Pile Dynamics, Inc.

Cross-Hole Analyzer (CHA)

Operation Manual

Version 2005.0010 Q

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1. About this Manual

This manual was created for WORD. If reading it from WORD, then in View / "Document Map" (or "Online_Layout") there is a helpful "Index" for using this manual.

This manual describes the data collection for the CHA-QX (the original CHA manufactured by PDI which is size of a briefcase) as well as reprocessing of data collected by the CHAMP (smaller battery operated touchscreen data collecting unit).

While this manual represents the best effort of description of various features, if you are having difficulty understanding some feature or function, or if the manual is unclear to you, please let us know so that we may improve this manual.

Realize also that software is never finished (unless the product is dead and support ended). We always value user suggestions and thus encourage you to submit your ideas for improvement of the product to us for consideration. Because this is a continuing product, new improvements will be added from time to time to enhance the features and effectiveness of our product, and thereby make your use easier or more powerful, and our manual may then from time to time lag behind the actual software. If you notice a new feature and cannot determine what it does or its application, then we encourage you to contact us for further description.

Finally, we encourage you to read the manual at least once as you learn a new product. The answers for many of your questions can be found even for the relatively experienced. The "Index" may shorten your search.

2. Overview of the Cross-Hole Sonic Logging Method (CSL)

By sending ultrasonic pulses through concrete from one probe to another (probes located in parallel tubes), the CSL procedure inspects the drilled shaft structural integrity, and extent and location of defects, if any. At the receiver probe, pulse arrival time and signal strength are affected by the concrete. For equidistant tubes, uniform concrete yields consistent arrival times with reasonable pulse wave speed and signal strengths. Non uniformities such as contamination, soft concrete, honeycombing, voids, or inclusions exhibit delayed arrival times with reduced signal strength. This procedure is covered by ASTM D6760 (which can be downloaded from the ASTM website (**www.astm.org**).

A suggested sample specification for application of the CSL method can be downloaded from the Pile Dynamics website (**www.pile.com**).

CSL Access Tube Preparation

Install access tubes in each drilled shaft to be tested to permit possible inspection by CSL. Note that the actual number of tubes installed in each shaft is often selected as one tube for every 0.25m to 0.35m (10 to 14 inches) of drilled shaft diameter, with a minimum of three access tubes (our personal preference is for at least four tubes). Drilled shafts with different diameters at the same site may require a different number of access tubes.

Note that it is advisable that every drilled shaft shall be equipped with access tubes, and this alone may inspire the installer into a more careful procedure. Certainly the cost of the access tubes is modest compared with the cost of the shaft and compared with the cost of a failed shaft. The best procedure and many job specifications require testing of every shaft to assure quality for every shaft.

In some cases, the actual number of drilled shafts to be tested by CSL may only be some percentage of all drilled shafts where the drilled shafts to be tested will be chosen after installation by the Engineer, either on a random basis or based on the installation records. If significant defects are detected, the number of drilled shafts tested may be increased by the Engineer. If access tubes are not installed at a relatively modest cost during installation, later inspection of a shaft (due to questions arising during construction from unusual or unplanned events) will be very difficult and very costly, or in some cases impossible. Every shaft might have some difficulty during installation (such as in extraction of the casing), so every shaft should be equipped with access tubes to permit evaluation of any shaft having any installation difficulty.

The recommended access tubes are nominal 38 to 50 mm (1.5 to 2.0 inch) **inside** diameter. Tubes may be steel tubes (standard weight schedule 40), or PVC pipes (preferred schedule 80, although schedule 40 is satisfactory for shorter shafts), to allow access for the probes in each drilled shaft. **Steel tubes are usually preferred.** Use round tubes that have a regular internal diameter free of defects and obstructions, including any tube joints, to permit free, unobstructed passage of the probes. Tubes should be watertight and free from corrosion with clean internal and external faces to ensure a good bond between the concrete and the tubes. Tubes may be extended with mechanical couplings. However, duct tape or other wrapping material to seal the joints and butt welding of joints are discouraged. Tubes should be installed by the Contractor such that the CSL probes will pass through the entire length of the tube without binding.

We suggest access tubes have an **inside** diameter of 1.5 inches (38 mm). The minimum **inside** diameter should be 1.25 inches (31 mm). Although some use even 2 inch pipes and even 3 inch pipes. Large diameter access tubes increase the probe location uncertainty and therefore the observed velocity uncertainty.

PVC tubes are sometimes used. They have the advantage of cleaner data due to the smoothness of the pipe, and also provide more signal transmission (allowing lower electronic gains). Both reasons show PVC tubes have significant advantages of steel pipes. However, **for piles cast in wet conditions, "debonding" of the PVC from the concrete is a potential serious problem**, as is the extra flexibility (meaning the tubes may become non-parallel after concrete casting so extra tie locations to the cage are suggested). **To obtain good CSL measurements with PVC tubes, it is absolutely essential to fill the PVC tubes with water during the entire curing process to reduce debonding problems**. If the PVC tubes are not filled with water, CSL data will be adversely affected, and in some cases the PVC tube integrity will be compromised. Concrete pressures are about 1 PSI per foot of depth (about 3 PSI per meter of depth), so for 50 meters depth, that would require a PVC rating of at least 150 PSI. We recommend schedule 80 PVC pipe for deeper depths. Note that PVC pipe pressure ratings are reduced by a factor of 2 if pipe is threaded (couplings). Larger diameter PVC tubes decrease the pressure rating. PVC tubes are also more fragile and more flexible and need more care in attaching to the cage and during installation of the cage into the hole.

Fit the tubes with a watertight shoe on the bottom and a removable cap on the top. If the bottom cap is PVC, then that may allow a drill to core through it if a "soft bottom" condition is determined and bottom pressure grouting is specified as the remedy. Secure the tubes at equally spaced regular intervals to the interior of the reinforcement cage such that all tubes are aligned parallel (equal spacing between tubes along the full length). Tubes should be spaced as far as possible from the main axial reinforcing steel. The access tubes are intended to be plumb after installation. Extend the tubes to within 150mm (6 inches) of the drilled shaft bottoms (Note: Many specifications do not allow the tube to rest on the bottom of the drilled shaft excavation.). Also extend the tubes to preferably at least 1.0m (3 ft) above the drilled shaft tops, and at least 0.6 m (2 ft), but not more than 1.5m (5 ft) above the ground surface. Do not damage the tubes during installation of the reinforcement cage.

After placement of the reinforcement cage, fill the access tubes with clean fresh water as soon as possible but within at the latest one hour of concrete placement. (Note: The tubes should preferably be filled with water prior to concrete placement, but MUST be filled with water within at most 4 hours after placing concrete to prevent debonding of the access tubes due to differential temperatures.)

Cap the tube tops to prevent debris from entering the access tubes. Do not apply excessive torque, hammering or other stresses which could break the bond between the tube and concrete when removing caps from the tubes.

(Note: If an existing drilled shaft does not contain access tubes, access holes can be installed by coring a borehole in the concrete. Locate cored holes about 150 mm inside the reinforcement cage. Log core holes and include descriptions of any inclusions or voids. For drilled shafts with access tubes which do not allow the probe to pass through the entire length of the tube due to poor workmanship, replacement access holes may be provided by core drilling.)

CSL Test Sequence

Test the drilled shaft at a time specified by the construction documents or as the construction sequence allows. CSL testing can be performed any time after concrete installation although 2 days is usually the absolute minimum acceptable wait. Because the concrete strength and quality generally increases as the concrete cures, longer wait times are usually desirable, particularly if minimum pulse wave speeds are specified or to reduce result variability between drilled shafts or even as a function of depth in a single drilled shaft. However, long wait times increase the tube debonding which is detrimental to the test (reportedly particularly for PVC tubes, although our experience is that debonding is not a problem for PVC tubes **if the pile is cast in dry conditions** and if tubes are properly filled with water immediately after casting, or prior to casting if the casting is very long due to a long pile). Production drilled shaft installation and subsequent construction influence the dates of CSL testing. The test should be performed preferably within 10 days after placement and prior to loading for test drilled shafts, or within 45 days after placement on production drilled shafts. It might be noted that if the concrete shows weakness during a very early CSL test, additional time and a repeat CSL test may possibly show markedly better results due to a delayed concrete curing (delayed curing can result from various admixtures in the concrete – delays of curing have been reported as long as 56 days).

> (Optional or as specified by the project documents: After all CSL testing has been completed, and after acceptance of the drilled shaft by the Engineer, remove the water from the tubes, place grout tubes extending to the bottom of the access tube, and fill all access tubes in the drilled shafts with grout.)

CSL Test Procedure

Prior to CSL testing, the test Engineer should obtain a record of all drilled shaft lengths with elevations of the top and bottom, and installation dates of all drilled shafts. The access tubes should be clearly labeled for identification (e.g. 1, 2, 3… or A, B, C… or perhaps N, S, E, and W for a 4 tube shaft). Measuring the inside tube lengths prior to testing helps assure the tube is free of obstructions and the probe can be lowered to the tube bottom. Measurement of tube lengths is proper procedure and information needed for test (to find when the probes are "level").

An alternate to measuring the tube lengths with a probe and tape rule is to use the CHA itself. Place ONE PROBE at the top of the tube, and "zero" the probe at the top (see REFERENCING THE DEPTH ENCODERS). Slowly lower the probes from the top until it reaches the pile bottom, effectively measuring the access tube length. Repeat this for each tube using the same probe. Document each tube length.

The CSL testing should initially be performed with the transmitter and receiver probes in the same horizontal plane in parallel tubes unless test results indicate potential defects, in which case the questionable zone may be further evaluated with angled tests (source and receiver vertically offset in the tubes). Using the labeling established for the tubes, perform CSL testing between all adjacent perimeter access tube pairs and across at least the major diagonals within the drilled shaft. In the event defects are detected in drilled shafts with more than four tubes, additional logs in other minor diagonal tube pairs may be required to better estimate the extent of the defect.

With the probes initially now at the tube bottoms, pull the probes simultaneously, taking CSL measurements at intervals of 50 mm (or less if specified) from the bottom to the top of the drilled shaft. Defects indicated by late pulse arrival times and significantly lower amplitude/energy signals should be immediately reported to the Engineer. Additional tests such as the offset elevation CSL testing may be required by the Engineer to further evaluate the extent of these defects. If debonding between the access tube and the concrete is indicated by the CSL results, an alternative test method will be required to determine the integrity of the concrete in the debonded region.

> (Note: In case defects are detected, additional tests or analysis options may include CSL tomography, Gamma-gamma nuclear density logging, sonic echo or impact response tests, high strain dynamic pile testing, static load testing, or concrete coring. If the drilled shaft is cored, an accurate log of the cores which include depth and core recovery shall be kept, and core and coring logs shall be properly identified and given to the Engineer. In case of a clear CSL defect, note that if the core does not detect the defect that means the core was not drilled in the defect location; the defect may still exist in a different planar location.)

3. Hardware and Software Setup

Many of the topics in this section apply mainly to the CHA-QX. Specifics for software application for data collection for the CHAMP are covered in the manual for the CHAMP. The software setup for the office PC and final processing of data is identical for either data acquisition unit.

Depth Encoders

A tripod is provided to support the two independent depth encoders. Tube guides (nylon inserts or rollers) are provided to keep the cables from being abraded by the edge of the tubes. The tripod should be placed near the shaft to be measured and close to the CHA unit. The encoders are connected to the CHA with the short junction cable. Prior to "zeroing" the probes, the cable should be tight (e.g. remove the excess slack before pressing ZERO).

Alternately, two remote encoder assemblies shall be inserted at the tops of the two tubes to be tested and are connected with a short junction cable. A single main cable then connects the encoders to the CHA main unit.

Motorized Cable System (MCS)

The MCS provides an excellent way to keep the cables organized (and avoid the mess of cables during pulling), and to reduce the physical effort required for testing. It is also helpful to minimize handling of wet cables (particularly appreciated in the winter). The two encoder assemblies are then placed on the top of the motorized cables, and separate cable guides are inserted at the tube tops. A shorter single main cable then connects the encoders to the CHA main unit. Only the probes themselves have cables from the engineer to the tubes, further simplifying the operation.

Transmitter and Receiver Probes

The receiver should be spooled out and inserted into the encoder assembly designated as the receiver. The receiver is color coded as red. The transmitter probe (color coded black) shall be similarly deployed in another tube. For manual cable pulling only, the connection to the CHA shall be made after the probes rest at the bottom of the tubes to be tested so that the spool is not rotated after connection – otherwise a twist is inserted into the cable for each spool rotation (the MCS has slip rings and can be deployed without this concern).

Both probes should be fitted with a small weight (attached to the bottom of the probe) to allow them to sink naturally in the tubes. Three weight sizes and shapes are currently available. More weight allows the probes to self spool easier (although very fast deployment may allow the probe to "wedge" into a bent tube and thus may not be retrieved – controlled decent is therefore encouraged). Rubber "centralizers" should be inserted between the probe and the bottom weights to keep the probe centered in the tube. Cuts in the cable may make a probe inoperable due to shorts. Cables for newer probes can be replaced.

> Having spare cables (and even spare probes) is recommended so the testing can continue without delay in case of unexpected problems.

Newer probes have higher power transmission, and therefore provide stronger signals. New CHA units automatically can power the new probes with maximum efficiency. The voltage sent to the transmitter probe is kept very low (for safety purposes), and boosted inside the probe itself to up to 800 volts. The transmitter probe has black band, and should be connected to the black cable. The receiver probe is all brass and should be connected to the red cable. The cable color then helps the user determine which cable to pull to affect a certain probe.

To determine if a probe is functioning, the following tests are sufficient (tests when connected to the operating CHA in data collection mode). The transmitter probe should make a pinging sound. The receiver probe shall generate a signal if tapped or rubbed.

> For some older CHA models, these newer probes require connection first into a small external box ("CHA High Power Transmitter Adapter"). The output of this box is then plugged into the CHA's transmitter input jack. This extra box requires the 12 volt DC power to be connected first to this box and then output to the CHA. For connection of the high powered probes to the adapter box, the following steps should be applied in the given sequence:
>
> > Connect the transmitter probe to the "TX PROBE" connection on the end of the CHA HIGH POWER TRANSMITTER ADAPTER (CHPTA) Box
> >
> > Connect the "CHA TX" from the CHPTA Box to the CHA Transmitter connector on the back of the CHA unit (BNC type connector).
> >
> > Connect the 12V Power Supply to the "12V IN" on the CHPTA Box.
> >
> > Connect the "CHA POWER" cable from the CHPTA Box to the CHA Power Input on the CHA unit.

Software

The CHA.exe executable program file should be loaded into a folder. The chaown.bin file contains the "owner name" which appears on all printout and should be in the same folder as the executable. A logo.bmp file can be created by the user to contain his personal company logo for inclusion on all printouts. The logo.bmp file should be in the folder with the other CHA software. This same software can be loaded onto any PC for final reprocessing and report outputs of existing files (from either the CHA-QX or CHAMP data collection units).

Setup

From a “Blank screen” (gray in color), the SETUP menu gives access to changing the **Units**. Viewing “**Monitors**” for both Depth Encoders and Hardware (where the probe functions can be examined in more detail on a scope-like viewer, and the probe voltage can be adjusted. Typically the probes are set to 600 volts. For longer concrete spacings, the voltage may be increased). Format as Feet_Inches adds inches to the length displays rather than decimal feet. The size of the font for various labels (**Scale_Height**) is determined by selecting a relative height scale factor.

4. Projects

In order to facilitate easy generation of reports, The Cross-Hole Analyzer organizes data into projects. While it is not absolutely necessary to adhere to the project method of organization, it is highly recommended. Information is stored in the "csl.project" file. If this file is missing, then the tube configurations will not be shown graphically, and certain other functions may be rendered inoperable (e.g. no tomography, etc).

