The peak amplitude display is useful in determining the precise peak amplitude of a gated signal which may be varying slightly due to "candle-flaming".

7. Press the MENU key to display GATE 2. Use steps 1 - 6 to examine and adjust parameters in GATE 2.

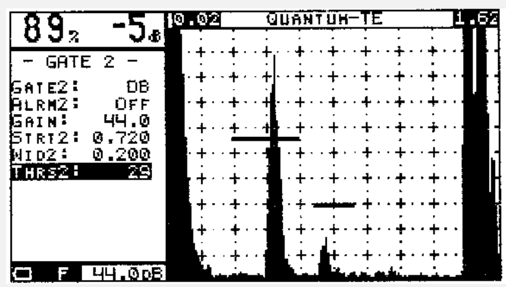


Figure 69

See Section 4.3.2.5. for Procedure For Longitudinal Wave Dual Element Transducer Flaw Detection Techniques.

4.4.2 Angle-Beam Shear Wave Flaw Detection Procedure.

It is assumed here that the operator has familiarity with establishing shear wave test setups using standard analog type ultrasonic instruments. The purpose of this procedure is to familiarize you on setup of the F- gate and FLAW TRIANGULATION features when using the ANGLE mode. The procedure is base on using a 0.25 x 0.25 inch, 5.0 MHZ transducer with a refracted angle of 60 degrees in steel (OPTIMA model MPA0526S) , mini IIW block, and welded ultrasonic test plate (Sonaspection model PL 2742) with flaws depths of 0.200. 0.467, and 0.358 inch.

1. Enter the MAIN menu and set the range at 5.00 inch

2. Enter PUL/REC menu and select the following:

RECT:	FW
DAMP:	500 ohms
PULSE WIDTH	Optimize for transducer being used.

3. Select ANGLE mode in MAIN menu. Couple the wedge to the top surface of the mini IIW and very carefully align the beam exit point with the index mark on the block that marks the 1.00 and 2.00 inch radii.

4. Adjust the gain to produce echos from the 1.00 and 2.00 inch radii of approximately equal amplitude and with maximum response at approximately 80% FS.

The display should look similar to that shown in the following figure.

5. Enter THICK menu. Since the FLAW TRIANGULATION tracks the front flank of echos, it will produce slightly refined accuracy to increase the T-gate level to 60%.

6. Cursor to and select ECHO 2. Adjust the EBLK gate to produce a readout for ECHO2 gate. Select The display should resemble that shown in the Figure below.

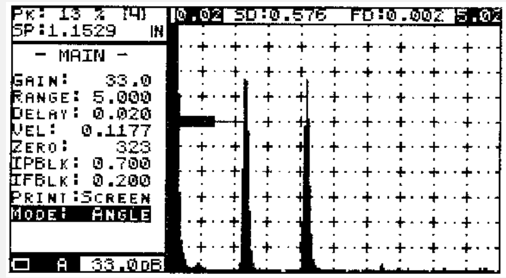


Figure 70

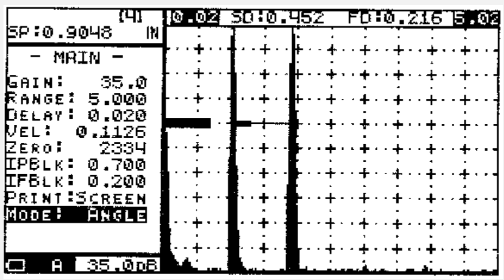


Figure 71

7. Cursor to and adjust VEL to calibrate the interval between the two echos to read 1.000 inch. The display should resemble as shown in Figure below:

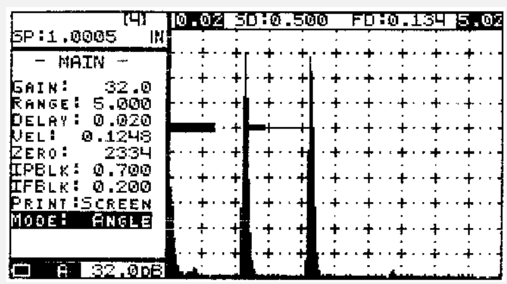


Figure 72

8. Cursor to MODE and select THICK. Cursor to ECHO and return to ECHO: 1 gate return to ANGLE mode to produce the following as shown in the following Figure:

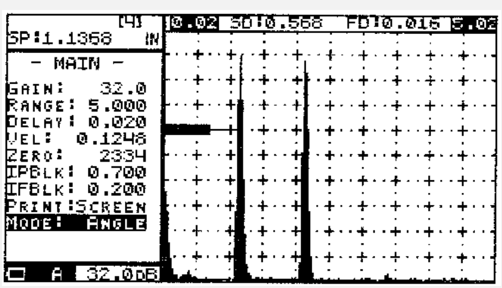


Figure 73

NOTE: The reading of 1.136 inch is the result of the sound path distances in the wedge and the metal to the 1.00 inch radius.

9. With the beam exit point and the index mark in careful alignment, adjust the ZEROA (in ANGLE mode) to produce the known metal path distance of 1.000 inch as seen in the next Figure.

10. As a double check on the accuracy of the distance calibration, enter MAIN menu, cursor to IPBLK, and extend the blocking gate past the 1.000 inch radius echo. The readout should be very close to 2.000 inch, as shown in the figure to the left.

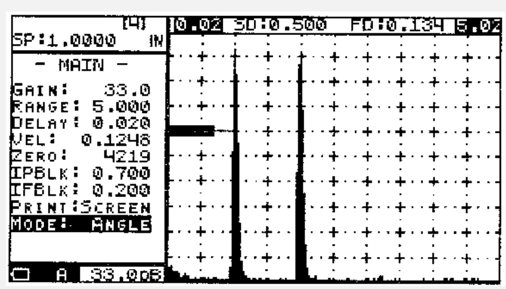


Figure 74

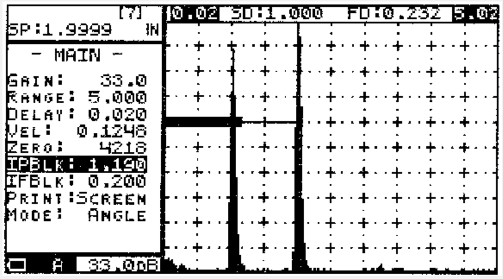


Figure 75

11. Set REFdB to 45.5 dB

12. Using the 1.00 inch thickness on the MINI IIW block, if a standard contact transducer is available, calibrate the Quantum TE for thickness and measure the thickness of the weld test plate. The plate used in this procedure averages 0.760 inch thick.

13. Re-enter ANGLE mode and set ANGLE to 60 degrees and THICK to 0.760.

14. Enter GATE 1 menu. Setup the following parameters:

GATE1:	ON
ALRM1:	POS
GAIN:	45.5 dB
STRT1:	1.500 inch
WID1:	2.500 inch
THRS1:	80%

15. Scan the weld plate at the distance marked with a sideways "V" which is the where maximum response from the embedded flaws lies.

WELD PLATE

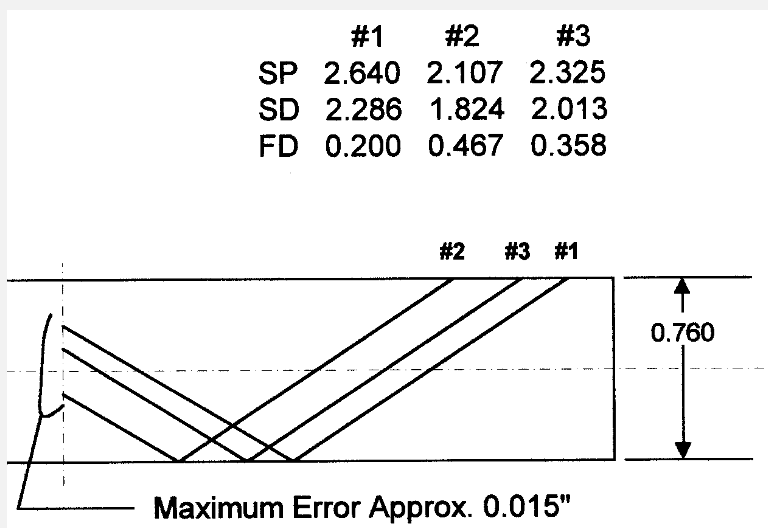


Figure 76

The following figures show responses from the three flaw areas:

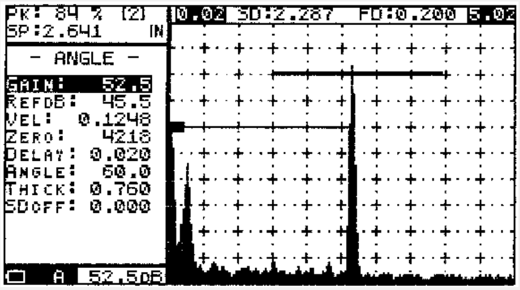


Figure 77

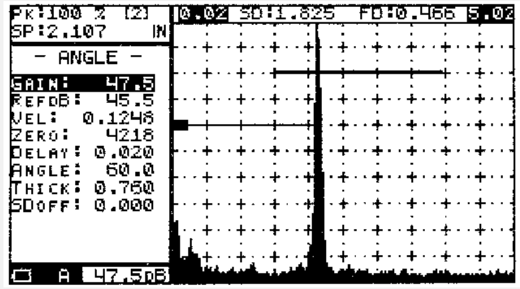


Figure 78

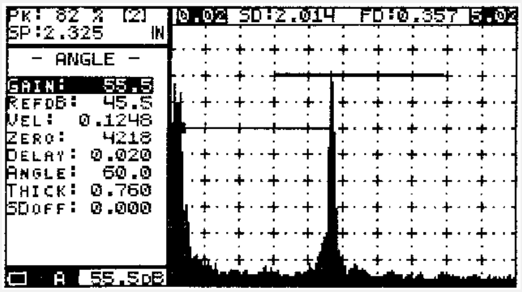


Figure 79

The following Figure shows the complete setup for the above inspection results:**<u>4.0 Quantum TE SETUP AND OPERATING PROCEDURES</u>**.

QUANTUM-TE Setup

Range:	5.000	Freez:	Off	Thrs1:	80
Delay:	0.020	PHold:	Off	Gate2:	Off
Vel:	0.1248	TThrs:	60	Alrm2:	Off
IPBlk:	0.249	Zero:	4218	Strt2:	0.720
IFBlk:	0.200	Echo:	1	Wid2:	0.200
Print:	Setup	EBlk:	0.331	Thrs2:	29
Mode:	Angle	Resol:	Normal	Angle:	60.0
Save:	DEFLT	THold:	last	Thick:	0.760
Rcall:	DEFLT	TAlrm:	Off	SDoff:	0.000
Units:	INCH	HiAlm:	10.000	Gain:	55.5
Disp:	BLKsol	LoAlm:	0.000	RefdB:	45.5
BkLit:	On	AGC:	Off	Step:	1
Contr:	64	Gate1:	PER	Probe:	Single
Lock:	Off	Alrm1:	Off	PVolt:	250
Click:	On	Strt1:	1.500	PWid:	115
Grid:	On	Wid1:	2.500	Sync:	IP
Freez:	Off	Thrs1:	80	IFThr:	75
PHold:	Off	Gate2:	Off	Rect:	FW
TThrs:	60	Alrm2:	Off	Damp:	500
Zero:	4218	Strt2:	0.720	Tune:	BB
Echo:	1	Wid2:	0.200	Rejct:	0
EBlk:	0.331	Thrs2:	29	CType:	Off
Resol:	Normal	Angle:	60.0	Draw:	CLEAR
THold:	last	Thick:	0.760	Point:	1
TAlrm:	Off	SDoff:	0.000	CAlrm:	Off
HiAlm:	10.000	Gain:	55.5	DelDB:	+/-3
LoAlm:	0.000	RefdB:	45.5	Curvs:	1
AGC:	Off	Step:,	1	Zoom:	Off
Gate1:	PER	Probe:	Single	Left:	0.260
Alrm1:	Off	PVolt:	250	Right:	0.690

Figure 80

For experienced Level I or Level II ultrasonic inspectors, setting up and operating the Quantum TE will be little different from analog-type ultrasonic instruments. Instead of using knobs and switches for control adjustments, the appropriate menu item must be found, then selected, then controlled by using one or more of the keys.

