

EXPIRATORY RESERVE VOLUME (ERV). The maximal amount of air forcefully exhaled after a normal inspiration and expiration.

EXPIRATORY TIME. The time required for the subject to reach his largest volume (FVC). For quality control purposes, total expiratory time is the time from the beginning of exhalation to the end of the subject's expiratory maneuver. As a rule of thumb, total expiratory time should be greater than 6-seconds.

EXTRAPOLATED VOLUME. The volume that was determined by a perpendicular line drawn from the point where time equals zero to where it intersects the FVC curve. The extrapolated volume must be less than 150 ml (for FVCs less than 3 L) or less than 5% (for FVCs greater than 3 L) for the tracing to be acceptable. A high extrapolated volume is due to a slow start or hesitation in the start of the maneuver.

FEF_{25-75%}. Mid forced expiratory flow measured from the point at which 25% of the FVC is achieved to the 75% point (during the middle half of the FVC). Also called mid-expiratory flow and abbreviated MMEF, MMFR, or MMF.

FEV₁/FVC (given as % or ratio). Forced expiratory volume in one second expressed as a percent of the forced vital capacity is the fraction of the total that is exhaled in the first second. It is the index of the speed of expiratory airflow. It is calculated by using the largest FEV₁ and the largest FVC, even if they are not from the same curve. A low FEV₁/FVC% is associated with airways obstruction.

FLOW/VOLUME LOOP. A tracing of flow rate (on the "y" or vertical axis) against volume (on the "x" or horizontal axis) for a forced expiratory maneuver followed by a maximal inhalation.

FLOW SPIROMETER. A type of spirometer that measures how fast the air moves in or out of the lungs. Flow spirometers are usually smaller than volume spirometers. Examples include pneumotachograph, hot wire anemometer, and rotating vane.

FORCED EXPIRATORY MANEUVER. The basic maneuver of spirometry where the subject takes the deepest possible breath and blows into the mouthpiece as hard, fast and completely as possible. Also known as the forced vital capacity maneuver.

FORCED EXPIRATORY VOLUME IN ONE SECOND (FEV₁). The volume of air exhaled during the first second of a forced expiratory maneuver. It may also be considered the average flow during the first second of the FVC maneuver.

FORCED VITAL CAPACITY (FVC). The maximal volume of air which can be exhaled forcefully after maximal inspiration. **NOTE:** The **vital capacity** is the amount of air that can be exhaled by an individual after taking the deepest breath possible, whether or not the air is exhaled forcefully (FVC) or slowly (VC).

INSPIRATORY RESERVE VOLUME (IRV). The maximal amount of air forcefully inhaled after a normal inhalation.

INSTRUMENT FACTOR. In certain water-seal spirometers, it refers to a constant indicating the volume of displacement per millimeter of vertical movement of the bell.

LLN. The lower limit of normal is the value below which only 5% of a “normal” reference population should have observed values. The specific value of the LLN is dependent on the study population and methods used to derive the reference values. LLNs should be available from the reference value source.

LONGITUDINAL STUDIES. Data collected from the same individual or group at regular intervals over an extended period of time. The values of a current test are compared to the individual's or group's previous test results.

OBSTRUCTIVE LUNG DISEASES. Diseases that reduce flow from the lungs. These diseases include asthma, chronic bronchitis, and emphysema.

PRECISE. Capable of giving consistent, reproducible results on successive times. A spirometer that is not properly calibrated may produce precise results that are not accurate.

PREDICTED NORMAL VALUES. Expected values for various lung volumes and flow rates, derived from healthy non-smoking populations. The values are adjusted for sex, age, height, and race.

REAL TIME TRACING. A spirogram that is made as the forced expiratory maneuver is performed.

REPRODUCIBILITY. The ability of a test to obtain the same result from an individual when it is repeated several times. Reproducibility is determined by checking for excess variability between the two largest values for FVC and FEV₁ obtained from three acceptable spirograms.

RESIDUAL VOLUME (RV). The amount of air remaining in the lungs after a complete exhalation. This cannot be measured by spirometry.

RESTRICTIVE LUNG DISEASES. Diseases that reduce the ability of the lungs to expand fully but do not necessarily affect air flow. Asbestosis and silicosis, two of the most common of the occupationally caused restrictive diseases, are caused by the development of fibrotic tissue in the lungs.

SPIROGRAM. A single tracing or graphic recording of breathing maneuvers. Given as volume/time or flow/volume tracings depending on the type of spirometer used.

SPIROMETER. An instrument for measuring lung volumes and flow rates. The two primary types are volume sensing and flow sensing spirometers.

SYNERGISM. The combined effect of two or more substances is greater than the effects of each substance added together.

TIDAL VOLUME (TV). The volume of air inhaled and exhaled during quiet, normal breathing.

TOTAL LUNG CAPACITY (TLC). The sum of the vital capacity and the residual volume.

VITAL CAPACITY (VC). The maximum amount of air that can be exhaled after the fullest inhalation possible. The sum of tidal volume, expiratory reserve volume, and inspiratory reserve volume. May be measured either during inhalation or exhalation.

VOLUME SPIROMETER. A type of spirometer that records the amount of air inhaled or exhaled within a certain time. Examples include water-seal, dry rolling-seal, and bellows instruments.

ZERO TIME POINT. In the measurement of the FEV₁, the point selected as the start of the test, obtained using back extrapolation.

APPENDIX B. AN OVERVIEW OF OCCUPATIONAL LUNG HAZARDS

Types of Lung Hazards

Occupational pulmonary contaminants come in many forms. Some can be seen, smelled, or felt as irritants in the nose or throat. But others can only be detected with special equipment. Short-term exposure to many toxicants can cause immediate, acute damage. However, most contaminants take repeated or constant exposure over months or years to cause disease or permanent harm. The impact of pulmonary hazards is also influenced by air pollution in general, age, smoking history, nutritional status, and other less well understood factors such as genetics and stress.

Many work processes generate several contaminants at the same time. The health consequences of these hazards can simply be additive or, worse, they can be synergistic. Thus it is essential to know what materials and processes are used on the job to be able to evaluate, monitor, and control potential pulmonary hazards. (It is beyond the scope of this guide to cover hazard control measures. However it should be noted that most occupational exposures to airborne hazards can be greatly reduced or eliminated through engineering controls, such as improving ventilation; good work practices; and the use of personal protective equipment, such as properly selected and maintained respirators. Refer to Fundamentals of Industrial Hygiene for an overview of control measures (43).

Two approaches are commonly used to categorize occupational lung hazards. The first approach uses a medical framework to classify hazards by their impact on the respiratory tract. Thus, hazards causing similar health effects are grouped together, whether or not the hazards themselves share similar properties. In the second approach, an industrial hygiene framework is used to group hazards by their common properties and the methods by which they are generated. Both approaches are given below.

Hazards Classified by Their Impact on the Respiratory Tract

ASPHYXIANTS: Gases that deprive the body tissues of oxygen.

Simple

Asphyxiants: Physiologically inert gases that displace oxygen in the blood and at high enough concentrations cause suffocation.

Examples: Nitrogen, methane, argon, neon, helium.

Chemical

Asphyxiants: Gases that interfere with the body's ability to utilize oxygen (e.g., by binding to hemoglobin or preventing chemical reactions needed to utilize oxygen in the cells).

