technology for network management and leakage control

Primayer Enigma® and Enigma® - Compact User Manual

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Primayer Limited provides a technical support service to assist on all matters relating to the configuration and use of its products. Customers are encouraged to make use of this service, by contacting support@primayer.co.uk or using the contact details provided above.

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1 The Primayer Enigma® Logging System

1.1 System Overview

Enigma is a compact, easy-to-deploy leak detection and location system for use with buried water pipes. Using the latest advances in digital acoustic technology allows the combination of noise logging (leak detection) and leak noise correlation (location) into a single, simple operation.

Actual sound is recorded by a network of Enigma loggers, typically deployed on valves or hydrants overnight. When downloaded from the loggers, the recorded sound files are subjected to a sophisticated software analysis, and any noise source locations are displayed.

Users who are new to the principle of leak correlation should read section 6 on Principles of Leak Noise Correlation.

1.2 Components

The Enigma systems comprise:

- Loggers (2 to 8 in number)
- Communications case (and USB lead)
- Enigma software (for installation on a PC).

1.3 System Features

- Multi-point correlation
- Easy-to-read analysis
- Easy to deploy
- Identifies multiple leaks in a single operation.

1.4 Logger Features

- Physically small – fits into a majority of underground locations
- Loggers powered for minimum of five years
- Magnetically attached - easy to deploy
- Fully submersible to IP68 (to 1 metre depth)

A hydrophone variant of Enigma is available – the hydrophones offer greater sensitivity over the accelerometers.

	The minimum expected battery life of an Enigma logger is 5 years. This is based on one logging run (of 3 epochs) 5 times every week. If the Enigma are being used to log several times every day, then battery life will be reduced.

1.5 Technical Support

Primayer Limited provides a comprehensive Technical Support service to assist on all matters relating to the configuration and use of the Enigma system. Customers are encouraged to make use of this service. Please use the email address support@primayer.co.uk or see the address and phone contact details at the front of this manual.

1.6 PC Hardware Requirements

Minimum host PC specification for Enigma:

- Pentium II 500 or equivalent CPU – 512 Mb RAM
- 50Mb available hard disk space
- One free USB port.

1.7 PC Software Requirements

Minimum software specification for Enigma:

- Windows Vista, Windows 7
- Windows XP or Windows 2000
- Windows Media Player 9.
- Microsoft .net framework v4.0

As with any software application, the higher the specification of the host system, the better Enigma will operate.

Please note that Primayer Limited cannot support technical enquiries relating to, or caused by, problems with the Windows Operating System installed on any host PC.

2 Hardware Overview

2.1 Enigma Loggers

Loggers – Accelerometer Version

The Enigma logger is a cylinder, approximately 11cm long by 6cm wide. At one end of the unit is a powerful magnet which is connected to the internal accelerometer sensor. At the other end is an optical window, through which the unit communicates with the communications case. Each logger is individually numbered; this number is used throughout the Enigma PC software to reference the data from loggers.

The magnet allows easy connection to any metallic point on the water network. Metal grip attachments can be used for connection to plastic pipes.

Each logger is powered from an internal battery pack which lasts typically 5 years. Low battery voltage is indicated by the PC software when communicating with the loggers. When it is necessary to replace the battery in a logger, the logger must be returned to Primayer. The magnet can be replaced if necessary, please contact Primayer for more details.

2.2 Enigma Hydrophone Logger

Logger – Hydrophone Version

For the hydrophone version of Enigma, the powerful magnet is replaced by a socket, allowing connection of an external hydrophone.

2.2.1 Hydrophone installation procedure

The standard hydrophone is mounted in a hydrant cap for use with any hydrant fitting. When fitting a hydrophone to a hydrant, follow this procedure.

1. Open the hydrant carefully to ensure there is no debris in the outlet, and clean water flows (the pressure can be assessed at this point).
2. Ensure the hydrant valve is shut.
3. Ensure the seal in the hydrophone is clean.
4. Fit the hydrophone to the hydrant and tighten in place. Tightening is best performed by fitting the adaptor provided onto the castellations on the upper side of the hydrant cap, then using the standard hydrant valve key to tighten the hydrophone assembly.
5. Ensure the bleed valve is closed, and that the fitting is secure.
6. *Slowly* open the hydrant valve, and check that no leakage occurs from the hydrophone.
7. Open the bleed valve *slightly* to allow air to escape.
8. Close the bleed valve when only water is escaping.

When fitted correctly the hydrophone may be connected directly to Enigma logger.

	Before removing a hydrophone fitting, it is essential to make sure that the hydrant valve is shut. The bleed valve may then be opened to release the pressure.

	Adhere to local water hygiene regulations when inserting hydrophones into potable water pipes.

2.3 The Communications case

The communications case, in addition to providing a protected environment to transport and store the loggers, provides the communications interface between the PC with host software and the loggers.

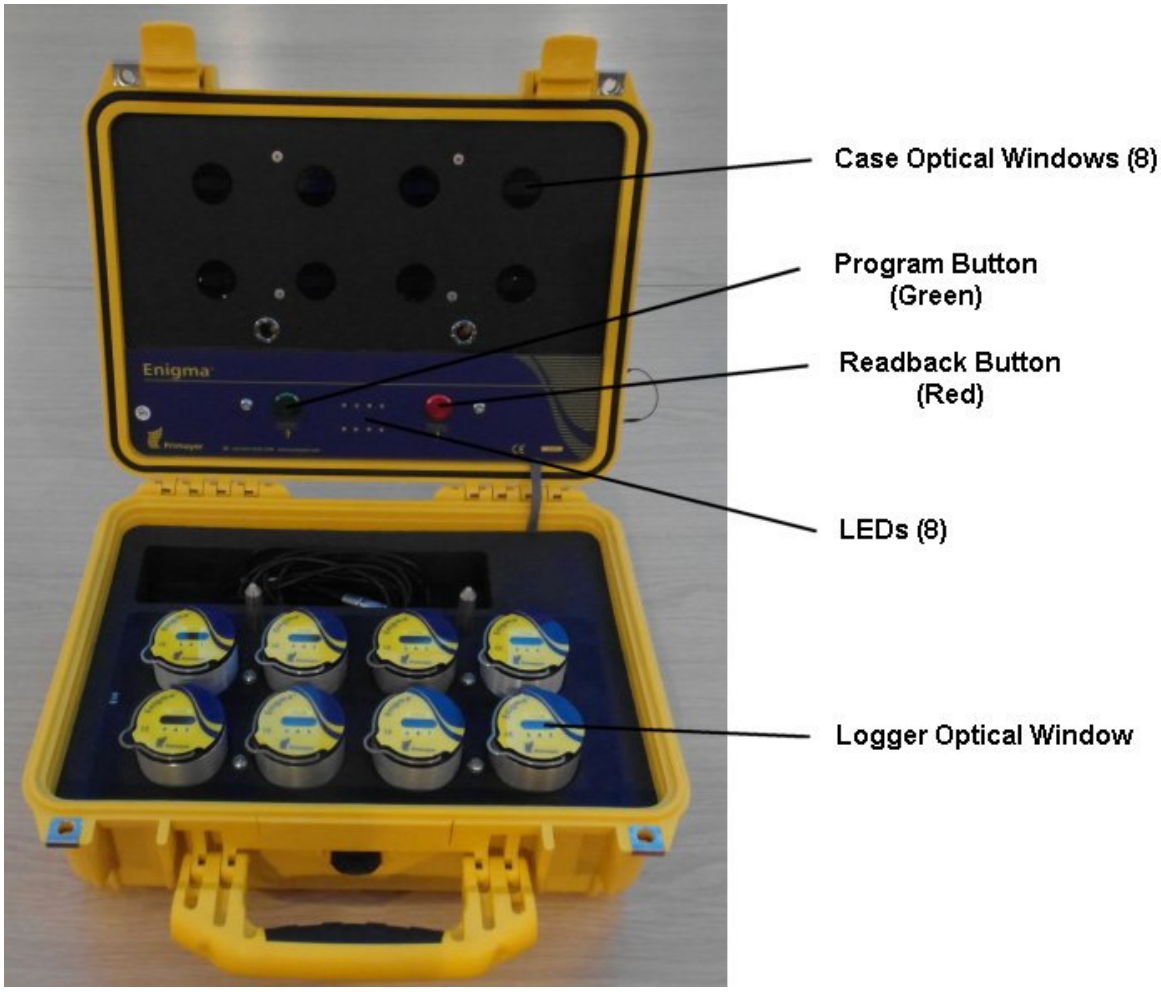
When connected to a PC via USB, the Enigma communications case allows configuration information (recording settings etc.) to be uploaded to Enigma loggers, and data to be downloaded after recovery from site. The case itself can also program loggers from a default configuration (programmed from the PC) and retrieve data from loggers, the case cannot analyse data.

The standard communications case provides eight bays for Enigma loggers and has 2 buttons and 8 LEDS. Opticalransducers in the lid of the station align (when the lid is closed) with the loggers and provide the programming and readback data link.

The compact communications case provides 3 bays for Enigma loggers and has 2 buttons and 3 LEDS. Optical transducers in the lid of the station align (when the lid is closed) with the loggers and provide the programming and readback data link.

Also stored in the case, above the battery, is the USB communication lead and a cloth to keep the optical windows on the loggers and in the top of the case clean.

2.4 Programming/Readback of Loggers with the Communications Case



The Compact case holds 3 loggers and has 3 LEDs.

The communications case offers the following logger facilities:

- Default programming
- Readback
- Program status check
- Readback status check.

The communications case can program a set of default logging parameters into the loggers and readback data after recording.

Default program (from factory) is logging at 02:00, 03:00 & 04:00. The parameters that are to be programmed by the case are programmed into the case by the PC, see the section ‘Communications Menu – Case Programming’.

Note that successful data communication between the case and the loggers relies on the tops of the loggers and the optical windows on the case being clean. A cleaning cloth is provided for cleaning these optical surfaces.

	Note: Hydrophone loggers cannot be inserted into the case with the hydrophone connected. Reconnect the hydrophone after programming and before the first epoch.

Controls for program and readback are as follows:

Item	Use/Indication	Meaning
Green Button	Short Press	Reports status of last case programming operation
Green Button	Long Press	Starts program sequence
Red Button	Short Press	Reports status of last case readback operation
Red Button	Long Press	Starts readback sequence
LEDs (8)	On	Success of appropriate program/readback
LEDs (8)	Flash	Logger detected but failed to program/readback
LEDs (8)	Off	No logger detected
Note: The Enigma – Compact version has 3 loggers and LEDs.		

2.5 Programming with case

To program loggers using the case use the following procedure:

- Make sure the loggers to be programmed are in the case
- Press and hold the green button for about 1 second, check the ‘walking LEDs’ and fast beeping, close the case
- After about 8 seconds the sound changes to a slow beep (about 1 per second) while the loggers are being programmed
- When a long beep is heard the case can be opened
- Check LED for each logger position is on to indicate successful programming, note logger status is only displayed for 8 seconds. The logger status can be displayed again by following the steps in section 2.5.1.

If programming fails for a particular logger, clean the top of the logger and the appropriate optical window in the top of the case, repeat the programming with the case.

2.5.1 Checking Status - Programming

Briefly press the green button:

- LED on shows logger was successfully programmed
- LED flashing shows logger detected but failed programming
- LED off shows no logger detected.

2.6 Readback with Case

To readback data from the loggers into the case, use the following procedure:

- Press the red button until fast beeping starts
- Close case
- Short beeping will be heard during readback
- When long beep is heard, readback process is complete
- Open case
- Check LED for each logger position is on to indicate successful readback; a flashing LED indicates failure to readback. The logger status can be displayed again by following the steps in section 2.6.1.

If readback fails for a particular logger, clean the top of the logger and the appropriate optical window in the top of the case, repeat the readback operation.

After case readback, the information stored in the case can be recovered by the PC. In the meantime the loggers can be reprogrammed as required and redeployed as necessary. Only one set of Enigma data can be stored in the case for download into the PC software.

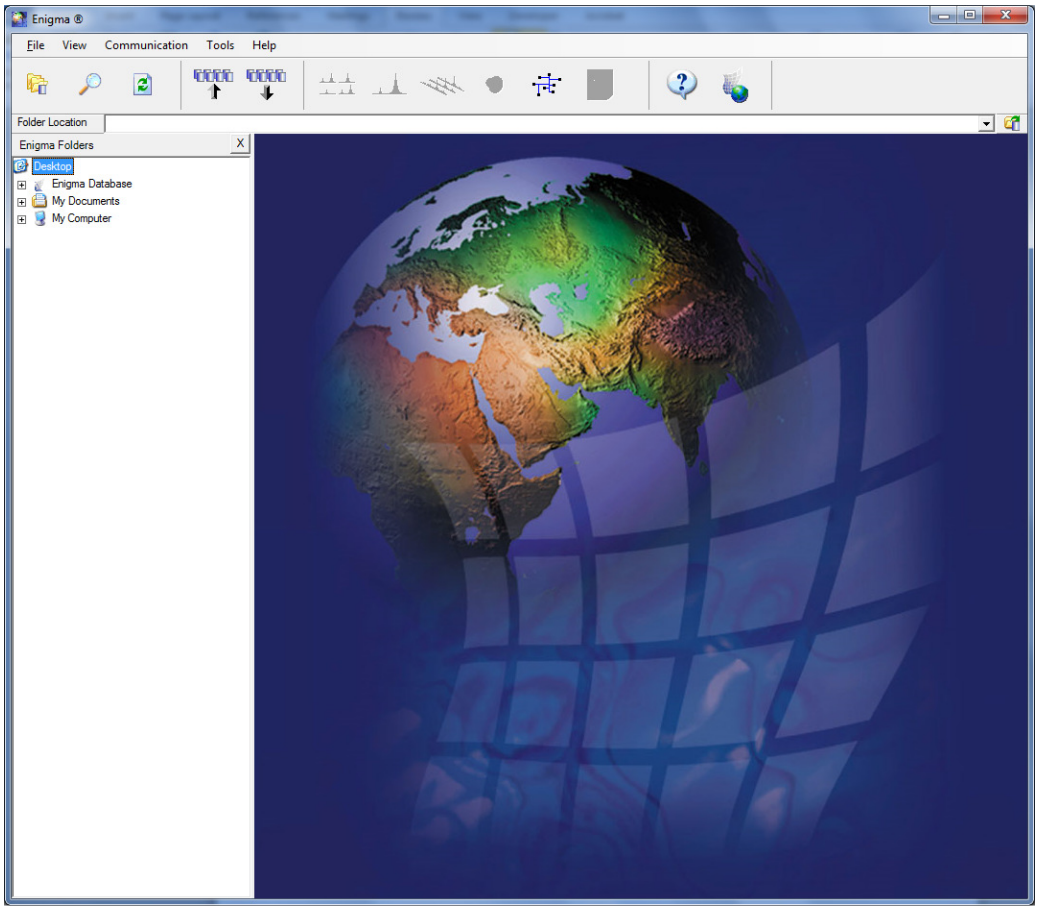
2.6.1 Checking Status - Readback

Briefly press the red button:

- LED on shows logger was successfully readback
- LED flashing shows logger detected but failed readback
- LED off shows no logger detected.

3 Software Description

3.1 Main Screen

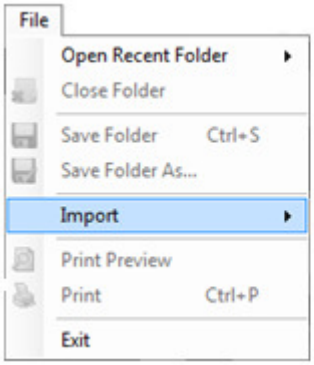


Main Screen

The main screen has five pull-down menus, 13 Icons, a folder area and a main screen.

3.2 Menus

3.2.1 File Menu



File Menu

The file menu has the following options:-

- Open Recent Folder
- Close Folder
- Save Folder
- Save Folder As
- Import
- Print Preview
- Print
- Exit

3.2.1.1 Open Recent

This option will provide a list of the recently opened Enigma data set. One of these tests can be selected for opening.

3.2.1.2 Close

This selection will close the currently open set of Enigma data.

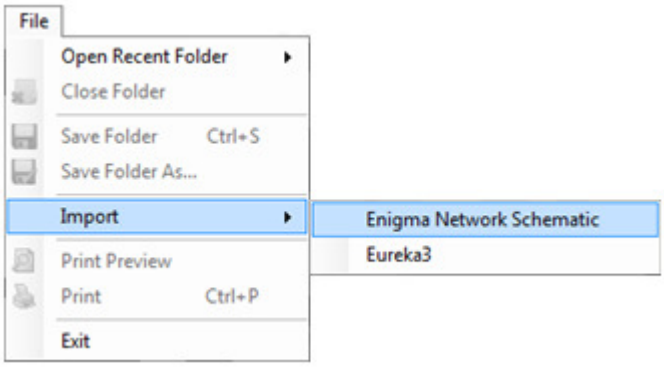
3.2.1.3 Save

This saves the currently open set of Enigma data.

3.2.1.4 Save As

This gives the option of saving the currently open set of Enigma data to another name and/or location.

3.2.1.5 Import



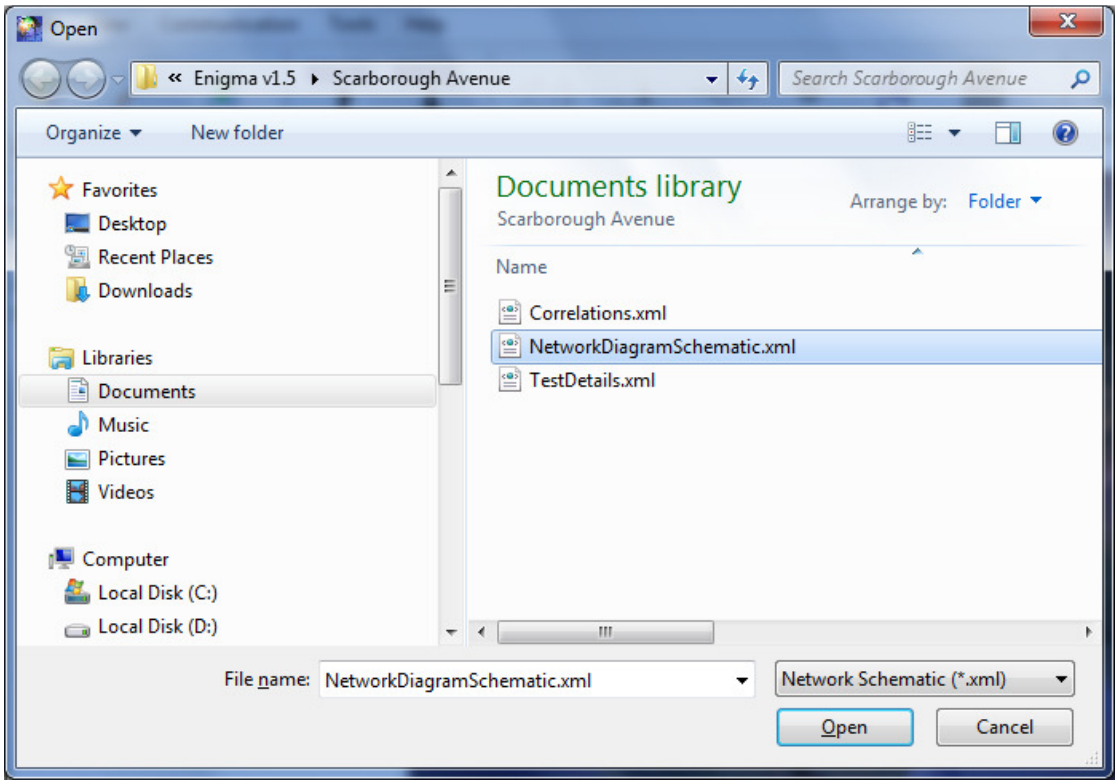
The Import menu has two options:-

- Enigma Network Schematic
- Eureka3

3.2.1.5.1 Enigma Network Schematic

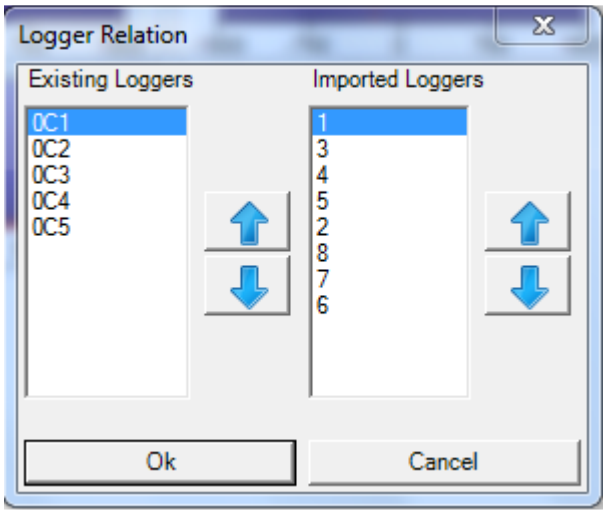
This selection allows the import of a network schematic file from a different Enigma folder.

Browse to the folder containing the appropriate network schematic and select the file NetworkDiagramSchematic.xml.



Please note only files network schematics created with v1.4 Enigma or above can be imported.

If there is a mismatch of the ids between the network schematic and the logger data then dialog will be displayed allowing selection of the mapping of the logger ids.



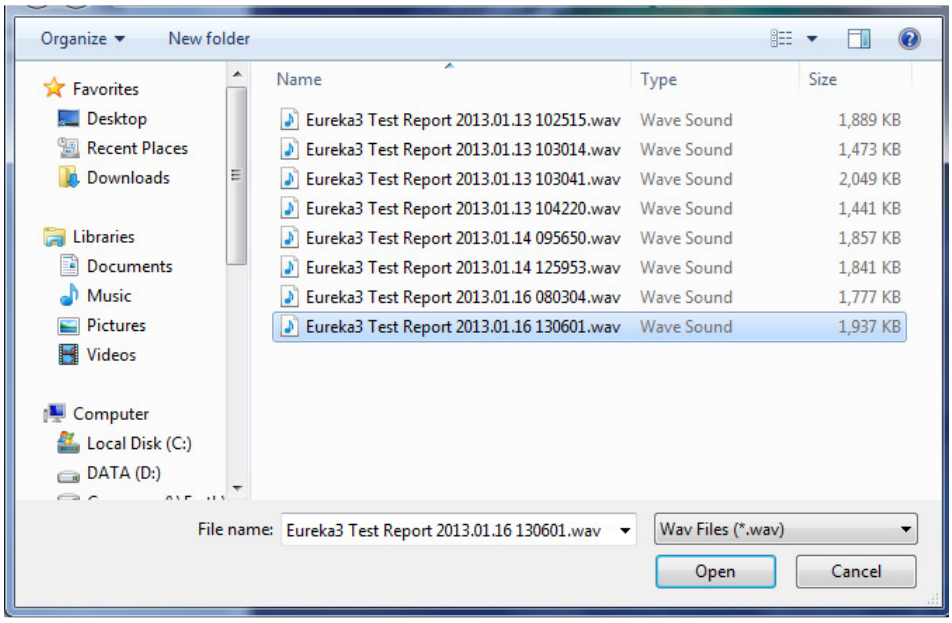
The ids on the left are those of the sound data which is currently open. The ids on the right are for the loggers as currently marked on the network schematic being imported. Use the arrow buttons to rearrange the ids in the list. In the example above, the data from logger 0C1 will be associated with the point 1 on the network schematic; the data from logger 0C2 will be associated with the point 3 on the network, and so on down the list. If the data from logger 0C3 should be associated with point 3 on the network simply highlight the id 0C3 and press the up arrow to move it up one place in the list. For ease of use both sides of the list can be rearranged as required. Any extra ids which do not have partners at the bottom of the list, will be removed from the network schematic when it is opened.

After pressing OK the network schematic will be imported and associated with the current sound data, and analysis can continue as required.