For persons unfamiliar with fully micro computerized instruments, perhaps the most frustrating part of learning is in the finding the item they wish to control. The Quantum TE is just about the only instrument on the market today in which the operator con perform a simple “screen” calibration without the use of ANY menus! :-) In designing the menus for the Quantum TE, particular attention has been paid to simplifying the process of locating items, then prompting the operator to do something intuitive in order to change control settings. To some extent, once the operator is familiar with the operation, digitally controlled instruments are easier, more intuitive to operate than analog types.

4.1 Quantum TE Display Characteristics.

A difference noticed by experienced operators of analog-type instruments is in the "stair-step" appearance of the display on instruments having digitally derived pixel-type displays, especially at relatively short ranges of the time base. There are two aspects of this type of display that should be considered:

1. The effect on determining vertical linearity, and
2. The effect on the appearance of horizontal linearity.

Horizontally, the Quantum TE display is 170 pixels wide. However, because of the way a smoothly curved analog waveform is sampled by analog-to-digital circuitry, "stair-stepping" can produce the appearance of being less smoothly shaped. This effect is visual only, being more pronounced when the time-base is at short range. However, the determining factor regarding horizontal linearity is in the digital sampling rate, not in the actual visible appearance. Because distance/thickness readouts in Quantum TE are determined from a Hi-Speed sampling or “digitizing” rate, the digital readout has inherent accuracy and resolution far superior to that which can be measured visually from a conventional CRT. Even at modestly short ranges, measurements made visually from Quantum TE’s display are essentially equivalent to those made from CRTs. Quantum TE’s thickness readouts are precise, regardless of the range or stair-stepped appearance of the A-trace display.

Within a short time of familiarization with Quantum TE’s display and alarm systems, the operator will adapt to the display and will especially appreciate the large area and visibility of the A-trace. Most experienced operators of analog-type instruments can effectively operate the Quantum TE without reference to the Operator's Manual. However, some of the procedures outlined below will guide the operator in quickly setting up and using the many features incorporated in Quantum TE that are not found in many "standard" ultrasonic instruments. The versatility of Quantum TE will be readily evident by following the procedures described below.

4.2 FACTORY Setup Variables.

When the Quantum TE is turned on by pressing the ON/OFF control, the LOGO screen is displayed automatically. When the gage is operated for the first time, or if FACTORY DEFAULT is selected from memory, all the control variables "default" to specific values (After that they will display the last previous setup parameters). For many common thickness gaging applications, it is only necessary to "fine tune" a few variables. Some applications can be started without any adjustments. The FACTORY setup variables have values that match or nearly match a variety of the most commonly used transducers for thickness gaging. By pressing any key to continue, then by depressing and holding the MENU key the FACTORY setup default variables are displayed as listed below.

With Quantum TE's broadband receiver and powerful square-wave type pulser, it is possible to achieve high resolution, penetration, and sensitivity by using relatively highly damped, broadband transducers for thickness gaging. Of course, there will be instances where reduced bandwidth transducers will be preferred, but a surprising number of applications can be satisfied with broadband transducers.

QUANTUM-TE Setup

Range:	2.000	Freez:	Off	Thrs1:	55
Delay:	0.000	PHold:	Off	Gate2:	Off
Vel:	0.2330	TThrs:	46	Alrm2:	Off
IPBlk:	0.200	Zero:	350	Strt2:	0.500
IFBlk:	0.200	Echo:	1	Wid2:	0.100
Print:	Setup	EBlk:	0.200	Thrs2:	45
Mode:	Thick	Resol:	High	Angle:	30.0
Save:	DEFLT	THold:	last	Thick:	0.250
Rcall:	DEFLT	TAlrm:	Off	SDoff:	0.000
Units:	INCH	HiAlm:	10.000	Gain:	48.0
Disp:	BLKlin	LoAlm:	0.000	RefdB:	48.0
BkLit:	On	AGC:	Off	Step:	1
Contr:	50	Gate1:	Off	Probe:	Single
Lock:	Off	Alrm1:	Off	PVolt:	250
Click:	On	Strt1:	0.200	PWid:	50
Grid:	On	Wid1:	0.100	Sync:	IP
Freez:	Off	Thrs1:	55	IFThr:	75
PHold:	Off	Gate2:	Off	Rect:	+HW
TThrs:	46	Alrm2:	Off	Damp:	50
Zero:	350	Strt2:	0.500	Tune:	BB
Echo:	1	Wid2:	0.100	Rejct:	0
EBlk:	0.200	Thrs2:	45	CType:	Off
Resol:	High	Angle:	30.0	Draw:	CLEAR
THold:	last	Thick:	0.250	Point:	1
TAlrm:	Off	SDoff:	0.000	CAlrm:	Off
HiAlm:	10.000	Gain:	48.0	DelDB:	+/-3
LoAlm:	0.000	RefdB:	48.0	Curvs:	1
AGC:	Off	Step:	1	Zoom:	Off
Gate1:	Off	Probe:	Single	Left:	0.600
Alrm1:	Off	PVolt:	250	Right:	1.400

Figure 81

4.3 Thickness Gaging Procedures

4.3.1 Sample Setup procedures (A Walk Through).

4.3.1.1 3/8" 5.0 MHZ Contact Transducers

Once the effects of variables affecting thickness gaging precision are understood, the operator can quickly diagnose which variables should be adjusted. A good way of observing these effects, and to become quickly familiar with Quantum TE's controls is to perform the following procedure:

1. Attach a highly damped, broadband transducer such as the OPTIMA CHG053 or NOVA C11 (5 MHZ, 3/8 inch element diameter) to the micro-dot connector on the ML-01 transducer cable supplied with Quantum TE. Insert the Lemo connector in the receptacle marked with a red dot on the top closure of Quantum TE.

2. Obtain a steel stepped wedge with several known thickness steps. An excellent choice, and the one upon which this procedure is based, is the OPTIMA Model TBS114. This wedge, made from 4340 vacuum-melted steel alloy and nickel plated, has five steps precision machined to thicknesses of 0.100, 0.200, 0.300, 0.400, 0.500 inch (2.54, 5.08, 7.62, 10.16, 12.70mm).

3. Couple the transducer to the 0.400 inch (10.16mm) step using a drop of glycerin, light machine oil, mineral oil, or low viscosity gel-type couplant. For this familiarization exercise, it will be

convenient to use a rubber band or a small weighted object that will hold the transducer in place. This procedure will relieve you from having to hold the transducer in place for an extended period during familiarization.

4. Press the ON/OFF control. Quantum TE’s screen will briefly be back-lit and a series of horizontal bars will be seen. During this very brief period, Quantum TE undergoes a host of internal diagnostic checks. Once these checks are complete, the LOGO screen automatically appears.

5. The darkened, reversed text area reads “PRESS ANY KEY TO CONTINUE”. Depress any key and the MAIN MENU will be displayed .

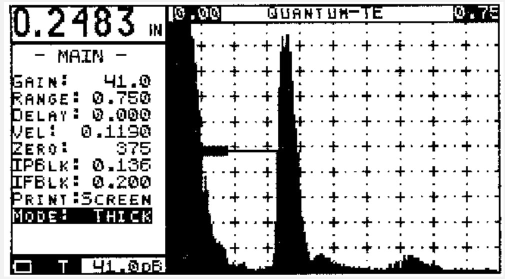


Figure 82 Main Screen

An A-trace will appear, along with the Main Menu items and a thickness readout, the large numbers in the upper left-hand corner of the A-trace. Note that immediately above the A-Trace is a highlighted STATUS field which displays “UNITS NOW : INCHES” (or MM, if metric units have been selected. See Section 2.1.4, SETUP Menu). This is the FACTORY setup default full-scale range of 2.00 inches (50mm). Also note the large back echo at the second major horizontal scale division and the thin horizontal bar at 46% full-scale (FS) amplitude. Observe that this horizontal line extends from the extreme left edge of the A-trace and terminates on the leading edge of the back echo. This line, or bar, represents the thickness gate (T-gate) and shows which echo stops the gate. In this example, since the 0.400 inch (10.16mm) step is the one being measured and the horizontal FS range is 2.00 inches, the T-gate terminates on the first echo above 46% FS amplitude, the back echo from the 0.400 inch (10.16mm) step. Along the left-hand vertical axis, a signal will also be seen. Since the FACTORY setup defaults to initial pulse synchronization (IP SYNC), this signal is the initial pulse (IP) with its leading edge coincident with the left-hand vertical axis.

One other feature that should be noted is the presence of a dark bar extending horizontally along the thickness gate on the A-trace from the left-hand axis. This bar represents the blocking gate (BLK gate) which serves to "block" out the string of high amplitude echos typically accompanying the IP. In its FACTORY setup default position, the IPBlk gate is at 0.200" to block out the IP echos and thus prevent the T-gate from terminating within the IP. Control of the IPBLK gate is explained in Section 2.1.7 and will be further examined later in this procedure. (If an undamped or lightly damped transducer other than those recommended for this exercise is being used, it may be necessary to make an immediate adjustment of the IPBLK gate in order to proceed. If so, go to Step 15, below, and perform the necessary adjustment.)

9. For the transducers and stepped wedge recommended, the thickness readout (T-readout) should be within a few thousandths of an inch (a few hundredths of a millimeter) from 0.400 inch (10.16mm) plus or minus. Position of the cursor in the Main Menu is at GAIN.

10 With the cursor at GAIN, right and left arrow keys increase/decrease effective gain accordingly. The increment/decrement values of gain change is 1.0 dB (FACTORY default). The increment/decrement values of gain change is selectable in 0.1 dB, 1.0 dB, 2.0 dB, 6.0 dB (go to step ? to adjust values). Use the down arrow to place cursor on REF dB.

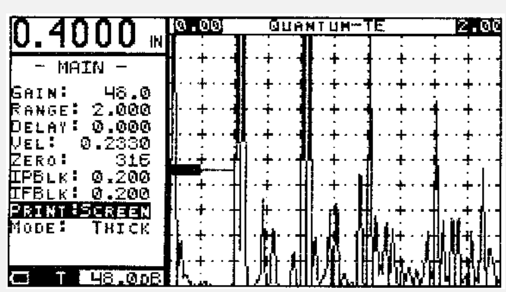


Figure 83

11. Reference gain (REF dB) is a function that facilitates compliance with several common specifications regarding establishment of the gain level used for evaluating flaw echos. Specifications usually require that scanning be done at higher gain than the acceptance level gain. With REF dB, at any time REF gain is greater than GAIN , GAIN resets to the same level as REF dB. REF dB is the operative gain and increase or decrease adjustments are made to satisfy the specification accept/reject gain level. GAIN when cursored to, “freezes REF dB gain and permits adding the amount of gain required by the specification for scanning. This procedure increases the likelihood that small flaw echos will be detected. Once a flaw is detected, REF dB is again selected and the flaw echo amplitude compared against the accept / reject criteria. To quickly adjust GAIN value to REF dB value, place cursor on REF dB and quickly press SEL.

12. To become familiar with the RANGE function, position the cursor at RANGE The left arrow key will move echos on the A-trace to the left, that is, except for the initial pulse. IF multiple back echos are present, they will move toward the left <u>and</u> approach each other more closely. In our 0.400 inch (10.16mm) steel block example, depress the right arrow key until the first back echo, originally at the second vertical division of the electronic graticule moves to the fourth full vertical division.

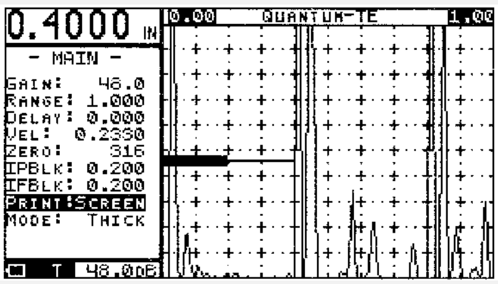


Figure 84 - Range

The second back echo will be aligned (or nearly so) at the 8th full division. The readout value under RANGE should be close to 1.00 inch (25.4mm). <u>**However, note that T-readout did not change unless the gain was substantially increased.**</u> <u>**With Quantum TE’s digital electronics, it is not necessary to use the graticule or other precise settings of range in order to calibrate for, and to readout precise thicknesses.**</u>

13. The DELAY function also has pronounced effects on the location of signals on the A-trace. Set the full-scale range at 1.00 inch (25.4mm), and position the cursor at DELAY. Depress the RIGHT arrow key and observe the effect. Signals move toward the left, including that of the initial pulse, which moves off-screen to the left. Note that the distance between multiple back echos <u>does not change</u> as it did when range was increased. Continued depression of the RIGHT arrow key moves echos toward the left until they are completely delayed off-screen. If calibration has been performed for the material under test, the readout under DELAY indicates how far the display has been delayed.

