OPERATOR'S MANUAL

TG400

Ultrasonic Thickness Gage

Featuring:
SplitView, SplitScan & AutoTrack

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1. INTRODUCTION

First and foremost we at NDT Systems, Inc would like to thank you for your purchase of the *NEW* TG400 full featured miniature A-Scan Precision Thickness Gage.

As you may have concluded, this manual contains a lot of various information. You do not necessarily have to read the whole manual in order to use the TG400. Much of the information is presented in a tutorial fashion to aid in the understanding of specific applications.

- The Table of Contents of this manual is actually a TABLE/INDEX. Each menu item is mentioned here for quick easy access to a description of the menu item you may have a question with.
- Chapter 2 deals with the menu, structure a description of the features. This would be recommended reading. There are a few images to help you better understand the concepts.
- Chapter 3 & 4 is where the features are described in more detail through tutorials on various methods of operation. You will also find this chapter help teach how to select the best transducer for the application. Keep in mind that the proper transducer selection ***IS*** the heart of the inspection, and the key to optimum performance of the TG400's (or any other ultrasonic instrument's) use. The wrong transducer can be compared to putting a 2" speaker on a 100 watt Macintosh receiver/amp in a stereo system. It may be the best system but it's going to sound lousy!

Again, thank you for your purchase of the TG400.

1.1 Specifications

Display	Super Twist LCD, 3.9" 240x320, transflective; backlit, contrast adjustable, battery status and mode icons, large thickness/soundpath display. Hollow or filled waveform, reversed field selectable.
Display Mode	RF; Positive Halfwave, Negative Halfwave, Full-wave rectified.
Graticule	Graphically Generated, 10 x 10 major divisions
Receiver	0.5 to 25 MHZ Broadband, 1 Band Pass Filter
Gain	100 dB; 0.1, dB selectable steps
Pulser	Broad Band Spike
Damping	8 values from 25 to 375 Ohms.
Linear Reject	Linear to 90% maximum.
Delay	0 to 20 inches (3807mm) FS (steel equivalent).
Velocity	0.0500 to 0.9999 inch per microsecond
Zero Adjust	0 to 20,000 nanoseconds
Synchronization	IP (Initial Pulse), IF (Interface), Delay
Transducer Modes	Single or dual-element.
Display Modes	RF; positive, negative, full-wave rectified.
Flaw Mode	Two (2) gates selectable; positive or negative threshold. Visible and audible alarms triggered at pulse repetition rate. Gate start variable over entire displayed range. Gate width variable from gate start to maximum displayed range. Gate level adjustable from 1% to 99% full screen.
Thickness Mode	Single echo or echo to echo thickness measurement. Independently adjustable IP, IF and echo blocking gates. High and low alarms, Large number readout low/high resolution selectable, last reading hold.
Resolution	0.0001 or 0.001 inch (0.01mm).
Stored Setups	30 user defined setups.
Input/Output	RS232; transfer setups to and from PC. Full instrument control by PC.
Units	Inches or millimeters

Battery Pack	Discharge time - Up to 20 hours, typical, depending upon display back light usage. (3 ‘AA’ NiMH furnished)
Battery Charger	5 hours for full charge.
Transducer Cable Connectors	Lemo Connectors.
Size	Top Section: 3.25"W x 7"L x 1.4"D
Weight (Including Battery Pack)	Approximately 1 pounds (0.6kg)

1.2 Operator Qualifications.

The TG400's unique design makes it the most portable A-Scan Based Ultrasonic Thickness Gage offered today. As a stand alone Thickness Gage, the TG400 has many features well beyond those of conventional gages. The same can be said for the TG400's thickness gaging capabilities; they are unmatched by any other instrument used for thickness gaging and having an A-trace.

In order for the owner of this advanced technology instrument to fully benefit from the unique features of TG400, the assigned operator(s) must be experienced and well-founded in the fundamentals of ultrasonic testing. It would be helpful, though not necessary to possess the qualifications of ultrasonic testing personnel as defined in Recommended Practice No. SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing, available from the American Society for Nondestructive Testing (ASNT), 1711 Arlingate Lane, P.O. Box 38518, Columbus, OH 43228-0518, phone (614) 274-6003, FAX (614) 274-6899, telex 245347.

1.3 Operational Notations.

In order to simplify these instructions, certain consistent notations are used. In some cases, a single key stroke produces a desired change; other changes may require a sequence of key strokes or require continued key activation to "scroll" changes. The following terms and operational notations will be used throughout. The operator is advised to become familiar with all of them.

KEYS

Sealed membrane keypad incorporating access to menus as well as direct access to specific functions

VARIABLES

A variety of keys & menu selections are available to change continuous variables such as range, delay, gate positions, alarm levels, and reject.

SCROLLING

When a key is continuously depressed to change a variable, the effect is referred to as "scrolling". Scrolling produces either a visible change in the display, a digital readout of the changing value of the variable, or both.

TOGGLING

Toggling refers to the kinds of changes made by "toggling" switches on an analog-type instrument. Functions such as OFF/ON, SINGLE/DUAL, and other discrete, limited value operations exemplify toggling. With The TG400, toggling requires depressing a key to change a function from one state to another (OFF/ON, for example), and again depressing the key to further advance or reverse the discrete function.

CURSOR

This term refers to the means for notifying the operator which menu item, function or variable can be currently acted upon. In The TG400, the cursor location is indicated by highlighting the menu item. Changing the location of the cursor is accomplished by using the arrow keys.

NOTE:

The TG400 is very much a type of computer in operation, relying heavily on extremely sophisticated software for much of it's operation. Should the unit ever seem non-responsive to the front panel keys or if the operator would like to set the instrument in the factory default use the following keystrokes. First, turn the TG400 off using the on/off key. If the unit won't turn off in this manner, open the rear panel & remove and replace the battery cap. Next, press and hold the SEL key down and while holding this key down press the ON/Off key. When the instrument turns on let go the SEL key. The unit is now in the factory default setting. This procedure can also be used if there were a complex setup where it may take more time to Change all the parameters rather than start from scratch or default.

In these instructions, the notation used to indicate positioning the cursor on an item will be shown. The box drawn around the menu or function item indicates that the operator should key the cursor to that item, or that the item is already cursored by virtue of a programmed default.

1.4 Transducers and Reference Standards.
Section 3.0, Transducer Selection, contains detailed information regarding the selection and application of ultrasonic transducers for use with The TG400. For best results, use transducers from the OPTIMA line of transducers produced by NDT Systems, Inc. A free catalog will be sent on request by contacting Customer Information at NDT Systems, Inc., 17188 Georgetown Lane, Huntington Beach, CA 92647, phone (714) 893-2438, FAX (714) 897-3840. In many cases, equivalent transducers produced by other manufacturers will also yield acceptable results.

