BenchLab 7000

Automated Porosity-Permeability measurement system

User's Manual

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Printed August 2016
Version 160801

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1 Introduction

Welcome to the NER BenchLab 7000 Porosity permeability laboratory system. This automated apparatus performs gas permeability measurements using the pressure falloff technique in the range 0.1mD to 10D under hydrostatic stress conditions up to 10,000 psi. Queuing capability allows for unsupervised "stressed perm" data set acquisition. Three reservoir sizes, and a real time permeability calculation allow for optimized test duration. Though the permeability system can be used to measure sample porosity, the BL7000 is also equipped with a pycnometry cell that can takes samples up to 4 inches in length and 1.5 inches in diameter as well as cuttings to accurately measure grain volumes.

Figure 1: BenchLab 7000

2 BL7000

2.1 Basic theory

2.1.1 Permeability

The permeability measurement workflow is based on the work of Jones (1972), Ruth and Kenny (1989), Rushing et al. (2004) and Pazos et al. (2009):

Jones, S.C., 1972. A rapid accurate unsteady state Klinkenberg permeameter. Soc. Eng. J. 12 (5), 383-397.

Ruth, D.W., Kenny, J., 1987. The unsteady-state permeameter. J. Can. Pet. Technol. 28 (3), 67-72.

Rushing, J.A., Newsham, K.E., Lasswell, P.M., Cox, J.C., Blasingame, T.A., 2004. Klinkenberg corrected permeability measurements in tight gas sands: steady-state versus unsteady-state techniques. In: SPE Annual Technical Conference and Exhibition, Houston, TX, 26-29 September, SPE 89867.

Pazos, F., Bhaya, A., Martins Compans, A.L., 2009. Calculation of Klinkenberg permeability, slip factor and turbulence factor of core plugs via non linear regression. J. Pet. Sci. Eng. 67, 159-167.

The figure below exemplifies the data that is being recorded during pressure falloff and the space in which all parameters of interest, namely the equivalent liquid permeability k_l, the Klinkenberg slippage coefficient b and the Forchheimer turbulence factor α, are retrieved.

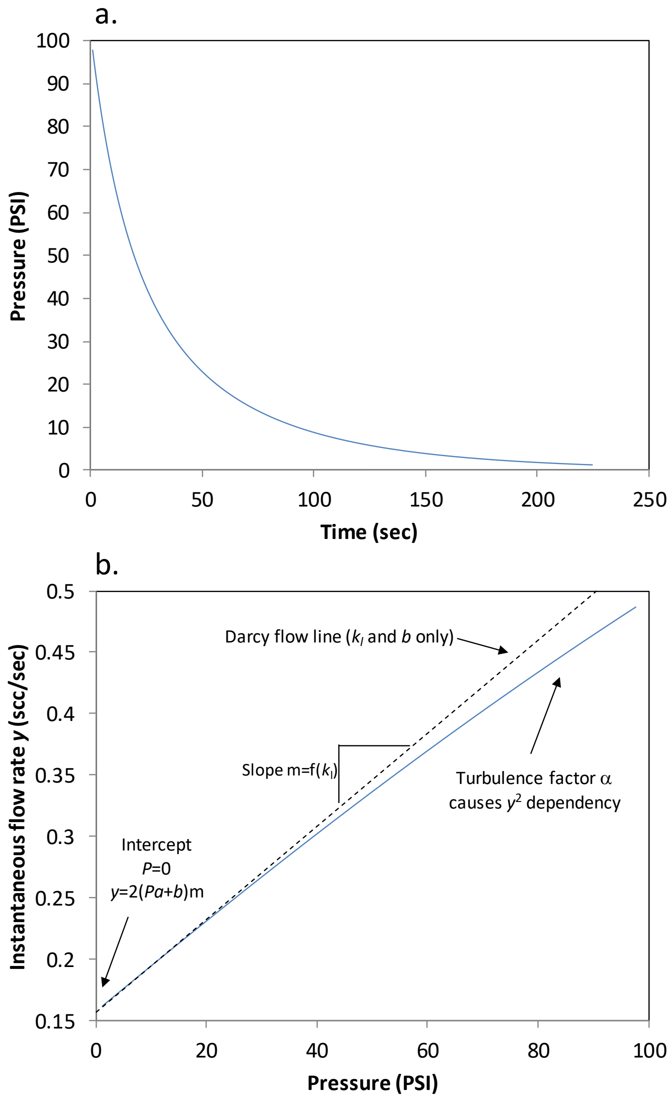


Figure 2: a. Modeled pressure falloff. b. Diagnostic plot for parameter determination

A notable feature of the BL7000 data inversion procedure is that inversion is conducted in real time and a modeled curve is produced which can be used to shorten the test by the operator.

2.1.2 Pycnometry

Gas pycnometry is a technique that allows to precisely measure the volume of a material regardless of its shape. In a porous rock it can produce an accurate measure of grain density and can also be used to derive porosity when the sample volume is known. The BL7000 pycnometry measurement is based on Boyle's law and uses the same protocol as traditional commercial gas pycnometers. The technique consists of emptying a pressurized reservoir into a cell containing the material sample. With the knowledge of the volumes of the pressurized reservoir and sample cell, the initial pressures in each of them and also the pressure after equilibration, the volume occupied by the materials framework can be calculated. The grain volume measurement workflow runs as follows:

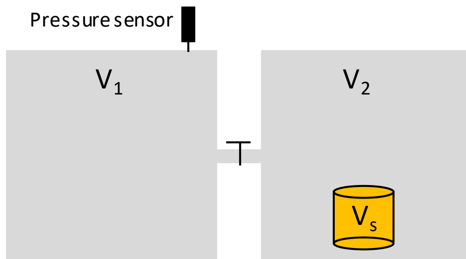


Figure 3: Schematic of pycnometry measurement

Initially, both reservoirs are vented to atmospheric pressure P_{atm}. Next, the valve in between the reservoirs is shut and the one that doesn't contain the sample is pressurized to P_{high}. Then, the valve is open and, after equilibration, P_{eq} is recorded. Using the ideal gas law at constant temperature T, R being ideal gas constant, we get:

Pressurization state:

$$P_{high}V_1 = n_1RT \tag{1}$$

$$P_{atm}(V_2 - V_s) = n_2RT \tag{2}$$

Equilibration state:

$$P_{eq}(V_1 + V_2 - V_s) = (n_1 + n_2)RT \tag{3}$$

Adding (1) and (2) and subtracting from (3) we get:

$$P_{high}V_1 + P_{atm}(V_2 - V_s) = P_{eq}(V_1 + V_2 - V_s) \tag{4}$$

$$V_s(P_{eq} - P_{atm}) = V_1(P_{eq} - P_{high}) + V_2(P_{eq} - P_{atm}) \tag{5}$$

$$V_s = V_1\frac{P_{eq} - P_{high}}{P_{eq} - P_{atm}} + V_2 \tag{6}$$

2.2 Overall system Architecture

Figure 4 shows the schematic diagrams of the two systems: the PoroPerm system and Pycnometry system. There is overlap between the two systems (such as the reservoirs, and the Pressure Enable valve), but each system has its own vessel and several dedicated valves.

