

SUNY Polytechnic Institute

Basic Vacuum Systems Training: Leak Rate Evaluation

A NEATEC Semiconductor Training Course

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Basic Vacuum Systems

Exercise #3 – Vacuum System Leaks (Real and Virtual)

Introduction: Vacuum systems are designed to perform a specific process or series of tasks at reduced pressure levels. In a manufacturing environment, a vacuum processing system must be able to reach the desired vacuum level consistently within a reasonable and repeatable timeframe. Leaks in the system due to defects in connectors, piping, or other physical damage are known as real leaks, since they have a physical source. Virtual leaks are those that are instead due to causes such as system contamination from water or other vapors, outgassing of materials used in the process, trapped air particles in fittings or components, or others. A pumpdown curve from the system taken under normal conditions is a useful reference in troubleshooting leak problems, since it reflects the volume, pumping speed and pressure levels of the vacuum system. In addition, this exercise will examine an effective leak rate for the system.

The old saying goes “Nature abhors a vacuum”. All vacuum systems will have some degree of leaks, be they real or virtual. Aging of seals, pumps that require rebuilding over time, contamination, and other factors will contribute to these, and at best, the designer can compensate for these leaks by sizing the components appropriately and ensuring that proper materials are used in the construction of the system. Leak rates provide a method to further characterize the system and a leak rate curve can also be used as a diagnostic tool. One method to characterize the leak rate is to use the rate of rise pressure test, which can be easily performed by use of an isolation valve. The system is pumped down to its operating pressure and the isolation valve is closed off, leaving the system without additional pumping. The pressure rate of rise vs. time curve under normal conditions can be compared to that found in a defective system. Typically, rates of rise in systems with real leaks tend to be more linear than those encountered in systems with virtual leaks.

Goal of Activity: In this exercise, (**Procedures 1-3**) the **pumpdown curve** and the **rate of rise** curve for the basic vacuum system assembled in Exercise 2 is acquired to characterize the system by determining the effective pumpdown speed and the effective system leak rate. In **Procedures 4-5** the **pumpdown** and **rate of rise** curves are re-acquired following the introduction of a virtual leak within the basic vacuum system to illustrate the effects on system performance.

Notes on Following the System Pumpdown and Rates of Rise Procedures: The system pumpdown and characterization procedures are designed for a two-person team consisting of a ‘**reader**’ and a ‘**worker**’. The ‘**reader**’ is tasked with reading the procedure and directing the ‘**worker**’ in the completing tasks. The ‘**worker**’ is tasked with following the ‘**reader**’ instructions and providing feedback as to completion of each procedure. Tasks to be completed by the team for this exercise are shown in **red bolded font**. The remaining text provides additional details for the assigned tasks. **Teams should read through the Procedure text prior to beginning the activity. The roles of ‘reader’ and ‘worker’ should alternate between exercises.**

Vacuum System Leaks Parts List: The parts for the **System Pumpdown and Characterization** exercise are shown in Figure 1 below. Each part is identified by an ‘Item #’ in a blue circle per Fig. 1 in Table 1 below.

Task 1 – Parts Checklist: Using the information in Figure 1 and Table 1, below, confirm the presence of each part required for the exercise by checking the appropriate box in the ‘**Checklist**’ column in Table 1.

Table 1. Vacuum System Leaks Parts List and Checklist

Item # (per Figs. 1)	Qty	Checklist	Description
1	1		Basic Vacuum System (previously assembled) with KJLC 275i pressure sensor installed
2	1		KJLC 275i Power Cord & Voltage readout wiring
3	1		Vernier DVP-BTA Differential Voltage Probe
4	1		LabQuest Data Acquisition System
5	1		LabQuest Data Acquisition System AC power adapter
6	1		Liquid application bottle (water)



Figure 1 – Parts for System Pumpdown Exercise. Blue circles denote part numbers for checklist

Notes on Basic Vacuum System (previously assembled) with KJLC 275i pressure sensor installed: It is presumed that the Basic Vacuum System used for this Exercise has been fully assembled and used for Exercises 1 and 2. It is also assumed that the KJLC 275i pressure sensor remains installed and connected to the appropriate power supply and data acquisition system. If that is not the case consult Exercises 1 and 2 to assemble system and prepare for system pumpdown and data acquisition.