It should be kept in mind, though, that no matter how capable the ultrasonic instrument, system performance and test results are highly dependent upon the characteristics, performance, and appropriate selection of the transducers used. Also, The TG400 incorporates an automatic probe recognition feature where many NDT Systems, Inc., Nova transducers will be recognized and a basic instrument setup invoked for the specific transducer type.

Many common reference standards are also available from NDT Systems, Inc. For custom reference standards or test blocks, contact Customer Information at the address on the cover.

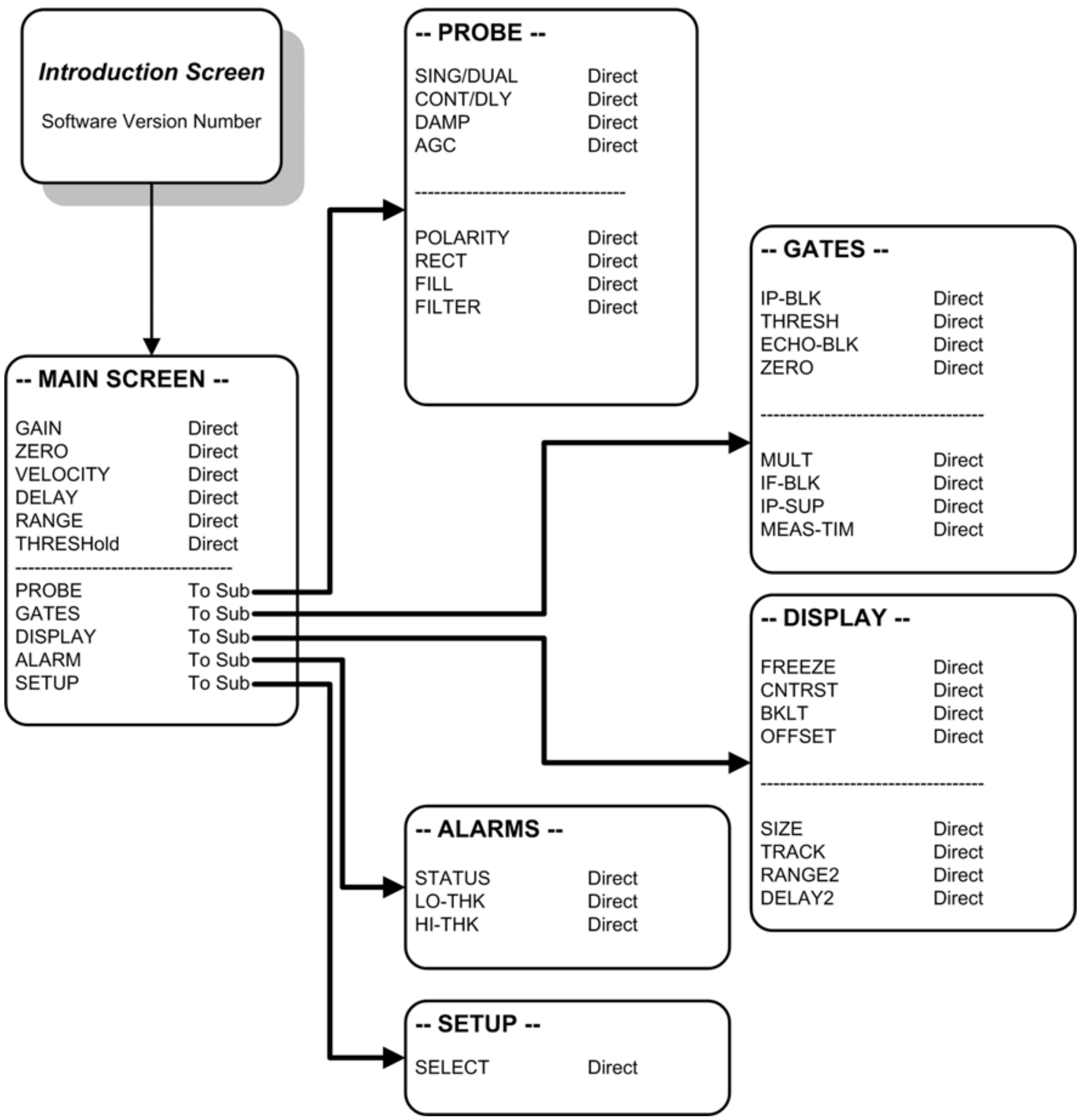
2. MENU DESCRIPTIONS

One of the significant features of the TG400 is the Direct Access Keypad. Velocity, Zero and Gain are just a single keystroke away. There are also 2 option keys. Opt2 is predefined as A-Trace split. Opt1 is reserved for future use.

MENU FLOW

The following represents the menu flow of the TG400. Pressing the MENU/ESC key repeatedly will sequence through the menus as shown.

Note: The branch if menu choices is determined by the MODE selection in the MAIN menu. I.E., if FLAW were selected in the main menu, under the MODE command then the branch would follow the flaw mode selected to GATE1 then GATE2 then PUL/REC.



With limited space available, some menu items are abbreviated. None-the-less, abbreviations and acronyms represent terms familiar to qualified ultrasonic NDT personnel. TG400 is based upon a powerful microcomputer, combining the absolute latest in high-speed digital electronics technology and high capability ultrasonic instrument features. TG400 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.

2.2 MENUS

Menu items are arranged Horizontally along the bottom 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. These items will display a Upon it ▲▼ lection. If an item has a sub menu selection the display will read “ENTER TO SELECT”

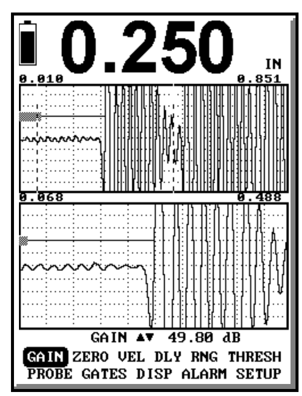
MAIN MENU (MENU/ESC Keypad Selection)
The functions grouped in the **MAIN** menu are used to select TG400 basic setup parameters. These items are logically among the first to be addressed during a new setup. Last setup/factory default values are automatically displayed. Even though the defaults permit 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.