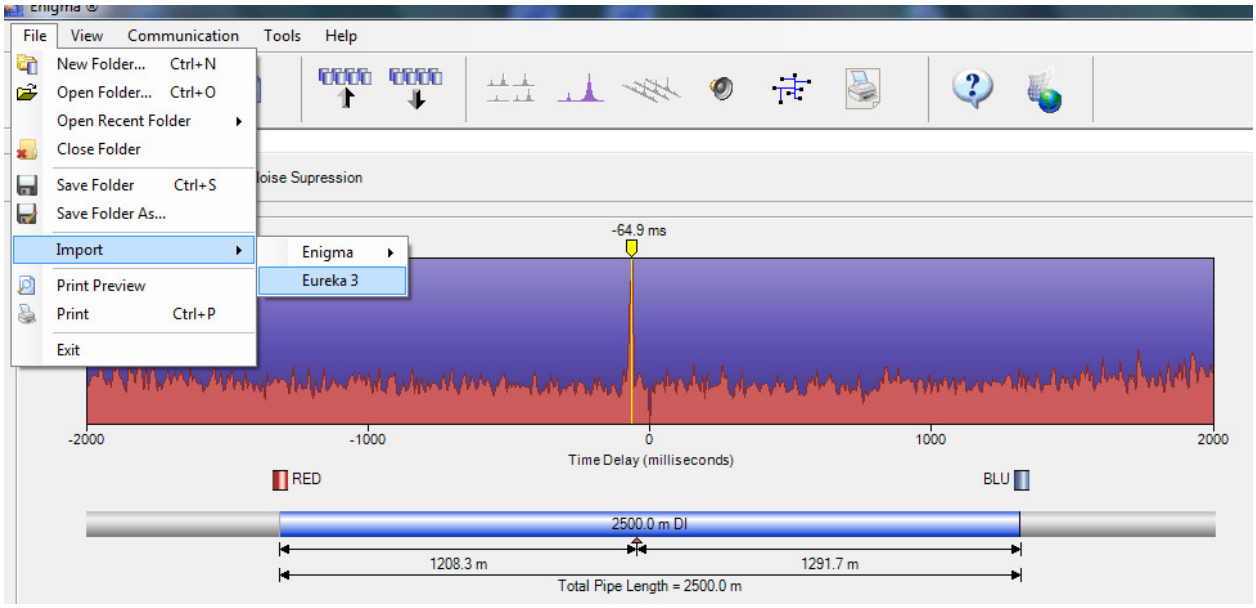
3.2.1.5.2 Eureka3

This option can be used to import data from the Eureka3 correlator. It is possible to save a report file to a USB key drive from the Eureka3. Every time that a report file is created, the stereo WAV file which generated the saved correlation report is also saved. This WAV file can be imported into the Enigma software for further analysis.

Select the Eureka3 report folder location and select the WAV file for the appropriate correlation. The WAV file name includes the date and time that it was saved.



The WAV file will be opened and the correlation displayed within the Enigma software.



If GPS location information has been saved for the transmitters this will be transferred, and the pipe model will be displayed at the appropriate location on a Google Map™. Some of the features, as described in this manual will be unavailable because there are only two sensors and one WAV file associated with a Eureka3 correlation (for example the thumbnail display, epoch displays and velocity measure).

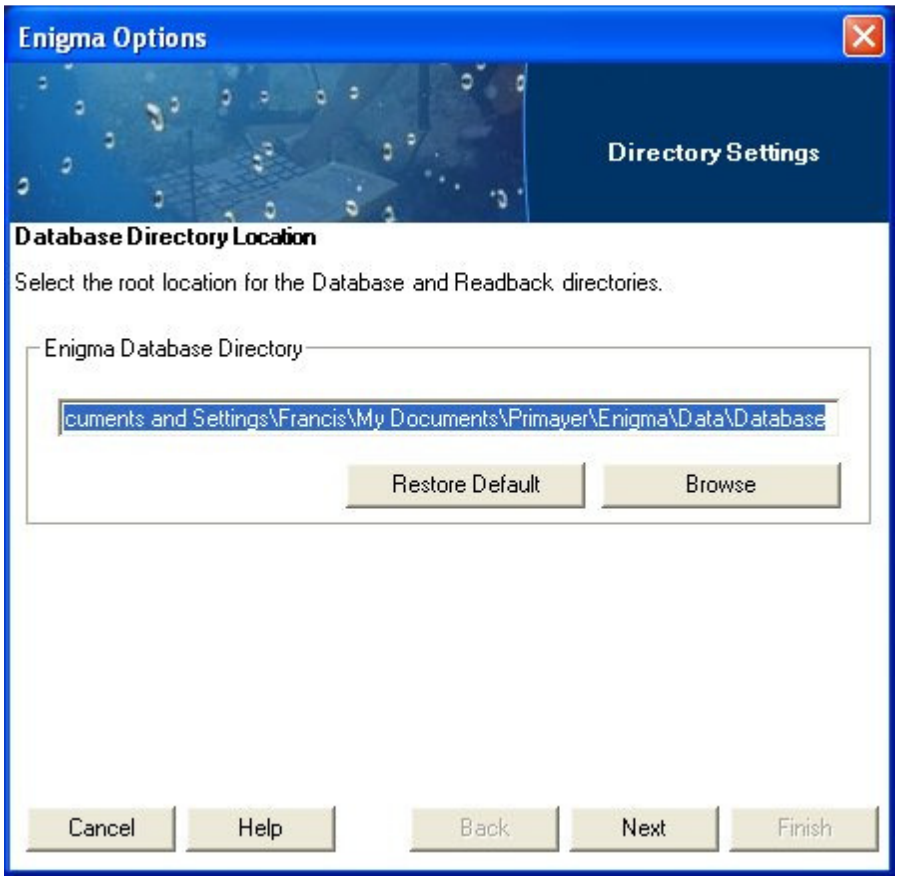
3.2.2 View Menu

View Menu

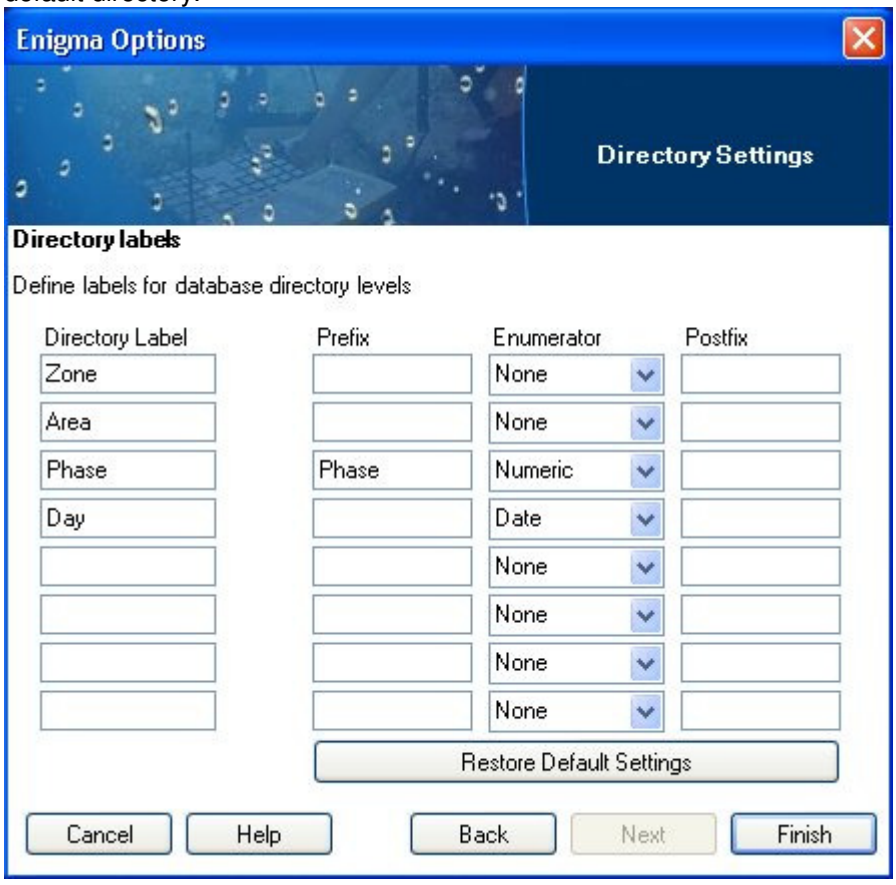
3.2.2.1 Directory Settings

This is where the default database directory is defined; default prefix and postfix information can also be set.

The first option screen is used to set the database directory. Press the Browse button to select the required directory. The restore default button restores to the original default Database Directory. All data saved will by default be saved as a folder underneath this database directory.

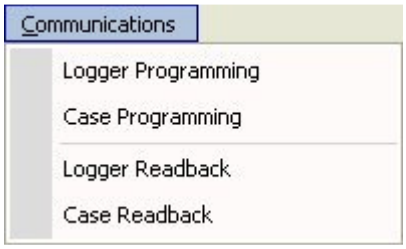


To set the prefix and postfix settings, click the next button, otherwise click on Finish to complete setting the default directory.



Prefix and postfix options can be used to help store multiple sets of data in an ordered manner. When automatically reading back sets of data automatic prefix and postfix strings can be used as the folder names. The choices for these can be a numeric, character or date.

3.2.3 Communications Menu



The menu options are:

- Logger Programming
- Case Programming
- Logger Readback
- Case Readback.

3.2.3.1 Logger Programming

This option is used to program loggers and starts the program wizard; see the Program icon section for more detailed information.

3.2.3.2 Case Programming

This option is used to program a default setting into the communications case so that loggers can be programmed using the case without a PC. Only one configuration can be stored in the case at one time. Selecting this menu starts the Case Configuration Wizard.

After the communications progress bar has been shown – the wizard window shows.

See the section on Program Icon for more detailed information, click on the Program button to program these settings into the case.

3.2.3.3 Logger Readback

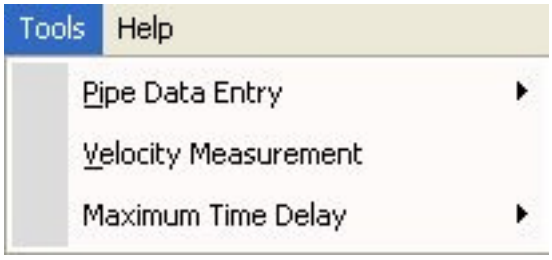
This starts the readback of data from the loggers in the attached case via the USB port on the PC. For more detailed information see section 3.3.6.

3.2.3.4 Case Readback

The Enigma case is able to readback and store one set of Enigma data (details on how to readback data into the case are in section 2.6). Selecting this option will communicate with the case to readback this stored data, rather than communicating with the loggers present inside the case.

For more detailed information see the section 3.3.6

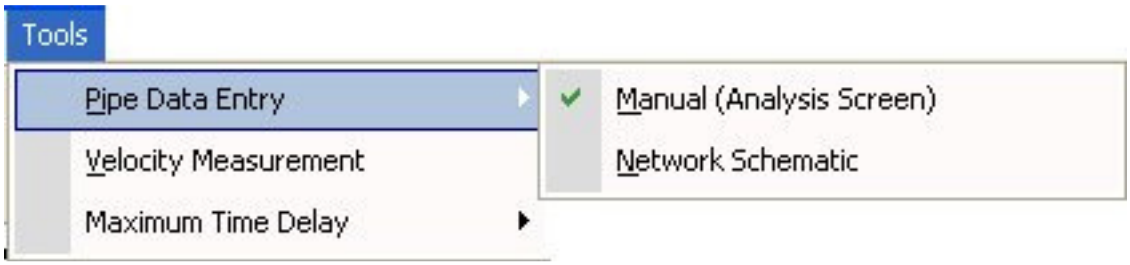
3.2.4 Tools Menu



The tools menu has three options:

- Pipe Data Entry
- Velocity Measurement
- Maximum Time Delay.

3.2.4.1 Pipe Data Entry



For leak correlations to be meaningful is it important to enter pipe data for each section of pipe, there are two methods of entering pipe data:

- Manual (Analysis Screen)
- Network Schematic.

3.2.4.1.1 Manual

Manual pipe data entry allows details to be entered ad hoc whilst performing the Analysis. The pipe details entered are purely used between the two loggers being analysed and no assumptions are made about how the network of pipe details connects together.

This method of entering pipe details is useful for initial investigation into data.

See section 3.3.8.8 on pipe data entry for more information.

3.2.4.1.2 Network Schematic

Alternatively the whole network schematic can be drawn or imported. This method will link all the loggers together with pipe sections. This data is then automatically used by the analysis screens to populate pipe details between all loggers used.

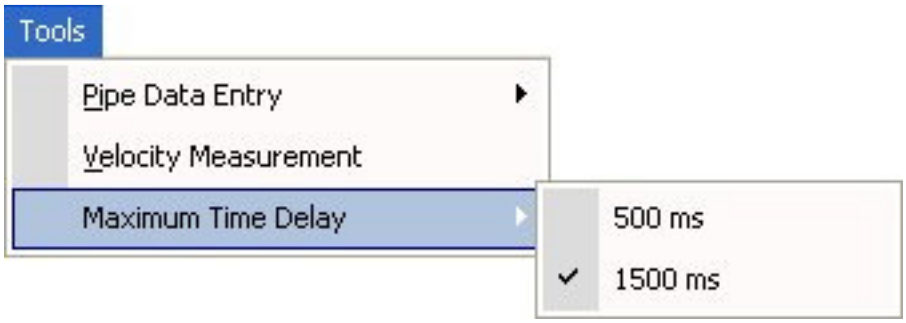
See section 3.3.11 for more information on drawing network schematics.

3.2.4.2 Velocity Measurement

To calculate leak positions using correlation it is important to know the velocity of sound in the pipe and water network, the software allows the use of default values, manually entered values – or for greater accuracy, the actual velocity can be calculated using data collected from 3 loggers.

The Enigma Compact is optimized with 3 loggers for calculating velocity to give improved accuracy of leak location. For more information see section 4 on Velocity Measurement.

3.2.4.3 Maximum Time Delay



The Maximum Time Delay is used when displaying the thumbnail correlations (see section 3.3.7). If the loggers have been deployed over short sections of metal pipe the 500ms setting should be used. If using over longer distances, with plastic pipe or with hydrophones the 1500ms setting should be selected to ensure that all possible peaks are available to view in the thumbnail correlations.

	Note: If the maximum time delay is set to 500ms the data between 500 and 1500ms will not be visible. If the time delay being measured is expected to be higher – so for example when using hydrophones or plastic pipes, this option should be set to 1500ms.

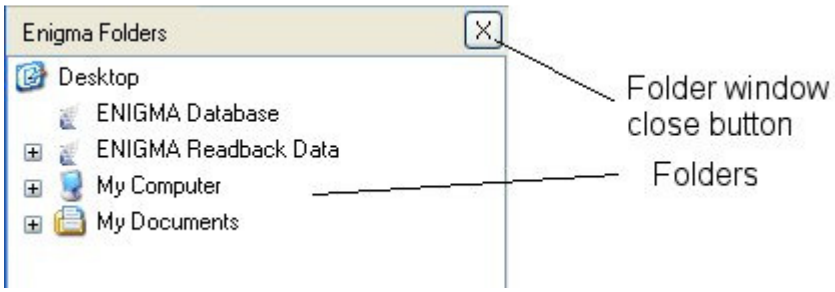
In Enigma v1.5 and above there is a 2000ms option which is automatically selected when Eureka3 data is imported. It is not available for selection for data readback from Enigma loggers.

3.3 Icons

There is a row of icons at the top of the program window:

3.3.1 Folders Icon

Clicking on the folders icon shows the folder window, this shows a standard windows folder tree where selection and navigation can take place. The folder window can be hidden by clicking on the cross in the top right corner.

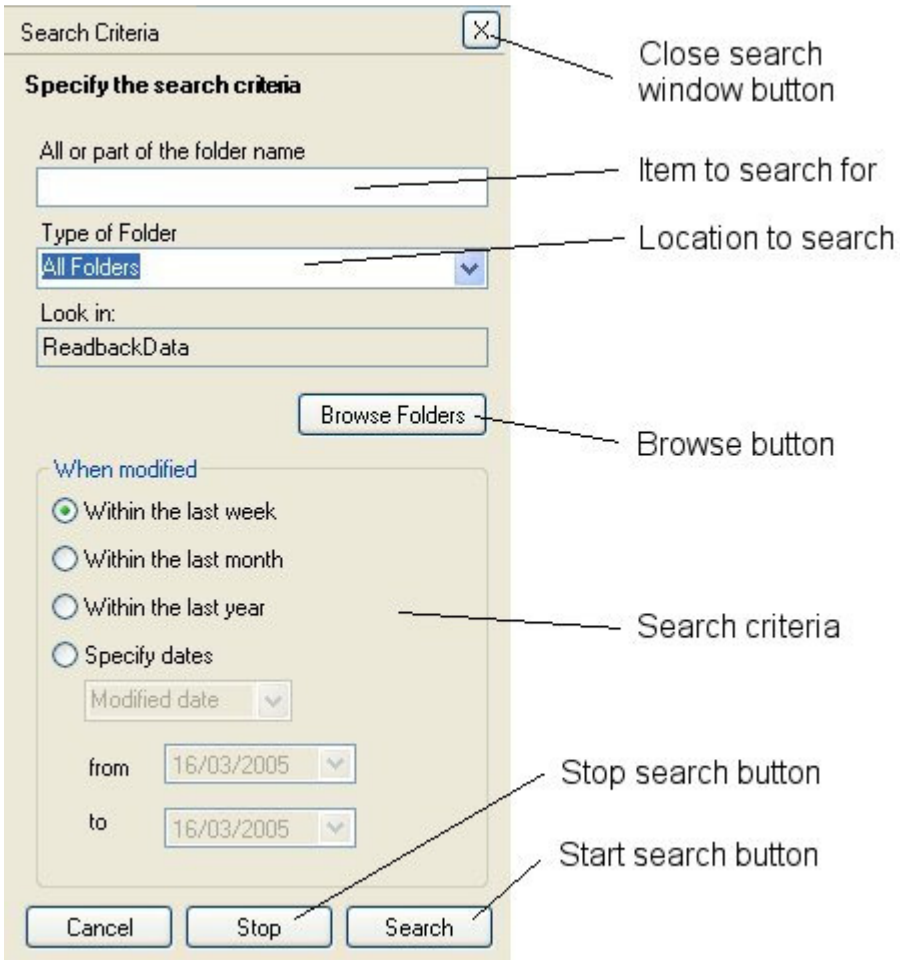


Folders

By double clicking on a folder, any Enigma data within this folder will be opened for analysis. If there is no Enigma data present in this folder then a warning message is displayed. If only a network schematic is present in the folder, then the Import option should be used to open the network schematic rather than opening through this method.

3.3.2 Search Icon

The search button opens the search window on the left side of the screen. The search window can be closed by clicking on the cross in the top right corner of the search window.



Search Criteria

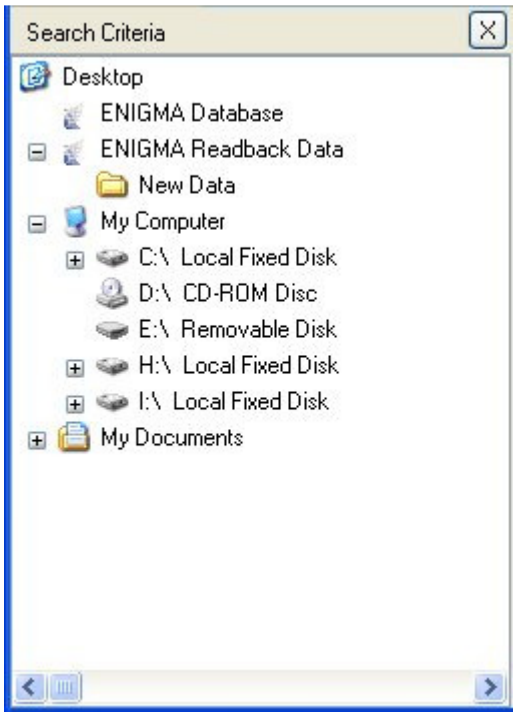
The search window has several options to enter search criteria and locations.

3.3.2.1 Search Criteria

Either the full name or partial name of the folder to search for can be entered. The search can be refined by only searching for folders already containing Enigma data sets by selecting Enigma folder from the pull down menu.

3.3.3 Browse Folders

The Browse Folders button opens the browse view.



Search Window

3.3.3.1 When Modified

Here the search parameters can be further defines; options available are:

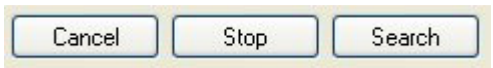
- Within the last week
- Within the last month
- Within the last year
- Specify dates.

With the specify dates options, there are options for Modified date, Created date or Accessed date, and specify the exact dates for the search.

Specify Options – Search Window

3.3.3.2 Search Buttons

There are three search buttons at the bottom of the search window.



Search Buttons

The Cancel button cancels a search, the Stop button stops the current search, the Search button starts a search using the selected parameters.

3.3.4 Refresh Icon

The refresh icon refreshes the tree structure in the folder window.

3.3.5 Program Icon

This option is the same as selecting the Logger Programming option from the Communications menu, and allows a case of Enigma loggers to be programmed directly. In this instance the case is used purely as a communications interface, so any program settings already programmed into the case are ignored.

Before attempting to communicate with the loggers, place all the loggers in the case, ensuring the tops of the loggers are clean, and close the case lid.

Clicking on the Program icon shows opens an Establish Connection progress bar window, and then the program wizard window shows.

Program Wizard

3.3.5.1 Epoch Times

This section of the window allows the user to select the required epochs. Epoch 1 is required; if epochs 2 and 3 are to be used then the checkbox adjacent to the required epoch should be checked. Best practice recommends that all three epochs are logged.

There are two types of logging setup possible:

- Timed Logging – select the specific time at which the epochs are to start.
- Delayed Logging – select a time delay until the epochs are to be logged.

3.3.5.1.1 Timed Logging

Use this option to set the loggers to start at a specific time. The start time of Epoch 1 is selected, and then a selection is made of the number of minutes to subsequent epochs. Epochs 2 & 3 can be disabled if required. The epochs can be between 2 and 60 minutes apart. Each epoch is 60 seconds long. The default times for the epochs are 02:00, 03:00 and 04:00.

	Ensure that all epoch times are set for the same day, do not have them crossing a midnight boundary.

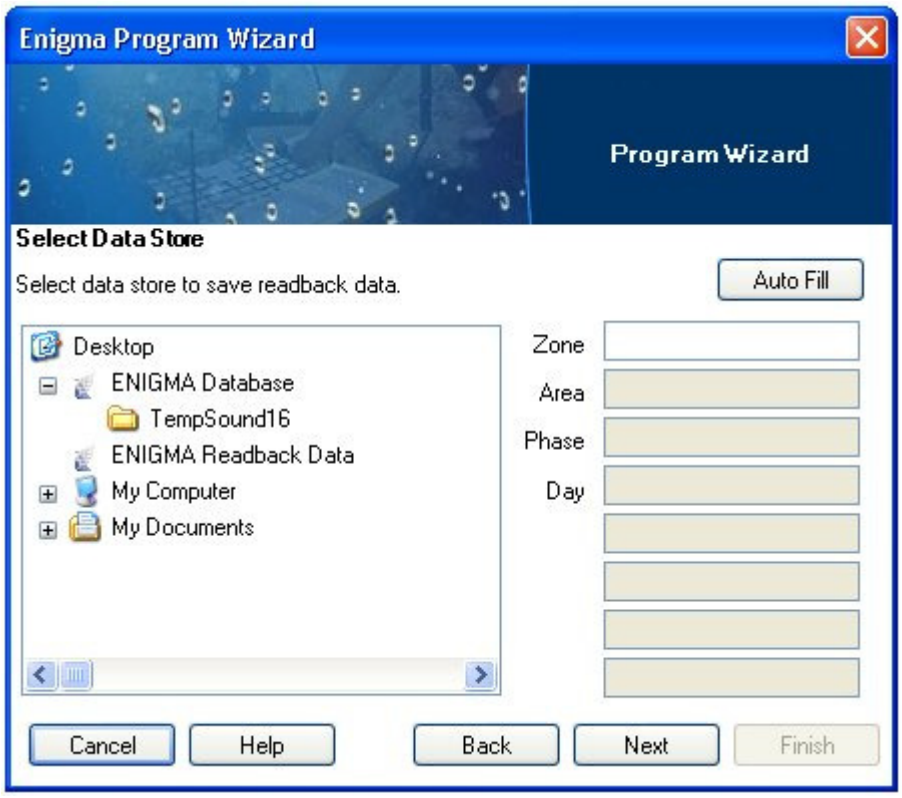
3.3.5.1.2 Delayed Logging

Use this option to set the loggers to start recording after a delay. The delay until Epoch 1 is selectedl and then a selection is made of the number of minutes between subsequent epochs. Epochs 2 & 3 can be disabled if required. The epochs can be between 2 and 60 minutes apart.