The valves are pneumatic and software controlled. Under normal circumstances, the software will open and close them in pre-programmed sequences in order to perform measurements and other tasks such as loading and unloading samples.

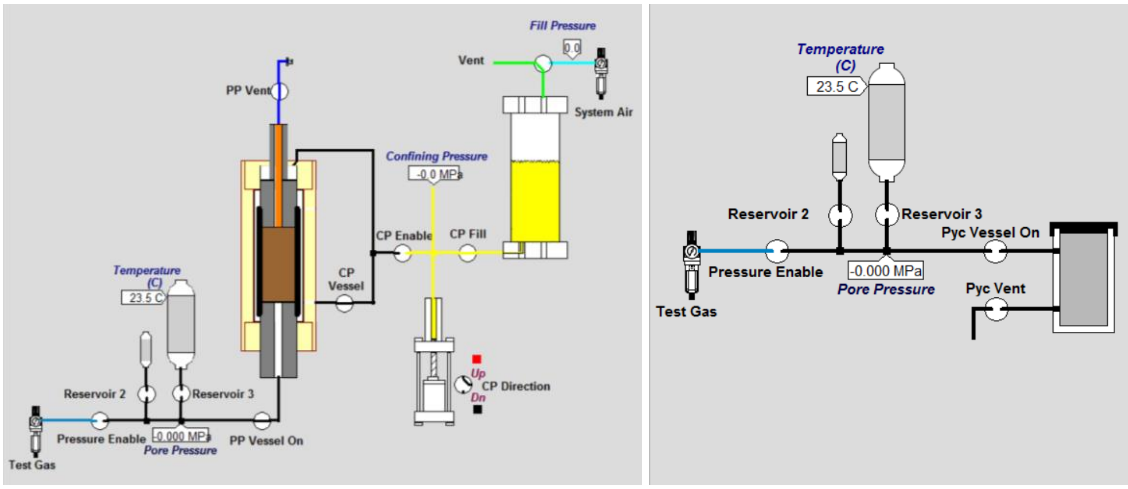


Figure 4: Schematic of (a) the PoroPerm measurement system and (b) the Pycnometry system

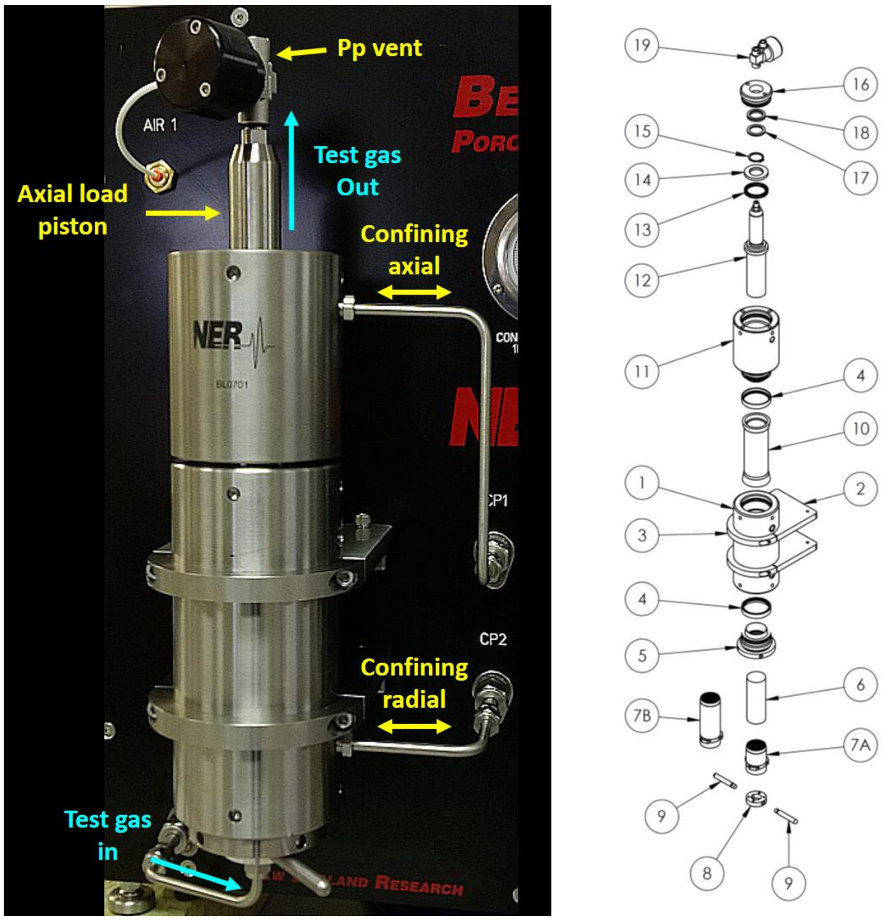
The BenchLab 7000 has three pressure sources.

Air Input/System Air (90 psi)	The site air pressure is attached to the confining pressure system. It can be used to apply initial amounts of confining pressure as well as move the piston up and down. As such, it’s primarily used during sample loading and unloading.
Confining Pressure Intensifier (up to 10,000 psi)	This “air-to-oil” intensifier uses the air input to drive the large diameter side of the intensifier. A smaller diameter piston on the other side of the intensifier creates high pressure with the confining oil. Due to the surface area ratio, an intensification of approximately 140:1 is achieved.
Test Gas (275 psi)	The test gas needs to be regulated to 275 psi. Commonly used gasses are Helium, Nitrogen, and Argon. This is the gas that will be used as pore pressure in the permeability vessel, and will also be used as the test gas in the pycnometer.

2.3 PoroPerm and Pycnometry Vessels

The PoroPerm vessel (Figure 5) is designed to apply hydrostatic pressure up to 10,000 psi using radial and axial pressurization chambers, the axial one being located behind a moving piston which can accommodate sample length. A sequence of valves opening and closing guarantees safe sample load and unload. Sample insertion is done from the bottom of the vessel.

Three check plugs and record sheet as of system shipping are also provided for monitoring of consistency.



1	Vessel
2	Clamp back
3	Clamp front
4	Sleeve ring
5	Bottom nut
6	Rock Sample
7A	Long sample end plug
7B	Short sample end plug
8	Handle mount
9	Handles
10	Rubber sleeve
11	Piston cylinder
12	Piston
13	Piston seal
14	Piston seal retainer
15	Retaining ring
16	Piston cylinder cap
17	Piston rod seal retainer
18	Piston rod seal
19	PP vent valve

Figure 5: PoroPerm vessel mounted on the BL7000

The pycnometry vessel's internal chamber can accommodate up to 4 in. length and 1.5 in. diameter samples. Cups and a volume filler are provided for use with different sample sizes as well as cuttings. Two billets are also available for volume calibration purposes.