Examples: Carbon monoxide, cyanide compounds, arsenic.

IRRITANTS: Substances that irritate air passages leading to airway constriction. Asthmatic symptoms, difficulty breathing, pulmonary edema and infection may result.

Examples: Chlorine, hydrogen chloride, hydrogen fluoride, ammonia, fluorine, sulfur dioxide, phosgene, oxides of nitrogen, ozone.

FIBROSIS

PRODUCERS: Substances that cause fibrotic tissues changes associated with restrictive diseases.

Examples: Asbestos, beryllium, silica, coal dust, other inorganic and organic dusts.

ALLERGENS: Substances that induce an allergic response characterized by bronchoconstriction. This can occur even if previous exposures produced no ill effects.

Examples: Isocyanates, fungal spores, formaldehyde, animal dander.

CARCINOGENS: Substances that can cause or lead to cancer.

Examples: Asbestos, cigarette smoke, chromium, uranium, arsenic, coke oven emissions.

Hazards Classified by Their Properties

Although some contaminants may not adversely affect the lungs, the lungs provide the means through which they enter the bloodstream and harm other organs or impair the blood's oxygen-carrying capacity. These types of health effects are not detectable through spirometry. However, the hazards that cause them are included to show the range of ways in which respirable contaminants damage the body.

The information below was adapted from Occupational Lung Diseases: An Introduction (44).

DUSTS

Mineral Dusts: Dusts and mineral fibers formed from stones, rocks, and ores. Examples include asbestos, crystalline silica, and coal dust.

Sources: Mining, quarrying, tunneling, blasting, smelting, grinding, milling, processing, etc.

Health Effects: Most are inert and not readily dissolved or broken down. They accumulate in the lungs after overloading lung-clearing mechanisms. Can lead to pneumoconioses, chronic bronchitis, emphysema, cardiac complications and can initiate other disease processes, such as fibrosis or cancer. They are associated with the class of fibrotic occupational lung diseases called pneumoconioses.

Organic Dusts: Dusts formed from living materials (e.g., microorganisms, plants, and animals) and natural products such as wood and leather.

Sources: Plant products (e.g., cotton, wood, cereal grains, spices, coffee beans, etc.): planting, harvesting, storing, transporting, processing (grinding, cutting, spinning, etc.). Animal husbandry: droppings, dander, feathers, etc.

Health Effects: Don't usually accumulate, but dissolve or break down. Can cause hypersensitivity reactions, such as occupational asthma, byssinosis (from cotton), or hypersensitivity pneumonitis. Can lead to permanent obstructive disease or diffuse lung fibrosis. Certain wood dusts have also been associated with cancer.

Chemical Dusts: Synthetic chemicals that come in powder form (e.g., pesticides, pharmaceuticals, dyes, bleaching agents, detergents, paints, etc.)

Sources: While making, drying, and packaging mixtures; preparing for use, applying, drying, as a result of weathering (such as paints on exterior walls), etc.

Health Effects: Dependent on the toxic properties of the specific chemicals. A number are irritants or allergens; others have a caustic effect and can cause chemical burns. Some are toxic to cells or tissue. Some enter the body through the lungs and cause cancer in the lungs or other parts of the body.

FUMES: Very small solid particles formed when hot vapors (usually from metals or polymers) cool rapidly and condense. Hazardous gases may be given off at the same time. In the lungs, fumes act like a very fine mineral dust.

Sources: High heat processes (e.g., welding, furnace work, smelting).

Health Effects: Difficult to assess effects of individual materials since usually several hazards are present at the same time. Can lead to Metal or Polymer Fume Fever, emphysema, and lung cancer.

NOTE: Smoke is not usually classified as a separate category because it is a mixture of gases and solid particles.

MISTS & SPRAYS: Liquid droplets suspended in air or other propellant gas.

Sources: Used widely in industry, especially for applying substances to hard-to-reach surfaces; or substances that might damage the skin if applied by hand (e.g., cleaning products, pesticides, paints, cosmetic products, rust removers, etc.) Also, as by-products from other processes, such as from cutting oils in machine shops.

Health Effects: The finer the spray, the deeper the penetration in the lungs. Effects depend on the material being sprayed, the concentration and the temperature. Can range from chemical burns to the lungs to various forms of cancer.

GASES: Fluids that expand to fill the space that contains them. Can travel quickly from the point of origin. Many are highly flammable, explosive when mixed with air, or chemically or physiologically reactive. Some are both colorless and odorless.

Sources: Natural chemical reactions (e.g., methane from coal fields, nitrogen oxides from fermenting silage, and methane and hydrogen sulfide from sewage treatment or landfills). Manmade chemical reactions (e.g., from industrial processes, ozone from smog, and interactions between cleaning products such as ammonia and chlorine bleach). In industrial settings, gases may be emitted during their manufacture, handling, or transporting, if protective measures aren't taken. Also produced during high-heat processes (e.g., furnace work, welding, brazing, smelting, oven-drying, accidental burning of some synthetic materials).

Health Effects: Physiologically inert gases (e.g., methane and nitrogen) can cause suffocation by displacing oxygen (simple asphyxiants). Others interfere with the use of oxygen (e.g., carbon monoxide and cyanide) (physiologic asphyxiants).

Gases that are immediately irritating (e.g., ammonia, bromine, sulfur dioxide, chlorine): Sudden intense exposure to these gases can cause severe irritation that burns the lungs or closes the trachea. Low level exposures may constrict airways and aggravate existing lung disease.

Gases that are not immediately irritating (e.g., phosgene and nitrogen oxides): These gases penetrate deeply into the lungs causing pulmonary edema and other serious complications without producing upper respiratory symptoms.

Carcinogenic gases (e.g., radioactive gases, nickel carbonyl, vinyl chloride gas): Cancers from these gases typically take years to develop and the exact cause may be hard to trace. The site of the cancer may be other than the lung.

VAPORS: The technical term for the gaseous form of a liquid that always is found over that liquid. More vaporizing occurs as the liquid approaches the boiling point. Vapors affect the lungs in similar ways to gases. The main difference between vapors and gases is that vapors are always found over their parent liquids while gases aren't always associated with their liquid forms.

Sources: Inorganic substances: Most have high boiling points and don't vaporize at room temperature. These usually are not associated with lung disease.
Organic vapors: Many vaporize at room temperature. Usually used as solvents (ketones, aromatic hydrocarbons, alcohols, acetates).

Health Effects: Many organic vapors enter the body through the lungs. Although the lungs are not harmed, extensive harm may be done to other organs. Damage to the brain and central nervous system, pulmonary edema, and tracheobronchitis (mercury and related compounds). Hypersensitivity reactions (polyvinyl chloride), cancer (benzidine and related compounds).

RADIATION: Non-ionizing radiation includes electromagnetic waves (e.g., infrared, ultraviolet, microwave, laser, radar, radio frequency). Ionizing radiation includes alpha, beta, and gamma rays; neutron particles, and X-rays.

Sources: Mining radioactive ores. Also used in medicine, weapons, power plants, industry (e.g., high energy electrical equipment, lasers, microwaves, and radar).

Health Effects: Electromagnetic waves do not appear to harm the lungs unless the energy is sufficient to cause thermal burns. However, it can cause eye damage. Ionizing radiation damages human tissue and can lead to various kinds of cancer, including lung cancer.