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. (Directly Adjustable via up or down arrow)

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. (Directly Adjustable via up or down arrow)

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. (Directly Adjustable via up or down arrow)

DELAY (DLY)
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. (Directly Adjustable via up or down arrow)



RANGE (RNG)
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. (Directly Adjustable via up or down arrow)

THRESHOLD (THRESH)
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. (Directly Adjustable via up or down arrow)

PROBE (to Probe Select & Adjustment Menu. See Below)

GATES (to Gates Adjustment Menu. See Below)

DISP (to Display Adjustment Menu. See Below)

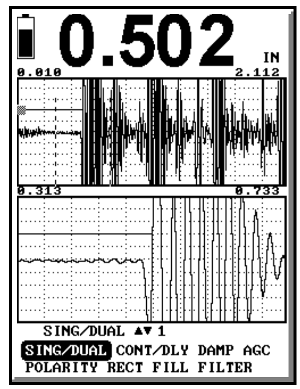
ALARM (to Alarm Setup Menu. See Below)

SETUP (to Instrument Setup, Save & Recall Menu. See Below)

PROBE MENU

SING/DUAL

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



CONTACT / DELAY MODE (CONT/DLY)

Contact or Delay style transducer. Must be in SINGLE Element Mode for Delay Menu selection

DAMPING (DAMP)

Changes receiver damping through these values : 25, 50, 75, 100, 125, 150, 175 and 375 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

AUTOMATIC GAIN CONTROL (AGC)

A unique feature of the TG400 is the Automatic Gain Control. This control is is under hardware control and is fully 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). It is generally not acceptable to use AGC with Dual Element Transducers used for corrosion surveys.

It is generally not acceptable to use AGC with Dual Element Transducers used for corrosion surveys as sensitivity will be adjusted based on the largest returned echo. In the case of pitting or corrosion the initial received signal will likely be somwhat smaller than the baseline material back wall.

POLARITY

Selects thickness trigger to either Positive or Negative half wave.
HINT: Select the half cycle which exhibits the strongest first half cycle throughout the calibration range.

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 permitted in RF RECTIFICATION as well as +HW, -HW or FW. Polarity bar indicator will also indicate appropriate half of the display when in RF mode.

FILL

ON - Fill the waveform when in +HW, -HW or FW mode
OFF - Display waveform in outline mode.

FILTER

A broadband frequency filter centered around 7MHz at 100% BW. Best used when probe is 10MHz or less

GATES MENU

IP BLOCKING GATE (IP-Blk)

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.

THRESHOLD (THRESH)

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. (Directly Adjustable via up or down arrow)

ECHO BLOCKING GATE (ECHO-BLK)

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.

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. (Directly Adjustable via up or down arrow)

ECHO MULTIPLE (MULT)

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.

IF BLOCKING GATE (IF-Blk)

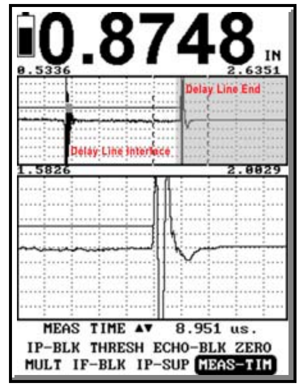
Used to Increase or Decrease the length of the gate that is used to block out any unwanted signals between the first back echo (IF) and the second back echo. Proper adjustment of the IF BLOCKING GATE will allow measurement of the first back echo to the second back echo in the thickness mode.

IP SUPPRESSION (IP-SUP)

Frequently transducers exhibit a broad roll off at the Initial Pulse. The IP Suppression can frequently compensate for this thereby permitting measurements closer the initial pulse when in Contact Mode. In many cases, a fine tuned setup will permit readings as thin as 0.020" using a 5 MHz 1/4" Transducer.

MEASUREMENT TIME (MEAS-TIM)

Measurement Time is a unique feature generally used in Delay Line Transducer Measurements. In the figure to the left we have used a standard NDT Systems, D11 Transducer. Currently the gage is triggering on the 2nd delay line multiple which is of no value and could potentially cause operator confusion when actual measurements approach the delay end. Therefore, the MEAS-TIM control acts like a blocking gate except but acts on the tail end of the measured zone. The area we highlighted in the figure is an area to block out. When this is done, any time the probe is coupled it will read over range rather than a fixed reading to the delay end.

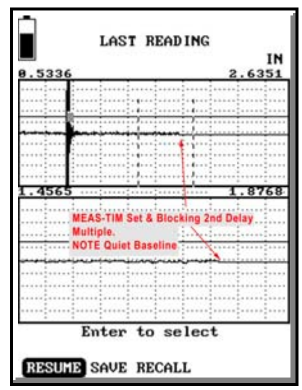


Meas-TIM Zone

DISPLAY MENU

FREEZE

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 ENTER key.



MEAS-TIM Set

CONTRAST (CNTRST)

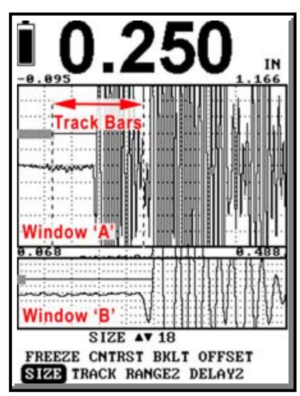
Using the up and down arrow keys, adjust the display to provide optimal personal viewing.

BACKLIGHT (BKLT)

Turns the backlight to AUTO, ON or OFF. Auto will turn the backlight on while making measurements. OO will turn the backlight on continuously and OFF will leave the backlight off at all time. It is recommended to leave the setting set to off if using the gage in high ambient light conditions. This will conserve battery life. You will not notice any better viewing while having the backlight on in high ambient light conditions.

The Following Features are NEW and Unique Productivity Features.

Note the figure to the left. You will note there are two traces annotated ‘A’ & ‘B’. The top trace ‘A’ is called the MAIN Trace Window. The Lower Trace, ‘B’ is known as the Tracking Window. Also, take note of the Vertical Cursors. The area between these Cursors is the section of the echo which will be automatically Zoomed as well as Tracked. Meaning, as the echo moves left and right on the Main Trace, the actual area of the echo is Tracked to show the half cycle the gage is triggering on.



SIZE

Pressing the up and down arrow key will resize the ratio of the Main Trace Window to the Tracking window. Pressing the Up Arrow increases the Main Window size until there would only be one A-Trace Screen presented, representing the Main Trace Window with no Tracking window. Conversely, if you press the Down Arrow Key, the Tracking window will increase in size, relative to the Main Trace. In this case the Track window will not ever exceed 90% of the Main Trace Window meaning the Main Trace window will always be at least 10% of the Track window.

AUTOTRACK (TRACK)

With this feature you can turn the AutoTrack feature ON or OFF.

When AutoTrack is ON, the Track window will follow the echo at the point of thickness trigger. This is where the Threshold line triggers on the echo. The Gage will automatically center the echo in the center of the Track window regardless of the actual thickness being measured.

When AutoTrack is OFF the Track window does not follow the echo but rather defines an area of Zoom which will not operate in a dynamic fashion. In this regard, the echo will move left or right throughout the Track window. If the echo moves outside the area defined by the vertical cursors there will be no echo displayed on the lower screen.

