UNIT FOUR: SPIROMETRIC TECHNIQUE

A well-trained technician is essential for achieving accurate and precise spirometric results. The consequences of not implementing quality assurance measures were discussed in units two and three. Poor subject preparation and coaching can also adversely affect results. This unit will cover the steps to be taken to help subjects produce the best tracings that they can. (See **Appendix G. Spirometry Procedure Checklist** for a summary of the material covered in this unit.)

A. Prepare the Equipment

1. Check that the **equipment has been properly cleaned** according to established policies. (See **Unit Three: The Quality Assurance Program** for infection control recommendations.)

2. Check that the **equipment is set up**:

    a. Attach breathing hose if applicable.
    b. Check paper supply.
    c. Set the paper speed.
    d. Check the position of the pens.
    e. Give the equipment a test run, preferably test yourself, since you will be familiar with your result if you have routinely performed forced expiratory maneuvers on your equipment (see **Unit Three: The Quality Assurance Program**).

3. Be sure that a **calibration check** of the equipment has been performed on the day of testing according to established policies. (See **Unit Three: The Quality Assurance Program** for more information.)

4. Check that there are **enough supplies** (mouth pieces, nose clips, denture cups, subject record forms, and any other materials used) to perform and record the tests. Note what supplies should be reordered soon.

5. Note the ambient or **room temperature** (temperature within the spirometer is preferred) and convert to centigrade if needed. (See **Unit Five: Basic Spirometric Calculations, Section I: Conversion to BTPS**, for conversion tables.) Note the barometric pressure if required.

6. Check that the **scales to measure weight and height** are working properly.

7. Set up an **area that is screened off** where subjects can loosen or remove restrictive clothing or loose dentures.

8. Have available a **chair without wheels** for subjects.

9. Make available **trash receptacles** for discarded gowns, mouthpieces, etc.

10. Follow your institution's requirements for **disposal of medical waste**.

B. Prepare the Subject

1. **Explain the purpose of the spirometry test**

   a. Introduce yourself and tell the subject that today you will be taking measurements to check on the health of his/her lungs. The word "test" often makes people nervous because they worry that they won't know the "right" answer or that they won't "pass". Try to avoid using that word when speaking to the subject to prevent him/her from developing "test" anxiety.

   b. Point to the spirometer and note that you'll be using it to record the amount of air he/she can exhale and how quickly he/she can do it. (**NOTE**: Exhaling as forcefully and quickly as possible into a spirometer is called the **Forced Expiratory Maneuver**.)

   c. Emphasize that the procedure doesn't hurt, but to get useful and valid results, he/she must breathe as hard and as fast as possible when told to do so and the procedure must be repeated a few times to obtain all of the information needed.

   d. Explain that you will tell him/her how to do the procedure and that you will also give a demonstration before he/she does it, but first you need to ask a few questions.

2. **Check whether the test should be carried out or postponed**. Certain conditions can affect test results. Follow the criteria established by your institution for postponing spirometry. If no criteria exist, the sample questions listed below can be used to guide your decision. Before using these questions, it is recommended that you review them with your organization's physician to determine if any should be deleted or others added.

   If the test is postponed, be sure to reschedule the subject before he/she leaves, and to indicate in the chart the date and the reason for the postponement.

   a. **How are you feeling today?** Find out if he/she has any acute illness that might affect his/her ability to take a deep breath or to blow out forcefully. If so, postpone spirometry at least three days.

   b. **Have you smoked any cigarettes, pipes, or cigars within the last hour?** If yes, postpone spirometry at least one hour. Smoking can have a short-term effect on the small airways.

   c. **Have you used any inhaled medications, such as an aerosolized bronchodilator within the last hour?** If yes, postpone spirometry at least one hour. These can have a short-term effect on the small airways.

   d. **What have you eaten in the last hour?** A heavy meal may have a short-term effect on the subject's ability to take the deepest breath possible. After finding out what the subject

has had to eat, decide whether or not the amount of food was sufficient to influence the results. If so, postpone spirometry at least one hour.

e. **Have you had any respiratory infections, such as flu, pneumonia, severe cold or bronchitis within the last three weeks?** If yes, consider postponing the test until at least three weeks after the symptoms have passed, or longer if there is a lingering cough. These illnesses may have a small short-term effect on the airways.

f. **Have you had any ear infections or problems in the last three weeks?** If yes, postpone the test at least three weeks. The subject may experience ear discomfort during a forceful exhalation.

g. **Have you had any recent surgeries?** If the subject has had any major surgeries, such as oral surgeries, surgeries to the trunk of the body, or eye surgery, consult with the surgeon to determine how long to postpone the test. The subject's ability to take as deep a breath as possible, or in the case of oral surgery, to obtain a tight seal, may be temporarily affected.

C. Position the Subject

1. **Sitting or Standing**: The subject may sit or stand. The standing position is preferable, particularly for obese subjects, since studies have shown that a larger FVC is obtained from standing (23). Put a chair behind subjects if they perform the test standing. They may wish to use it between tests. If subjects sit, encourage them to sit up straight. **Note in the chart the position in which the test was conducted.**

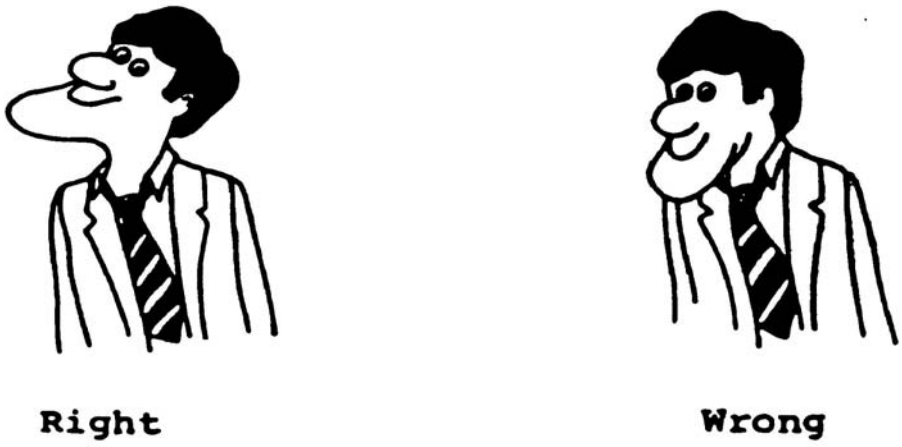
   Whenever possible, when spirometry is performed on subsequent dates, subjects should be tested in the same position as was used the first time. If a subject stands for the first testing, but sits for testing at a later date, his/her FVC may show a decrease that is the result of the position rather than lung disease. This will make interpretation of the test results difficult unless the position is noted in the chart each time. **Note: the standing position should be used for pregnant women, obese men and women, and children to obtain the best results**.

2. **Clothing**: Instruct the subject to loosen tight clothing, such as ties, belts, bras or girdles, which tend to restrict hard and fast breathing. You may want to have available disposable gowns and a screened area where the subject can loosen restrictive clothing or remove it and put on a gown if needed.

3. **Chin and Neck Position**: Instruct the subject to elevate the chin and extend the neck slightly. This position allows for the most forceful exhalation possible. (See **Figure 4-1. Chin and Neck Position**.)

4. **Nose clip**: We recommend that the subject use a nose clip. Show him/her how to use it. This clip prevents air from escaping through the nose during the test. If this is not possible, have the subject pinch his/her nostrils with fingers.

FIGURE 4-1. CHIN AND NECK POSITION.



5. **Dentures**: Ask the subject if he/she has dentures and whether they are loose. Dentures should be left in place if they are not loose, since it is often difficult to keep a tight seal around the mouthpiece without the dentures in place. Make a note in the chart if the test is to be attempted while wearing them. Watch the shape of the curves closely to determine if the dentures are obstructing the subject's airflow. Keep a supply of plastic denture cups for possible use.

D. Perform the Test

1. **Explain to the subject how the forced expiratory maneuver is performed**:

   a. Hold the spirometer tube near a shoulder so that it will be close by when needed.

   b. Take the deepest possible breath after breathing in and out normally for several seconds.

   c. Bring the spirometer tube to the mouth and place it on top of the tongue between the teeth. Put the mouth firmly around the mouthpiece, making sure not to purse the lips as if blowing a musical instrument. Instruct the subject not to inhale from the mouthpiece unless information on inspiration as well as expiration is to be recorded. (See **Figure 4-2. Correct Mouth Position**.)

   d. Keep the chin slightly elevated and make sure that the tongue is out of the mouthpiece.

   e. Without further hesitation, **BLAST** into the mouthpiece of the spirometer as hard, fast and completely as possible.

f. Keep blowing as long as you can or until you are told to stop.

