LISST-PORTABLE | XR

Manual

Version 2.1

April 2022

Applies to instrument serial numbers 592 and above, and units upgraded to firmware 3.0 or higher

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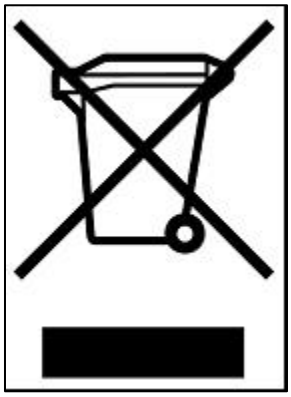


Waste Electrical and Electronic Equipment

Revisions:

2.1, April 2022: Remove warranty statement (available at www.sequoiasci.com/support/warranty); add temperature specification (page 22); add electronic temperatures to .ASC file format (page 20), as of firmware 3.020; update Sequoia contact information on cover.

2.0A, September 2020: Correct broken cross-references.

2.0, September 2020: Completely rewritten, and incorporating user-interface changes of firmware version 3.0.

Contents

1 Introduction

The LISST-PORTABLE|XR is a highly portable, self-contained measurement system that analyzes the size distribution and volume concentration of particles suspended in liquid. Using the widely accepted laser diffraction method of measurement, the LISST-PORTABLE|XR employs the full Mie theory in its calculations, delivering the concentration of suspended particles in 44 size classes from 0.4 to 500 µm.

The LISST-PORTABLE|XR is extremely simple to operate through its integrated touch panel display. It does not require an external computer, except to offload stored data files. Its internal rechargeable batteries allow it to operate even in places without AC power.

Key features include:

- Truly portable - completely self-contained with built-in processor, file storage, rechargeable battery, and 7" touch panel color display
- Touch panel allows easy programming of standard operating procedures (SOPs), sample analysis and display of data
- Shock-mounted optics
- Particle analysis using Fraunhofer or multiple Mie scattering models
- Data processing is performed on-board and stored in ASCII format. No post-processing is necessary.
- Outputs: Total volume concentration, mean size, standard deviation, optical transmission, D5, D10, D16, D25, D50 (median grain size), D60, D75, D84, D90, D95, D60/D10 (Hazen uniformity coefficient), particle surface area, silt fraction, silt volume, size distribution, battery voltage, sample notes.
- Resistant to Ethanol, IPA, diesel.
- Built-in ultrasonic probe for complete particle dispersion.

Many of the questions that arise during routine operation are answered on the user's guide attached to the inside lid of the instrument. The front side shows the general menu structure and the back side has additional instructions.

2 Getting Started

2.1 Contents and unpacking

The LISST-PORTABLE|XR ships in a rugged outer case with foam cushioning, as shown at left. Included in the case are the yellow LISST-PORTABLE|XR, the accessory kit, and this manual.

IMPORTANT: Always ship the LISST-PORTABLE|XR inside its black foam-lined case. The yellow housing alone cannot protect it against rough handling!

The accessory kit contains the 110/220VAC charger/power supply and charging cable (shown at right), drain tube, funnel for filling chamber, a small quantity of test particles, and the LISST File Transfer software on a USB memory card.

2.2 Install software

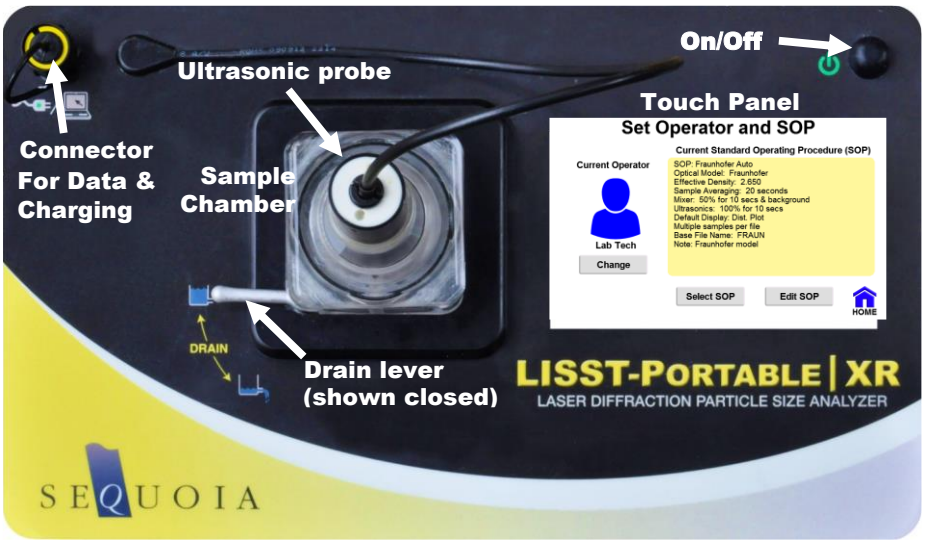
In the accessory kit, locate the yellow USB memory card (it resembles a business card). Insert this into a USB port on a Windows computer. Find and run the file named 'LISST File Transfer Setup.exe'. This will install the software used to download files from the LISST-PORTABLE|XR.

After installation, the software is accessible from the Start Menu or Desktop shortcut. The path is Start > Programs > Sequoia Scientific, Inc. > LISST File Transfer.

2.3 Setup

Take the instrument out of the box and place it on a level surface. Open the lid. Locate the drain tube in the accessory kit and insert it into the black push-to-connect fitting on the back of the instrument. Before running fluid through the instrument, place the free end of the tube in a bucket or drain to catch fluid later when you drain the sample chamber. Turn on the instrument by pushing the on/off button on the top right corner.

You may immediately experiment with the controls on the touch panel, and review the user's guide in the lid of the instrument. Note the user's guide can be pulled out and has information on both sides.



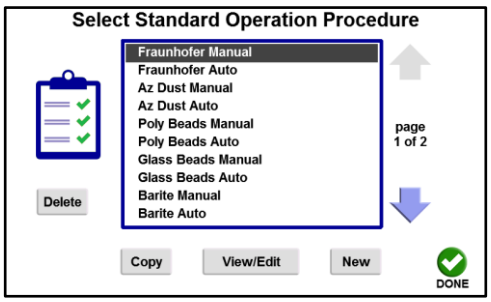
2.4 Connecting Battery Charger and USB Cable

You are not required to connect the cable for basic operation, but you are also free to connect it at any time. The connector for the cable is on the top left corner of the instrument panel. On the other end of the cable, a standard USB connector is available for communication with a Windows computer (using the software installed in section 2.2).

2.5 Set Operator

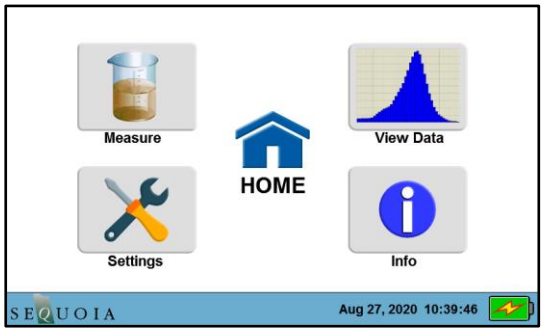
The initial screen upon starting the LISST-PORTABLE|XR shows the currently selected operator. The operator's name is stored in all saved data files. To select a different operator, or to edit the list of operators, press the Change button under the operator icon. You can define up to 10 operators.