Data for each individual project is stored in a project directory which is a sub-directory of the master project directory. By default, the master project directory is located in the same directory as the CHA executable file.

Creating or Selecting an Existing Project

Before any work on Cross-Hole Analyzer data files begins, whether it be collecting data in the field - or generating reports later, a "Project" should be selected or created.

To create a new project or select an existing project, first make sure all documents are closed, then from the main menu select "Project / Open". ("New" performs the same function.)

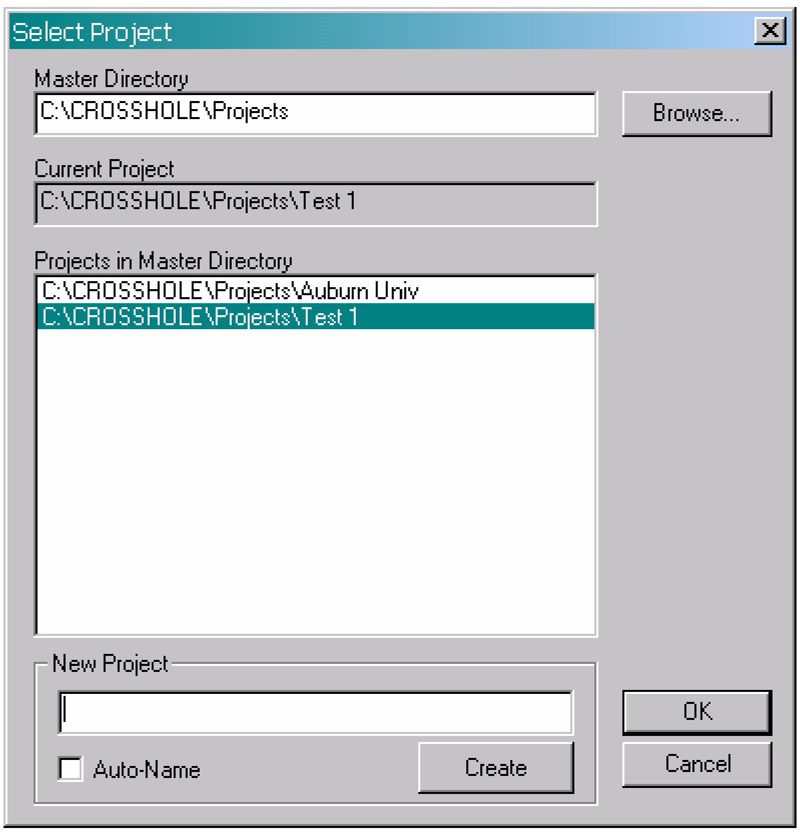


Figure - Select Project Dialog

At the bottom of this dialog box, either enter the desired folder name in New Project, or check the Auto-Name box (creates a folder with today's date), and then press "Create". Next highlight the desired project in the center window (Projects in Master Directory) and press "OK". This then defines the location where new data will be either saved to, or existing data retrieved from. The folder location can be changed either during saving or retrieving with minor extra effort if this "Project" selection step is not taken.

5. Data Acquisition

This option is useful only on PDI Cross-Hole Analyzer (CHA) hardware model CHA-QX.. For more information about CHA hardware contact **info@pile.com**, visit our website **www.pile.com**, write Pile Dynamics, Inc. 4535 Renaissance Parkway, Cleveland Ohio 44128, U.S.A., or call 216-831-6131 (U.S.A.). The hardware includes data acquisition and processing circuitry that both transmits and receives the sonic pulses which characterize pile integrity.

Actual data acquisition is disabled in the demo version, but a simulator is available to demonstrate field use.

Creating a Document to Acquire Data

From the 'File' menu, select 'New Project' if this is a new project. You can allow the CHA to create a “name” for you with the Auto-Name function (based on the date), or you can create your own name (e.g. based on a project site name). This will be the “folder” where the data will be stored for your test. The name of the “folder” will be used in the CHA report (so the project name is helpful).

To acquire new data from a particular shaft on this site, from the 'File' menu, select 'New'. You will be presented with a series of 'Property Pages' that allow you to set-up various parameters for data acquisition. The first page is the “Tube Wizard”.

Tube Wizard

To create a new document for a new pile, click on the **Add New Pile** button, which will cause the **Tube Configuration** dialog box (described in next section) to appear.

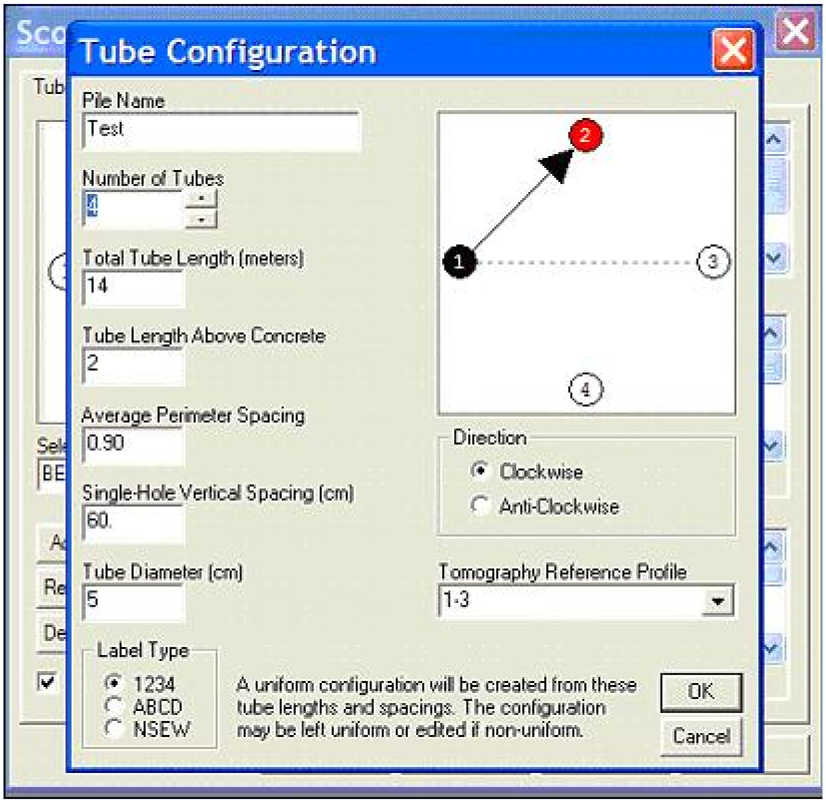


Figure - Tube Configuration Dialog

Tube Configuration

The basic parameters are input here. The **Pile Name** must be entered here. The **Number of Tubes** in the shaft is entered here. The nominal **Total Tube Length** (inside total length of the access tube from tube top to bottom) is entered. The **Tube Length Above Concrete** is the length of tube protruding above the concrete surface. The difference between these two lengths is the tube length embedded in the concrete.

These lengths are hopefully the same value for all tubes. If lengths or spacings are not uniform they can be edited in the **Tube Wizard** dialog box.

The **Average Perimeter Spacing** should be entered (the program will then calculate the diagonal spacings assuming the tubes are spaced uniformly around the perimeter. This **Spacing** is the average distance between a pair of tubes (affects calculated wavespeed). If the spacings are not uniform, the correct individual spacings can and should be adjusted later in the main Tube Wizard dialog box.

A **Label Type** designation scheme can be chosen from numerical, alphabetical or orientation (by compass points – intended for 4 tube shafts only). The tubes would typically be labeled clockwise from a selected starting point as 1, 2, 3... or A, B, C... or N, E, S, W... etc. If the transmitter is placed in the N (north) tube and the receiver is placed in the E (east) tube, then this data set would probably be named N-E (or might be labeled 1-2 or A-B if using other than compass point designations). The **Direction** (e.g. clockwise) of labels should be selected. Finally, the **Reference Profile** should be selected from the drop down menu. This **Reference Profile** is a major diagonal indicating two particular tubes from which all other measurements are referenced to minimize the measurements required to define the tube geometry.

After completing entry of that information (see next section for details), click **OK** to return to the **Tube Wizard**.

Tube Wizard Edits

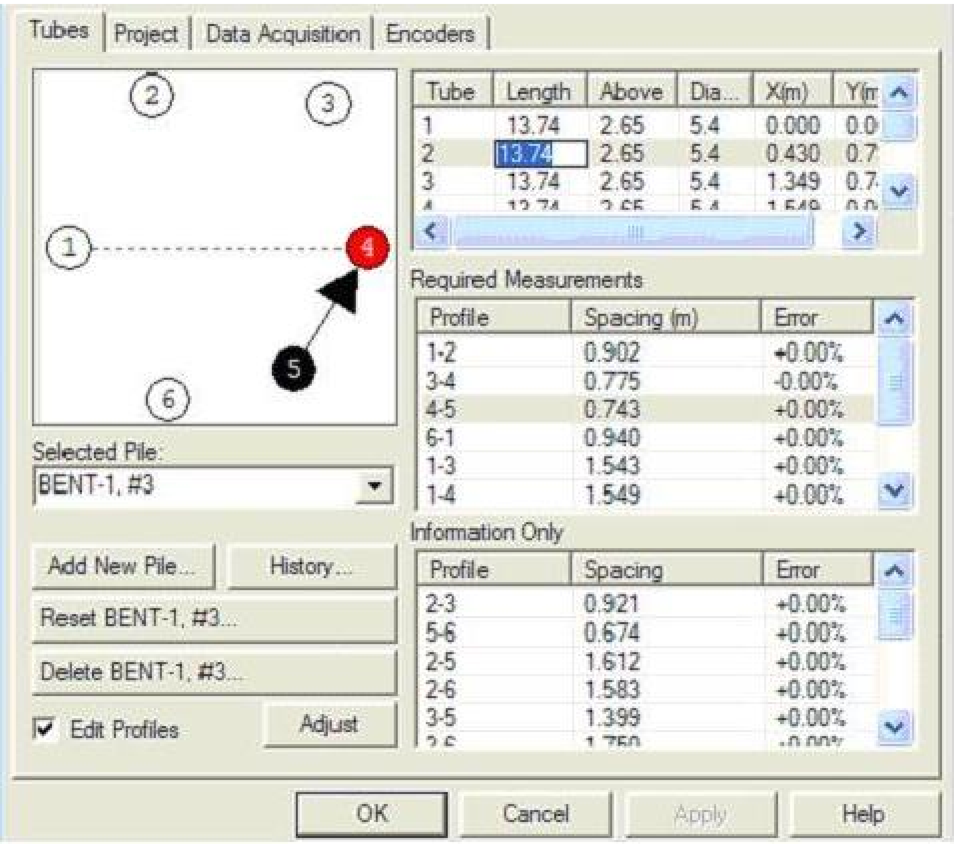


Figure – Tube Wizard

This "Tube Wizard" page shows a summary of information on individual total tube lengths (**Length**) and the length of each tube protruding above the concrete surface (**Above**) and Diameters of the tubes **(Dia…)**. Any of the numerical entries can be edited by (as shown for the Length of tube 2). Double click on any field to edit.

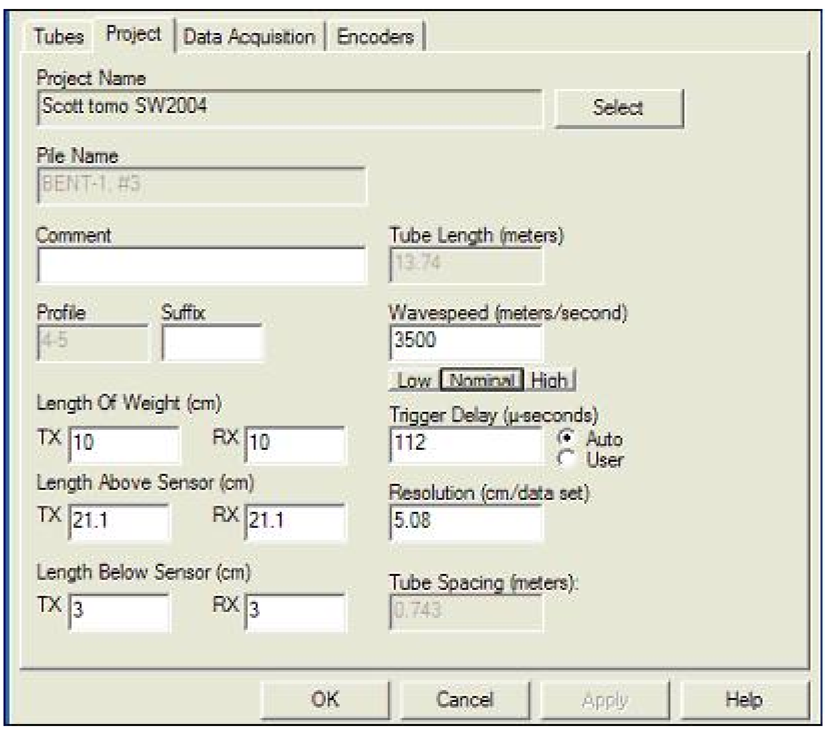
A diagram of the tubes configuration is shown at the left. Clicking on a **Profile** combination in the Table will highlight the selection in the graphical diagram. Note that this defines the next test configuration (which in this example shows the **black** transmitter in tube 5 and the **red** receiver in tube 4). It is important that the transmitter and receiver be placed in the correct tubes (and is essential to do this if the tube lengths and tube stickups are not identical).

Clicking the **History** button generates a listing of completed tests for this shaft, allowing you to assess if the data acquisition has been completed for this shaft (checking the "Auto-display" option will cause this History to appear prior to the tube wizard for each new scan requested).

The various tube combinations are shown under **Required Measurements** in the "**Profile**" column along with the **Spacing** between each of the tube pairs (double clicking any field allows that value to be edited). It is important (e.g. **required**) to enter the correct spacings if you want the wavespeed to be properly computed or if you intend to use the data for tomography analysis. Spacings listed for other tube pairs are shown under the **Information Only** section (they will be calculated from geometry).

Project Information

The second page of setup contains basic project information, most of which is self-explanatory. The **Suffix** is appended to the file name for a tube pair Profile (allows a repeat sounding of a tube pair). The **Comment** will also be attached to the data. (A good comment might be the date the shaft was cast).



The transmitter and receiver probes have weights attached to facilitate lowering the units into their respective tubes. Currently, transmitters and receivers have **Length of**

Weights which are about 7 to 10cm (3 to 4 inches). The position of the actual sensing elements in the probes is documented with **Length Above (Below) Sensor**. Current brass probes have either 16.5 or 18.5 cm (6.5 or 7.3 inches) above the sensing element and 2.5 cm (one inch) below the actual sensing element.

"Wavespeed" is currently used only to estimate the **Trigger Delay** based on the Tube Spacing input. Nominal wavespeeds can be selected by the Low, Medium and **High** buttons ("High" is the normally recommended setting), or any value can be entered directly with numerical entry. The Trigger Delay can be selected either in an Automatic mode or by User entry. **Trigger delay** is the amount of time that the software waits between generation of a sonic pulse and the start of data acquisition for detecting and capturing the received signal. It is suggested that the trigger delay be set to a value that results in the leading edge of the real sonic pulse being about 20-30 percent from the left edge of the graph. This will allow for modest time shifts of the leading edge of the real signal because of tubes that are not parallel (adequate margin to the left of the real first arrival) and will provide enough signal to calculate energy (on the right of first arrival). Suggested values for TD use this guideline:

```
TD = 1E6 * ( tube spacing / wave speed ) - 100
```

Tube spacing divided by wave speed results in the theoretical time for a pulse to travel between the tubes. Multiplying by 1E6 converts to micro-seconds. Subtracting 100 (micro-seconds) offsets the arrival time by 20% (of 500 micro-seconds). Typical wave speeds will be 11000-13000 feet/second or 3600-4000 meters/second. Note that the TD value can not be re-adjusted in post-processing (unlike the following parameters) so **<u>it is crucial that this TD value be set properly during data acquisition.</u>**

> **If unreasonable values (wavespeed to trigger delay) are input, then the first arrival time (FAT) may be missed. If the FAT is not observed, then change the assumed wavespeed value and repeat the test. Any test that does not clearly result in FAT determination is an invalid test (e.g. useless).**

"Resolution" refers to the smallest resolvable linear segment of pile depth to be measured. A data sample will be collected along the pile at this length spacing. Typically, this number will be 5 cm (2 inches), but may be set to a smaller value for short shafts.