FIGURE 4-2. CORRECT MOUTH POSITION

2. **Always demonstrate for the subject the proper technique using a mouthpiece**. Check to see if the subject has any questions.

3. **Perform last minute equipment preparations if applicable**:

   a. Place the recorder pen in the appropriate position on the chart paper.

   b. Start the paper moving at least one second before the subject blows into the mouthpiece.

4. **Coach the subject**

   a. Instruct the subject: "Whenever you are ready, take the deepest possible breath, place your mouth firmly around the mouthpiece, and without further hesitation, blow into the spirometer as hard, fast, and completely as possible." Watch the subject inhale fully, place the mouthpiece, and BLAST out the air.

   b. Actively and forcefully coach the subject as he/she performs the maneuver. **Emphasize**, "**BLAST** the air out, blow, keep blowing, keep blowing!" Studies have shown that active coaching during both inspiration and expiration help the subject to give a maximal effort.

   c. Keep coaching them to continue to exhale until the point at which the tracing becomes almost flat -- an obvious plateau in the volume-time curve. Since the end of test is hard for the technician to determine during the maneuver, tell the subject to blow as long as he/she can. After each maneuver let him/her relax for a few minutes.

OSHA Cotton Dust Standard Definition of Plateau: less than 25 ml volume change in 0.5 seconds (see **Appendix E. OSHA Cotton Dust Standard, Appendix D.**). This is hard to visualize and requires that the technician become familiar with this degree of change. In addition, one study has shown that strictly following the 25 ml in 0.5 seconds criterion results in premature termination of the FVC maneuver and correspondingly lower FVCs (24).

ATS 1994 Definition of Plateau: The American Thoracic Society defines the end of the test as: A plateau in the volume-time curve, as defined by no change in volume for at least 1 second, or a reasonable expiratory time. In a *normal* young subject, the expiration would *usually* be completed in less than 6-second. In an obstructed or older healthy subject, a longer expiratory time is required to reach a plateau. However, **multiple** prolonged exhalations are seldom justified (1). (See **Appendix F. American Thoracic Society Standards**.)

5. **Check the acceptability of each tracing before continuing the testing.** (See below)

E. Check the Acceptability and Reproducibility of the Maneuver

Rationale. Spirogram results are used to detect possible conditions that affect the subject's ability to exhale as fully and forcefully as possible. The results are compared either to the subject's previous spirogram results if they are available or to established tables of results that would be expected for a person with his/her characteristics (e.g., sex, age, height, etc.). (Comparing results will be discussed in greater detail in **Unit Six: Comparing Observed to Predicted Normal Values** and in **Unit Seven: Comparing Changes in Follow-Up Spirograms**.) If inaccurate results are obtained, the information from the comparisons will not be correct, creating the potential for not detecting serious lung diseases, or, diagnosing *disease* where none exists. Therefore, the goal of each testing session is to obtain **acceptable** maneuvers and a **reproducible** test.

1. For the purposes of spirometric testing, **acceptable** is defined as free from error. **Reproducible** is defined as being without excessive variability. Criteria for determining whether tracings are acceptable and reproducible are discussed below.

2. **Criteria for an Acceptable Spirogram**: A Forced Expiratory Maneuver which is free from the errors listed below (examples of tracings with errors are given in Section H.). Some errors can be easily seen, others require calculation.

    a. **Hesitation or false starts**, indicating that the subject did not exhale as forcefully as possible at the start of the maneuver. One check for this is the ATS criterion that the extrapolated volume be no more than 5% of the Forced Vital Capacity (FVC) or 150 ml, whichever is greater. (**See Unit Five: Basic Spirometric Calculations** for a definition of FVC and instructions for calculating extrapolated volume.) Some automated spirometers calculate and display this at the end of each maneuver. If you use an automated spirometer, verify that these calculations and extrapolated volume checks are indeed performed.

b. **Cough.**

ATS 1994: Coughing during the first second of the maneuver or at other times that might affect the results. Coughing during the first second may affect the Forced Expiratory Volume in One Second (FEV_1). However, coughing and sputtering toward the end of the maneuver does not affect spirometric calculations (1). (**See Unit Five: Basic Spirometric Calculations** for a definition and instructions for calculating FEV_1.)

c. **Variable effort**, where the subject forced out the air at an inconsistent rate.

d. **Glottis closure**. Sometimes the (epi)glottis closes involuntarily, temporarily cutting off the flow of air completely. A similar pattern will be observed if a subject stops his active pushing and keeps his mouth on the mouthpiece.

e. **Early termination**, before an obvious plateau is reached (no change for at least 1 second after an exhalation time of at least 6 seconds (10 s is optimal)). (Plateau is defined in **Section D. Perform the Test**, in this unit.)

f. **Leaks**, which are caused when the subject does not have a tight seal, or if a volume spirometer is not airtight.

g. **Baseline error**. The recording pen must start the tracing of the subject's effort at zero for the volume line and must begin moving upward when the forced expiratory maneuver begins.

3. **Criteria for Reproducible Spirograms** (after three acceptable maneuvers). The two highest values for FVC and FEV_1 taken from acceptable forced expiratory maneuvers must show minimal variability. (See **Unit Five: Basic Spirometric Calculations** for definitions and instructions for calculating for FVC, FEV_1, and excessive variability.) While it is important to calculate and determine if the test satisfies the reproducibility criteria, it is equally import to visually inspect the volume-time curves (and flow-volume curves if available) to determine if the size and shapes of the curves are reproducible (See Figures 4-20 through 4-23).

4. **Number of maneuvers to perform: Ask subjects to perform at least 3 maneuvers that are acceptable, with the highest FVCs and FEV_1s within 200 milliliters of the second highest FVC and FEV_1s** (The reproducibility criterion has changed over time: ATS - 1994 within 200 ml; ATS-1987 - within 5%; Cotton Dust - within 10%) **from acceptable maneuvers**. The ATS recommends that 8 maneuvers be the upper limit performed during any one testing session (1). However, eight maneuvers may cause too much discomfort for many individuals, particularly those with lung diseases with severe airway obstruction. If, after five attempts, the number of tracings needed to meet acceptability criteria have not been meet, check that the subject is able to proceed. Consider rescheduling another session at a later date.

After each maneuver, check to determine whether it is acceptable according to the criteria above before taking additional tests. If errors are found, discuss with the subject ways to prevent them before proceeding. (See **Section F. Retest as Needed** later in this unit for suggestions for coaching the subject.)

After three acceptable maneuvers have been obtained, check for excessive variability before proceeding (see **Unit Five: Basic Spirometric Calculations** to calculate excessive variability.)

NOTE: Individuals with normal lung functioning generally are able to perform forced expiratory maneuvers with reproducible results. However, a recent study reported that individuals of short stature may have more difficulty satisfying the reproducibility criteria (25). In addition, individuals with lung impairment, especially those with obstructive diseases, often require longer exhalation times. This can lead to more variable results and poor reproducibility (26). The ATS Standardization of Spirometry--1994 Update points out that eliminating test results not meeting reproducibility criteria can lead to bias since subjects with lung impairment may be excluded from analyses (1). The importance of this concern is illustrated in the occupational setting where group data are sometimes used to detect possible exposures to pulmonary hazards. If subjects with excessive variability are not included, the data may indicate that the workplace exposure had no adverse effect, when in fact it had. Thus, workers might continue to be subjected to hazards.

The ATS 1994 Update recommends that reproducibility be a goal to strive for during testing. It suggests that the reproducibility criteria be used as a guide to determine whether more maneuvers are needed and not to exclude subjects:

"Labeling results as being derived from data that do not conform to reproducibility criteria...The acceptability criteria must be applied before the reproducibility criteria. Unacceptable maneuvers must be discarded before applying the reproducibility criteria...The only criterion for unacceptable subject performance is fewer than two acceptable curves. No spirogram should be rejected solely on the basis of its poor reproducibility. Reproducibility of results should be considered at the time of interpretation... Use of data from maneuvers with poor reproducibility is left to the discretion of the interpreter. In addition, use of data from unacceptable maneuvers due to failure to meet the end-of-test requirements is left to the discretion of the interpreter." (1)

F. Retest as Needed

1. **Coach the subject**. Review with the subject these common problems before proceeding with additional maneuvers:

    a. Quitting too soon or not completely emptying the lungs due to insufficient effort at the end of the maneuver (low FVC or no plateau).

    b. Not taking the deepest breath possible (low FVC and FEV_1).

    c. Not blowing as completely and forcefully as possible, particularly during the initial portion of the maneuver, (low peak flow, large extrapolated volume, and variable effort).

    d. Failure to maintain an airtight seal around the mouthpiece or on the nose (leaks).

    e. Pursing the lips as with a musical instrument.

    f. Obstructing the mouthpiece with the tongue or dentures. If dentures seem to be the problem, ask the subject to remove them for the remaining tests.

    g. Bending over or not extending the chin.