2.6 Standard Operating Procedure (SOP)



SOPs are sets of parameters that streamline management of the LISST-PORTABLE|XR's many settings. These will be described in greater detail in section 4. For demonstration purposes, start with the "Fraunhofer Manual" SOP. The name of the current SOP is shown at the top of the yellow field on the right side of the Set Operator and SOP screen. If it does not show Fraunhofer Manual, press Select SOP and select Fraunhofer Manual from the list of SOPs. Tap the DONE button to return to the Set Operator and SOP screen, then tap HOME.

2.7 Home Screen



The home screen is the starting point for the main functions of the LISST-PORTABLE|XR. These are described further in separate sections:

1. Measuring new data (section 3)
2. Viewing stored data (section 4)
3. Setting the parameters of the instrument and measurement process (section 5)

Many other screens include a Home button you can use to return directly to this screen.

Proceed to section 3 for instructions on the measurement process.

3 Measuring Samples

WARNING: Use only water, isopropyl alcohol (IPA), or non-corrosive oils in the LISST-PORTABLE|XR. Solvents such as acetone, toluene, xylene, etc. will permanently damage the instrument and immediately void the warranty!

3.1 Overview

The measurement process has these steps that require operator input:

1. Clean the mixing chamber to remove any contamination from previous tests.
2. Measure the background scattering with fluid but no particles.
3. Add the particle suspension, and prepare it with mixing and optional ultrasonication.

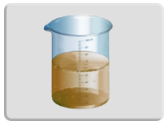
After these steps, the instrument automatically collects, analyzes, and stores the data.

3.2 Setup

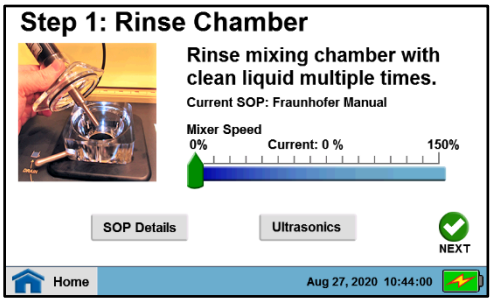
Before starting, make sure you have the following for best results:

1. Particle-free liquid for background measurements. This should be the same liquid used for suspending your particle sample. The following instructions assume water. This can be de-ionized, milli-Q, or steam-distilled water.
2. Funnel for filling the mixing chamber,
3. Particle sample suspended in water or other appropriate liquid,
4. A container to capture liquid drained from the instrument,
5. The supplied tube connected between the drain of the instrument and the container.

3.3 Rinse Chamber



Begin by pressing the Measure button on the Home screen. This opens the Rinse Chamber screen.



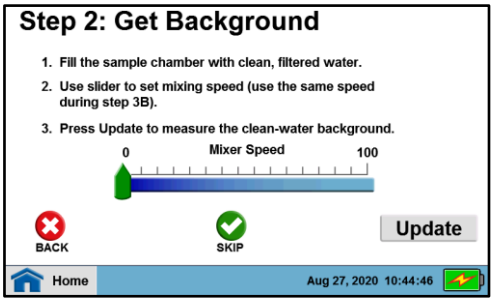
- Lift off the lid of the mixing chamber, and make sure the drain lever is in the closed position. If the lid is difficult to remove, try rotating it so you can grip its corners.
- Fill the chamber approximately half with clean water, replace the lid, and use the slider control to set the mixer to full speed.
- After running the mixer for 5 to 10 seconds, open the drain lever and let the water drain completely, then turn off the mixer.
- Depending on what was in the chamber previously, you may need to repeat this process for complete cleaning. When there is fluid in the chamber you can also insert and run the ultrasonic probe.
- When satisfied with the cleaning, tap NEXT.

3.4 Measuring Background

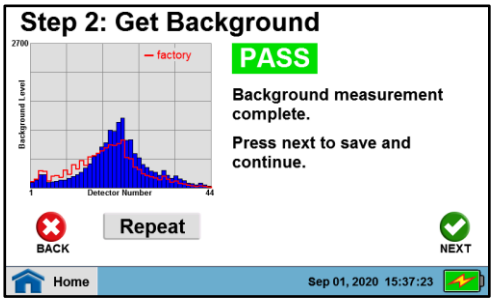
The laser diffraction technique used by the LISST-PORTABLE|XR requires accurate measurement of the signals generated by fluid with no particles. We call this the background scattering. Careful measurement of the background is crucial.

After cleaning the chamber as in section 3.3, fill it with clean fluid. It is very important to avoid introducing air and bubbles, so:

- Pour fluid slowly onto the inside wall of the chamber so the fluid clings to the wall, not making bubbles.
- Use the tall chamber lid that accommodates the ultrasonic probe, and fill it to the point shown at right.
- Insert the ultrasonic probe (but do not energize it). If the chamber is properly filled, a small amount of fluid will overflow the top of the chamber. That is OK. It leaves the chamber completely filled and sealed against intrusion by air bubbles.



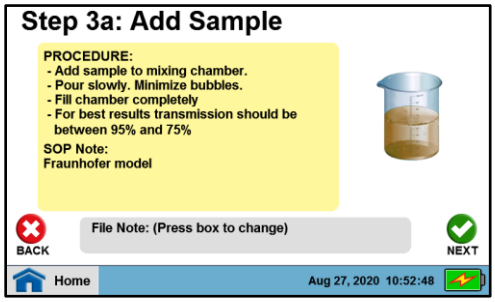
- Tap the Update button. The instrument will average data for a length of time determined by the current SOP (see “Averaging” in section 5.5).



After collecting the background data, the LISST-PORTABLE|XR shows a plot of the measured data compared with the factory background, and PASS/FAIL indicator. If the background fails, the screen will describe the problem and suggest solutions. If it passes, tap NEXT.

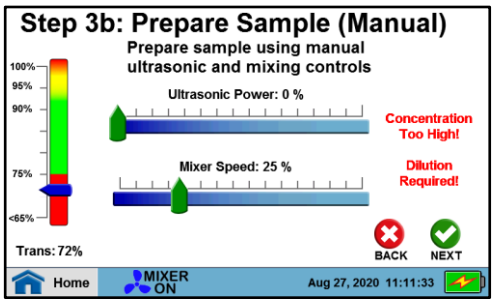
3.5 Adding Sample

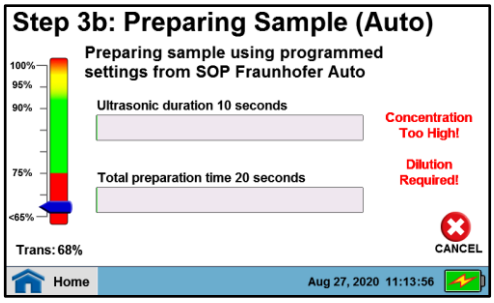
- Remove the ultrasonic probe to open the chamber.
- As necessary, use the drain lever to release the water used for the background measure and make room for the sample.