RANGE2 & DELAY2

These controls adjust the independent time base Range & Delay for the Tracking window. The total Range for the Track window can not exceed the set Range of the Main Trace window. For instance if the Main Trace is set to 3" the Track window can not be set to 4". Usually the Track window is something like 20-40% of the Main Trace window. This operates with AutoTrack Mode ON or OFF.

ALARM MENU (ALARM)

STATUS -	Turns Alarms on & off
LO-THK	Sets Low thickness alarm point
HI-THK	Sets High thickness alarm point

STATUS MENU

ALRM OFF

No Alarms active

LO

Only values at or below the low thickness setting will trigger the alarm light.

HI

Only values at or above the high thickness setting will trigger the alarm light.

BOTH

Values at or below or above the low/Hi thickness setting will trigger the alarm light.

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.

SETUP MENU

The functions grouped in the **SETUP** menu are used to select Factory stored and user modified and Saved transducer setups.

PICK

Use the Up & Down arrow to select transducer types. PICK recalls any ultrasonic setup stored in the TG400's memory. This includes User setup, Factory Default setup or any of the other 30 instrument setups. Note: If the gage is powered ON with the ENTER button depressed, the Factory Default setup will be loaded.

MODIFY

When selecting any of the NDT Setup #s the MODIFY select allows the user to modify a Factory setup and save it as a specific "User" setup. This allows the user to start with a probe that may be similar and then modify it to suit a specific probe or application.

UNITS

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

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 initially 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. This could represent the interface of water to metal if using Immersion or bubbler test method or the interface of a plastic tip to an entry surface is using a delay line transducer. The Interface Pulse will appear at the left edge of the display.

One is the MAIN range. This is adjusted in the IP mode. Both the menu selectable range and keypad range change values. The main range will incorporate the total range of the delay material (water, plastic tip etc) as well as the thickness of the material under test.

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 (GATES menu)
3 You can adjust these parameters in RF , FW, HW- or HW+
4 On the GATES 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 Interface position or the Interface (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 MAIN or GATES menu, set an IF threshold level (THRESH). User adjustable. 20% - 75% depending on noise.
6 Set rectification HW+, HW-, RF or FW as desired.

3.0 TRANSDUCER SELECTION

The TG400 is a capable precision thickness gage. Virtually any broad band or general purpose transducer (application dependant) used with the TG400, as can equivalent transducers produced by other manufacturers. NDT Systems, Inc. Manufacturers a line of NOVA Series thickness gage transducers which utilize our patented AutoProbe recognition technology. When using these probes press PROBE ID and the instrument will recognize the attached probe and set up for a general purpose test for that probe. The user can then adjust and save the modified setup.

While the discussion 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 or homogeneous 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 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.

Thickness Gaging Applications.

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.

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. TG400 fulfills this requirement admirably. For a procedure to demonstrate this capability, see Section 4.3.2.3, below.

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.

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

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.

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.

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 TG400.

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.

3.3 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, The TG400'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.

4.0 TG400 SETUP AND OPERATING PROCEDURES.

In designing the menus for the TG400, 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.

4.2 FACTORY Setup Variables.

When the TG400 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.

With TG400's broadband receiver and Spike 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.

4.3 Thickness Gaging Procedures

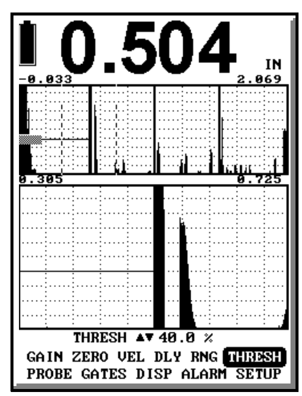
Sample Setup procedures (A Walk Through using a 3/8" 5.0 MHZ Contact Transducer

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 TG400'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 TG400. Insert the Lemo connector in the receptacle marked with a dot on the top closure of TG400.

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 0.500 inch 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 key. During this very brief period, TG400 undergoes a host of internal diagnostic checks. Once these checks are complete, the LOGO screen automatically appears.

5. An A-trace will appear, along with the Main Menu items and a thickness readout, the large numbers in the upper area of the A-trace. 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 40% full-scale (FS) amplitude. Observe that this horizontal line extends from the

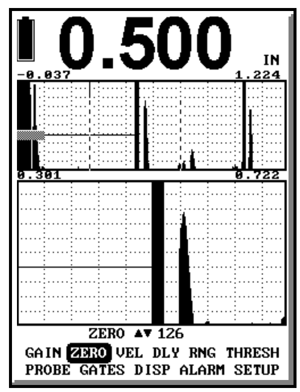
extreme left edge of the A-trace and terminates on the leading edge of the back echo. This line, or bar, represents the thickness gate (T-gate) and shows which echo stops the gate. In this example, since the 0.500 inch step is the one being measured and the horizontal FS range is 2.00 inches, the T-gate terminates on the first echo above 40% FS amplitude, the back echo from the 0.500 inch 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, in this case on the MAIN A-Trace window from the left-hand axis. This bar represents the IP blocking gate (IP-BLK gate) which serves to "block" out the string of high amplitude echos typically accompanying the IP. In its FACTORY setup default position, the IP-BLK gate is at 0.070" to block out the IP echos and thus prevent the T-gate from triggering in or on the IP. Control of the IP-BLK gate is explained further 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 IP-BLK gate in order to proceed. If necessary, 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 from 0.500 inch plus or minus. Position of the cursor in the Main Menu is at GAIN.

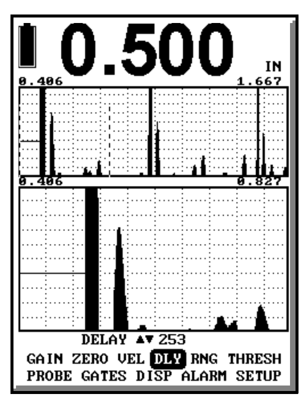
10 With the cursor at GAIN, Up & Down arrow keys increase/decrease effective gain accordingly.

11. To become familiar with the RANGE function, position the cursor at RNG. The up arrow key will squeeze the 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 and approach each other more closely. In our 0.500 inch steel block example, depress the UP arrow key until the first back echo, originally at the second vertical division of the electronic graticule moves to approximately fourth full vertical division. The second back echo will be aligned (or nearly so) at the 8th full division. The readout value under RNG should be close to 1.2 inch.



However, note that T-readout did not change unless the gain was substantially increased. With TG400'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.

13. The DELAY function also has pronounced effects on the location of signals on the A-trace. Set the full-scale range using the RNG menu selection at about the 1" inch and position the cursor at DELAY. Depress the UP 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 does not change 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.