Notes on LabQuest Data Acquisition System: The Vernier LabQuest is a data acquisition, plotting and recording device. It is used to acquire, display, and record pumpdown data for this exercise. The LabQuest utilizes the DC output voltage from the KJLC 275i pressure sensor. Each LabQuest unit has been calibrated to correspond to the digital readout of the KJLC 275i to within 10%. If discrepancies between the digital readout of the KJLC 275i and the LabQuest exceed 20% contact your instructor.

Notes on ‘Physical Leaks’: All vacuum systems have some degree of intrinsic physical leaks. (Obviously, this applies to the Basic Vacuum System assembled and characterized in Exercises 1 and 2.) Typically, vacuum systems are designed such that the fittings used and the pumps employed maintain the appropriate purity and pressure of the system for application requirements given a baseline leak rate. Increased physical leak rates are almost always undesirable even if a given pumping system has sufficient pumping capacity to overcome the leak and achieve the required base pressure. For example, leaks in low pressure systems may introduce other gases that contaminate a process. Consequently, physical leaks in a vacuum system almost always require some level of intervention.

Procedure 1 – Preparation of Vacuum System for Pumpdown

(Note: If the KLJ 275i pressure sensor and the LabQuest Data Acquisition System have been previously connected and configured, skip Task 1 and move to Task 2.)

Task 1. Connection of KLJ 275i pressure sensor and LabQuest Data Acquisition System:

Gather the components shown in Figure 1. Follow the steps below:

1. Connect the 9 pin power supply cable to the KJL 275 pressure sensor (do not tighten screws from 9-pin connector to the KJL 275i sensor).
2. Connect the Vernier DVP-BTA Differential Voltage Probe clip leads to the red and black leads from the 9 pin power supply cable, following the color coding on both sets of leads.
3. Plug the Differential Voltage Probe into the Channel 1 jack on the side of the LabQuest (see Fig. 2).
4. Turn on the LabQuest by pressing the power button. The Voltage Probe will be recognized and a Channel 1 Potential will be displayed.
5. Plug the 9 pin power supply adaptor into a 120VAC wall outlet. The KJL 275 digital display should light and display pressure of approximately 760 Torr after a few seconds. The LabQuest display (if used) should indicate approximately 3.90 V (+/-10%). See Fig. 3 below.

Task 2 Prepare LabQuest for data acquisition.

Load ‘pumpdown’ data acquisition file on LabQuest and prepare for data acquisition.

- Using the stylus included with the LabQuest unit tap the ‘File’ menu (see Fig. 4).
- Tap on ‘Open’ to access the file list (see Fig. 5).
- Tap on ‘pumpdown.qmbl’. The file name will become highlighted in gray (see Fig. 6).
- Tap the ‘Open’ button on the lower right hand corner of the screen to load the data acquisition file. Notice that at the left side of the LabQuest display the ‘Rate’ now reads ‘2 samples/s’ and the ‘Duration’ reads ‘600.0 s’ (Fig. 7).
- Tap the graph  icon on the upper right hand corner of the LabQuest screen to go to the data acquisition display screen (Fig. 8).

Notes for System Assembly: If the KJL 275i sensor display does not light or display, check the 9 pin power supply plug to see that it is securely fastened and that the unit is plugged into a live outlet. If the LabQuest does not indicate the voltage shown, check the clip leads to ensure a good connection and be sure the probe plug is fully inserted and locked into the LabQuest. If you have further difficulties, contact your instructor.