- If desired, you can enter a note about the sample by tapping the grey field at the bottom of the screen. A keyboard screen will appear for entering the note.
- Tap NEXT to proceed.

3.6 Preparing Sample





"Preparation" means mixing and, optionally, using ultrasonication to disaggregate particles and evenly distribute them in the fluid. As described in section 5.5, the SOP may specify automatic or manual preparation. During manual preparation, the operator can freely adjust the mixer speed and ultrasonic power. But for consistency, it is often preferable to use automatic preparation, the exact duration and intensity controlled by the SOP. During automatic preparation, the slider controls on the screen are replaced by automated progress indicators.

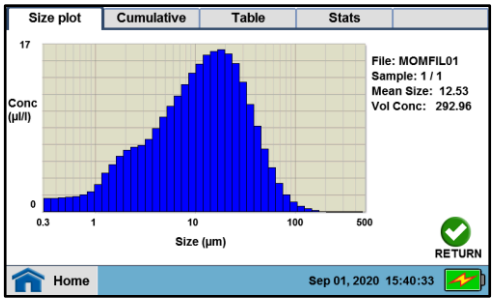
Another function of sample preparation is to ensure the concentration of particles is within the measurable range. This is measured in terms of the optical transmission. Low transmission corresponds to high concentration, and vice versa. For accurate results, the transmission should be between 75% and 95%. The LISST-PORTABLE|XR will prevent collecting data if the transmission is below 75% or above 97% (transmissions above 95% are tolerable if the averaging time is long enough to reduce noise in the readings).

If preparing the sample in manual mode, you should leave the mixer running to keep the particles properly distributed during the measurement. In manual mode, the instrument will show a warning if you attempt to measure with the mixer off.

3.7 Measurement and processing

Once you tap NEXT on the manual sample preparation screen, or the automatic preparation completes, the LISST-PORTABLE|XR will

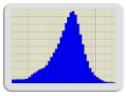
- Average data over the length of time specified by the current SOP (5 seconds to 2 minutes),
- calculate the size distribution,
- store the results in files, and
- show the results on the screen.



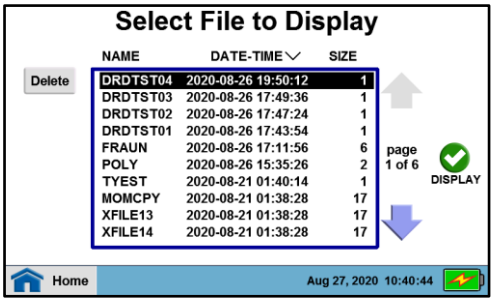
Results will be shown in one of four formats, depending on the default format specified by the current SOP. Press on the tabs at the top of the data screen to switch between the different views.

4 Viewing And Managing Data

4.1 File List



To see a list of the stored data files, tap the View Data button on the Home Page. This opens a screen listing the files in memory. - The screen shows 10 files at a time. If the list is longer, use the up and down arrows to move between pages.

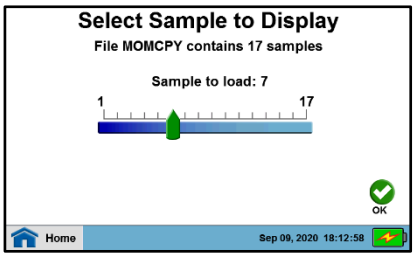


By default, the list is sorted by date and time, with the newest files at the top. You can change the sorting by pressing on the NAME, DATE-TIME, or SIZE heading to set which parameter is used for sorting. You can reverse the sorting order by pressing the active heading again. A caret (⌄ or ⌃) shows the sorting parameter and direction.

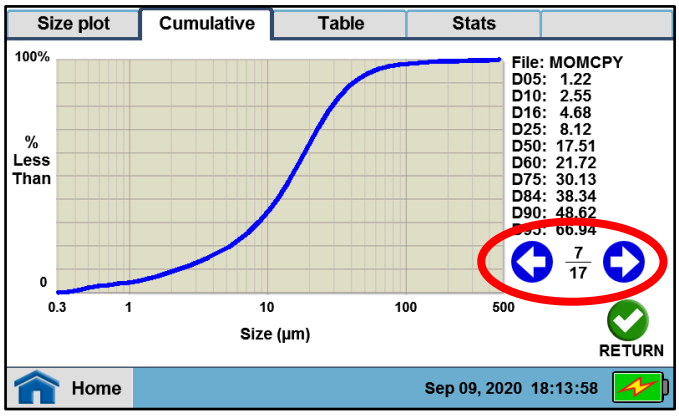
The listed size is the number of samples in the file. When using an SOP that specifies single-sample files, the size will always be 1.

Each item in the list represents a set of three files (.DAT, .ASC, and .LOG), as described in section 9.1, that are normally handled as a group. If either the .DAT or .ASC file is missing, the data will not display properly.

4.2 Data Display



When you press the DISPLAY button on the Select File screen, and the file contains multiple samples, you will see a screen with a slider for selecting the sample to display. When a multi-sample file is displayed, the display will also include a pair of blue buttons for moving from sample to sample within the file.



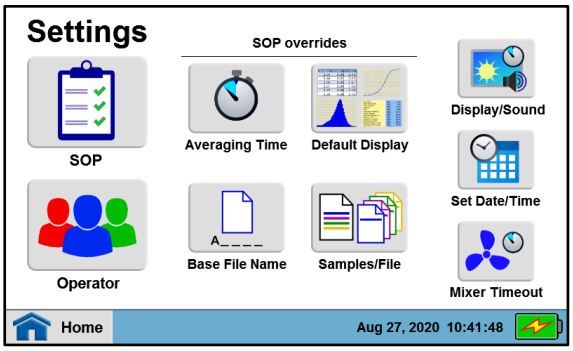
4.3 Deleting Files

On the Select File screen, tap the Delete button to delete the selected file. After you confirm your choice, this will delete the .DAT, .ASC and .LOG files associated with the selected item.

The touch screen interface allows selecting and deleting only one item at a time. If you need to delete many items, it may be easier to use the LISST File Transfer software, described in section 6.

5 Settings and SOPs

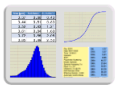
For access to the instrument settings, tap the Settings button on the Home screen.

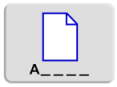


5.1 Operator button

As on the initial startup screen (section 2.5), this opens a screen where you can select an operator name and icon. Any data files you generate will include the operator name you select.

5.2 SOP Overrides





These buttons allow temporarily overriding some settings that are normally controlled by the SOP. Settings you make in this way will be reset the next time you select an SOP or restart the instrument. These temporary overrides are sometimes useful during testing or experiments. For example, you may wish to reduce the averaging time to quickly test a procedure, or set a temporary file name to cache experimental results.

On screens that display the full SOP, settings that are overridden are highlighted in red and marked as temporary.