2. **Allow the subject to recover between maneuvers**. The subject may require several minutes before proceeding.

G. Record Keeping

Below are guidelines to consider for keeping subject records.

1. **Consistent systems**. Consistency in the record keeping system is important to ensure that all of the information needed is obtained.

2. **Data Sheets**: At a minimum, the following information should be obtained each time spirometry is performed:

    a. Test date and time.

    b. Subject's name, identification number, age, height, sex and race.

    c. Spirometer used (e.g., type, serial number, etc.).

    d. Ambient air and spirometer temperature.

    e. Sitting or standing position used.

    f. Source of reference values used (predicted normals).

g. Test results.

h. Technician's name or initials.

i. Barometric pressure. This information should be included if it is not too difficult to obtain. Barometric pressure changes are especially important when testing is conducted at different altitudes.

j. Any technician comment on subject cooperation/effort or other comments regarding the test session.

When spirometry is used for medical surveillance it is often helpful to have a data sheet that summarizes spirometric test results and comparisons in the subject's record. This provides a quick way to keep track of changes. Some spirometers are connected to a computer with a database of results which automates this process. (On the last page of this unit, the **Pulmonary Function Studies Flowsheet**, is a sample of a data sheet).

3. **Tracings**: The actual spirogram should also be incorporated into the permanent record. Federal regulations affecting spirometry require a permanent record and this ensures access to the tracing at a later date, even if computerized records are not available. Some recommend that the subject sign each tracing as it is produced. This eliminates any possibility of a mix-up, especially on mechanical tracings that don't print out the subject's name.

4. **Confidentiality**: Remember that spirometric test results and tracings are confidential, as are all medical records.

5. **Length of time to keep records**: Most federal regulations for certain workplace exposures require retention of medical records for 30 years following the date of an employee's termination. Check the requirements applicable for your company or industry.

6. **Back-up copies**: Make backup copies of all critical computerized information.

H. Sample Tracings

1. **Hesitation or false start** (this can include excessive extrapolated volume): (**Figures 4-3 and 4-4**). The volume time curves starts slowly instead of climbing sharply. The peak of the flow volume curve is displaced to the right, away from the ‘y’ or vertical axis.

FIGURE 4-3. VOLUME TIME CURVE
- EXTRAPOLATED VOLUME (VEXT)

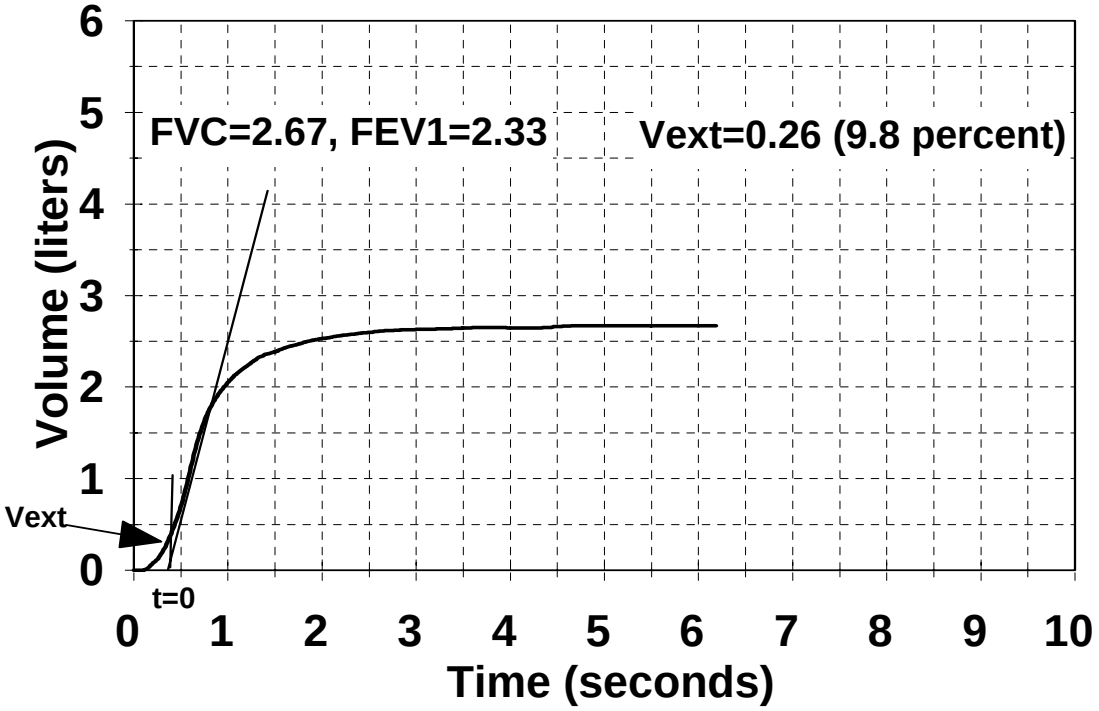
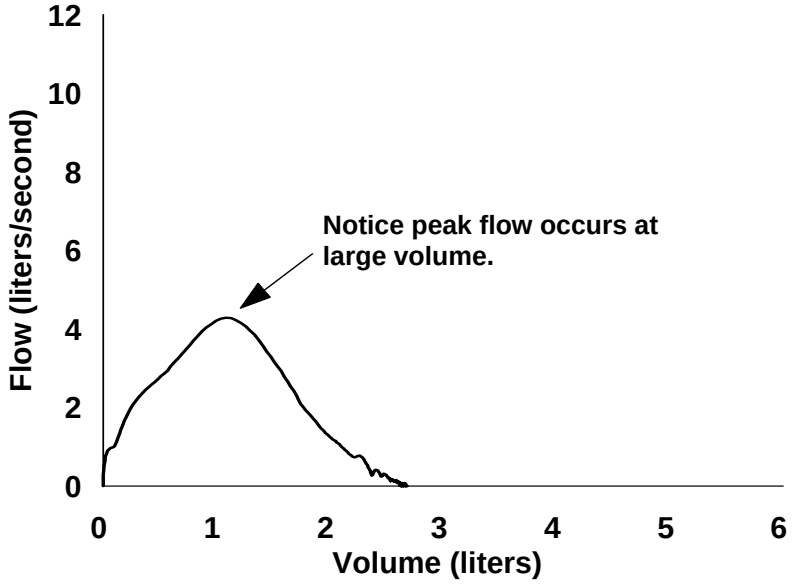


FIGURE 4-4. FLOW VOLUME CURVE - VEXT



2. **Cough:** (**Figures 4-5 and 4-6**). Both the volume time and the flow volume curves show dips instead of a smoothly-formed line.