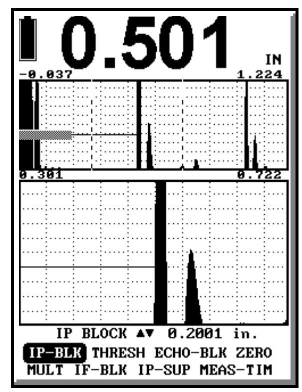
14. With the RANGE at 1.00 inch cursor to Select GATES from the MAIN Menu and select IP-BLK. The Up & Down arrow keys control the length of the blocking gate, referred to as "IP-BLK gate", and represented by the Thick dotted bar extending horizontally along the thickness gate line on the A-trace from the left-hand side of the

screen. Its purpose is to "block" the trailing edge echos associated with the initial pulse or any spurious signals which might interfere with what is known as the true interface. This group of echos contains ring-down echos from the transducer and "noise" accompanying stray reflections resulting from coupling. The "noise" 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 (IP-BLK gate) is about 0.200 inch equivalent in steel. With medium to broadband transducers of 2.25 MHZ or greater, the distance is usually sufficient to block IP echos and coupling noise from standard test blocks. Note, however, that it would not be possible to material less than the width of the calibrated IP-BLK gate, less than 0.200 inch at FACTORY defaults. If the total IP signal is greater, and the blocking gate must be increased, any significant echos within the blocking gate, transducer back echos or otherwise, will be blocked and will determine 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. With highly damped, broadband transducers of 5 or 10 MHZ, it should be possible to shorten the IP-BLK gate to permit IP to first back echo digital readout of 0.030 inch steel or equivalent.

15. At this point, use the Up/Dn arrow keys to change the length of the IP-BLK gate in order to observe the effects of the control.

16. The IF-BLK (interface echo blocking) functions in a similar fashion as the IP-BLK 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.

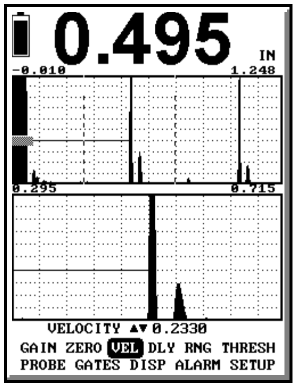


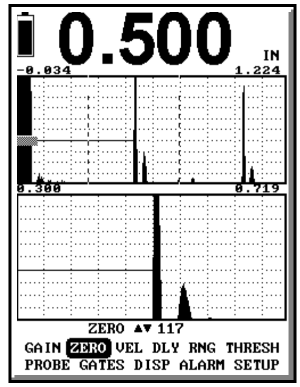
17. Before examining the function of THICKNESS THRESHOLD (THESH),press MENU to display the MAIN Menu. At THRESH, note that the horizontal T-gate bar is at 40%. Up or Down arrow keys change the threshold level of the T-gate, and the actual level of the T-gate is readout in % full-scale amplitude, variable from 10% minimum to 90% maximum. The FACTORY default amplitude of generally 40% (probe selection dependant) 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).

18. Move the cursor to ALARM Menu item. Using the left or right arrow will move to the item. Press ENTER to enter ALARM setup

19. Both LO-THK and HI-THK 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 front panel visual LED) when pre-set thickness levels, low, high or both low and high, have been exceeded. The level sets are scrolled when the Up or Down arrow keys are depressed. With the cursor at the STATUS position, arrow keys select the alarm system (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.

ZERO & VELOCITY
The next two functions, VEL and ZERO are adjustments necessary to "calibrate" the gage to the accurately measure the specific material under test.





In our example, using a 0.500 inch thickness step, we have yet to perform any operations to "calibrate" the Thickness readout. Most probably the reading is close to 0.500 inch, 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.

21. As a first step in becoming familiar with the VEL and ZERO functions, lets complete the calibration for thickness measurement using the step block in our example.

    VEL - Set the cursor at VEL and adjust it to 2330 In/us.

    ZERO - Using the Left/Right arrow, reposition it at ZERO, probe zero control position. Using the Up/Dn arrow keys adjust the thickness reading to 0.500". When 0.500 inch [or whatever the known actual thickness of the step] is achieved in Thickness readout, the upper range calibration is complete. Note that zero may change through up to 5 or 10 counts (on the display) before the indicated thickness changes. Choosing zero roughly at the mid-point of the range needed to move from 0.499 inch to 0.501 inch. This procedure can improve thickness gaging precision.

22. Remove the transducer from the 0.500 inch step and couple it to the other steps on the block. If the test block has been accurately measured and the material is steel with a VELOCITY (VEL) of 0.2330 in/us, the other step measurements should be within ±0.001 inch of the actual measured values and reproducible.

NOTE : to measure to thinnest step on the block it may be necessary to adjust IP-BLK as per step 15 above

21. If some material other than steel is used, a different procedure will be required. For a transducer of similar type as used in these procedures, reset the ZERO to approximately that of the default (130). Depress the up arrow key to position the cursor at VEL (velocity). With the transducer coupled to the thickest step, use the Up & Down arrow keys to increase/Decrease the velocity until the known thickness of the material is displayed on the thickness readout.

Now couple the transducer to the thinnest step. If thickness readout does not agree with the known thickness, reposition the cursor at ZERO and use the Up or Down arrow keys to produce the known thickness on the thickness readout.

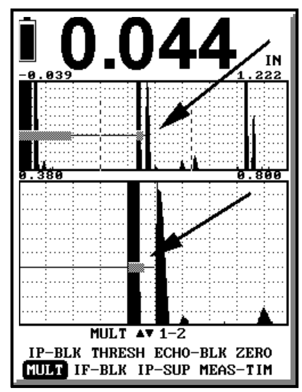
Then, again check the thickest step. If thickness readout still does not agree with known thickness, reposition the cursor at VEL (velocity) and use the Up or Down arrow keys to obtain the known thickness.

Continued adjustments between ZERO and VELOCITY will produce correct thickness readout on both the thickest and thinnest steps. At this point, the steps in between will read correctly [within the resolution, ±0.001 inch]. The velocity value below VEL is the velocity of the material of the specific material of block under test.

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

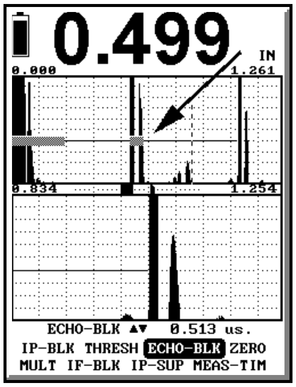
ECHO - ECHO Setup Using 3/8" 5MHz Contact Transducer as above.