5.3 System Controls

The rightmost buttons control some basics of the LISST-PORTABLE|XR hardware:

The **Display/Sound** button provides controls for

- Brightness of the display,
- Timeout of the display backlight, and
- Volume of the beep that signals touches of the screen

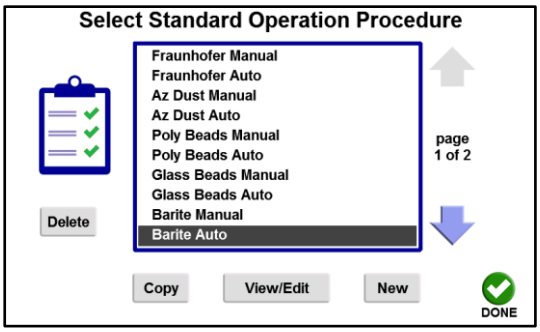
The display timeout saves battery power if the instrument is idle for an extended time (from 1 to 15 minutes). If the instrument is running from battery, and the given time passes without any touches on the screen, the screen will go dark. Any touch of the screen will reactivate the light.

The **Set Date/Time** button presents a screen with keypad for setting the instrument's clock.

The **Mixer Timeout** button presents a screen for setting the maximum time the mixer will run continuously when under manual control. The timeout does not apply when an SOP is automatically controlling the mixer.

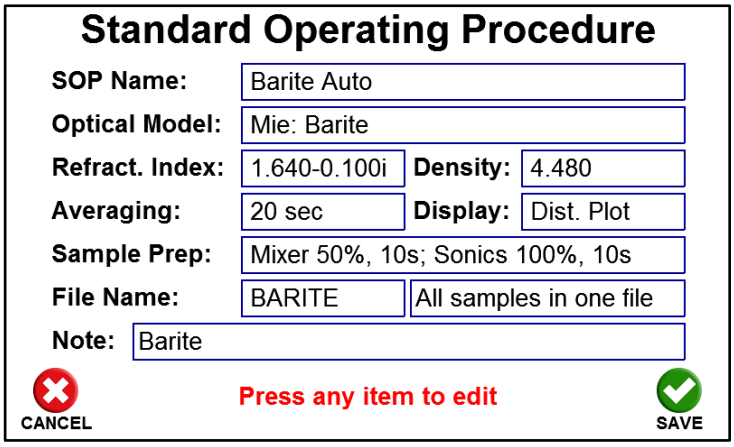
5.4 SOP Selection

The SOP button opens a screen with a scrolling list of available SOPs. To activate a listed SOP and return to the previous screen, press to highlight it, then tap the DONE button.



You can also delete, copy or edit the selected SOP by pressing the appropriate button. See the next section for description of all the SOP settings.

5.5 SOP Editing



The SOP editing screen appears when you choose to edit or copy an SOP, or create a new one, from the SOP Selection screen. It displays a compact summary of all SOP parameters. To edit any parameter, press directly on it. The response is different for each of the parameters.

1. **SOP Name:** Pressing this field opens a keyboard allowing you to enter a name of up to 32 characters. The name will be used to refer to this SOP on screen, and in files.
2. **Optical Model:** opens a screen with two choices: Fraunhofer and Mie. If you choose Fraunhofer, it returns to this screen. If you choose Mie, it opens a list of materials and their corresponding refractive indices. Select an item from the list to return. For more about how to select a model, see the FAQ 11.1 on page 23.
3. **Refractive Index**: this is not active if the Optical Model is Fraunhofer. If a Mie model is active, pressing this item opens the list of materials.
4. **Density**: the laser diffraction method used by the LISST-PORTABLE|XR measures the volume, not the mass, of particles. Therefore, any parameter stated in mass units, such as the mg/l concentration, must be calculated by multiplying the measured volume and the density. However, the effective density of a suspension may be difficult to determine. In that case you can set the value to zero. The size distribution and most of its derived parameters will not be affected, but mass parameters will be reported as zero.
5. **Averaging**: this opens a page with a selection of times from 5 seconds to 120 seconds. This is the length of time over which each sample will be measured. Longer times generally improve data quality by smoothing natural random variation. This is especially important for samples with transmission of 95% or higher.

6. **Display**: this presents four choices for the initial display of processed data: 1) size distribution plot, 2) cumulative distribution plot, 3) size distribution table, or 4) summary statistics. This setting does not restrict the views you can choose manually, it only sets the first view that is shown by default.
7. **Sample Prep**: this describes the preparation of the sample, with mixing and ultrasonics, before collecting data. This includes several parameters.
    - First, preparation may be manual or programmed (automatic). If you select manual preparation, there are no further parameters to set. The operator will be free to adjust the preparation at the time of sampling.
    - If you select programmed preparation, which is recommended for the best consistency, two more screens will appear. On one, you enter the intensity and duration of ultrasonication (possibly including zero). On the other screen, you enter the speed of mixing, and its duration after ultrasonication.

    NOTE: during programmed sample preparation, the mixer and ultrasonics turn on simultaneously (if the ultrasonic power and duration are not zero), then the mixer runs alone for the specified mixing time. In other words, the mixing time is the sum of the two times.
8. **File Name**; Opens a keyboard for entering a base name for data files. The base name is limited to 6 characters.
9. **All samples in one file / New file each sample**: you select this setting by simply pressing it to toggle between the two options.
    - "All samples in one file" means that this SOP will create a single file, with the base name you specified above, containing as many samples as you collect with this SOP. This approach minimizes the number of files you must manage, and allows you to easily scan through multiple samples when displaying data (as described in section 4.2).
    - "New file each sample" means the SOP will only save one sample per file, and will give each new a file that combines the base name with a 2-digit number. For example, the base name FILEX will result in files FILEX00, FILEX01, etc.

    WARNING: in "New file each sample" mode, the file number is limited to 99. Once the number reaches 99, you must offload and erase the files or change the base name! It is not enough to erase the lower-numbered files, because each new file's number is based on the highest existing number. If FILE98 exists, the next file will be FILE99 regardless of whether the lower numbers are used.
10. **Note**: Opens a keyboard for entering a note of up to 40 characters. This note will be displayed on the "Add Sample" screen (see section 3.5), so it is suitable for reminders to the operator.