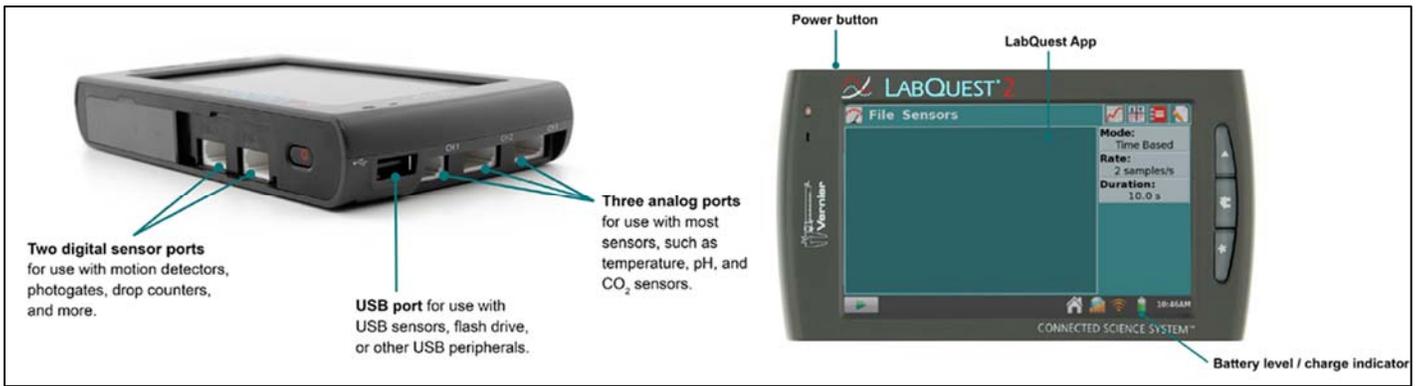


Figure 2 – Side and front views of LabQuest

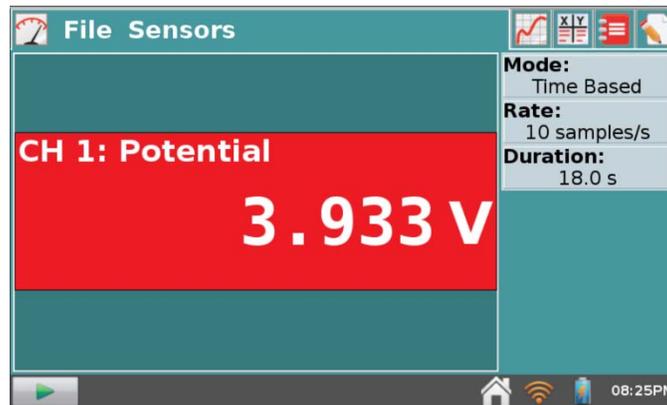


Figure 3 – LabQuest Screen with voltage reading from KJL 275i pressure sensor (at ~ 760 Torr)

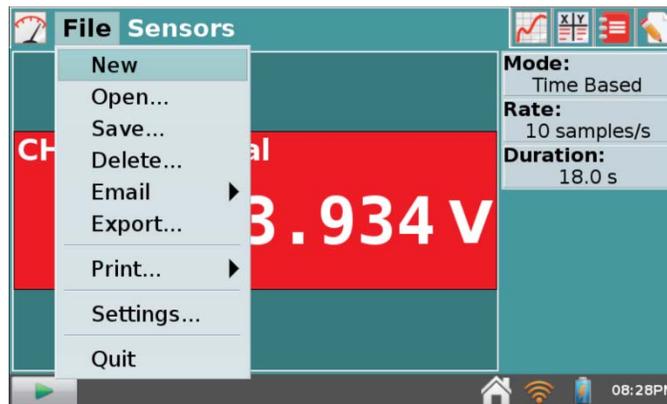


Figure 4 – 'File Menu' from LabQuest.