3.3.5.2 Current Time

This shows the current PC time. If the Set to PC clock checkbox is checked, the logger clocks will be synchronised with the PC clock when programmed. To set the logger clocks to another time, set the date by clicking on the date display and select the required date. To change the selected date click on the down arrow and a calendar display will open; select the required date by clicking on the appropriate day.

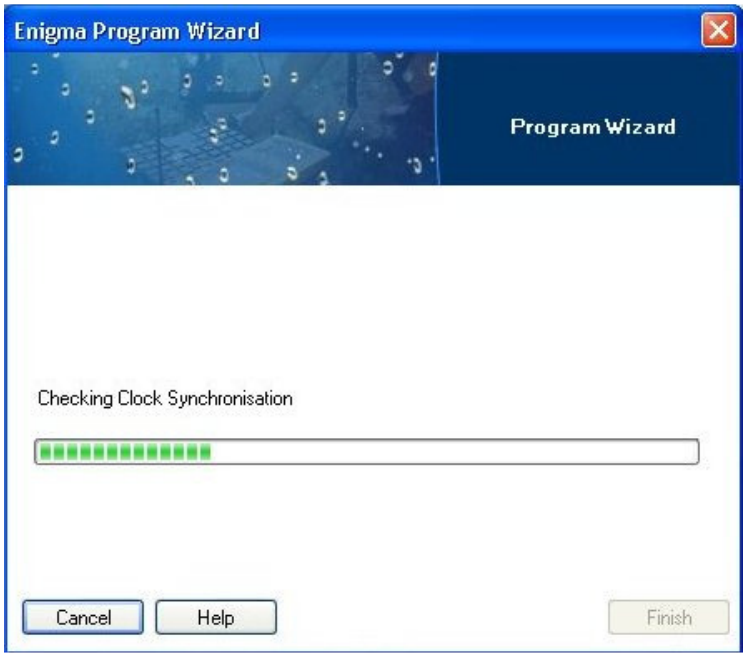
3.3.5.3 Define Data Source



The data store defines the location for saving the logged data when readback. The location information may be entered manually or may be prefilled by clicking on the navigation tree as required (this is useful when revisiting a site previously surveyed). When selecting a folder containing tests for a specific zone or area, click on the Auto Fill button to create a new test (which will be given another phase number and the current date).

3.3.5.4 Program

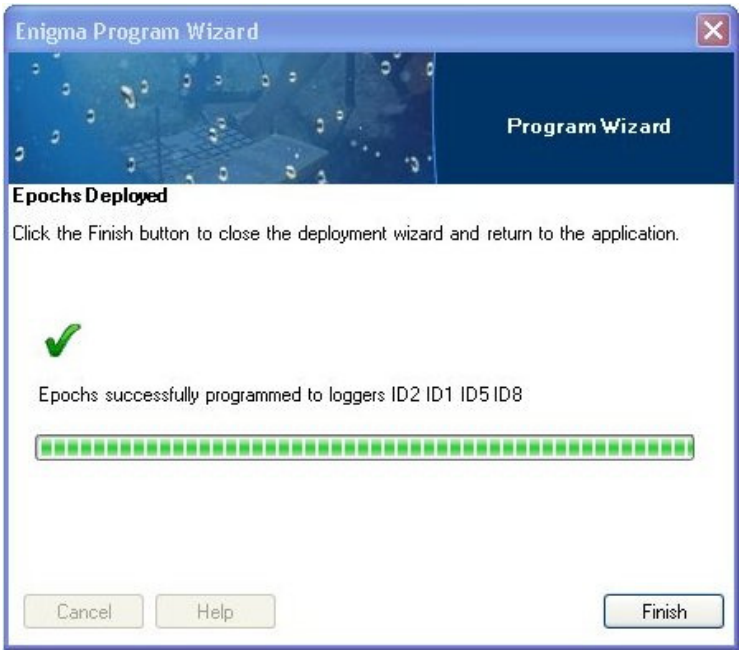
Pressing the Program button will start the programming of the attached loggers.



Programming Loggers

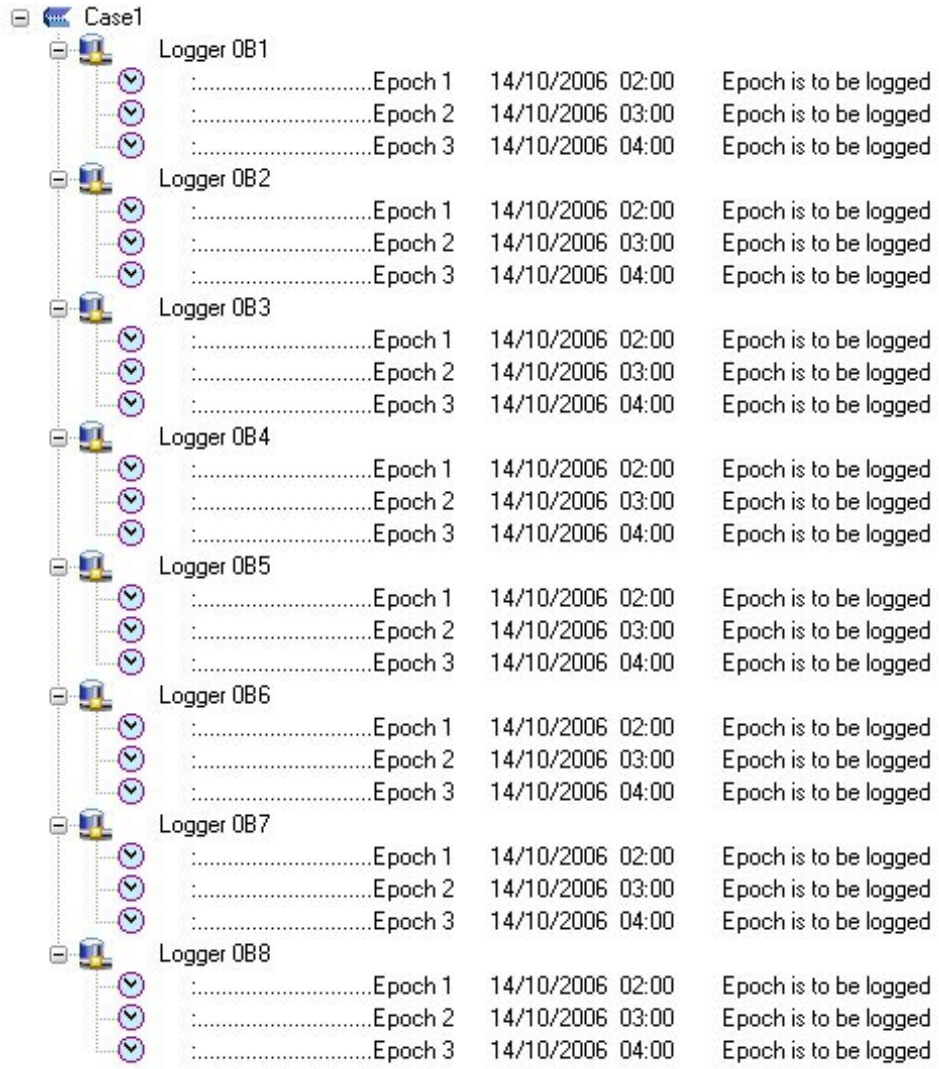
A confirmation dialog box is shown giving the number of loggers detected; click on OK to continue with the programming. If the correct number of loggers is not found, clean the optical windows in the case and on the loggers and restart the programming sequence.

When programming is complete, the dialog shows the success. The screenshot shows that 4 loggers were in the case and successfully programmed.



Program Completed Display

The results of the programming are then shown in the main screen view.



Confirmation of programming

The screen confirms the loggers that were programmed and show details of the Epochs that are now programmed. Note the example above shows a full set of 8 loggers; if only 4 loggers were used only 4 would appear in the confirmation list.

3.3.6 Readback

This option is the same as selecting the Logger Readback option from the Communications menu, and allows a case of Enigma loggers to be readback directly. In this instance the case is used purely as a communications interface, so any data already readback into the case is ignored.

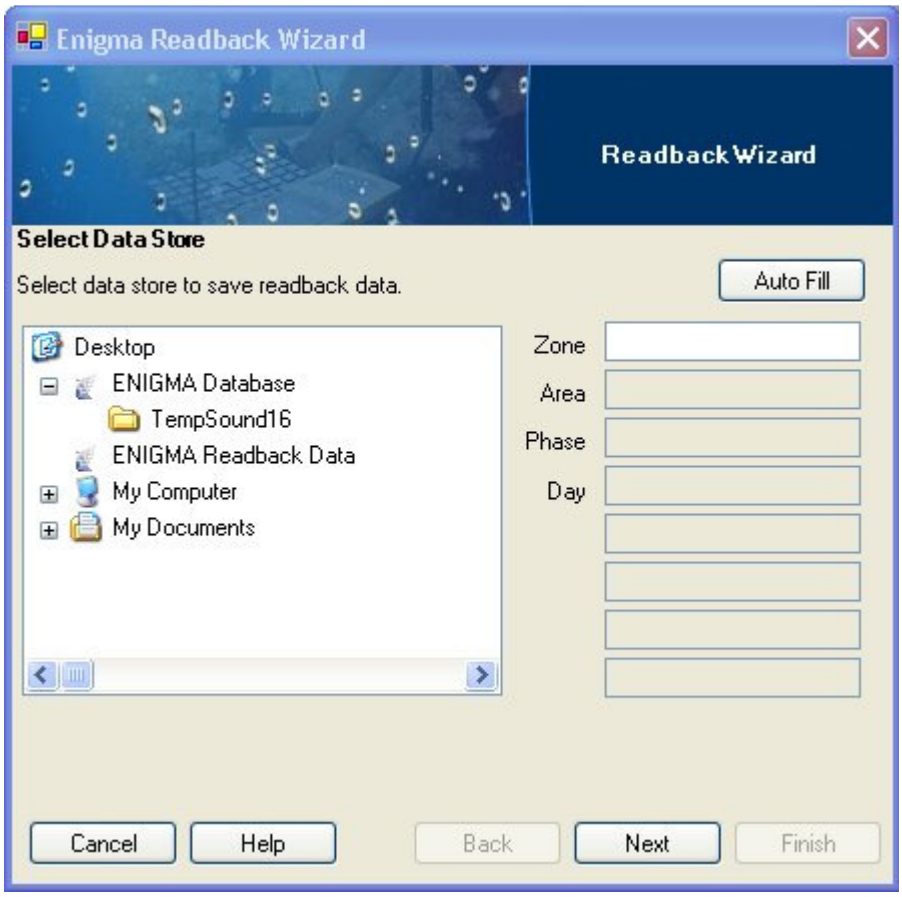
Before attempting to communicate with the loggers, place all the loggers in the case, ensuring the tops of the loggers are clean, and close the case lid.

Readback has the following stages:

- Establish Communication with the loggers
- Select Data Store (manual selection)
- Readback.

Readback – Establishing Communications Progress

A confirmation dialog box is shown giving the number of loggers to be read back; click on OK to continue with the readback. If the correct number of loggers is not found, clean the optical windows in the case and on the loggers and restart the readback sequence.

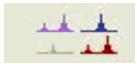


This screen allows selection of where the data will be stored. By default the data store programmed into the logger will be displayed. New information may be entered manually or may be prefilled by clicking on the navigation tree as required (this is useful if revisiting a site previously surveyed). On selecting a folder containing tests for a specific zone or area, use the Auto Fill button to create a new folder (which will be given another phase number and the current date).

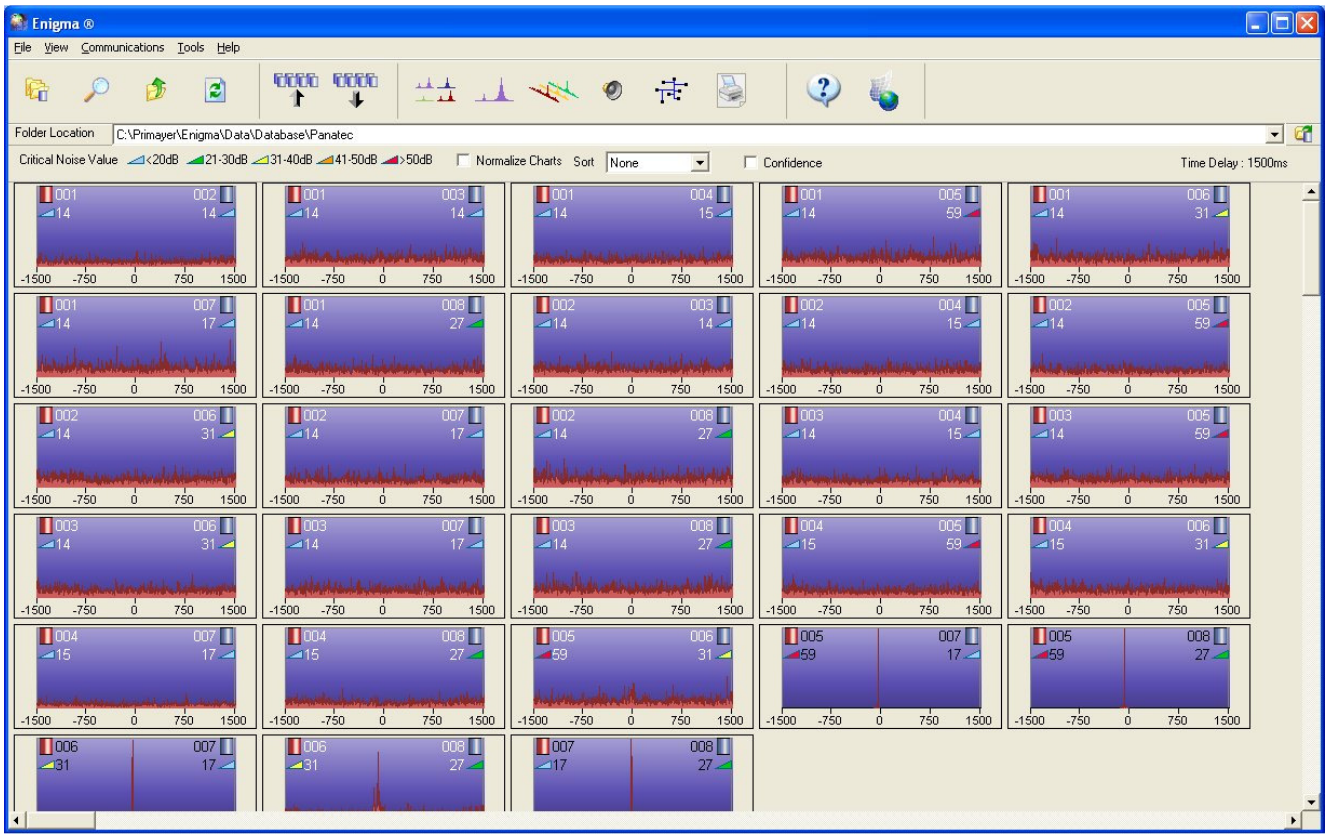
A confirmation dialog giving the number of loggers successfully readback is given, and the option for immediate opening of the data for analysis is given. If analysis is not required immediately then answering no to this option will still save the data for opening in the future.

The new Enigma folder will be added to the folder list to the left of the screen.

3.3.7 Results Icon



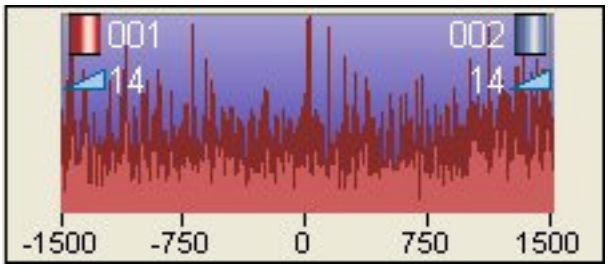
Clicking on the results Icon displays the thumbnail correlations of the current open Enigma test. This screen is displayed as the default when opening an Enigma test for analysis, unless there are only two loggers in the test. In this case there is only one correlation available for view, so the software will automatically display the Analysis screen.



Results – Main Display

The number of thumbnail correlations displayed depends on the number of loggers used. The above example shows results from 8 loggers, giving the correlation result between each individual logger pair. If only 3 loggers were used only 3 thumbnail correlations are displayed.

3.3.7.1.1 Correlation Thumbnail Example



Correlation thumbnail example

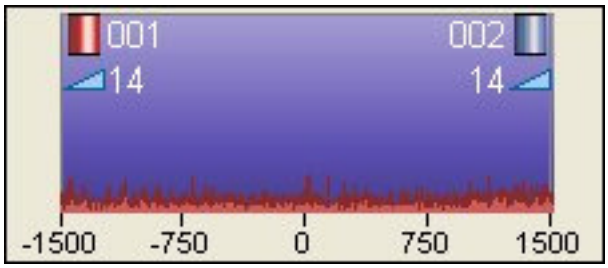
Each thumbnail correlation shows the logger numbers that were used for analysis (top left and right of the data) and the correlation function of the analysis. The time delay available on the thumbnail correlations can be changed using the Max Time Delay option from the Tools menu (see section 3.2.4.3).

Displayed under each of the logger ids is the critical noise value in dB recorded by this logger. This is the lowest consistent noise value recorded by the logger. Generally the higher the dB, the closer to a source of noise (or leak location) this logger has been placed.

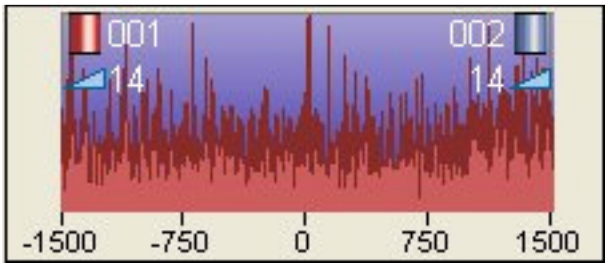
Double clicking on the data will open the Analysis screen for the selected logger pair.

3.3.7.2 Normalize Checkbox

The Normalise Charts check box enables/disables the normalise function which equalises the height of each correlation thumbnail.



Correlation thumbnail

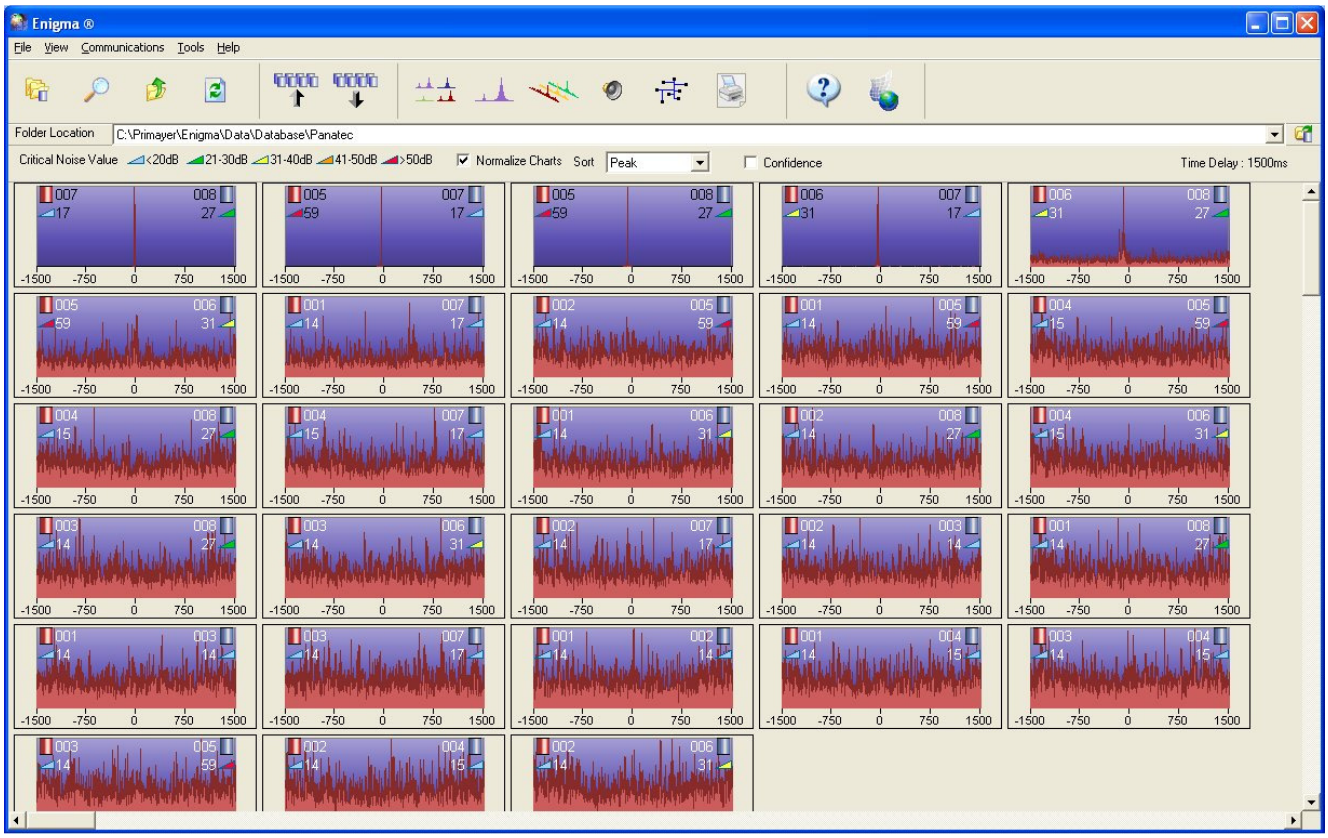


Correlation thumbnail normalized

3.3.7.3 Sort Checkbox

The display order of the thumbnail correlations can be changed, moving the best correlation results to the top of the window.

Sorting correlations by Peak will place the thumbnail with the sharpest peak first in the list. Sorting by time will place the correlation which has a peak at the smallest time delay at the top of the list. No sorting will put the thumbnail correlations from logger 1 first, followed by those from logger 2 and so forth.



The screen capture shows a leak analysis with the sort function enabled and showing the best correlation peaks in decreasing order, starting at the top left of the screen.

3.3.7.4 Confidence Checkbox

When this checkbox is checked, the software will colour the background of the correlation thumbnails with respect to the confidence that the correlation peak is caused by a leak. Confidence is calculated on the peak being present in all epochs, being of approximately the same shape and in the same position on all epochs.

The background colours are:

- Red
- Yellow
- Blue.

3.3.7.4.1 Red

This background colour is set when the software has high confidence that the correlation is due to a leak

3.3.7.4.2 Yellow

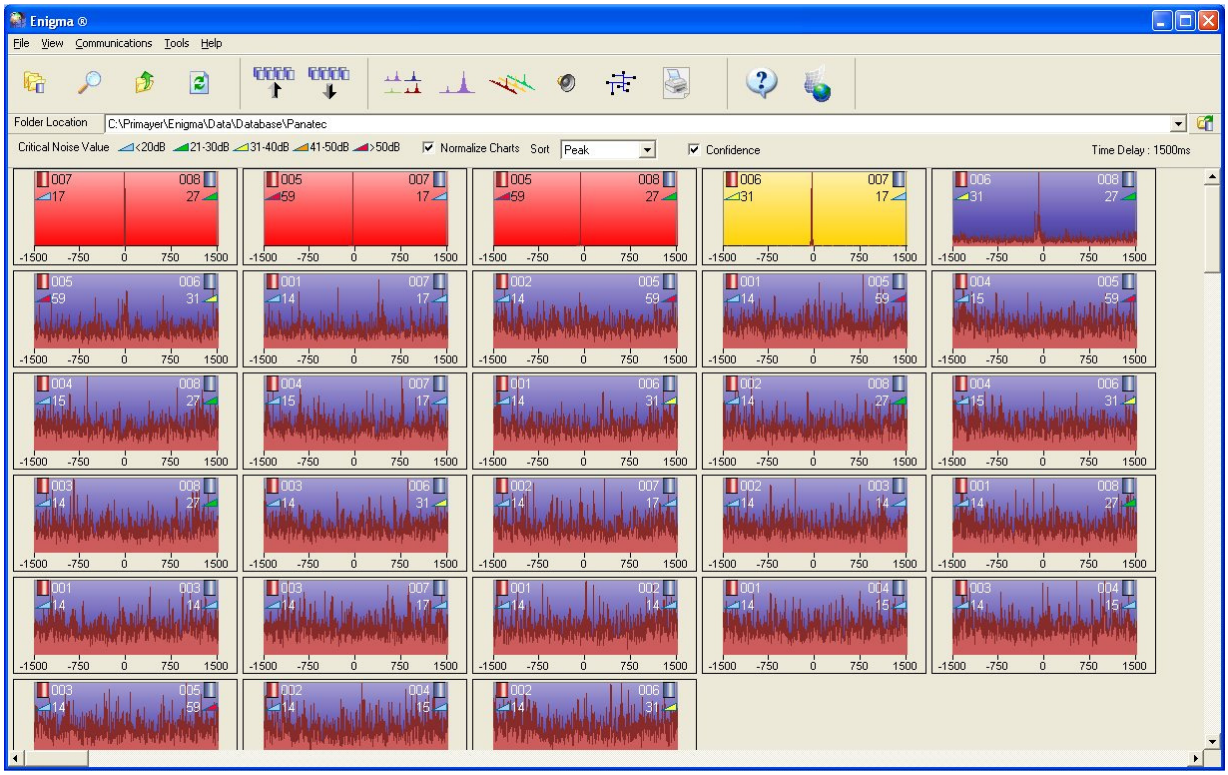
This background colour is set when the software has found a source of noise but it is not confident that it is because of a leak. This could be because the peak is not present in all epochs, the peak is not the same in all epochs or the peak is in a different position in different epochs. Where a yellow background has been produced, the user should look more closely at the epoch display to analyse the data further.

