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Standard Practice for Respiratory Protection—Respirator Use—Physical Qualifications for Personnel[1]

This standard is issued under the fixed designation F3620; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides information that is useful for the medical evaluation of respirator users.

1.2 This practice does not deal with medical surveillance or biological exposure monitoring. It is understood that since local circumstances vary, no set of guidelines can cover all situations, and specific programs and procedures should be modified for each individual workplace. Medical evaluation is only one element of a complete respiratory protection program. A complete respiratory protection program is defined in Practice F3387.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3387 Practice for Respiratory Protection

2.2 *Federal Standards:*[3]

29 CFR 1910.134 Respiratory Protection

29 CFR 1910.155 Fire Protection

3. Terminology

3.1 *Definitions:*

3.1.1 *body mass index, BMI, n*—measurement used to assess weight relative to height.

3.1.1.1 *Discussion*—BMI is calculated by dividing body weight in kilograms by height in metres squared (kg/m^2).

3.1.2 *canister (air purifying), n*—container with (*1*) gas and vapor-removing sorbent or catalyst, or (*2*) gas and vapor-removing sorbent or catalyst that removes gases and vapors and filter that removes particles from inspired air (or air drawn through the unit).

3.1.2.1 *Discussion*—Typically attached to a full face piece, either mounted directly to the chin or connected to a breathing tube so the canister may be worn in the front or back of the person. Respirators with air-purifying canisters are approved by National Institute for Occupational Safety and Health (NIOSH) as gas masks and contain approval number TC-14G-XXXX.

3.1.3 *cartridge, n*—small container filled with sorbents or catalysts that remove gases and vapors from the inspired air.

3.1.3.1 *Discussion*—The cartridge may also have particulate filters that are an integral part or ones that are replaceable.

3.1.4 *emergency situation, n*—any occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment that may or does result in an uncontrolled significant release of an airborne contaminant.

3.1.5 *employee exposure, n*—exposure to a concentration of an airborne contaminant that would occur if the employee were not using respiratory protection.

3.1.6 *end-of-service-life indicator, ESLI, n*—system or device that warns the wearer of the approach of the end of adequate respiratory protection.

3.1.7 *escape-only respirator, n*—respirator intended only for use during emergency egress from a hazardous atmosphere.

3.1.8 *exercise stress test, EST, n*—standard graded exercise test used to assess an individual's ability to tolerate increasing intensities of exercise while electrocardiographic (EKG), hemodynamic, and symptomatic responses are monitored for manifestations of ischemia, electrical instability, or other exertion-related abnormalities.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

3.1.9 *filter, n*—material used in air-purifying respirators to remove solid or liquid aerosols from inspired air.

3.1.9.1 *Discussion*—Some filters are encapsulated in a container and some are not.

3.1.10 *filtering face piece*—negative pressure respirator in which the filter is an integral part of the face piece or comprises the entire face piece.

3.1.11 *fit factor, n*—numeric expression of how well a tight-fitting respirator fits a wearer during a quantitative fit test, and it is the ratio of the measured challenge agent concentration outside the face piece (C_{out}) to its concentration inside the respirator (C_{in}) (fit factor = C_{out} / C_{in}).

3.1.11.1 *Discussion*—A fit factor resulting from a qualitative fit test has been validated to 100.

3.1.12 *fit test, n*—use of a qualitative or quantitative protocol to evaluate sealing surface leakage of a specific tight-fitting respirator while worn by an individual.

3.1.13 *helmet, n*—hood that offers head protection against impact and penetration.

3.1.14 *hood, n*—tight or loose-fitting respiratory inlet covering that completely covers the head and neck and may cover portions of the shoulders.

3.1.15 *immediately dangerous to life and health, IDLH, n*—any atmosphere that poses an immediate hazard to life or immediate irreversible debilitating effects on health.

