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INSTITUTE OF SOUND AND VIBRATION RESEARCH

FLUID DYNAMICS AND ACOUSTICS GROUP

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Authorized for issue by
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Group Chairman

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Contents

Abstract

This report describes the experimental procedure and data processing required to obtain the viscous sound absorption of particles suspended in water. The technique involves measuring the response of a volume of water to a short burst of noise and converting this information to a reverberation time. Initial measurements are made without the sediment and then again once the sediment has been added. The difference in the reverberation time of the two conditions is used to obtain the acoustic losses due to viscous absorption. The raw data is acquired using a program written with LabVIEW software. The majority of the postprocessing is done in two stages, again with LabVIEW programs. Final processing to obtain graphical output and to incorporate theoretical predictions is performed on a spreadsheet. A list of programs used and their functions is appended to this report.

1. Introduction

The aim of the technique described here is to measure in the laboratory the acoustic absorption due to particles suspended in water. This entailed developing the experimental methods necessary to obtain reliable measurements of the low level of absorption due to this phenomenon. The technique uses the reverberation behaviour of a suspended plastic bag containing approximately 16 ℓ of water with and without suspended particles present to determine the attenuation of the particles added to it. This report details the experimental procedures and the data analysis involved in obtaining the absorption due to the particles.

The measurement of the reverberation time is controlled by a PC running a program written with LabVIEW software. Two programs are used to obtain measurements: one to generate the transmitted sound burst, and the other to acquire the received acoustic response via a LeCroy digital storage oscilloscope (DSO).

The analysis of the acquired data is principally performed by two programs, again written with LabVIEW software. The first step in the analysis is to calculate the reverberation time from the acquired acoustic decay traces. The second program is then used to average a number of measurements and calculate the absorption of measurements containing particles relative to particulate-free reference measurements. This program also calculates the error in the acoustic measurements. The final stage of the analysis is the presentation of the results in graphical format and the calculation of the error for each concentration under examination. This is done using an Excel spreadsheet file.

Another aspect to the experimental method is the measurement of the concentration of particles dynamically using a light scattering sensor (LSS). The use of this device is also detailed in this report.

A step-by-step guide to the data acquisition and analysis is given in the following sections. A list of programs, descriptions of the controls and instrumentation, and the naming conventions used can be found in the appendices. The procedures presented in this report have been used to obtain data for comparison with theory, and details of this work can be found in the contract reports relating to the project [1-6], in peer-reviewed [7, 8] and other [9-14] conference papers, journal papers [15-19], a Technical Report [20] and a PhD thesis [21]. In keeping with the LabVIEW documentation, filenames and file paths are denoted by a monospace font, e.g., `My program.vi`. Note that LabVIEW program files, if they are stored within a LabVIEW library, can have long file names which include spaces. To keep to the convention, all programs for a virtual instrument (or VI) end with the extension `.vi`. Also, the names on menu items or control or indicator names are shown in **bold**.

2. Methods

2.1 Setting up the apparatus

Figure 2.1 shows the experimental apparatus required to perform the measurement of the reverberation time for a volume of water contained within a suspended plastic bag. The following sections describe the setting up of the apparatus and the methodology of obtaining experimental results and their subsequent analysis. The programs used are detailed in Appendix A.

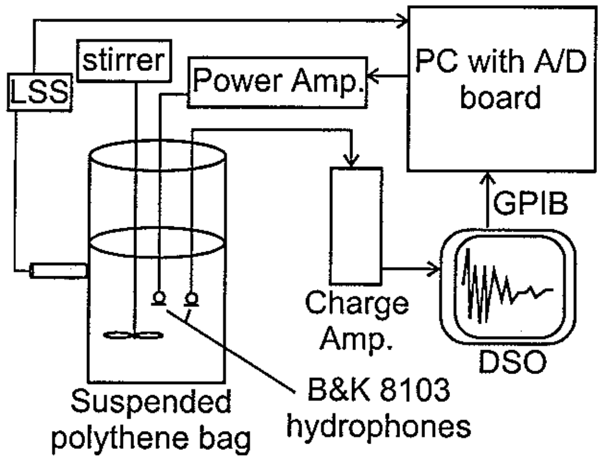

Figure 2.1: Schematic diagram of the experimental apparatus.

2.1.1 Mounting and filling the plastic bag

To mount the bag the following procedure should be followed.

(i) Remove the plastic support ring from the suspending wire and remove the bag retaining ring by loosening one of the two retaining nuts.

(ii) Carefully fit the plastic bag over the plastic support ring ensuring that there are no tears or creases in the bag. The bag should fold over the support ring down to the level of the three mounting screws (approximately 30 mm).

(iii) Refit the retaining ring and tighten firmly. Take care not to tear the bag when refitting.

(iv) Attach the suspending wire to the three mounting screws on the mounting ring. A single wire can be used. It is attached to two of the screws then threaded through the large metal ring and looped over the third mounting screw. A short twist of electrical wire can be slid down the supporting wire to prevent the loop of wire slipping off the third mounting screw.

(v) The bag is suspended by the large metal ring attached to a hook on the support frame. The length of the supporting wire should be such that the supporting ring is just below the bottom of the supporting frame which rests above the large plastic tank.