BIOLOGICAL
HAZARDS:

Bacteria, viruses, fungi, and rickettsial, chlamydial, and parasitic agents.

Sources: Health care facilities, child care facilities, poorly maintained ventilation systems, biological research laboratories, animal care and processing facilities.

Health Effects: Depends on the type of hazard. Can range in severity from minor allergies and respiratory infections to lethal nervous system disease and cancers. Vaccinations are available for some.

APPENDIX C. OVERVIEW OF OCCUPATIONAL LUNG DISEASE

A. Some of the Pulmonary Diseases that Show Obstructive Patterns

Occupational Asthma

Occupational asthma is caused by repeated exposure to certain airborne contaminants, which results in sensitization, leading to a chronic allergic response. On subsequent exposures, the smooth muscles of the bronchial tubes go into a spasm and some of the smaller airways close down. Excessive mucous is also produced, which further aggravates the problem by clogging small airways. Coughing, difficulty breathing, and wheezing are common symptoms. A wide variety of sensitizing agents can induce attacks. These may occur in people who are essentially normal and who become sensitized, or in individuals with a prior history of allergies or childhood asthma. (Certain agents, such as the diisocyanates, are such potent sensitizers and irritants that they cause respiratory reactions in most individuals.) Workers can sometimes relate their asthmatic symptoms to a specific exposure, or at least to a specific part of the workplace. In many cases, however, the symptoms begin after the work shift and subside by the following morning.

Reactive Airways Dysfunction Syndrome (RADS)

Reactive Airways Dysfunction Syndrome mimics asthma, but is due to an irritant rather than an allergic stimulus. Individuals with RADS will experience airflow obstruction at exposure levels much lower than would produce a response in non-affected individuals.

One special case of RADS involves a heightened response to cold air. It is known that asthmatics can have their attacks initiated by cold air. Other individuals with no known history of asthma may develop bronchoconstriction and tightness and shortness of breath when exposed to cold air, either on the job or during exercise. Removal from the exposure usually causes symptoms to subside within 1-2 hours.

Emphysema

Chronic exposure to irritant substances, most notably cigarette smoking, can cause emphysema. These exposures lead to the destruction of the elasticity of the smaller bronchi. When pressure in the chest begins to increase upon exhalation, these bronchi may collapse, trapping air inside. As a result, the air sacs remain partially expanded. Shortness of breath is a permanent problem and trying to breathe faster or more deeply only causes more air to become trapped inside. The lungs frequently become distended, causing a barrel-chested appearance. The disease is progressive and damage to the heart is a frequent side effect.

Chronic Bronchitis

Chronic bronchitis is caused by repeated infections and/or exposure to irritants such as fumes and dusts (including wood dusts and mineral fibers), oil aerosols, gases such as ozone and nitrogen dioxide, and smoke from cigarettes or exposure to fire (such as fire-fighting). Inflammation, swelling, and increased mucous production occur, fostering chronic bacterial infections in the mucous-plugged small airways. Symptoms include shortness of breath and a persistent and productive cough.

B. Some of the Pulmonary Diseases that Show Restrictive Patterns

Pneumoconioses

The three major types of pneumoconioses in the United States are asbestosis, silicosis, and coal worker's pneumoconiosis (Black Lung Disease). The pneumoconioses are some of the best-known of the occupational lung diseases, yet for a long time the courts doubted their existence and refused to consider them as compensable illnesses. Most causes of pneumoconioses are inorganic dusts or fibers, with particles less than 5 microns in size. Particles of this size are called "respirable particulates." Since these particulates are invisible, it is possible to be exposed without knowing it. However, many of the heaviest exposures were accompanied by larger particulates so that the industries were recognizably "dusty".

The pathology in the lung is fibrosis, a profusion of fibrous tissue between the alveoli which interferes with the normal expansion of the lungs. The fibrosis can take two forms: nodular and localized around the bronchi (peribronchial), (typical of silicosis), or interstitial (between the alveoli) and diffuse (typical of asbestosis). With continued exposure, the fibrosis increases, leading to shortness of breath and a persistent cough, and, in late stages, heart failure. Pneumoconioses are almost exclusively occupational diseases and therefore are compensable.

Hypersensitivity Pneumonitis

Hypersensitivity Pneumonitis is also referred to as Extrinsic Allergic Alveolitis. The disease occurs mainly in the alveoli and terminal bronchi in response to organic dusts associated with specific occupations. In some cases the offending agents are fungi, such as in Farmer's lung and Bagassosis. In other cases they are animal proteins (such as bird breeder's lung, and furrier's lung) or vegetable proteins (such as coffee worker's lung). The workers develop an acute illness with cough and shortness of breath, usually without wheezing, but often accompanied by chills and fever. The first occurrence may be mistaken for a "flu syndrome". Once workers are sensitized, they may respond to very small doses of the allergen. Fluid accumulates in the alveoli interfering with the oxygen diffusing capacity. Termination of exposure allows the acute phase to resolve over a period of 1-2 weeks. However, recurrent exposures may produce a chronic disease with interstitial fibrosis and severe shortness of breath.

Granulomatous Disease

Granulomas are inflammatory responses that occur as a reaction to infections (e.g., tuberculosis) or toxins. Large inflammatory cells move in and begin to collect around the point of exposure. Later fibrous tissue migrates in and surrounds the site, producing a globular mass that can be seen under the microscope. Berylliosis is the best known occupational example of this class of lung diseases.

Other Health Conditions

Several preexisting conditions can cause restrictive patterns. These include pregnancy, obesity, anatomical abnormalities, and thoracic or abdominal surgery. Although these conditions are not occupationally induced, they are mentioned here because their impact must be considered when reviewing spirometric results.

C. Some of the Pulmonary Diseases that Show either Obstructive or Restrictive Patterns

Pneumonias

Pneumonias may have a restrictive effect due to accumulation of fluid and inflammatory cells in the alveoli (much like alveolitis) or an obstructive effect due to accumulation of cells around the bronchi (bronchial pneumonia). Pneumonias can arise as part of a toxic process, or more commonly through infections. Occupational lung disease of infectious origin occurs primarily in health care workers, child care workers, and animal care workers. The offending agents may be fungi, bacteria, viruses, or other microorganisms. In many cases these diseases are accompanied by chills and fever.

Pneumoconioses

Although pneumoconioses are primarily restrictive diseases, in advanced cases the fibrous tissue may impinge on the bronchial tree causing obstructive symptoms as well.

Occupational Lung Cancer

Lung cancer is characterized by an enlarging mass of cells that grow uncontrollably. Smoking is the single most important cause and has a synergistic effect with some occupational carcinogens. Epidemiological studies have shown higher than normal rates of lung cancer for individuals exposed repeatedly to bis-chloromethyl ether, coal tar, pitch volatiles, mustard gas, arsenic, asbestos, radium, petroleum, chromates, and uranium. Lung cancer is especially insidious because symptoms frequently do not appear until it is too late to intervene medically. Depending on where the tumor(s) grows, in late stages it may cause obstructive or restrictive pattern

APPENDIX D. RESPIRATORY SURVEILLANCE PROGRAMS

Employment settings where workers use or are potentially exposed to pulmonary hazards should have a respiratory surveillance program. Although lung diseases are not the most common occupational diseases, they are the most significant due to their severity. The human and economic toll from occupational asthma, the pneumoconioses (asbestosis, black lung disease, silicosis, etc.), and occupational lung cancer is very large. These diseases are significant causes of morbidity, disability, early retirement, and death. Moreover, they are entirely preventable once their causes are recognized. Therefore, recognition of the hazards associated with occupational lung disease and prevention of exposure must be a high priority.