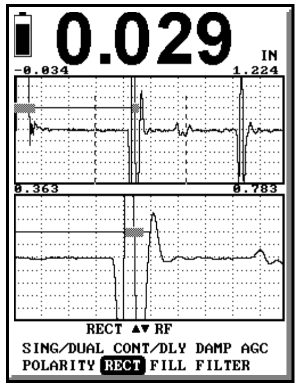


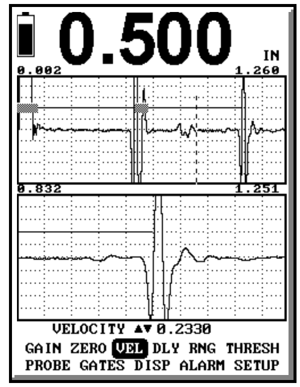
22. To examine ECHO to ECHO function, place the transducer on the 0.500 inch thickness step. ESC back to MAIN Menu using the MENU/ESC keys. Cursor to and set RANGE to 2.00 inch. Scroll back to GATES Menu. Cursor to MULT. Use right arrow key to select “1-2". ECHO allows the selection of a multiple echo from which the thickness measurement (Thickness gate) will begin. Up to the 3rd multiple echo can be selected using the Up/Dn 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 (ECHO-BLK). Note the thick horizontal bar on the Thickness gate. Use the right arrow key to select the length of the echo blocking gate that is appropriate to block out any unwanted signals between multiple echos in the thickness mode. The FACTORY default value is .200 inch. ECHO-BLK is actively displayed when MULT is set at 1-2 or 2-3. Look at the upper, Main Trace window. There are 2 multiple echos in it. One at about half screen and another at about 80% across the screen. However, if you look at the Tracking (lower window) you will notice the gage is currently triggered between a single echo’s half cycle producing a reading of 0.044" which is wrong. Note the short blocking bar is about half way between. Now, look at the following image. In the Main Trace window you’ll note the ECHO-BLK gate is set just beyond the echo half cycle set. With the gate set in this manner note the Thickness Measurement bar extends to the echo set at the 80% screen position which, is the correct position. The track window now displays the echo being measured to and where the gate terminates.

For clarification regarding echo half cycles refer to the following RF based images. The one at 0.029 is triggered on successive positive half cycles. Note the position of the ECHO-BLK Gate. Then look the image displaying 0.500" and note the position of the ECHO-BLK gate.



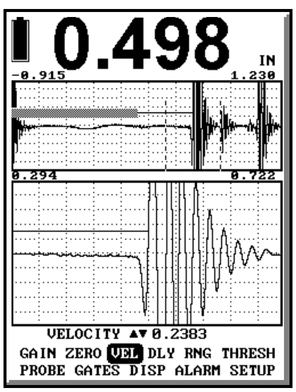


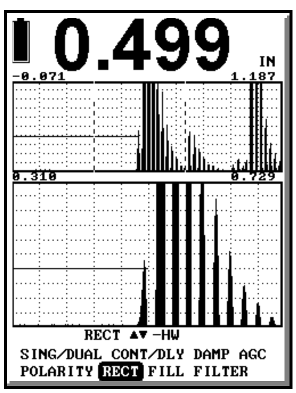


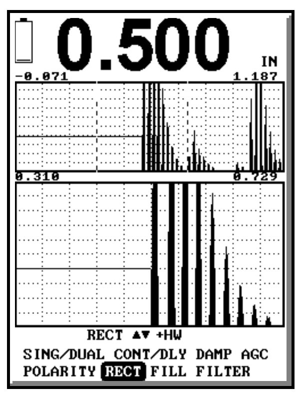
For precision thickness gaging, the type of waveform used for setups has a significant effect on gaging results. Note that the RECT default is +HW, meaning that the current display is of signals that are positive half-wave rectified.

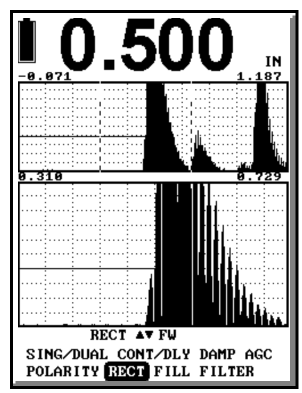
Appropriate Selection of Echo Half cycle

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. 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 , 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 GAIN 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 with respect to each following half cycle (+ or -), 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.

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 the Figure 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 Thickness readout changes as a function of gain.

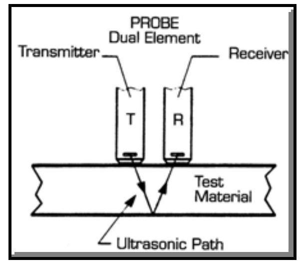
There are other good reasons for offering this variety of display modes. There are instances where the more prominent half-cycle is not positive-going. In cases where the back wall is lined with another material (e.g. some elastomers), the first negative-going half-cycle is more prominent. This phenomenon 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.

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 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 TG400 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.

From the MAIN Menu select PROBE and then DAMP. The default value is specific to the transducer selected, but 50 Ohms is a usually good match for the type of transducer being used in this example. To observe the effect of damping changes, depress the Up/Dn arrow key and note a new, higher or Lower 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). 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 DAMP and use the 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.

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 a few more. The sound beam of a dual element transducer is generally directed into the test object at a small angle. 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.

A dual element transducer is always in a “listening” mode as one half is transmitting. The real benefit with a dual can be found when inspecting corroded, pitted or eroded materials. Dual element transducer have the ability to discriminate the peaks and valleys of corrosion and or pitting.

Key Concept

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. Therefore a process called Probe Zeroing needs to be done which eliminates the added material in the sound path, such as the internal delay lines. Also, if a probe designed for the gage is used the instrument compensates for the non-linearaity due to the V-Path.

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 considerations 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 ZERO 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.

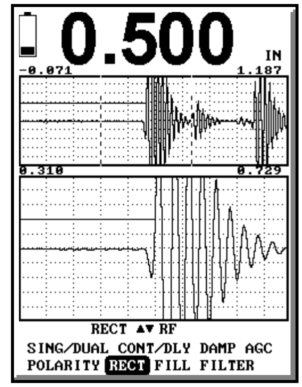
Dual Element Delay Line ZEROing Procedure.

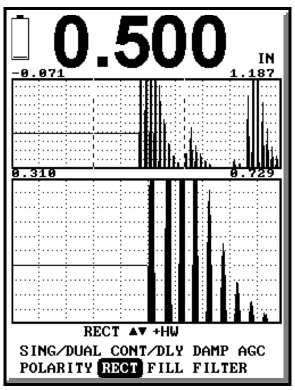
Most dual element transducers are either undamped or lightly damped. As a consequence, the setup must be carefully optimized. The first step is to decide upon which form of display rectification will best serve. In the following procedure, a 5 MHZ, 3/8 inch (9.5mm) diameter transducer (NOVA Model TG506) was used to produce measurements in the range from 0.200 to 0.500 inch.