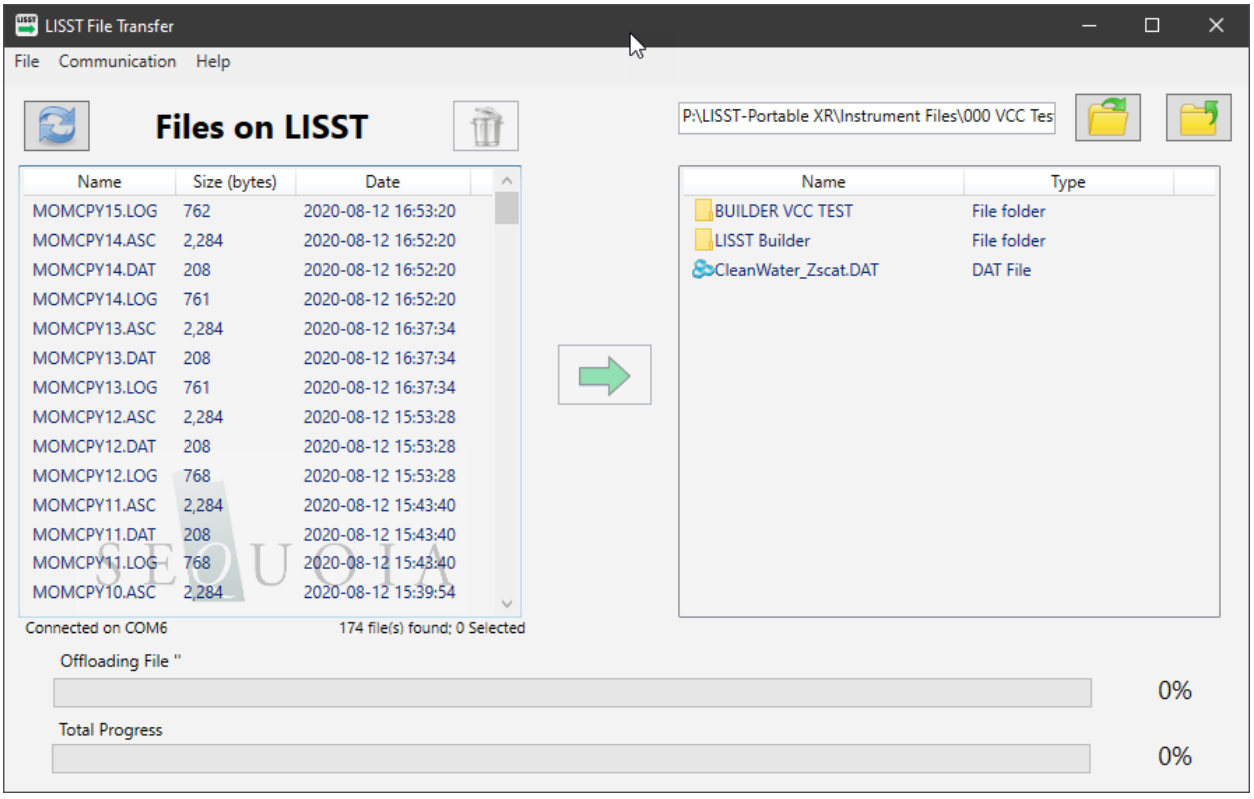
6 Windows Software: LISST File Transfer

6.1 Software Installation

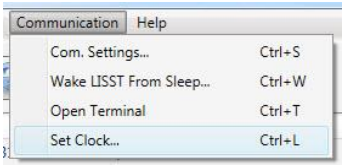
See section 2.2 for installation instructions.

6.2 Connect Instrument and Start LISST File Transfer Software

- Turn on the LISST-PORTABLE|XR. Connect the cable between the instrument and a USB port on your computer.
- Start the LISST File Transfer program. The software will automatically search and connect to the LISST-Portable|XR instrument. If the software fails to find your instrument, go to Help menu and explore the LISST File Transfer Help document.
- A list of files stored on the instrument will be displayed on the left of the screen. If there are many files, there may be a delay while the list loads..



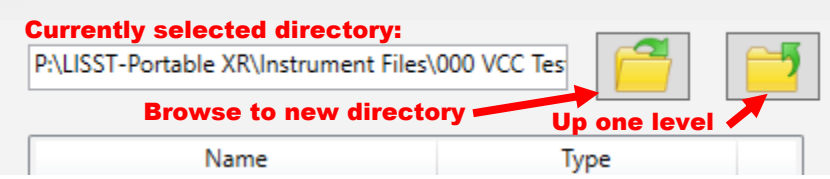
6.3 Set Date and Time



After connecting to the instrument, Select Communication->Set Clock… You will be asked to confirm that you want to set the clock. Press 'Yes' and the instrument's clock will be set to match the computer's.

6.4 Offload Files

After you connect, a list of files stored on the instrument will be displayed on the left of the screen. The list box on the right displays the contents of a local directory on your computer. Use the buttons on the top right to navigate to the directory you would like to offload your files to.



Choose the files to offload by clicking on the file name. Multiple files can be selected by hold down the CTRL key while clicking on files. Use the SHIFT key to select a range of files.

Note that files are stored in sets of three, with the same base name and .ASC, .DAT and .LOG extensions. See section 9 for details of the formats.

NOTE: Always offload and archive corresponding .ASC, .DAT and .LOG files as a set. The .ASC files are the processed data in a comma-separated format (for display in spreadsheets), the .DAT file is a binary data file containing the raw data (to be used by Sequoia for troubleshooting data), and the .LOG file is a file displaying instrument info and settings.

Press the green arrow in the center of the screen to begin offloading the files.

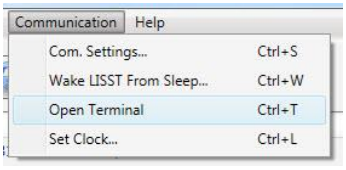
A status bar will be displayed for each file offloaded. Text in the lower left corner will display the current file being offloaded.

6.5 Delete Files

When connected to instrument as described above, select the files you would like to delete. Select multiple files by holding down the <Shift> or <CTRL> key while selecting. Press the trash icon to delete the files. You will be asked to confirm deletion of the files.

NOTE: You should always delete corresponding .ASC, .DAT and .LOG files, but not until you are sure that they have been properly offloaded and saved in a secure location.