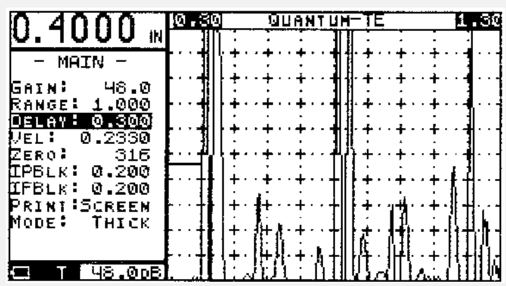


Figure 85 - Delay

14. Move cursor past VEL (VELOCITY). <u>**NOTE**</u>: <u>VELOCITY adjustment will be covered in step 21 below.</u>

15. With the RANGE at 1.00 inch (25.4mm), cursor to IPBLK. The right/left arrow keys control the length of the blocking gate, referred to as "IPBLK gate", and represented by the dark bar extending horizontally along the thickness gate on the A-trace from the left-hand axis. Its purpose is to "block" the trailing edge echos associated with the initial pulse. This group of echos contains ring-down echos from the transducer and "noise" accompanying stray reflections resulting from coupling. The "noise" figure is minimal when both the front surface of the transducer and the surface of the test object are smooth. This is the usual case with new,

unworn transducers and with many finely-machined test blocks or reference standards. However, actual test objects seldom have clean, smooth surfaces. They often have rough machined or mill-finished surfaces (as-cast surfaces on castings), sometimes corroded and sometimes painted surfaces. In these cases, the extent of coupling noise will be greater than that returned from test blocks.

At default, the length of the blocking gate (IPBLK gate) is 0.200 inch (5.08mm) equivalent in steel. With medium to broadband transducers of 2.25 MHZ or greater, that distance is usually sufficient to block IP echos and coupling noise from standard test blocks. Note, however, that it would not be possible to thickness gage steel less than the width of the IPBLK gate, less than 0.200 inch (5.08mm) at FACTORY defaults. If the total IP is greater, and the blocking gate must be further extended, any significant echos within the blocking gate, back echos or otherwise, will be blocked and will dictate the minimum thickness that can be gaged with the correct digital thickness readout. In such cases, it may be necessary to use a different transducer or a different technique (such as visual isolation of the back echo and non-digital measurement, or gating between multiple back echos). With highly damped, broadband transducers of 5 or 10 MHZ, it should be possible to shorten the IPBLK gate to permit IP to first back echo digital readout of 0.030 inch (0.8mm) steel or equivalent. Even with some transducers of 2.25 or 3.5 MHZ, the blocking gate can be reduced to permit gaging from between 0.030 inch (0.8mm) to 0.040 inch (1.0mm) on smooth surfaces.

15a. At this point, use the right/left arrow keys to change the length of the IPBLK gate in order to observe the effects of the control.

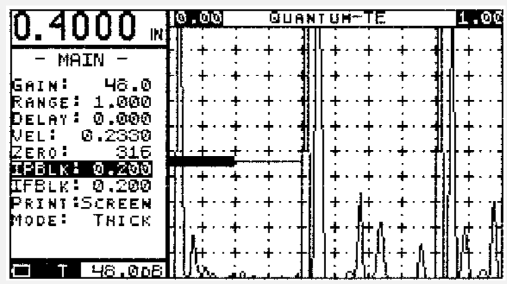


Figure 86 - IP Block

16. IFBLK functions in a similar fashion as the IPBLK but when Interface Synchronization (IF) is selected. IF Sync automatically starts the T-gate at the leading edge of the interface echo (the echo between the delay line and the test object surface. The delay line could be a plastic tip or a water path). Whenever practical, if delay lines are used, interface synchronization (IF Sync) should be selected. A complete description of IF Sync is discussed in step 25e.

17. When the cursor is on MODE, the right or left arrow keys allow you to select the inspection method as described in para. 2.1.2. THICK is the current mode the Quantum TE is displaying. FLAW and ANGLE will be discussed in para 4.4.1 and 4.4.3

18. Before examining the function of THICKNESS THRESHOLD (TTHRS),press MENU to display the THICKNESS (THICK) Menu. At TTHRS, note that the horizontal T-gate bar is at 46%. Right / left arrow key controls change the threshold level of the T-gate accordingly, and the actual level of the T-gate is readout in % full-scale amplitude, variable from 10% minimum to 90% maximum. The FACTORY default amplitude of 46% is a good compromise and generally effective when the first back echo amplitude is maintained between approximately 70% full-scale and to somewhat greater than saturation amplitude (greater than 100% full-scale).

19. Move the cursor to TALRM. Using the left or right arrow will turn on or off THICKNESS ALARM

20. Both LO ALR and HI ALR function in the same manner. These selections represent low thickness alarm and high thickness alarm, respectively. They can be used to alert the operator (through the visual and audible alarms) when pre-set thickness levels, low, high or both low and high, have been exceeded. The level sets are scrolled when the right /left arrow keys are depressed. With the cursor at the TALRM position, arrow keys toggle the alarm system (audible

tone and visual LED) on and off. In gaining familiarization with these features, note that it is not possible to "cross" these levels. That is, the high alarm setting cannot be set lower than the low alarm setting and vice-versa.

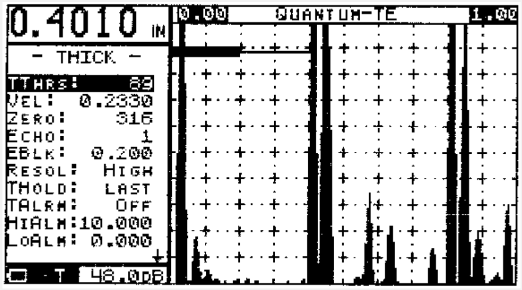


Figure 87a Thickness Threshold @ 89dB

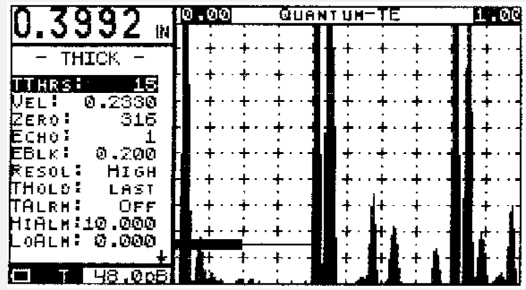


Figure 88 - Thickness Threshold @ 15dB

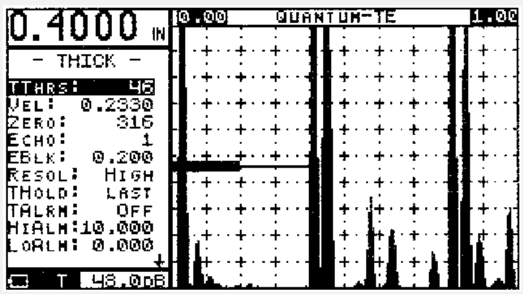


Figure 89 - Thickness Threshold @ 46dB

The next two functions, VEL and ZEROA are adjustments necessary to "calibrate" all the timing functions, since all timing functions have effects on the horizontal aspects of the A-trace

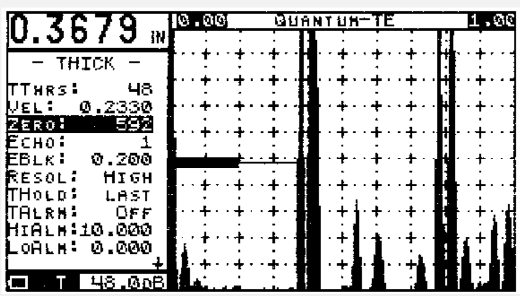


Figure 90

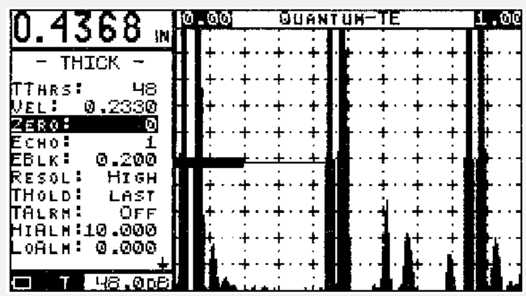


Figure 91

In our example, using a 0.400 inch (10.16mm) thickness step, we have yet to perform any operations to "calibrate" the T-readout. Most probably the reading is close to 0.400 inch (10.16mm), since the FACTORY setup defaults are deliberately designed to produce nearly correct calibration for a contact transducer being used on steel having longitudinal sound velocity of 0.2330 inches/microsecond (5.92mm / microsecond).

21. As a first step in becoming familiar with the VEL and ZEROA functions, let us complete the calibration for thickness measurement using the stepped wedge in our example. The cursor will be at VEL. Using the down arrow, reposition it at ZEROA, the probe zero control position. Note the reading next to ZEROA on the horizontal menu line. The default setting of 350 ns (nanoseconds) will increase or decrease when the right or left arrow keys are activated. Depress the right arrow key and hold it. The value at ZEROA will increase continuously as long as the key is depressed. Repeated or continued depression of the left arrow key has two effects:

A. If held for continuous "scrolling" of the ZEROA value, the position of echos on the A-trace will move slowly left.
B. The T-readout will decrease.

The opposite effect takes place when the left arrow key is depressed. When 0.400 inch (10.16mm) [or whatever the known actual thickness of the step] is achieved in T-readout, the upper range calibration is complete. Note that zero may change through up to 10 ns before the indicated thickness changes. Choosing zero roughly at the mid-point of the range needed to move from 0.399 inch to 0.401 inch (10.13mm to 10.19mm). This procedure can improve thickness gaging precision.

21a. Remove the transducer from the 0.400 inch (10.16mm) step and couple it sequentially to the other steps. If the test block has been accurately measured and the material is steel with a VELOCITY (VEL) of 0.2330 inch/microsecond (5.22mm/micro-second), the other measurements should be exact within ±0.001 inch (±0.02mm) and reproducible. **NOTE : to measure to thinnest step on the block it will be necessary to adjust IPBLK as per step 15 above**

21b. IF some metal other than steel is used, a somewhat different procedure will be required. For a transducer of similar type as recommended for these procedures, reset the ZEROA to approximately that of the default (350 ns). Depress the up arrow key to position the cursor at VEL (velocity). With the transducer coupled to the thickest step, use the right and left arrow keys to decrease/increase velocity until the known thickness is at T-readout.

Now couple the transducer to the thinnest step. If T-readout does not agree with the known thickness, reposition the cursor at Z (ZEROA) and use the right and left arrow keys to produce the known thickness in T-readout.

Again check the thickest step. If T-readout still does not agree with known thickness, reposition the cursor at VEL (velocity) and use the right/left arrow keys to obtain the known thickness.

Continued adjustments between ZEROA and VELOCITY will soon produce correct T-readout on both the thickest and thinnest steps. At this point, the steps in between will read correctly [within the resolution, ±0.001 inch (±0.02mm)]. The velocity value below VEL is the velocity of the material of the test block.

A short-cut in the calibration routine for metals other than steel is to scroll the value at VEL to the nominal velocity for that material. Velocity values are tabulated in a variety of publications, including NDT Systems, Inc.' OPTIMA transducer catalog. **NOTE: Tabulated velocity values have been obtained from a variety of sources that do not always agree. It is strongly recommended that accurately known thicknesses of the same material as the test object be used to calibrate for accurate thickness measurement**

22. To examine ECHO function, place the transducer on the 0.400 inch (10.16mm) thickness step. Scroll back to MAIN MENU using the MENU key. Cursor to and set RANGE to 2.00 inch (50.80mm). Scroll back to THICKNESS MENU. Cursor to ECHO. Use right arrow key to select “2". ECHO allows the selection of a multiple echo from which the thickness measurement (T-gate) will begin. Up to the fifth multiple echo can be selected using the left / right arrow keys. This function is useful when using single element transducers with thin-elastomeric membranes or on coated test objects.