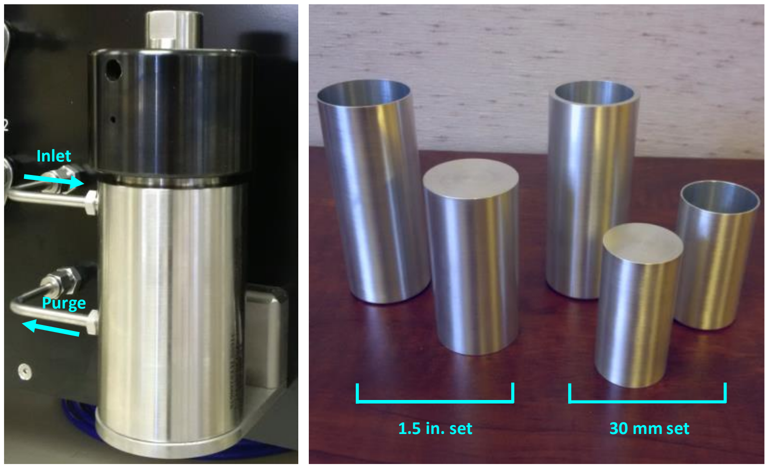


Figure 6: Pycnometry vessel and set of cups and billets

3 Operations

Before starting PoroPerm make sure that the system is powered on and system air pressure and test gas input pressure are at their appropriate values (nominally 90 and 275 psi, respectively). Also, make sure the right permeability vessel has been mounted.

3.1 Starting BenchLab Software

Click on the BenchLab icon on the desktop. The Info Panel opens to specify project information, sample information and run setup.

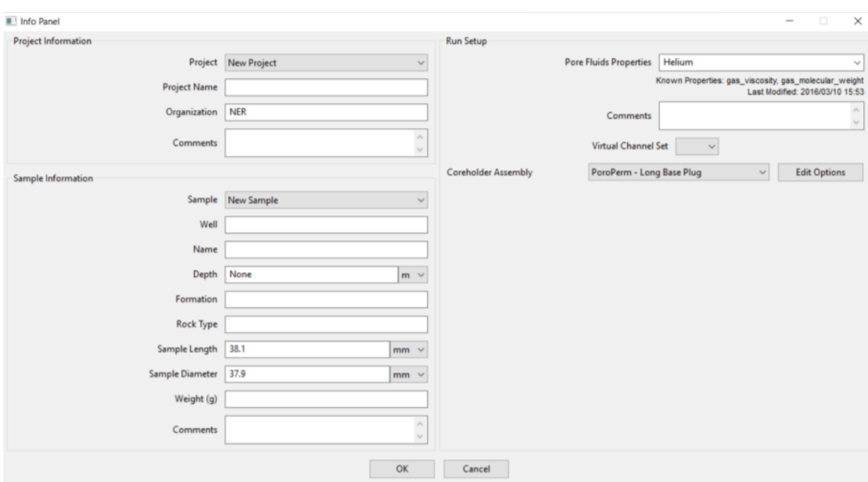


Figure 7: Sample Info Panel

There are three main sections of Info Panel:

1. Project Information:

If a project has already been defined it can be selected using the drop down menu. Selecting New Project will create a new database entry with the information provided. Comments written in this section are associated with the project.

2. Sample Information

   If a sample has been run before it can be selected using the drop down menu. Selecting New Sample will create a new database entry with the information provided. The Well` and Name are used as a unique sample identifier. The newly added sample will show up as "Well: Name" in the drop down list in the future. This will also be used in Dataviewer.

   Enter sample information into the remaining fields. Fill in all possible entries. This will provide you with access to the information in the future and it will also allow the software to make some sample property computations for you. For example, the software will compute the porosity of a sample based on measured pore volume (or grain density when measured with the pycnometer), but can only do this if the sample dimensions have been provided.

   Comments entered here will be associated with the sample. Sample preparation notes or observations would be appropriate.

3. Run Setup

   Select the Pore Fluid to be used during this test. This is the "Test Gas" connected to the system. Saturant is a non-critical field. Comments can be added which will be associated with the Run. Virtual Channel Sets are optional. When selected they will load in extra computer channels.

   <u>The Coreholder Assembly field is critical</u>. Calibrated volumes are associated with each of the selections. The selection here must match the hardware setup, or else all results will be invalid.

When finished, press OK to open the main software interface.

3.2 PoroPerm Measurements

3.2.1 Sample Loading

Two PoroPerm vessels are available for sample diameters of 1.5 inch and 30 mm. For each of these vessels, two base plugs are available to accommodate sample length. The base plug selection dictates the Coreholder Assembly field in the Info Panel. The two options are:

- PoroPerm – Long Base Plug: For samples up to 2 in. in length
- PoroPerm – Short Base Plug: For samples 2 in. to 4 in. in length

Note that using 'PoroPerm – Short base plug' with a sample shorter than 2 in. in length will result in improper loading of the jacket and potentially case a leak of the confining system fluid into the sample chamber. This may cause damage to the pore pressure regulator

Once the appropriate base plug is chosen, insert the sample + base plug assembly as showed in the picture below. When inserted appropriately, the zero clearance fitting should make an angle of about 45 degrees with the front panel. Use a pair of wrenches to tighten the pore pressure fitting just passed ‘finger tight’.

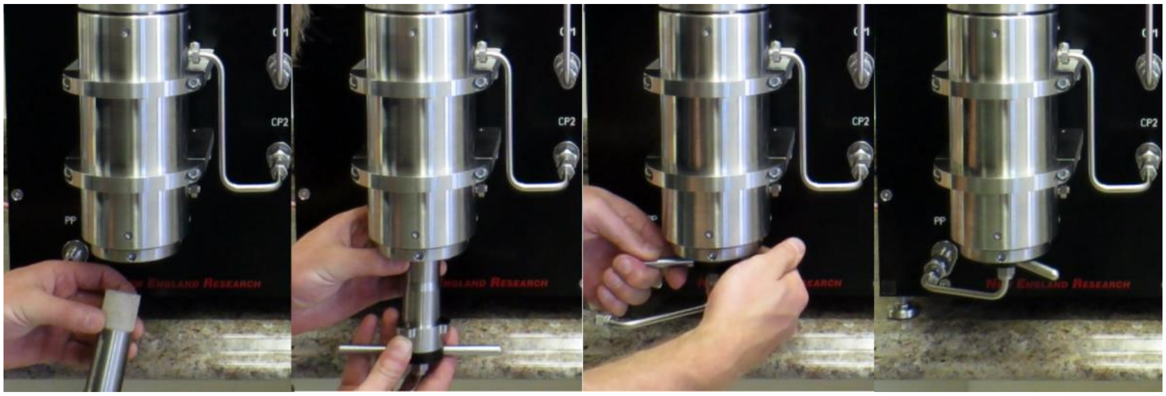


Figure 8: Inserting a sample into the vessel

Tip: The sample may sometimes stick inside the vessel instead of dropping out smoothly at the end of the test. This is most often the case with high pressure and longer duration tests, especially with high porosity samples. This can be avoided by wrapping the sample with Teflon tape before loading the sample in to the vessel.

The zero clearance fittings found on PP1, CP1, and CP2 are a metal gasket face seal. This includes two small parts: the metal gasket, and the metal gasket retainer. Make sure these are still in place and do not fall off. If the retainer easily slips off of the bulkhead, you can bend the clips (slightly) on the retainer to make it tighter.

Figure 9: Metal Gasket and Retainer (assembly, and separated)

3.2.2 Queuing an Experiment

Hitting ‘OK’ in the Info Panel window launches the main interface as showed in Figure 10. The schematic of the permeability system is shown in the center pane. On the left side are 3 panes. The first is the Channel Viewer, which shows each of the incoming channels and their values. The PoroPerm pane gives access to experiment parameters. The Plot updates in real time to give a time history of whichever channels are selected (by right-clicking on the plot).