Data Acquisition Parameters

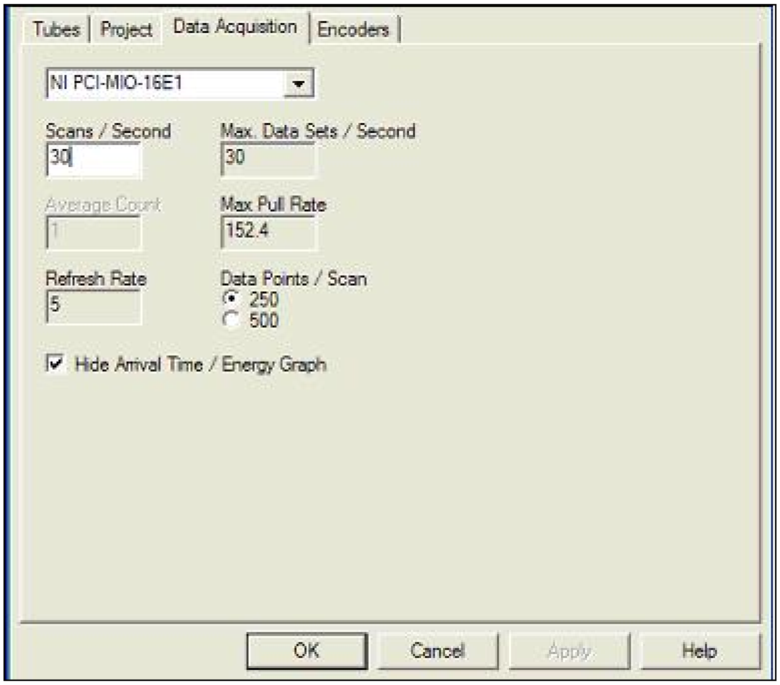


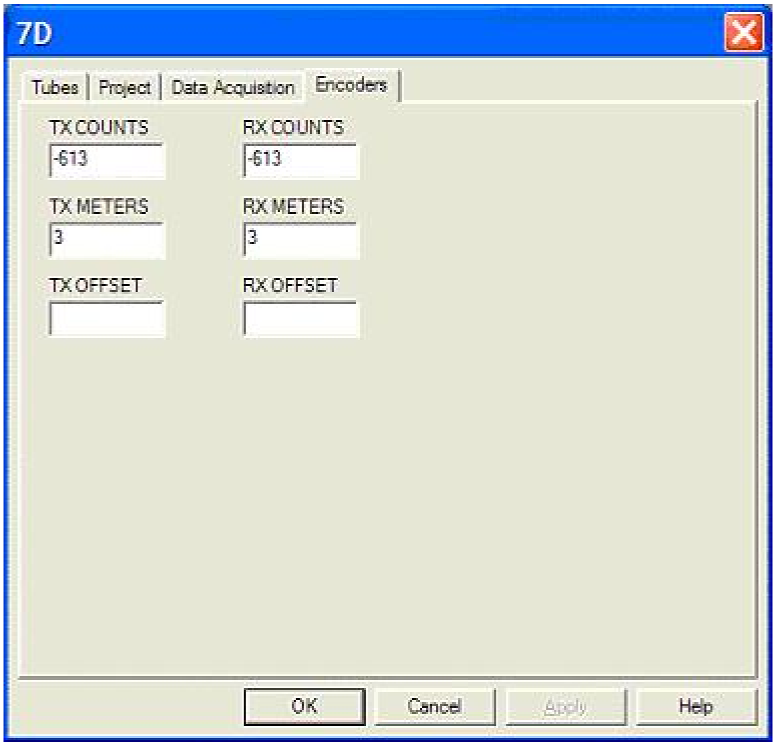
Figure – Data Acquisition Parameters

The third page of setup is for "Data Acquisition". The CHA-QX uses a National Instruments A/D card (NI PCI-MIO-16E1), which **must** be selected in the top drop down menu. The rate of sonic pulse generation and averaging are defined here. The rate is normally set to 30 **Scans/Second** (maximum value allowed is 60)**.** If this sample rate is higher than 30, then reduced power will be applied to the probes. This sample rate means that individual data traces for each depth resolution (e.g. data set) will be typically acquired at a maximum rate of 30 per second. If the sample depth **RESOLUTION** is 5 cm (2 inches), then at 30 scans/second the cables can theoretically be pulled at up to 150 cm/second (1.5 m/second 60 inches per second; 5 ft per second). Since individual data sets have a depth resolution, the combination of scan rate and resolution defines a **Maximum Pull Rate** (inches/second or cm/second) which is displayed when these parameters are changed. The maximum pull rate is also used to regulate a 'speed meter' during data acquisition to guide the user to pull the sensors up the tubes at an efficient rate without losing data. Generally a pull rate of about half the maximum pull rate will result in efficient operation with no "missing data" points.

The **Data Points / Scan** defines the time for each data record. The data is sampled at 500 kHz. Thus 500 data points represents 1 millisecond, and 250 points only 0.5 milliseconds. Smaller number of samples makes smaller data files, but might more easily miss the FAT, particularly for larger diameter shafts.

Click to HIDE ARRIVAL TIME from view during data collection.

Depth Encoder Calibration



The last page of setup is for calibration of depth encoders. The depth encoders are mounted on top of the tubes and have grooved wheels attached to the shafts which guide the transmitter (TX) and receiver (RX) probes up and down the tubes. *Calibration of depth encoders is essential for accurate depth measurements.* The TX Counts and RX Counts values convert the rotation of the encoder into a distance. Values for **TX Counts** and **RX Counts** are constants supplied by Pile Dynamics for each encoder depth assembly. The current encoders shipped by PDI and current cables used require a calibration similar to value (-613; note that the value is negative) as shown above for a 3 meter (TX meters or RX meters) entry. For the motorized cable system, with correct orientation the value should be positive (not negative). For older encoders the value is more like (-1538) but this was limited to then shafts with lengths less than about 60 m. For still older systems and older yellow cables, see note below:

> **Caution:** Due to differences in the cable diameter it is necessary to enter different encoder calibrations depending on the probe's cable diameter (which can be a variable diameter) and the diameter and resolution of the encoder wheel (encoder wheels are all manufactured with nominally identical diameters). The following suggested values are for old and new sensitivity encoders.

Transmitters or Receivers	**old**	**new**
(black, red or green **cable)**	**TX–1538**	**-601**
Receivers with yellow cable (older style)	RX-1553	-601

When connecting the CHA with the encoder wheels to take data, make sure the **R**eceiver (**Red probe**) is connected to the encoder which has a **Red ring** on the connector for the "Y" cable.

The "Simulator" page allows the user to enter various parameters that will affect the creation of simulated data. This is primarily a test feature and is not likely to be useful to you. This page is only shown if the A/D has been set to Simulator (not recommended for normal applications).

New Document Creation

After correct parameters have been entered on all of four the property pages (Tubes, Project, Data Acquisition, Encoders) as describes above, click the **OK** button - a new document will be created. This document will have two re-sizable views split down the middle. The right side view contains up to three graphs: a pulling speed history graph, a sonic map (also called a "waterfall" diagram), and a processed result graph (this optional graph is often hidden: with selected arrival time or wavespeed and calculated relative energy).

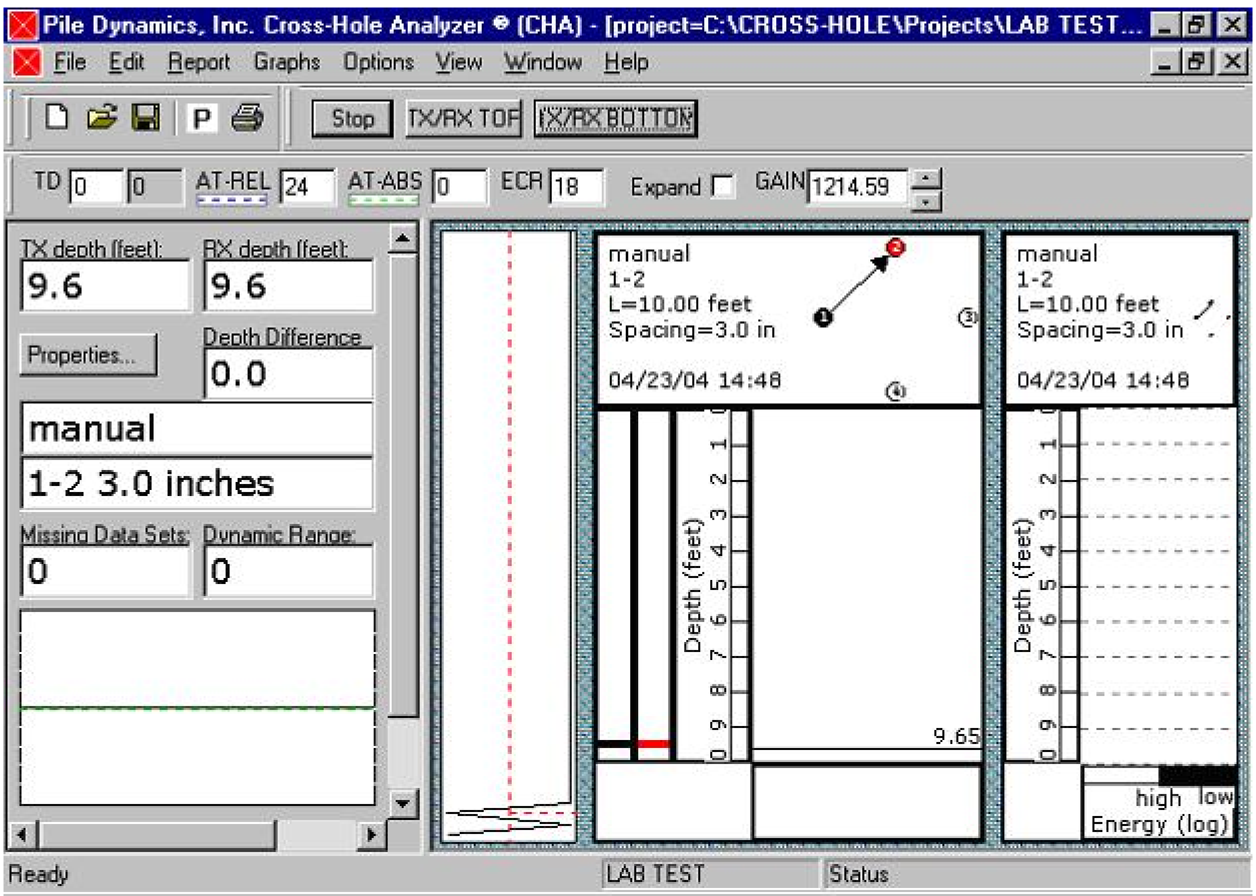


Figure – Data Collection Screen

Data Collection Indicators and Controls

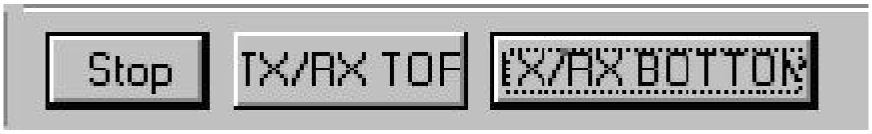


Figure - Data Acquisition Tool Bar #1

The data acquisition tool contains three buttons useful for controlling the depth encoders.

The first button (labeled Start/Stop) toggles the status of data acquisition (active or inactive).

> **When acquisition is inactive, the button is labeled START. Pressing the button when it is labeled "Start" starts the data acquisition process.**
>
> **When acquisition is active, the button is labeled STOP. When data acquisition is active, pressing the button will stop the data acquisition (and allow you to save the acquired data).**

The other two buttons on this toolbar set the reference depth of the encoders.

Referencing the Depth Encoders

The position of the probes in the tubes must be established. Since the depth encoders measure relative distances only, measurement of absolute depths requires that a reference point be given whenever data acquisition is begun. There are basically two methods of referencing the depth encoders: either to the top of the tubes, or to the bottom of the tubes.

One method is when both TX (transmitter) and RX (receiver) are located at the TOP of their respective tubes. Pressing the button labeled "TX/RX TOP" sets the reference depths (e.g. current probe locations) to zero minus the length above concrete of the tubes (if tubes protrude above the concrete, the reference or current locations will be a negative number indicating the probes are above the concrete surface).

> An additional minor adjustment is introduced because the active transmitter and receiver elements in the probes themselves are located near the bottom of the physical probe housing, just above the bottom weights. The probe length dimensions must be properly entered in the Tube Wizard.

The second method of referencing is when both probes are at the BOTTOM of their respective tubes. Pressing the "TX/RX BOTTOM" button sets the reference depths to the total tube length minus the length above concrete (minus probe housing offset and bottom weight length as described in Tube Wizard above).

Both of these methods effectively reference zero depth to the top of the concrete.

> **Accurate measurement of depths requires that carefully measured dimensions of each tube (such as: total tube length and length of tube above concrete) have been entered properly in the tube wizard, and that the probes are in the correct tubes as indicated by the wizard.**

Data Acquisition Settings

Data Acquisition Tool Bar #2

The second data acquisition tool bar contains edit boxes that allow user entry of the critical calculation parameters for arrival time and signal strength. Additional controls are optional and can be later adjusted in data editing.

TD - trigger delay (left edit box in this sequence) is the amount of time that the software waits between generation of a sonic pulse and the start of data acquisition for detecting and capturing the received signal. For best results, the trigger delay should be set to a value that results in the leading edge of the sonic pulse being about 20-30 percent from the left edge of the graph. This will allow for variation of the first arrival time ("FAT" – left edge of the waterfall diagram) because of tubes that are not parallel (adequate margin to the left of or prior to the real first arrival) and will provide enough signal after FAT to calculate the relative energy in the signal. The CHA can automatically calculate a suggested value for TD (if automatically selected in New setup, or hover over this TD edit box to see the suggested value) using this guideline:

> (**TD = 1E6 * (tube spacing / wave speed) – 100**)

Tube spacing divided by wave speed results in the theoretical time for a pulse to travel between the tubes. Multiplying by 1E6 converts to micro-seconds. Subtracting 100 (micro-seconds) offsets the arrival time by 20% (of 250 points which is 0.5 milliseconds), or 10% (of 500 data points which is 1 millisecond). Typical wave speeds will be 11000-13000 feet/second or 3600-4000 meters/second. Note that the TD value can not be re-adjusted in post-processing (unlike the following parameters) ***<u>so it is crucial that this TD value be set properly during data acquisition.</u>*** If the signals do not contain the desired data during data collection, then they cannot be created later. You should adjust the TD value until data and specifically the FAT or left edge of the waterfall is observed (the suggested value is based on an assumed wavespeed; if you do not see data, it may be that the assumed wavespeed or tube spacing at deeper depth is different than input). **TD must be constant for the entire data set (e.g. it must not be changed during the pulling of the probes). If a change is made to TD, the probes should be lowered to the tube bottom and the test repeated.**

The **GAIN of the signal processing circuitry** can be adjusted up or down by means of the edit box on right end of the tool bar. The results of this adjustment can be seen in the strength of the signal data display graph (lower left of the data acquisition screen). Ideally, the gain should be set high enough so that the signal is nominally at least 50 percent of the full scale, yet low enough so that the most of the peaks are not clipped. Larger tube spacings require higher gain. **The GAIN should never be changed during a test. If the GAIN needs adjusted, the entire depth scan must be repeated**.