23. Cursor to ECHO BLOCKING GATE (EBLK). Note the thick horizontal bar on the T-gate. Use the right arrow key to select the length of the echo blocking gate that is used to block out any unwanted signals between multiple echos in the thickness mode. The FACTORY default value is .200 inch (5.08mm). EBLK is actively displayed when ECHO is set at 2 to 5

24. Cursor to THICKNESS RESOLUTION (RESOL).use the right /left arrow keys the selection either NORMAL or HIGH thickness measurement resolution on LCD display. NORMAL resolution is 0.001 inch or 0.01 mm. However, when high frequency delay line transducers are used, stable and reproducible resolution of 0.0001 inch is achievable in HIGH resolution. This display is set to Lo resolution.

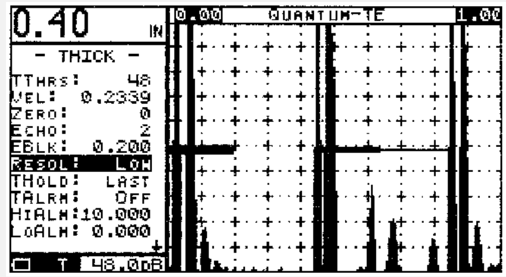


Figure 92 - RESOL

25. The PULSER / RECEIVER menu contains the variables that have to do with optimizing the damping and pulse characteristics with the transducer (probe) being used It is worth while to experiment with these variables as the over all quality of the received echo envelope can be effected greatly. In many higher frequency tests, these variables can “make-or-break” an inspection. Pay particular attention to Pulse Width!

25a. The functions of GAIN and REFdB have already been examined (please refer to steps 10 and 11 above).

25b. Move cursor past REFdB to STEP. The right / left arrow keys change the increment / decrement values of gain changes through 0.1, 1.0, 2.0, and 6.0 dB.

25c. Move cursor to highlight PULSE VOLTAGE (PVOLT). This refers to the Amplitude of the square-wave type pulse available from Quantum TE’s variable pulser. By switching back and forth between dB and PVOLT and continuously increasing/decreasing the pulse voltages between its extremes of 50 to 400 volts, the effect of pulse voltage on back echo (and IP) amplitude can be observed. For most transducers used in precision thickness gaging, pulse voltages between 150 and 250 volts are usually optimum; pulse voltage increases beyond 200 to 250 volts produce little effect on signal amplitude.

25d. Perform the same exercise with the cursor on PULSE WIDTH (PWIDTH). Note the units of the variable are ns (nanoseconds). By observing the unsaturated amplitude of the back echo, the effect of continuous increases and decreases in pulse width tend to cause the back echo amplitude to pass through an optimum high amplitude. However, somewhat lesser values of pulse width (less than maximum amplitude) do not degrade the performance of broadband transducers. In fact, using low pulse widths can result in best minimum thickness resolution performance from undamped transducers. NOTE: Unnecessarily high pulse voltage or pulse width can reduce the life of high frequency, undamped, broadband transducers. In addition, since the product of pulse voltage and pulse width are the measure of pulse energy, unnecessarily high values of either will drain the battery pack more rapidly than at lower values.

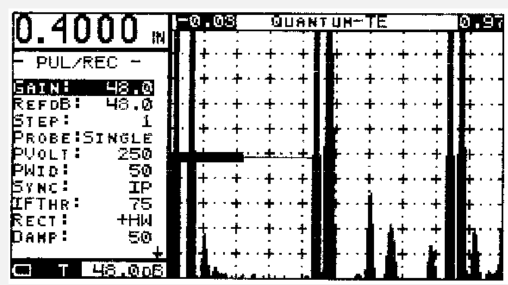


Figure 93 - PUL/REC Menu

25e. Yet another important selection in the PUL/REC menu is that of SYNC. Note that IP SYNC is the default setting. IP SYNC (initial pulse synchronization), synchronizes the start of the A-trace and the various gates (blocking gate, thickness gate) from the time the pulser "fires". With contact transducers having thin wearplates, this time is nearly coincident with the leading edge of the initial pulse signal. Most thickness gaging inspections using contact transducers will be done with IP SYNC.

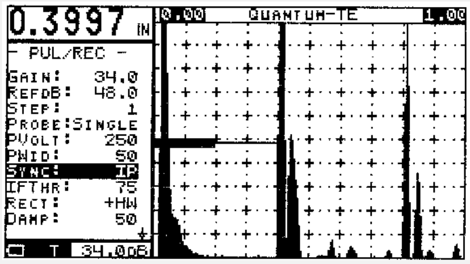


Figure 94 - IP Sync

Interface synchronization (IF SYNC) is most often selected when delay line, dual element, or immersion transducers are being used. The common factor in using any of these transducer types is that the transducer element is removed by some distance from being in contact with the test object surface. Delay lines and dual elements have a stand-off material coupled to the transducer element. The stand-off is usually plastic, but could be other materials. Quartz, ceramics and, occasionally, metals are sometimes used as the stand-off (or delay) materials. In immersion testing, the delay material is a liquid, usually water. Whatever the case, it is usually desirable to start the A-trace and synchronize the gates from the entry surface echo of the test object. When IF SYNC is selected, Quantum TE does just that. Whenever IF SYNC is selected, the mode icon in the top left corner of the display flashes. This is a reminder that IF SYNC is in effect.

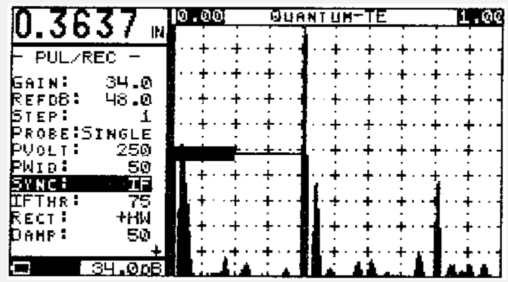


Figure 95 - IF Sync

25f. Before we examine INTERFACE THRESHOLD (IFTHR), one precaution should be kept in mind when IF SYNC is selected. The A-trace will synchronize on the <u>first echo</u> that exceeds the threshold set. In immersion testing, if there is dirt or other particulate matter in the immersion bath, or if squirter parts or other obstacles intervene, the IF SYNC circuitry attempts to resynchronize on the echo(s) from the obstructions. This can produce "jitter" in the A-trace display. Further, if there is no interface echo (as when a dual element transducer is not coupled to the test object), there is no signal upon which the IF SYNC can synchronize. The A-trace is essentially blank. If, IF SYNC is active and, for any reason, the operator is unaware of that fact, the impression could be that the instrument is malfunctioning. For that reason, INTERFACE THRESHOLD (IFTHR) allows Increase or Decrease of the threshold level to which an Interface Sync is detected. Once the interface sync is detected, the Interface signal is positioned to the left edge of the display.

<u>NOTE: Cursor back to SYNC and select IP before next step.</u>

For precision thickness gaging, the type of waveform used for setups has a significant effect on gaging results. Note that the RECT default is +HW, meaning that the current display is of signals that are positive half-wave rectified.

25g. To better illustrate the effects produced by the various waveform displays, press MENU to return to the Main Menu. Cursor down to RANGE. Use the left arrow key to change the RANGE readout to 1.00 inch (25.4mm). Press MENU key to return to **PUL/REC** menu. With the cursor positioned on RECT, use right / left arrow keys to select RF. For this example, the display will be similar to that shown below:

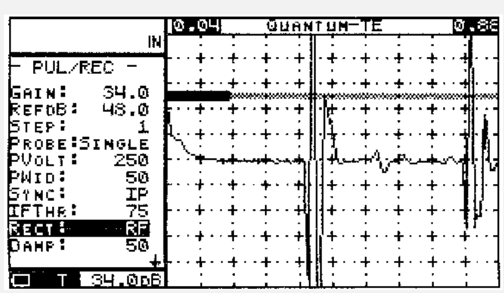


Figure 96 - RF Display

Note that the back echos are now displayed on a centered horizontal baseline and have both positive and negative components. This mode of display, RF (radio frequency), reveals all the details of the signal. IF necessary to more faithfully reproduce the waveform in the figure above, it may be necessary to key to dB and change the gain. Now examine the details of the back echo. The first half-cycle is negative-going, but has less relative Amplitude than the next half-cycle, which is positive-going. This being the case, imagine what the back echo would look like if everything below (on the negative side of) the base line were removed from the display. Vertically enlarged, that is what actually happens when +HW is selected. Selection of -HW results in the converse -- only the negative-going components of the back echo signal are displayed. On the A-trace, the negative-going parts of the signal are "flipped" upright (rectified). FW represents full-wave rectification; that is, both the positive half-cycles and the flipped over negative half-cycles are displayed simultaneously.

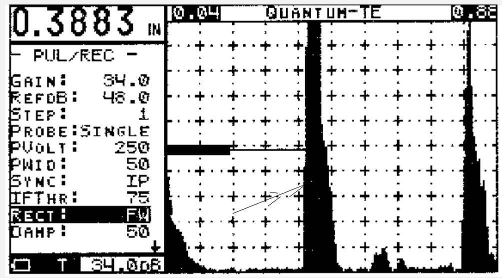


Figure 97 - FW Display

25h. Look at each of the responses and make a mental note of the differences. These are important differences in thickness gaging. For example, under the current test setup conditions, if FW (full-wave rectification) is selected, the lower Amplitude negative cycle appears as the first, or leading edge of the back echo. By manipulating the gain to cause the T-gate to terminate on the negative component, then on the positive part, a significant difference in T-readout occurs.

Referring back to Figure 4.3.7 which shows the RF display, a good reason to select +HW over -HW or FW is because the first positive-going component of the signal has greater Amplitude than does the first negative, produces a "cleaner" display than FW and is less sensitive to producing T-readout changes as a function of gain.

There are other good reasons for offering this variety of display modes. There are instances where the more prominent half-cycle is <u>not</u> positive-going. In cases where the back wall is lined with another material (e.g. some elastomers), the first negative-going half-cycle is more prominent. This phenomenon has to do with the relative acoustical impedance characteristics of the two materials that make up an interface. Many liquids, elastomers and polymers forming an intimate interface with metals produce echos whose phase is reversed from that of the metal/air interface.

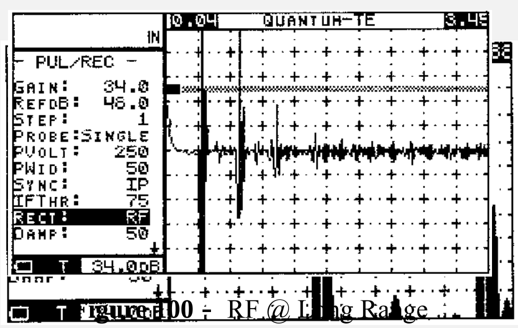


Figure 100 - RF @ Long Range

Figure 98 (-HW)

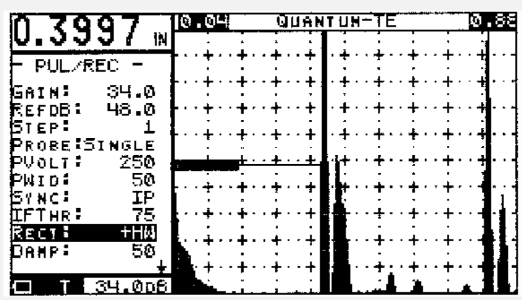


Figure 99 (+HW)

The RF display can be referred to if there is any question about which waveform should be selected. For thickness gaging metals much beyond one inch (25mm) thick, it will be necessary to "expand" the RF display. If, for example, for a 2 inch thick test specimen, the full-scale range of the Quantum TE has been set to a long range, and the RF display is selected, there will be poor detail in the presentation of the RF.

In order to expand the RF display of the back echo under such condition, delay can be used to reposition the back echo very near the left side of the A-trace. Then, reducing full-scale range to 0.50 (12.7mm) reproduces the RF of the back echo similar to that of a much thinner test object.