3.3.7.4.3 Blue

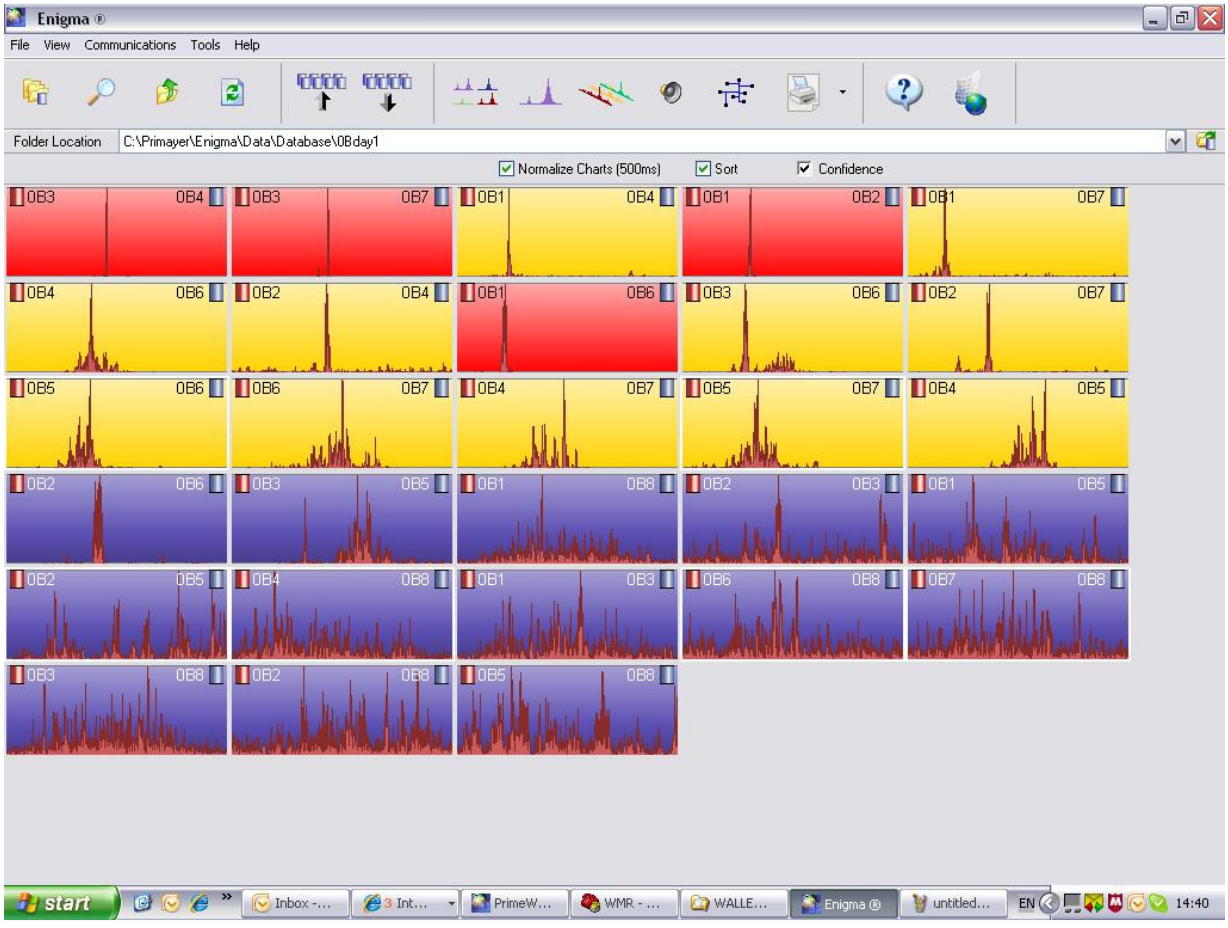
The background colour is set to blue when the software has not found any noise indication.

3.3.7.4.4 Sort and Confidence

The following screen shot shows an ideal sort and confidence display where the leaks are in order and the red thumbnails are at the top left of the screen.



There may be instances where the sort and confidence processing produces a result where the order of the thumbnails with red and yellow backgrounds are mixed. Again the user should look at the three epochs of the correlations and check to see why the colours seem to be out of order. See the screenshot below:



3.3.7.5 Disable

Correlations can be disabled and not included in the thumbnail sorting. To disable a correlation, right click and select the disable option, a check symbol will indicate this option is selected. Disabled correlations move to the end of the main display and are coloured grey. When a correlation thumbnail is disabled, the double click to open the analysis screen for this correlation is also disabled.

To turn off the disable function on a particular correlation, right click on the correlation and uncheck the check next to the menu item. The correlation will then return to the correct position on the main screen and will no longer be coloured grey.

Disabling thumbnails can be useful to remove known sources of noise from the analysis. If a strong correlation peak of a known noise has been picked up by the Enigma loggers, the thumbnails containing this can be moved to the bottom of the display to prevent detracting from the analysis of the other loggers' data.

3.3.8 Analysis Icon

Clicking on the Analysis icon opens the Analysis screen.

	Note Accelerometer and Hydrophone loggers should not be used together.

	Note dB values are not displayed when using a hydrophone logger.

The Analysis screen displays the selected correlation function and contains various tools for further analysis to find the leak position.

3.3.8.1 Analysis Tool Bar

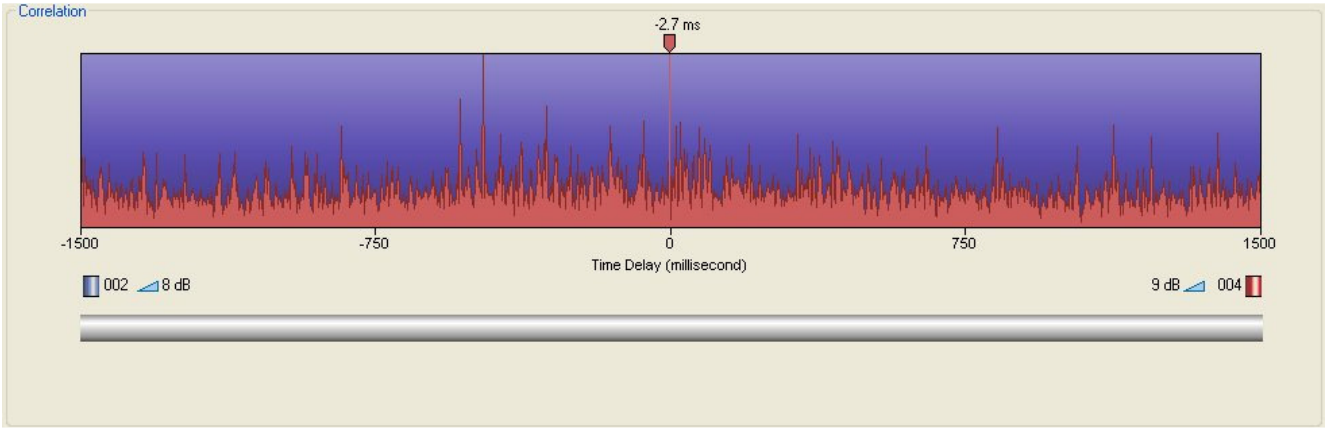
At the top of the display, the numbers for the two loggers being analysed are shown. It is possible to switch to the correlation function between different loggers by changing the selection in these pull down menus. The red logger is always shown to the left of the correlation function and the blue logger to the right of the correlation function.

Analysis Tool Bar

3.3.8.2 Correlation Display

The top part of the screen shows the Correlation function. Sources of noise are represented by peaks in this graphical display. The function is displayed in the time domain (in milliseconds). The centre of the display shows 0ms (i.e. no time delay), positive time delay is toward the right and negative toward the left. Below the correlation function is a graphic representation of the pipe network between the two selected loggers, along with a critical dB value for the appropriate logger.

The lower part of the screen shows the noise data in the frequency domain. Individual traces for each logger are displayed, along with coherence (providing this option is selected for display). Looking at areas of high coherence can give an idea of the frequency components of any consistent noise which is present.



Correlation Display

Note that the leak position will only be displayed after pipe details have been entered. Without this distance information the leak position cannot be calculated.

3.3.8.2.1 Noise Suppression

This option allows suppression of one source of noise temporarily to see if there are other sources of noise within the correlation function. To suppress a particular peak, place the cursor to the left of the peak, press the left mouse button and drag the box over the peak. A range of time delays will show as selected. Once the mouse key is released the remaining correlation function will adjust in height. This enables the other information to be inspected for peaks without the effect of the suppressed peak. To disable the suppression simply uncheck the box and the correlation function will be displayed as before.

3.3.8.2.2 Epochs

Three checkboxes allow each separate epoch to be selected for use in generating the overall correlation function. This selection should only be made after the Epochs have been viewed in more detail (see section 3.3.9)

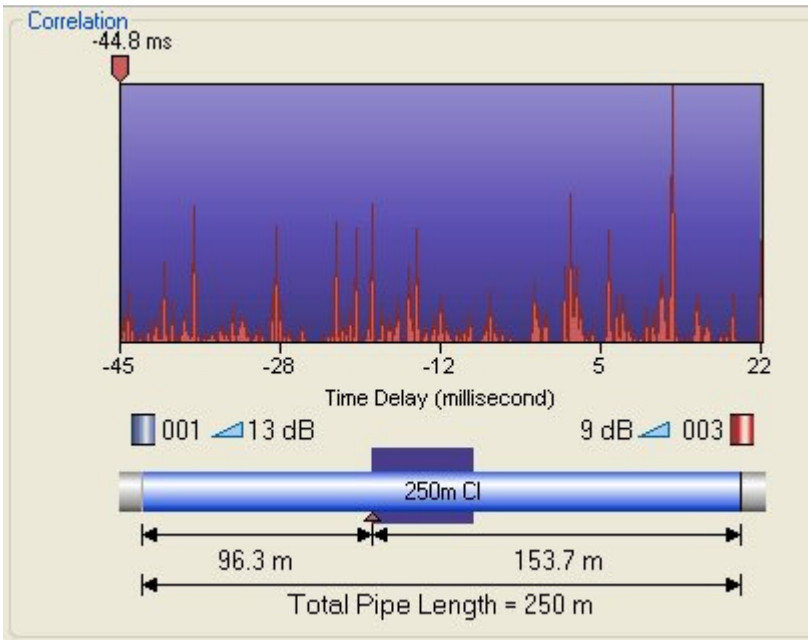
3.3.8.3 Critical Noise Value

The critical noise value is defined as the lowest noise level recorded during the logging time, ie it is the lowest consistent value of noise in dB. This is an important parameter because it indicates the noise level when no other random noise (such as traffic noise) is adding to the leak noise – it is only caused by leak noise. Thus a comparison of Critical Noise Values between loggers provides a clear indication of logger position relative to a leak. The higher the *critical* value then the closer this logger is to a leak.

3.3.8.4 Correlation Zoom

It is possible to zoom the correlation function display. Simply select an area on the correlation screen; press the left mouse button to start the selection and then drag and release. The correlation will update for the time delays selected during the zoom action, allowing a more detailed view of the selected peak position (and so potentially more accurate leak position). A blue box is drawn around the section of the pipe which corresponds to the time delays on screen, as in the example screenshot below:

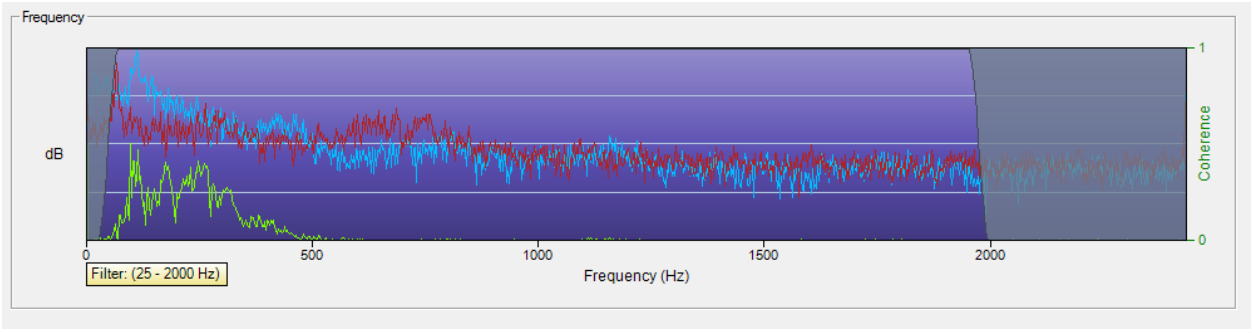
To view the full correlation function again, press the unzoom button within the Correlation Function Tools (Section 3.3.8.6.2)



Zoomed section of display – showing the highlighted zoomed section of pipe

3.3.8.5 Frequency Spectrum Display

The lower part of the screen shows the noise data in the frequency domain. Individual traces for each logger are displayed, along with coherence (providing this option is selected for display). Looking at areas of high coherence (where there are higher values on the green trace) can give an idea of the frequency components of any consistent noise which is present. Areas of high coherence should be used for filter selections.



3.3.8.6 Correlation function tools

The following buttons are available:

- Find Peak
- Zoom Out
- Pipework
- Filters
- Leak Markers

3.3.8.6.1 Find Peak

Pressing this button moves the cursor on the correlation display to the peak position as determined by the software. The time delay of the cursor position is shown above the correlation function.

The cursor can also be moved by dragging with the left mouse key or by use of the left and right cursor keys.

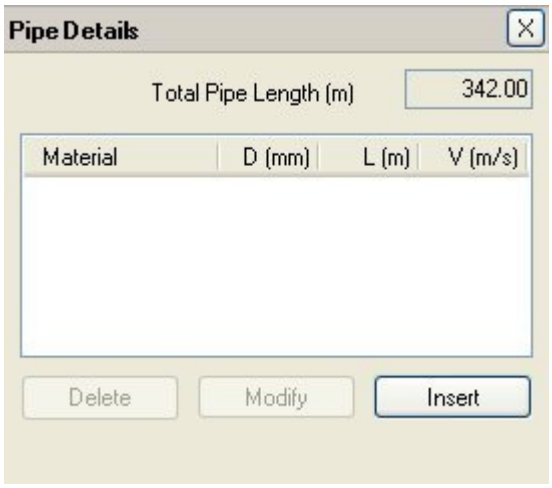
3.3.8.6.2 Zoom Out

Pressing this button will restore the correlation function to its original status, showing either the selected maximum time delay or the full pipe model between the two loggers (if pipe details have been entered).

3.3.8.7 Pipework

	Note Pipework can only be modified or deleted in Network Mode and cannot be inserted.

This option is used to manually add the pipe details, this is necessary before the position of a leak can be accurately measured.



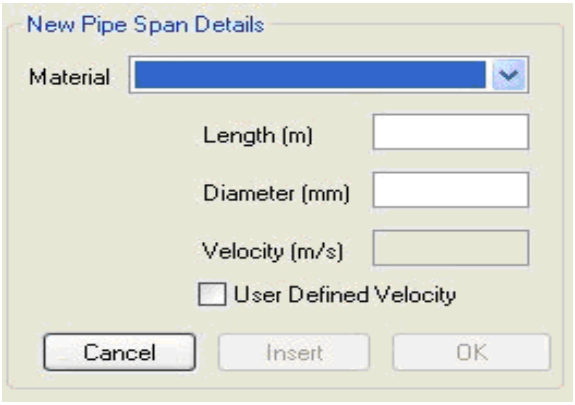
Blank Pipe Details

3.3.8.8 Pipe Details Entry

Before a full leak analysis can be made, the details of the pipe between the loggers must be entered. Multiple sections of pipe can be added where different materials or diameters are used. The user must add pipes in the correct order, from the left logger to the right logger.

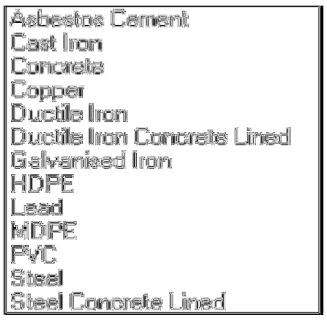
3.3.8.9 New Pipe Entry Procedure

To add a section of pipe, click on the Insert button, this opens the ‘New Pipe Span Details’ section of the window.



Pipe Entry Window

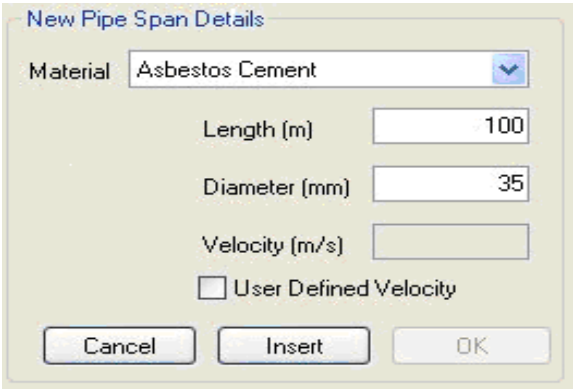
Select the material of the pipe from the list:



Available pipe types

Enter the pipe length.

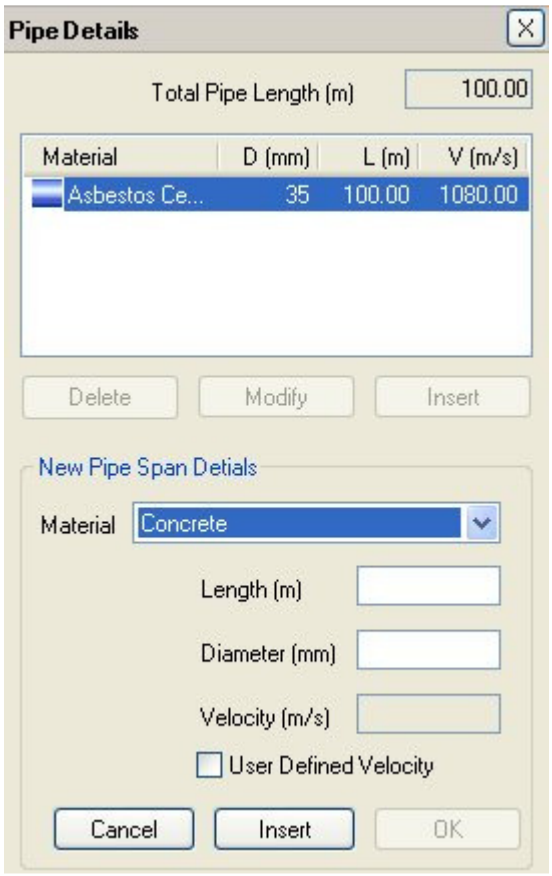
Enter the internal pipe diameter.



Pipe type, length and diameter added

To use a user defined velocity for this pipe, click the checkbox and enter the velocity value. Otherwise the default velocity figures defined within the software will be used.

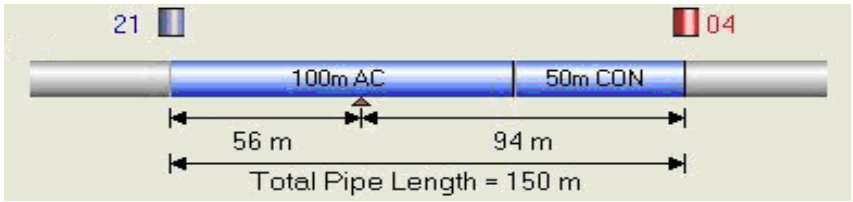
Click on the Insert button to add the pipe section.



New pipe section added

If there is more than one pipe section between the two loggers, the next section can be added by clicking on the Insert button and repeating the new pipe procedure.

When all the pipe sections have been added, click the OK button and the pipe details will be displayed under the correlation function.



3.3.8.9.1 Delete button

To delete a section of pipe, click on the pipe in the pipe details window, and then click on the Delete button. Click on the OK button to confirm the changes.

3.3.8.9.2 Modify button

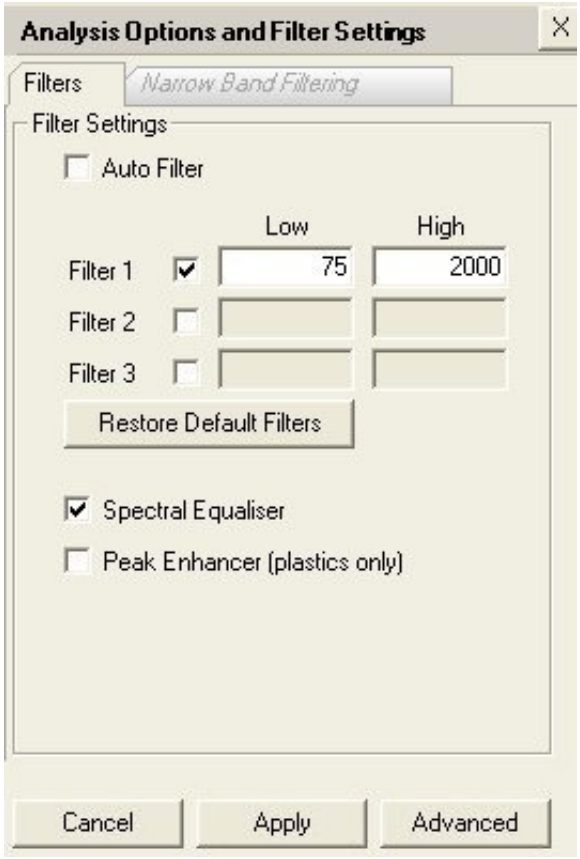
To modify a section of pipe, click on the pipe section in the pipe details window, click on the Modify button, make the changes to the pipe details as required, and then click on the OK button to confirm the changes.

3.3.8.10 Filters Window

Various filtering options are available to help with leak location. Any frequencies outside the selected filters will be ignored and not use when the correlation function is generated.

The filters window has two tabs, Filters and Narrow Band Filtering

3.3.8.11 Filters



Analysis Options and Filter Settings

	Note the default values for hydrophones are different to those shown above. When using hydrophones Primayer do not recommend the use of auto-filter.

Up to three band pass filters can be entered manually. If only one is required, the others can be left disabled. Alternatively a filter can be set by dragging the selected area on the frequency spectrum display. For more than one filter to be activated there must not be any overlap between the end of one filter and the start of the next.

The Restore Default Filters button will restore the filter to be a single wideband filter, the frequencies of which depend on the pipe material and the sensor used (standard Enigma or hyQ variant).

3.3.8.12 Auto Filter

Selecting to use the Auto Filter will make the Enigma software choose filters based on the highest coherence between the two logger sound files. It should be noted that the auto-filter mode can often provide very good results, but in certain cases, manual control of the filtering may be required. Auto Filter is not recommended when using Hydrophones.

After auto filter has been applied, the automatically selected filter(s) will be displayed in the Filter 1, 2 and 3 entry boxes. To cancel the affect the auto filter has on the correlation function, simply select to Restore Default Filters and press the Apply button.

3.3.8.13 Spectral Equaliser

Applying the Spectral Equaliser will even the power across the frequency spectrum. This means that each frequency has an equal weighting when used to generate the correlation function. This feature will help to search for sources of noise which may only be intermittently heard during the sound recording because they are being masked by louder sounds.