FIGURE 4-5. VOLUME TIME CURVE - COUGH

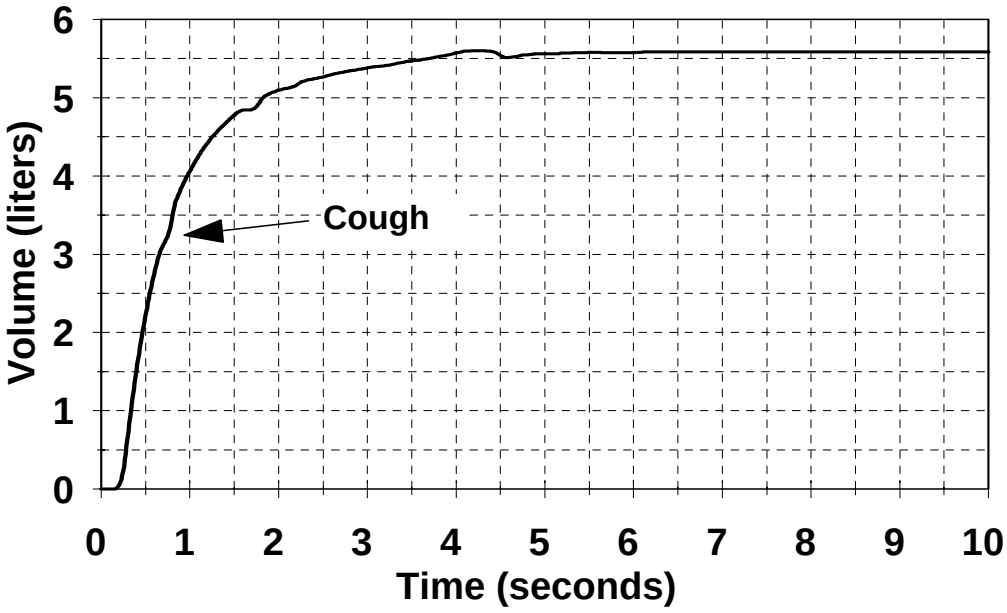
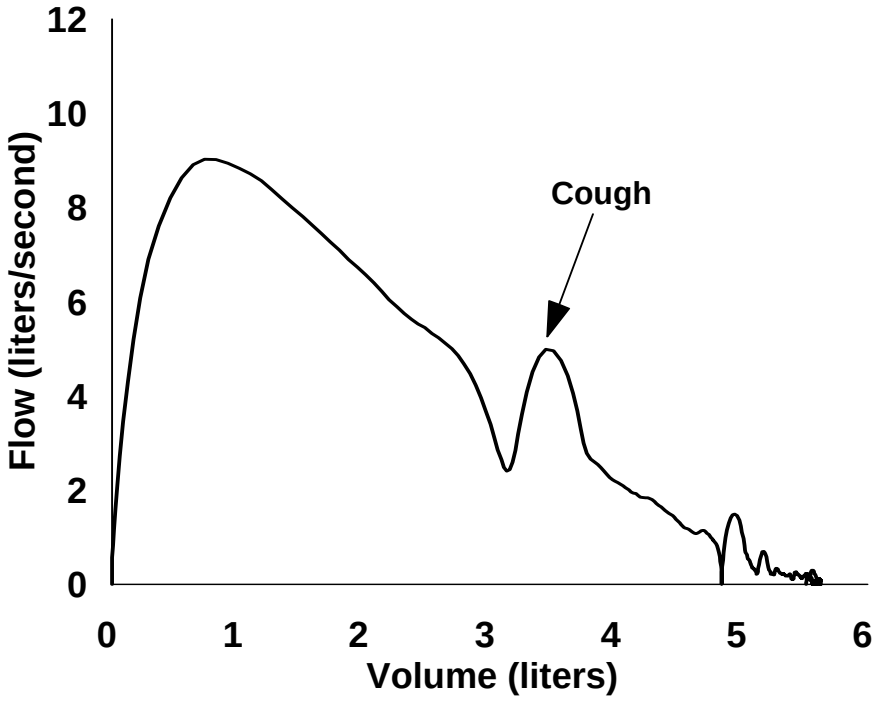


FIGURE 4-6. FLOW VOLUME CURVE - COUGH



3. **Variable effort**. (**Figures 4-7 and 4-8**). Both curves show dips in the line similar to those for a cough. It is usually difficult to distinguish between a cough and variable effort on a tracing. However, either cause during the first second will make the tracing unacceptable to use for calculations. Note that the variable effort tracings also terminate early in this sample.

FIGURE 4-7. VOLUME TIME CURVE - VARIABLE EFFORT

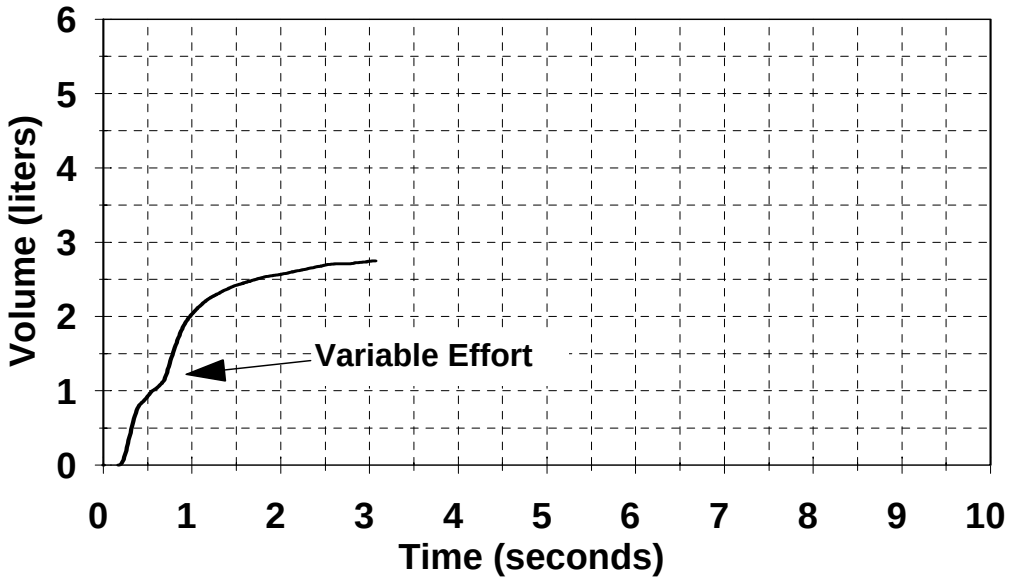
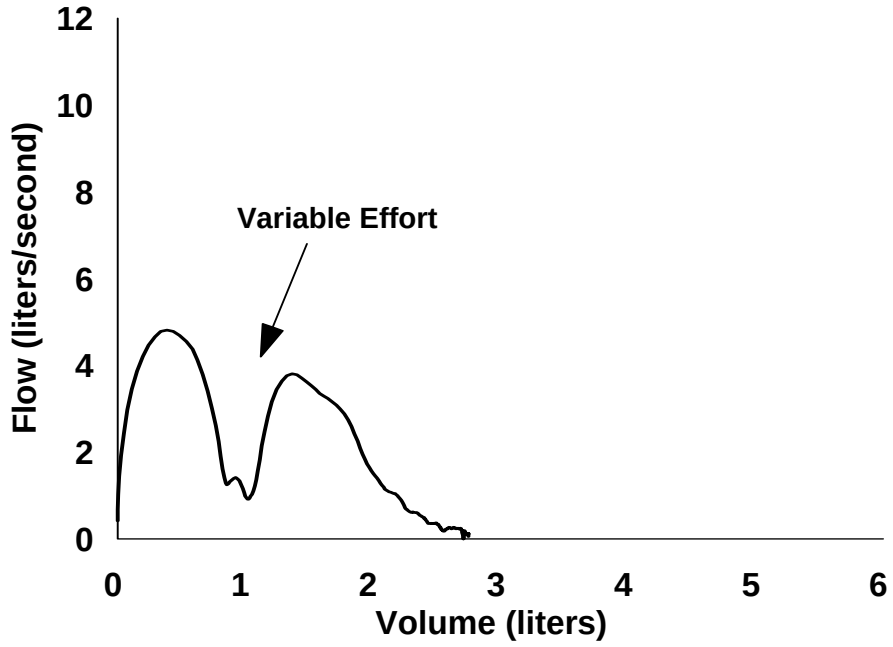


FIGURE 4-8. FLOW VOLUME CURVE



4. **Glottis closure**: (**Figures 4-9 and 4-10**). Both curves stop abruptly. On the volume time curve, an artificial plateau is reached, with a bend or knee in the curve where expiratory effort stopped. On the flow volume curve, the line drops sharply.