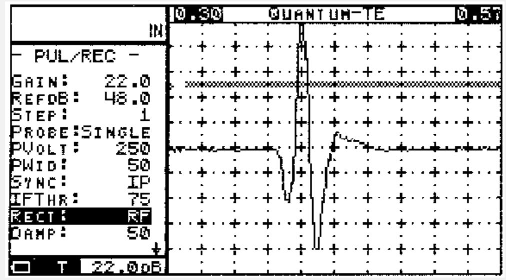


Figure 101 - RF Expanded

25g Cursor down until DAMPING is highlighted. The default value is 50 ohms, a usually good match for the type of transducer being used in this example. To observe the effect of damping changes, depress the right arrow key and note a new, higher damping resistance value displayed. Also note that the IP echos tend to extend farther at higher damping resistance. Damping changes likewise increase both the Amplitude and shape of the back echo. To observe the effect of damping on the back echo, cursor up to highlight GAIN. Now, press the left arrow and keep it depressed. You are controlling the gain (dB) in this selection without having to go to the dB selection in the Main menu. With down and up arrow key adjustments as required, establish the Amplitude of the first back echo at approximately 50% FS (the precise location is unimportant). Then, return the cursor to DAMPING and use the right arrow key to once again increase the damping resistance. Observe the Amplitude of the back echo increase, perhaps substantially, with increased damping resistance. While this effect can be used to advantage under some conditions, for precision, high resolution thickness gaging, it is usually desirable to select relatively low damping resistance. With experience, through careful observation of the changing shapes of the IP and back echo, it is possible to optimize the damping for the job at hand. For now, return the damping resistance value to 50 ohms, the default value.

25h. TUNE FREQUENCY (TUNE) allows you to select the frequency range of the receiver to match the transducer. A broadband frequency range(BB) of 0.5 to 25MHz, tuned channels of 0.5, 1.0, 2,25, 5.0, 10.0 MHZ (nominal) are selectable.

25i. Procedure for Using Linear Reject. Quantum TE's linear reject feature performs in the same manner as in any other high-capability flaw detector. When the PULSER/ RECEIVER menu is displayed, advance the cursor to REJECT. With the cursor at REJECT, pressing the right arrow key scrolls the reject level from 0% upward. Any signals in the A-trace having amplitude equal to or less than the reject level will be "clipped off" or rejected. Signals having amplitude greater than the reject level will be unaffected above the reject level. While establishing the desired level of reject, it may be necessary to also adjust gain.

Most inspection documents either forbid the use of or require that, if reject is used, that fact is signaled by a unique annunciator. For that reason , whenever the reject level is increased above 0%, a reject icon (R) flashes intermittently in the display status bar above the A-scan display.

25j. First note that SGL is highlighted in a column of another selection, DUAL. Press the right / left arrow key once to select DUAL and note that the A-trace essentially blanks out. This selection is for using a dual element transducer and will be discussed later. Press the left / right arrow key to return to SINGLE.

4.3.1.2 Procedures for Using Dual Element Transducers with Delay Lines.

Dual element transducers combine the advantages of single element delay line transducers with the addition of one more: the sound beam can be directed into the test object at a small angle. This effect offsets, to some extent, the natural tendency of the sound beam from a single element transducer to diverge. Beam divergence "wastes" a large portion of beam energy. The dual element transducer has two active elements mounted side-by-side with a barrier strip of sound-absorbing material between them. One element is connected to the instrument pulser and the other to the receiver. Otherwise, they are electrically isolated from one another. The elements are mounted at slight angles with respect to the barrier strip, thus forming the shape of a shallow angle roof. The transmitted longitudinal beam centerline enters the test object at the "roof angle". The beam continues into and through the test object, reflects from the back wall and returns at the same angle toward the receiving transducer. The time it takes to traverse this path includes the sum of times through the transmission delay line, through the test object thickness to the back wall, from the back wall through the test object again, and through the receiving element delay line.

By "ZEROING" out the constant distance paths taken by the sound beam in traversing the dual delay lines, a measurement can be made of the travel distance in the test object only.

Since the sound beam travels at a slight angle into and out of the test object, the path taken is slightly longer than in the case where the sound beam enters and exits perpendicular to the test object surface. Calibration at a specific thickness applies only for that thickness, plus or minus. While the error at other thicknesses is small, for high precision measurements, it should be taken into account. While the error can be calculated, it is usually more convenient to determine it experimentally, or to recalibrate for different ranges of expected test object thickness. This point will be illustrated in the following setups. The error is referred to as "V-Path Error", so-called because of the V-shaped path the soundbeam takes in traveling from the transmitting element to the receiving element of the transducer.

There are several approaches to dual element transducer setups:

1. If the temperatures of the test object and transducer are essentially the same and the setup is made at basically ambient conditions, the delay line ZEROA procedure is relatively easy.

2. If the test object is at a substantially different temperature than the transducer, setting up for multiple echo interval measurement will be more precise. This technique is also applicable if the test object is coated or painted.

3. Less precise measurements can be made by using the A-trace screen graticule points. By "calibrating" convenient thickness values to the graticule divisions, thickness can be estimated reasonably well.

4. Quantum TE's delay is "calibrated" with readout in units of distance ("mils" -- milli-inches). A procedure utilizing this feature will be outlined.

4.3.1.2.1 Dual Element Delay Line ZEROING Procedure.

Most dual element transducers are either undamped or lightly damped. As a consequence, and particularly with the square-wave pulser in Quantum TE, the setup must be carefully optimized. The first step is to decide upon which form of display rectification will best serve. In the following procedure, a 5 MHZ, 3/8 inch (9.5mm) diameter transducer (NOVA Model DV506) was used to produce measurements in the range from 0.200 to 0.500 inch (5.08 to 12.70mm).

1. In the PUL/REC Menu, select DUAL. Then, in the MAIN Menu, change RANGE to 1.00 inch (25mm) and use ZEROA to delay the first back echo to approximately mid-screen. In the PUL/REC Menu, select RF. Adjust gain to produce and maintain an echo pattern with less-than-saturation elements. In the PUL/REC Menu, set DAMPING at 500 ohms and adjust pulse WIDTH and PVOLT to produce the sharpest, or "cleanest" echo pattern.

2. Study this echo pattern carefully. Notice that there is a low amplitude negative-going half-cycle, then larger amplitude positive and negative half-cycles. During the optimization step above, observe that the amplitude of the first small negative-going half-cycle changes very little as a consequence of varying pulse width and amplitude. In the PUL/REC Menu, alternately observe the effects of +HW and -HW rectification. While -HW (shown on the right, below) could be used, the echo half-cycle on which the T-Gate terminates varies considerable with changes in echo amplitude. At +HW, the first positive-going

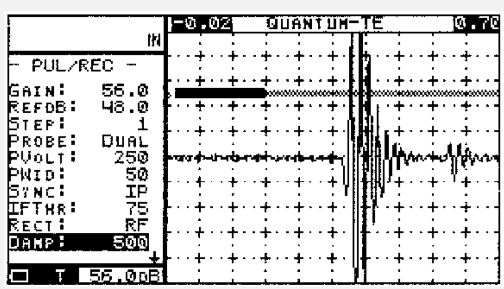


Figure 102 RF with small Neg. Half Wave

half-cycle is at full-scale amplitude (shown in the left-hand example). Since both displays were produced at the same level of gain, +HW rectification should be chosen.

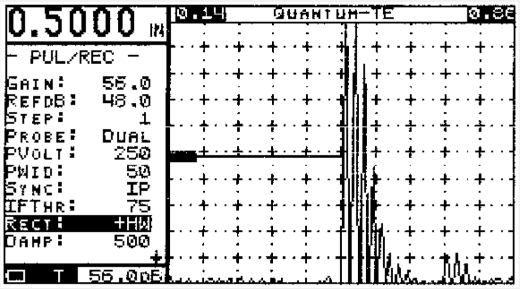


Figure 103 (+HW) selected

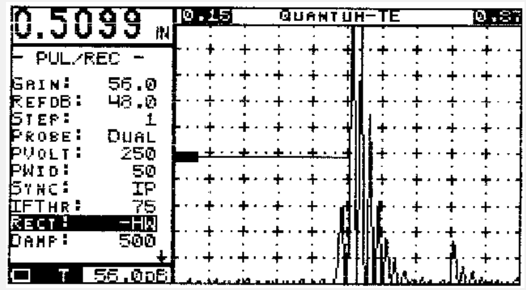


Figure 104 (-HW) Selected

3. The next step is to complete the calibration. In the THICK menu, adjust ZEROA to produce the thickness readout corresponding to a known thickness (in this case, 0.500 inch). Measurement of the 0.200 inch step produces 0.205 inch. This error is due to "V-Path Error", mentioned above.

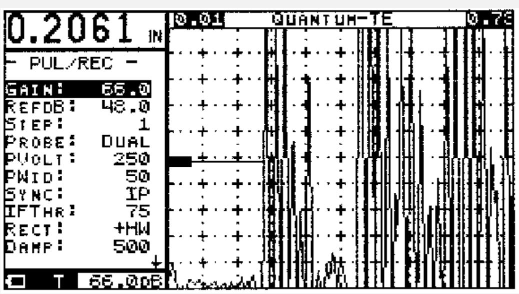


Figure 105

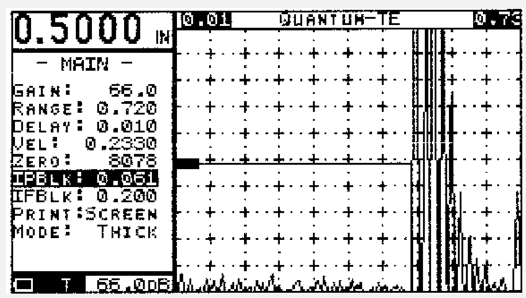


Figure 106

4. With the error having been determined to be 0.005 inch in the range from 0.200 to 0.500 inch, the "safer" way to calibrate is to establish the known thickness at the lower extreme of the measurement range. Thus, ZEROING at 0.200 inch produces the "conservative" error of 0.006 inch at the 0.500 inch step. Note the ZEROA difference of 8249 ns, above, to 8288 ns, below.

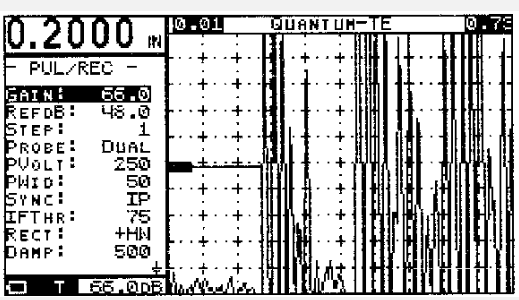


Figure 107

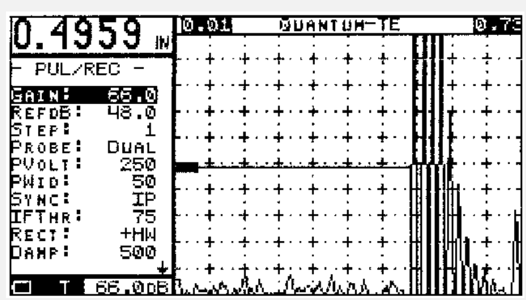


Figure 108

4.3.1.2.2 Dual Element Multiple Echo Interval Measurement Procedure.

With careful optimization and setup, multiple back echo intervals can be used for thickness measurement using dual element transducers. In the example shown below, multiple back echo intervals as far as the fifth back echo could be selected in the THK Menu. In this case, the first back echo was ZEROED to the left-hand start of the A-trace.

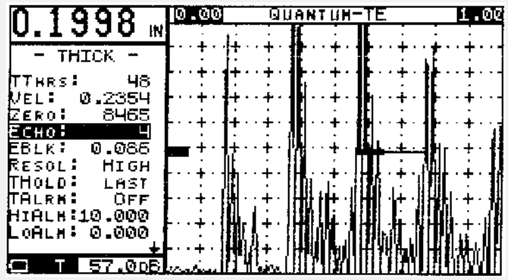


Figure 109 - Dual Element Multi-Echo

This technique can be used with many dual element transducers to measure objects at elevated temperatures. With the ZEROING technique described in the preceding procedure, when the transducer delay lines contact a hot surface, they rapidly expand. Expansion changes the V-path significantly, and consequently produces sizeable errors. IF the temperature of the test object is known, the temperature coefficient of expansion can be applied to the measurement obtained, while the calibration can be performed at ambient temperature.

4.3.1.2.3 Dual Element Measurements Using The Display Graticule.

In all the sequences illustrated above, Range was set at either 1.00 or 0.50 inch full-scale. Echos can be seen to align with graticule points accordingly. For quick checks, this technique produces reasonably accurate results. However, with Quantum TE's precise thickness measurement capabilities, very few additional steps are needed to achieve accuracy, by using the procedure in 4.3.2.5.1.