The above two settings can only be adjusted during data collection, so it is critical that theses two settings be correct during data acquisition. Additional adjustments (which can be adjusted in later editing of the data) are:

AT-REL - arrival time relative threshold. The CHA detects arrival time by locating the peak value of a signal, then using a relative percentage of that peak as a threshold for locating the leading edge. This value can be monitored visually by the horizontal blue dotted line on the signal trace graph. We currently recommend using a number between 15-25 as the starting default AT.

AT-ABS - arrival time absolute threshold. The CHA can use an absolute percentage of the full scale range as a threshold for locating the leading edge. This value can be monitored visually by the horizontal green dotted line on the signal trace graph. We currently recommend using a number between 10-15 as the starting default AT.

These AT values should be set higher than the background noise in the system to avoid early false triggers. The trigger might be on the POSITIVE, NEGATIVE, or ABSOLUTE signal strength (Absolute is preferred).

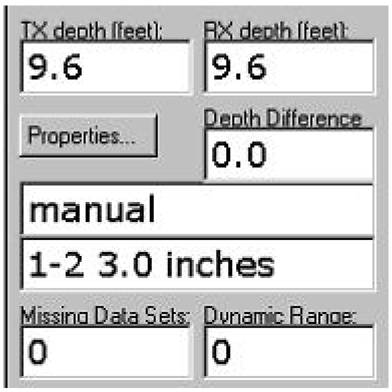
> The detected arrival is set at the first time the signal exceeds both the AT-REL and AT-ABS thresholds. The detected arrival time is shown as the left vertical dashed red line on the signal trace graph (lower left of the screen).

ECR - energy calculation range. ECR is simply the number of sampled data points used for integration of the acquired signal voltage. The signal received by the sonic pulse sensor is a complex combination of direct signals and reflections. Values of 50 or 60 are often used (low values of 12 to 18 are the suggested lower limits). ECR is shown as the time between the pair of vertical red dashed lines in the signal graph.

AT and ECR can be completely re-specified in post-processing and are only important during data acquisition if you require accurate real-time calculation of arrival time, wave speed and energy.

The **'Expand'** check box is used to increase the resolution of the sonic map display in the vertical direction. This is most useful for very long piles where the entire depth cannot be displayed with sufficient resolution, and is recommended for when the automated cable system (MCS) is in use to help keep the probes tracking at the same speed. For example a 50 meter pile with data resolution of 5 cm would require at least 1000 pixels in the vertical direction to display every data set - this would not be possible on a 640x480 screen. If the expand button is checked, CHA will allocate a minimum of 4 screen pixels for every data set in the vertical direction and then automatically scroll to the proper current location.

Profile Monitor Window

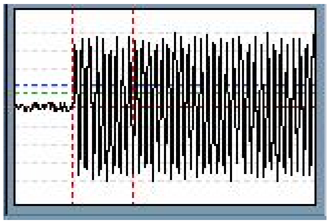


Information Parameters

The left side view during data acquisition displays several parameters that are useful when acquiring data. These include **transmitter TX and receiver RX depth locations** (in large font), and a **Depth Difference**, which is the difference between the TX and RX locations (useful if the probes are to be kept at a certain vertical offset, either positive or negative, as when a defect is found and its precise location is to be investigated).

Next in the middle left is the current pile name (e.g. in this example it is called "manual" for this CHA manual documentation), and tube pair designation (e.g. 1-2), with the spacing between tubes (3.0 inches – an unrealistic value for normal testing).

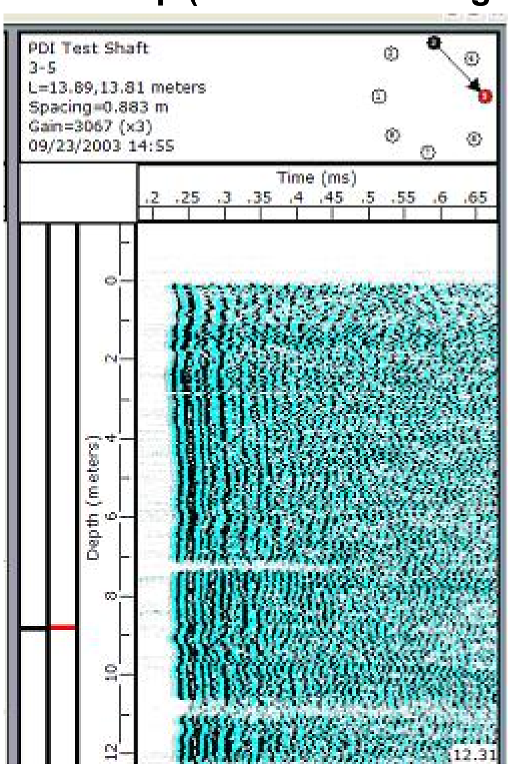
This information can be edited by pressing the "**Properties**" button. CAUTION: If you edit the tube pair designation, be careful to follow the "format" and include the hyphen in the final label (or else the sorting will be disabled). It would be preferred if there is a mistake in either the name or the tube pair labels or spacings that you stop data acquisition and return to the NEW input and correct the value and then proceed. Changing values in Properties can result in problems for the careless….
The next display is the number of **Missing Data Sets**. This reports the result if the cable is pulled too fast and the signal is therefore skipped for a particular data set. Obviously, if a data set is missing, stop pulling, and lower the probes until the data set is recovered and the value returns to zero, and then resume pulling the probes. Good accepted practice is to result in scans with zero missing data sets.



The Data Acquisition Signal

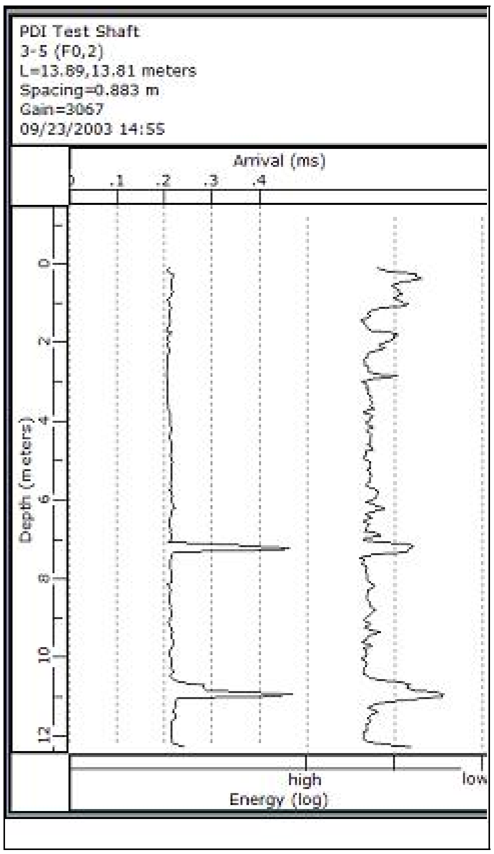
The **current actual data acquisition signal** graph (250 data points, or 500 data points, either sampled at 500 kHz) is displayed at the lower left. This trace is one of the individual data sets that are nested with depth to comprise the "sonic map" and is offset by the trigger delay (TD). The intensity of the signal voltage levels of this trace is related to the strength of the color in the Sonic Map (also traditionally called the "Waterfall Diagram"). The graph represents a range of –10 to +10 volts (center is zero). The peak signal value is shown in the **Dynamic Range** window as a percent of full scale. This may help when adjusting the GAIN.

Sonic Map (or "Waterfall Diagram")



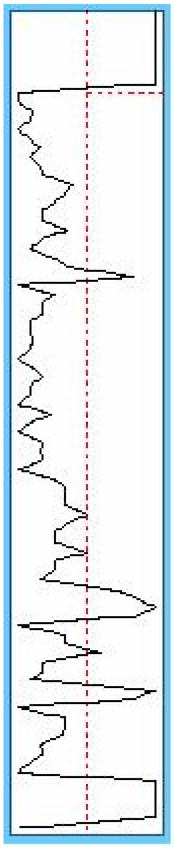
The **"Sonic Map"** is a three dimensional display of acquired data (center main graph). It represents a "nesting" of the individual data signals from all depths. The **vertical axis is the "depth"** of the pile (as entered on the properties page above) - there is a graphical depth encoder position display on the left side of the sonic map, one for the transmitter and one for the receiver. The small horizontal black bar represents the current position of the transmitter, and the red bar the receiver position with respect to the depth scale. The **horizontal axis is "time"** - the total width of the axis is 500 micro-seconds (250 data points sampled at 500 kHz), or 1 millisecond (for 500 data point acquisition) and is offset on the left by the user specified trigger delay (TD) in micro-seconds. The **third dimension (out of plane) represents** "**signal strength"** detected by the receiver and is distinguished by "color" on the sonic map. The default colors are white for 0 volts, black for -10 volts and green for +10 volts. Default colors can be viewed or modified by right-clicking on the sonic map and selecting 'Colors' from the menu (if you want yellow instead of green, add "255" in the RED field). **The color intensity can also be modified by the SCALE selection (accessed by right clicking on the waterfall diagram).**

The Energy / Arrival Time Graph



At the right of the sonic map (at right edge of screen) is the **"Processed Results" graph**. Processed results include either "arrival time" or "calculated wave speed", and the "relative energy". The software calculates **"Arrival Time"** by using the AT threshold values to locate the leading edge of the transmitted sonic pulse in the acquired data, then adding the "trigger delay" (if any) to this value. **"Wave speed"** is calculated from the "tube spacing" divided by the "arrival time". **"Energy"** is calculated by integrating the absolute value of the acquired data over a user-specified interval (ECR - energy calculation range) which is specified in sampled data point counts. Energy is measured as volt-seconds, but actual values are not important and the energy is therefore only displayed in "relative" terms on a log scale (low values to right, and high values to left; the relative log scale grid depicting "factors of 10" is shown). This graph can be hidden during data acquisition (recommended) by right clicking the graph and checking the **Hide** control in the Tube Wizard.

The Pull-Rate Indicator



The "**pull-rate indicator**" shows the rate at which TX/RX probes are being pulled or lowered. The center position on this bar (indicated by the vertical red dashed line) indicates maximum pull rate according to the sample rate and sample depth resolution entered on the data acquisition property page above. If the current graph is to the left of center, it indicates that TX/RX could be pulled faster and if it is to the right of center, it indicates that occasionally data will be lost. The optimum efficiency for the pull rate is just left of center.

6. Profile Editing

Data files may be edited to fine-tune the processing parameters.

From the **'File'** menu, select **'Open'**. Select any of the '.chx' files in the current project directory (or change the directory from the Open dialog box; or using Project / Open from a gray screen) and open it. The views are similar to those used during data acquisition. The signal for an individual depth is shown in the upper left, the processed results in the center, and the waterfall diagram (sonic map) at the right. However, controls at the left under the signal have been optimized for editing.

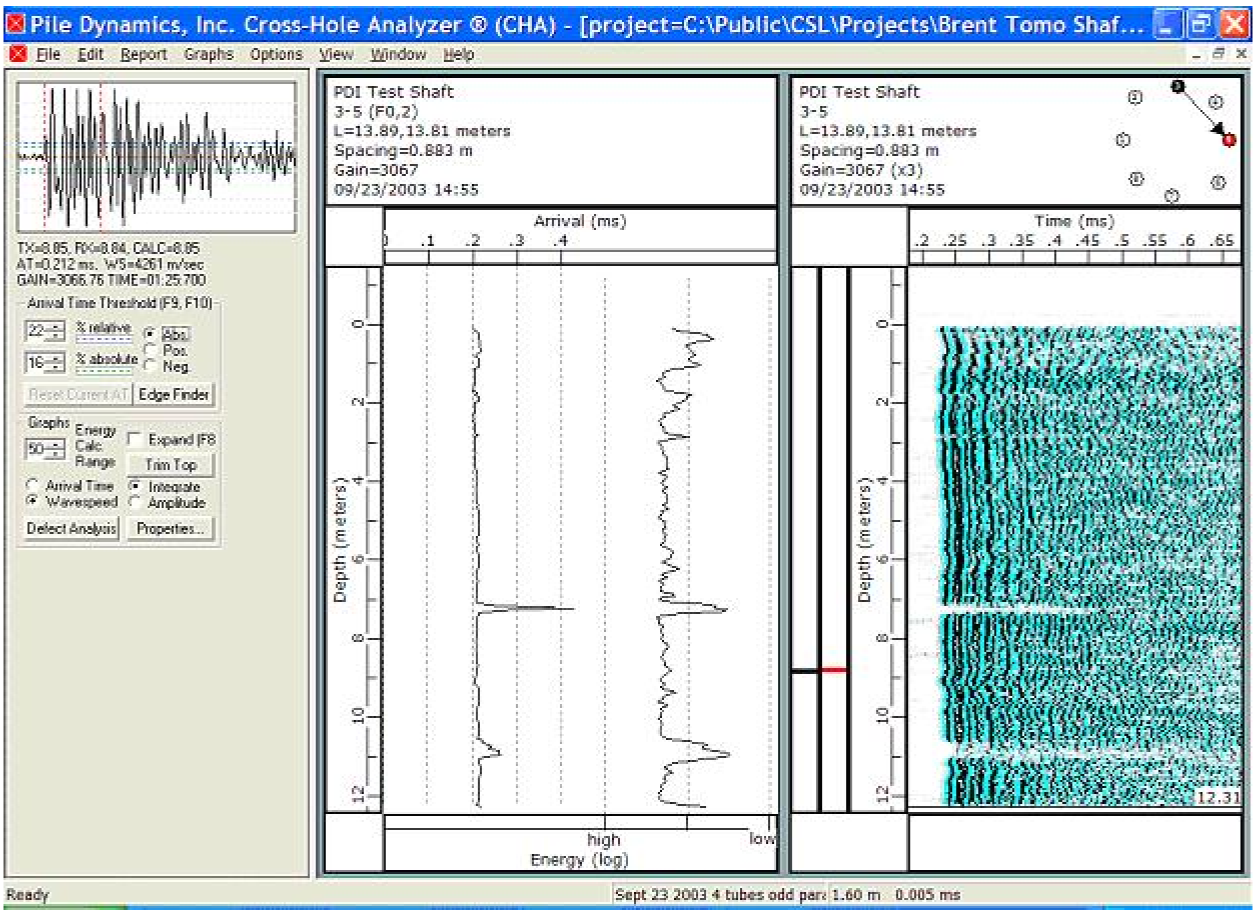
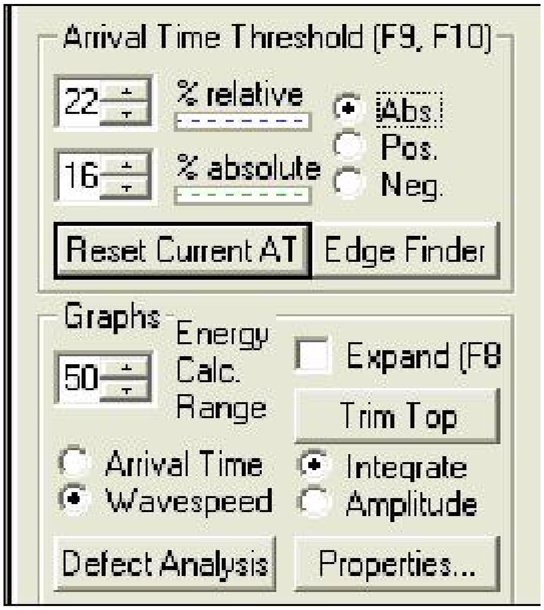


Figure – Edit Display Screen

You can drag and drop the **vertical Windows divider** control (located just to the left of the processed graph); moving it toward the right allows resizing the display to reveal all the left section controls.