Ideally a respiratory surveillance program has four primary objectives:

1. To reduce the human suffering and economic impact of occupational disease. Prevention, early detection, and treatment are less expensive both to a company and to society than reduced productivity, worker's compensation payments, litigation, higher insurance premiums, and medical bills.
2. To detect occupational and non-occupational lung diseases in their earliest stages when reduction of exposure is likely to be most effective. For example, early detection and removal of the offending allergens reduces the chances of permanent damage for individuals with occupational asthma.
3. To identify working conditions that are hazardous so that improvements in industrial hygiene can be made. Ideally this should not be necessary. However, occupational health is not an exact science. As more is learned about the relationship between exposure and disease, it may be found that current standards are not adequate. In addition, some individuals develop occupational lung disease at exposure levels below those considered safe.
4. To establish baseline function for new employees and to identify job applicants with preexisting pulmonary damage so that they can be placed in positions that do not jeopardize their health. For example, a job that requires using a respirator may not be appropriate for someone with emphysema (45).

Spirometry plays an important role in a respiratory surveillance program. It is portable, safe for both the subject and the technician, non-invasive, inexpensive, and reproducible. With skilled and experienced staff, it is also relatively simple to perform. However, as discussed earlier, spirometric test results must be evaluated in the context of other medical information to offset its limitations. Respiratory surveillance programs should contain at least the following regularly scheduled components:

1. A detailed health history, with emphasis on smoking patterns, previous lung disease, and current respiratory symptoms.
2. A comprehensive employment history, with emphasis on potential occupational exposures to pulmonary hazards and respirator usage. Information should also be sought on potential exposures from hobbies, recreational activities, and part-time employment.

3. A thorough physical examination, with emphasis on the chest.
4. Chest radiographs (X-rays) where appropriate. It is important to consult with radiologists who have had special training in reading chest x-rays for occupational diseases, such as B-readers. These are physicians trained and certified by NIOSH to read chest x-rays for evidence of pneumoconioses.
5. Spirometry.

A respiratory surveillance program should also interface with an industrial hygiene program that identifies and controls potential pulmonary hazards and oversees employee respirator training and fit testing activities.

The frequency with which spirometry is used to monitor workers depends on the level of exposure and the severity of the potential impairment. However, as with every medical test, one must have a clear reason for performing spirometry, and guidelines for interpreting the tests and applying the results.

Medical surveillance itself must be used in conjunction with environmental monitoring and engineering controls to limit, if possible, the amount of exposure. In this context, medical surveillance is really a quality control procedure, designed to detect whether excessive exposure is occurring despite the control procedures in place.

After ruling out technical causes for low or declining pulmonary function, if abnormalities are detected or if a decline in pulmonary function compared with previous tests is detected, efforts must be made to identify the cause. If the cause is a workplace exposure, then steps must be taken to reduce the exposure and prevent further damage to the individual's lungs. It is unethical to use spirometry to detect workers with occupational pulmonary damage if no attempt is made to reduce their exposure or if the information is used as a reason for dismissal.

APPENDIX E. APPENDIX D OF THE OSHA COTTON DUST STANDARD

Appendix D of 29CFR1910.43 - Pulmonary Function Standards for Cotton Dust Standard

The spirometric measurements of pulmonary function shall conform to the following minimum standards, and these standards are not intended to preclude additional testing or alternate methods which can be determined to be superior.

I. Apparatus

- a. The instrument shall be accurate to within ± 50 milliliters or within ± 3 percent of reading, whichever is greater.
- b. The instrument should be capable of measuring vital capacity from 0 to 7 liters BTPS.
- c. The instrument shall have a low inertia and offer low resistance to airflow such that the resistance to airflow at 12 liters per second must be less than 1.5 cm H₂O/(liter/sec.).
- d. The zero time point for the purpose of timing the FEV₁ shall be determined by extrapolating the steepest portion of the volume time curve back to the maximal inspiration volume (1, 2, 3, 4) or by an equivalent method.
- e. Instruments incorporating measurements of airflow to determine volume shall conform to the same volume accuracy stated in (a) of this section when presented with flow rates from at least 0 to 12 liters per second.
- f. The instrument or user of the instrument must have a means of correcting volumes to body temperature saturated with water vapor (BTPS) under conditions of varying ambient spirometer temperatures and barometric pressures.
- g. The instrument used shall provide a tracing or display of either flow versus volume or volume versus time during the entire forced expiration. A tracing or display is necessary to determine whether the patient has performed the test properly. The tracing must be stored and available for recall and must be of sufficient size that hand measurements may be made within requirement of paragraph (a) of this section. If a paper record is made it must have a paper speed of at least 2 cm/sec and a volume sensitivity of at least 10.0 mm of chart per liter of volume.
- h. The instrument shall be capable of accumulating volume for a minimum of 10 seconds and shall not stop accumulating volume before (1) the volume change for a 0.5 second interval is less than 25 milliliters, or (2) the flow is less than 50 milliliters per second for a 0.5 second interval.

- i. The forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV₁) measurements shall comply with the accuracy requirements stated in paragraph (a) of this section. That is, they should be accurately measured to within ± 50 ml or within ± 3 percent of reading, whichever is greater.
- j. The instrument must be capable of being calibrated in the field with respect to the FEV₁ and FVC. This calibration of the FEV₁ and FVC may be either directly or indirectly through volume and time base measurements. The volume calibration source should provide a volume displacement of at least 2 liters and should be accurate to within ± 30 milliliters.

II. Technique for Measurement of Forced Vital Capacity Maneuver

- a. Use of a nose clip is recommended but not required. The procedures shall be explained in simple terms to the patient who shall be instructed to loosen any tight clothing and stand in front of the apparatus. The subject may sit, but care should be taken on repeat testing that the same position be used and, if possible, the same spirometer. Particular attention shall be given to insure that the chin is slightly elevated with the neck slightly extended. The patient shall be instructed to make a full inspiration from a normal breathing pattern and then blow into the apparatus, without interruption, as hard, fast, and completely as possible. At least three forced expirations shall be carried out. During the maneuvers, the patient shall be observed for compliance with instruction. The expirations shall be checked visually for reproducibility from flow-volume or volume-time tracings or displays. The following efforts shall be judged unacceptable when the patient:
 - 1. has not reached full inspiration preceding the forced expiration.
 - 2. has not used maximal effort during the entire forced expiration.
 - 3. has not continued the expiration for at least 5 seconds or until an obvious plateau in the volume time curve has occurred.
 - 4. has coughed or closed his glottis.
 - 5. has an obstructed mouthpiece or a leak around the mouthpiece (obstruction due to tongue being placed in front of mouthpiece, false teeth falling in front of mouthpiece, etc.)
 - 6. has an unsatisfactory start of expiration, one characterized by excessive hesitation (or false starts), and therefore not allowing back extrapolation of time 0 (extrapolated volume on the volume time tracing must be less than 10 percent of the FVC).
 - 7. has an excessive variability between the three acceptable curves. The variation between the two largest FVCs and FEV₁s of the three satisfactory tracings should

- not exceed 10 percent or ± 100 milliliters, whichever is greater.
- b. Periodic and routine calibration of the instrument or method for recording FVC and FEV₁ should be performed using a syringe or other volume source of at least 2 liters.