The right side shows the Graphical Queue Viewer (GQV) pane and the Capture Results pane. The GQV shows a representation of any actions that are added to the Queue, such as PoroPerm captures. The Capture Results pane will become populated as captures are collected. This is a miniature version of Dataviewer and lets you interact with captures from this Run only. You can Edit, Reprocess, Export Table/Data, Delete, etc.

The location of each individual pane may vary, and is fully customizable by the user. The organization of the panes is called the ‘Perspective’. A user can create their own perspective and save it, or revert to the default perspective all using the Perspectives menu.

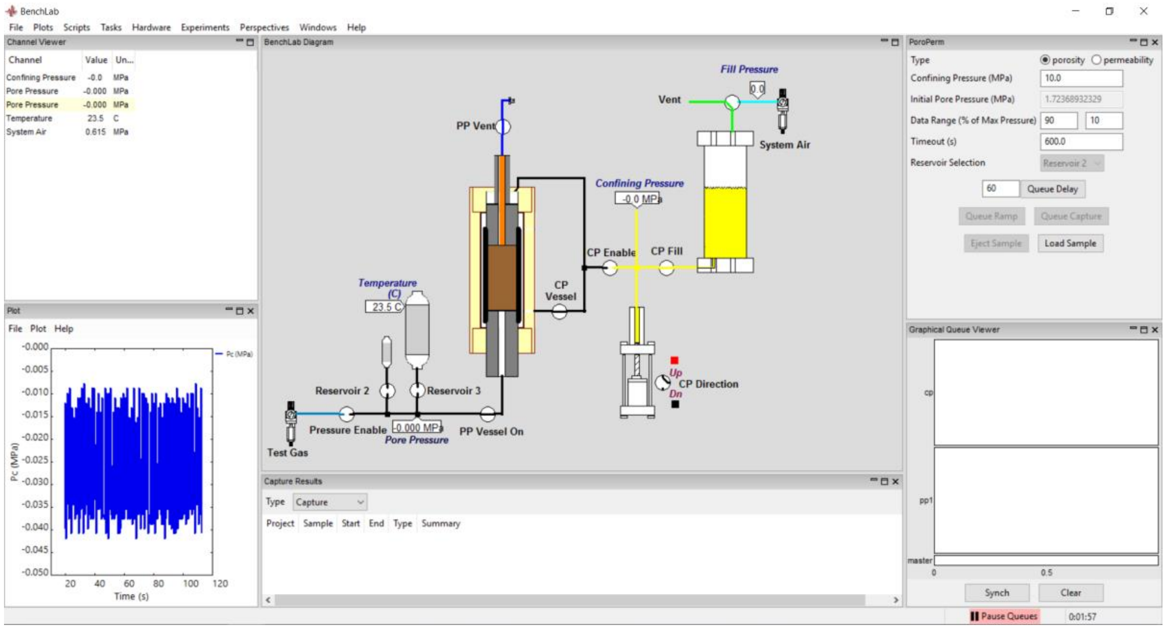


Figure 10: BenchLab main interface (PoroPerm measurement)

Before any measurement can take place, the piston has to be in contact with the sample. This is achieved by hitting ‘Load Sample’ in the PoroPerm pane. Once the piston has advanced to the sample, a check window asks the operator for confirmation

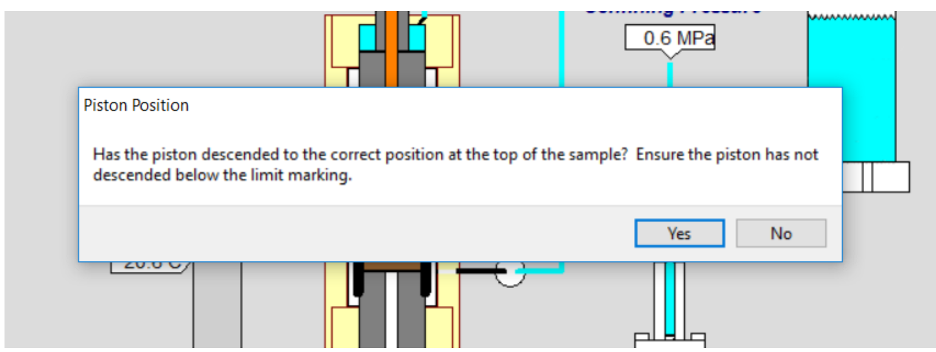


Figure 11: Software query that the piston has moved

If ‘No’ is picked, the system will attempt to move down the piston once again. In case of improper function, see the troubleshooting section. If the piston has properly moved against the sample, hitting ‘Yes’ will allow the system to move on and hydrostatically pre-pressurize the sample at current system air pressure.

The PoroPerm pane can now be filled with desired acquisition parameters. Choose between permeability and porosity. Depending on the choice, different parameters must be entered:

- Porosity:
    - Confining Pressure – Choose the confining pressure at which to measure permeability. The range is from 2 to 69 MPa
    - Data Range - The relative bounds of the pressure range that should be used in evaluating the permeability.
    - Timeout – The maximum time allotted of the capture.

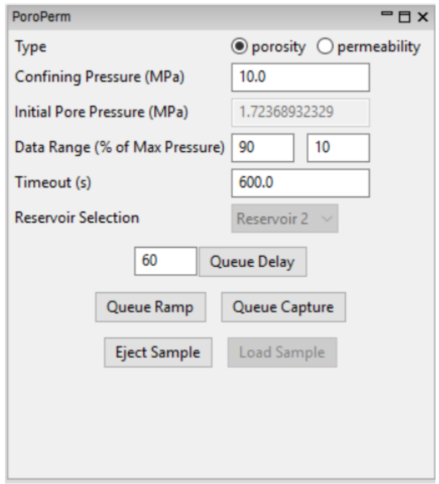


Figure 12: Parameters for porosity measurement

- Permeability:
    - Confining Pressure – Choose the confining pressure at which to measure permeability. The range is from 2 to 69 MPa
    - Initial Pore Pressure – Choose the pore pressure to measure permeability at. The range is from 0.5 to 1.7 MPa (maximum pressure depends on the Test Gas source)
    - Data Range - The relative bounds of the pressure range that should be used in evaluating the permeability.
    - Timeout - The maximum time allotted of the capture.
    - Reservoir - Pick which reservoir to use or choose ‘auto’. Auto will use the smallest reservoir first. If the decay is too fast it will use the next reservoir.

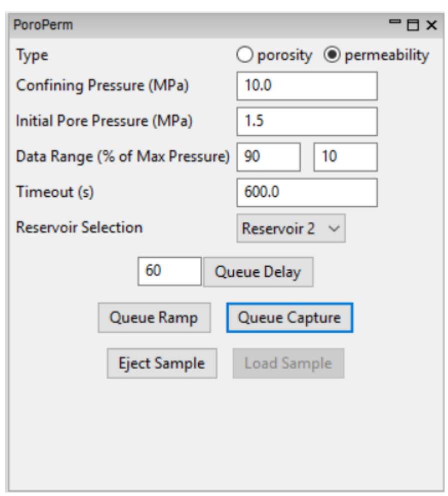


Figure 13: Parameters for permeability measurement

When ready, select ‘Queue Capture’. The measurement will begin right away and the Graphical Queue Viewer will populate with the outline of the confining and pore pressures for the test duration. Note that the ‘Queue Capture’ button is only available to select after the ‘Load Sample’ procedure has been completed. Alternatively, selecting ‘Queue Ramp’ will only ramp the confining pressure to the selected value, and no test measurement will be taken.