6.6 Open Terminal Window

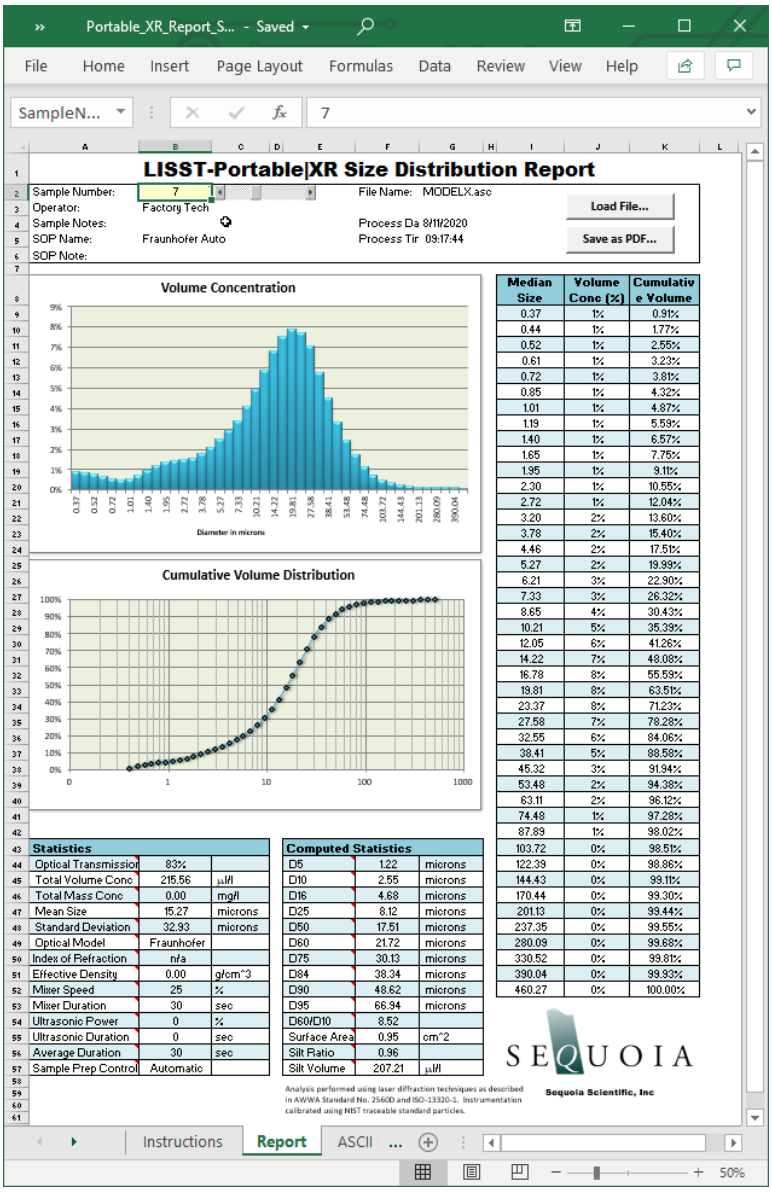


For troubleshooting purposes, Sequoia may ask you to send serial commands directly to the instrument. Communication -> Open Terminal will open a window where you can send command to the instrument. For example, send the ‘CONFIG’ command to see general information about the instrument configuration.

NOTE: Do not issue commands in the terminal unless instructed to do so by Sequoia Scientific. Incorrect use of these commands can cause loss of data.

7 Creating reports using the Excel template

The USB Software card delivered with the LISST-PORTABLE|XR includes a template for Microsoft Excel. With macros in this template, you can quickly load data from the instrument into a formatted report, and save the report as a PDF file.



To use it, simply open the file in Excel, and click the Load File… button. Depending on the security settings of your Excel installation, you may need to authorize macros. Select the file and you will see a display like the one at left. If the file contains multiple samples, you can use the scroll control in the upper left of the sheet to select the sample number to display.

When satisfied with the display, press the Save as PDF… button, or print the report in the standard way.

If the security settings of your computer or network do not allow documents with macros, you must use the non-macro version of the spreadsheet. In that case, the “Instructions” sheet in the workbook has instructions for manually copying data into the sheet.

8 Handling, Cleaning, and Storage

8.1 Handling

- WHEN HANDLING, REMEMBER THAT THE LISST-PORTABLE|XR IS A HIGH-PRECISION OPTICAL INSTRUMENT.
- AVOID MECHANICAL SHOCKS AND IMPACT TO THE HOUSING, AS THIS MAY CAUSE MISALIGNMENT OF THE OPTICAL PARTS.
- AVOID SCRATCHING THE TOUCH PANEL DISPLAY.
- WHEN CHARGING THE BATTERIES, USE ONLY THE CHARGER SUPPLIED. If you need a replacement, contact Sequoia Scientific.

8.2 Cleaning

- CLEAN THE PANEL USING ONLY LUKEWARM WATER, A MILD SOAP (E.G. LIQUID HAND SOAP) AND A SOFT CLOTH.
- TO CLEAN AFTER USING LIQUIDS WITH HIGH VISCOSITY (E.G. OILS): first circulate lukewarm water with a mild soap solution. Then finish with lukewarm water alone.
- NEVER USE SOLVENTS SUCH AS TOLUENE OR ACETONE – THIS WILL CAUSE DAMAGE AND VOID THE WARRANTY!
- IF ANALYZING CEMENT POWDERS: rinse out the system thoroughly using isopropyl alcohol (IPA), LEAVING NO CEMENT IN THE INSTRUMENT.

For cleaning of the windows, rinse out the mixing chamber with clean (filtered or de-ionized) water several times in order to flush out all particles from the mixing chamber and the mixing system.

Now gently wipe the windows in the optical cell with a cotton swab dipped in a mild soap solution (e.g. liquid hand wash soap). INSERT THE COTTON SWAB FULLY INTO THE MIXING CHAMBER AND MAKE SURE IT IS IN CONTACT WITH THE WINDOWS. Rinse several times with clean water and check the background again.

8.3 Storage

For storage for more than a few days, drain the instrument completely, clean the windows as described above, and put the lid on the mixing chamber to avoid dust falling into it. Store the instrument in a dry location with a maximum temperature of 50°C.

Fully charge the batteries before long-term storage.

9 File Formats

9.1 Overview

The LISST-PORTABLE|XR produces three file types. Data from every sample measured is placed in all three of these files. When offloading data from the instrument, you should offload and archive all three file types.

- .ASC files contain processed size distributions in a comma-separated text format readily imported into Microsoft Excel or other data processing software. This is the primary file format for routine use, and can be imported directly into the Excel report template provided by Sequoia Scientific.
- .LOG files contain metadata about instrument settings during sampling, in human-readable text. Information includes the average duration, particle model, instrument serial number, firmware version, file names for processed data and raw data, sampling date and time, and battery voltage.
- .DAT files contain raw binary data. This is not required for routine processing, but may be needed for troubleshooting or reprocessing.

9.2 File Names and Multiple Samples Per File

The instrument allows a choice of whether files contain single or multiple samples. If you choose single-sample files, file names will have a sample number appended to their names. For example, if you specify a base name of BASNAM, files will be named BASNAM00, BASNAM01, etc. through a maximum of BASNAM99. If you allow multiple samples per file, only one file will be created, with the given base name.

Whether you choose single or multiple samples per file, the LISST-PORTABLE|XR will always save data in all three file types, for example BASNAM01.ASC, BASNAM01.LOG and BASNAM01.DAT.

9.3 ASC File Format

Row 1	Header identifying file as a LISST-PORTABLE|XR data file and the date, time and day number of file creation.
Row 2	Instrument serial number
Row 3	Firmware version and date
Row 4, elements 1-21 (columns A-U)	Headers used for displaying the data in the enclosed EXCEL spreadsheet.
Row 4, elements 22-65 (columns V-BM)	Midpoint of the 44 LISST-PORTABLE|XR size classes in µm.