Once the bag has been fitted it can be filled with the appropriate liquid. This is typically degassed, filtered water. The degassing procedure used in the past has been to place a container of water in the vacuum chamber and leave overnight at the maximum obtainable vacuum. Using the vacuum pump available, this has been at a level of approximately 80 torr. Once the vacuum has been reached, the outlet valve can be closed and the vacuum pump turned off. The level of vacuum usually reduces to around 150 torr overnight.

To avoid regassing the water, it can be siphoned from the water container into the bag using the plastic tubing located adjacent to the rig. If the siphon tube is placed at the bottom of the bag, the amount of air entrained into the water is minimised. To measure the mass of the added water, hang the bag from the spring balance, which is attached to the supporting frame, before adding water to it. The empty mass of the bag and ring support is approximately 1 kg. The adjustment nut at the top of the balance can be turned to set the empty mass to a convenient value, e.g., exactly 1 kg. Typically, 16 kg of water is added to the bag. This fills the bag to a reasonable level without overstressing the bag.

Once the bag has been filled it should be mounted on the hook rather than left on the spring balance for the duration of the test. Transferring the bag from the spring balance to the hook is a two-man job. One person should lift and support the bag while the other manoeuvres the large metal ring onto the hook. At this point the bag should be checked for leaks. There may be small pin holes which exude drops of water. Depending on the anticipated duration of the test, they can be ignored or the water can be siphoned back into its container and a new bag fitted. This is more preferable. Also, small bubbles attached to the walls of the bag can be dislodged by firmly tapping on the bag with an open hand.

2.1.2 Mounting the hydrophones

The hydrophones are mounted on an attachment which is held on the supporting ring by a single screw opposite one of the supporting wires. Prudent selection of the position allows this attachment to be free of the supporting frame whilst still allowing the stirrer to be positioned between the supporting wires. Attach the hydrophone-mount attachment before mounting the hydrophones in it.

Two B&K 8103 hydrophones are used in the measurement of the reverberation time: one transmitting , the other receiving. The hydrophones are mounted in stainless steel tubes. These tubes are then held in the retort clamps on the hydrophone-mount attachment. The hydrophones should be vertical. Their position is not critical though their depth in the water should be noted. By inserting them at least 100 mm into the water, the sound field seems to be slightly more uniform. Typically they are positioned 140 mm into the water. Ensure that there are no bubbles attached to the hydrophones, paying particular attention to the area between the hydrophone and the mounting tube.

If the water is in the bag for any length of time, the bag stretches which effectively lowers the water level. Throughout a test, check that the hydrophones remain immersed to the same depth so that their contribution to the total absorption remains the same.

2.1.3 Mounting the Light Scattering Sensor

The Light Scattering Sensor (LSS) is mounted horizontally, in contact with the outside of the bag at the desired height. It can be mounted on a retort stand with appropriate clamps. The contact area between the bag and the face of the sensor should be wetted with water to provide optical coupling to the water in the bag. This can be verified if the bag contains clear water by looking at the face of the sensor through the water in the bag. If it is correctly coupled, the face of the sensor will be clearly visible.

2.1.4 Connecting the equipment

The equipment should be connected according to Fig. 2.1. The PC is connected to the B&K Type 2713 Power Amplifier via the BNC-2080 breakout board. The breakout board is attached to the MIO data acquisition board in the PC via a 50-pin ribbon cable. Connector DAC0 OUT on the BNC breakout board is the analogue output channel through which the transmitted sound burst is sent to the power amplifier. This is attached to the input BNC connector on the back of the power amplifier via a BNC T-piece connected to the External connector on the LeCroy DSO. This is necessary because triggering is done using the output random noise burst, which, although being random, is always the same random signal. N.B. Ensure that the gain on the power amp. is set to the minimum before switching it on. The overload light will come on when it is switched on for approximately 10 seconds. This is normal.

The transmitting hydrophone is attached to the output BNC connector on the back of the power amp. via a BNC-microdot adapter.

The receiving hydrophone is attached to a B&K Type 2635 Charge Amplifier in the usual way. Consult the B&K user manual for details. Check the sensitivity of the hydrophone and dial it in to the charge amp..

The charge amp is connected to Channel 1 of the LeCroy DSO via the BNC output connector on the back of the charge amp..

The LeCroy is connected to the GPIB port on the PC from the GPIB port on the back of the DSO, labelled IEEE Std 488-2, using the GPIB cable. This completes the standard acoustic equipment set-up procedure.

For LSS measurements, the LSS is connected to its power supply by the waterproof connector on the integral cable. The BNC outlet from the LSS power supply is the voltage out of the LSS. This is connected to the ACH0 connector on the BNC-2080 breakout board attached to the PC. The gain of the LSS can be set to high or low with the switch on the LSS power supply according to the concentration. For most practicable particles and concentrations the gain should be set to "low." Refer to the operating instructions of the LSS for details.

2.2 Taking measurements

Once the apparatus has been set up according to the description in the previous sections, acoustic measurements can be made. The following section describes the standard experimental procedure used in measuring the reverberation time. The process is essentially the same whether the water contains particles or not.