Figure 14 shows the view of BenchLab during a porosity capture. In this case, one porosity capture has already been run which can be seen in the plot, and also in the Capture Results pane. A second capture has just been queued, which shows up in the Graphical Queue Viewer.

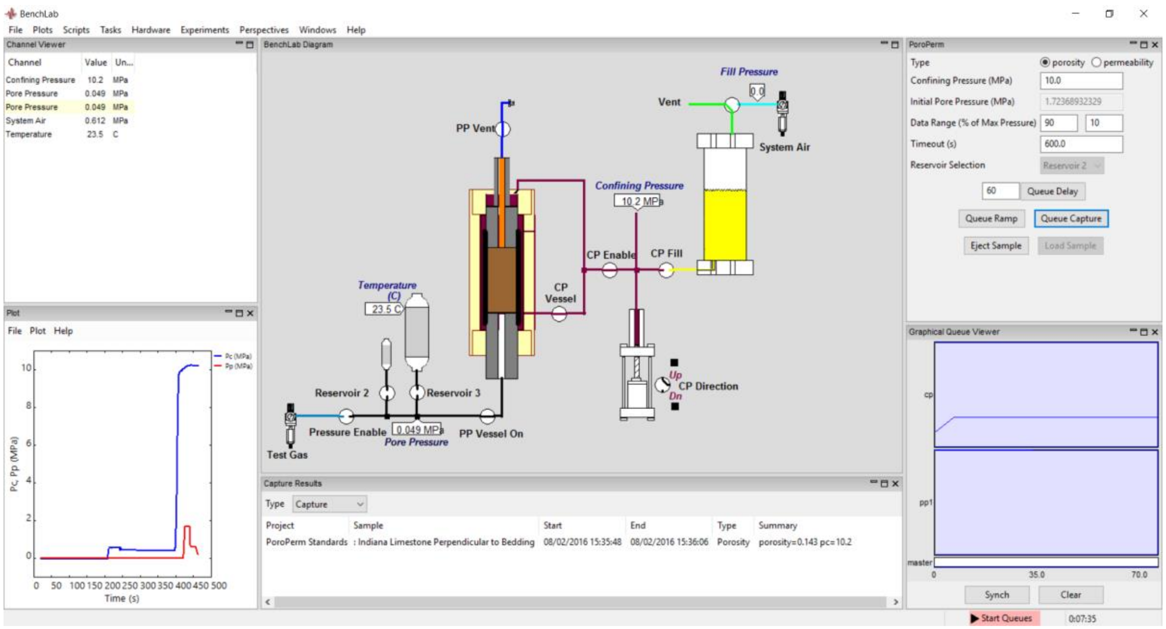


Figure 14: BenchLab during a porosity capture

Figure 15 shows the view of BenchLab during a permeability capture. In the plot you can see evidence of two porosity captures, followed by one completed permeability capture and another one still in progress. The in-progress capture can be seen in the Graphical Queue Viewer. In the center is the PoroPerm Monitor. This pane has been placed over the Diagram. You can switch back and forth by using the tabs at the bottom of the pane. The PoroPerm Monitor has two plots. The top plot shows the pore pressure data being captured (blue line) and the mathematical fit to this data (red dashed line). Early in the measurement there may be some discrepancy between the two, but by the end of the measurement it is expected that these two lines will match. The lower plot shows the real-time computation for sample permeability.

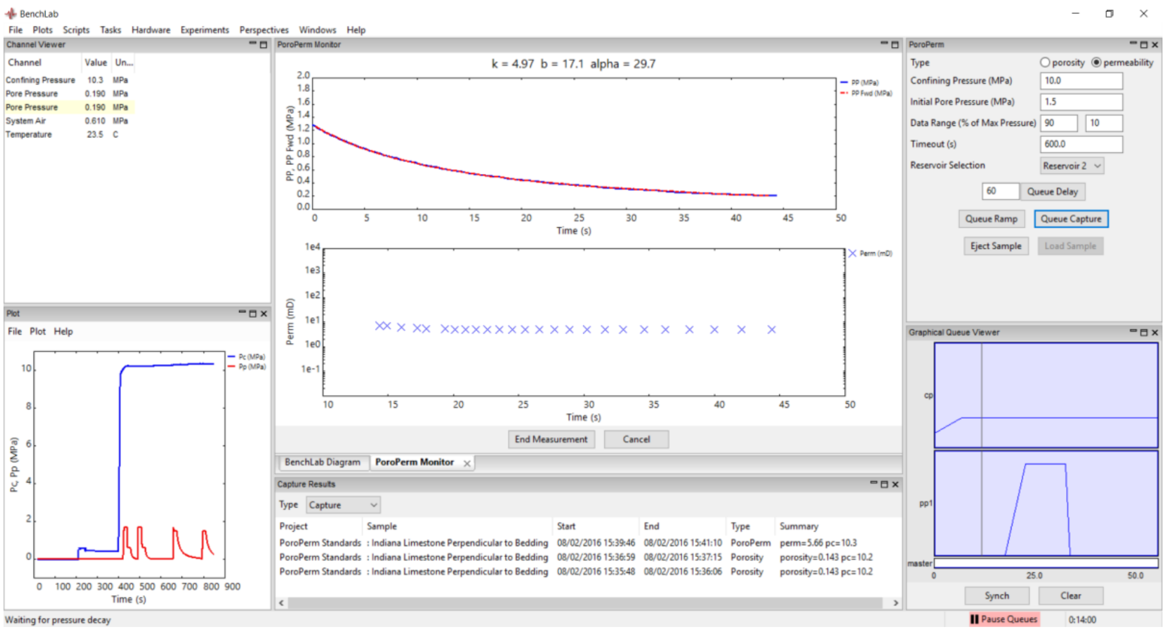


Figure 15: BenchLab during a permeability capture

3.2.3 Queueing Multiple Captures

If desired, multiple measurements can be placed in the queue. This can be done by selecting 'Queue Capture' when the desired parameters are selected, as mentioned before. After doing so (while the system is currently performing a measurement), the user can adjust the parameters/test types and select 'Queue Capture' again. This will add test measurement to the end of the current queue and the measurement will start once the first one is completed. This method can be used to build a test frame to capture porosity and permeability measurements at a variety of confining pressures.

The user has the option to pause the queues if desired. To do this, select 'Pause Queues' at the bottom of the BenchLab window. This allows the user to build a test outline by using the method described above. No measurements will start until the user selects 'Start Queues', at which point the system will perform all of the measurements the user has added to the queue. Additionally, prior to starting the queue, the user can save the test outline as a script. This script can be loaded and executed again on future samples. To do this select 'Create Script from Queue' from the Scripts menu. Save the script using 'Save to File' from the File menu. If you would like easier access to the script for commonly run experiments, you can use 'Save to Menu' and the script will appear in the Scripts menu.