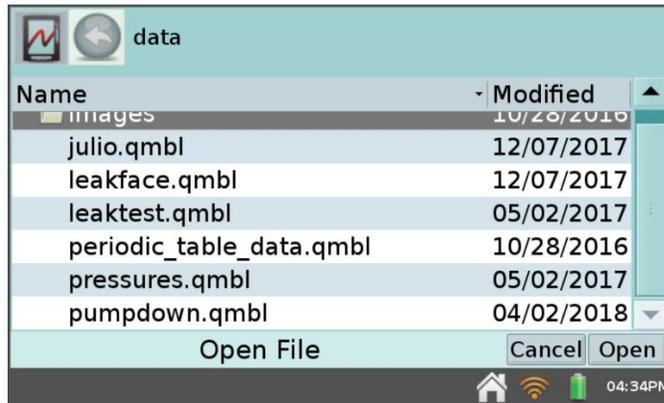


Figure 5 – 'File Menu' from LabQuest.

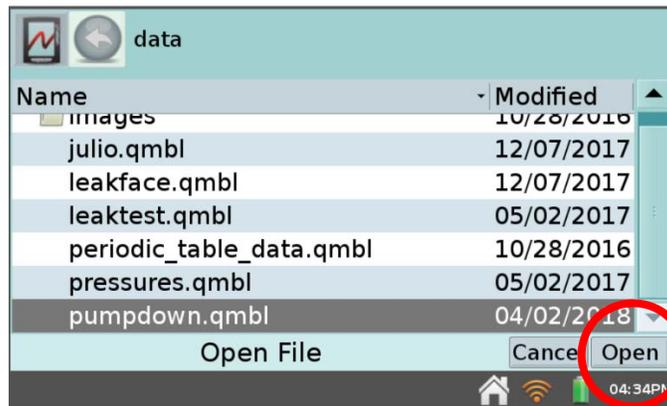


Figure 6 – LabQuest file list with 'pumpdown.qmbl' file highlighted.

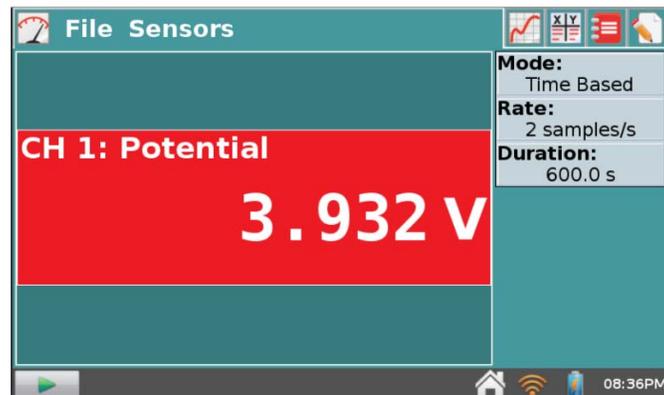


Figure 7 – LabQuest screen showing parameters (at left) for 'pumpdown' data acquisition file.

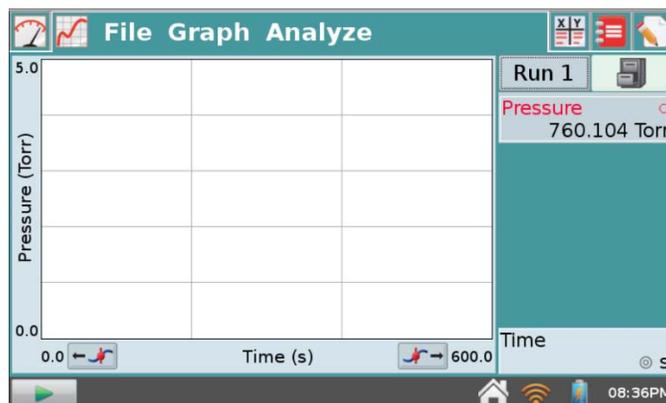


Figure 8 – LabQuest data acquisition display screen.

Procedure 2 – System Pumpdown:

Task 1 Prep system and initiate pumpdown and pressure vs time data acquisition.