Row 4, elements 66-84 (columns BN-CF)	Headers used for displaying the data in the enclosed EXCEL spreadsheet.
Row 5	Units for the headers in row 4.
Row 6, column A	Date in MM/DD/YYYY format
Row 6, column B	Time in HH:MM:SS format
Row 6, column C	Optical Transmission [dimensionless]. The optical transmission is the fraction of emitted laser light power that is passing undisturbed through the sample volume, and which therefore does not contribute to the scattering of light off of the particles.
Row 6, column D	Total Volume Concentration [µl/l]. The Volume Concentration is the total volume of sediment within the size ranges covered by the instrument. It is computed by summing up the volume concentration in each of the 44 size classes.
Row 6, column E	Total Mass Concentration [mg/l]. The Mass Concentration is computed from the volume concentration multiplied by the effective density specified in the active SOP (see “Density” in section 5.5)
Row 6, column F	Mean Size [µm]. This is the mean size of the particle size distribution. See the FAQ (chapter 9) for information about how it is computed.
Row 6, column G	Standard Deviation [µm]. This is the standard deviation of the particle size distribution. See the FAQ (chapter 9) for information about how it is computed.
Row 6, column H	D5 [µm] is the 5^{th} percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column I	D10 [µm] is the 10^{th} percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column J	D16 [µm] is the 16^{th} percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column K	D25 [µm] is the 25^{th} percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column L	D50 [µm] is the 50^{th} percentile of the cumulative percentage undersize by volume of the sediment. It is the median diameter of the sample.
Row 6, column M	D60 [µm] is the 60^{th} percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column N	D75 [µm] is the 75^{th} percentile of the cumulative percentage undersize by volume of the sediment.

Row 6, column O	D84 [µm] is the 84th percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column P	D90 [µm] is the 90th percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column Q	D95 [µm] is the 95th percentile of the cumulative percentage undersize by volume of the sediment.
Row 6, column R	D60/D10 [dimensionless] is Hazen's Uniformity Coefficient. It is a measure of the range of particle sizes present in a given sample.
Row 6, column S	Specific Surface Area [m^2/g] is the effective surface area per gram of all particles in the size range covered by the instrument (assuming the particles are spheres).
Row 6, column T	Silt Volume [µl/l]. The total volume concentration of particles < 64 µm.
Row 6, column U	Silt Ratio [dimensionless]. The proportion (by volume) that particles < 64µm makes up of the total volume (Row 6, element 4).
Row 6, columns V through BM	Volume concentration [µl/l] in each of the 44 size bins.
Row 6, column BN	Sample Name
Row 6, column BO	Operator Name
Row 6, column BP	SOP Name
Row 6, column BQ	SOP Note
Row 6, column BR	Optical model (Fraunhofer or Mie)
Row 6, column BS	The real and imaginary parts of the refractive index for the particles selected for the optical model, or "n/a" for Fraunhofer
Row 6, column BT	Effective Density [g/cm^3]
Row 6, column BU	Mixer Speed during sample preparation [%]
Row 6, column BV	Mixer Duration during sample preparation (-1 if manual control) [seconds]
Row 6, column BW	Ultrasonic Intensity during sample preparation (-1 if manual control) [%].
Row 6, column BX	Ultrasonic Duration during sample preparation (-1 if manual control) [seconds]
Row 6, column BY	Average Duration [seconds]

Row 6, column BZ	Single or Multiple Sample flag. 1 if samples are saved as individual files, 0 if samples are appended to file.
Row 6, column CA	Manual Control. 1 is SOP mode is manual control, 0 is SOP mode is automatic control
Row 6, column CB	Battery voltage [V].
Row 6, column CC	Laser reference power in digital counts
Row 6, column CD	Laser transmitted power in digital counts.
Row 6, column CE	Mixer Speed during background measurement [%] (-1 if manual control)
Row 6, column CF	Internal electronics temperature (prior to firmware version 3.020, was undefined and always -1)
Row 6, column CG	Temperature of display controller (not present prior to firmware version 3.020)

10 Technical Specifications

10.1 Concentration Ranges

- 0.34-500 µm in 44 size classes.
- 30-1,900 mg/l*. Concentration range depends on the size distribution of the particles, as per examples in the table below.
- Concentration resolution < 1 mg/l.
- Concentration accuracy: ± 20%.

The measurable range of concentrations varies with particle size, and is based on the optical transmission through the sample chamber. Transmission is inversely related to concentration, with 100% transmission indicating pure water with zero particle concentration. Transmission above 95% indicates very low particle concentrations, so the resulting measurements tend to be noisy. When transmission is below 75%, multiple-scattering effects can bias the particle size distribution toward smaller sizes. Therefore, we recommend measurements only within the range of 95% to 75% transmission. The following table shows the measurable mass concentration ranges of several sizes of particles, within that transmission range.

*Note that the LISST-Portable|XR, like any laser diffraction instrument, measures *volume* concentration, not *mass* concentration. Mass concentration is calculated by multiplying volume concentration by the effective density of the material being measured.

Material	Concentration [mg/l] @ 95% transmission	Concentration [mg/l] @ 75% transmission	D10 [µm]	D50 [µm]	D90 [µm]	SMD [µm]
ISO Fine	30	170	1.5	7	41	3
ISO Coarse	95	395	4	38	99	10
20-30 µm glass beads	195	1075	19	24	34	24
Sieved sand 75-125 µm	345	1925	85	122	175	112

10.2 Mechanical and Electrical

- Dimensions and weight, instrument alone: 17.7 cm (7”) tall × 29 cm (11.5”) deep × 44.3 cm (17.5”) wide; 7.5 kg (17 lbs).
- Dimensions and weight in shipping box: 78 cm (31”) × 53 cm (21”) × 28 cm (11”); 23 kg (50 lbs).
- Data storage: 1 GB, space for more than 100,000 size distributions.
- USB data interface for transferring data files to a Windows computer.
- Rechargeable Lithium-ion battery provides for 8 hours of sample processing.
- DC input is 15V at up to 4.3A for operating the instrument and charging the battery. 115-240VAC power adapter is provided. The instrument can be used normally while battery is charging.
- 25W, 40kHz ultrasonic probe is managed through the touch panel.
- Operating temperature: 0 to 40 C
- Storage temperature: -20 to 50 C (no fluid in reservoir)

10.3 Size ranges

The 44 size classes cover the size range from 0.34-500 µm. The table shows the lower and upper limit of each size bin in µm, together with the median size (also in µm).

Bin #	Lower	Median	Upper	Bin #	Lower	Median	Upper
1	0.343	0.372	0.405	23	13.1	14.2	15.4
2	0.405	0.439	0.477	24	15.4	16.8	18.2
3	0.477	0.519	0.563	25	18.2	19.8	21.5
4	0.563	0.612	0.665	26	21.5	23.4	25.4
5	0.665	0.722	0.784	27	25.4	27.6	30.0
6	0.784	0.852	0.926	28	30.0	32.5	35.4
7	0.926	1.01	1.09	29	35.4	38.4	41.7
8	1.09	1.19	1.29	30	41.7	45.3	49.2
9	1.29	1.40	1.52	31	49.2	53.5	58.1
10	1.52	1.65	1.80	32	58.1	63.1	68.6
11	1.80	1.95	2.12	33	68.6	74.5	80.9
12	2.12	2.30	2.5	34	80.9	87.9	95.5
13	2.50	2.72	2.95	35	95.5	104	113
14	2.95	3.20	3.48	36	113	122	133
15	3.48	3.78	4.11	37	133	144	157
16	4.11	4.46	4.85	38	157	170	185
17	4.85	5.27	5.72	39	185	201	218
18	5.72	6.21	6.75	40	218	237	258
19	6.75	7.33	7.97	41	258	280	304
20	7.97	8.65	9.40	42	304	331	359
21	9.40	10.2	11.1	43	359	390	424
22	11.1	12.1	13.1	44	424	460	500

11 Frequently Asked Questions (FAQs)

11.1 What is an optical model? What model should I choose?

The foundation of the LISST-PORTABLE|XR is the laser diffraction principle. This principle relies on the fact that if you know the optical properties of the particles in your sample, then you can compute the size distribution of the particles. The optical properties of a wide range of materials are included in the LISST-PORTABLE|XR.