To load a previously saved script, select ‘Load Script’ and select the file. Within the Script pane, you can add the script to the queue by selecting ‘Run’ in the Script menu. ‘Validate’ will check for syntax errors.

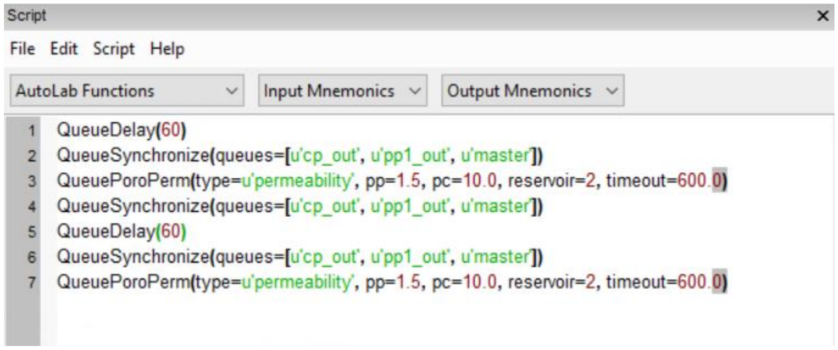


Figure 16: Example script

3.2.4 Sample Unload

Once the desired acquisitions are completed, hit ‘Sample Unload’. This will relieve all pressures and fully retract the piston, getting the sample ready for extraction. The main window will close and the Info Panel will open again getting ready for a new experiment. If attempting to close the Software interface directly, the program will run the eject procedure by default before shutting down.

3.3 Pycnometry Measurement

At the Info Panel, choose the appropriate Pycnometer option as the Coreholder Assembly.

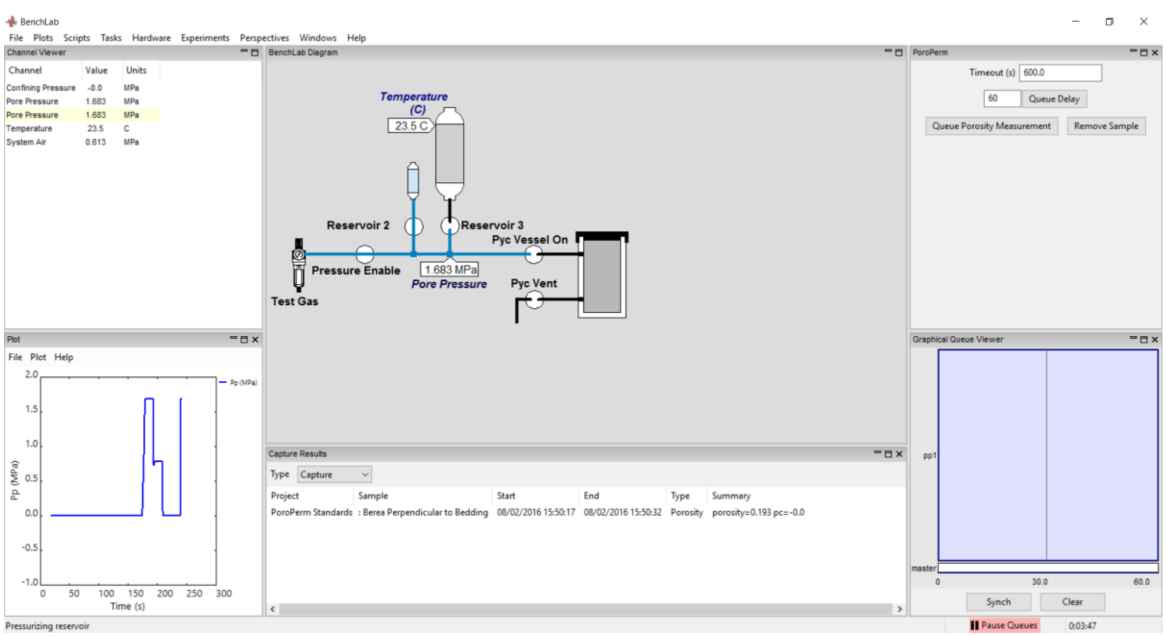


Figure 17: Diagram of the pycnometry system for grain volume measurement

In its design, the pycnometry cell allows for two chamber volumes that are adapted to 1.5in. and 30mm diameter samples, respectively. The 1.5in. diameter sample chamber is the whole cell volume plus an aluminum cup that has about 1.5in. internal diameter. The 30 mm diameter sample chamber option consists of the pycnometry cell plus a solid insert and a 30mm ID cup that is also 60 mm in height and fits inside the insert. The system is delivered with the volumes calibrated for these options. Make sure to pick which one is being used in order for the software to use the appropriate value for the ‘empty’ sample chamber volume. Change to these two configurations must be accompanied by a re-calibration of the sample chamber volume (cf. section on this topic)

3.4 Results in Dataviewer

There are 4 quick ways to sort data within Dataviewer.

- **Run**
  - View events only from the selected Run. Runs are listed by date and time that the run began.
- **Sample**
  - View events that are associated only with the selected sample. Samples are listed by a conjunction of the sample's well and name entered in to the Info Panel. "Well" – "Name"
- **Project**
  - View events that are associated with a certain project, which was entered (or selected) at the Info Panel
- **Type**
  - After applying one or several filters above, you can further limit the display to show only certain types of data. The table below will describe each option.

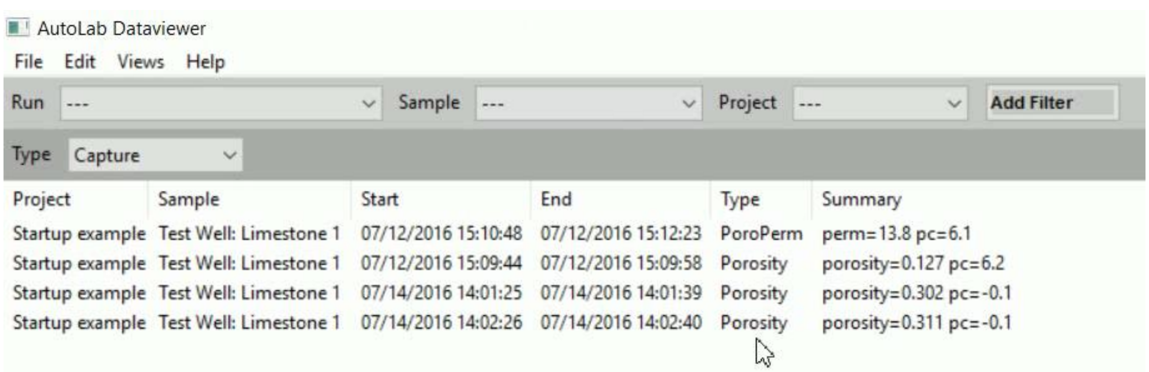


Figure 18: Dataviewer

3.4.1 Viewing/Reprocessing Captures

Double-clicking on a capture will reprocess the capture. In doing so, the default report for that capture type will appear.