FIGURE 4-9. VOLUME TIME CURVE - GLOTTIS CLOSURE

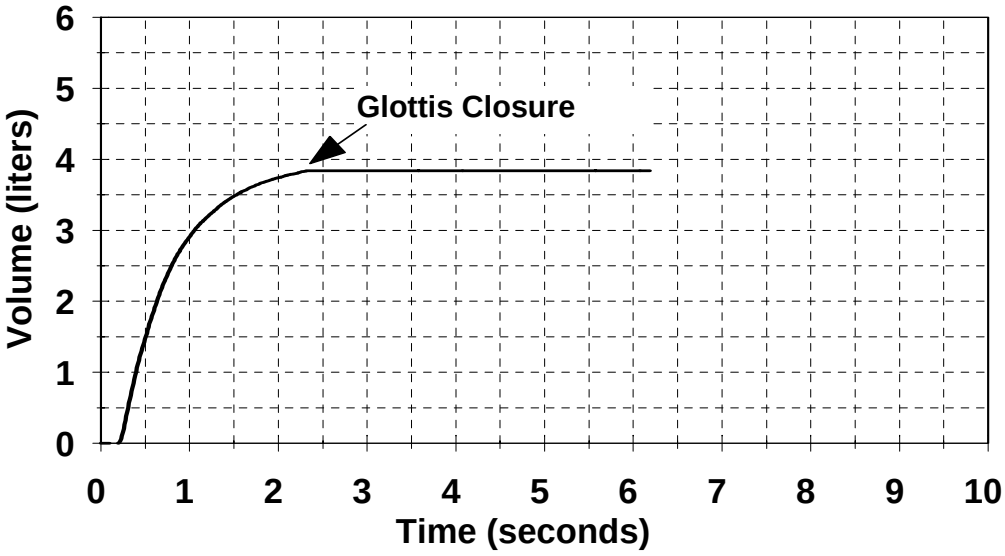
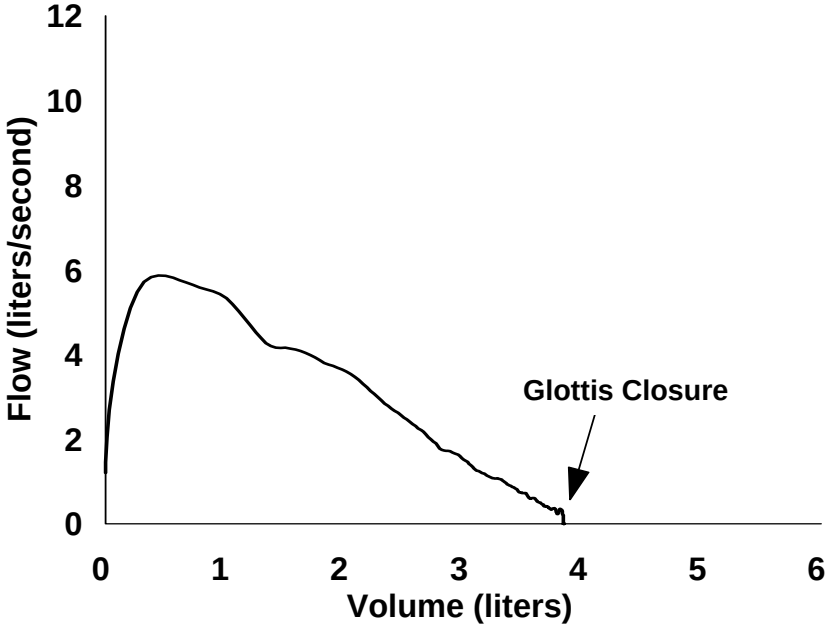


FIGURE 4-10. FLOW VOLUME CURVE



5. **Early termination**: (**Figures 4-11 and 4-12**). The volume time curve does not plateau and is less than six seconds in this example. The flow volume curve shows a low total volume and the line (flow) drops sharply at the end of expiration.

FIGURE 4-11. VOLUME TIME CURVE - EARLY TERMINATION

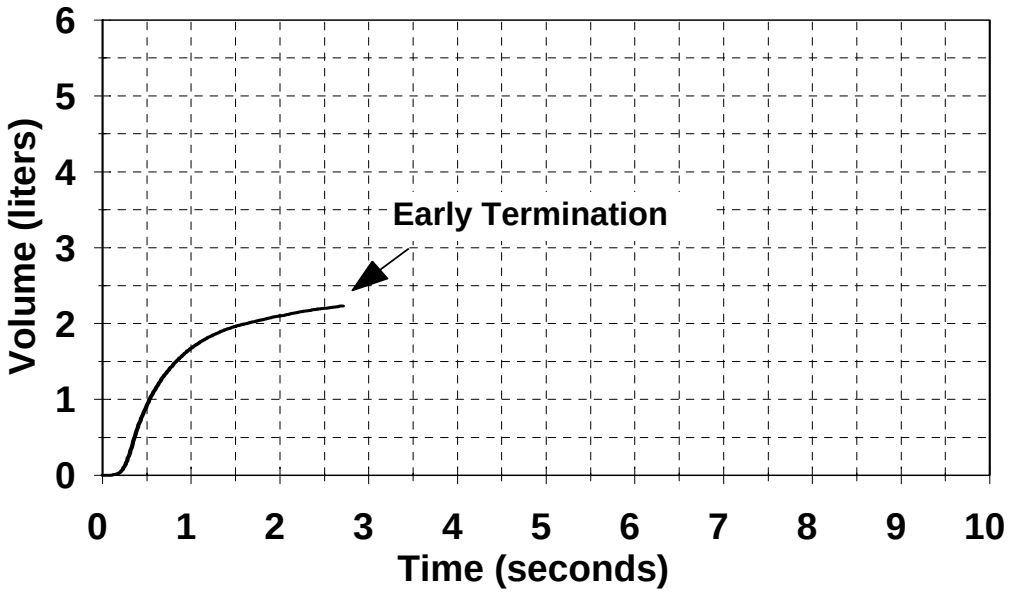
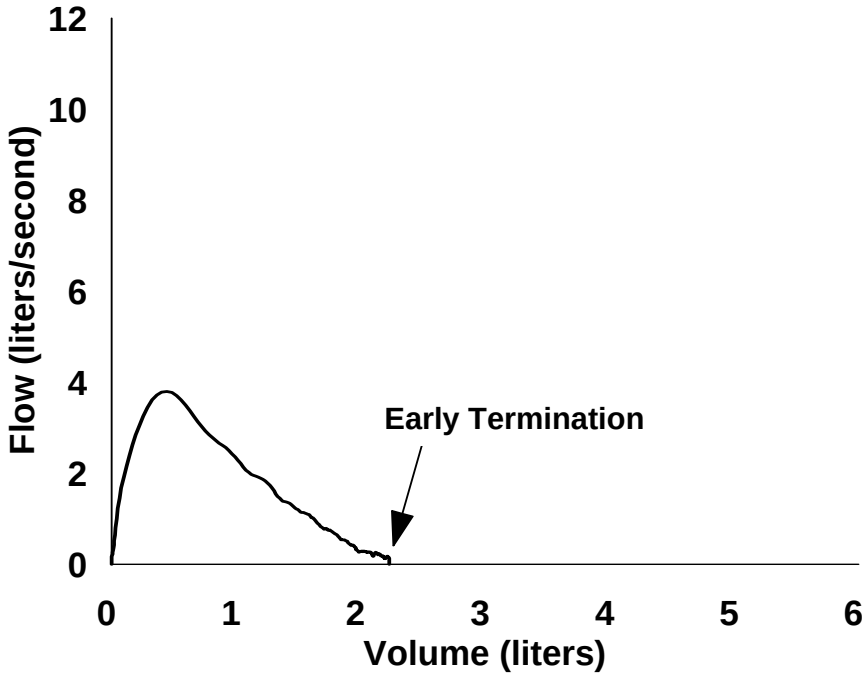


FIGURE 4-12. FLOW VOLUME CURVE



6. **Leaks**: (**Figures 4-13 and 4-14**). The volume-time curve drops instead of reaching a plateau. The flow volume curve "backtracks" at the end. This pattern can be caused by leaks in a volume spirometer or around the mouthpiece.