4.3.1.2.4 Dual Element Measurement Using Calibrated Delay.

As with the technique using visual estimates from the screen graticule, this technique requires visual alignment of echos; hence, it will be less than precise.

1. Prior to selecting the dual mode in PUL/REC, note the thickness readout; it corresponds closely with the steel equivalent of the delay line length.

2. Use delay to enter the T-readout and record it for later reference. This positions the delay line/steel surface interface at the left or starting edge of the display, even though there is no visible interface echo when DUAL is selected in PUL/REC.

3. For a reasonably accurate thickness measurement, use added delay to position the first back echo at the left vertical axis, read the FACTORY delay and subtract the original ZEROA interface reading from it. The result is thickness. IF multiple echos are present, the delay readout difference between them is also thickness.

4. For enhanced precision in using delay readout, use an expanded range, say 0.50 inch (12.7mm) full scale. The leading edge of the echo can be more precisely aligned with the vertical axis.

4.3.3 Thickness Gaging Procedures for Non-Metallic and Composite Materials.

To some extent, all of the previously described procedures can be applied to thickness gaging of engineering materials other than metals. Because there are so many such materials, there will be no attempt in this manual to detail them. Materials other than metals have their own unique properties with respect to the transmission and propagation of ultrasonic energy. In general, the velocity of ultrasound is lower and attenuation greater. Characteristics such as the presence of scattering reflectors, impedance, an isotropy, Modula, and other physical and mechanical properties all interact with ultrasonic sound beams somewhat differently than in metals.

Despite the differences, most polymers and glasses, some ceramics and composite materials can be tested with the same transducers and procedures as for metals, except for the obvious adjustments that may be required in calibration. Once the procedures for thickness gaging metals are understood, experimentation with other materials is generally straightforward. Feel free to consult with NDT Systems, Inc.' factory engineering personnel or technical field sales representatives on special techniques/procedures.

4.4 <u>Flaw Detection Procedures</u>.

Preliminary to flaw detection, most of the foregoing procedures incident to thickness gaging are required to be followed, at least to some extent. The major differences result when narrow-beam transducers are used. In the large majority of field inspection flaw detection applications, it is unnecessary to use transducers having narrow-beam spectral characteristics. Broadband transducers most often produce excellent results for flaw detection. If there is difficulty in penetrating some of the more highly attenuative materials, simply choosing a broadband transducer of lower frequency may suffice. However, there is a marked tendency for broadband transducers to produce a frequency spectrum that is more reactive to scattering and reflection from grain structure in metals. This tendency is less pronounced for corresponding frequency narrow band transducers By selecting a tuned receiver frequency to match the narrow band transducer frequency will yield good results.

For the flaw detection procedures to be outlined below, assume the use of the lowest frequency broadband transducer that will produce the flaw detection sensitivity called for by the Code, Standard or Specification in effect. If sensitivity or signal-to-noise requirements cannot be satisfied, assume the use of the lowest frequency medium- or narrow-bandwidth transducer that produces the required response.

4.4.1 Straight Beam Longitudinal Wave Flaw Detection Procedure.

While it may not be required to perform the detailed calibration routine necessary for precision digital thickness gaging, no harm is done by following the procedures of Section 4.3.1. on the Effect of Adjusting Variables. The combination of transducer/reference standard/test object variables are external; adjustments of QFT-100 to compensate for these variables are essentially the same, whether for flaw detection or thickness gaging. The only major extension of the thickness gaging procedures for flaw detection is to establish the flaw gate (F-gate) and echo amplitudes properly. FLAW is a special menu that contains all the features necessary to accomplish those needs.

1. Position the cursor in the Main menu to MODE. Use the left arrow key to select FLAW, and press MENU key. The following is displayed, as in Fig 31:

Use the left/right arrow keys turn GATE1: ON. Note the small, short horizontal line located at 55% FS amplitude at the first major division on the active A-trace . This is the default position of the flaw gate (F-gate).

2. To adjust START GATE 1 (STRT1), position cursor to STRT1. Use the left/right arrow keys to position the start of the F-gate. Note that the F-gate width is constant as the F-gate is positioned at 0.200 inch (10.16mm).

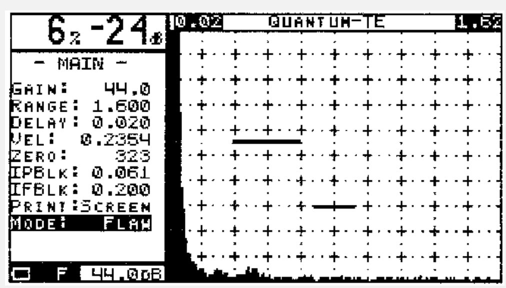


Figure 110 - Flaw Mode

3. Place the cursor on WIDTH GATE 1(WID1), press and hold the right arrow key. The left-hand side of the F-gate will remain stationary and the right-hand side will extend towards the first back echo. If the time-base has been calibrated visually by the usual procedures for flaw detection tests and those of QFT-100's digital thickness gaging procedures of Section 4.3.1, the digital starting position of the F-gate is 0.200(5.08mm) inch displayed under STRT1. WID1 is set at 0.400 inch (10.16mm)

4. Now move the cursor THRESHOLD LEVEL 1 (THRS1). Use right / left arrow keys to position the F-gate threshold level between 10% and 90% FS.

5. The default position of ALARM 1 (ALRM1) is OFF. Use right / left arrow keys to select POSITIVE (POS). This signifies that the flaw alarms will activate whenever any signal within the F-gate exceeds the level set in threshold. When NEGATIVE (NEG) is selected, the opposite alarm condition can occurs. Signals within the F-gate below the level set in THRS1, will activate the alarms. feature permits monitoring the loss or reduction in amplitude of back-wall echo, a requirement of some Codes and Specifications.

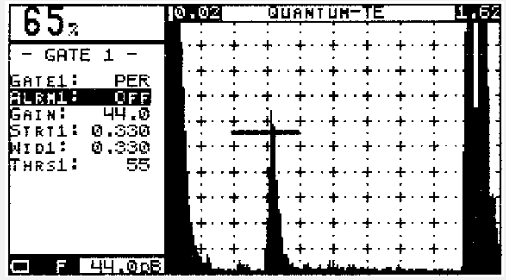


Figure 111

6. With the positive gate configuration (+GATE), note that there is a digital percentage displayed on the large LCD display above the menu. This number represents the peak amplitude, in % to FS, whenever an echo signal within the F-gate exceeds the level set amplitude. The opposite condition exists for -GATE selection. The peak amplitude display is useful in determining the precise peak amplitude of a gated signal which may be varying slightly due to "candle-flaming".

7. Press the MENU key to display GATE 2. Use steps 1 - 6 to examine and adjust parameters in GATE 2.

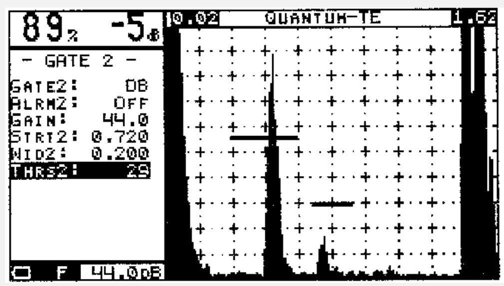


Figure 112

See Section 4.3.2.5. for Procedure For Longitudinal Wave Dual Element Transducer Flaw Detection Techniques.

4.4.2 Angle-Beam Shear Wave Flaw Detection Procedure.

It is assumed here that the operator has familiarity with establishing shear wave test setups using standard analog type ultrasonic instruments. The purpose of this procedure is to familiarize you on setup of the F- gate and FLAW TRIANGULATION features when using the ANGLE mode. The procedure is base on using a 0.25 x 0.25 inch, 5.0 MHZ transducer with a refracted angle of 60 degrees in steel (OPTIMA model MPA0526S) , mini IIW block, and welded ultrasonic test plate (Sonaspection model PL 2742) with flaws depths of 0.200. 0.467, and 0.358 inch.

1. Enter the MAIN menu and set the range at 5.00 inch

2. Enter PUL/REC menu and select the following:

RECT:	FW
DAMP:	500 ohms
PULSE WIDTH	Optimize for transducer being used.

3. Select ANGLE mode in MAIN menu. Couple the wedge to the top surface of the mini IIW and very carefully align the beam exit point with the index mark on the block that marks the 1.00 and 2.00 inch radii.

4. Adjust the gain to produce echos from the 1.00 and 2.00 inch radii of approximately equal amplitude and with maximum response at approximately 80% FS.

The display should look similar to that shown in the following figure.

5. Enter THICK menu. Since the FLAW TRIANGULATION tracks the front flank of echos, it will produce slightly refined accuracy to increase the T-gate level to 60%.

6. Cursor to and select ECHO 2. Adjust the EBLK gate to produce a readout for ECHO2 gate. Select The display should resemble that shown in the Figure below.

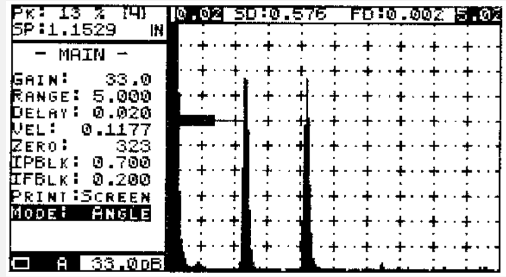


Figure 113

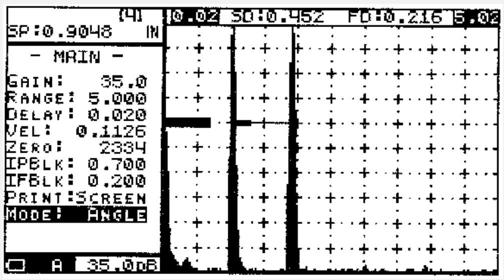


Figure 114

7. Cursor to and adjust VEL to calibrate the interval between the two echos to read 1.000 inch. The display should resemble as shown in Figure below:

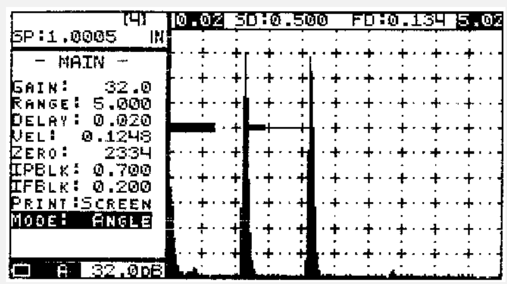


Figure 115

8. Cursor to MODE and select THICK. Cursor to ECHO and return to ECHO: 1 gate return to ANGLE mode to produce the following as shown in the following Figure:

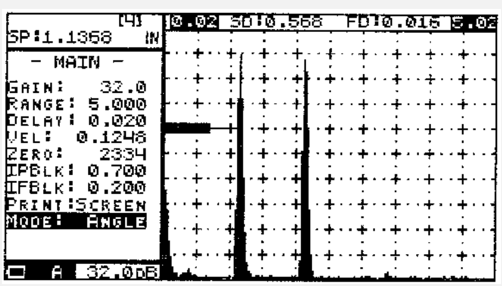


Figure 116

NOTE: The reading of 1.136 inch is the result of the sound path distances in the wedge and the metal to the 1.00 inch radius.

9. With the beam exit point and the index mark in careful alignment, adjust the ZEROA (in ANGLE mode) to produce the known metal path distance of 1.000 inch as seen in the next Figure.

10. As a double check on the accuracy of the distance calibration, enter MAIN menu, cursor to IPBLK, and extend the blocking gate past the 1.000 inch radius echo. The readout should be very close to 2.000 inch, as shown in the figure to the left.

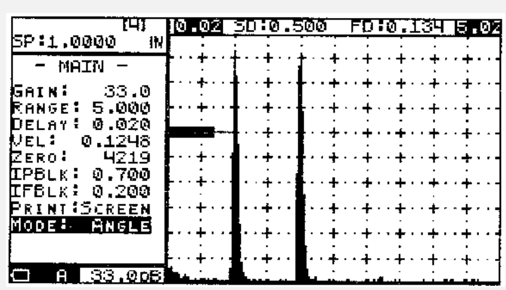


Figure 117

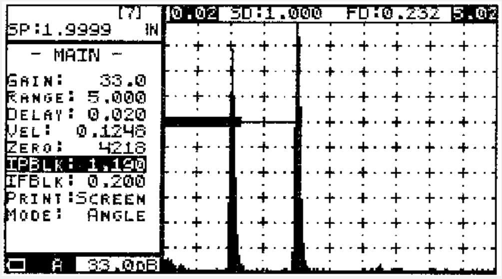


Figure 118

11. Set REFdB to 45.5 dB

12. Using the 1.00 inch thickness on the MINI IIW block, if a standard contact transducer is available, calibrate the Quantum TE for thickness and measure the thickness of the weld test plate. The plate used in this procedure averages 0.760 inch thick.