3.4.2 Exporting

Exporting data is done by right-clicking on a capture. There are two main options for exporting: `Export Data` and `Export Table`. You can select multiple captures by using control-click to select individual captures, or shift-click to select a range.

‘Export Data’ will export the time history channel data from the capture.

‘Export Table’ will create a data table. You will be prompted to select which fields you would like included in the table.

3.4.3 Reports

If desired, users can create custom reports. To edit the report, select ‘Edit Layout’ from the File menu. This changes the view to display an outline of each element contained in the report.

Reports are modified by right-clicking on the report elements and selecting from the resulting menu. Selecting ‘Remove’ will remove that element from the report. The element's settings can be modified by selecting ‘Edit’. New elements can be added next to the clicked on element by selecting one of the menu options starting with Add.

Selecting one of the Add menu options will show a dialog which lets you customize how and where the report element will appear. The first part of the dialog are settings which are specific to the report element type being added. For more information about creating custom reports, contact NER.

When right-clicking on a capture you can view that capture with a particular report by selecting it in the Reports option.

4 APPENDIX

4.1 Check plugs

A set of check plugs are shipped with the system. They include documentation detailing the permeability ranges and uncertainties. Testing these check plugs is a routine way to check the performance of the system. Similarly, if the system is behaving strangely, testing the check plugs is often the first step in troubleshooting.

4.2 "Manual Mode"

The BenchLab 7000 is designed to be as automated as possible. Valve states and pressures are controlled automatically by the software. However, it may become necessary to control valves and pressures directly. This can be used when troubleshooting the system, or performing actions such as calibrating volumes described later in this Appendix.

Manual mode gives complete control of the system, and significantly reduces the number of fail-safes to prevent the user from making errors. This can lead to improper pressurization of the system. It is recommended that the user contact NER before attempting to use the system in manual mode for any reason.

In order to enable manual mode, you must access the site.alab file, found at:

C:NER/config/autolab/site.alab

Two Lines need to be changed:
no_commander = True
interactive_diagram = False

Should be changed to:
no_commander = False
interactive_diagram = True

This will enable the commander pane and allow for the diagram to be interactive. The commander gives slider bar control over the confining and pore pressure systems. The interactive diagram means that you can double-click on valves in the diagram to open and close them. **When this is enabled, be very careful when opening and closing valves.** Make sure that opening a valve with pressure behind it is safe. You have complete control over the system and can quickly make a mistake like having pore pressure greater than confining pressure and unseating the jacket inside the vessel.

4.3 Determination of reservoirs and pycnometry chamber volumes

The figure below illustrates what volumes are being considered in the calibration and how those contribute to making up reservoirs 1, 2 and 3 for the pycnometry measurements and for the permeability measurements.

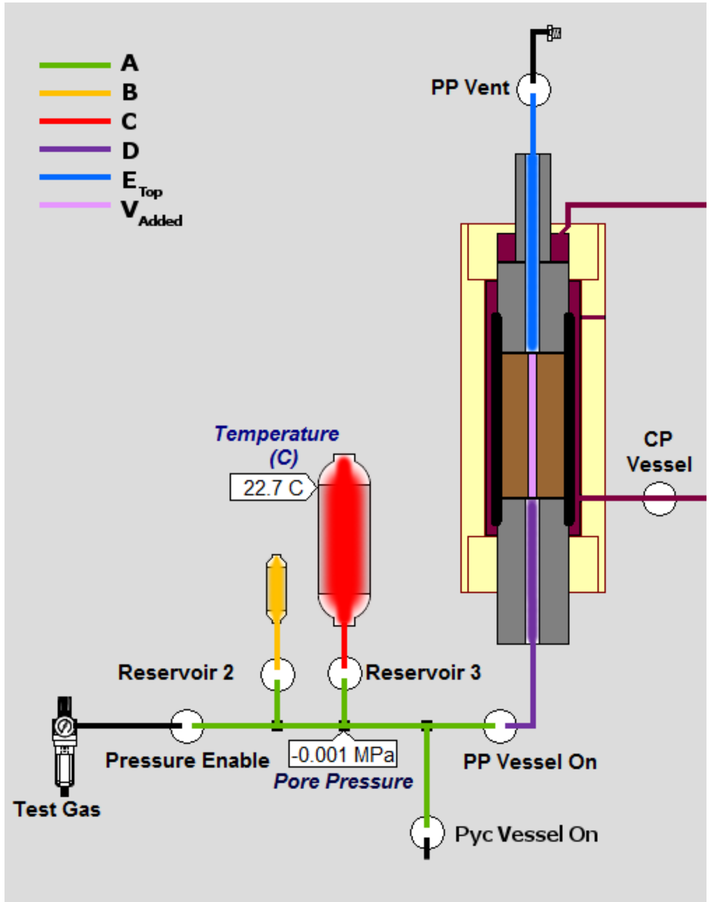


Figure 19: Distribution of reservoirs volumes

Pycnometry configuration:
Res1 = A
Res2 = A+B
Res3 = A+B+C

Permeability configuration:
Res1 = A+**D**
Res2 = A+B+**D**
Res3 = A+B+C+**D**

The volumes of the pycnometry chamber and either one of the three reservoir sections A, B and C can be measured jointly by running two successive depressurizations, one with a sample of known volume in the pycnometry chamber, and one without. Note that as the pycnometry measurement will be conducted with an initial reservoir pressure of 250 psi, it is desirable to use 250 psi for this calibration.

Depressurization of reservoir section X (X being either A, B or C) into the empty pycnometry chamber (using the result of equation (4)):

$$P_{high}V_X + P_{atm}V_{Pyc} = P_{eq1}(V_X + V_{Pyc}) \qquad (7)$$

Depressurization of reservoir component X into the pycnometry chamber containing a billet of volume Vs (using the result of equation (4) again):

$$P_{high}V_X + P_{atm}(V_{Pyc} - V_s) = P_{eq2}(V_X + V_{Pyc} - V_s) \quad (8)$$

Subtracting (8) from (7) yields:

$$(P_{atm} - P_{eq2})V_s = (P_{eq1} - P_{eq2})(V_X + V_{Pyc}) \quad (9)$$

And defining V_{total} as:

$$\boxed{V_{total} = (V_X + V_{Pyc}) = \frac{(P_{atm} - P_{eq2})}{(P_{eq1} - P_{eq2})}V_s} \quad (10)$$

We can rewrite (7) to isolate V_X:

$$\boxed{V_X = \frac{(P_{eq1} - P_{atm})}{(P_{high} - P_{atm})}V_{total}} \quad (11)$$

And similarly to isolate V_{Pyc}:

$$\boxed{V_{Pyc} = \frac{(P_{high} - P_{eq1})}{(P_{high} - P_{atm})}V_{total}} \quad (12)$$

Equations (10), (11) and (12) can be used to evaluate jointly the volumes of a reservoir and the pycnometry cell.