Automatic Adjustments



The **Arrival Time Thresholds** (AT-REL and AT-ABS) and **Energy Calc. Range** (ECR) values (as described in the data acquisition section of this manual) can be **adjusted for the current profile** by either direct entry or by clicking the up or down arrows associated with each quantity. Thresholds can also be adjusted down with the F9 function key, or up with the F10 function key. The effects of these adjustments are immediately displayed on the processed results. The adjustment should result in as smooth a curve as possible. The polarity of the thresholds can be assigned as positive (Pos), negative (Neg), or absolute value (Abs). The absolute value polarity is preferred.

Processed signals can be shown as Arrival Time or Wavespeed, and signal Amplitude or Energy (Integrate). Checking the **Expand** box causes the vertical scale to isolate on a section only of the shaft (can scroll up or down).

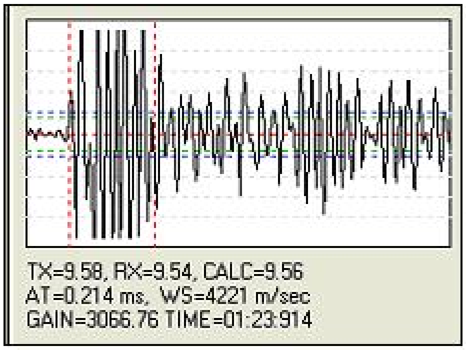


Figure – Signal at Selected Depth, With Numeric Information on the Signal

Left-Clicking on either of the two right graphs (processed data or waterfall) will go to the corresponding depth location clicked. The signal graph at top left will then display the raw signal acquired for the depth selected. The arrival time, computed wavespeed, gain, and time stamp for this particular data are shown numerically below the signal. To move up or down through the profile, you can click at a different depth location, or simply use the **PgUp** and **PgDn** keys. The depths of transmitter TX and receiver RX probes are shown numerically below the signal graph, and are shown graphically with the bars on the waterfall diagram (sonic map). Note the receiver is the red bar.

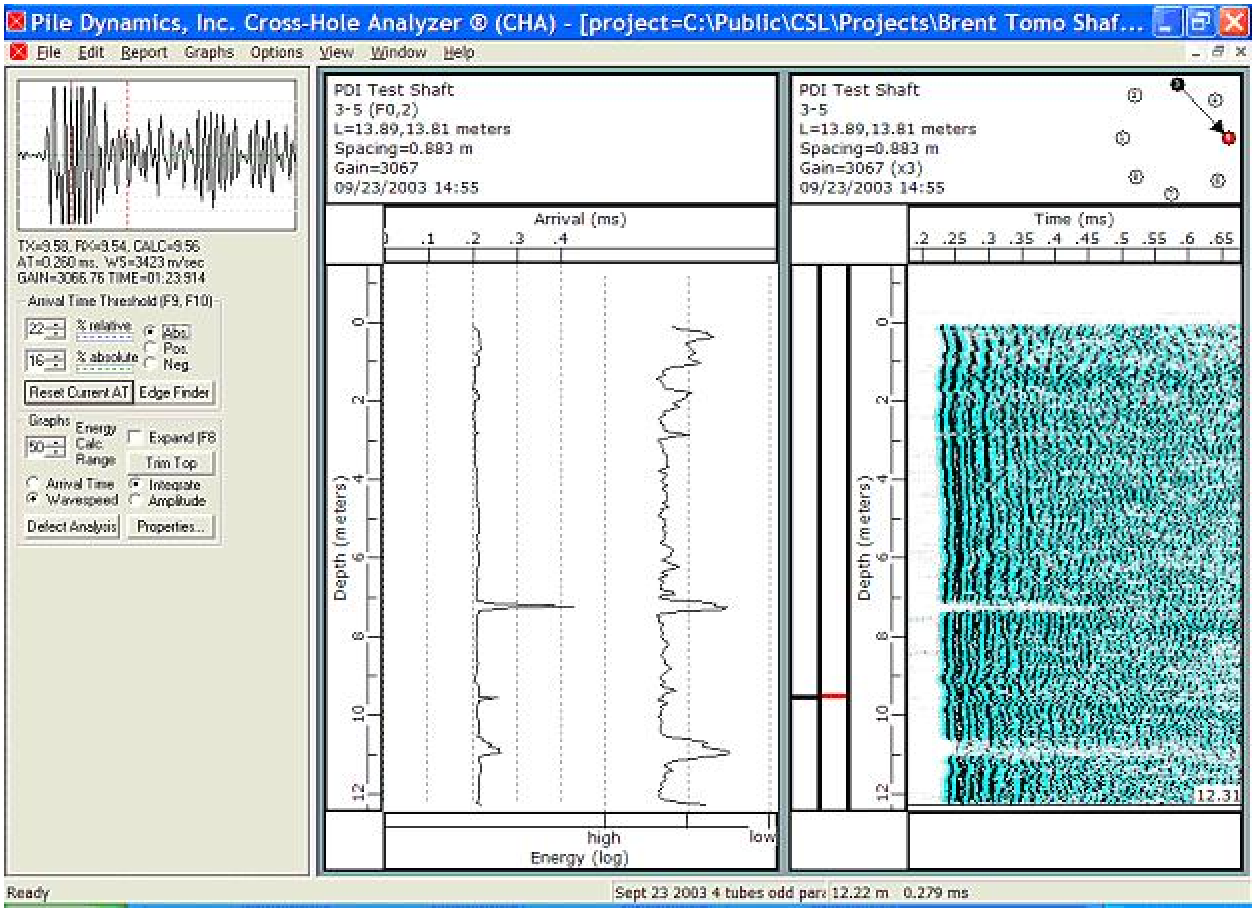


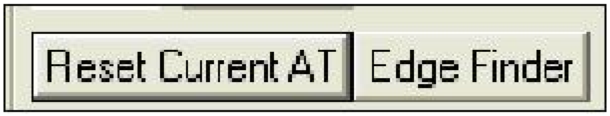
Figure – Edit Display Screen

Right-clicking on the sonic map allows you to **intensify the colors** using the **Scale** selection. You can further specify your own color scheme for the waterfall sonic map by clicking on **Colors**. Setting the +10 v inputs each to zero will produce Black. Setting all the zero volt inputs to 255 will produce White. Setting the –10 v inputs to 255 for Red and Green, and zero for Blue will produce Yellow (you can experiment with other colors to satisfy your own aesthetic desires; Yellow photocopies fairly well as on B/W copiers).

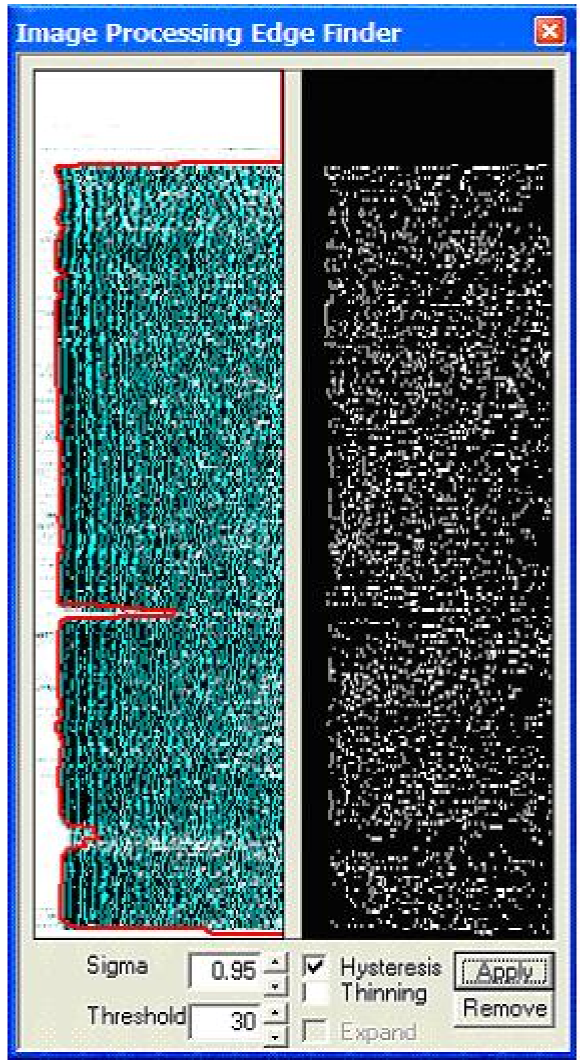
Right-clicking on the processed data graph allows you to "**Auto-Scale**" the graphs. The "individual and group selections relate to the Report section of the program.

Right-Clicking on either of the two right graphs will allow you to **Copy** the data onto the clipboard so it can be pasted into a spreadsheet for further processing (this same feature is available clicking **Save Raw Sonic Map Data)**.

Edge Finder



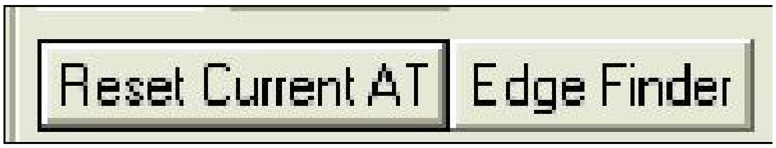
Clicking the **Edge Finder** button activates a special image processing tool to assist in finding the first arrival time, FAT. (When using Edge Finder, the AT Thresholds are disabled and are grayed out.) The dialog box displays the sonic map on the left and a processed image of the map on the right. The controls at the bottom of the box allow some adjustment by the user to select the first arrival time shown as the red line at the left edge of the sonic map. The **Threshold** is typically between 15 and 30 for good data, but is limited a maximum value of 40. **Sigma** will typically be between 0.3 and 0.6 for good clean data. For "noisy" data, the Threshold and Sigma will be larger (although Sigma greater than about 1.2 is discouraged). **Hysteresis** is usually checked. **Thinning** often makes little difference in FAT, but occasionally is useful. When FAT has been adjusted, click **Apply** to accept. For particularly noisy data, it may not be possible to find a perfect combination of parameters and some manual override selection will be necessary. **Remove** can be used to return to AT Threshold selections. User can use the relative energy and his judgment to decide how aggressive to be on the selection of parameters.



Right clicking the edit screen waterfall diagram, and then on FAT, allows this red FAT line to be included in that diagram for all output.

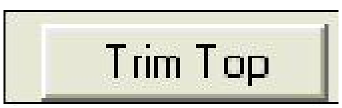
Manual Selection of Arrival Time

If the automatically selected arrival time (from your Arrival Time Threshold selection) for any depth seems to be in error, you can click on the raw signal graph (upper left) itself **to manually select the arrival time**. In general the automatic selection usually does a sufficient job and thus manual selection should be limited to only a few depth locations. You can reset all manually selected arrival times back to the automatically chosen locations with EDIT / RESET ARRIVAL TIMES. You can reset individual arrival time selections with the **Reset Current AT** button.



Trimming Pile Top

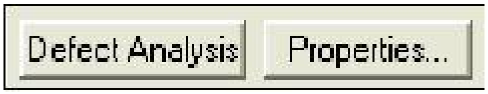
To remove the unwanted to processed result from the pile top (due to tubes protruding above the top of concrete, or lack of water in tubes), click on the sonic map at the location where the real data begins (or use the PgUp and PgDn to locate the top most real signal). Next click on **TRIM TOP** and the processed result above that location will be deleted. Note the real data remains so the top location can be restored, so can be trimmed by process of trial and error.

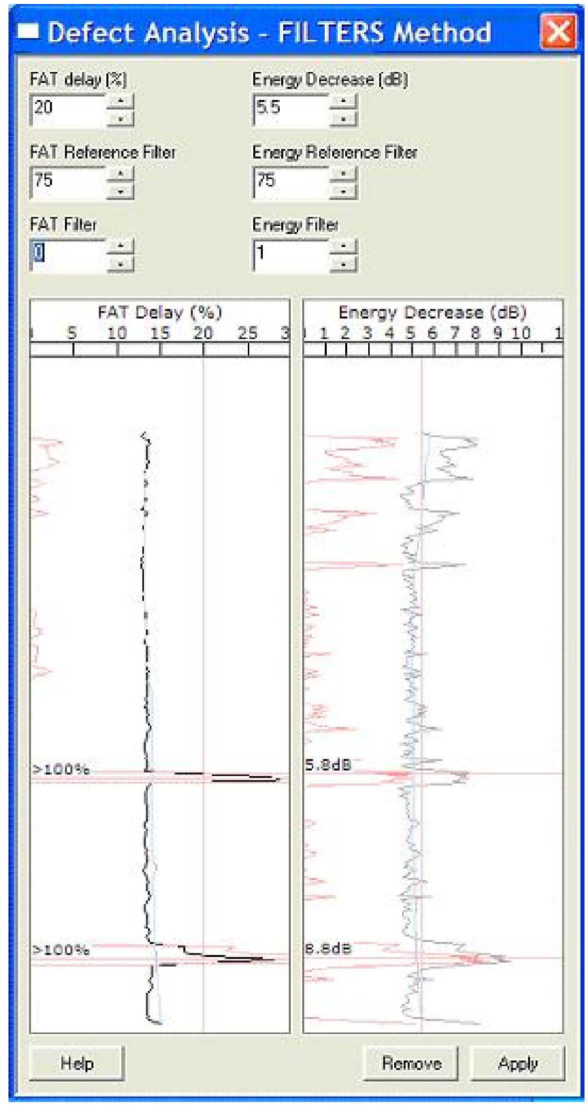


Result Selection

The processed FAT can be presented as either **arrival time** or **wave speed**. The wave speed is computed from the assigned tube spacing divided by the arrival time. Note that this assumes that the tubes are parallel (since you can only measure the location at the pile top). If the tubes are not parallel then the wave speed processed result will be in error (and may show unusual looking results). Thus great care in placing the tubes in construction will aid in interpretation of results. The processed signal can be presented as either **amplitude** or relative **energy (integrate).**

Defect Analysis





Clicking the **Defect Analysis** button creates a dialog box with user adjustable controls. The **Help** button gives a full listing, or hovering over any input box gives the help and suggested input for that box. User can determine the thresholds for "defects" from setting the **FAT delay** and/or the **Energy Decrease**. The two **Reference Filters** are the number of points in a consecutive running average (smaller values follow the measured signal more closely while larger values make the line straighter; values of 75 are a good starting point and work for most applications). The curves themselves can be "filtered" (see description of **Properties**). If the difference between the real data (either FAT or Energy) and the Reference Filter curve exceeds the user input threshold, a defect is declared and the location shown graphically (horizontal red line) and numerically. Pressing **Apply** places the graphic defect locators on the main processed result curves, and numerically in the defect table. Pressing **Remove** deletes these indicators.

An alternate defect analysis method is used in China that uses statistics on both the **wavespeed** and the **amplitude** curves (not energy). This method is accessed by clicking EDIT / DEFECT ANALYSIS METHOD / STATISTICS. In this method the average (wavespeed or amplitude) and standard deviations are computed. If the value of wavespeed is less than the average minus some multiple of the standard deviation (where the multiple depends on the number of samples in the scan), then a defect is determined. The method works best for parallel tubes. If the tubes are not parallel, then the function has more difficulty. Results for the same scan used previously are shown in the following figure. An additional curve for the "PSD" method is shown in the middle of the processed results. PSD is a graphical aid to locate defects and is activated (for this statistical method only) by checking PSD after right clicking the graph.