3.3.8.14 Peak Enhancer

The peak enhancer should only be used for plastic pipes. It will enhance any peaks which are present, giving a better indication of the exact location of the sound.

3.3.8.15 Buttons

The following buttons control the filters:

- Advanced
- Cancel
- Apply

3.3.8.15.1 Advanced

This opens the Advanced Filter options dialog – see the Advanced Filters section 3.3.8.16 for more information.

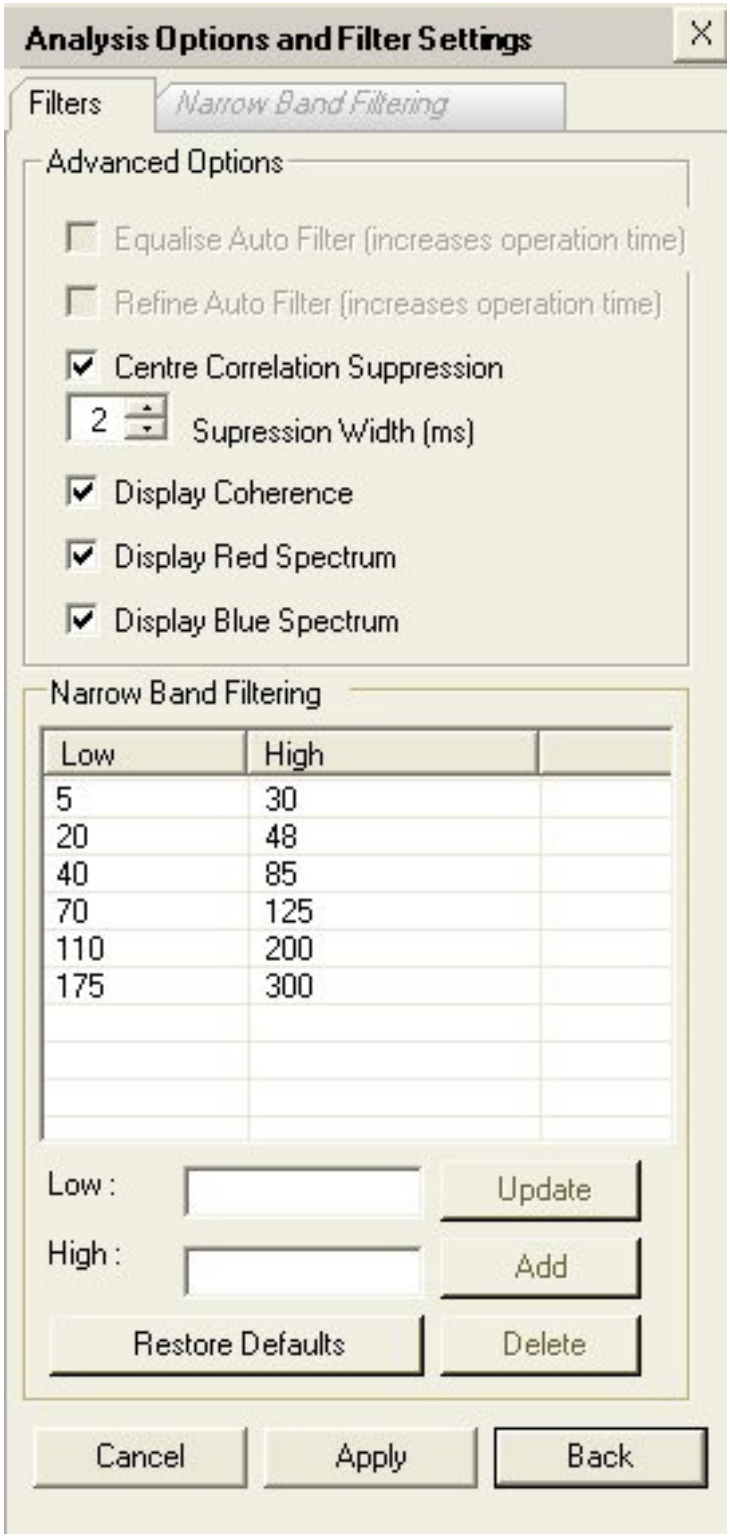
3.3.8.15.2 Cancel

This cancels any changes made to the filter settings.

3.3.8.15.3 Apply

This applies the selected filters to the sound data producing an updated correlation function display. Filter application can take a while to apply depending on the quantity of data, and the speed of the PC. A progress bar is shown.

3.3.8.16 Advanced Filters



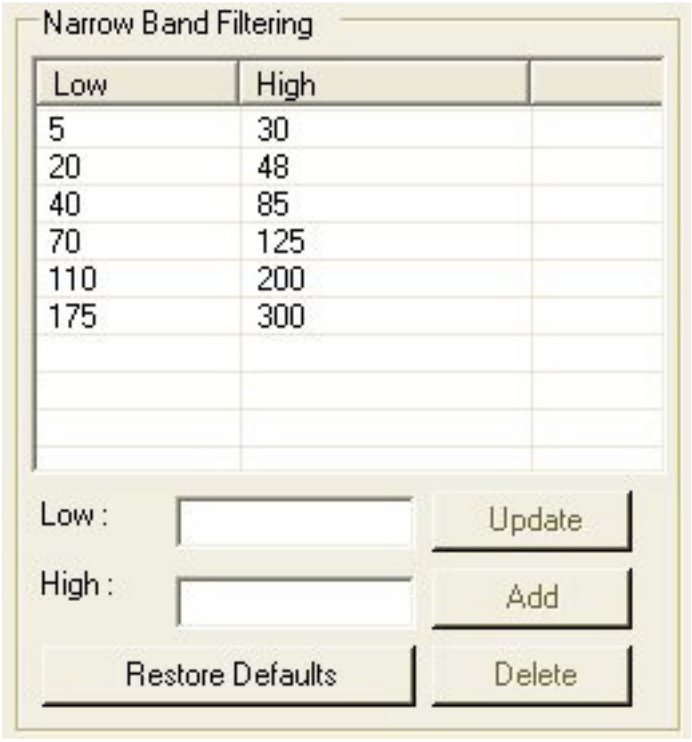
Advanced filters

After changing any of the advanced filter settings, press the Apply button to use these settings. Pressing the Back button will return to the main filter window.

3.3.8.16.1 Narrow Band Filters

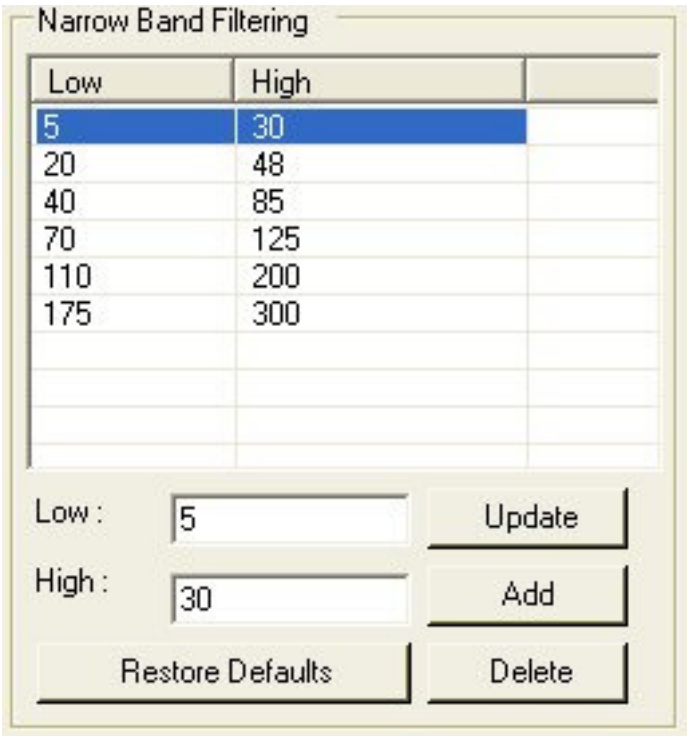
This advanced option allows the settings for the Narrow Band Filters to be changed. The use of Narrow Band Filters is described in section 3.3.8.17

By default there are 6 Narrow Band Filters. These filters can be updated or new filters added as below:



Update a filter

To change the filter settings for a particular filter, click on the filter to highlight the data.



The low and high data will pre-fill in the text boxes, edit the figures as required and click on Update to change the filter settings.

Add a filter

Enter the low and high values for the filter and click on the Add button, this will add the filter into the list.

Delete a filter

Highlight the filter to be deleted and click on the Delete button.

Restore Defaults

Click on the Restore Defaults button to return the filters to the factory default settings; all user changes to the filters are lost.

3.3.8.16.2 Equalise Auto Filter

This option applies the Spectral Equaliser whilst the Auto filter is processing data (rather than afterwards). This filter can sometimes improve the correlation result. When this option is used the operation time will be increased.

3.3.8.16.3 Refine Auto Filter

This option applies some extra refinement to the Auto Filter algorithm. When this option is enabled data processing will take longer. This option should only be enabled if the standard auto filter has failed to give adequate results.

3.3.8.16.4 Centre Correlation Suppression & Suppression Width

Centre correlation peaks can occur due to unwanted noise which is common to both loggers. This option controls whether to suppress any correlations formed due to this noise, and the number of milliseconds of correlation data to suppress.

3.3.8.16.5 Display Coherence

When this option is enabled a third green trace is added to the frequency spectrum display. The coherence shows the similarity between the two logger recordings at each frequency. Where the coherence is higher, the filters should be selected to use these frequencies.

3.3.8.16.6 Display Red Spectrum

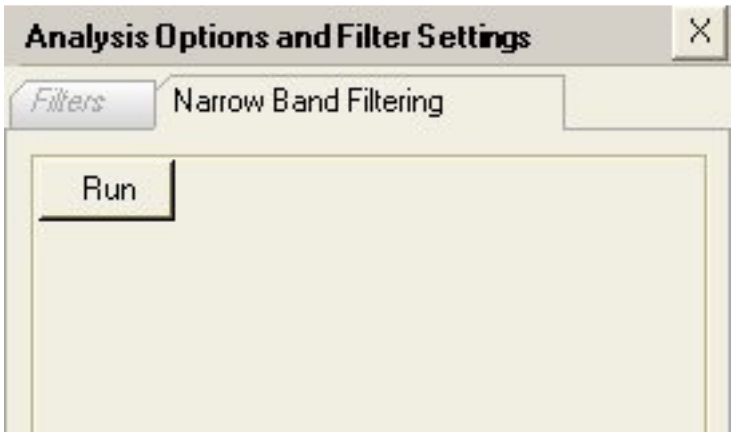
This turns on or off the display of the frequency spectrum from the red logger – the one to the left of the correlation function.

3.3.8.16.7 Display Blue Spectrum

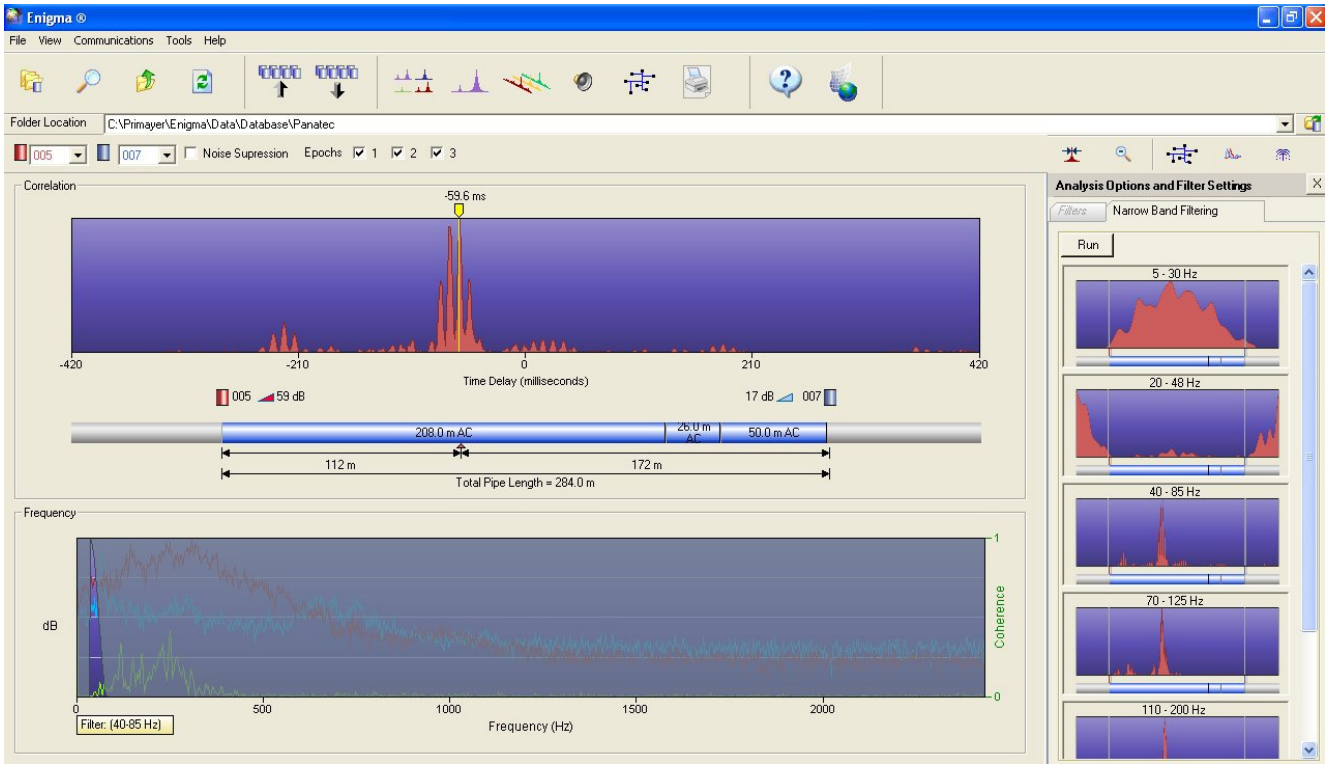
This turns on or off the display of the frequency spectrum from the blue logger – the one to the right of the correlation function.

3.3.8.17 Narrow Band Filtering

Using narrow band filtering removes some of the guess work out of selecting different filters in an attempt to find a low frequency source of noise – so particularly when correlating over long distances, on large diameter mains, on plastic pipes or when using hydrophones.



When the Run button is pressed, a series of narrow band filters will be applied to the correlation function, and the results shown as thumbnails on the Narrow Band Filtering display tab. The narrow band filter which provides the best results is then pre-selected by the software and the results displayed in the main analysis window.

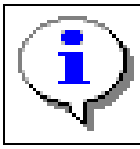


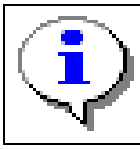
To view any of the other results in more detail simply double click on the appropriate thumbnail. After applying narrow band filtering, the filters can be changed manually by changing values in the main Filters tab.

The Narrow Band Filters to be applied when using this option can be updated using the Advanced button on the Filters Tab.

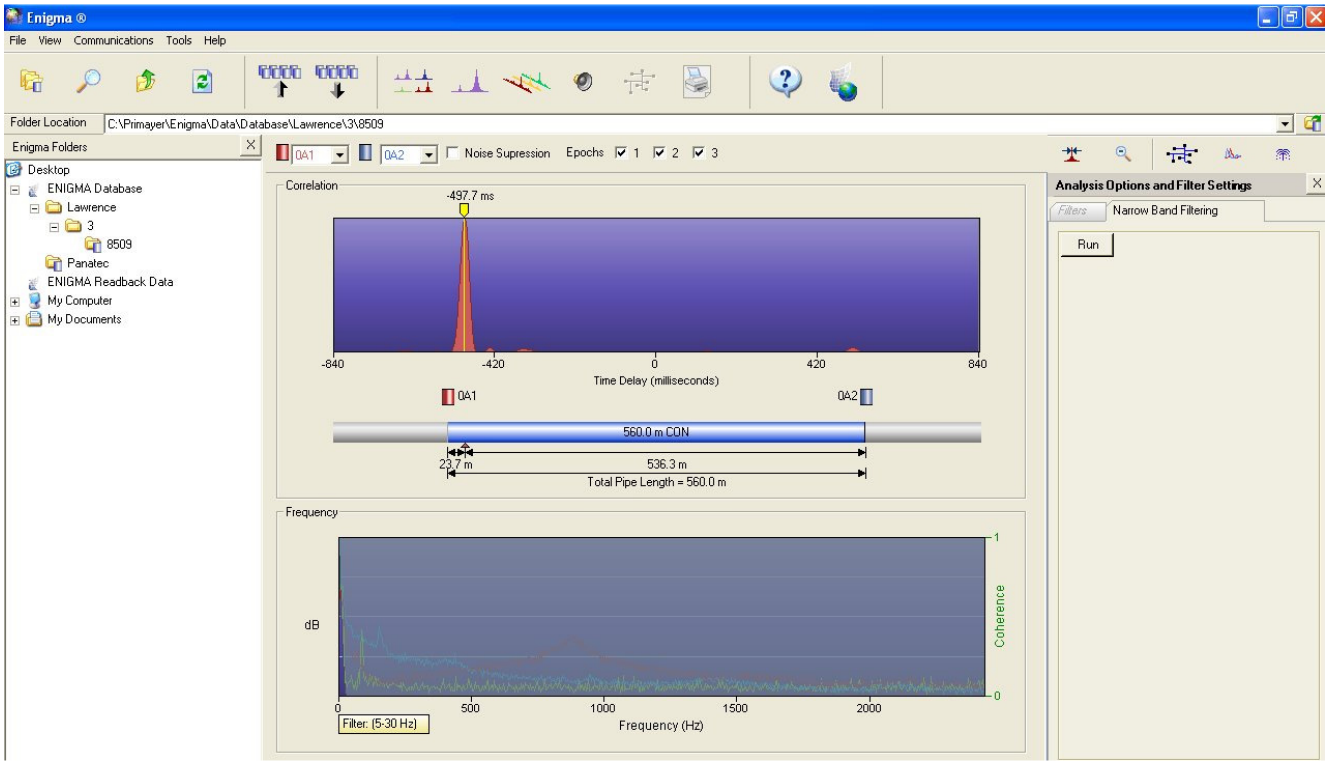
3.3.8.18 Auto Velocity at Out Of Bracket

Sometimes it is known that the noise source being heard by the loggers is out-of-brackets, i.e. beyond the logger position. In this case, the correlation peak should appear at the logger position. If the velocity being used is inaccurate the peak position may appear within brackets, very close to the logger position. Enigma contains a feature to allow auto-correction of the velocity being used if this is the case.

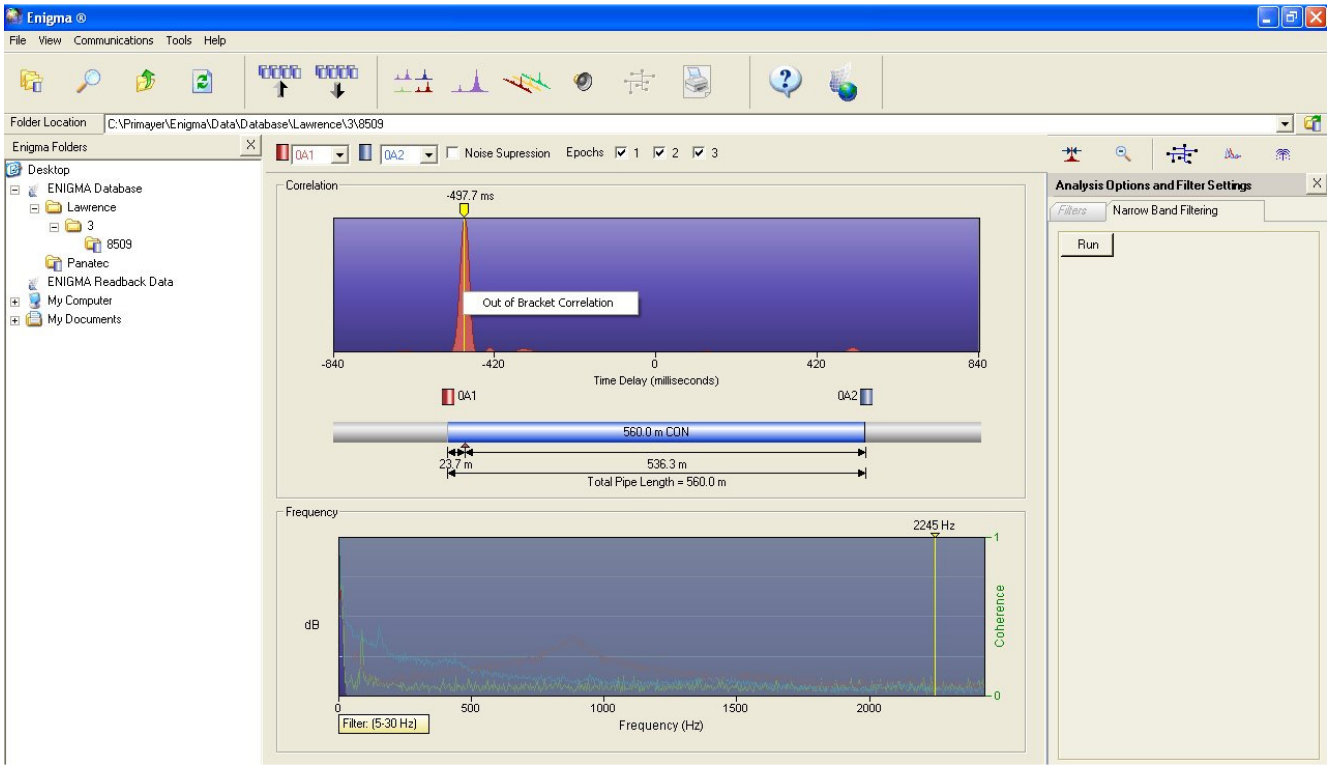
	This function must only be used when it is known an Out Of Bracket condition exits.

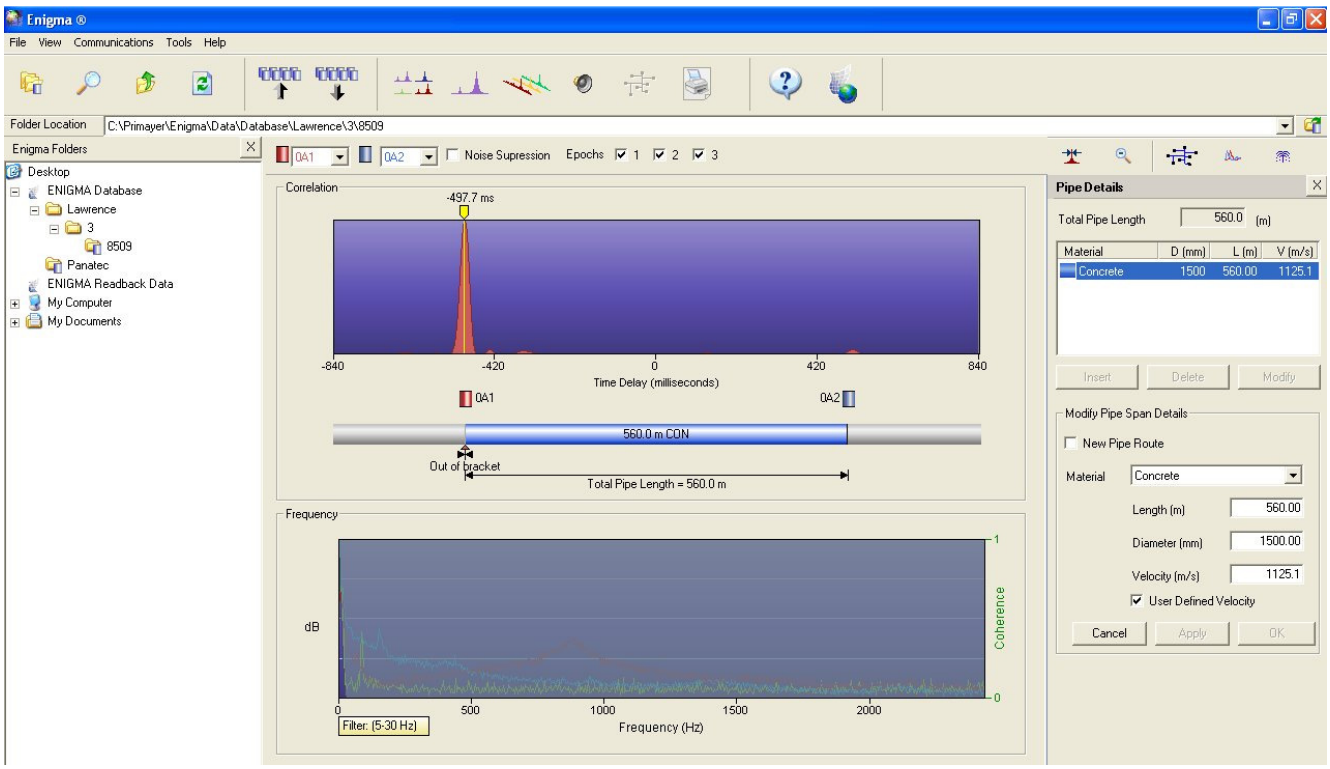
	To get an accurate result with this function, the correct distance between sensors must be set.