For these reservoir volumes to be used in a permeability measurement, a small volume (D) must be added which corresponds to the plumbing from the ‘PP Vessel On’ valve to the surface of the sample. This volume can be measured as follows:

1. Insert a non-porous plug into the permeability vessel
2. Use a small amount of pressure to push the piston down against the top of the sample
3. Pressurize the confining chamber to a few MPa (2-3)
4. Open all gas flow system valves and vent to atmospheric pressure
5. Close the ‘PP Vessel On’ valve as well as the Reservoir 2 and 3 valves
6. Pressurize the plumbing (reservoir 1 for the pycnometry measurement) to 250 psi
7. Close ‘Pressure Enable’ valve
8. Open ‘PP Vessel On’ and write equilibration pressure

Volume D can therefore be obtained using equation (4) and setting V_S to zero yielding:

$$P_{high}V_A + P_{atm}V_D = P_{eq}(V_A + V_D) \quad (13)$$

$$\boxed{V_D = \frac{(P_{high} - P_{eq})}{(P_{eq} - P_{atm})}V_A} \quad (14)$$

For these reservoir volumes to be used in a porosity measurement, a small volume (E) must be added which corresponds to the plumbing from the 'PP Vessel On' valve to the ‘PP Vent’ valve (excluding any volume in the vessel). In reference to Figure 19, $E = D + E_{Top} - V_{Added}$. This volume can be measured as follows:

1. Insert an aluminum plug into the permeability vessel which has a hole going through its center connecting both ends. This hole is a known volume (V_{added})
2. Use a small amount of pressure to push the piston down against the top of the sample
3. Pressurize the confining chamber to a few MPa (2-3)
4. Open all gas flow system valves and vent to atmospheric pressure
5. Close the 'PP Vessel On' valve as well as the Reservoir 2 and 3 valves
6. Pressurize the plumbing (reservoir 1 for the pycnometry measurement) to 250 psi
7. Close 'Pressure Enable' valve
8. Open 'PP Vessel On' and write equilibration pressure

Volume E can therefore be obtained the same way as volume D and subtracting the added volume:

$$V_E = \frac{(P_{high} - P_{eq})}{(P_{eq} - P_{atm})} V_A - V_{added} \quad (15)$$

4.4 Saving Volume Calibrations

4.4.1 Reservoir Volumes:

The 3 reservoir volumes (A, B and C) are saved in the software in the file site.alab. This file is accessed through the path: C:NER/config/autolab/site.alab

The volumes are located near the top of the file and are listed in cubic centimeters. Here they are listed as ‘reservoir1’,’reservoir2’,’reservoir3’.

4.4.2 Coreholder and Pycnometry Cell Volumes:

The volume of the coreholders (Volume D and E) and pycnometry cell are saved in the following directory: C:NER/config/autolab/coreholders/

For each file two values are represented. In the coreholder files the first volume corresponds to Volume D, and the second value to Volume E. In the pycnometry cell files there is only one volume value, but it is repeated twice. This is the volume corresponding to the ‘Pyc Vessel On’ valve to the ‘Pyc Vent’ valve.

To use one of these new values, you need to add it to the list in the Info Panel. Click Edit Options and Import to add a calibration to the list of options.

4.5 Switching poroperm vessels

The operations described below are also shown in a video provided with this manual.

1. If the base plug and a sample are still in the vessel, remove them now.
2. Turn off pressure inputs to the BenchLab system. This includes the input air and test gas sources.
3. Disconnect the Air 1 tube at the top of the vessel.
4. Remove the CP1 and CP2 tubing. Be careful not to remove the metal gasket face seal on the bulkhead fitting.
5. Loosen the Vessel Lock screw.
6. Lift and remove the vessel.
    a. There is still oil in the vessel chamber, around the jacket. You can leave it if you store the vessel upright. Otherwise, drain the oil out through the CP2 port in the vessel, and/or the plugged port at the bottom of the vessel.
7. Place the new vessel on the vessel hinges.
8. Swing it in to place and tighten the Vessel Lock screw.
9. Attach the CP1 and CP2 tubing. Make sure that the metal gasket face seal is in place on the bulkhead fitting.
10. Attach the Air 1 tube to the valve at the top of the vessel.
11. Insert a sample and the new base plug into the vessel. Make sure the cloverleaf is fully engaged by twisting it until it hits the stop.
12. Remove the PP1 tube from the bottom of the base plug previously used.
13. Attach the PP1 tube to the bulkhead fitting and to the base plug. When tightening the fitting on the base plug, be sure to hold the base plug in place so it does not twist as you tighten the fitting.
14. Now the vessel chambers (above the piston and around the jacket) need to be filled with oil.
15. Open the PoroPerm software. Since we are not performing a real test, most of the Info Panel sample information is not important. However, be sure to select the appropriate Coreholder.
16. With the software open, we are going to use the Fill Vessel option found in the Tasks menu.
17. The software will prompt you to make sure that a sample has been loaded. After this, the software will go through a series of cycling in order to push mineral oil into the vessel chambers and displace the air that is currently there.
18. After the cycles are finished, you can use the Eject Sample button, and then remove the sample from the vessel.

4.6 Replacing rubber jacket in poroperm vessel

The operations described below are also shown in a video provided with this manual. Many of the parts mentioned below can be found in Figure 5.

1. Follow steps 1-6 of Section 4.5 to remove the vessel.
2. As you lift the vessel, you will need to drain the remaining oil from the cavity surrounding the jacket.
3. Place the vessel in a table vice.
    a. If you don't have a table vice, you can leave the vessel mounted after step 4 of Section 4.6. Drain the oil in the vessel by removing the bottom plug, below the CP2 port in the vessel.
4. Use the spanner wrench to remove the bottom nut from the vessel
5. Use the spanner wrench to remove the top section of the vessel. The piston will remain inside of this section of the vessel. The jacket will also be attached to this section of the vessel as you remove it.

6. Remove the jacket and the sleeve ring by rocking them back and forth.
7. Remove the sleeve ring from the jacket. Note its orientation.
8. Going back the bottom side of the vessel, remove the collar from inside the vessel.
9. Place the top section of the vessel in the vice.
10. The jacket has one tapered end and one non-tapered end. Place the non-tapered end over the piston cylinder. Make sure that the jacket is completely vertical.
11. Slide the sleeve ring over the jacket, with the thin edge down. Place it so there is just a small amount of rubber jacket extending past the end of the ring.
12. Make sure the jacket is still vertical.
13. Carefully attach the top portion of the vessel to be bottom portion. Be careful to keep the jacket straight. Tighten it by hand.
14. Tighten with the spanner wrench. Tighten it until the CP1 and CP2 ports are aligned and there is only a ~0.1 in (~2.7 mm) gap between the two vessel sections.
15. At the bottom of the vessel, insert the other sleeve ring into the space around the jacket. The ring should go in with the thinner edge toward the bottom of the vessel.
    a. Make sure that the ring is fully inserted. You may need to shift the rubber jacket to get it to slide past the end.
16. Now thread in the bottom collar. As you thread this in check the jacket with your finger to make sure it is even all the way around. If it gets pinched, you will need to remove the nut and try to thread it in again. Tighten this nut all the way until it bottoms out.
17. The vessel is now ready to be mounted and filled. Follow steps 7-18 of Section 4.5.

4.7 Videos

A selection of instructional videos can be found online at:

https://www.youtube.com/playlist?list=PLicuZ0vjs5Y2qzEEixoeZLxIqOZhEUtrP

This includes the videos for Sections 4.5 and 4.6 as well as installation and training videos.