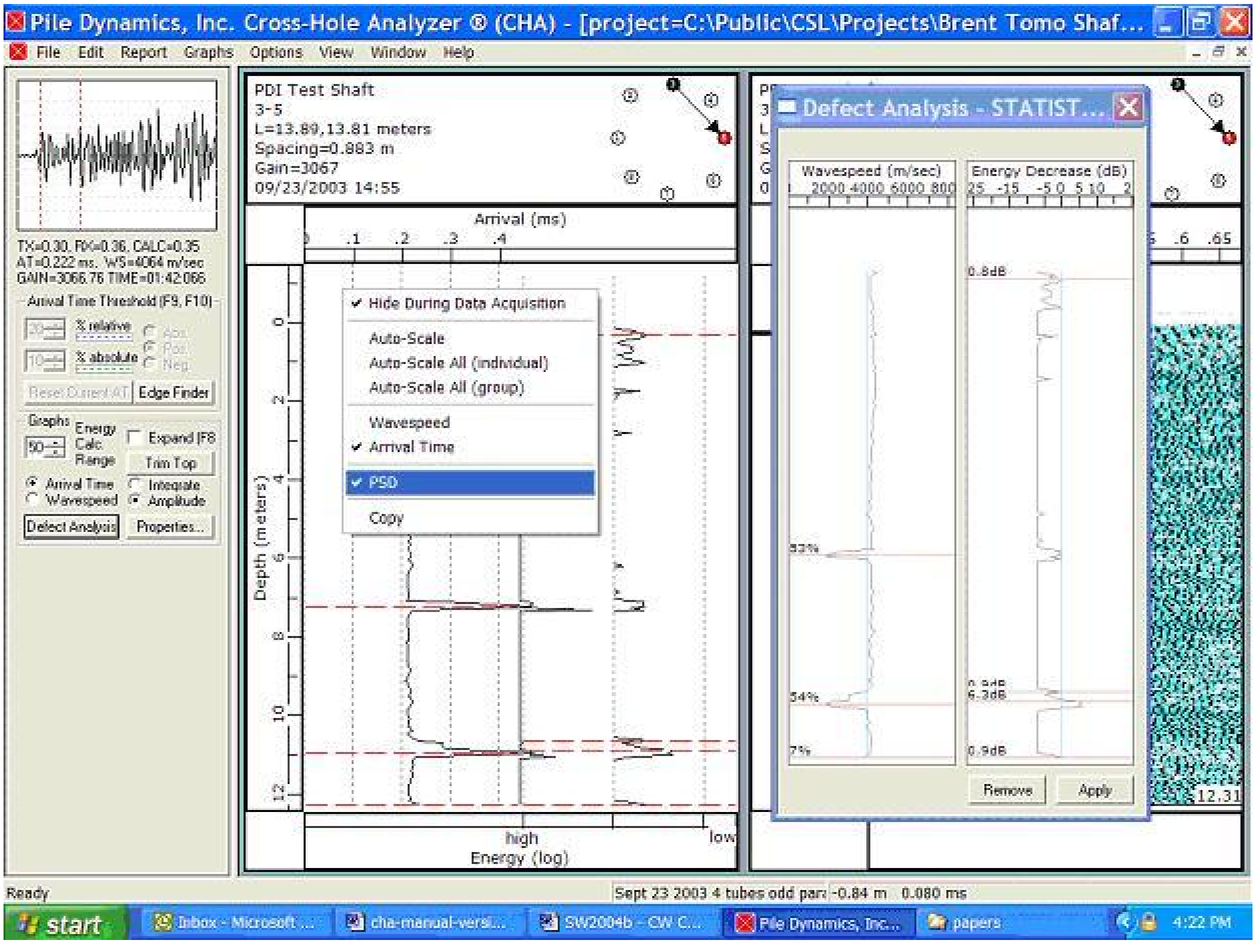
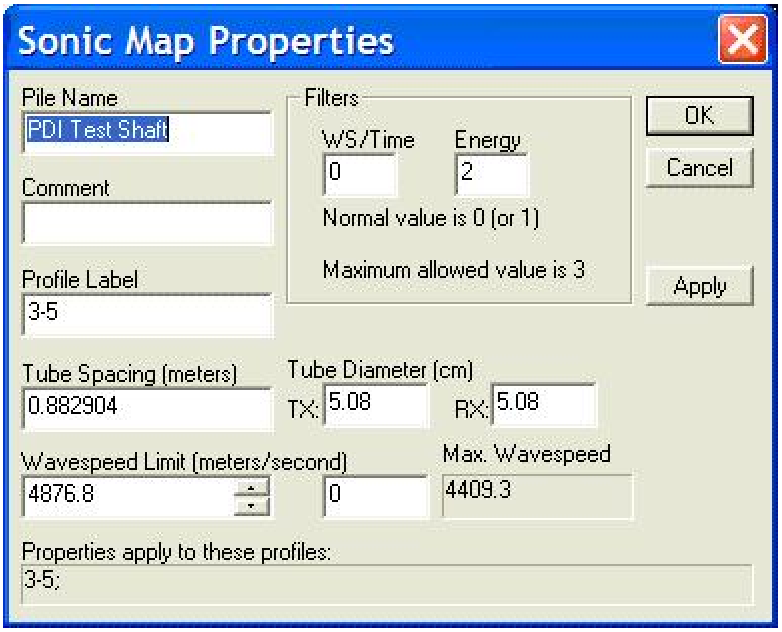


Figure – Screen Showing Chinese Statistical Method

Properties



Pressing the "**Properties**" button allows editing of the **Pile Name** and **Profile Label** or **Comment.** Caution: make sure a label change is justified, and it is critical to not change the Profile Label format (with the dash). The **Filters** (a multi point smoothing) can be adjusted. Such filtering, while allowed, is discouraged for the WS/Time since a local defect could be hidden if smoothing becomes too severe. **Tube Spacing** and **Tube Diameter** can be altered (but again changes should be justified). The **Wavespeed Limit** (and the following box shows the number of data points in violation of this limit) can be adjusted. This adjustment might be needed if tube spacings were not accurately input, of if the tubes are not parallel. The "Max. Wavespeed" for any point in the data set is shown as a guide. Click on **Apply** to accept changes.

Expand

Checking the **Expand** box, increases the vertical scale visual resolution.

Data

The actual data in numeric format can be accessed by EDIT and then COPY ARRIVAL TIMES / ENERGIES. This data can then be pasted into spreadsheets for further investigation and manipulation.

Saving Edits

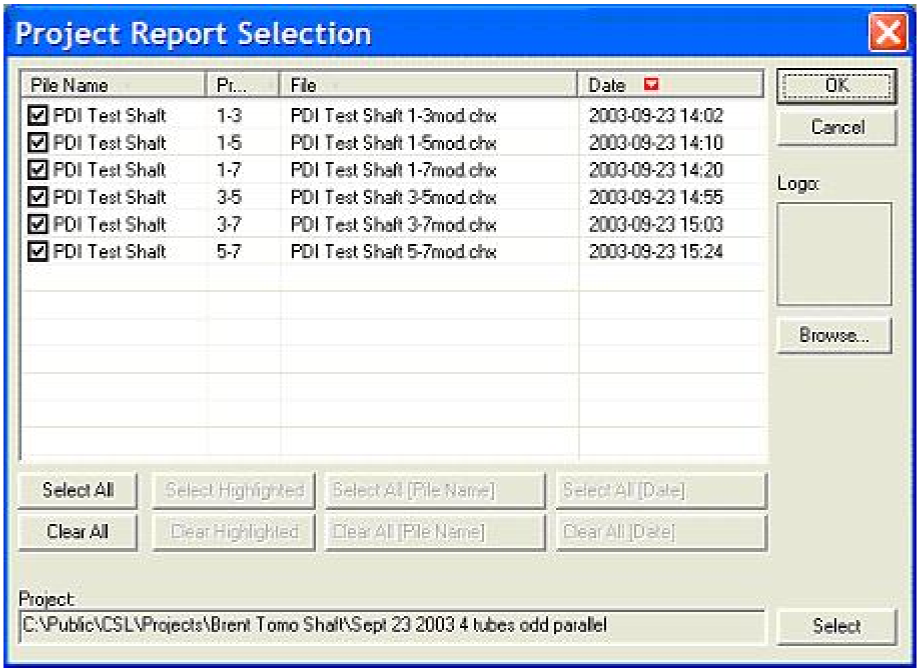
Once edited, you should **save the file with your changes** as you want them so they appear in the Report correctly. Access Save functions through the FILE menu (or press the SAVE icon (traditional floppy disk icon).

7. Reports

Creating a New Report

First close all editing windows (screen should then appear as a blank gray screen) prior to Report Generation.

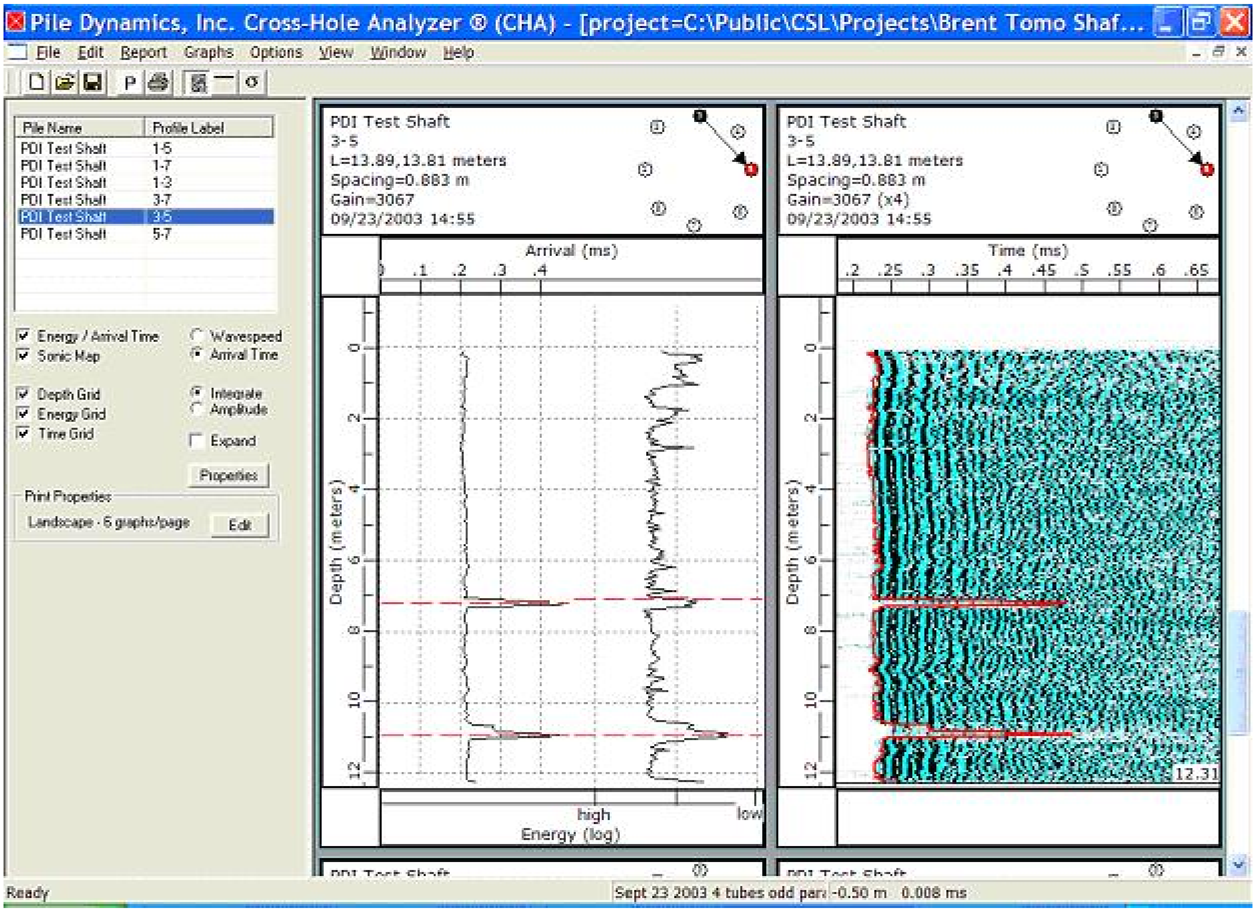
From the **'Report'** menu, select **'New Report'**. This opens the "Project Report Selection" dialog box. This dialog box has a logo **Browse** button that allows you to select your company logo (in bitmap format) for use on the report output.



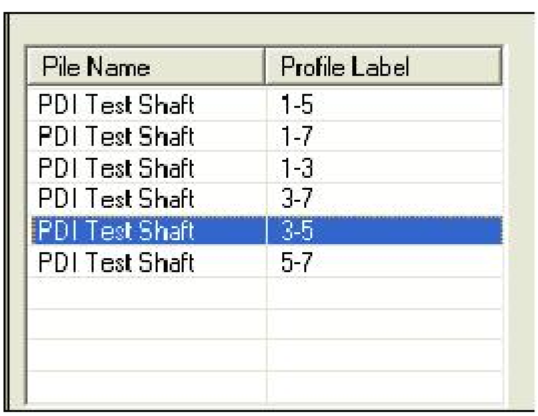
This dialog box lists all data files in the current project. These files can be temporarily sorted by clicking on the column headings. You may select or de-select files as appropriate by either clicking the check box for the individual files, or clicking a single file to highlight that particular file, or using the "group keys" at the bottom to either select or clear (de-select) scans matching the criteria. Clicking on the data highlights the files (multiple files can be highlighted). If multiple shafts are in the current project, or were tested on different days, highlighting ONE file in one shaft will activate the [Pile Name] and/or [Date] group selection functions.

When the desired files (tube pair scans) have been selected, simply click the **OK** button to begin generating a report.

If no files are present, then the PROJECT name [or path] has been lost, or the csl.project file is missing (or does not contain the information for the piles). You might be able to use PROJECT / OPEN to find the missing data path.



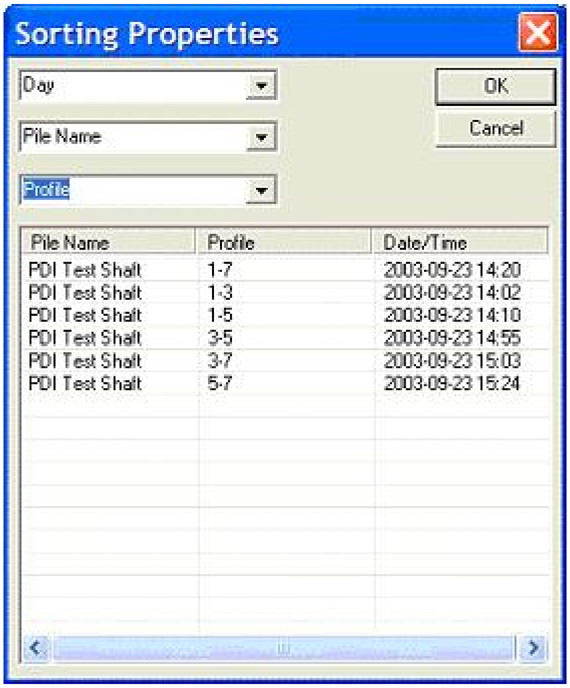
One data set from among the selected files is then graphically displayed. In the upper left box, a different graph to be viewed can be selected by highlighting the file containing the **Pile Name** and **Profile Label** that you wish to view.



With a **right click** on this scan list (and using the resulting dialog box), you can insert other scans or delete the highlighted scans. You can also **EDIT Document**, meaning that you can adjust the parameters for the selected scan (and then save the edits). Clicking **Properties** allows you to change some information and to smooth the curves.