FIGURE 4-13. VOLUME TIME CURVE - LEAKS

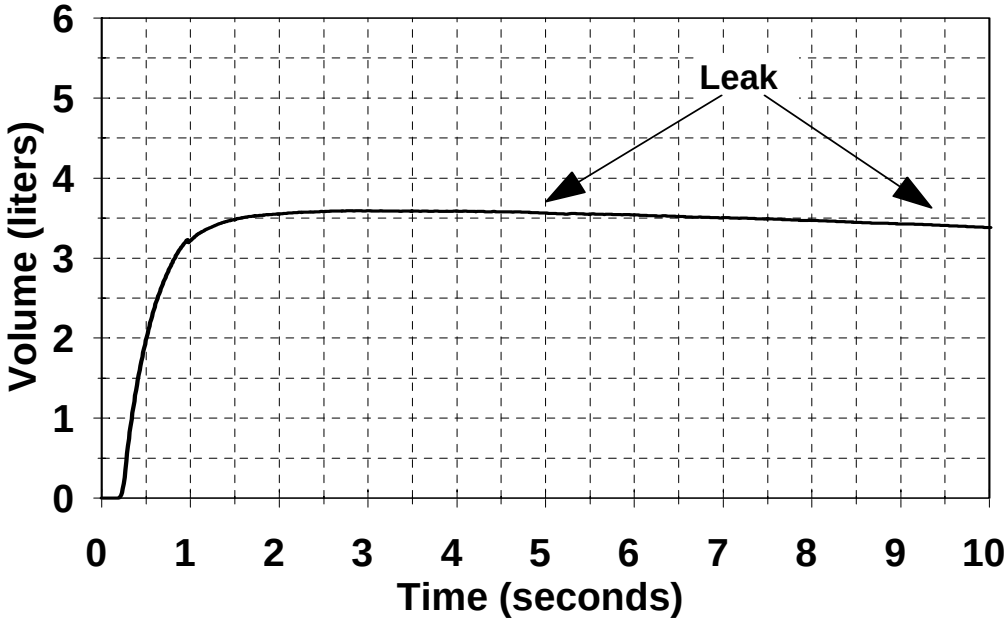
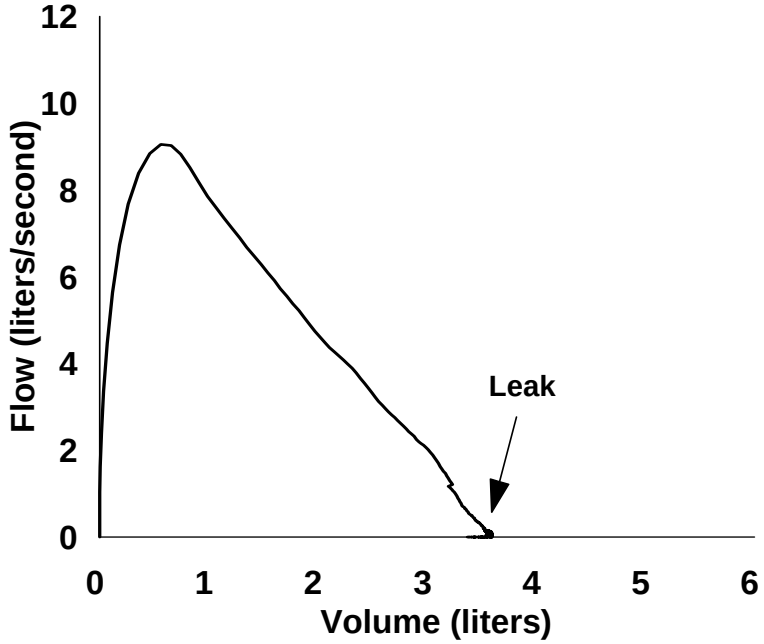


FIGURE 4-14. FLOW VOLUME CURVE



7. **Baseline error**: (**Figures 4-15 and 4-16**). Neither tracing starts at zero for volume. If other acceptability criteria are met, these tracings could be used by adjusting calculations to reflect where the baseline should have been.

FIGURE 4-15. VOLUME TIME CURVE - BASELINE ERROR

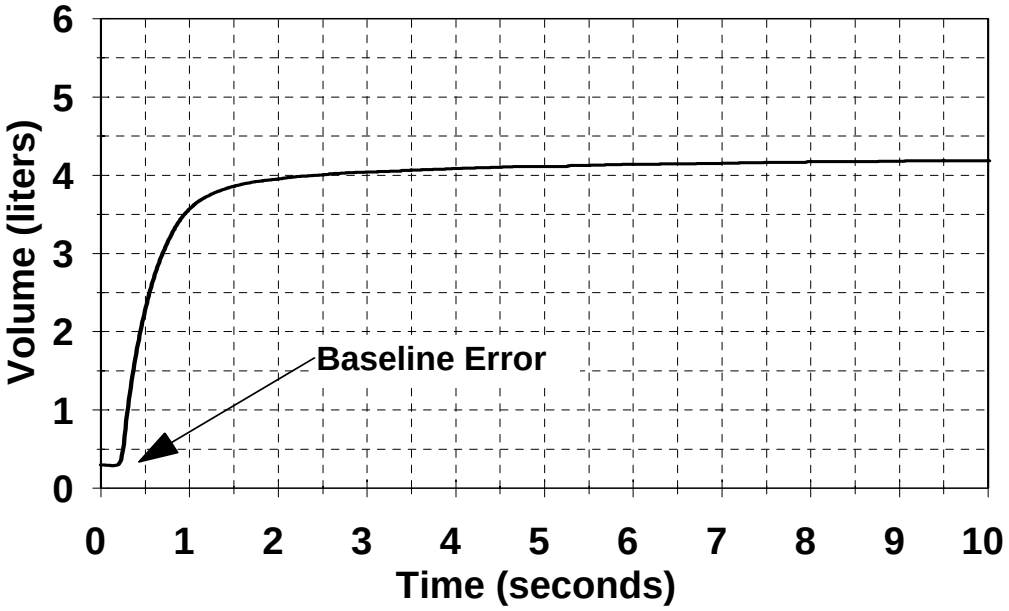
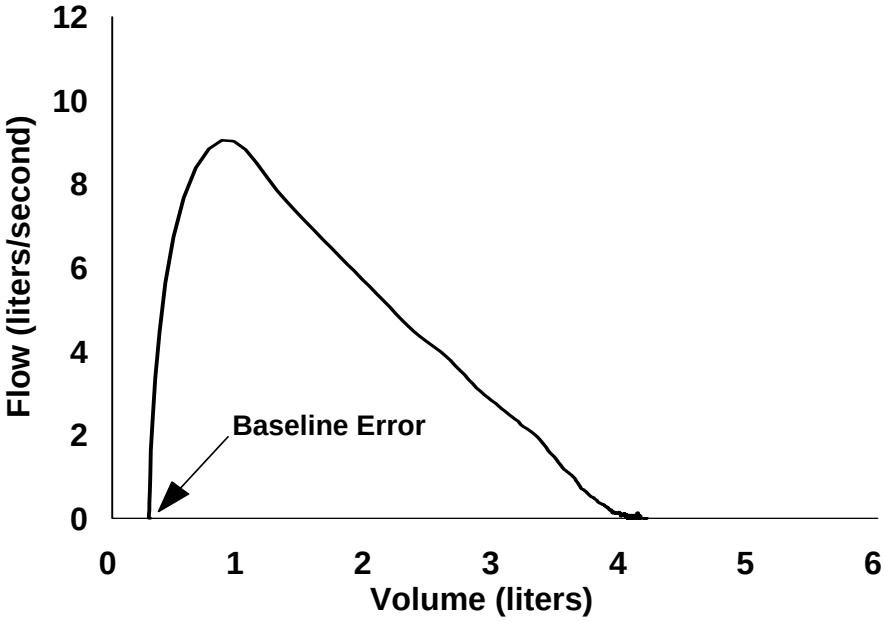


FIGURE 4-16. FLOW VOLUME CURVE



EXAMPLE: 8a. Visual inspection of curves for non-reproducible test. Figures 4-17 and 4-18 show a non-reproducible test **with** 3 acceptable curves. The actual calculation of excessive variability will be covered in Unit 5, but a visual inspection of the curves below reveal an obvious variability in the size (FVC) of the curves. Since variable volumes (FVCs) are most likely due to an incomplete inhalation, the subject should be coached to **take a deeper breath** in before performing the forced exhalation.