2.2.1 The measurement of the reverberation in the bag

(i) Ensure the equipment is set up according to the procedures outlined above and that all equipment, including the PC, is switched on and warmed up.

(ii) Start the LabVIEW software package by selecting it from the Start menu or task bar. Note that all VI files are stored in VI libraries which are denoted by the `.llb` extension. These are in turn contained within a LabVIEW directory denoted by the `.lib` extension. To access these files from the LabVIEW palette menus, they must be stored in the `User.lib` directory within

LabVIEW. All VI libraries related to this report are found within the `Aim.lib` directory in the `LabVIEW\User.lib` directory.

(iii) Open the following files:

- `Noise, one-shot.vi` from the `Generate.llb` which controls the output pings to the transmitting hydrophone.
- `LeCroy 9310AM Acquire.vi` from the `Aquisitn.llb` which transfers the measured time trace captured by the LeCroy.
- `LSS acquisition.vi` from the `Aquisitn.llb` if the LSS is to be used.

(iv) In most cases the default settings for the signal generation and LeCroy reading programs should be used. The defaults and a description of each of the controls are given in Appendix B.

(v) Run `Noise, one-shot.vi` using the **Run continuously** button on the toolbar. This VI will then repeatedly send a burst of random noise to the transmitting hydrophone at the user-defined rate (the default is every 500 ms) until it is stopped by clicking on the **Run continuously** button again. If the instrumentation is correctly set up, the pings can be heard radiating from the bag.

(vi) Check the level of the received pings on the LeCroy. The set up for the LeCroy used in previous tests has been saved as SETUP3 19-Mar-1998. The various settings are listed in Appendix C. Adjust the gain on the Power Amplifier to just less than the level which causes overload. This is approximately 38 dB (i.e., the gain controls set to 40 dB and 8 dB). Adjust the gain on the Charge Amplifier to the maximum level which does not cause overload. This is usually 3.16 mV/unit out. Once the various levels have been adjusted, measurements can begin.

(vii) Set the controls on the `LeCroy 9310AM Acquire.vi` so that the time traces captured by the LeCroy can be written to file by turning on the **Log** button. Usually ten pings are measured at a time. This is the default setting for the number of **iterations**. The controls for timed beeps can be set to zero and the **beeps** button turned off if no stirring is required. If the files are being logged, enter an initial output file path, including the file name. This avoids the default dialogue box asking for a filename for the first file which increases the time between the first and second pings. Subsequent file names are automatically generated according to the naming convention outlined in Appendix D. Run the program using the **Run** button on the toolbar. It will acquire and write to disk the given number of traces from the LeCroy.

(viii) If stirring is required, the default values for the timed beeps are a five second pause from when the test is started, a beep to indicate the stirrer should be switched on, another beep after ten seconds to turn the stirrer off, and a final beep after five more seconds, which allows time for the stirrer to be lifted from the water before the acoustic measurements are made. The stirrer is usually run at constant speed of approx. 600 r.p.m.. The stirrer is held loosely in the chuck so that it can be quickly extracted without the need to loosen the chuck. It is lowered down until it rests on the tape collar on the stirrer shaft. This should be deep enough so that it turns under the hydrophones whilst allowing sufficient clearance from the bag.

(ix) The usual format for a sequence of tests is to take ten sets of ten pings for each condition. This is usually ten sets of calm, clear-water reference signals, ten for stirred, clear water, then ten sets for each of the concentrations of particles. This gives one hundred pings at each condition.

(x) The particles are weighed on the mechanical balance. This is accurate to approximately 0.05 g. The amount of particulate added depends on the level of absorption of the particulate. The usual starting concentration would be 0.5 kg/m^3. For 16 ℓ of water, this is 8 g of particulate. If necessary, the particulate can be dispersed in a small quantity of water taken from the bag. This is particularly important for clays and other sediments.

(xi) Once the tests have been made the `Noise, one-shot.vi` can be stopped by clicking on the **Run continuously** button again. The VIs can then be closed.

2.2.2 Other measurements during the reverberation tests

Two other measurements should be made throughout the test: the water temperature and the level of dissolved oxygen. The temperature is required to calculate the sound speed in the water. It can be measured using the temperature probe which attaches to the Jenway 3071 pH and temperature meter. To date, the only method of checking for bubbles that has been used, apart form visually checking for large bubbles in the clear water, has been to monitor the level of dissolved oxygen using the Jenway 9010 probe which also attaches to the Jenway 3071 pH and temperature meter. The level of dissolved oxygen should be measured as soon as the degassed water is added to the bag and should then be regularly monitored throughout the test. This is particularly important once sediment is added and the water needs to be stirred. N.B. If the dissolved oxygen probe has been out of use for any length of time, it should be recalibrated according to the instructions enclosed with the device.

2.3 Calculating the reverberation time from the measured time traces

The reverberation time is calculated from the measured time traces using a LabVIEW program called `Calculate reverberation time.vi` from the `Analysis.llb`. Again, the system defaults are appropriate for most conditions. Before analysing the data, check the analysis using a few selected files. In particular, check that the reference files give sensible results and that the analysis procedure works sufficiently well when the concentration of particles is high. This is particularly so at the extremes of the frequency range where the signal-to-noise ratio is less good. This affects the IIR analysis and typically leads to an overestimation of the reverberation time because the linear regression begins to include the part of the IIR curve which asymptotes off to the background noise level.