If you have absolutely no knowledge about the material in your sample, you should choose the Fraunhofer model.

However, if you have just some information it might often be better to choose the Mie model, and then select the optical model that best fits your knowledge of your sample. For example, for sediment particles use either Fraunhofer or a model based on the most common mineral in your sample (e.q. quartz or orthoclase).

No matter what model you choose it is extremely important that you only compare measurements analyzed using the same model. The same measurement of light scattering can give two very different size distributions if two different optical models are used.

11.2 How do I dilute a sample?

Do a background measurement and confirm that it is OK. Drain out the water.

Pour the suspended sediment sample into the mixing chamber so that it fills to the top of the lid. Use the funnel to top off the chamber through the small hole at the top of the lid, if necessary. Seal the hole in the top of the lid with the black fitting. Start the mixer. Observe if the instrument gives you a warning that the concentration is too high.

If this is the case, use a pipette to siphon off 50 ml of the sample, while it is circulating, then add 50 ml of clean, particle free water and let it mix for 5-10 seconds with the mixer pump running.

Observe if the concentration is still too high. If it is, siphon off another 50 ml, and add 50 ml of clean water. Repeat this procedure until the concentration is in the correct range, and then add a note about how the number of dilutions, and proceed with the analysis.

When you offload the data, you must use the number in the note to correct your volume concentrations to the actual values. Because it is a diluted sample, the data file will contain the concentration for the diluted sample, but you want the concentration for the un-diluted sample.

The volume of the mixing chamber is 117 ml. If you had performed 2 dilutions, and each time siphoned off 50 ml, then the original, undiluted

concentration (VC_org) can be computed from the measured concentration after dilution (VC_dil) as follows:

$$\mathrm{VC\_org} = \frac{\mathrm{VC\_dil}}{\left(1 - \frac{50}{117}\right)^2}$$

A more general formula would be

$$\mathrm{VC\_org} = \frac{\mathrm{VC\_dil}}{\left(1 - \frac{\mathrm{SV}}{117}\right)^{\mathrm{N}}}$$

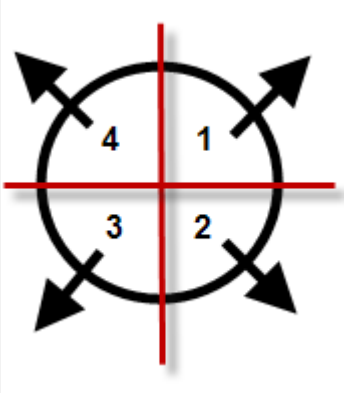
Where SV is the volume (in ml) you have siphoned off for each dilution and N is the number of dilutions you have performed.

Note that the above equations only work if the mixing chamber is filled completely to the top and if the volume siphoned off is the same each time.

11.3 How do I take a representative subsample?

This is a fundamental question that everybody involved in particle size analysis will have to consider at some point. There is no universal answer, but the following guidelines may be useful.

If you have a sediment sample from, say a dry grab sample or a dry soil sample, you can pile it up into a cone-formed shape. The figure shows the cone from above. Divide it into the 4 quadrants using a ruler or similar object and move them apart from each other.



Now combine 2 diagonally opposed quadrants (e.g. 1 and 3) into a new and smaller cone shaped pile, and then repeat until your sample is small enough to be suspended and analyzed.

This procedure obviously does not work if you have a sample already suspended in a liquid. In that case, pour the sample into the instrument and measure it. If the concentration is too high you can dilute the sample as per the description in the ‘How do I dilute a sample?’ FAQ.

	However, if the volume of your sample is already larger than the volume of the LISST-PORTABLE|XR mixing chamber, then you must split the sample first. Wet splitting a sample requires specialized laboratory equipment - do a Google search for 'Wet sample splitter' or 'Wet sample divider'.
11.4 Can I reprocess a set of data on board the instrument?	No. This is not possible. However, it is possible to first process a sample using one optical model or SOP, then change the optical property model or SOP to another model, and then measure the sample again, retaining the same zscat as for the first sample.
11.5 Does the LISST-PORTABLE|XR require any calibration?	No. All that is required is that the user makes a background measurement before the sample is measured. This is necessary for evaluation of the state and cleanliness of the optical system. If this is good (e.g. the current background measurement is close to the factory background, see FAQ above) the instrument will deliver good data.
11.6 What if there are particles present outside of the size range covered by my LISST-PORTABLE|XR?	This does not have a simple answer. Very briefly, the presence of sediment particles outside the size range covered by the instrument will cause some additional scattering on the inner- or outermost rings of the ring detector. In turn, this increased scattering will be detected as particle volume, so that the net effect is to increase the particle volume in the smallest and/or largest size classes. Typically, the effect can be seen if there is a significant amount of particles outside the size range, so that a rising tail will appear in the coarse and/or fine end of the size spectrum.
11.7 Does the instrument measure NTU, FTU or any other turbidity units?	No. All laser diffraction based instruments measure the volume distribution of the suspended particles. This may or may not be related to NTU.
11.8 What liquids can I use for suspending my particles?	Use ONLY water (fresh or salt water), isopropanol (isopropyl alcohol) or non-corrosive oils for suspending particles! **Use of solvents such as acetone, toluene, xylene, etc. for suspending particles will permanently damage the instrument and void the warranty!!**
11.9 Does the instrument detect	Regardless of the type of suspended particles, the LISST-PORTABLE|XR will measure the size and volume concentration of the particles. However,

different types of particles?	it cannot discriminate different types of particles (e.g. quartz and feldspar; organic and inorganic) from each other.
11.10 What is the volume of the mixing chamber?	When the mixing chamber is filled to the top with the lid in place it contains 117 ml.
11.11 What are the units for the concentration measurements?	The units for the concentration are in terms of particle volume per unit volume of liquid – micro-liters / l or µl/l.
11.12 Can I convert volume concentration or mass concentration to ppm (parts-per-million)?	Yes. If you are looking for ppm by VOLUME, then the volume concentration in µl/l is equivalent to ppm by VOLUME. If your ppm is by MASS, then you must convert the volume concentration to mass concentration (see above) with units of mg/l. The units of mg/l are equivalent to ppm by MASS.
11.13 What is the operating range of the instrument in terms of optical transmission?	The operating range of the LISST-PORTABLE|XR in terms of optical transmission is 75-95%. Above 95% transmission the data will become increasingly noisy. Below 75% optical transmission the data will become increasingly influenced by multiple scattering and you may end up 'inventing' fine particles.