FIGURE 4-17. VOLUME-TIME CURVE - NON-REPRODUCIBLE TEST

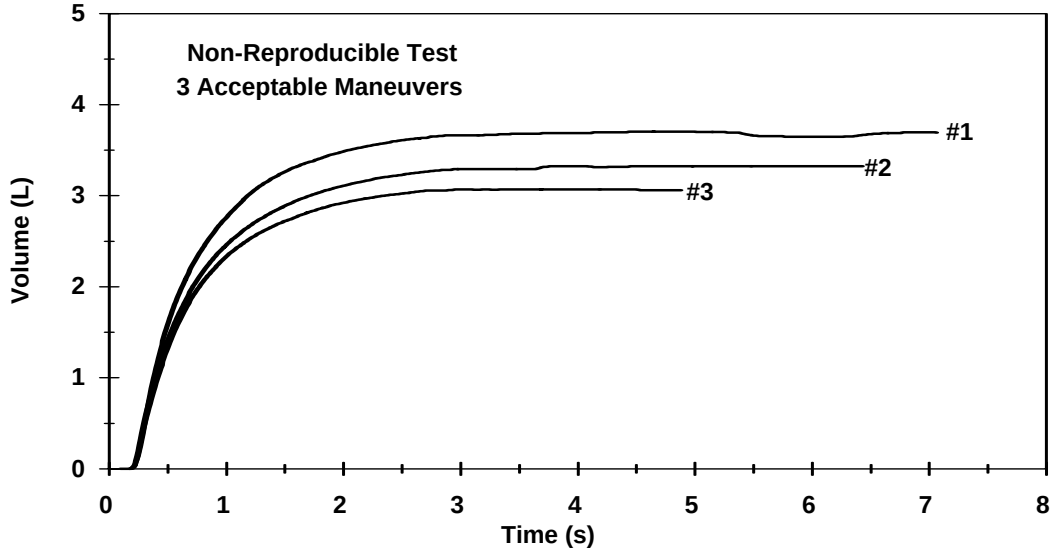
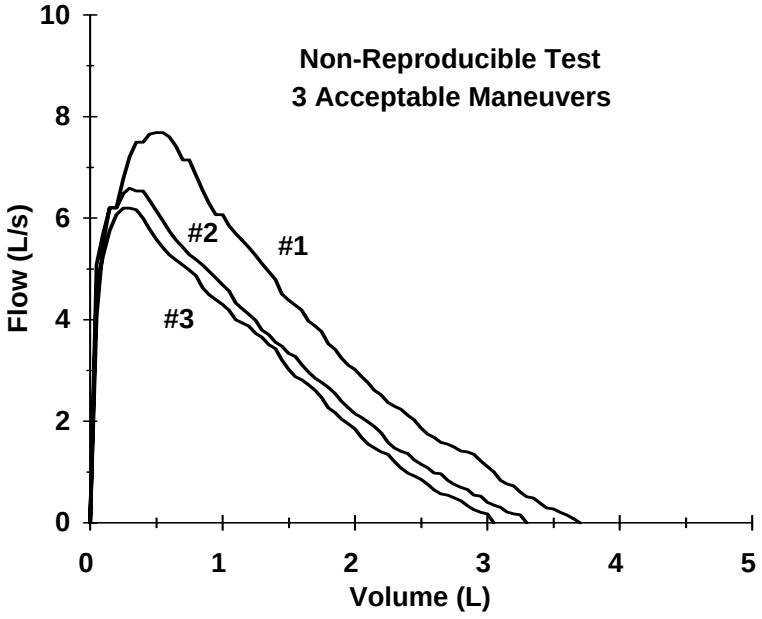


FIGURE 4-18. FLOW-VOLUME CURVE - NON-REPRODUCIBLE TEST



EXAMPLE: 8b. Visual inspection of curves for non-reproducible test. Figure 4-19 and 4-20 show a reproducible test with 3 acceptable curves. Visual inspection of the curves below reveals an obvious reproducibility in the size (FVC) of the curves. This indicates that the subject most likely completely inhaled, before performing a forced exhalation. If a flow-volume display is available, then the flows around peak flow should also be reproducible (highest flow values in Figure 4-20). If peak flows are not reproducible, then the subject should be coached to **Blast the Air Out**.

FIGURE 4-19. VOLUME-TIME CURVE - REPRODUCIBLE TEST

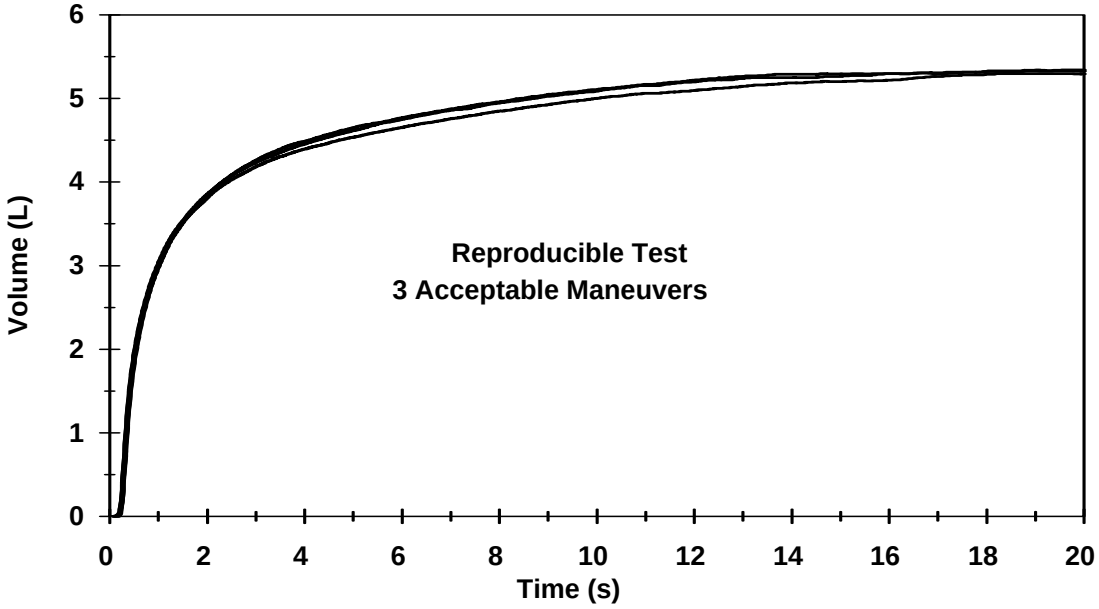
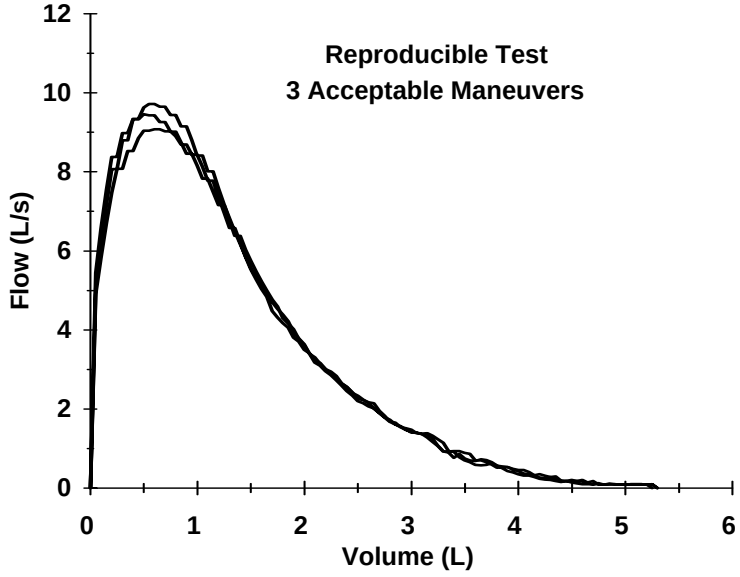


FIGURE 4-20. VOLUME-TIME CURVE - REPRODUCIBLE TEST



EXERCISES:

Exercises are given on the following pages so that students can practice selecting acceptable tracings. Determining hesitations or false starts, such as excessive extrapolated volume, will be covered in **Unit Five: Basic Spirometric Calculations**. Students can further practice acceptability skills by completing the first ten exercises in **Unit Nine:**

EXERCISE 1: (Refer to Figure 4-21.) Do the curves below meet acceptability criteria?