Sorting a Report

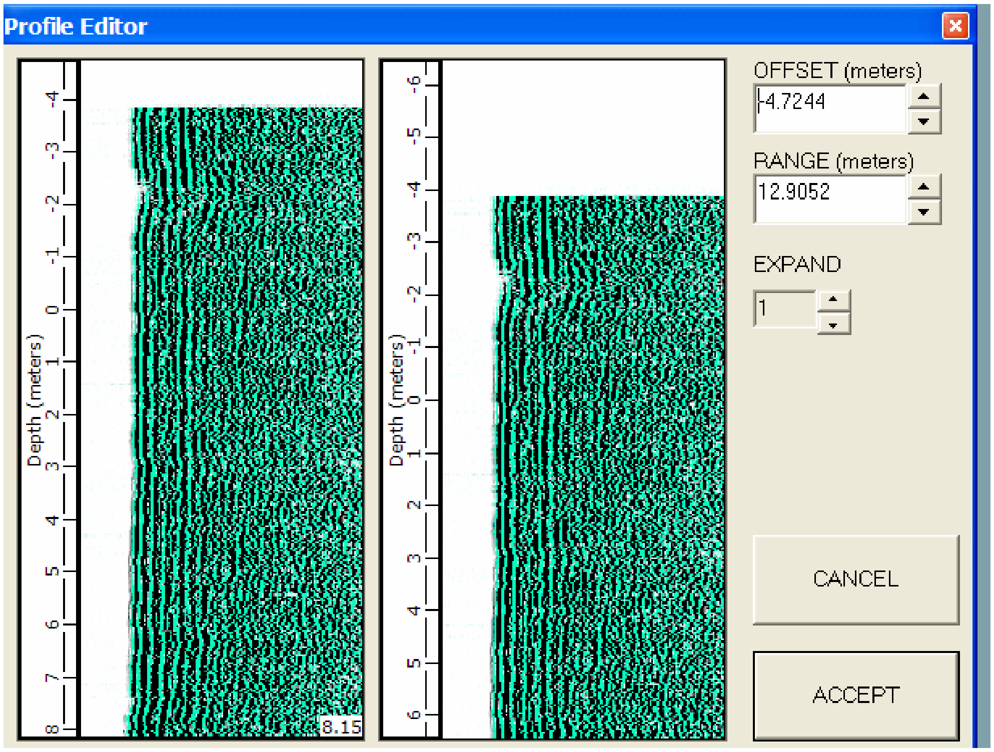
Also from this right click of the scan list, you can **Sort** the profiles. The dialog box provides up to three sort criteria. Usually sorting is prioritized by "profile" first where the perimeter scans are given priority (in order) followed by major diagonals. It is again mentioned that the Pile Label must be of the proper format (e.g. removing the hyphen between tube designators will disable the search ability).



Editing a Report

If the top of concrete appears to not correspond to "zero" depth (perhaps because of faulty measurement, or because top of concrete was below water or ground surface and could not be measured), then the "offset" might be adjusted. This adjustment assumes certain fixed conditions; namely, the tube lengths were correctly individually measured and entered, and the tube stickups were all measured above some uniform reference depth (e.g. ground surface for buried shafts) and were also correctly entered. So in effect, you need to just redefine the ground surface elevation (defined as the initial zero) to the top of the concrete (which you want to be called zero). Note you very well might want to keep the ground surface reference as zero so that the toe elevation is better known.

To change to top zero reference, select EDIT / PROFILE or right click on the Profile in the upper left selection box and choose EDIT_OFFSET/RANGE.

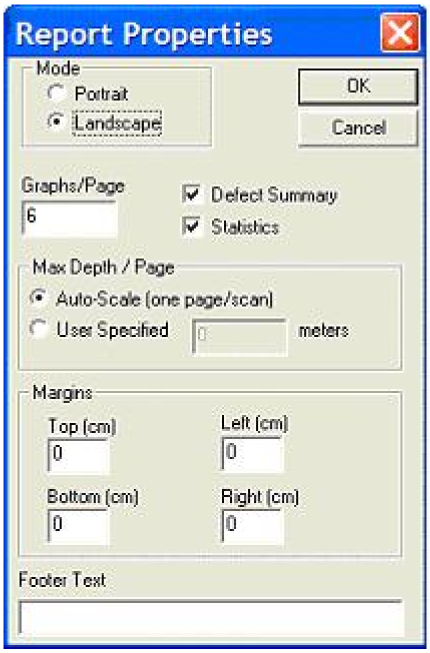


In the above example, the PROFILE EDITOR will allow to change the OFFSET until the top of the apparent data (about at -4 in the graph) shifts to the zero location. The bottom (initially at 8.15 in this example) will have the same offset applied so it will become about 12 when the top is shifted to zero. EXPAND may help you locate the pile top with more precision for longer shafts. RANGE allows you to ADD (increase the total length shown, or DELETE unused pile top points (whitespace with no data points). Click ACCEPT to implement your changes.

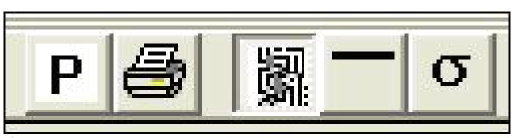
Preparing a Report

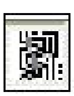
What will be printed in the report can be selected from the check boxes below the pile list. You will probably plot **Energy/Arrival time** and the **Sonic Map**. Both results are complementary and recommended (and are required by ASTM D6760). The Arrival Time can alternatively be plotted as computed **Wave Speed**, and **Energy** (**Integrate**) as **Amplitude**. Grids may be added or deleted as desired. The results of the processed data graph (Energy and/or Arrival Time) can be "scaled" to improve resolution and appearance with the **Auto-Scale** feature (accessed by right clicking the processed result graph). The graph shown can be scaled as the only one scaled, or all graphs selected (highlighted) scaled but using a scale that is best for each individual graph, or all graphs can be scaled to a single scale selection that best fits all graphs. **Properties** can be adjusted (but the user is cautioned, and it is probably better to have done all adjustments from the Edit screen). Selecting GRAPHS / HEADERS from the MENU allows deleting some header items (not recommended for most applications since it contains valuable information). Selecting GRAPHS / LINE_STYLES allows customizing the processed result line styles and colors.

Clicking the **Edit** button for **Print Properties** allows you to specify either portrait or landscape printing, the margins, and the number of graphs per page (4 recommended for portrait and 6 for landscape for normal resolution). The page margins can be set. The depth per page can be selected so that the graphs all fit on a single page (Auto-Scale) or with a "User Specified" depth increment per page if more vertical resolution is desired (e.g. if set to 25 for a 65 m shaft, then three pages of printout would be generated for each scan). A "Footer Text" can optionally be added to all plots. User can select if the numerical **Defect Summary** and **Statistics** (e.g. average wavespeed per scan and C.O.V.) are to be included in the final report.



Right-Clicking on the Sonic Map itself will allow you to **COPY** the map to the clipboard and later paste it into your report as a graphic image. Right-Clicking on the processed result will allow you to COPY that graph to the clipboard and paste it into your report.



Clicking  displays the sonic map. Clicking the overscore button displays the defect analysis results, while pressing **σ** shows the statistics.

The **"P" icon** allows you to **Print Preview** the result (also accessed by FILE / PRINT_PREVIEW). If acceptable, you can simply print the result. It should be noted that the header for each scan contains the pile and tube pair designation (with "filters if specified), the tube length (both tube lengths if different), tube spacing, the electronic gain (and the “Scale” multiplier for the sonic map: e.g. “x4”), and finally the date and time of data acquisition. The size of the font is determined from a gray screen by pressing SETUP / SCALE_HEIGHT.

Saving an Existing Report

A “report” is a series of individual scans saved together into a single file (CHR file). These files are obviously considerably larger since all the data is still accessible. With a report being already created by the report generator, it may be saved by File / Save As. This allows faster access to a finished project result than creating the report fresh a second time.

Opening of Existing Report

Previously saved “reports” (CHR files) can be opened from a (blank) gray page using **REPORT / Open_Report.**

8. Interpretation of Results

If the logs of processed results are smooth and at a time corresponding to a reasonable wave speed in the concrete for the entire length of the scan, then no defect is apparent. Defects would appear as either a delayed arrival time (or a reduced wavespeed since wavespeed is computed from arrival time and tube spacing), or a reduced relative energy, usually over a localized section of depth along the shaft or at the toe. Since the tubes are not necessarily straight or parallel (the spacing is only measured at the very top of the concrete; PVC tubes are particularly susceptible to local distortions), an absolute minimum value of wavespeed is not usually a good criteria. If the wavespeeds determined are consistent for all tube pair combinations with depth, then the tubes are likely parallel and the wavespeed more reliable. It should be noted that the wavespeeds for the main diagonals are more reliable than wavespeeds from the perimeters since the distance or spacing is more constant. Wavespeeds for the main diagonals that show very low wavespeeds might also indicate low concrete strength.

A better measure is to look for “local” delayed arrival time or decreased wavespeed with more than some percentage (e.g. 10 or 20% change) over some relatively short depth change.

Defects can also be determined by the processed energy graph. Set ECR to some value (almost any value is acceptable as it is a RELATIVE value anyway) between 20 and 50 (if you change ECR you generally see that the SHAPE remains fairly constant, but the MAGNITUDE goes up and down). The CHA calculates RELATIVE energy from the integral of the square of the absolute value of the signal. The energy plot is actually on a LOG ENERGY scale, with low values plotted to the right (the scale markers are factors of ten). If a “local” energy reduction of a factor of 10 (-20 dB) is observed, then that is almost certainly a defect. If the reduction is only a factor of 2 (-6 dB) then that could result from minor changes (or probe centering in the tube, or tube couplers, etc) and we would be hesitant to declare a defect. Having said that, where is the real dividing line between -6 and -20 dB? Therein lies the subjective evaluation or "judgment" of the engineer. In this discussion, note that heavy averaging of the signals may hide the defect (averaging is limited for this reason to at most a “three point sliding averaging”).

It is our current opinion that energy may be as important to data evaluation as is arrival time. The combination of local delayed arrival and local reduced energy is a fairly sure sign of a pile defect.

The lateral extent of the defect then becomes of prime importance. Defects that occur in multiple profiles are more serious than defects that occur in a single profile. When a defect is detected, a core is often required for further investigation. Unfortunately the core may not detect the defect because of the core’s limited size, and because axial location is difficult to control, the core may wander from the intended x-y location. Further it is usually not possible to determine the precise location of the defect from

CSL testing alone (e.g. being able to say the defect is “in the vicinity” of tube 4 is often not sufficiently precise). In some cases the visual appearance of the core might be acceptable, but the strength still can be low; strength tests of the cores should be considered.

Shafts that have no obvious defects, or shafts that have continuous obvious defects at the same depth for all profiles need no further discussion. They are evaluated as either good or bad respectively. Shafts that have local defects in some but not all profiles may benefit from additional tomography analysis. The more tubes and profiles measured, the more accurate the tomography analysis is likely to be. “Offset” measurements (probes at different elevations) in addition to the standard level measurements are suggested for the best definition for perimeter tube pairs or when there are 5 of less access tubes per shaft.

Some researchers report delayed curing even up to 50 days in extreme events and thus retesting anomalies after additional wait might in some cases resolve the problem.

Of course the location of the anomaly should also be considered. Defects (and particularly partial defects) near the shaft bottom might not affect the shaft performance for a shaft designed for friction only. On the other hand, large defects near the shaft top may seriously affect the compression or lateral strength of the shaft.

CSL tests the concrete between the tubes, with the focus on concrete on the direct path line. Generally this precludes any inspection or conclusion about the concrete cover. Placing the access tubes outside the reinforcing cage is not generally recommended because the steel can interfere with the data, particularly for highly reinforced shafts. Further if the number of tubes is less than one per foot of shaft diameter, then relatively large defects might be missed (particularly for smaller shafts). PDI would recommend a minimum of four tubes for any shaft to be tested. For large diameter shafts, while the CSL test can send signals across the main diagonal, defects are more difficult to detect in the shaft center because the ray paths can and do “bend”.

In summary, CSL can be a useful tool to assess concrete quality, but ultimately it is the user’s sole responsibility to evaluate the data based on his judgment. The user must clearly understand the analysis tools and their functions, and make recommendations based on his judgment of the results.

CSL Rating Scale for Shaft Integrity

A CSL log shall be presented for each tube pair. The rating of the shaft integrity considers the increases in "first arrival time" (FAT) and the energy reduction relative to the arrival time or energy in a nearby zone of good concrete.

While the Engineer may adopt any evaluation method and select tolerance or thresholds for FAT and Energy reduction, the following criteria for evaluation of the concrete from the CSL test may be considered a starting point for discussion. Similar rating scales have been widely proposed.

(G) (Good)	FAT increase 0 to 10% and Energy Reduction < 6 db
(Q) (Questionable)	FAT increase 11 to 20% and Energy Reduction of < 9 db
(P/F) (Poor/Flaw)	FAT increase 21 to 30% **or** Energy Reduction of 9 to 12 db
(P/D) (Poor/Defect)	FAT increase >31% **or** Energy Reduction > 12 db

When the CSL has detected a shaft with concerns for integrity in one or more profiles, the Engineer must then consider the consequences and possible remedial actions. One potential course of action may follow the following guidance. Flaw or Defect zones, if any, shall be indicated on the logs, listed in a table, and their horizontal and vertical extent and location discussed in the report text. Flaws must be addressed if they affect more than 50% of the profiles. Defects must be addressed if they affect more than one profile (a profile is the result of complete investigation from bottom to top between two tubes) at the same cross section. Flaws or Defects covering the entire cross section define a full layer concern requiring repair. "Addressing" a Flaw or Defect means as a minimum an evaluation by tomography if the concern is localized (e.g. not across the full section), and/or, depending on the depth to the concern, additional measures like core drilling, repair or replacement, repeat tests after a longer waiting time or testing by other methods (gamma-gamma, low strain, high strain).

CSL Results

Present the results of the CSL in a written report within five (5) working days of completion of testing. The report shall include presentation of CSL logs for all tested tube pairs including:

I. Presentation of the traditional signal peak diagram (e.g. "waterfall") as a function of time plotted versus depth.

II. Computed initial pulse arrival time or pulse wave speed versus depth.

III. Computed relative pulse energy or amplitude versus depth.

A CSL log shall be presented for each tube pair. Defect zones, if any, shall be indicated on the logs and their extent and location discussed in the report text. Defect zones are defined by an increase in arrival time of more than (____, 20) percent relative to the arrival time in a nearby zone of good concrete, indicating a slower pulse velocity.

(Note: Because the tubes might not be perfectly straight or even parallel, a fixed absolute limit of a wave speed value cannot be used for evaluation. It should also be noted that if the referenced good concrete exceeds the specifications, then a concrete with a local 20% wave speed reduction might still exceed the specifications.)

The log for each tube pair shall be clearly identified and oriented relative to the structure. The Engineer shall have five (5) working days to evaluate the results and determine whether the drilled shaft construction is acceptable or not. The Contractor shall not perform any load testing or other construction associated with these drilled shafts until after acceptance by the Engineer. If the drilled shaft is accepted by the Engineer, the Contractor may then proceed with construction. If the Engineer determines the drilled shaft is not acceptable, the drilled shaft must be cored, repaired or replaced by the Contractor at the Contractor's expense and with no increase in contract time.

9. Codes and Specifications

A Standard Test Method for Crosshole testing was written by Pile Dynamics' experts for ASTM. Obviously our methods and equipment therefore comply fully (and usually exceed) the minimum standards (minimum standards allow other less featured systems to comply). The ASTM D6760 is entitled "Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing." The PDI compliance statement can be found on the PDI website (www.pile.com).

A recommended guide specification was prepared and is also available for downloading from the Pile Dynamics website. This guideline reflects the best features of several similar guidelines from several state departments of transportation. This guide can be either printed or downloaded in electronic form for inclusion in your project specifications.