III. Interpretation of Spirogram

- a. The first step in evaluating a spirogram should be to determine whether or not the patient has performed the test properly or as described in II above. From the three satisfactory tracings, the forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV₁) shall be measured and recorded. The largest observed FVC and largest observed FEV₁ shall be used in the analysis regardless of the curve(s) on which they occur.
- b. The following guidelines are recommended by NIOSH for the evaluation and management of workers exposed to cotton dust. It is important to note that employees who show reductions in FEV₁/FVC ratio below .75 or drops in Monday FEV₁ of 5 percent or greater on their initial screening exam, should be re-evaluated within a month of the first exam. Those who show consistent decrease in lung function, as shown of the following table, should be managed as recommended.

IV. Qualifications of Personnel Administering the Test

Technicians who perform pulmonary function testing should have the basic knowledge required to produce meaningful results. Training consisting of approximately 16 hours of formal instruction should cover the following areas. Persons who successfully complete the course will be certified by OSHA or their designee.

- a. Basic physiology of the forced vital capacity maneuver and the determinants of airflow limitation with emphasis on the relation to reproducibility of results.
 - b. Instrumentation requirements including calibration procedures, sources of error and their correction.
 - c. Performance of the testing including subject coaching, recognition of improperly performed maneuvers and corrective actions.
 - d. Data quality with emphasis on reproducibility.
 - e. Actual use of the equipment under supervised conditions.
 - f. Measurement of tracings and calculations of results.
2. Part 1928 of Title 29 of the Code of Federal Regulations is hereby amended by adding a new paragraph (a)(5) to Section 1928.21 to read as follows:

Section 1928.21 Applicable standards in 29 CFR Part 10.

(a) * * *

(5) Exposure to cotton dust in cotton gins - Section 1910.1046.

(Secs. 6, 8, 84 Stat. 1593, 1599 (29 U.S.C. 655, 657); Secretary of Labor's Order 8-76 (41 FR 25059); 29 CFR Part 1911) [FR Doc. 78-17233 Filed 6-19-78; 11:53 am]

of the FEV₁/VC%. Manufacturers should note that several of the 24 test waveforms have durations longer than 20 s.

Achieving an end-of-test criterion is one measure of maneuver acceptability. Maneuvers that do not meet an end-of-test criterion should not be used to satisfy the requirement of three acceptable maneuvers. However, early termination is not by itself a reason to eliminate a maneuver from further consideration. Information such as FEV₁ and FEV₃ may be valid (depending on the length of exhalation) and should be reported from these early terminated maneuvers. When the subject does not exhale completely, the volume accumulated over a shorter period of time (e.g., 4 s) may be used as an approximate surrogate for FVC. In such cases, the volume label should reflect the shorter exhalation time (e.g., FEV₄ for a 4-s exhalation).

Recommendation: VC and FVC—Maximum Number of Maneuvers

Although there may be some circumstances in which more than eight consecutive FVC maneuvers may be needed, eight maneuvers is considered a practical upper limit for most subjects. After several forced expiratory maneuvers, fatigue begins to take its toll on subjects, and thus on their spirometric parameters, so additional maneuvers would be of little added value. In addition, some subjects with asthma may exhibit spirometry-induced bronchospasm. Ferris and associates (70) and Kanner and colleagues (71) have reported that for adults and children, eight maneuvers is a practical upper limit. For VC, four is considered a practical upper limit. Because of the potential for muscular fatigue and volume history effects, it is preferable that VC maneuvers be performed before FVC maneuvers.

Recommendation (Monitoring): PEF—Number of Trials

The subject must perform and record a minimum of three trials.

Recommendation: VC and FVC—Environmental Conditions

Spirometric testing with ambient temperatures less than 17° C or more than 40° C may pose problems. Ambient temperature must *always* be recorded and reported to an accuracy of $\pm 1^\circ$ C. In situations where the ambient air temperature is changing rapidly ($> 5^\circ$ C in less than 30 min), continuous temperature corrections should be made. Spirometer users should be aware of the problems with testing done at lower temperatures, which in some subjects can cause airflow limitation. Due to other technical reasons, 17° C is judged to be an acceptable and reasonable lower limit (32–38, 72) for ambient temperature. Ranges of barometric pressures that are acceptable for the spirometer must be published by the manufacturer.

Rationale. There is evidence that some subjects may develop airflow limitation with the inhalation of very cold air. Therefore, spirometry should not be conducted when the ambient temperature is cold enough to induce airflow limitation.

Studies also point out the problem of finite cooling times of gases in volume-type spirometers and their associated tubing (32–35) when BTPS correction techniques usually assume instantaneous cooling. In one of these studies, it was found that a 7.7 to 14% error in FEV₁ results if the volume-type spirometer is at an ambient temperature of 3° C and the standard BTPS correction is used. This error is less if the spirometer is warmer (nearer body temperature) (32). As a result, 17° C was judged to be an acceptable and reasonable lower limit.

Complexities related to temperature are also encountered with flow-measuring devices (34–38). Air exhaled from the mouth is estimated to be 33 to 35° C (36, 38, 39). If any connecting tubing is used between the mouthpiece and the flow sensor, the exhaled gas will experience a variable amount of cooling if the room temperature is not at approximately 33° C. Details of the cooling pattern for many types of flow spirometers have not been stud-

ied, but they may result in errors similar to those for volume devices (34–38).

Because not all spirometers are used at sea level (blood pressure = 760 mm Hg), the range of barometric pressures allowed by the spirometer and its associated computational equipment must be specified by the manufacturer.

Recommendation: VC and FVC—Use of Nose Clips

In most people, not wearing nose clips does not appreciably influence the FVC when using the open circuit technique. However, some people breathe through the nose and the use of nose clips is encouraged, especially when performing a slow VC maneuver. Nose clips must be used if a closed circuit technique with carbon dioxide absorption is used.

Recommendation: VC and FVC—Sitting Versus Standing

Testing may be done either in the sitting or standing position. Indication of position is necessary on the report (1, 73). The standing position may not be appropriate in some circumstances, such as in hospitals where many patients may not be able to tolerate the standing position, especially when making forced maneuvers. The selection of the position for testing is, therefore, an individual one. If the standing position is used, an appropriately shaped chair should be placed behind the patient/subject so he/she can be quickly and easily eased into a sitting position if he/she becomes light-headed during the maneuver.

Rationale. Studies by Townsend show that for adults there are significantly larger FEVs in the standing position than in the sitting position (73). The earlier ATS recommendation indicates that in children, VC is greater when standing (1).

Recommendation (Monitoring): PEF—Nose Clips and Subject Position

Nose clips are not necessary when using PEF meters. Although the test can be conducted while sitting, the standing position is preferred.

Rationale. Because the PEF is dependent on a complete inhalation and an exhalation with maximal force, the standing position is preferred.

Bronchodilator Testing. Spirometry is often performed before and after inhalation of bronchodilators (or bronchoconstrictors) from a metered dose inhaler (MDI) or nebulizers. Although specific recommendations are beyond the scope of this document, it should be remembered that this is a complex procedure. Factors that can significantly affect a patient's response include: (1) activity, dose, and airway deposition of the medication; (2) recent prior medication; (3) timing of the postmedication maneuver; (4) choice and variability of the measurement used to detect a response; and (5) the method of calculating the magnitude of change after administering the bronchodilator.