If the file naming convention has been followed, all the data files can be analysed by setting the **number of tests** control to the actual number of sets of tests. For example, if ten sets of calm-water reference data with filenames commencing `A000.000` to `A009.000`, tens sets of stirred-water reference data named `A010.000` to `A019.000`, tens sets of 0.5 kg/m^3 sediment data named `A020.000` to `A029.000`, and ten sets of 1.0 kg/m^3 sediment data named `A030.000` to `A039.000` were taken, then a total of 40 data sets (0-39), each containing ten pings per set, would have been recorded. Because the filenames are sequential, the **number of tests** control can be set to 40 and the **pings per test** control should be set to 10, which is the default. If the analysis parameters are set to satisfactory values then enter the path and name of the first data set (e.g., `C:\Aim\Data\Alpha\A000.000`) in the **initial input file path** control, uncheck the **reset input file** box, enter a path and name for the **initial output file path** (by convention this would be A000.out) and uncheck the **reset output file** box. By setting up the control parameters this way, the program can be left to run through all the tests without further need for user intervention.

As mentioned above, the naming convention for the output files from the `Calculate reverberation time.vi` is the original data set root with the extension `.out`, e.g., for the data set containing the files A012.000 to A012.009, the output file name would be A012.out. These files are arranged as shown in Figure 2.2. They can be viewed using a spreadsheet package: the results are presented in four columns. The first row lists the centre frequency and bandwidth in Hz for the data which follows. If ten pings have been processed for the data set, as is usual, then the following ten rows will have, from left to right, the decay rate (dB/s), the reverberation time (s), the mean squared error from the linear regression, and a time stamp which indicates the time (in seconds) of the ping relative to the first one in the set. In general, there is no need to read these output files as they are used directly to calculate the viscous absorption as described in the following section.

50000	10000		
-226.269	0.2652	0.0707	0
-225.846	0.2657	0.0804	4
-223.884	0.2680	0.0657	8
-225.292	0.2663	0.0788	11

Figure 2.2: Example of format for the output files from the `Calculate reverberation time.vi`.

2.4 Calculating the viscous absorption from the reverberation time

Once all the data sets have been analysed the second of the analysis programs can be used to calculate the viscous absorption due to the presence of suspended particles. The VI `calculate attenuation.vi` from the `attenu8.llb` is used to calculate the average reverberation time of the reference pings and the particulate pings and, thus, the attenuation due to the particles. This VI can calculate averages of output files with consecutive filenames, e.g., the ten output files named A010.out to A019.out. It requires an **initial reference file path** and an **initial sample file path** and also the **number of reference tests** and the **number of sample tests** to be read. Also the number of pings per test should be entered. The defaults of 10 for these controls reflects the usual test protocol. The other controls that require an input value are:

- the **concentration**, which is used to draw the normalised attenuation plot,
- the **speed of sound** for the water (N.B. this can be calculated at any temperature using the spreadsheet `H2Ospeed.xls` located in the `C:\Aim\Technicl` directory),
- the **abs. error in speed of sound (m/s)** for the error in the water sound speed (the default value is 5 m/s which is usually sufficient to account for variations in temperature throughout the test and the inaccuracy in the temperature measurement), and
- the **% error in reverberation time (4%)** which has a default of 4%. This is in line with the measurements made on the spatial variation of the sound field.

The other parameters allow a file containing theoretical data to be read and plotted (**plot theory** and **theory file in**) and there is a check-box to write the results of the absorption calculations to a file (**write results to file (F)**).

The graph of **Attenuation (dB/m) vs frequency (kHz)** shows the results of the absorption calculation along with the upper and lower limits of the error. For the normalised attenuation plot to be accurate, the correct sediment concentration must be entered in the **concentration** control.

If the results are written to a file, a dialogue box will appear once the calculations have been performed asking for an output file name. The standard naming convention is to use the file name of the reference files then an underscore followed by the three numbers of the sample file name and then the extension `.out`, e.g., for the initial reference file `A010.out` and the initial sample file `A020.out`, the file name containing the absorption results would be called `A010_020.out`. The output file contains three columns of data: the centre frequency of the filter band (kHz), the absorption (dB/m), and the absolute error in the absorption (dB/m). This information can be pasted directly into the analysis spreadsheet to obtain graphical output of the absorption data as described in the following section.

One of the subVIs in the `calculate attenuation.vi` is useful for verifying that the various data sets contain reliable data. The `mean RT for n tests.vi` produces a visual representation of the mean of the ten pings for each of the data sets as well as the overall mean of the data sets for a given concentration. By running this VI before calculating the absorption, rogue data sets or significant trends in the data can be observed. In the past, data sets which were clearly inconsistent with the other results have been identified. This is often due to over stirring the bag and is usually identified during the data acquisition stage by observing the DSO trace which, under certain conditions, will show a marked and uncharacteristic drop in the level of the signal received. If certain data sets need to be excluded from the averaging process, the file names of the output files from the `Calculate reverberation time.vi` must be renamed so that they are consecutively numbered. However, if the rogue data sets happen to be either the first or last sets, then the name of the initial data set and/or the number of data sets to be analysed can be adjusted so that they will not form part of the averaging process. For example, if data set `A010.out` was to be removed, the **initial reference file path** control could be set to `C:\aim\data\alpha\A011.out` and the **number of reference tests** control could be reduced from ten to nine.