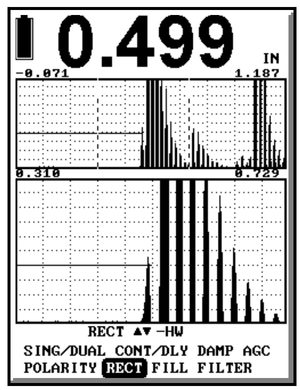
1. In the PROBE Menu, select DUAL. Then, in the MAIN Menu, change RANGE to 2.00 inch.

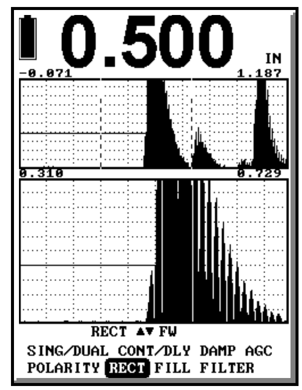
In the PROBE Menu, select RECT then RF.
Adjust gain to produce and maintain an echo pattern which is less-than-saturated.
In the PROBE Menu, set DAMP at 375 ohms or adjust to produce the sharpest, or "cleanest" echo pattern.

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 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.









3. The next step is to complete the calibration. In the MAIN menu, adjust VEL to 0.2330. Then move to and adjust ZERO to produce the thickness readout corresponding to a known thickness (in this case, 0.500 inch). Note, when you check the measurement of the 0.200' inch step note, it produces ~0.205 inch. This error is due to "V-Path Error", mentioned above. Then check the thicknesses in between and note the variations.

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 ZERO difference.

AUTO PROBE ZERO

Although the TG400 was designed as a general purpose precision thickness gage, able to use transducers of any manufacturer, one of the most significant advantages is the Probe Auto Zero function. When used with the appropriate NDT Systems, Inc. NOVA Series transducers, incorporating a patented Auto Probe mechanism, setup and calibration are made significantly easier. Also, errors due to V-Path are corrected and linearized in software. Since each manufacturers V-Path factor can be different it is not possible to provide a full table of possible variations.

In order to calibrate using an NDT Systems Probe (such as the TG506) follow the following simplified procedure:

Option - A

- Connect TG506 Transducer
- From PROBE Menu, Select SINGLE or DUAL transducer
- Press PROBE ID Key - The gage will recognize the attached transducer ad select the appropriate transducer from the list.
- Press ZERO/ECHO front panel key. The gage will display the screen to the right, requesting you to place the probe on the ZERO Disc and then pressing the ENTER key.
- From this point, place the transducer on a thickness representing the upper limit of thickness to be expected. Place it on the 0.500" step in this case and verify the gage reads 0.500. If it close adjust the VEL to adjust to exact material velocity.

Option - B

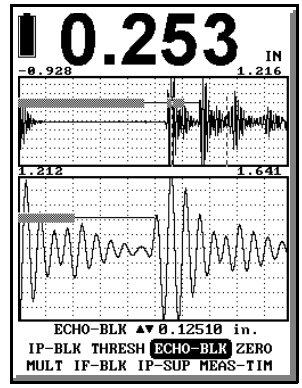
- Connect TG506 Transducer
- From MAIN Menu, Select SETUP and PICK the appropriate transducer from the list
- Press ZERO/ECHO front panel key. The gage will display the screen to the right, requesting you to place the probe on the ZERO Disc and then pressing the ENTER key.
- From this point, place the transducer on a thickness representing the upper limit of thickness to be expected. Place it on the 0.500" step in this case and verify the gage reads 0.500. If it close adjust the VEL to adjust to exact material velocity.

Set range to desired range. For instance, if the material is expected to be no thicker than ½" nominal than a range of 0.75" would be an appropriate range to start with.

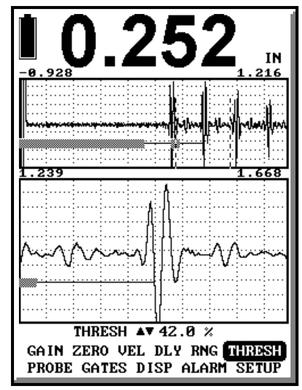
Dual Element Multiple Echo Interval Measurement Procedure.

With careful optimization and setup, multiple back echo intervals can be used for thickness measurement using dual element transducers. In the example shown to the right, multiple back echo intervals as far as the 4th back echo can be seen. In this case, the first back echo was set to the left-hand start of the windowed A-trace.

Go to GATES, MULT, 1-2,
Got to ECHO-BLK and set to a minimum point between the 1^{st} and 2^{nd} echo where the gage will trigger reliably on the proper second echo. As a point of reference, compare the two screens to the right. In the upper screen, a "standard" fingertip dual transducer is connected. Not how the waveform extends in a decaying fashion between the first and 2^{nd} echo. In this case the ECHO-BLK will need to be extended out far enough to pass the multiple echo cycles of the first echo. This will limit the low end thickness capability. In the lower image, a TG560P transducer is attached. In this case the transducer is optimized to allow for thinner material measurement.



Typical "Standard" Dual Element Echo Pattern

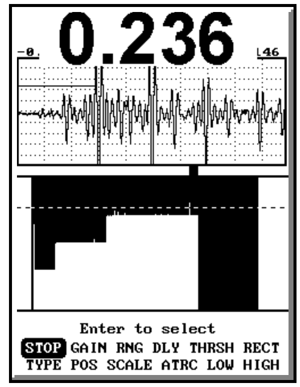


Typical "specialized" dual element optimized for echo-echo mode

This technique can be used with many dual element transducers to measure painted or coated objects or object 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. Using a multi-echo mode eliminates this error.

In general, multi echo measurements in a dual element mode are limited to a top end thickness of about 3", probe, material, coating and application specific.

B-SCAN SETUP



MENU Selections

STOP
- SAVE
  - Save as a user
- EDIT
  - To Keyboard for user file naming and scan annotation
- RECALL
  - BSCAN#
    - Select Saved B-Scan from list
  - EDIT
    - Annotate and re-save a stored B-Scan

GAIN
- Up or Down Arrow to adjust.

RNG
- Up or Down Arrow to adjust.

DLY
- Up or Down Arrow to adjust.

THRESH
- Up or Down Arrow to adjust.