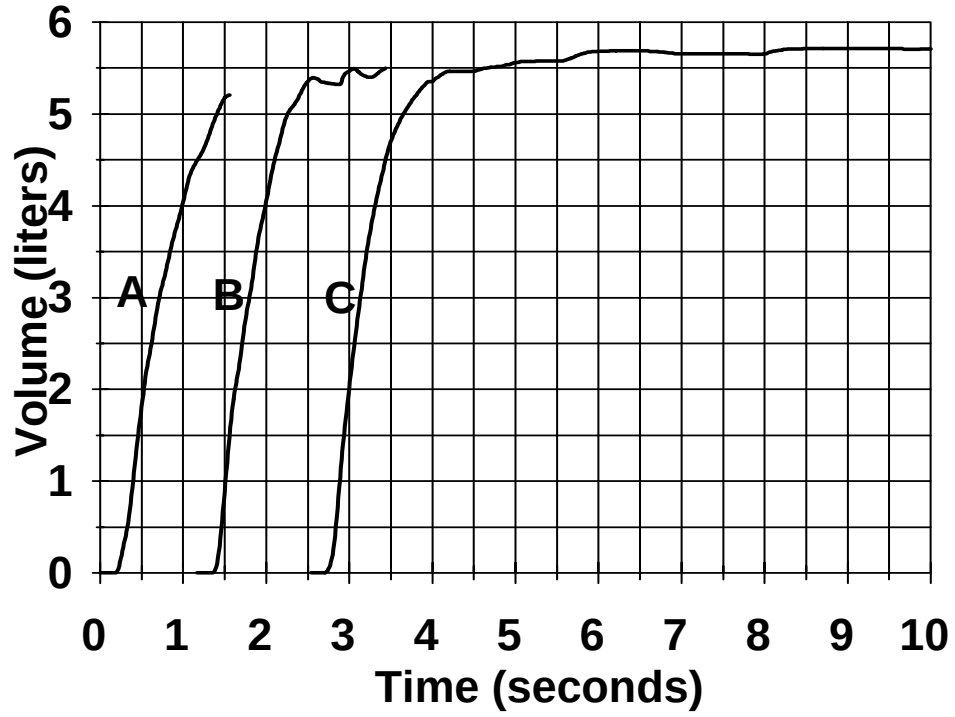


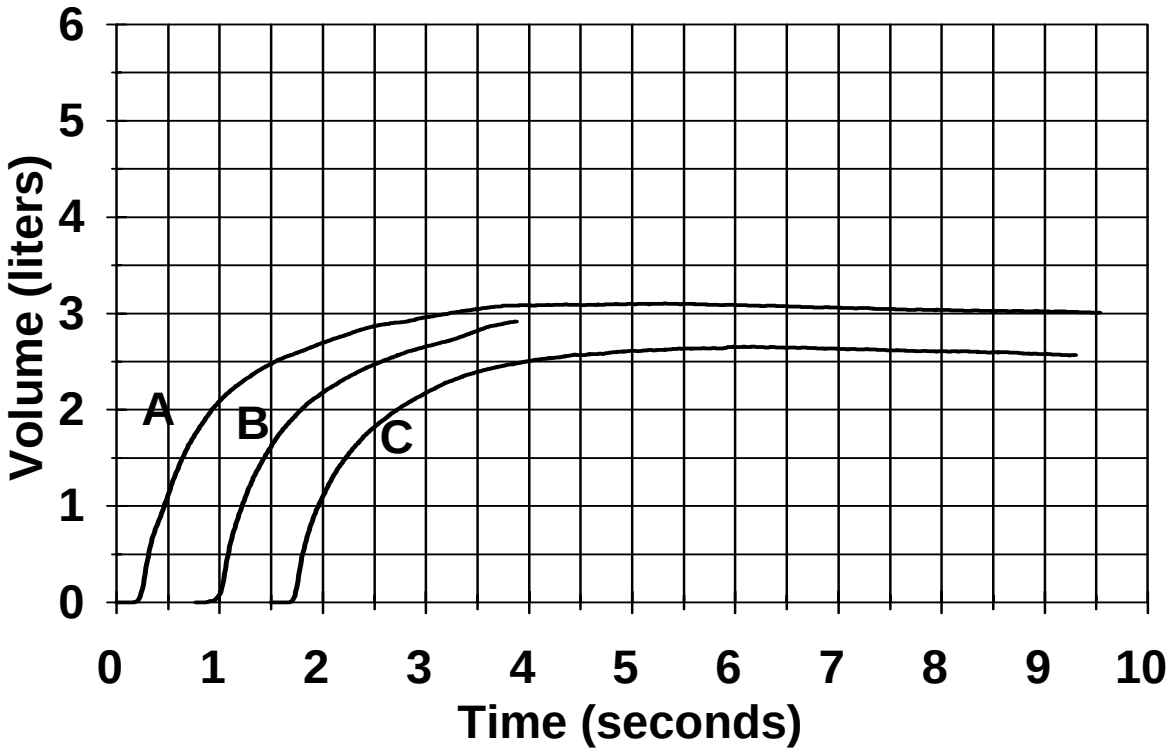
FIGURE 4-21. VOLUME TIME CURVE - EXERCISE

FEEDBACK:

No. Curves A and B show early termination. Curve B also shows a cough. Curve C shows a cough or variable effort.

EXERCISE 2:
(Refer to Figure 4-22.) Do the curves below meet acceptability criteria?

FIGURE 4-22. VOLUME TIME CURVE - EXERCISE

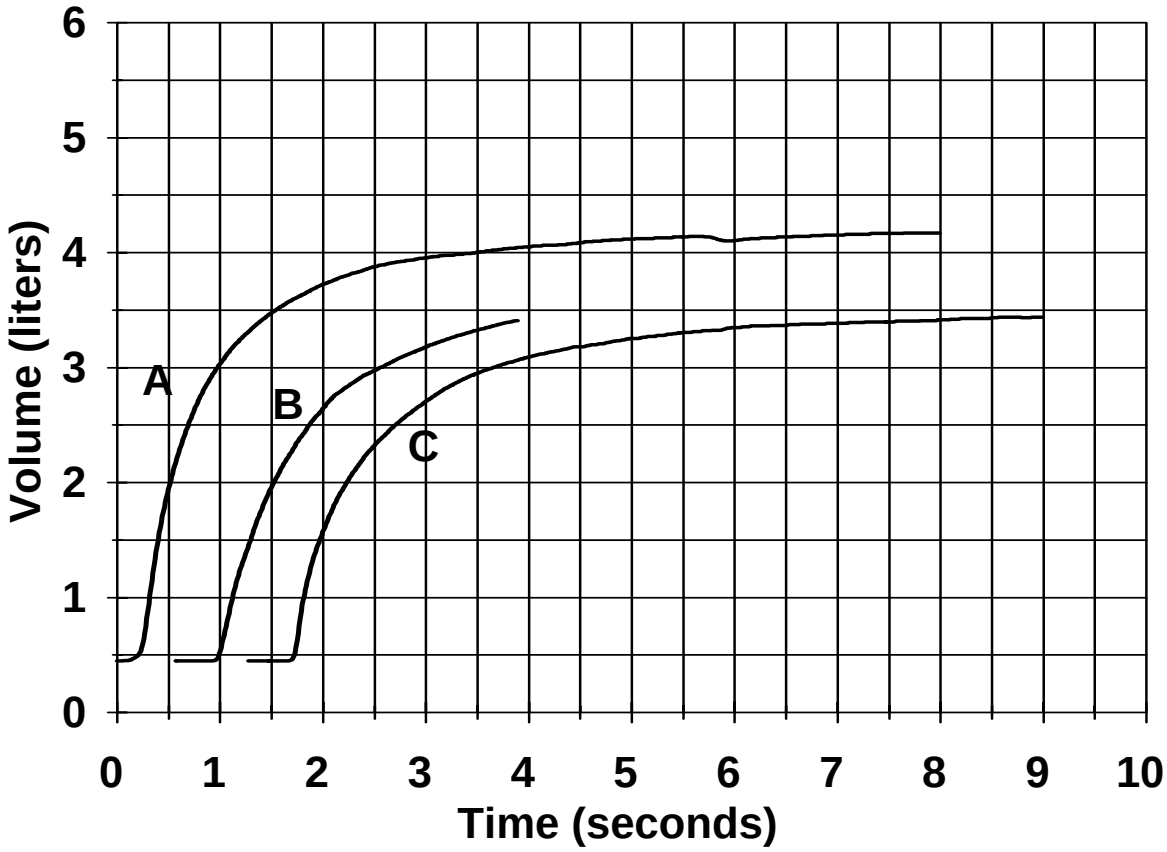


FEEDBACK:

No. Curves A and C show possible leakage. Curve B shows early termination. Check for a leak, particularly around the mouthpiece, and coach the subject to **Blow Out Longer**.

EXERCISE 3: (Refer to Figure 4-23.) Do the curves below meet acceptability criteria?

FIGURE 4-23. VOLUME TIME CURVE - EXERCISE



FEEDBACK:
No. All three tracings show a baseline error. Curve B doesn't plateau. Curve C is a judgment call on whether or not a plateau was reached.

SPIROMETRY FLOWSHEET (SAMPLE DRAFT)

Name:		SS#:
Sex:	Race[1]:	Birthdate:
Job Location:		Job Title:

Date:								
Tech. Initials:								
MD Initials:								
Spirometer type or serial #[2]								
Predicted used								
Reason for test[3]								
Temperature °C								
Position: Sit or Stand								
Age								
Height[4]								
Smokes[5] yes/no								
Job change[6] yes/no								
Subject effort (good, fair, poor)								
Observed Values (BTPS)	FVC							
	FEV_1							
	$\frac{FEV}{FVC}$ 1%							
Predicted Normal Value	FVC							
	% Pred.							
	FEV_1							
	% Pred.							
Change ± % or liters	FVC							
	FEV_1							

NOTES:
1. The predicted FEV_1 and FVC in non-Caucasians (blacks and asians) must be multiplied by 0.85.
2. Be sure serial # and other relevant information are recorded in the spirometer logbook.
3. E.g., routine, asbestos, cotton dust, etc.
4. In stocking feet.
5. If yes, record smoking history in subjects' chart.
6. Note job change information below: date, workstation, process, building, etc. Use additional paper if necessary.

a: _____ c: _____

b: _____ d: _____