2.5 Obtaining graphical results of the viscous absorption

To generate graphs of the absorption data, a spreadsheet template, which is called `C:\Aim\Technicl\Analysis.xlt`, has been developed. When this template is opened, a copy of it is created into which new results can be pasted. Information which should be changed for each test is shown in **bold**. The two columns in the output files from the `calculate attenuation.vi` containing the viscous absorption and error data can be pasted into the `Analysis.xls` spreadsheet created by the template in the appropriate place under the heading of `Raw attenuation data for` **`SIGMA`** `data test`. The other details which should be changed are the file names from where the absorption data have been taken, the concentrations of the various tests, and the data relating to the theoretical calculation of the absorption. The only other parameter which can be set is the percentage error in the concentration which is usually fixed at 0.4% (or 0.004). All the other values in the spreadsheet are calculated. Note that the error in the concentration is only used to calculate an additional error in the normalised attenuation data. Its contribution to the total error is, in general, very small.

As the new data are pasted in, the graphs will automatically update. The template has provision for four different concentrations. This can easily be increased by copying the appropriate cells in the spreadsheet. If fewer than four concentrations have been used then the curves representing the default data in the template can simply be deleted from the graph by selecting them from the legend and pressing delete. The only thing on the graphs which must be adjusted by hand is the series names in the legends of the graphs. These can be accessed by double clicking the graph in order to edit it, then double clicking the appropriate trace and changing the name in the Name and Values section of the Format Data Series dialogue box. Similarly, the text description of the concentration in the small graphs showing a single concentration with error bars can be edited to show the correct value. The new graphs can then be cut and pasted into a report or paper in the usual way. Remember to save the new spreadsheet, giving it a file name which clearly associates it to the test series it represents.

3. Conclusion

This report has outlined the experimental and analysis procedures to follow to obtain the viscous absorption from particles suspended in water. In most cases, the default settings of the programs mentioned will guide the user to a successful result. Perhaps the most important detail is to follow the naming conventions for the files as these are required by the analysis programs in order to automatically perform their desired task. Apart from that, the experimental process and data analysis procedures are quite simple and, in the main, automated.

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APPENDIX A

List of principal LabVIEW VIs and subVIs written at ISVR

The following VIs were written at ISVR as part of the DERA contract. The level of indentation in the list below indicates subVIs within VIs and subVIs within subVIs though some subVIs may be called by other subVIs. VIs will generally also include standard LabVIEW VIs as subVIs but these are not shown here. The complete VI hierarchy of any VI can be seen within LabVIEW by selecting **Show VI hierarchy** from the **Project** menu.

VI or subVI name	Library within LabVIEW\User.lib\Aim.lib
LeCroy 9310AM Acquire.vi	Aquisitn.llb
Big-to-Little-Endian Converter.vi	General.llb
Convert 12hr time to seconds.vi	General.llb
Filter & Decimate.vi	General.llb
Increment filename suffix.vi	General.llb
LeCroy 9310AM Auto-Range.vi	Aquisitn.llb
LeCroy 9310AM Display Setup (GPIB 488.2).vi	General.llb
LeCroy 9310AM Maths Setup (GPIB 488.2).vi	General.llb
LeCroy 9310AM Trigger Setup (GPIB 488.2).vi	General.llb
Read LeCroy Format to Double.vi	General.llb
Timed beeps.vi	General.llb
WAV Player.vi	General.llb
Write Double to LeCroy Format.vi	General.llb
Noise, one-shot.vi	Generate.llb
(no ISVR subVIs)	
LSS acquisition.vi	Aquisitn.llb
Convert 12hr time to seconds.vi	General.llb
Timed beeps.vi	General.llb
WAV Player.vi	General.llb
Write time and one value.vi	General.llb
Calculate reverberation time.vi	Analysis.llb
Big-to-Little-Endian Converter.vi	General.llb
Convert to dB.vi	Analysis.llb
Data filtering.vi	Analysis.llb
Frequency header for output file.vi	General.llb
Generate incremental array.vi	General.llb
Increment filename extension.vi	General.llb
Increment filename test counter.vi	General.llb
Integrated Impulse Response.vi	Analysis.llb
Read 9310 data file.vi	General.llb
Reduce array between limits.vi	General.llb
Calculate attenuation.vi	Analysis.llb
Calculate attenuation error.vi	Analysis.llb
Get RT for n pings.vi	Analysis.llb
Increment filename test counter.vi	General.llb
Mean RT for n tests.vi	Analysis.llb

Miscellaneous VIs not called by the principal VIs

Calculate delta for linear regression.vi	General.llb
Calculate delta for stats.vi	General.llb
Convert MSE to sigma_B.vi	General.llb
File renamer.vi	General.llb
Split double 9310 data files.vi	General.llb

APPENDIX B

Description of controls and their default settings of main LabVIEW VIs

There are five main VIs used in this work which have default settings. SubVIs within these VIs use values passed from the calling VI to set the controls. The following list details the controls and indicators and their default settings. Not all controls or indicators are documented. If they are not, the default value will invariable be the best value. The data type of the control is shown on the left. Refer to LabVIEW documentation for details. The information below is also shown in the **Help** window of LabVIEW.