Prep vacuum system for pumpdown

- Ensure that the venting valve on the side of the trainer base is closed (finger tight only).
- The **‘worker’** should hold the KF-16 blank/O-Ring assembly under the fixed flange on the trainer. (Once the system starts pumping down, you can remove your finger from the assembly and it will stay in place.)

Initiate Pumpdown AND data acquisition simultaneously (read carefully before pumping down)

- The **‘reader’** should locate the ‘start acquisition’ icon () at the lower left side of the LabQuest screen. The **‘worker’** should prepare to open the ball valve that connects the system to the vacuum hose. Notify your instructor that you are ready for pumpdown.
- When prompted by your instructor, the **‘reader’** should tap the start icon while the **‘worker’** simultaneously opens the ball valve connected to the vacuum hose to begin pumping down the system.
- You should see the elapsed time of the data acquisition run displayed at the lower right corner of the LabQuest display. If the data acquisition does not start notify your instructor.
- At the conclusion of the 15 minute data acquisition the elapsed time displayed at the lower right corner of the LabQuest display will reset to ‘0.0 s’.
- Upon completion of the data acquisition insert the USB drive into the USB port on the LabQuest unit adjacent to the Channel 1 sensor input (see Fig. 2).
- Using the stylus tap the ‘File’ menu at the upper left (see Fig. 8) and tap the ‘Save...’ menu. A dialog box will appear (see Fig. 9). Tap the word ‘untitled’ and a keypad will appear (see Fig.10). Enter the filename ‘Procedure3-2’ and tap the ‘Done’ button at the lower right of the screen. The filename will appear at the top of the LabQuest ‘Save’ screen (see Fig. 11). Tap the ‘Save’ button at the lower right of the LabQuest screen.
- **NOTE: Do NOT switch off the LabQuest. It will be used in Procedures 2-4.**
- **NOTE: Do NOT close ball valve. Do NOT vent system.**

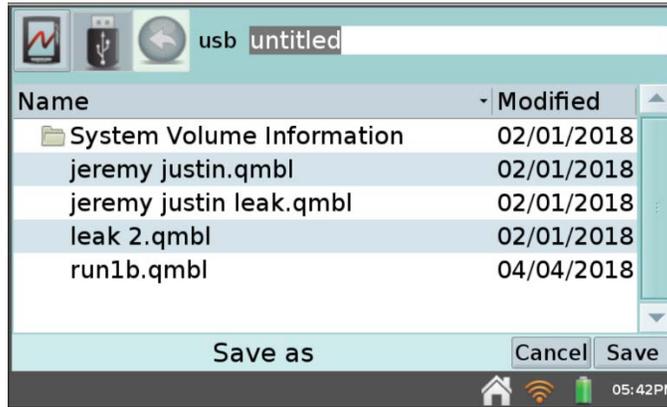


Figure 9 – LabQuest data file ‘Save’ screen.



Figure 10 – LabQuest data file ‘File name’ screen.

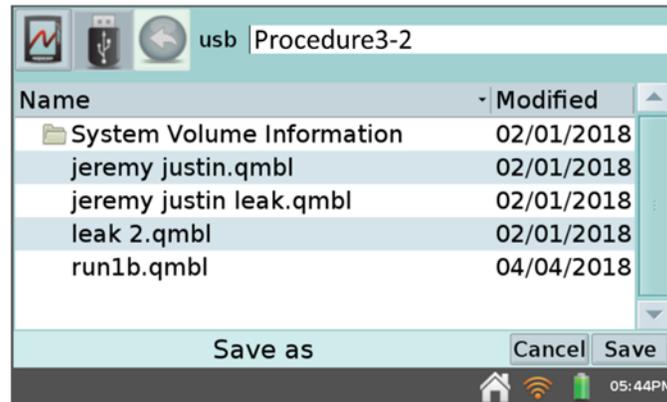


Figure 11 – LabQuest data file ‘Save’ screen with filename.