13. Re-enter ANGLE mode and set ANGLE to 60 degrees and THICK to 0.760.

14. Enter GATE 1 menu. Setup the following parameters:

GATE1:	ON
ALRM1:	POS
GAIN:	45.5 dB
STRT1:	1.500 inch
WID1:	2.500 inch
THRS1:	80%

15. Scan the weld plate at the distance marked with a sideways “V” which is the where maximum response from the embedded flaws lies.

WELD PLATE

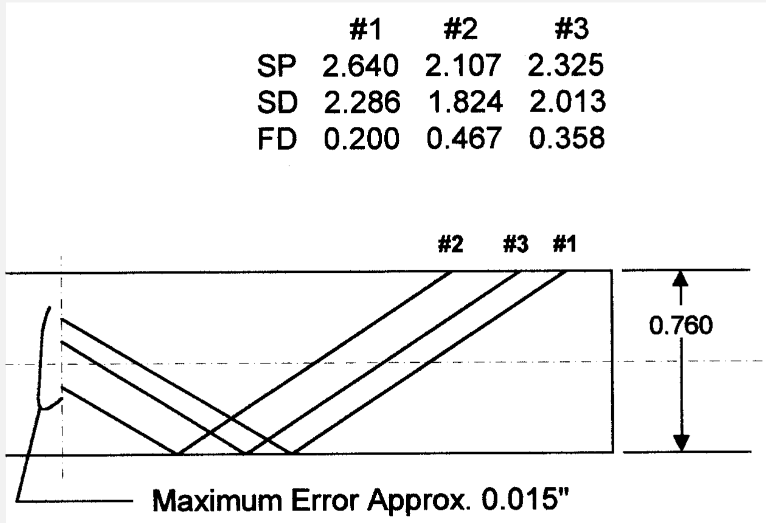


Figure 119

The following figures show responses from the three flaw areas:

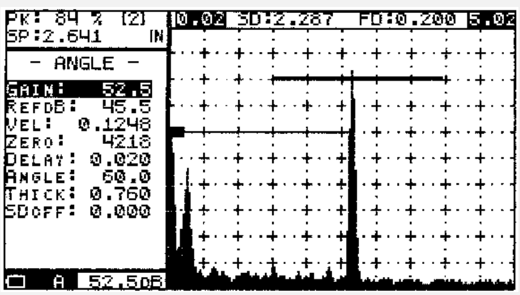


Figure 120

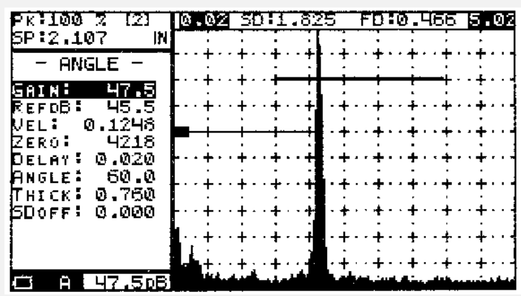


Figure 121

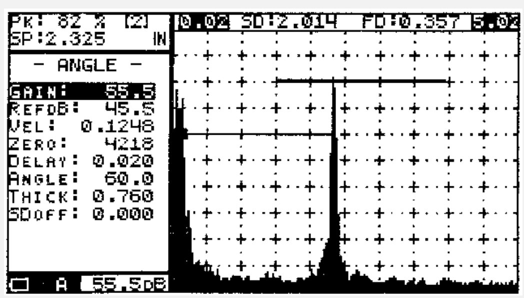


Figure 122

The following Figure shows the complete setup for the above inspection results:

QUANTUM-TE Setup

Range: 5.000	Freez: Off	Thrs1: 80
Delay: 0.020	PHold: Off	Gate2: Off
Vel: 0.1248	TThrs: 60	Alrm2: Off
IPBlk: 0.249	Zero: 4218	Strt2: 0.720
IFBlk: 0.200	Echo: 1	Wid2: 0.200
Print: Setup	EBlk: 0.331	Thrs2: 29
Mode: Angle	Resol:Normal	Angle: 60.0
Save: DEFLT	THold: last	Thick: 0.760
Rcall: DEFLT	TAlrm: Off	SDoff: 0.000
Units: INCH	HiAlm:10.000	Gain: 55.5
Disp: BLKsol	LoAlm: 0.000	RefdB: 45.5
BkLit: On	AGC: Off	Step: 1
Contr: 64	Gate1: PER	Probe:Single
Lock: Off	Alrm1: Off	PVolt: 250
Click: On	Strt1: 1.500	PWid: 115
Grid: On	Wid1: 2.500	Sync: IP
Freez: Off	Thrs1: 80	IFThr: 75
PHold: Off	Gate2: Off	Rect: FW
TThrs: 60	Alrm2: Off	Damp: 500
Zero: 4218	Strt2: 0.720	Tune: BB
Echo: 1	Wid2: 0.200	Rejct: 0
EBlk: 0.331	Thrs2: 29	CType: Off
Resol:Normal	Angle: 60.0	Draw: CLEAR
THold: last	Thick: 0.760	Point: 1
TAlrm: Off	SDoff: 0.000	CAlrm: Off
HiAlm:10.000	Gain: 55.5	DelDB: +/-3
LoAlm: 0.000	RefdB: 45.5	Curvs: 1
AGC: Off	Step: 1	Zoom: Off
Gate1: PER	Probe:Single	Left: 0.260
Alrm1: Off	PVolt: 250	Right: 0.690

Figure 123

5.0 OUTPUTS

There is a DB9-pin sub-D type female receptacle on the back of the enclosure of Quantum TE. There is an RS-232C serial output available at this receptacle. A suitable connector and cable is supplied . This cable can be wired to Customer specifications, or supplied to interconnect the Quantum TE with an option battery powered printer. For details concerning the technical specifications of the RS-232C output and the optional printer see Section 5.2 on the following page.

5.1 Output Choices.

For data or images stored on-board Quantum TE, it is also possible to immediately output, screens or current setups provided a serial data printer or other serial data peripheral device is at hand.

In the main Menu, one of the menu selections is PRINT. By positioning the highlight cursor at PRINT and quickly pressing and releasing the SELECT key. Three beep tones will be heard and the "**HOLD MENU TO PRINT**", prompt appears on the display. If the SEL/HELP key is held to long the HELP screen will appear. Another quick tap on the SEL/HELP key will return the display to normal again. Retry the above steps to invoke print capability except this time depress the SEL/HELP key quicker. Once the "**HOLD MENU TO PRINT**" prompt appears, you are free to select any menu or field and print that screen simply by pressing the MENU button for:

Use the right or left arrow key to select two choices of output:

1. ***SCREEN*** **-** The displayed A-trace can be output by depressing and holding the MENU key for approximately 1 second, after which three beep tones and the "**PRINTING**" prompt appears. The full screen will be output, including the A-trace, digital readout and currently displayed menu or submenu. During the output, the screen freezes and, all key controls are inoperative.

. Note: Select the menu or sub menu to be displayed with the A-trace by using menu key to select desired menu or submenu before initiating print screen.

2. ***SETUP*** **-** The current setup can be output from QUANTUM by quickly depressing SELECT key. All setup functions will be printed out.

3. ***BOTH*** **-** Prints both the A-Trace and current setup values

5.2 Output and Optional Printer Technical Specifications.

5.2.1 RS-232C Output Specifications.

Baud Rate	9600
Parity	None
Data Bits	8
Stop Bits	1

The Quantum's RS-232C output connector (9 pin sub-D) is located on the back side of the enclosure. Connector/cable wiring diagrams for the optional printer are shown in Figure 5.2.1. Cables for other peripheral devices can be supplied. The Customer must specify the peripheral device connector type and pin connections.

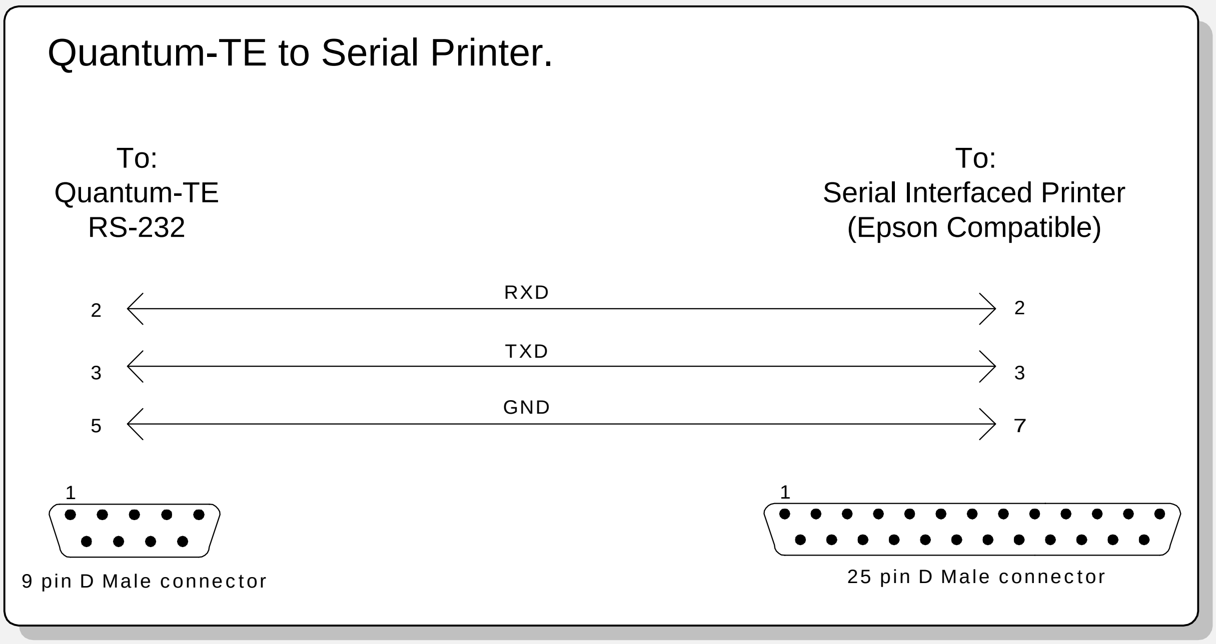
5.2.2 Printers

Due to the rapid changes in the computer industry the availability of any particular printer may change. Due to this fact, please contact NDT Systems, Inc. for current printer recommendations

Figure 5.2.1 Communications Connection

The NDT systems part number for this cable is TE232. One was included with the instrument when shipped. Please use this part number when ordering replacement cables.

NOTE:
The one thing for sure with IBM compatible computers is that there may be several types of RS-232 connection schemes. These ports are commonly referred to as COM1 thru COM4. We would suggest connection to COM1 if possible but COM2 will also work. Avoid the use of COM3 & 4 if possible. Sometimes COM1 & COM2 are 25 Pin Sub-D’s and sometimes COM1 is a 9 Pin and COM2 is a 25 Pin. Try to use the port with the same connector as the TE232 cable. If the connector configuration is not compatible you may obtain an adaptor from any computer supply house such as Radio Shack, Staples etc. You may also contact NDT Systems, Inc. for assistance & the appropriate adaptor.