LeCroy 9310AM Acquire.vi

TF **Trigger Setup** Make changes to the trigger setup. Default is off.

TF **Display Setup** Make changes to the display setup. Default is off.

TF **Maths Setup** Make changes to the maths setup. Default is off.

TF **Continuous** Make continuous or single acquisitions. Default is single.

TF **Initialise** Press initialise to reset the LeCroy setup. Default is off.

Display Channel Channel to acquire from the LeCroy. Default is channel 1 (C1).

TF **Log** Save output time waveform to a user specified log file using custom vi.

TF **Alert** Make a beep once trace has been acquired. Default is on.

Channel If the auto ranging is used, use this channel to range on. Default is channel 1 (C1).

TF **Auto** Turn auto ranging on or off. Default is off.

I32 **Order** Order of the auto ranging. Default is 2.

initial output path Enter the full file path for the first of the output files. Make sure the directory path exists.

I32 **number of samples** Number of traces to acquire. Default is ten.

U32 **delay to stirring start (s)** Pause between first beep and the beep to indicate stirring should begin. Default is 5 seconds. Set to zero if no stirring required.

U32 **stirring time (s)** Time between beeps to indicate when stirring should stop. Default is 10 seconds. Set to zero if no stirring required.

U32 **pause after stirring (s)** Time between beeps to indicate the acoustic test is beginning. This allows time to remove the stirrer from the water. Default is 5 seconds. Set to zero if no stirring required.

TF **beep** To beeps on or off for stirring. Turn off if no stirring required. Default is on.

[DBL] **Output Waveform** Plot of acquired trace.

output path Indicates the current output path.

abc **time** Indicates time for file header information.

I32 **iteration** Current iteration.

Noise, one-shot.vi

DBL **Output Time (s)** Duration of noise burst in seconds. Default is 20 ms.

DBL **Sample Frequency (Hz)** Sampling frequency of the noise burst. Default is 450 kHz.

I32 **iterations** Number of iterations to perform. Default is five. Note that in normal operation this VI is run continuously and so loops around and around making this redundant.

U32 **milliseconds to wait** Delay between pings in milliseconds. Default is 500 ms.

I32 **seed (87)** The seed for the random number generator. If a seed is used, the same random pattern is made each time. The default value of 87 ensures that the LeCroy is correctly triggered.

TF **beep** Make a beep each time it pings. Default is off.

I32 **current iteration** Current iteration number indicator.

LSS acquisition.vi

U16 **type of acquisition** Select type of acquisition. Either single for just one sample, multiple for "number of samples" samples, or continuous.

DBL **time between samples (s)** Time, in seconds, between successive samples for multiple or continuous acquisition. NB there is a lower limit on the time between samples which is dependent on the system and other applications running.

TF **stop** Stops continuous acquisition. Also multiple acquisition can be stopped but not from a calling VI.

number of samples Set loop counter to measure the desired number of samples when multiple samples are being acquired.

channel Input channel for the LSS.

file path Enter the output file path here.

log Write the test to file. Must be checked prior to the test if the data is to be logged.

GAIN Indicates whether low or high gain is set on the LSS power supply unit. This information is written to the output file. N.B. This must be set manually. It is not set by the LSS device.

value (V) Latest value, in Volts, from the LSS.

values (V) Array of values, in Volts, for multiple or continuous measurements. Empty for single measurement.

iteration Show current iteration number.

Output (V) Display of LSS voltage.

time Time information for output file time stamp.

file path out Shows the current output file path.

Concentration (g/l) Shows the actual concentration in g/l but this must be adjusted for each type of material. Only valid for glass beads. Shown greyed.

Calculate reverberation time.vi

Controls and Indicators

Bandpass Filter Type of filter. Default is Butterworth.

output sensitivity The output sensitivity, K, is defined as:

K = Sca/(Mq * Vu)

Sca =charge sensitivity indicated by TRANSDUCER SENSITIVITY (pC/unit)

Mq = charge sensitivity of hydrophone (pC/Pa)

Vu = Volt/Unit out setting

IIR start time (s) Time at beginning of integration interval for the Integrated Impulse Response. Note that this is actual the end of the integration period because of the reverse integration process.

[DBL] **IIR stop time (s)** Time at end of integration interval for the Integrated Impulse Response. Note that this is actual the beginning of the integration period because of the reverse integration process.

[DBL] **reference pressure (Pa)** 1 microPascal for water.

[I32] **samples/bin** The number of samples per time bin defines the number of samples whose RMS value is used as the value in the time bin. Default is 100.

[DBL] **LR start time (s)** Time at start of the Linear Regression on the IIR curve.