<<BREAK: BALL-VALVE VENTING PRIOR TO RATE OF RISE PROCEDURE>>

Procedure 3 – Acquisition of System ‘Rate of Rise’ Curve for a Physical Leak:

Task 1 Reset LabQuest data file and start data acquisition for Rate of Rise

Reset ‘Run’ Number on LabQuest data acquisition system.

- From the data acquisition display screen on the LabQuest (see Fig. 8) tap the file cabinet icon (). You will see that the ‘Run’ number has increased (see Fig. 12).

Initiate Rate of Rise curve acquisition

- When prompted by your instructor, the ‘reader’ should tap the start icon while the ‘worker’ simultaneously closes the ball valve connected to the vacuum hose.
- You should see the elapsed time of the data acquisition run displayed at the lower right corner of the LabQuest display. If the data acquisition does not start notify your instructor.
- At the conclusion of the data acquisition the elapsed time displayed at the lower right corner of the LabQuest display will reset to ‘0.0 s’.
- Using the stylus tap the ‘File’ menu at the upper left (see Fig. 8) and tap the ‘Save...’ menu. A dialog box will appear (see Fig. 9). Tap the word ‘untitled’ and a keypad will appear (see Fig.10). Find the filename ‘Procedure3-2’ on the dropdown list and tap it. Then, tap the ‘Save’ button at the lower right of the LabQuest screen. A dialog box will warn you about overwriting this file. Tap the ‘Overwrite’ button at the lower right of the LabQuest2 screen.
- Remove the USB drive and give to your instructor.
- **NOTE: Do not switch off the LabQuest. It will be used in Procedures 4-5.**

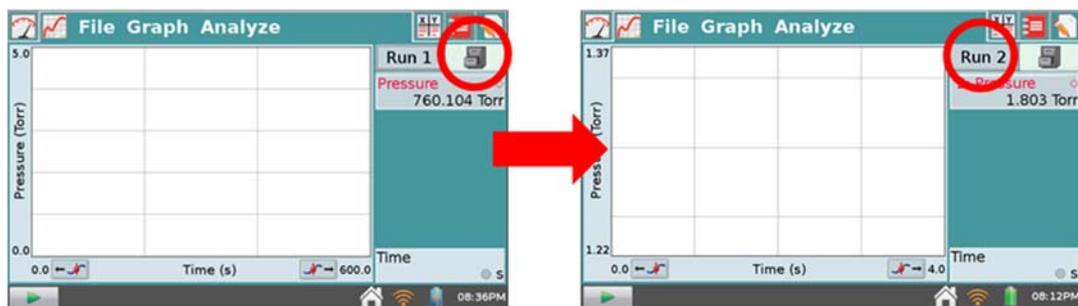


Figure 12 – To reset data file on LabQuest tap the file cabinet icon (red circle on left panel). Note that the ‘Run’ number increases by 1 (red circle on right panel).

<<BREAK FOR PUMPDOWN & RATE OF RISE DATA DISPLAY & DISCUSSION>>

Notes on ‘Virtual Leaks’: A virtual leak is defined as one that adds to the regular gas load needing to be pumped out of the chamber. Porous materials, such as some types of tubing, will outgas, releasing air or other trapped gases, when subject to low pressure environments. Contaminants such as water vapor in the air can also add to the gas load. Water vapor could be introduced from the atmosphere, in humid conditions, from contact with ungloved hands, or from process materials that have been improperly stored. In this exercise, the effects of water vapor will be seen. Liquid water, used in this exercise, poses an even more complicated issue, since its effect as a gas load does not appear until the water changes phase from liquid to gas, which occurs at approximately 18T (the vapor pressure of water).intervention.

Procedure 4 – System Pumpdown with Introduction of Liquid Water Droplet:

Task 1 Vent system to restore chamber to atmospheric pressure.