MEASUREMENT PROCEDURES

Measurement

Spirometric variables should be measured from a series of *at least* three acceptable forced expiratory curves.

Recommendation: VC and FVC—Test Result Selection/Reporting of Results

The largest VC should be reported from all acceptable curves, including the forced maneuvers (FVC). The largest FVC and the largest FEV₁ (BTPS) should be recorded after examining the data from all of the acceptable curves, even if they do not come from the same curve. Other measures, such as the FEF_{25–75%} and the instantaneous expiratory flows, should be obtained from the single curve (1, 2, 15) that meets the acceptability criteria and gives the largest sum of FVC plus FEV₁ (best test).

APPENDIX G. SPIROMETRY PROCEDURE CHECKLIST

The list below is summarized from Unit Four: Spirometric Technique. Refer to that unit for further information.

1. Prepare the equipment.
 - a. Set up and clean equipment.
 1. Check paper supply.
 2. Set the paper speed if applicable.
 3. Check the position of the pens.
 4. Attach the main tubing if applicable.
 - b. Check to calibration of the equipment.
 - c. Do a test run.
 - d. Check that there are enough supplies.
 - e. Note room temperature (and barometric pressure if applicable.)
 - f. Check that the weight and height measuring scales are working properly.
2. Prepare the subject.
 - a. Explain the purpose of spirometry--"I want to learn how hard and fast you can breathe."
 - b. Determine if spirometry should be postponed using your institution's criteria or the sample questions below:
 1. How are you feeling today?
 2. Have you smoked any cigarettes, pipes, or cigars within the last hour?
 3. Have you used any inhaled medications, such as aerosolized bronchodilators, within the last hour?
 4. What have you eaten within the last hour?
 5. Have you had any respiratory infection, such as flu, pneumonia, severe cold, or bronchitis, within the last three weeks?
 6. Have you had any ear infections or other ear problems within the last three weeks?
 7. Have you had any recent surgeries?
 8. If you wear dentures, are they loose?
3. Position the subject.
 - a. Note the previous position used (sitting or standing) in past spirometric tests and use the same position if possible. Record the position to be used in the chart.
 - b. Instruct the subject to loosen tight clothing, elevate the chin, and extend the neck slightly.
 - c. Show the subject how to apply a nose clip and check to see that it is on properly.

4. Perform the test.

- a. Explain how to position the mouthpiece (in mouth without obstruction from teeth or tongue, with a tight lip seal).
- b. Explain and demonstrate how to perform the forced expiratory maneuver. -- "When 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, without stopping until I tell you."

5. Perform last minute equipment preparations.

- 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.

6. Coach the subject.

- a. Actively and forcefully coach the subject as he/she performs the maneuver! (Blow, blow, blow!)
- b. Keep coaching until a plateau is reached -- ATS-1994. (Cotton Dust: less than 25 ml volume change in 0.5 seconds.)

7. Check the acceptability of each tracing before continuing the testing.

- a. Acceptable spiograms are free from:
 1. Hesitation or false starts.
 2. Cough.
 3. Variable effort.
 4. Glottis closure.
 5. Early termination, before a plateau is reached.
 6. Leaks.
 7. Baseline error.
- b. Review causes of errors with the subject if needed.
- c. Continue testing until three acceptable tracings have been obtained, allowing the subject to recover between tests, up to a maximum of eight trials.

8. Check for excess variability of the two largest FVCs and FEV₁s. (See **Unit Five: Basic Spirometric Calculations** and **Appendix H: Outline of Spirometric Calculations** for more information.) Have the subject perform additional forced expiratory maneuvers as needed or as is appropriate for his/her medical condition.

- 9. Record information in the subject's chart.** At a minimum, note the information below in the subject's chart:
- a. Name.
 - b. Age
 - c. Sex.
 - d. Height.
 - e. Race.
 - f. Position of previous testing.
 - g. Previous predicted values used.
 - h. Date and time of test.
 - i. Ambient temperature.
 - j. Barometric pressure (if possible).
 - k. Test results.
 - l. Technician identification

APPENDIX H. OUTLINE OF SPIROMETRIC CALCULATIONS

The list below is summarized from **Unit Five: Basic Spirometric Calculations**. Refer to that unit for further information.

1. **Use only the tracings that meet acceptability criteria** (see **Appendix G. Spirometry Procedure Checklist** and **Unit Four. Spirometric Technique** for instructions).
2. **Forced Vital Capacity (FVC)**
 - a. Measure the FVC from baseline to plateau for all acceptable tracings.
 - b. Determine if there is excess variability, difference between the two largest FVCs should be less than 200 ml (**Optional:** for ATS-1987, FVCs that are 2 liters or less, use 100 ml; for FVCs greater than 2 liters, use 5%; Cotton Dust - FVCs less than 1 liter use 100 ml or 10% for FVCs greater than 1 liter).
 - c. Use the largest FVC obtained from all acceptable tracings.
 - d. Convert to BTPS as needed (see below).
3. **Forced Expiratory Volume in One Second (FEV₁)**
 - a. Measure FEV₁ on the acceptable tracings.
 - b. Find t=0 and t=1 second.
 - c. Do back extrapolation if t=0 is not obvious. ATS recommends to do it for all FEV₁ calculations. Draw a straight line along the steepest portion of the curve and extend the line to intersect the baseline.
 - d. Calculate the volume at t=1 second.
 - e. Determine if there is excessive extrapolated volume at t=0. Extrapolated volume is not acceptable if it is greater than 5% of the FVC for FVCs exceeding 3 liters -- use 150 ml for FVCs less than 3 liters.
 - f. Determine if there is excess variability, difference between the two largest FEV₁s should be less than 200 ml. Optional: for ATS-1987, use 100 ml for FEV₁s that are 2 liters or less, use 5 % for those that are greater than 2 liters; Cotton Dust - for FEV₁s less than 1 liter use 100 ml or 10% for FEV₁s greater than 1 liter.
 - g. Convert to BTPS as needed (see below).
4. **FEV₁ as a Percent of FVC**
 - a. Use the largest acceptable FVC and FEV₁, even if not from the same tracing.
 - b. $FEV_1/FVC \times 100 = FEV_1/FVC\%$
 - c. Don't convert to BTPS, since the answer is a ratio.
5. **Forced Mid-Expiratory Flow Rate (FEF_{25-75%})**
 - a. Use the "best curve" (acceptable tracing with the largest sum of the FVC and the FEV₁).
 - b. Calculate 25% and 75% of the FVC and mark those points on the tracing.
 - c. Draw a straight line through the 25% point and the 75% point.
 - d. Find two adjacent time bars that are one second apart.
 - e. Determine the volume at each of those two time bars.
 - f. Determine the difference between those two volumes.
 - g. Convert to BTPS (see below).

h. The answer is in liters per second.

6. Conversion to BTPS

- a. Convert the ambient temperature to Centigrade if needed.
- b. Find the ambient temperature and the corresponding conversion factor on the **BTPS Conversion Chart**.
- c. Multiply the FVC, FEV₁, and FEF_{25-75%} by the conversion factor to obtain the correct volume at BTPS.