[DBL] **LR stop time (s)** Time at end of the Linear Regression on the IIR curve.

initial input file path Enter the initial input file path here. If this is done the "reset input file" checkbox can be unchecked.

[TF] **use time bins** Using time bins reduces the amount of processing required. Default is on.

[I32] **pings per test** Number of pings per test. Default is ten.

[TF] **write to file** Check to write the results to the output file.

initial output file path Enter the initial output file path here. If this is done the "reset output file" checkbox can be unchecked.

[U16] **Filtering Frequency type** Select the type of filtering required. The default is fixed step the size of which is controlled by the "Fixed Step Filtering" cluster. The other options are 1/3 Octave, Octave, or none.

[[I32]] **1/3 Octave Centre Frequencies (Hz)** Choose the range of centre frequencies to filter over for 1/3 octave filtering. Two values must be selected.

[[I32]] **Octave Centre Frequencies (Hz)** Choose the range of centre frequencies to filter over for octave filtering. Two values must be selected.

Fixed Step Filtering Sets the filter controls for fixed step filtering.

  [DBL] **Initial Centre (kHz)** Low frequency limit.

  [DBL] **Final Centre (kHz)** High frequency limit.

  [DBL] **Step Width (kHz)** Width of bandpass filter at each frequency step.

[TF] **reset input file** Check to reset the input file. Default is checked but this should be unchecked if the input file path is defined.

[TF] **reset output file** Check to reset the output file. Default is checked but this should be unchecked if the output file path is defined.

number of tests The number of sets of tests to analyse. Each set will consist of "pings per test" number of pings. Default is one but once the results have been quickly checked, this should be set to the total number of tests performed. This is usually ten per experimental condition.

Signal (V) Raw signal (V).

Signal (dB re ref. pressure) Raw signal (dB).

Sampling Freq. (kHz) Sampling frequency of the signal.

dB slope (dB/s) Current decay rate in dB/s.

current filename Current file name.

T 60 (s) Current reverberation time in seconds.

RMS binned signal (V) Filtered and time binned signal (V).

delta t (s) Time step between points in the signal.

bin delta t (s) Time step between points in the time binned signal.

bin loop counter Indicates the number of time bins that will be used. This is usually 1000 if 100k data points have been acquired.

RMS binned signal (dB) Filtered and time binned signal (dB).

IIR binned (dB) Overlay of time binned and filtered data, integrated impulse response curve to that data, linear regression to the IIR curve, and the polynomial which is fitted to the IIR curve so that the slope of the IIR curve can be continuously calculated. This is only used for display purposes.

current input file path Indicates the current input file path.

derivative of IIR Derivative of the polynomial fitted to the IIR curve. Used for display purpose only to see if the linear regression value is reliable. Polynomial is prone to fluctuate more than reality.

mse Mean squared error of the linear regression for the current file.

High cutoff (Hz) Current high frequency cutoff.

Low cutoff (Hz) Current low frequency cutoff.

current output file path Indicates the current output file path.

RT v Freq Plot of the reverberation time as a function of frequency. This will show all the ping values at each of the centre frequencies of a particular test in a continuous plot.

SGL **time** Time stamp of current file.

DBL **Centre frequency (Hz)** Current centre frequency.

first path value

Calculate attenuation.vi

Controls and Indicators

initial reference file path File path of the first reference signal output file (filename.OUT) in the series to be analysed. The filename should consist of a letter and three numbers and the series of files must be sequential. The file path is used by the get RT for n pings.vi.

initial sample file path File path of the first suspension output file (filename.OUT) in the series to be analysed. The filename should consist of a letter and three numbers and the series of files must be sequential. The file path is used by the get RT for n pings.vi.

I32 **number of pings / test (10)** The number of pings per test. Default is 10. This is used by get RT for n pings.vi to correctly read the Reverberation Analysis.vi output file.

DBL **% error in reverberation time (4%)** Set the fixed percentage error of the reverberation time. Default is 4%. Used by the get RT for n pings.vi to calculate the error in the reverberation time.

I32 **number of sample tests (10)** The number of tests to be averaged. Default is 10.

TF **write results to file (F)** Write transposed output array to a spreadsheet file.

DBL **speed of sound (m/s)** Speed of sound in water.

DBL **concentration (kg/m^3)** Concentration of suspension. Used to normalise the attenuation values.

TF **plot theory** Write transposed output array to a spreadsheet file.

theory file in file path is the path name of the file. If file path is empty (default value) or is Not A Path, the VI displays a File dialogue box from which you can select a file. Error 43 occurs if the user cancels the dialogue.

I32 **number of pings / reference test (10)** The number of pings per test. Default is 10. This is used by get RT for n pings.vi to correctly read the Reverberation

Analysis.vi output file.

number of reference tests (10) The number of tests to be averaged. Default is 10.

abs. error in speed of sound (m/s) Speed of sound in water.

normalised attenuation due to particles 2-D array containing rowwise the frequency (kHz), and the normalised attenuation (dbm^2/kg).