- Ensure that the ball valve that connects the system to the vacuum hose is closed.
- Slowly open the venting valve on the side of the trainer base.
- You should see the pressure on the KJL 275i gauge begin to rise.
- As the pressure approaches 100T you may open the venting valve more to accelerate venting.
- As the chamber pressure approaches atmospheric the **‘worker’** should hold the KF-16 blank/O-Ring assembly under the fixed flange on the trainer to prevent it from falling. When the chamber has reached atmospheric pressure place the KF-16 blank/O-ring assembly on the vacuum system base.

Task 2 Insertion of ‘Virtual Leak’ in System

Place droplet of water inside chamber to create ‘virtual leak’.

- Remove the bell jar from the chamber base plate and place it on the lab bench.
- Using the squeeze bottle place a droplet of water (roughly a quarter-inch diameter) on the polycarbonate base of the vacuum chamber. Avoid excess water in the system.
- Replace the bell jar on the chamber base plate.

Task 3 Reset LabQuest data file and pump down system

Reset ‘Run’ Number on LabQuest data acquisition system.

- From the data acquisition display screen on the LabQuest (see Fig. 8) tap the file cabinet icon (). You will see that the ‘Run’ number has increased (see Fig. 14).

Prep vacuum system for pumpdown

- Ensure that the venting valve on the side of the trainer base is closed (finger tight only).
- The **‘worker’** should hold the KF-16 blank/O-Ring assembly under the fixed flange on the trainer. (Once the system starts pumping down, you can remove your finger from the assembly and it will stay in place.)

Initiate Pumpdown AND data acquisition simultaneously (read carefully before pumping down)

- As in Procedure 2, the **‘reader’** should locate the ‘start acquisition’ icon () at the lower left side of the LabQuest data acquisition display screen. The **‘worker’** should prepare to open the ball valve that connects the system to the vacuum hose.
- When prompted by your instructor, the **‘reader’** should tap the start icon while the **‘worker’** simultaneously opens the ball valve connected to the vacuum hose to begin pumping down the system.
- You should see the elapsed time of the data acquisition run displayed at the lower right corner of the LabQuest display. If the data acquisition does not start notify your instructor.
- At the conclusion of the data acquisition the elapsed time displayed at the lower right corner of the LabQuest display will reset to ‘0.0 s’.
- **NOTE: Do not switch off the LabQuest. It will be used in Procedure 5.**

<<BREAK: BALL-VALVE VENTING PRIOR TO RATE OF RISE PROCEDURE>>

Procedure 5 – Acquisition of System ‘Rate of Rise’ Curve for a Virtual Leak:

Task 1 Reset LabQuest data file and start data acquisition for Rate of Rise

Reset ‘Run’ Number on LabQuest data acquisition system.

- From the data acquisition display screen on the LabQuest (see Fig. 8) tap the file cabinet icon (). You will see that the ‘Run’ number has increased (see Fig. 12).

Initiate Rate of Rise curve acquisition

- When prompted by your instructor, the ‘**reader**’ should tap the start icon while the ‘**worker**’ simultaneously closes the ball valve connected to the vacuum hose.
- You should see the elapsed time of the data acquisition run displayed at the lower right corner of the LabQuest display. If the data acquisition does not start notify your instructor.
- At the conclusion of the data acquisition the elapsed time displayed at the lower right corner of the LabQuest display will reset to ‘0.0 s’.
- Using the stylus tap the ‘File’ menu at the upper left (see Fig. 8) and tap the ‘Save...’ menu (see Fig. 9). A dialog box will appear. Tap the word ‘untitled’ and a keypad will appear (see Fig. 10). Enter the filename ‘Procedure3-5’ and tap the ‘Done’ button at the lower right of the screen. The filename will appear at the top of the LabQuest ‘Save’ screen (similar to Fig. 11). Tap the ‘Save’ button at the lower right of the LabQuest screen.
- Remove the USB drive and give to your instructor for plotting and printing.

<<BREAK FOR PUMPDOWN & RATE OF RISE DATA DISPLAY & DISCUSSION>>