In the following example the default velocity was used to determine the peak position and the peak appears just inside the limit of the left end of the pipe model.



Move the cursor to be on the peak, and right click in the correlation window. Select the Out of Bracket Correlation option. This will force a velocity calculation which will place the correlation peak at the end of the pipe model (i.e. the logger position).

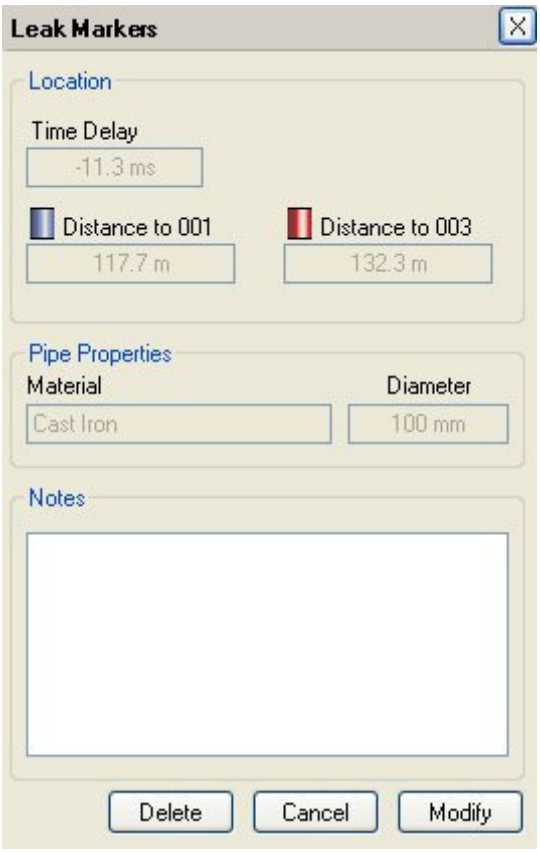




After re-correlation the peak has moved to the logger position at the end of the pipe. The velocity for the pipe model has been updated based on this change of distance.

3.3.8.19 Leaks (Leak Markers)

This facility allows the user to mark leaks or points of interest on the pipe model when they have been found. Leak markers will auto display in Network Mode. Note leak markers out of bracket will show in the analysis screen but will not show in Network Mode.

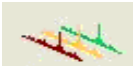


Leak Markers

To add a leak marker, make sure the cursor on the correlation window is in the desired position and click the OK button in the Leak Markers window, this will mark the correlation graph with a leak symbol. Notes about leak positions can be entered. Leak marker positions will also be displayed in reports generated.

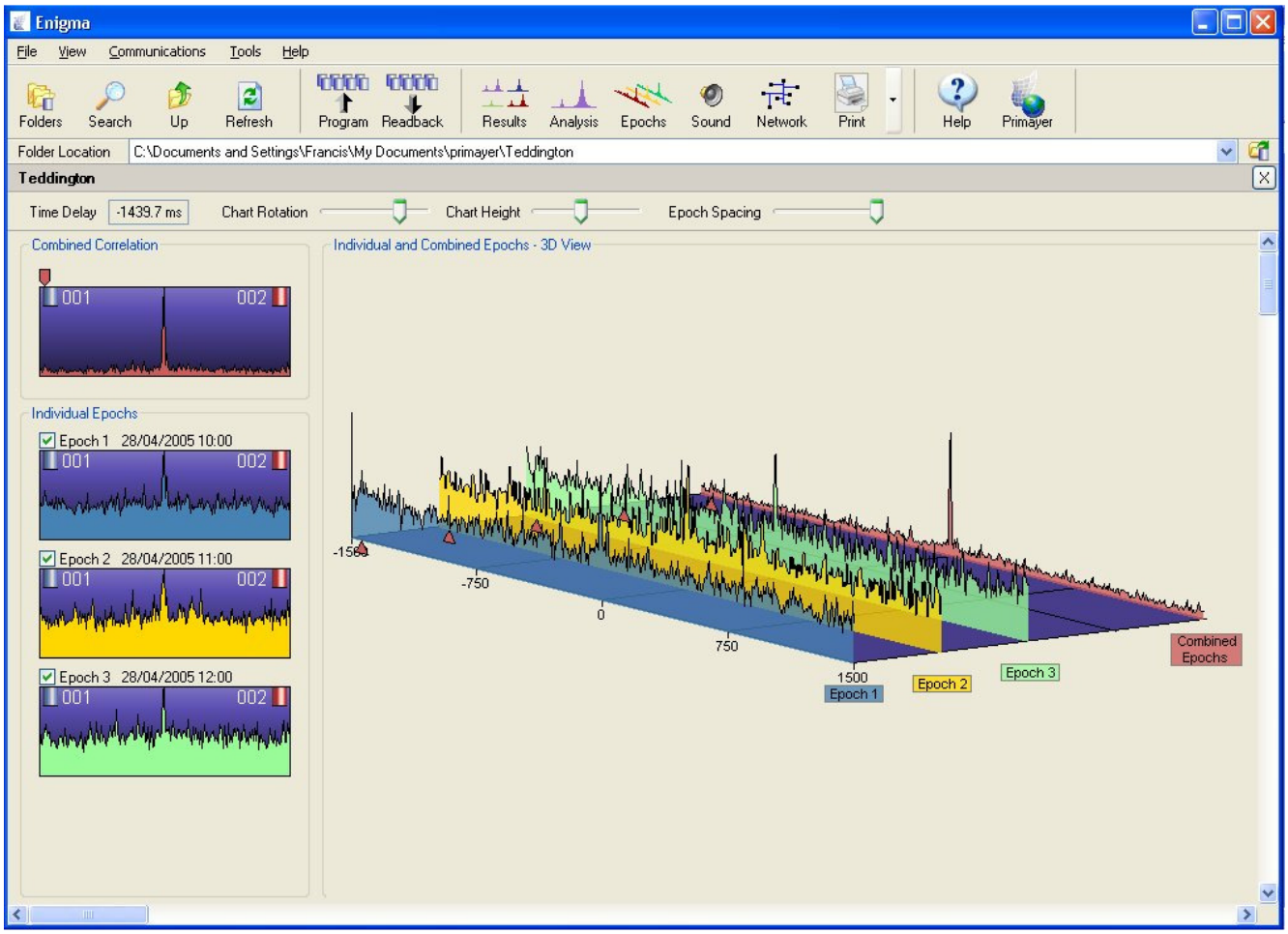
To modify or delete a Leak Marker, click on the Leak Marker icon above the pipe model in the correlation screen and make the changes as appropriate.

3.3.9 Epochs Icon



This icon opens the Epoch display which shows two dimensional and three dimensional views of the correlation functions produced by each epoch. Viewing the epochs is beneficial to determine if a correlation peak is caused by a leak (present in all epochs) or non-leak noise, perhaps customer water use (not present in all epochs).

The epochs display is for the logger pair as selected under the Analysis screen.



The display has the following items:

- Time Delay
- Chart Rotation
- Chart Height
- Epoch Spacing
- Combined Correlation
- Individual Epochs.

3.3.9.1 Time Delay

This shows the time delay at the cursor position, this position is shown by the marker above the Epochs on the left side of the display, and the triangle under the lower edge of the 3d display. The cursor can be moved by dragging the cursor marker above the epoch on the left side of the screen with the mouse, or moved finely using the left and right cursor keys.

3.3.9.2 Chart Rotation

This alters the rotation of the 3D display to aid visual analysis.

3.3.9.3 Chart Height

This alters the vertical scale of the 3D display to aid visual analysis.

3.3.9.4 Epoch Spacing

This alters the spacing between the Epochs on the 3D display to aid visual analysis.

3.3.9.5 Combined Correlation

This graph shows the result of the combined correlation from all the selected epochs..

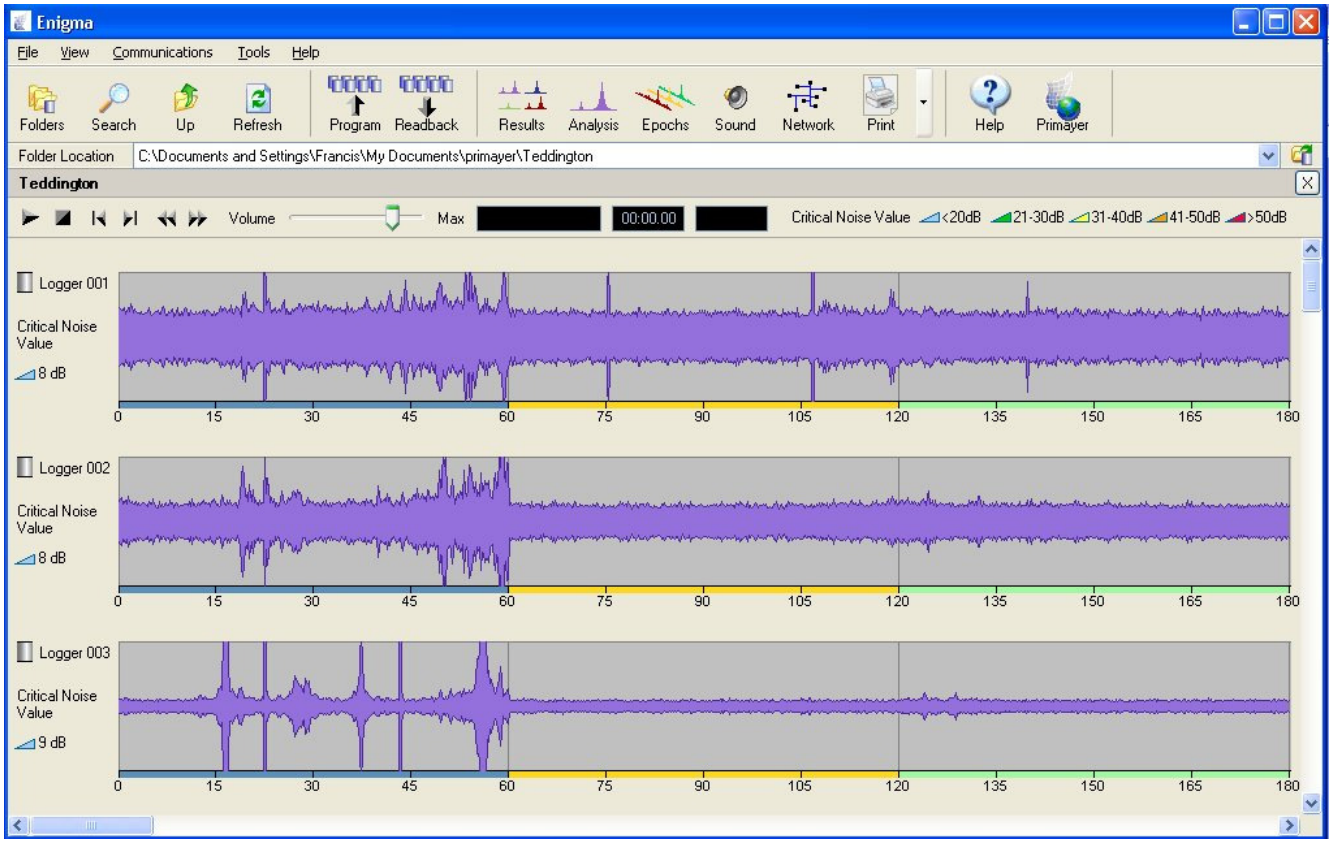
3.3.9.6 Individual Epochs

This shows the correlation function for each individual Epoch, the date and time of the recording, and the numbers of the loggers in the analysis pair. Above each graph is a checkbox that can be used to choose whether this epoch is used to generate the combined correlation or not.

3.3.10 Sound Icon

Clicking on this icon opens the sound window.

The sound window displays a graphical representation of the sound files from all of the loggers.



Sound Display

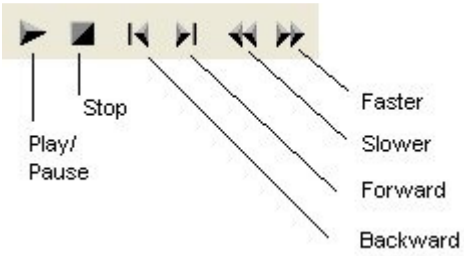
The display has the following features:

- Control Buttons
- Volume Control
- Logger Number
- Critical Noise Value
- Sound Graph.

Click on a sound graph to select which sound to 'play'.

3.3.10.1 Control Buttons

The control buttons control the playback of sound through the PC speaker or headphones if fitted.



3.3.10.2 Volume Control

This adjusts the playback volume, note it may also be necessary to use any additional software and hardware sound controls to set the required volume on the PC.

3.3.10.3 Logger Number

This shows the number of the logger, this is also shown on the top of the logger.

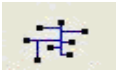
3.3.10.4 Critical Noise Value

This shows the critical nose value (i.e. the lowest consistent noise value for the logger during the epochs). The closer the logger is to a source of leak noise the larger this value will be.

3.3.10.5 Sound Graph

This shows the sounds recorded in graphical format. If there is more than one epoch these are marked in different colours. A cursor shows progress of the playback through the sound files. The sounds files from all loggers within an Enigma test are available to view, and the sound from the different loggers can be listened to by selecting the graph and using the Control buttons as above. The cursor position can also be dragged along the graph to skip to a different part of the sound file.

3.3.11 Network Icon



The network screen allows the user to enter a pictorial pipe network showing pipe lengths and logger locations. The network can be overlaid on a map background.

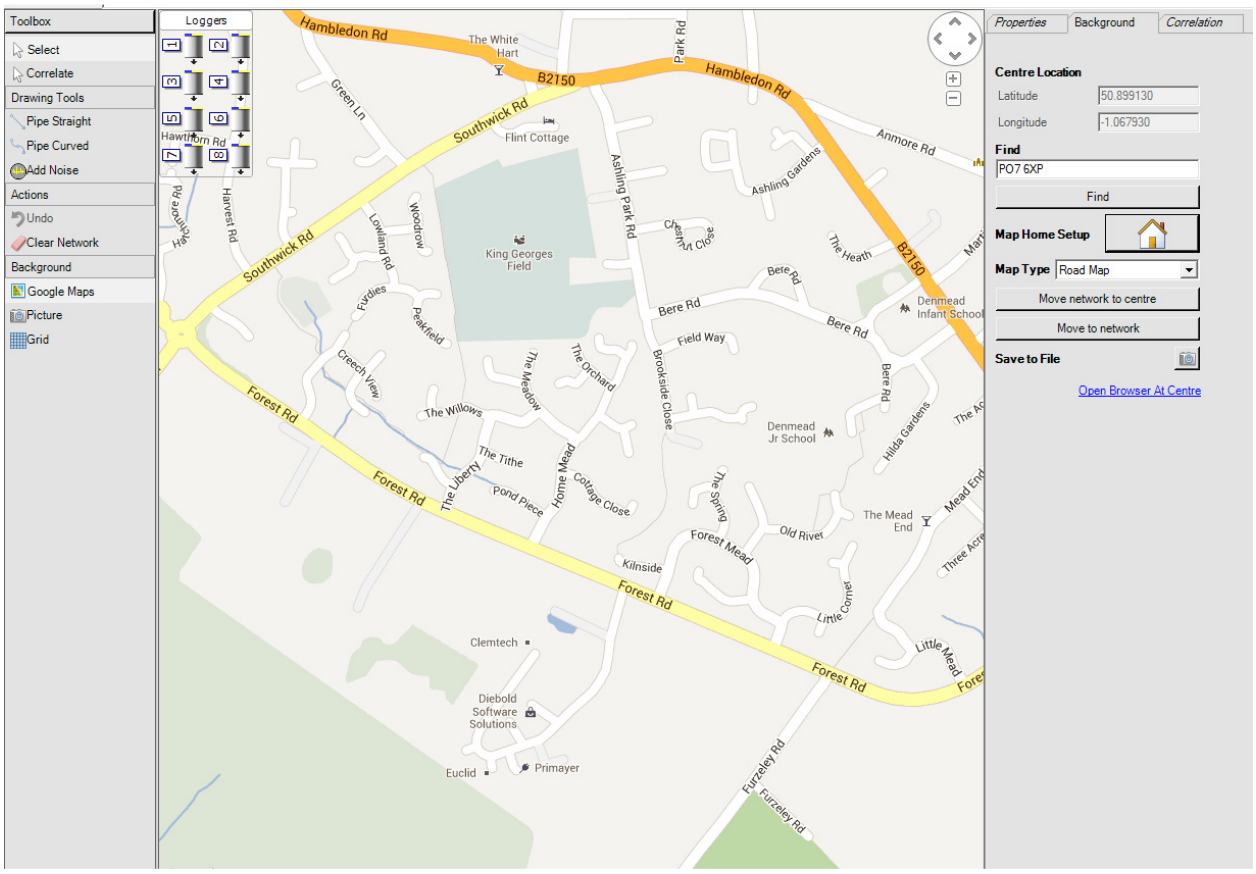
The Network screen copies pipe data into the database and can be used as an alternate way of entering pipe data instead of via the Analysis Screen method. Note that entering pipe data in the Analysis screen does not create a pipe network on the network screen.

Clicking on the Network Icon opens the network screen. Note that either the Network Screen or the Manual entry mode can be used, but not both at the same time, selection of the mode used is from the Tools, Pipe Data Entry menu, a tick is show against the current selected mode. It is possible to switch between modes if required.

The user can draw a network as required and enter pipe data on the sections; this adds the pipe information into the database as well as creating a pictorial pipe network. When pipe data is entered by drawing the network all pipe lengths must be entered for accurate pipe details to be used in the Analysis screen.

3.3.11.1 Background – Google Maps

By default, the network options will attempt to display a Google map of the home location.



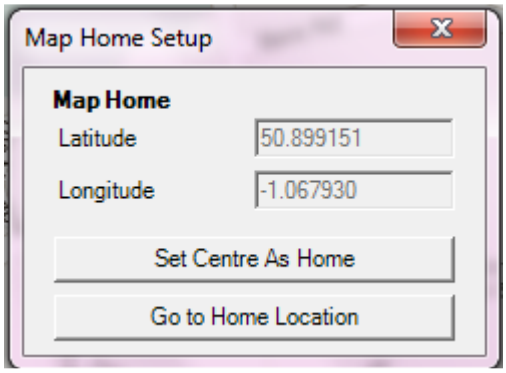
Google Maps

When this selection is made, Google maps is used as the background for the map area. The map can be zoomed or panned using the standard Google maps tools in the top right hand corner.

Centre Location
This gives the latitude and longitude of the current centre of the map.

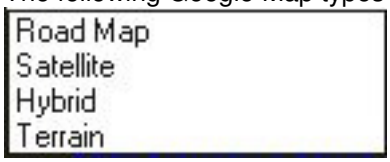
Find
This selection can be used to find a location on the Google mapping system. Search for an address, postal code, location or GPS co-ordinates.

Map Home Setup Button
Pressing this button will open another window:



This allows setting of the Home location, and also allows moving of the map to display the Home location. This can be used to return to the Home location after a Find operation has been undertaken.

Map Type
The following Google Map types are available:-

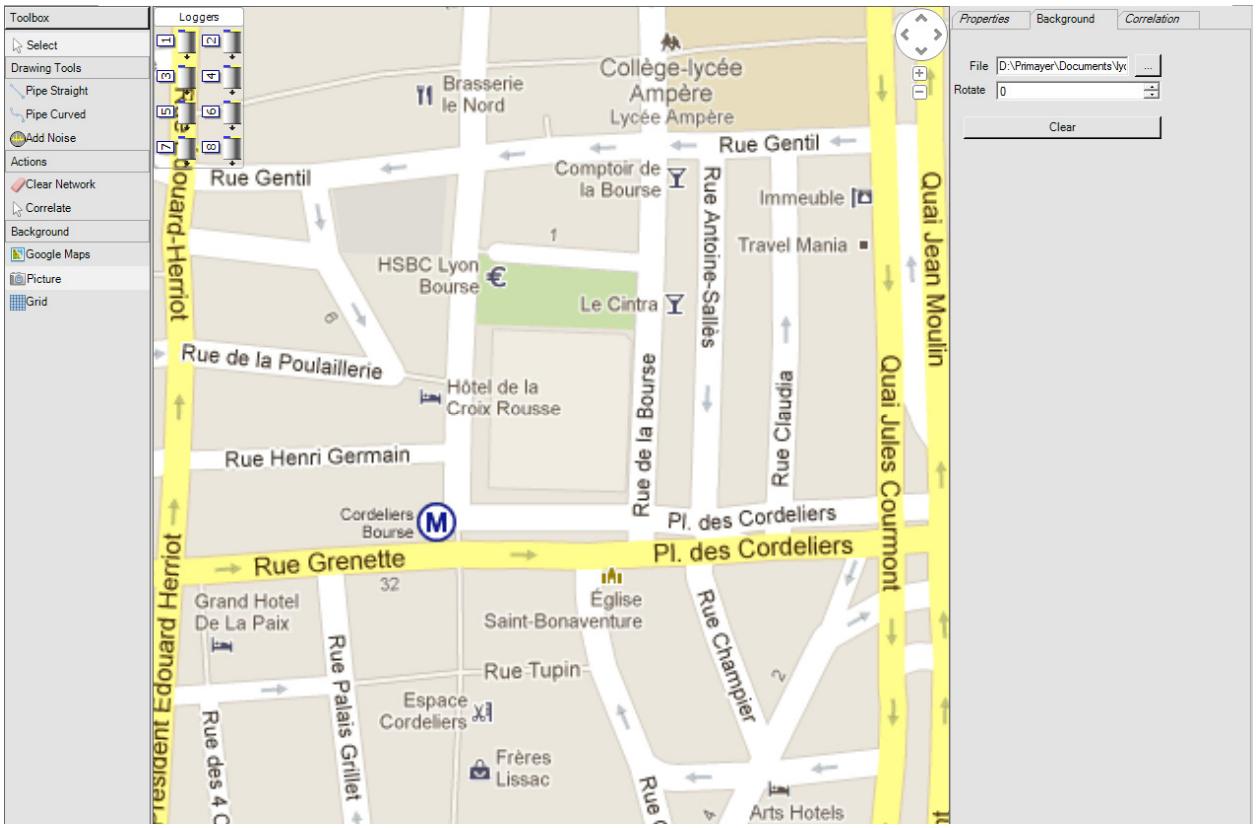


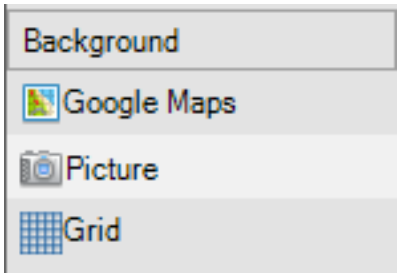
Move Network to Centre
When pressed, this button will take any pipe network drawn and place at the centre of the current map. This option can be used in conjunction with the Find button to move a network from one location to another. This may be required when initially displaying the Google map for a network file which is already drawn. By default the network will be placed at the Home location. To move to an alternative location, simply search for the new location and press this button to move the network to the new location.

Move to Network
When pressed, this button will move to the position of the currently drawn network, if there is one. If the Find button has been used to move to a different location temporarily, pressing this button will then return to the location of the currently drawn network.

Save to File
This option saves the current map to a file so that it can be reloaded in future when access to the internet is not available.