7. Predicted Normal Values

- a. Be consistent in which predicted tables are used.
- b. Locate predicted values for FEV₁ and FVC, using subject's age, race, height, and sex.
- c. In some non-Caucasians, multiply the predicted values by 0.85 (the race correction factor).
- d. Calculate the percent of the predicted value:
FVC observed/FVC predicted x 100 = FVC% of predicted normal. (Do the same for FEV₁ and FEF_{25-75%}).

8. Changes in Follow-Up Spirograms

- a. Calculate as an absolute difference (e.g., FVC at time₁ - FVC at time₂ = + or - liters difference).
- b. Or calculate as a percent change from the previous value (e.g.,
$$\frac{\text{FVC at time}_1 - \text{FVC at time}_2}{\text{FVC at time}_1} \times 100 = + \text{ or } - \%$$
- c. Use the same steps for calculating percent change in FEV₁ and percent change in FEF_{25-75%}.

APPENDIX I. BASIC MATHEMATIC CALCULATIONS

ADDITION: $a + b = c$

Example: $3 + 2 = 5$

SUBTRACTION: $c - b = a$

Example: $5 - 2 = 3$

MULTIPLICATION: $a \times b = d$

Example: $3 \times 2 = 6$

DIVISION: $\frac{d}{b} = a$ or $d / b = a$

Example: $6 / 2 = 3$

FRACTIONS: $\frac{a}{b} = \frac{\text{numerator}}{\text{denominator}}$ or a/b

Example: $3/5$

DECIMALS: 1. Numbers to the left of the decimal point are whole numbers.

Example: 3.

2. The first number to the right of the decimal point is in tenths.

Example: $.2 = 2/10$

3. The second number to the right of the decimal point is in hundredths.

Example: $.05 = 5/100$
 $.67 = 67/100$

4. The third number to the right of the decimal point is in thousandths, etc.

Example: $.009 = 9/1000$
 $.872 = 872/1000$

CONVERTING FROM

**FRACTIONS TO
DECIMALS:**

$$a/b = .c$$

Example: $4/5 = .8$

**CONVERTING FROM
DECIMALS TO
FRACTIONS:**

$$a.bc = abc/100$$

Example: $3.75 = 375/100$
 $= 3 \frac{3}{4}$

**CONVERTING DECIMALS
TO PERCENT:**

$$.a = a \times 100 = a \%$$

Example: $.8 = 80\%$
 $(.8 \times 100 = 80\%)$

**CONVERTING PERCENT
TO DECIMALS:**

$$a\% = a\% \div 100 = .a$$

Example: $80\% = .8$
 $(80/100 = .8)$

APPENDIX J. METRIC CONVERSIONS

The metric system follows an orderly sequence for prefixes that indicates the unit of measurement:

<u>Prefix</u>	<u>Units in</u>	<u>Example</u>
kilo-	thousands	1 kiloliter = 1,000 liters
hecto-	hundreds	1 hectoliter = 100 liters
deca-	tens	1 decaliter = 10 liters
no prefix	ones	
deci-	tenths	1 deciliter = 0.1 liter
centi-	hundredths	1 centiliter = 0.01 liter
milli-	thousandths	1 milliliter = .001 liter

Commonly used metric measurements and their U.S. equivalent are given below:

<u>Metric Unit</u>	<u>Abbreviation</u>	<u>Approx. U.S. Equivalent</u>
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Distance

kilometer	km	0.62 miles
meter	m	39.37 inches
centimeter	cm	0.39 inches
millimeter	mm	0.04 inches

Capacity (liquids)

liter	l	1.057 quarts
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Capacity (dry)

liter	l	0.908 quarts
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Weight

kilogram	kg	2.2046 pounds
gram	g	0.035 ounces
milligram	mg	0.015 grains

	<u>U.S. Unit</u>	<u>Metric Equivalent</u>
<u>Distance</u>		
	1 mile	1.609 km
	1 yard	0.914 m
	1 foot	30.480 cm
	1 inch	2.540 cm
<u>Capacity (liquid)</u>		
	1 gallon	3.785 l
	1 quart	0.946 l
	1 pint	0.473 l
	1 fluid ounce	29.573 ml
<u>Capacity (dry)</u>		
	1 bushel	35.238 l
	1 quart	1.101 l
	1 pint	0.550 l
<u>Weight (avoirdupois)</u>		
	1 pound	.453 kg
	1 ounce	28.349 g

APPENDIX K. OTHER FACTORS TO CONSIDER WHEN CALCULATING BTPS

1. Ambient Pressure: Some physicians prefer to use BTPS conversion factors that correct for ambient pressure as well as temperature. Fluctuations in ambient pressure produce changes of less than 1% in the usual spirometric tests. However at high altitudes or during research studies, the use of ambient pressure conversion factors should be considered.

To obtain ambient pressure, use a barometer or call the weather service and use reported barometric pressure. Convert the reading from inches of mercury to millimeters if necessary (1mm = 0.04 inches).

To take ambient pressure into account when calculating BTPS, use the following formula:

$$V_{\text{BTPS}} = V_{\text{ATPS}} \times [310 \times (\text{PB} - \text{PH}_2\text{O})] \div [(\text{PB} - 47) \times (273 + \text{T})]$$

PB = Barometric pressure, mm Hg.

PH₂O = Vapor pressure of water at
spirometer temperature.

T = Temperature in Centigrade.

47 = Vapor pressure of water at 37°C.

310 = Absolute body temperature.

2. Instrument or Bell Factor: The Instrument or Bell Factor is occasionally mentioned in addition to BTPS. In certain water-seal spirometers, it refers to a constant indicating the volume of displacement per millimeter of vertical movement of the bell. If you use this type of spirometer, a bell factor correction is necessary. Consult the manufacturer's manual for instructions.
3. Instruments with Graph in BTPS Units: Some instruments have graph paper which assumes the spirometer is at 25°C and 760 mm of mercury (the barometric pressure at sea level). If the ambient temperature is not 25°C, data collected from this type of instrument must be corrected to the appropriate BTPS factor. Consult the manufacturer's manual for instructions.

APPENDIX L. REFERENCE VALUES TABLES FROM NHANES III (Hankinson et. al. - 1999)

Table 1. Caucasian-Males

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
170cm	20	5.10	4.25	4.30	3.58	83.9%	74.3%
	30	4.97	4.12	4.08	3.36	81.9%	72.2%
	40	4.79	3.94	3.83	3.11	79.8%	70.1%
	50	4.55	3.70	3.55	2.83	77.7%	68.1%
	60	4.26	3.41	3.23	2.51	75.7%	66.0%
180cm	20	5.75	4.80	4.79	3.98	83.9%	74.3%
	30	5.62	4.67	4.58	3.77	81.9%	72.2%
	40	5.44	4.49	4.32	3.52	79.8%	70.1%
	50	5.21	4.25	4.04	3.23	77.7%	68.1%
	60	4.92	3.96	3.72	2.91	75.7%	66.0%
190cm	20	6.44	5.38	5.31	4.41	83.9%	74.3%
	30	6.31	5.25	5.10	4.20	81.9%	72.2%
	40	6.13	5.07	4.85	3.95	79.8%	70.1%
	50	5.90	4.83	4.56	3.66	77.7%	68.1%
	60	5.61	4.54	4.24	3.34	75.7%	66.0%