RECT
- +HW
- -HW
- FW
- RF

TYPE
- T-Scan - Time Encoded B-Scan (Cross Section View)

POS
- TIMED
- ENCODED L-R
  - (left to right) when you move the encoder cart to the right the B-Scan & Cursor move to the right and when you reverse to the left the B-Scan and Cursor move to the left
- ENCODED R-R
  - (Right to Right) - When you move the cart to the right the B-Scan & Cursor move right, when you move the cart to the left the B-Scan & Cursor move to the right
- ENCODED L-L
  - (Left to Left) - When you move the cart to the right the B-Scan & Cursor move right, when you move the cart to the left the B-Scan & Cursor move to the right

SCALE
- Adjusts the speed of the timed B-Scan OR the represented Distance the scanner moves. For instance, when in the TIMED mode, a scale of 10 takes 10 seconds per screen width. The lower numbers represent a faster sweep across the screen. I the ENCODED mode the scanner would need to be moved a further distance with a value of 10 to scan across the screen. A value of 1 would scan very quickly across the screen

ATRC
- Turns the A-Trace ON & OFF. When OFF, the B-Scan fills the entire active area of the display.

LOW
- Moves a Low Thickness Limit Reference cursor on the screen

HIGH
- Moves a High Thickness Limit Reference cursor on the screen

Quick Start B-Scan Setup

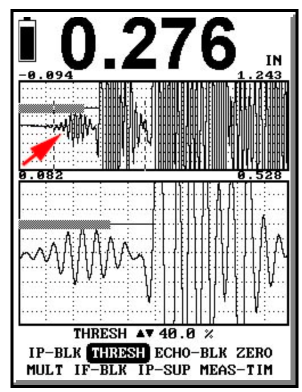
Assumptions:

Stock Transducer - PX506
0.500" Thick Pipe/Plate

Assembly:

Connect and secure cable to Phoenix bottom
Connect Lemo end to Scanner
Assure transducer is flush to recessed into swivel sled. Recess should not be more than 0.004" This is about the thickness of 1 piece of scotch tape. (0.1mm) below sled surface. If the probe is recessed too much there will be excess crosstalk which will make scan setup more difficult. The transducer is loosened and secured by the 2 screws used in mounting of the swivel sled. The transducer is removed by placing a thin screwdriver in a groove at the base of the transducer as shown in the figure. Once the transducer is secure in it's proper position re-secure the two screws on the side.

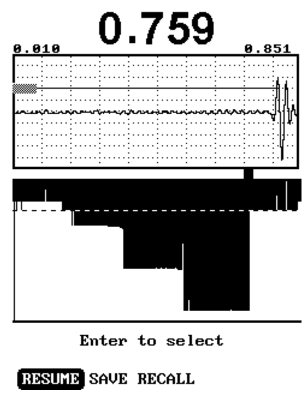
Calibration: Note - Quick Reference for the Ultrasonic Calibration is shown on back side of unit.



1. The first thing when calibrating a unit which can display an A-Trace is to set you Gain, Range and Delay on a clean reference sample such as a step block. This will assure you have a good signal on screen, from the thickest area to the thinnest area of your sample.
2. Go to the SETUP Menu and select the PX506 if it is shown. If not select TG506. This should set the instrument up in general terms. Adjustments for a particular probe now will have to be made.
3. Set Range to about 0.750"
4. Set Delay to about 0.000
5. Set probe on thin section of test block. For instance 0.250" Do not worry yet about the thickness reading. Adjust the gain to be sure you see the first echo for the 0.250. Move the probe to 0.500" & then to 0.100" to be sure you are observing an echo from the test block. All the waveforms should remain on screen assuming you do not exceed the 0.750" set in the prior step.
6. Once the waveform is on screen in the proper positions we will need to adjust the IP-BLOCK control which is in the GATES menu. The IP-BLOCK is used to ignore noise from crosstalk or surface roughness. Set the bar for the IP-BLOCK just past the steady noise signal if there is one. Otherwise, set the probe on a test block at about 0.100" and move the IP-BLOCK to stop just in front of the 0.100" echo.
7. Now we are ready to calibrate. Press the PROBE ZERO button the front of the gage. The Gage will then tell you to place the probe on the ZERO DISC (on the side of the

gage) and when you have a steady echo, press the ENTER key. This sets the probe Zero and any offset between the probe and surface under inspection.

8. Place the probe on the 0.500"(or thicker) Step of the step block
9. Select VEL on the Keypad, then use the Up & Dn arrow keys to adjust the Velocity. It should range between 0.2320 to 0.2350 in general terms for un-coated steel.
10. Check the thickness in between and they should be very close. If you would like the values closer you can continue by placing the probe on the Low Step and use the ZERO/LoCAL to set the low thickness closer then move the probe to the thicker section and press the VEL/HiCAL Key and adjust the thickness to read the thick step. Repeat until satisfied. Under most conditions you should not have to go through the extra steps.
11. Once calibrated press the B-SCAN Key.
12. Cursor to TYPE and use the Up & Dn arrows to select T-SCAN. This will provide a Cross Section view of the area being inspected.
13. Move the Cursor to Select POS on the Menu.
14. Use the Up & Dn arrows to select ENCODED L-R or any other desired plotted motion.
15. Place the cart on a surface to be inspected and the pointer above the B-SCAN graphic screen should move with the movement of the scanner.
16. Adjust the SCALE as desired to either speed up the motion (less distance information) on the screen or slow down the motion (more info on screen).
17. Finally, re-check your gain for the material you re testing to be sure you are receiving good echo height to trigger the gage. If the gain is too low, there will be dropout (white or blank areas) on the B-SCAN. If the B-Scan shows the same number all the time be sure the gage is not continuously triggered on surface noise of some sort.



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.

5.0 OUTPUTS

There is a Mini-Phono type female receptacle on the top of the enclosure of TG400. There is an RS-232C serial output available at this receptacle. There is also a connector on the bottom of the gage which supports USB as well An optional cable assembly is available from NDT Systems.

5.1 Output Choices.

5.2.1 RS-232C Output Specifications.

Baud Rate	19200
Parity	None
Data Bits	8
Stop Bits	1

The TG400's RS-232C output connector (Mini Phono) is located on the Top side of the enclosure.

6.0 BATTERY PACK AND CHARGER

The TG400 is powered by 3 NiMH Rechargable 'AA' style batteries inserted into the bottom panel via the rear panel access cap. The gage is charged via an external battery charger. Once fully charged the TG400 will run for up to 20+ hours before requiring another charge. Charge time is 6-8 hours for a full charge from empty.

The TG400 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. if the charger/eliminator is plugged in, as the alkaline batteries are installed damage to the gage by leaking batteries will be likely. The damage is obvious and is not covered under warranty.

Batteries are to be installed with the tip facing into the gage. Installing the batteries in the wrong will cause damage to the gage.

8.0 OPTIONAL TG400 ACCESSORIES

In addition to NDT Systems, Inc.' OPTIMA transducers, cables, reference standards and other transducer accessories, the following optional TG400 accessories are available:

- ATRP1 - TG400 Carry Pouch - A light-weight leatherette protective case. The TG400 fits firmly into a case like compartment supported at an adjustable angle stand. The integrated stand also snaps around a belt.

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.

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