3.3.11.2 Background – Picture





Picture

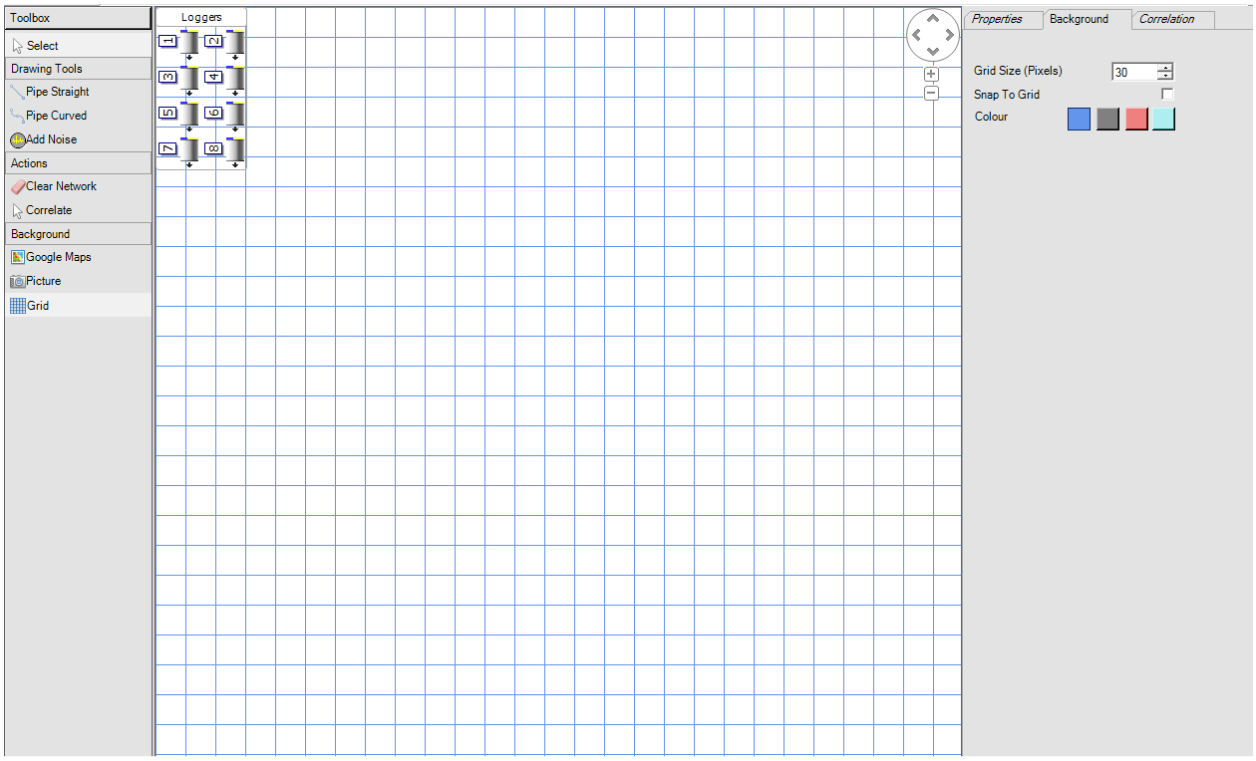
When this selection is made, a user selectable picture is used as the background for the network; this could be a map exported from a GIS system, or a map downloaded and saved from Google Maps, using the Save to File option as outlined above.

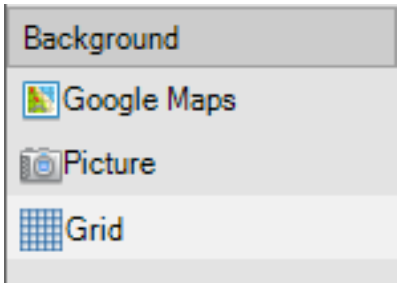
File
The background graphic file is selected here, click on the button to open a standard windows navigation window, navigate to the location of the required file and double click on the file to set it as the background image.

Rotate
This selection is used to rotate the background by a number of degrees as required. The required rotation figure can be typed into the field or the existing figure increased or decreased by clicking on the up or down arrow. Rotating by 180 degrees will turn the picture upside down.

Clear
This option will clear the selected graphic from the map area. Any network drawing which has been made on top of the file will not be cleared.

3.3.11.3 Background – Grid





Grid

When this selection is made, a grid is used as the background for the map area.

Grid Size
This selects the size of the grid on the map area. The value required can be entered in the field from the keyboard, or the existing figure can be scrolled up or down by clicking on the up and down arrows.

Snap To Grid
When this checkbox is selected any pipe sections drawn on the grid will snap to the grid squares.

Colour
This section allows the user to select one of four colours for the grid.

3.3.11.4 Network Drawing

The tools for network drawing are located in the Toolbox.

3.3.11.5 Toolbox - Drawing Tools

3.3.11.5.1 Pipe Straight

This tool is used to draw straight pipe sections. To add a pipe on the background, left mouse click and hold on the start point, move the mouse to the desired position at the end of the pipe and release the mouse button. This adds the pipe to the map. The process can be repeated by clicking on the end of a pipe to add pipe sections to form a network as required.

Each pipe section will end in joints. Connecting two joints together is shown by the colour of the joint being highlighted in green

3.3.11.5.2 Pipe Curved

This tool is used to create a curved pipe section, to allow overlaying of pipe sections onto maps. Click and hold on the start location of the pipe, draw along the required path of the pipe, release the mouse button at the end of the pipe section. The pipe appears on the map with waypoints at the major changes of pipe direction. These waypoints can be selected and moved as appropriate.

3.3.11.5.3 Add Noise

This option can be used to place a manual noise point on the network. This could mark the location of a known noise source in an area. The noise source should be placed onto the pipe location and a comment to define the source can be added.

3.3.11.6 Toolbox - Select

Use this option to select items on the network drawing by simply clicking on the desired item. The selected item is highlighted and can be dragged around the map area as required. Pipe joints, waypoints, loggers and other items can be selected and moved as required.

To select several items use the CTRL key and left mouse button to select each item.

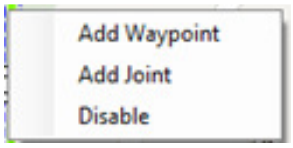
To clear the current selection, use the Esc key.

When selected, items can be deleted using the delete key. If a pipe joint is deleted all the pipe sections and loggers attached to this joint will also be deleted.

After having used any of the Drawing Tools as above, pressing the Esc key will return the software to this Select mode.

Logger Select
When a logger is selected, there is a **Play** option under the right click context menu. If there is more than one sound file, an additional selection of which epoch to play is available. Whilst the sound is playing, the option under the menu changes to **Stop**.

Pipe Section Select
When a pipe section is selected the following context menu is available through the right mouse click:

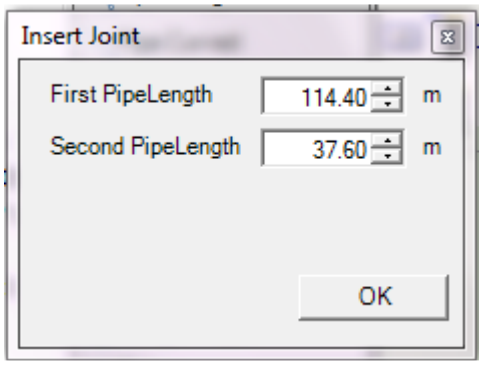


Add Waypoint/**Add Joint** allows addition of new joints or waypoints along the pipe length. The waypoint or junction will be created at the point on the pipe where the mouse was clicked. If a joint is added, a confirmation window allowing editing of the two new pipe section lengths is displayed.

Disable will disable the currently selected pipe section. If two loggers are linked by more than one pipe route, the analysis tools will always use the shortest pipe distance as the pipe model for analysis. By selecting to disable pipe sections, it is possible to force the analysis tools to use the longer pipe distance. When a pipe section is disabled it is shown in a darker colour. To enable the pipe section again, simply select **Enable** from the context menu.

3.3.11.7 Positioning Loggers

Loggers are positioned on the map by dragging the required logger out of the logger box area onto the appropriate point on the map. Loggers can be added onto either pipe joints or directly onto pipe sections. If a logger is positioned on a pipe section, a dialog is opened to allow entry of the distance along the pipe that the logger is located.



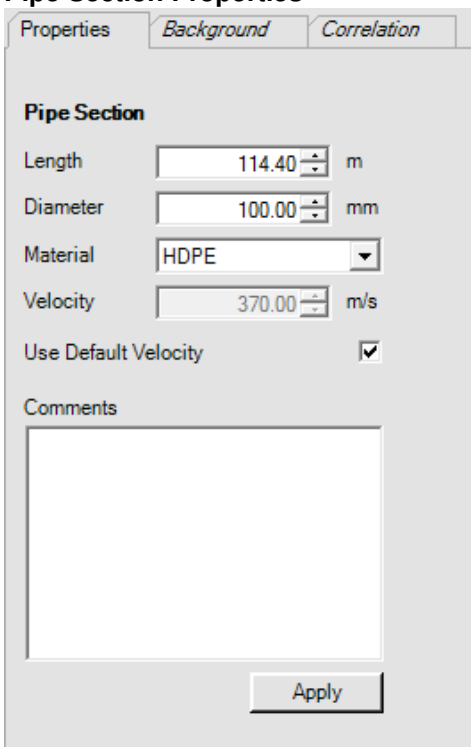
3.3.11.8 Toolbox - Correlate

After selecting this option, select two loggers on the network. The software will then switch to the analysis screen for these two loggers. If this option is selected in error, simply use the ESC key to de-select this mode.

3.3.11.9 Properties

The properties tab to the right hand side of the map can be used to change locations and properties of the selected item.

Pipe Section Properties



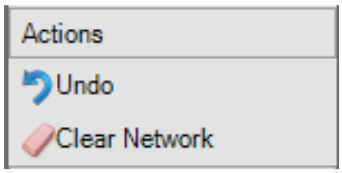
The length, diameter and material of the pipe section can all be entered. When initially drawn on the map the pipe section will remain highlighted in red until this properties tab has been edited and the Apply button pressed. This is as a visual reminder to ensure all pipe details are entered correctly. Once details have been confirmed the pipe section will turn green. All pipe sections when initially drawn use the Default Pipe details as entered under the Tools – Options menu.

If a manually entered velocity is required, untick the Use Default Velocity checkbox and adjust the velocity as appropriate.

The pipe details entered here will be used by the analysis part of the Enigma software to determine any leak locations.

Any comment associated with a pipe section will be displayed on the network drawing.

3.3.11.10 Actions



Undo
Use this option to undo the previous change to the network diagram. Up to 5 actions are saved for the Undo process. This action can also be accessed by using the standard Windows Crtl-Z shortcut.

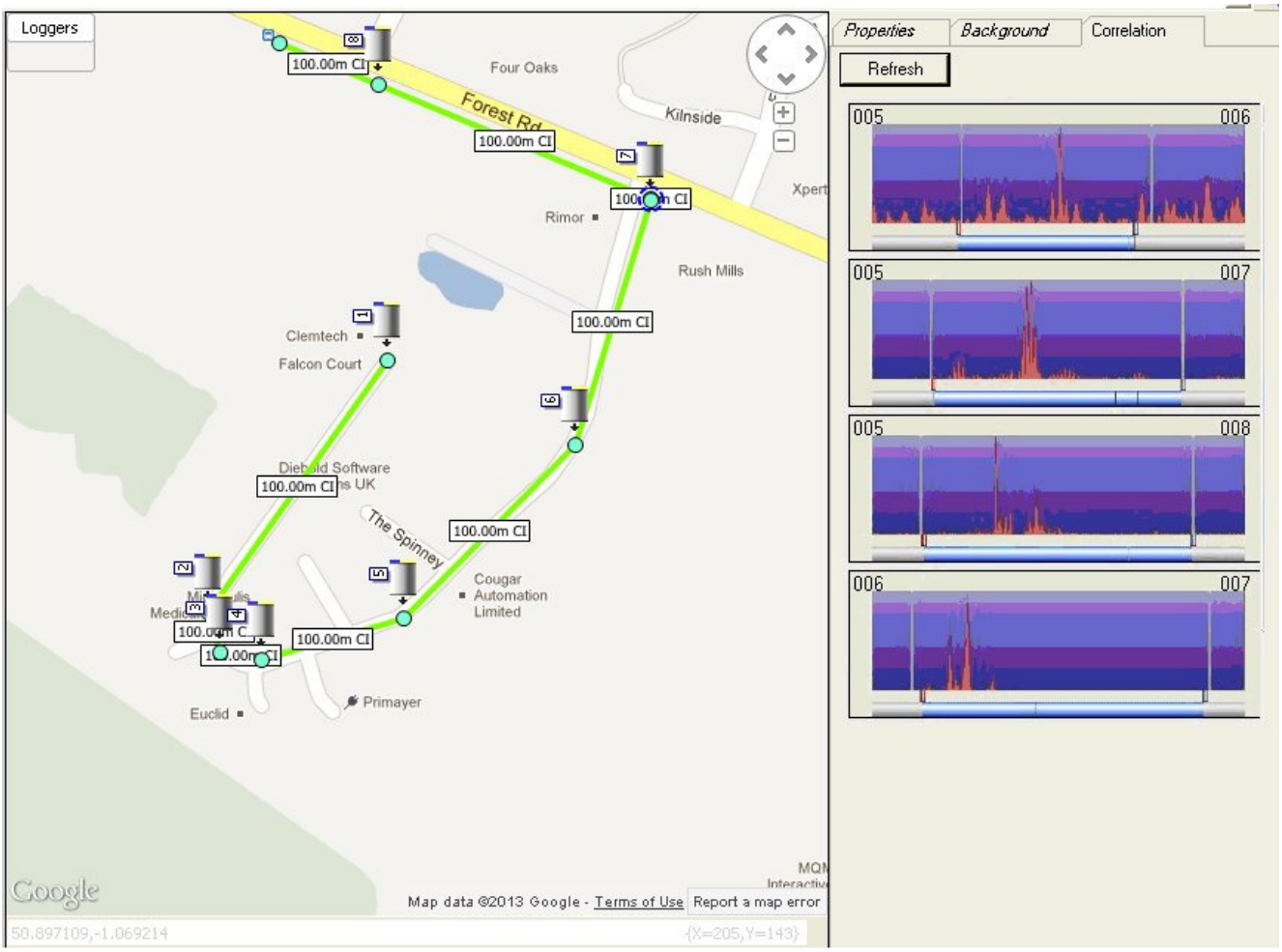
Clear Network
This option clears the network items. The background will remain as before. Once this has been done, it is no longer possible to Undo this action

3.3.11.11 Leak Markers

If a leak marker is added on the analysis screen, it will be displayed at the correct distance along the pipe within the network schematic.

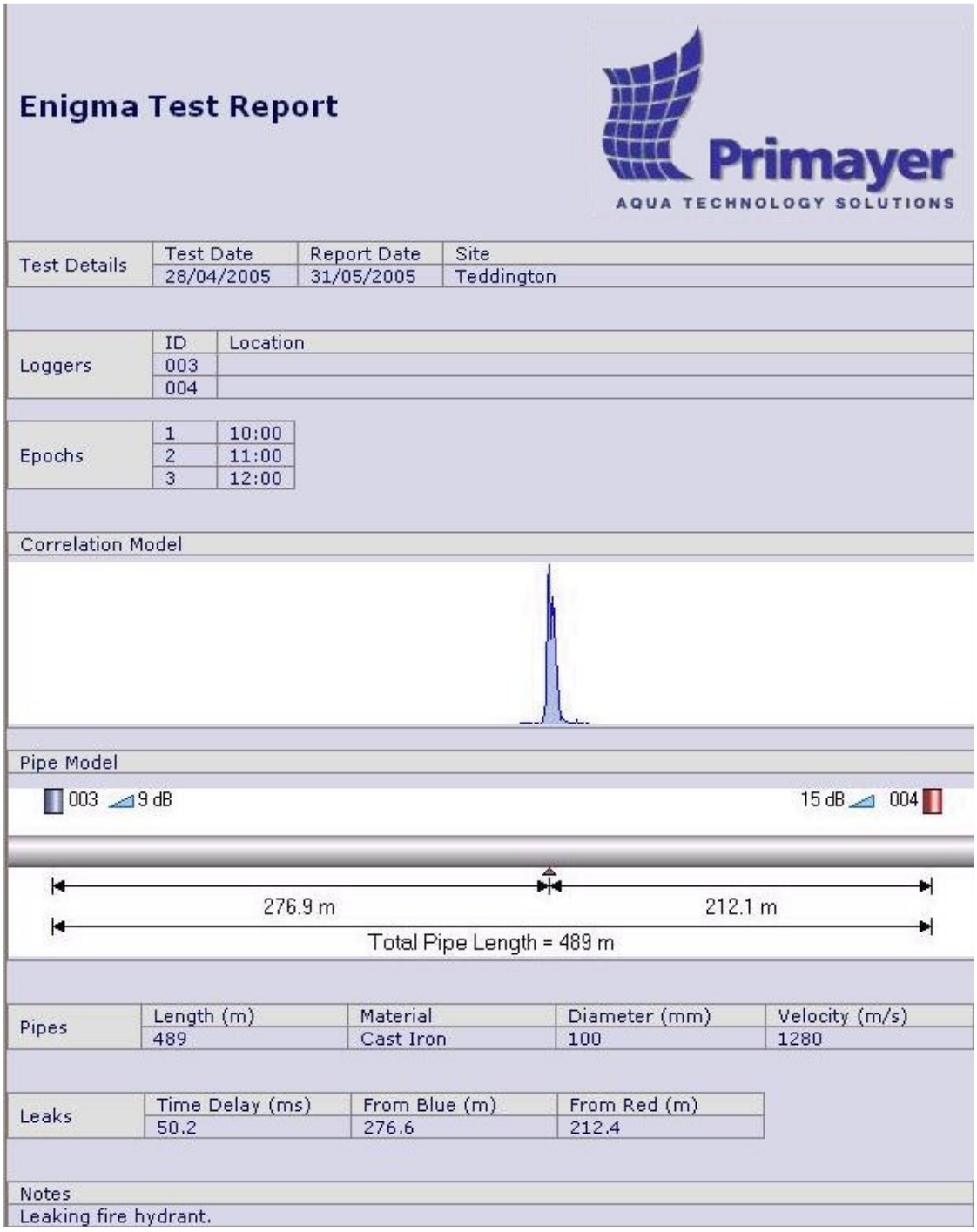
3.3.11.12 Correlation Tab

The correlation tab will display thumbnails for all logger pairs where there are pipe details available. The limits of the pipe are included in the thumbnail to allow quick analysis of any out of bracket noise. To generate the thumbnails press the Refresh button. If pipe details are changed after the thumbnails have been displayed, the Refresh button should be pressed again to update this display. Double clicking on a specific correlation will switch to the analysis screen for this logger pair.



3.3.12 Print Icon

Clicking on the Print icon opens a test report for the currently selected logger pair.



Enigma Test Report

Primayer
AQUA TECHNOLOGY SOLUTIONS

Test Details	Test Date	Report Date	Site
	28/04/2005	31/05/2005	Teddington

Loggers	ID	Location
	003	
	004	

Epochs		
	1	10:00
	2	11:00
	3	12:00

Correlation Model

Pipe Model

003 9 dB 15 dB 004

276.9 m 212.1 m

Total Pipe Length = 489 m

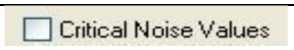
Pipes	Length (m)	Material	Diameter (mm)	Velocity (m/s)
	489	Cast Iron	100	1280

Leaks	Time Delay (ms)	From Blue (m)	From Red (m)
	50.2	276.6	212.4

Notes
Leaking fire hydrant.

3.3.12.1.1 Print Screen - Icons

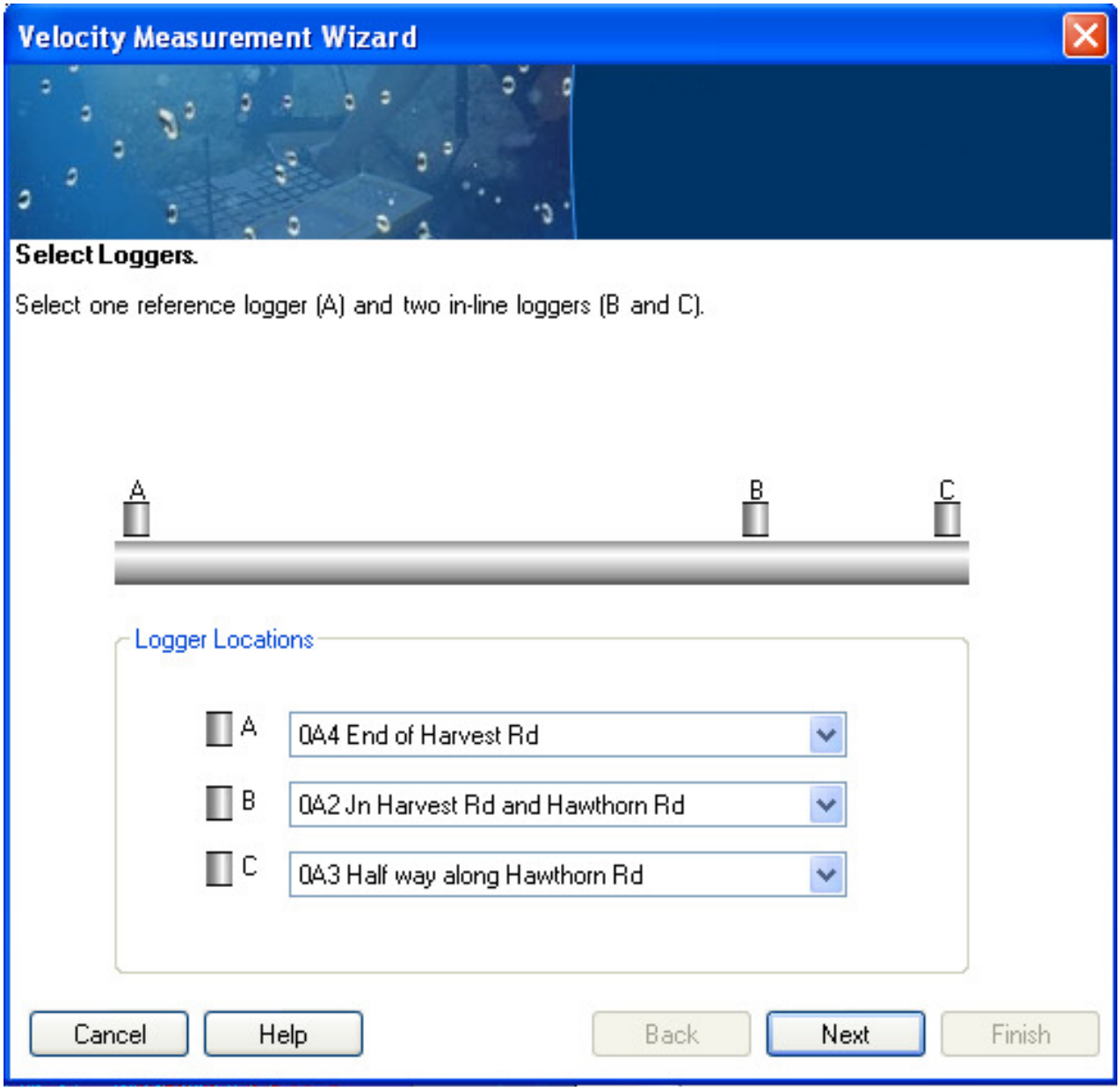
The print icons have various functions as follows:-

Icon	Function
	Save
	Page Setup
	Print
	Print Preview
	Copy
	Export to Word
	This checkbox shows/hides the Critical Noise Values (dB) on the report

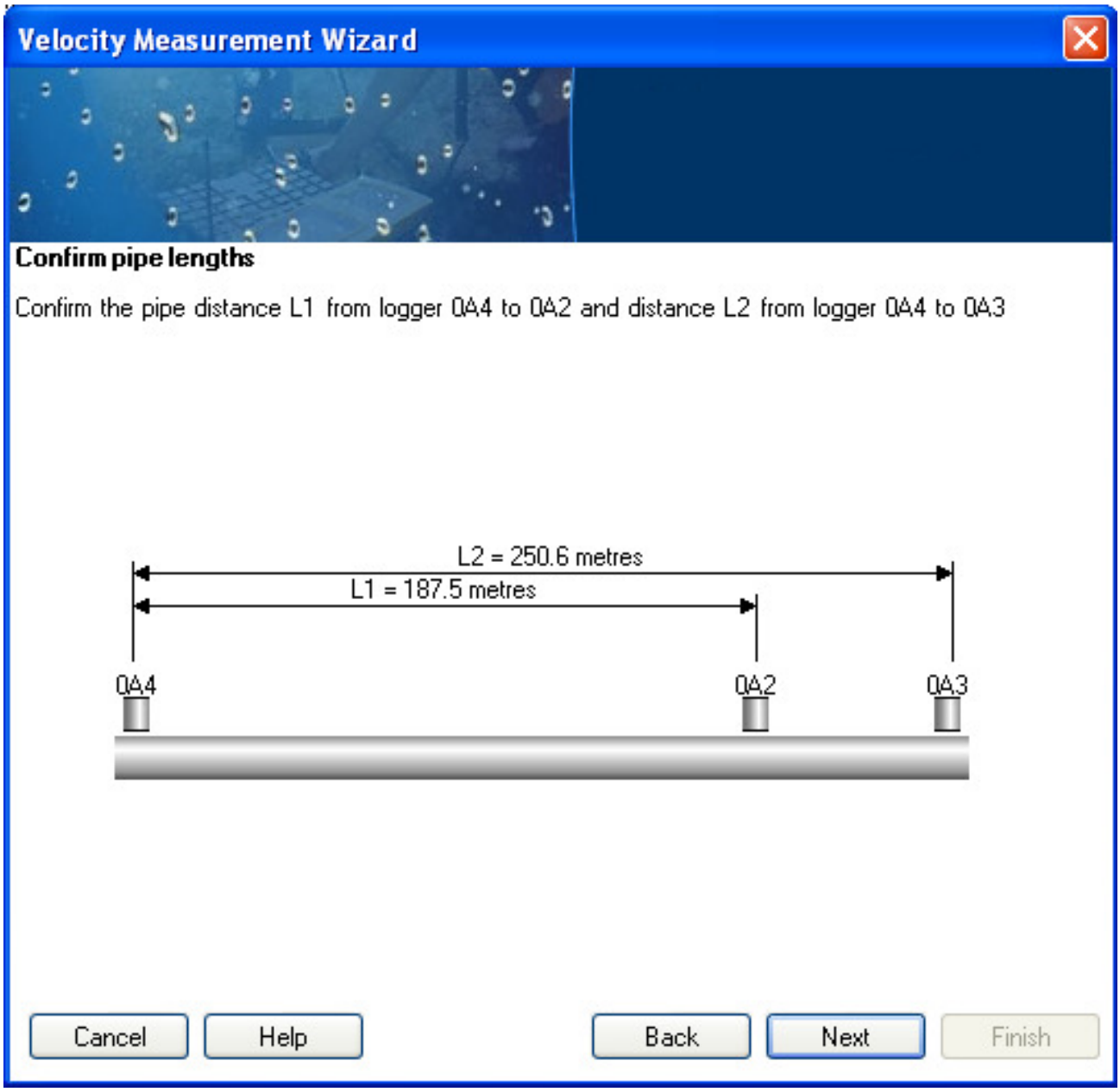
4 Velocity Measurement

It is possible to use three loggers to calculate a real value for the sound velocity in the pipe network; this is done to produce a more accurate leak position. For this to function correctly a reference logger and two in-line loggers must be selected. Leak noise must have been detected in both of the correlations between the reference logger and in-line loggers.