10. Appendix A. - Depth Encoders

The depth encoders output a value 'counts' (range -32767 to 32768) which is proportional to angular shaft rotation. Since a pulley is attached to the shaft, the output of the encoders is also proportional to the circumferential displacement of the pulley. And likewise, since the sensor cables ride in the grooves of the pulleys, the output is also proportional to the linear displacement of the cables (i.e. depth).

The calibration numbers that are used with CHA depth encoders are simply the ratio of the number of counts to the linear displacement of the cable. It is also important to note that this calibration only provides a differential depth measurement. When the cable is placed in the grooves of the pulleys, the current count values of the depth encoders are essentially random, so while differential depths may be determined when the cable moves, absolute depth cannot be determined without a reference value (offset).

The CHA uses this basic equation to determine depth:

`depth=(countsMeas-countsOffset)*metersCal/countsCal [eq.1]`

`countsOffset` is a zero reference value.
`countsMeas` is the current value output by the encoder.
`metersCal` is the calibration distance (i.e. 3 meters).
`countsCal` is the calibration counts (i.e. -1553 or -1532).

From this equation, it should be obvious that to obtain accurate depth readings:

(1) You must have accurate calibration numbers. PDI provides accurate calibrations with each CHA system, but it is also important to note that these calibrations are not always the same. They are dependent on several factors, most important of which are the type of depth encoder, the diameter of the pulley and the diameter of the cable. Since PDI has used different types of encoders, different diameter pulleys, and different diameter cables, these numbers may have to be adjusted.

(2) An accurate reference depth must be provided. The reference depth is provided by the user before data acquisition begins by means of two buttons in the software labeled "TX/RX Zero" and "TX/RX Bottom". When you click either one of these buttons, what you are in effect doing is reading the current value of the depth encoder counts and telling the software that this value is the offset from which all subsequent depth measurements are to be referenced. If you click "TX/RX Zero" it means that the current value is used as the zero offset which means that this must be done when both sensors are in the position that you want to indicate zero depth (i.e. probes are at top of tubes). When you click "TX/RX Bottom" it means that the current value is assumed to be the final depth measurement (e.g. probes are at bottom of the tubes) and the zero offset is calculated by subtracting **pileLength * countsCal / depthCal**.

The only other factor in calculating depth is the currently measured value (**countsMeas**) which is updated constantly as you take data. If each of these values is accurate, then your depth readings should be accurate.

One other thing that is very important to note. After you have provided a reference offset by clicking "TX/RX Zero" or "TX/RX Bottom", you must not let the cables slip in the grooves of the pulleys. This would cause errors in the differential distance calculation as described above - or referring to [Eq. 1] - **countsMeas** will no longer be valid.

Checking Depth Calibration

As mentioned before, PDI calibrates all CHA systems, but you may want to check the calibration yourself. There is a depth encoder monitor window available from the main menu - make sure all files are closed, then select "Setup/Monitor Depth Encoders". This will bring up a window which allows you to view the actual output counts from the encoders. Press the reset button for TX or RX and you should see the counts value change from a random value to zero. Now move the depth encoder pulley and you should see the current counts value change. This is essentially how PDI calibrates the depth encoders. We monitor the values in this window while measuring the actual displacement of a cable that is riding in the groove of a pulley. For example, we pull the cable exactly three meters and notice that the counts change from 0 to -613 (or -1538 for the more sensitive encoders). We actually measure much more than three meters and divide the total counts by the appropriate distance amount to get a more accurate reading. If you check your calibrations this way and they don't agree with the numbers we have provided, please feel free to change your calibrations to the numbers you have determined. Obviously, pulling horizontally may allow the cable to slip and thus the calibration may be in error. We would suggest that calibration be performed by placing the probe in a vertical access tube after marking two known locations on the cable a known (measured) distance apart.

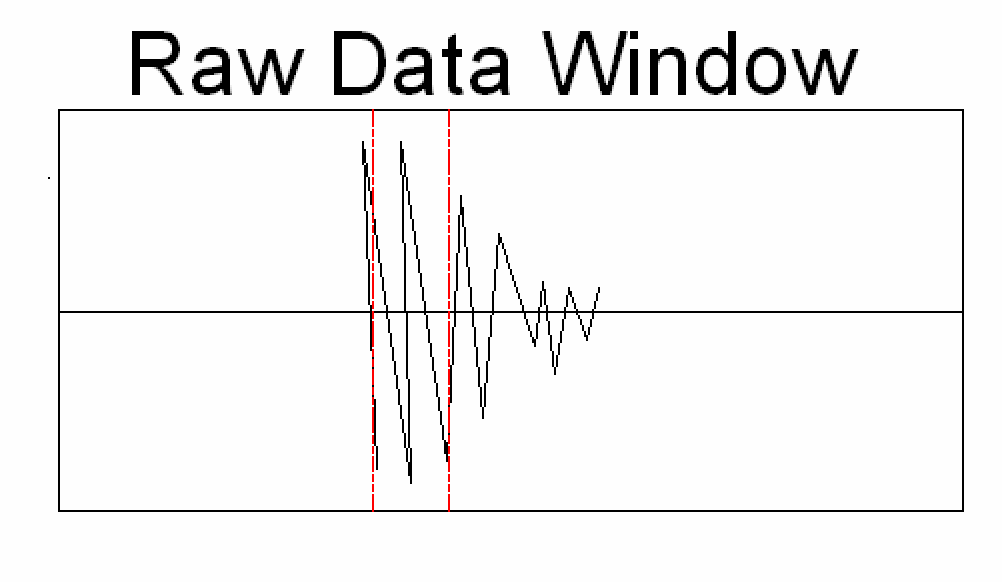
11. Appendix B. - Field Trouble Shooting

Daily Transmitter (TX) and Receiver (RX) Test

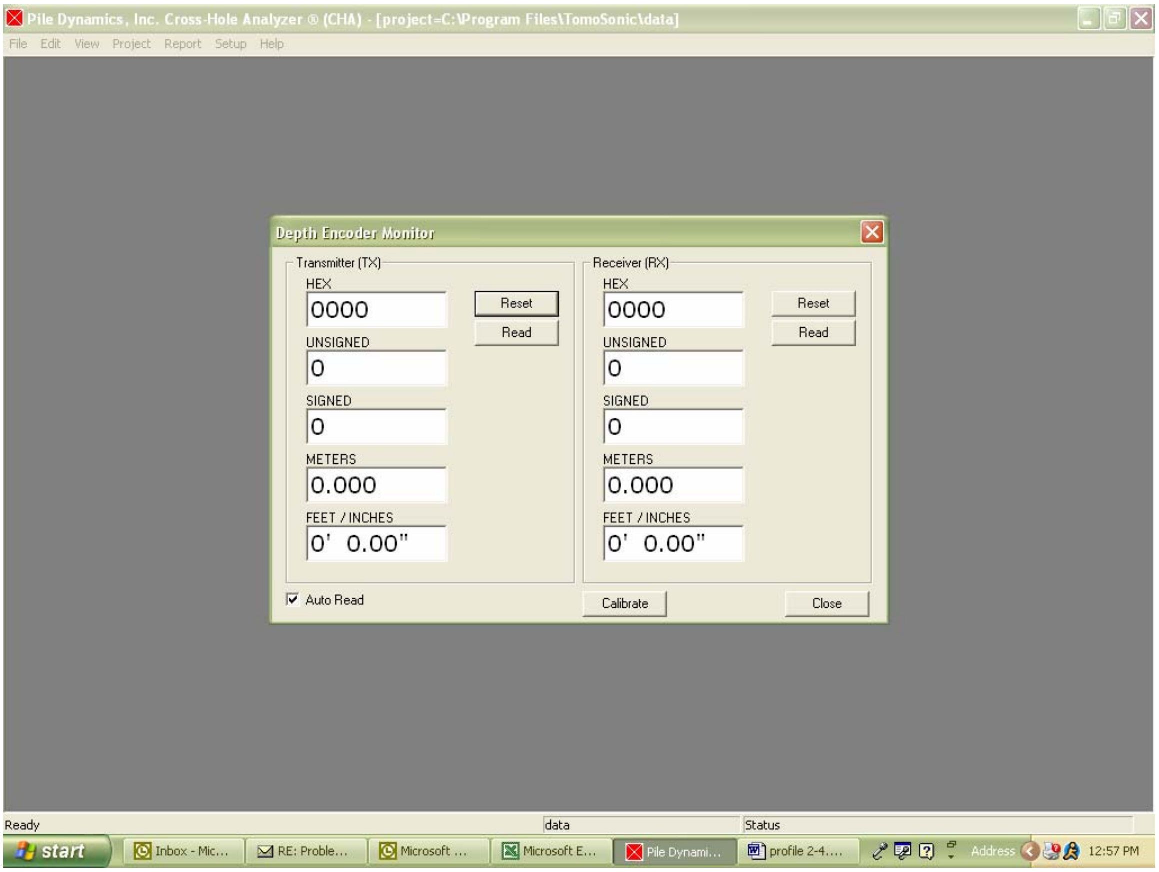
1.) Provide power and turn on Main unit, Make sure that **(TX) and (RX)** are connected to the main unit and set them down next to each other. Open the CHA-W program.
2.) On the File menu click on "setup", under "setup" scroll down until you find **" monitor Hardware"** then open that window.
3.) Now that you are in the **"Monitor Hardware"** window set the parameters to the following
    a.) Set the Delay (microseconds) to..................... **Zero---0**
    b.) Set the Trigger Rate to.................................... **Thirty---30**
    c.) Set the AT threshold to................................... **Twenty five---25**
    d.) Set the X-Scale to... **Full**
    e.) Set the Y-Scale to... **One---1**
    f.) Set the Transmitter power to...........................**Six hundred---600**
    g.) Set the Gain to **9711**

4.) **TRANSMITTER CHECK (TX):** Hold the **Transmitter (TX**) to your ear if you hear a constant ticking sound then you know the (TX) sensor is working properly.
5.) **RECEIVER CHECK (RX):** Take Receiver **(RX),** while the main unit is in the "Monitor Hardware window" close your fist around the receiver **(RX)** and rub (RX). If you see a signal generated in the **"Monitor hardware**" window while you are rubbing the receiver then the receiver is working properly.
6.) **Now that you have verified that (TX) and (RX) are working properly. Hold the sensors in mid air and parallel to each other. Then move them apart 3 inches, but keeping them parallel to each other while they are moved apart. When you do this you will see a signal like the following.**

THIS PROCESS WILL VERIFY THAT THE SENSORS ARE SENDING AND RECEIVING AND ALSO WORKING PROPERLY!

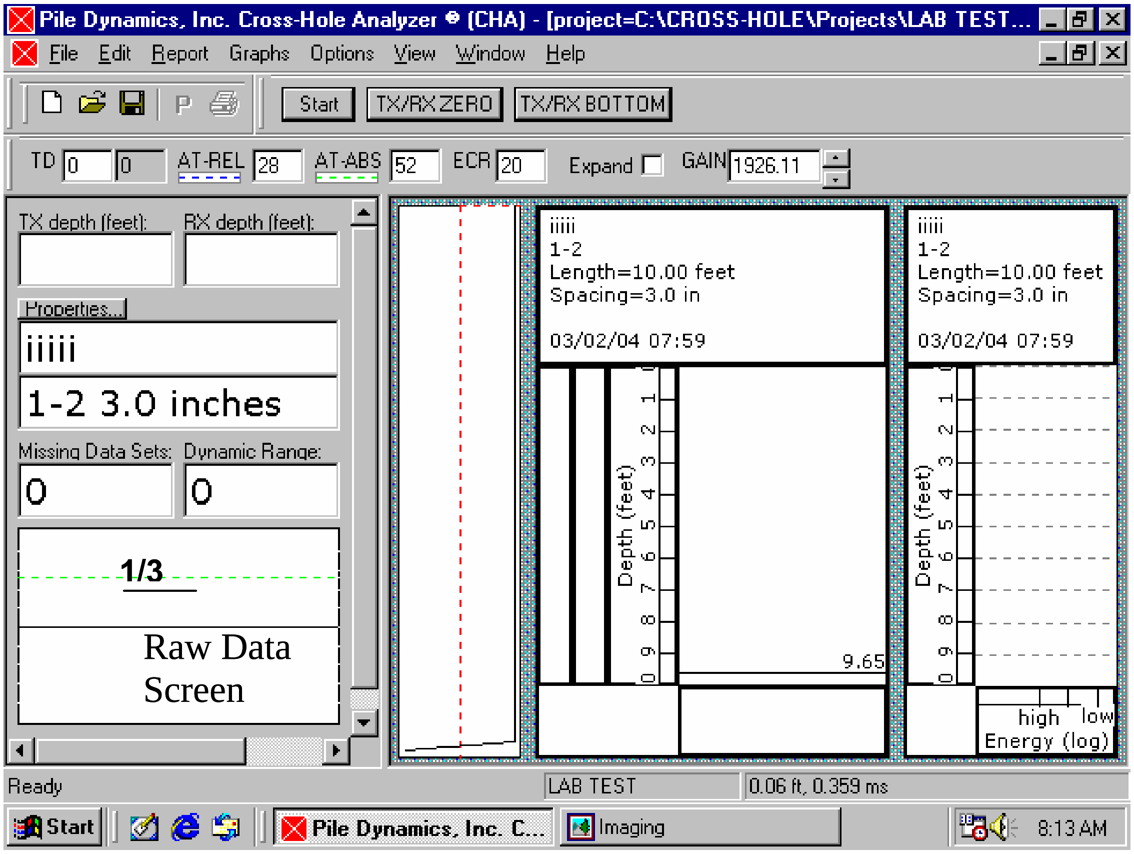


Encoder Test



1.) Take the Encoders and connect them to the splitter cable, also connect the splitter cable to the main unit
2.) Open CHA-W, on the menu bar please go to SETUP, under setup click on "Depth Encoder Monitor"
3.) On the left side of the "Depth Encoder monitor" press reset. Immediately after that turn the encoder reel clockwise. In the SIGNED box you should see that number increase negatively. NOTE: If it increases positively make sure you are turning the reel clockwise.
4.) Do the same exercise to RECEIVER RX. IF they both increase negatively the encoders are working properly.
5.) Next close that window and go to the data acquisition screen and hit TX/RX Zero and rotate the encoder reel counterclockwise. The depth should go down.
6.) If the encoders work properly in step 3) but not in the main program it is possible that your unit has a problem with its A/D board. When we get the results of this test we will decide what to do.

Parameters to Look at Before Taking Each Profile of Data



1.) In the data acquisition screen such as the above picture it is mandatory that the tester check the following parameters before he acquires data:
   a.) First, raise both sensors 60cm from the bottom of the pile.
   b.) Then increase the **GAIN** so the raw signal between the two red dotted lines will fill (70-90% Dynamic Range). This is all in the **Raw Data Screen. The area between the two red dotted lines is the ECR Range.**
   c.) Second, adjust the Trigger Delay **(TD)** to the recommended value given by the CHA-W Software. We determine this value by allowing the mouse arrow to hover over (TD). Then manually input that recommended TD value
   d.) When **(TD)** is set properly the Raw Data signal will be shifted over 1/3 from the left edge of the **Raw Data screen**.
   e.) Final, lower the both (TX) and (RX) back to the bottom of the installation tubes then press **“TX/RX BOTTOM”** To zero the data out and then you are ready to start the testing for that **PROFILE**.

<u>**IMPORTANT REPEAT THIS PROCESS FOR EVERY PROFILE**</u>

**Definition of a profile is the following: Profile =1-2; Profile =2-3; Profile =3-4; Profile =4-1; Profile =1-3; Profile =2-4.