Normalised attenuation (dBm^2/kg) vs frequency (kHz) Plot of the normalised attenuation vs frequency.

theory file new file path is the path of the file from which the VI read data. You can use this output to determine the path of a file that you open using dialogue. new file path returns Not A Path if the user selects Cancel from the dialogue box.

abs. error in attenuation 2-D array containing rowwise the frequency (kHz), and the normalised attenuation (dbm^2/kg).

Attenuation (dB/m) vs frequency (kHz) Plot of the normalised attenuation vs frequency.

APPENDIX C

Description of typical instrumentation settings

B&K Power Amplifier

Voltage Gain	40 dB and 7 dB (which is a gain of 37 dB)
Voltage limit	100V

B&K Charge Amplifier

Transducer sensitivity	dependent on hydrophone
mV/unit out	3.16
Unit out	1.0:2 Hz
Upper Frequency Limit	>100 kHz

LeCroy 9310AM Digital Storage Oscilloscope

The following settings are stored in SETUP3 19-Mar-1998.

Trigger:

Edge trigger on	Ext.
Coupling Ext	DC
Slope Ext.	Neg.
Ext.	DC 1MΩ
Holdoff	off
Level	-400 mV

Timebase:

T/div	20 ms
100,000 Samples	@ 500 kS/s (2μs/pt) for 200 ms
Sampling	single shot
Clock	internal
Sequence	off
Record up to 100k	

Channel 1:

Coupling	DC 1 MΩ
V/div offset	Normal
Global BWL	30 MHz
Probe attn	x1

APPENDIX D

Naming conventions for files

For each different test, the convention used in the past was to create a directory in the `C:\Aim\Data` directory to store all the data files. These have typically used a letter from the Greek alphabet, e.g., alpha, so the file path for a particular series of tests would be `C:\Aim\Data\Alpha`. The files containing the trace acquired by the LeCroy DSO using the VI `LeCroy 9310AM Acquire.vi` should then consist of a leading letter corresponding to the appropriate letter in the Greek alphabet, e.g., `a` for alpha, followed by three numbers and then a three-number file extension, e.g., `a123.456`. The value of the numbers is critical.

The three numbers in the extension, i.e., `456` according to the above example, describe the ping number within a particular set of measurements. Usually a set of measurements made when the `LeCroy 9310AM Acquire.vi` is run once consists of ten pings numbered `.000` to `.009`.

The first three numbers following the letter, i.e., `123` in the above example, describe the particular set of measurements. Typically ten sets of ten pings are made for each different experimental condition, e.g., ten sets of ten pings for the calm, clear-water reference, then ten sets of ten pings for the stirred, clear-water reference, etc. These sets of data must have sequential numbers in order to best use the automated features of the `Calculate reverberation time.vi`. So, the first set of ten tests will have the numbers `000` to `009`. The next set `010` to `019`, and so on. A typical sequence of file names would be as follows:

`a000.000` to `a000.009`	the first set of ten pings for the calm, clear-water pings
`a001.000` to `a001.009`	the second set of ten pings for the calm, clear-water pings
...	
`a009.000` to `a009.009`	the tenth set of ten pings for the calm, clear-water pings
`a010.000` to `a010.009`	the first set of ten pings for the stirred, clear-water pings
`a011.000` to `a011.009`	the second set of ten pings for the stirred, clear-water pings
...	
`a019.000` to `a019.009`	the tenth set of ten pings for the stirred, clear-water pings
`a020.000` to `a020.009`	the first set of ten pings for the first concentration of particles
...	
`a029.000` to `a029.009`	the tenth set of ten pings for the first concentration of particles
`a030.000` to `a030.009`	the first set of ten pings for the second concentration of particles, and so on
...	

The next step is the processing of the raw data files using the `Calculate reverberation time.vi`. The output files from this VI contain the reverberation data for one set of ten pings. The file name is simply the first part of the filename of the ten pings but with the extension `.out`. For the above example, the output file for the data files `a000.000` to `a000.009` would be `a000.out`, for `a001.000` to `a001.009` it would be `a001.out`, and so on.

The next step in the processing is calculating the absorption by comparing the reverberation times of clear-water reference tests with particulate tests using the `calculate attenuation.vi`. If all the stirred water reference measurements and all the first concentration measurements are used, according to the above example, then the output file form the `calculate attenuation.vi` is typically called `a010_020.out` which indicates that the `a010` files (stirred, clear water) have been used as the reference file and that the `a020` files (first concentration of particles) have been used for the sample files. Similarly, if the same reference files were used for the second concentration of particles, the output file name would be `a010_030.out`. This is a non-critical convention as the file name is not used by any other program; it merely provides a simple and clear method of describing the file.

The final part of the analysis is to paste the absorption and error values from the preceding files into an Excel spreadsheet to obtain graphs of the results. The template called `analysis.xlt` located in the `C:\Aim\Technicl` directory will create a model spreadsheet called `analysisn.xls` where `n` is a number. This should be saved as an Excel Workbook called `a_anal.xls`, the `a` relating to the alpha set of test in accordance with the above example and the `_anal` being shorthand for analysis (this work was started using Windows 3.1 - no long file names!).

Once the analysis is completed, be sure to delete at least the original data files (making sure, of course, that they have been archived on tape or zip drive) as each one is nearly 200 kbytes in size.