The pipe details between all three loggers must be entered correctly before selecting velocity measurement. Select Velocity Measurement from the Tools menu, this opens the Velocity Measurement window. From the pull-down arrows, select the loggers that are going to be used in the velocity measurement calculation. Loggers 0A1, 0A2 and 0A3 are used in the example above. The estimated leak position must be between the reference logger (A) and the first in-line logger (B).

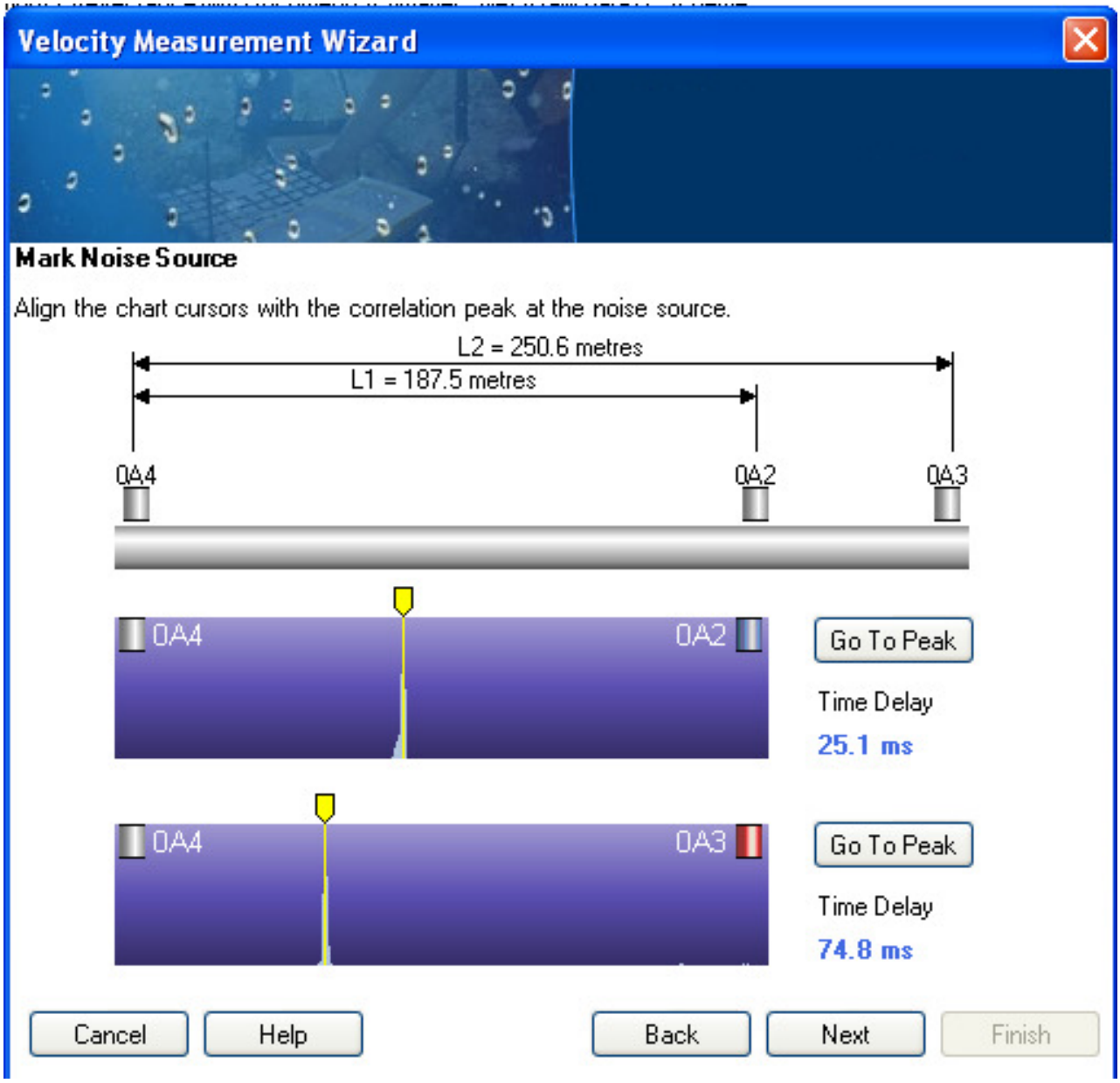


Click on the next button.



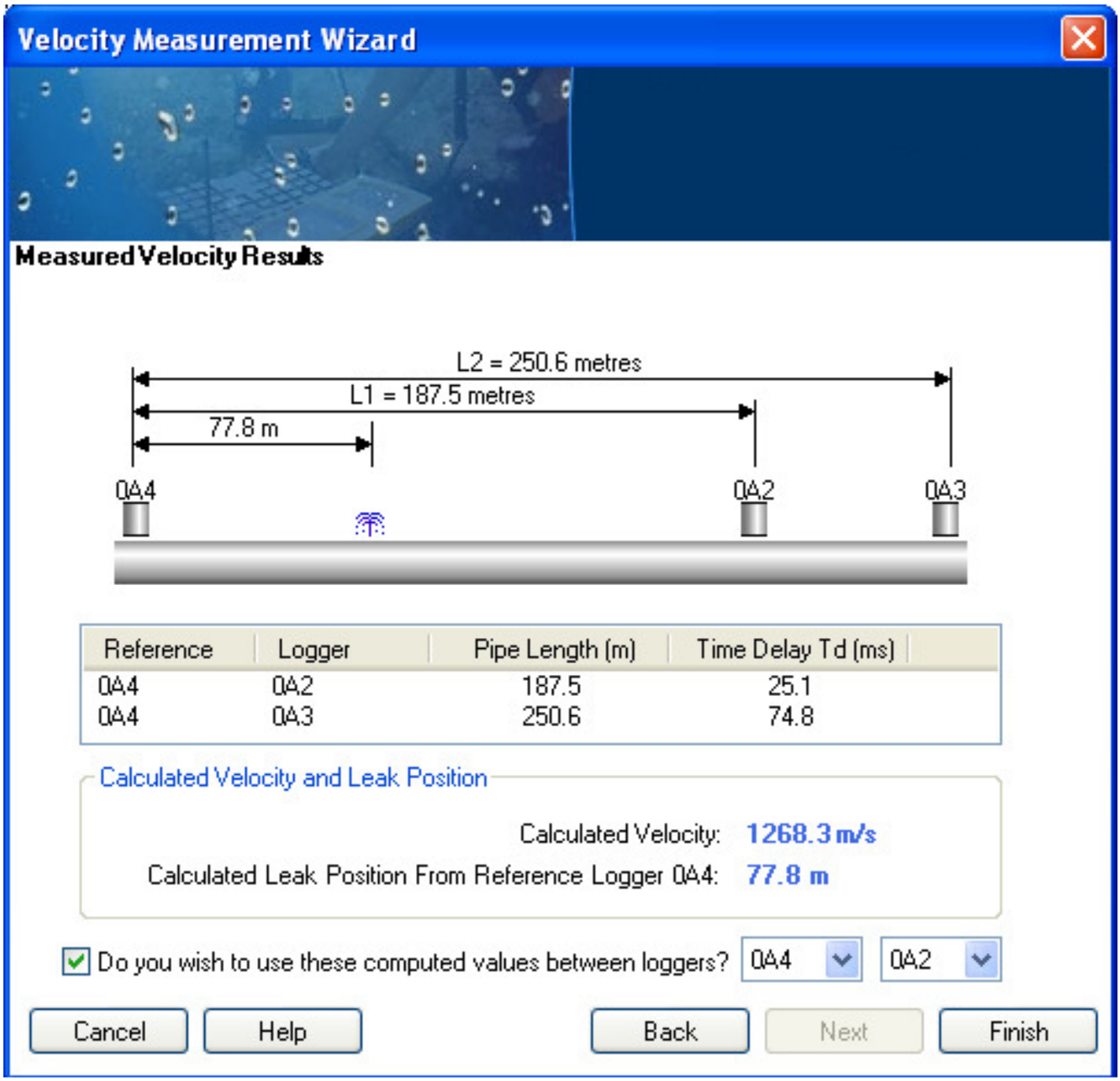
Check that the distances are correct; if no distances have been entered a warning is displayed and the wizard will close. (Enter pipe details between the appropriate logger pair using the pipe data entry screen).

Click Next to go to the next step.



Move the cursors to the peak values by clicking on the Go To Peak buttons or by sliding the cursors.

Click on Next.



If the peak values selected are valid, the calculated velocity and a revised (improved) leak position are displayed. The velocity value can be used in the Analysis display by clicking on the question displayed and entering the logger numbers.

5 Batteries

The communications case is powered by a disposable battery that nominally lasts 5 years. When necessary, the battery can easily be replaced by the user. The old battery should be disposed off taking into consideration local approved procedures.

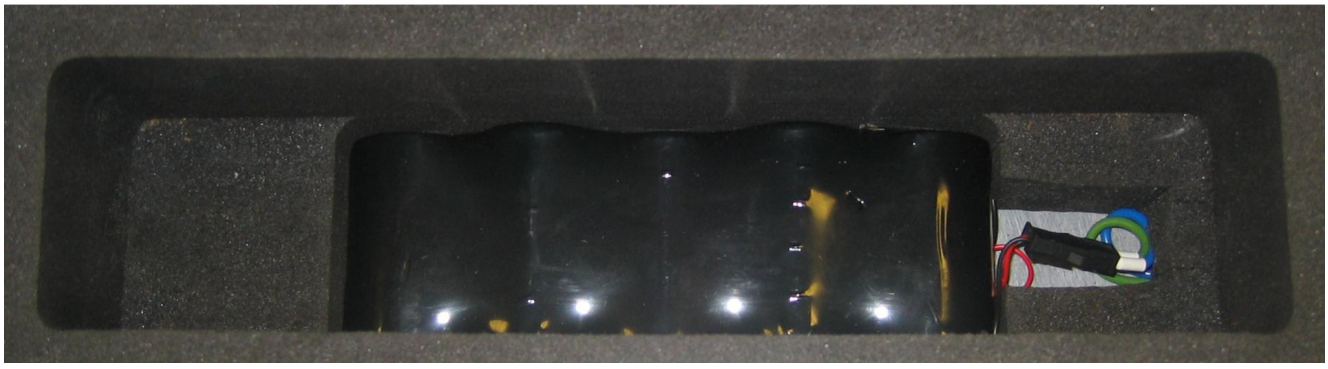
A low battery voltage is indicated by the PC Software when in communication with the case or loggers.

5.1 Logger Batteries Replacement

To maintain the IP68 integrity of the loggers, it is not possible for the user to replace the batteries in the loggers; battery replacement must be done by Primayer or an approved service centre. Please contact Primayer for more information.

5.2 Communications Case Battery Replacement Procedure

Lift the foam panel up and away to expose the battery.



Disconnect the battery connector and lift the battery free (secured with Velcro) from the communications case.

Insert new battery unit (secured with Velcro), connect the battery connector (note the connector will only fit one way), and refit the battery foam panel.

	The Primayer part number for the Enigma communications case battery pack is PP375-029.

6 Principles of Leak Noise Correlation

	It is strongly recommended that you read this section, even if you have had previous experience with correlation techniques.

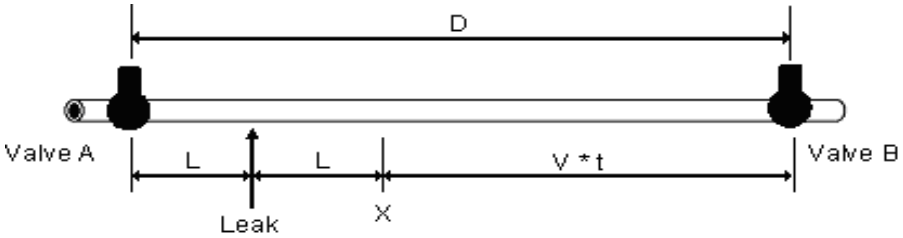
6.1 Leak noise

The loss of water though the leak causes a noise source. This noise travels in both directions from the leak and is used to determine the leak location.

6.2 Leak location

Leak noise correlation works by comparing the noise detected at two different points in the pipeline. Noise travels from the leak in both directions along the pipeline at a constant velocity (which depends on various factors), so that if the leak is equidistant between two loggers then these loggers will detect the noise at the same time. Conversely, if the leak is not equidistant then the loggers will detect the same noise at different times, and the difference in time can be measured by the correlation software.

The following diagram illustrates this:



The loggers are located on valves A and B (convenient access points for underground pipes), and as shown the leak site is closer to A.

By the time a particular noise from the leak has reached A, the same noise heading towards B has only travelled as far as X. The distance from X to B causes a delay t before the noise arrives at B, thus the correlation software detects the delay t between the arrival of the noise at A and its arrival at B. If the velocity of sound is V and the distance between the loggers is D, then as the distance from X to B = V * t, then D = (2 * L) + (V * t). This equation may be rearranged to give L, the distance from the nearer logger to the leak site:

$$L = \frac{D - (V * t)}{2}$$

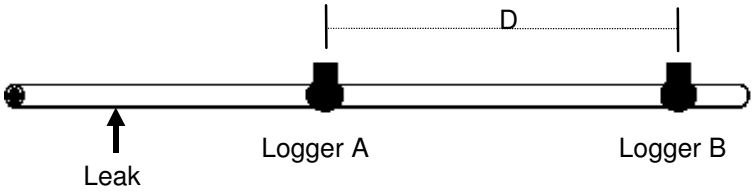
As the sound velocity can be calculated from knowledge of the pipe diameter and material while the distance between the loggers can be determined by measurement, the correlation software can calculate and display the location of the leak as a direct distance from the nearer logger.

6.3 Positioning errors

Operation depends on having the leak located between two loggers. However, there are two special situations where this is not the case.

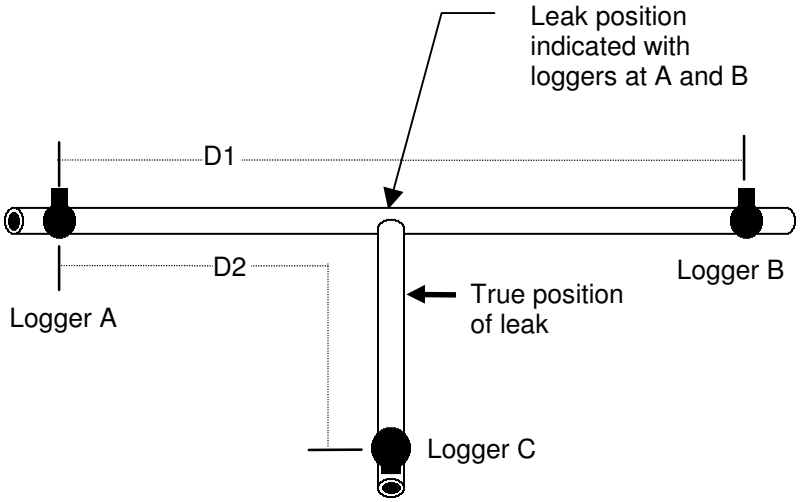
6.3.1 Leak beyond loggers

If the leak is located outside the length of pipe between the loggers, then the correlation software will ignore the transit time from the leak to the nearest logger. This will give the result that the leak will appear to be located directly at the logger nearest to the leak (this is termed “out-of-bracket”). It is an indication that one logger must be moved to locate the leak position.



6.3.2 Leak on connecting pipe

If there is a leak on a pipe that connects to the pipe being sensed, then the noise will appear to spread from the point of connection of the pipes, and so will appear as a leak at that point. It is then necessary to move one logger to the connecting pipe (in other words, to place the leak between the loggers) in order to locate the leak accurately. A thorough knowledge of the layout of the entire pipe network is required to ensure that the loggers are making measurements on the correct section of pipe and that there is no possibility of leaks on branch pipes causing false readings.



6.3.3 Noise Sources Close to Loggers

If a logger is directly over or very close to a leak, it is possible that loggers may not be able to accurately locate the source of the noise. In this case, move the affected logger further away from the noise source.

6.4 Problems with Trunk Mains and Plastic Pipes

It may be difficult to obtain satisfactory correlation when examining trunk mains or long lengths of plastic pipe. The nature of such pipework causes low frequency leak noise to predominate, as high frequencies attenuate rapidly.

7 Appendices

7.1 Appendix 1: Maximum Deployment Distances

The maximum permissible distance between deployed loggers varies according to the pipe material. Do not exceed the distances given in the table below for a particular pipe material.

Pipe Material	Max. range (m)
Asbestos Cement	1400
Cast Iron	1800
Concrete	1700
Copper	1800
Ductile Iron	1800
Ductile Iron (concrete lined)	1800
Galvanised Iron	1800
HDPE (high density poly)	500
Lead	1000
MDPE (mid-density poly)	500
PVC	500
Steel	1800

Please note that these are maximum distances.
The actual distance the leak noise travels will vary with pressure, pipe diameter, wall thickness and amount/frequency content of noise generated by the leak.
There is no guarantee that the leak noise will actually travel the maximum distance quoted above.

7.2 Appendix 2: Sharing Enigma Data

Enigma deployment and correlation analysis data may be shared with other PCs, if required. This is done by simply copying the data folders as required between machines using typically windows file manager and any suitable transfer media, for example memory sticks.

7.3 Appendix 3: Lithium batteries contained in equipment

Important transport safety data

1. Introduction

Lithium metal batteries are fitted into some Primayer products as single cell or multi-cell batteries. These batteries are classified as *dangerous goods* for the purpose of transportation and must be handled in accordance with the regulations governing air, road and sea transportation *(see section 3 below).* In addition to this transportation requirement, prior to being transported each type of lithium battery (used in the products) must have already successfully been certified to UN test requirements *(see section 4 below).* Primayer specifies only cells that meet the relevant UN certification.

This is a guide and should not be used as an alternative to the official regulations. The regulations are subject to change and this document is not intended to track those changes.

2. Primayer products containing lithium metal batteries

Current and recent Primayer products with lithium metal batteries are listed with lithium content;

Product	Lithium content (grams)
PrimeLog - single and dual channel	2.5
PrimeLog - four channel	5.0
PrimeLog+	5.0
XiLog+	10.0
XiLog+ double battery pack version	20.0
XiLog	10.6
XiLog double battery pack version	20.6
XiLog-S - single, dual and four channel	10.0
XiLogEco	3.0
XiLog.wmr - IP66 and IP68	10.6
Xstream	10.0
Phocus2 / Phocus.sms / Phocus.hr logger	2.5
Enigma logger	3.15
Primeprobe2	10.0
Socrates	20.0
ZetaCorr logger	2.5

3. Transportation

3.1 Applicable Regulations

The primary authorities responsible for issuing dangerous goods regulations are:

- **Air** - International Air Transport Association (IATA), Dangerous Goods Regulations (DGR)
- **Road** - European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)
- **Sea** - International Maritime Organisation (IMO), International Maritime Dangerous Goods Code (IMDG)

Dangerous goods are assigned to UN numbers and proper shipping names according to their hazard classification. For Primayer's products the lithium metal batteries are contained in the equipment and the regulations identified by UN classification ***UN3091 Lithium metal batteries contained in equipment, Class 9, Packing Group II, Packing Instruction 970***

Batteries used in Primayer products must not be transported separately from the equipment. Separate freighting is covered by another UN classification and not covered in this document.
Lithium batteries transported within the United States are subject to additional limitations as specified in the US national dangerous goods regulations contained in Code of Federal Regulations Title 49 (49 CFR). These limitations are not covered in this document.

3.2 Requirements
The person/company wanting to transport the goods is termed *The Shipper* and they must choose a *Freighting Agent* who is familiar with the UN3091 packing instruction. Only qualified personnel are permitted to process the packing and shipping of dangerous goods to ensure the correct packing and labeling are met as follows and as detailed in the applicable regulations.

- Correct packing of product
- Maximum quantity of lithium not exceeded
- Correct labelling of package which should include Class 9 hazard label and markings that identify *UN3091 Lithium metal batteries contained in equipment*
- Completion of a Shipper's Declaration for Dangerous Goods

3.3 Transportation from Primayer
Primayer Limited (UK) holds certification for meeting the above requirement. All new or repaired products leaving Primayer are packed in accordance with the regulations. If the product(s) is to be transported to a second destination (after leaving Primayer) it must be declared as *Dangerous Goods* to the *Freighting Agent* together with the information required by the above regulations. It is the responsibility of *the Shipper* to ensure they are working to the current regulations.

3.4 Transportation other than at 3.3 above
Lithium batteries that have been damaged or have the potential of producing a dangerous evolution of heat, fire or short circuit are forbidden for transport. Therefore before equipment is transported it is essential that it is opened and the battery examined. If any sign of battery damage, or ingress of water to the product, is observed then the battery must be removed before transportation. For advice do contact ***Primayer Customer Support*** (contact details below).

4. UN test requirements and design safety

Primayer specifies Tadiran SL-700 and SL-2700 cells in sizes AA, C and D and Saft LSH20 cells only in battery packs. Tadiran and Saft cells are safety tested in accordance with International Standard IEC 60086-4. Alternatives may be approved only by Primayer Limited (UK).

5. Disposal

All batteries and cells must be disposed in accordance with local regulations.

For further information on air-freighting these products or the air-freighting regulations, please contact Primayer as follows:

Primayer Customer Support
Telephone: +44 (0)23 9225 2228
Email: support@primayer.com

Technical Note Reference: IXD-613-TN iss5

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