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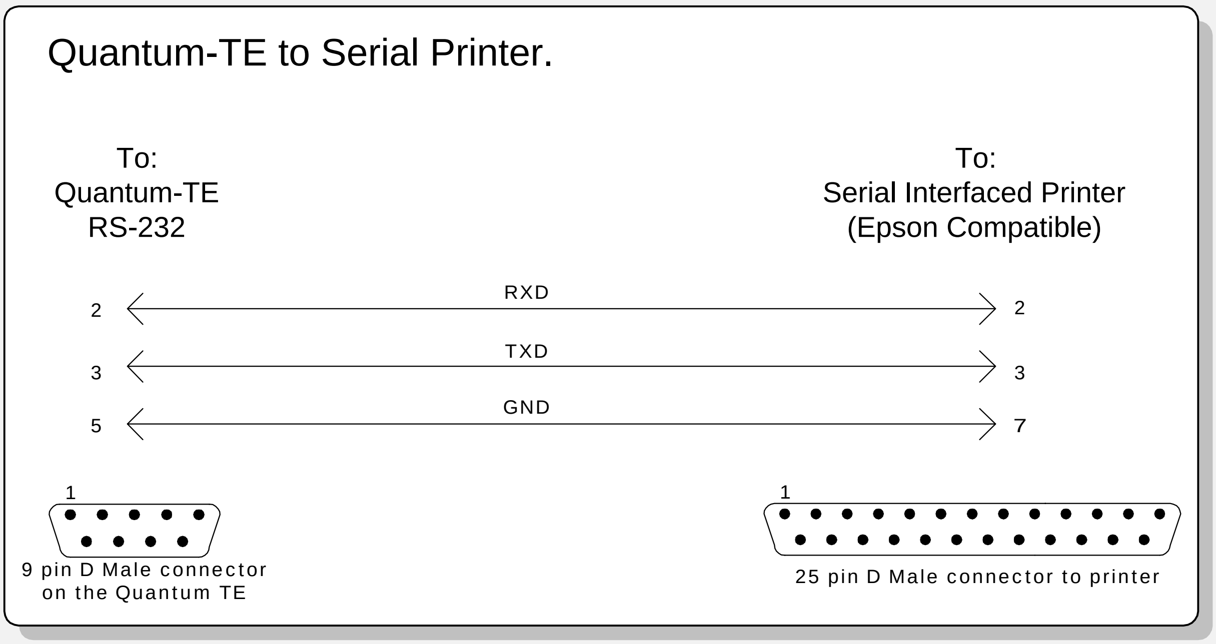

Alarm Output Connector Pin Definition:

Pin	Function
1	N/C
2	GND
3	GND
4	Relay Pin1
5	Relay Pin2
6	N/C
7	N/C
8	N/C
9	TTL Alarm

6.0 BATTERY PACK AND CHARGER

The Quantum TE is powered by 5 replaceable ‘D’ style batteries inserted into the rear panel via the rear panel access door. The Quantum TE is shipped with 5 Hi Capacity rechargeable NiCad batteries installed along with an external battery charger. Once fully charged the Quantum TE will run for up to 20+ hours before requiring another charge. Charge time is 14 - 16 hours for a full charge from empty.

The Quantum TE is also capable of running from Alkaline batteries, available from many outlets, should you need to use the unit where remote power for charging is not available. Please note that there is a small slide switch located on the rear panel for NiCad / Alkaline battery selection. It is incumbent on the user to assure the switch is in the correct position for the type of batteries being used. Should the battery selection be incorrect (IE alkaline batteries with the switch in the NiCad position) severe damage to the Quantum TE will most likely result if the charger/eliminator is plugged in, as the alkaline batteries will most likely rupture.

Please read and observe the warning on the back of the unit!

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7.0 POWER MANAGEMENT AND AUTO-SHUTOFF

With power on, and after three and a half minutes of non-use, Quantum automatically enters the Power Saver Mode if in the THICKNESS mode. The following beep tone and flashing STATUS screen is displayed:

Gage will turn off

Figure 7.0

In the power saver mode, the pulser/receiver and other power-consuming devices are turned off in order to conserve power. The"Gage will turn off" STATUS will beep and flash for thirty seconds, at which time Auto-Shutoff occurs. If any function key or waveform displayed will automatically terminate the power save mode.

After Auto-Shutoff occurs, pressing ON immediately restores all previous setup parameters, the normal display reappears, and testing can be resumed.

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8.0 OPTIONAL Quantum TE ACCESSORIES

In addition to NDT Systems, Inc.' OPTIMA transducers, cables, reference standards and other transducer accessories, the following optional Quantum TE accessories are available:

- TEP1 Quantum TE Carry Pouch - A light-weight, easily donned pack permits hands-off use of the Quantum TE. The Quantum TE fits firmly into a case-like compartment supported at an adjustable angle and height such that the screen can be viewed just below normal line-of-sight. Adjustable neck and waist straps are padded for comfort and have quick-clip attachments. For climbing or moving about in confined spaces.

- Battery-Powered Serial Input Printer - For full-screen image or thickness printouts, a light-weight NiCad battery-powered printer is available. Operation and Specifications for this printer will be found in Section 6.0, Outputs. An interconnecting cable is included.

- Other Optional Printers - Contact NDT Systems, Inc. for information about other printers that can be used with Quantum TE. In some cases, custom interconnecting cables can be supplied to Customers' specifications for printers already owned by the Customer.

- TE-DL Data Logger Adds data logging and storage to the Quantum TE. The logger provides the ability to store up to 4500 data points or a combination of data points and A-Traces. Store data along with up to 16 alpha numeric location designators in a serial or “grid” style. The supplied software also allow the user to export data in an ASCII format to common spreadsheet programs.

Refer to the appropriate section within this manual for instructions on the use of the Data Logger if installed.

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Refer to the appropriate section within this manual for instructions on the use of the Data Logger if installed.

9.0 WARRANTY

1. WARRANTY:
NDT Systems, Inc. warrants that reasonable care was used in the choice of materials and the manufacture of this instrument, and that the instrument conforms to the published ratings and characteristics applicable to the instrument at the time the instrument is shipped to the Buyer. This warranty shall extend for a period of one year from the date of shipment of the instrument (FOB) Seller's plant) and shall in no event extend beyond such term. The Buyer shall notify NDT Systems, Inc. by registered or certified mail, return receipt requested, of any claim of discovery of such defect. Failure to notify NDT Systems, Inc. within the time and in the manner specified herein shall constitute a waiver of any such claim of defect or breach of warranty. The final determination of the existence of a defect or breach of this warranty shall be made by NDT Systems, Inc. This warranty shall extend to the Buyer only, and shall not be assignable or transferable to any other person.

2. DISCLAIMER OF WARRANTIES:
THERE ARE NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANT ABILITY OR FITNESS FOR A PARTICULAR PURPOSE, OTHER THAN THOSE WARRANTIES SET FORTH IN THE PARAGRAPH ENTITLED "WARRANTY" ABOVE.

The above warranty shall not apply to digital panel meters and items with a limited life, such as batteries, probes or cables, nor to any instruments which have been subjected to misuse, improper installation or repair, alteration, or use beyond the published maximum ratings of the instrument.

3. BUYER'S REMEDIES:
The Buyer's sole and exclusive remedy for breach of the above warranty shall be the repair or replacement of the instrument by NDT Systems, Inc. free of charge. The Buyer shall return the instrument to NDT Systems, Inc., transportation prepaid. NDT Systems, Inc. shall promptly repair or replace the instrument and return same to Buyer, FOB Seller's Plant, collect.

If, for any reason, NDT Systems, Inc. is unable or unwilling to repair or replace the instrument or, because of circumstances, the exclusive remedy provided herein fails of its essential purpose, or operates to deprive either party of the substantial value of its bargain, then the Purchaser's exclusive remedy will be the return of the purchase price for the instrument. The liability of NDT Systems, Inc. shall in no event be greater then the full amount of the purchase price for the instrument.

Any attempt by NDT Systems, Inc. to repair or replace any instrument sold hereunder shall not constitute an admission that the instrument, or any part thereof, is defective within the meaning of the above warranty, nor that NDT Systems, Inc. has any legal responsibility to make such repair or effect such replacement.

Any such attempts, if unsuccessful, shall not create any liability on the part of NDT Systems, Inc. and the purchaser is limited to the remedy set forth herein.

4. LIMITATIONS ON LIABILITY:
NDT Systems, Inc. shall not, under any circumstances, be liable for direct, incidental or consequential damages for any breach of contract, breach of warranty or misrepresentations, including the negligence of NDT Systems, Inc., including, but not limited to damages resulting directly or indirectly from the use, or loss of use, of the instrument sold hereunder, or the business of the Buyer or third persons wherein the instrument is utilized.

The above warranty, and the obligations of NDT Systems, Inc. hereunder, are expressly in lieu of, and the Buyer expressly waives, any other liability of NDT Systems, Inc. based upon warranty, express of implied, contract, or the negligence of NDT Systems, Inc., including but not limited to, negligence in the design of the instrument or in the choice of the materials therefor, or negligence in the repair or replacement of the instrument, whether such repair or replacement is required by the terms hereof or is voluntary, upon the part of NDT Systems, Inc.

Except as provided herein, no person is authorized to assume on behalf of NDT Systems, Inc. any other or additional liability or responsibility in connection with the instrument. These terms and warranty are applicable to and complete acceptance of such a binding legal agreement.

NDT Systems, Inc.
17811 Georgetown Lane
Huntington Beach, CA 92647
October 2005 (714) 893-2438

9.0 WARRANTY

1. WARRANTY:

NDT Systems, Inc. warrants that reasonable care was used in the choice of materials and the manufacture of this instrument, and that the instrument conforms to the published ratings and characteristics applicable to the instrument at the time the instrument is shipped to the Buyer. This warranty shall extend for a period of one year from the date of shipment of the instrument (FOB) Seller's plant) and shall in no event extend beyond such term. The Buyer shall notify NDT Systems, Inc. by registered or certified mail, return receipt requested, of any claim of discovery of such defect. Failure to notify NDT Systems, Inc. within the time and in the manner specified herein shall constitute a waiver of any such claim of defect or breach of warranty. The final determination of the existence of a defect or breach of this warranty shall be made by NDT Systems, Inc. This warranty shall extend to the Buyer only, and shall not be assignable or transferable to any other person.

2. DISCLAIMER OF WARRANTIES:

THERE ARE NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANT ABILITY OR FITNESS FOR A PARTICULAR PURPOSE, OTHER THAN THOSE WARRANTIES SET FORTH IN THE PARAGRAPH ENTITLED "WARRANTY" ABOVE.

The above warranty shall not apply to digital panel meters and items with a limited life, such as batteries, probes or cables, nor to any instruments which have been subjected to misuse, improper installation or repair, alteration, or use beyond the published maximum ratings of the instrument.

3. BUYER'S REMEDIES:

The Buyer's sole and exclusive remedy for breach of the above warranty shall be the repair or replacement of the instrument by NDT Systems, Inc. free of charge. The Buyer shall return the instrument to NDT Systems, Inc., transportation prepaid. NDT Systems, Inc. shall promptly repair or replace the instrument and return same to Buyer, FOB Seller's Plant, collect.

If, for any reason, NDT Systems, Inc. is unable or unwilling to repair or replace the instrument or, because of circumstances, the exclusive remedy provided herein fails of its essential purpose, or operates to deprive either party of the substantial value of its bargain, then the Purchaser's exclusive remedy will be the return of the purchase price for the instrument. The liability of NDT Systems, Inc. shall in no event be greater then the full amount of the purchase price for the instrument.

Any attempt by NDT Systems, Inc. to repair or replace any instrument sold hereunder shall not constitute an admission that the instrument, or any part thereof, is defective within the meaning of the above warranty, nor that NDT Systems, Inc. has any legal responsibility to make such repair or effect such replacement.

Any such attempts, if unsuccessful, shall not create any liability on the part of NDT Systems, Inc. and the purchaser is limited to the remedy set forth herein.

4. LIMITATIONS ON LIABILITY:

NDT Systems, Inc. shall not, under any circumstances, be liable for direct, incidental or consequential damages for any breach of contract, breach of warranty or misrepresentations, including the negligence of NDT Systems, Inc., including, but not limited to damages resulting directly or indirectly from the use, or loss of use, of the instrument sold hereunder, or the business of the Buyer or third persons wherein the instrument is utilized.

The above warranty, and the obligations of NDT Systems, Inc. hereunder, are expressly in lieu of, and the Buyer expressly waives, any other liability of NDT Systems, Inc. based upon warranty, express of implied, contract, or the negligence of NDT Systems, Inc., including but not limited to, negligence in the design of the instrument or in the choice of the materials therefor, or negligence in the repair or replacement of the instrument, whether such repair or replacement is required by the terms hereof or is voluntary, upon the part of NDT Systems, Inc.

Except as provided herein, no person is authorized to assume on behalf of NDT Systems, Inc. any other or additional liability or responsibility in connection with the instrument. These terms and warranty are applicable to and complete acceptance of such a binding legal agreement.