Table 2. African-American-Males

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
170cm	20	4.29	3.43	3.69	2.93	85.6%	75.2%
	30	4.11	3.25	3.46	2.70	83.8%	73.3%
	40	3.93	3.07	3.23	2.47	81.9%	71.5%
	50	3.75	2.89	3.00	2.24	80.1%	69.7%
	60	3.57	2.71	2.77	2.01	78.3%	67.9%
180cm	20	4.88	3.91	4.15	3.30	85.6%	75.2%
	30	4.69	3.73	3.92	3.07	83.8%	73.3%
	40	4.51	3.55	3.69	2.84	81.9%	71.5%
	50	4.33	3.37	3.46	2.61	80.1%	69.7%
	60	4.15	3.18	3.23	2.38	78.3%	67.9%
190cm	20	5.49	4.42	4.64	3.69	85.6%	75.2%
	30	5.31	4.24	4.41	3.46	83.8%	73.3%
	40	5.13	4.05	4.18	3.23	81.9%	71.5%
	50	4.95	3.87	3.95	3.00	80.1%	69.7%
	60	4.76	3.69	3.72	2.77	78.3%	67.9%

Table 3. Mexican-American-Males

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
170cm	20	5.14	4.31	4.41	3.71	85.7%	76.6%
	30	4.96	4.13	4.12	3.41	83.5%	74.4%
	40	4.74	3.91	3.82	3.12	81.3%	72.2%
	50	4.49	3.66	3.53	2.83	79.1%	70.0%
	60	4.20	3.37	3.24	2.54	76.9%	67.8%
180cm	20	5.76	4.83	4.94	4.15	85.7%	76.6%
	30	5.58	4.65	4.65	3.86	83.5%	74.4%
	40	5.36	4.43	4.35	3.56	81.3%	72.2%
	50	5.11	4.18	4.06	3.27	79.1%	70.0%
	60	4.82	3.89	3.77	2.98	76.9%	67.8%
190cm	20	6.42	5.38	5.50	4.62	85.7%	76.6%
	30	6.24	5.20	5.20	4.33	83.5%	74.4%
	40	6.02	4.99	4.91	4.03	81.3%	72.2%
	50	5.77	4.73	4.62	3.74	79.1%	70.0%
	60	5.48	4.44	4.33	3.45	76.9%	67.8%

Table 4. Caucasian-Females

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
150cm	20	3.20	2.61	2.87	2.37	86.6%	76.8%
	30	3.19	2.61	2.74	2.24	84.4%	74.6%
	40	3.11	2.53	2.57	2.07	82.3%	72.5%
	50	2.96	2.37	2.35	1.86	80.2%	70.4%
	60	2.72	2.14	2.10	1.61	78.1%	68.3%
160cm	20	3.66	2.99	3.23	2.66	86.6%	76.8%
	30	3.65	2.98	3.09	2.53	84.4%	74.6%
	40	3.57	2.90	2.92	2.35	82.3%	72.5%
	50	3.42	2.75	2.71	2.14	80.2%	70.4%
	60	3.18	2.51	2.46	1.89	78.1%	68.3%
170cm	20	4.15	3.39	3.61	2.97	86.6%	76.8%
	30	4.14	3.39	3.47	2.83	84.4%	74.6%
	40	4.06	3.31	3.30	2.66	82.3%	72.5%
	50	3.91	3.15	3.09	2.45	80.2%	70.4%
	60	3.67	2.92	2.84	2.20	78.1%	68.3%

Table 5. African-American-Females

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
150cm	20	2.76	2.15	2.49	1.97	87.6%	76.9%
	30	2.68	2.07	2.31	1.79	85.5%	74.9%
	40	2.55	1.94	2.12	1.60	83.5%	72.8%
	50	2.36	1.76	1.90	1.38	81.5%	70.8%
	60	2.13	1.52	1.66	1.15	79.4%	68.7%
160cm	20	3.18	2.49	2.82	2.24	87.6%	76.9%
	30	3.10	2.41	2.65	2.06	85.5%	74.9%
	40	2.97	2.28	2.45	1.86	83.5%	72.8%
	50	2.78	2.10	2.24	1.65	81.5%	70.8%
	60	2.55	1.86	2.00	1.41	79.4%	68.7%
170cm	20	3.63	2.85	3.18	2.52	87.6%	76.9%
	30	3.55	2.77	3.01	2.34	85.5%	74.9%
	40	3.42	2.64	2.81	2.14	83.5%	72.8%
	50	3.23	2.46	2.59	1.93	81.5%	70.8%
	60	3.00	2.22	2.36	1.69	79.4%	68.7%

Table 6. Mexican-American-Females

Height	Age	FVC		FEV1		FEV1/FVC%	
		Pred	LLN	Pred	LLN	Pred	LLN
150cm	20	3.29	2.69	2.91	2.40	87.9%	78.5%
	30	3.21	2.60	2.73	2.22	85.6%	76.3%
	40	3.07	2.47	2.54	2.03	83.4%	74.1%
	50	2.89	2.29	2.32	1.81	81.1%	71.8%
	60	2.66	2.06	2.07	1.56	78.9%	69.6%
160cm	20	3.73	3.05	3.28	2.70	87.9%	78.5%
	30	3.65	2.96	3.11	2.53	85.6%	76.3%
	40	3.51	2.83	2.91	2.33	83.4%	74.1%
	50	3.33	2.64	2.69	2.11	81.1%	71.8%
	60	3.10	2.41	2.45	1.87	78.9%	69.6%
170cm	20	4.20	3.43	3.68	3.03	87.9%	78.5%
	30	4.12	3.34	3.51	2.86	85.6%	76.3%
	40	3.98	3.21	3.31	2.66	83.4%	74.1%
	50	3.80	3.03	3.09	2.44	81.1%	71.8%
	60	3.57	2.80	2.85	2.20	78.9%	69.6%

APPENDIX M. TABLES OF OBSTRUCTIVE/RESTRICTIVE PATTERNS

The information below represents a method for interpretation of spirometric results. This method is not required practice and other methods exist.

LUNG DISEASES AND SPIROMETRY RESULTS

<u>Interpretation</u>	<u>FEV₁/FVC%</u>	<u>FVC</u>	<u>FEV₁</u>
Normal person	normal	normal	normal
Airway obstruction	low	normal or low	low
Lung Restriction	normal	low	low
Combination of Obstruction/Restriction	low	low	low

Adapted from Chronic Obstructive Pulmonary Disease, 5th Edition [1977]. American Lung Association (46).

GUIDELINES FOR ASSESSING DEGREE OF VENTILATORY IMPAIRMENT

<u>Interpretation</u>	<u>Obstructive Pattern</u>	<u>Restrictive Pattern</u>
Normal	FEV ₁ /FVC% ≥ LLN	FVC ≥ LLN
Borderline	FEV ₁ /FVC < LLN & FEV ₁ ≥ LLN	
Mild	FEV ₁ < 100 & ≥ 70% Pred	FVC < LLN & ≥ 70% Pred
Moderate	FEV ₁ < 70 & ≥ 50% Pred	FVC < 70 & ≥ 50% Pred
Severe	FEV ₁ ≤ 50% Pred	FVC ≤ 50% Pred

Adapted from American Thoracic Society: Lung function testing: Selection of reference values and interpretative strategies [1991]. American Review of Respiratory Diseases 144:1202-1218 (30).

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