3.1.16 *interior structural firefighting, n*—physical activity of fire suppression, rescue, or both, inside of buildings or enclosed structures that are involved in a fire situation beyond the incipient state (see 29 CFR 1910.155).

3.1.17 *loose-fitting face piece, n*—respiratory inlet covering that is designed to form a partial seal with the face, does not cover the neck and shoulders, and may or may not offer head protection against impact and penetration.

3.1.18 *metabolic equivalents, METs, n*—unit of energy expended; one MET is 3.5 mL O_2/kg/min and represents the energy expended at rest.

3.1.18.1 *Discussion*—Standardized exercise protocols express energy expended in terms of multiples of resting metabolic energy or METs.

3.1.19 *negative pressure respirator, n*—respirator in which the air pressure inside the respiratory inlet covering is negative during inhalation with respect to the ambient air pressure.

3.1.20 *oxygen-deficient atmosphere, n*—oxygen partial pressure of 96 to 122 mm Hg shall be considered an oxygen-deficient atmosphere that is not immediately dangerous to life and health (IDLH).

3.1.20.1 *Discussion*—An oxygen partial pressure of 95 mm Hg or less shall be considered IDLH. The oxygen deficiency may be caused by a reduction in the normal 20.9 % oxygen content by reduced total atmospheric pressure or any combination of reduced percentage of oxygen and reduced pressure.

3.1.21 *physician or other licensed healthcare professional, PLHCP, n*—individual whose legally permitted scope of practice (that is, license, registration, or certification) allows them to provide independently, be delegated the responsibility to provide independently, or be delegated the responsibility to provide some or all of the healthcare services required by 29 CFR 1910.134(e).

3.1.22 *positive pressure respirator, n*—respirator in which the pressure inside the respiratory inlet covering is normally positive with respect to ambient air pressure.

3.1.23 *qualitative fit test, QLFT, n*—pass/fail test that relies on the subject's sensory response to detect a challenge agent.

3.1.24 *quantitative fit test, QNFT, n*—fit test that uses an instrument to measure face seal leakage.

3.1.25 *respiratory inlet covering, n*—that portion of a respirator that connects the wearer's respiratory tract to an air-purifying or atmosphere-supplying respirator.

3.1.25.1 *Discussion*—They may be a face piece, helmet, hood, or mouthpiece/nose clamp.

3.1.26 *self-contained breathing apparatus, SCBA, n*—atmosphere-supplying respirator in which the respirable gas source is designed to be carried by the user.

3.1.27 *service life, n*—time that a respirator provides adequate protection to the wearer.

3.1.28 *tight-fitting respiratory inlet covering, n*—respirator component designed to form a complete seal with the face or neck.

3.1.28.1 *Discussion*—A half face piece (includes quarter face piece, filtering face piece, and half face piece with elastomeric face pieces) covers the nose and mouth; a full face piece covers the nose, mouth, and eyes. Tight-fitting hoods seal at the neck.

3.1.29 *wearer seal check (namely, user seal check), n*—procedure conducted by the wearer to determine if a tight-fitting respirator is properly donned.

3.2 *Acronyms:*

3.2.1 *APR*—air-purifying respirator

3.2.2 *BP*—blood pressure

3.2.3 *CAD*—coronary artery disease

3.2.4 *DBP*—diastolic blood pressure

3.2.5 *EKG*—electrocardiogram

3.2.6 *IDLH*—immediately dangerous to life and health

3.2.7 *NIOSH*—National Institute for Occupational Safety and Health

3.2.8 *PAPR*—powered air-purifying respirator

3.2.9 *PVC*—premature ventricular contraction

3.2.10 *SBP*—systolic blood pressure

4. Significance and Use

4.1 This practice provides information and guidance to PLHCPs to assist them in determining the medical suitability of personnel for respirator use. It identifies the responsibility of management to provide the PLHCP with supplemental information before the PLHCP makes a recommendation concerning an employee's ability to use a respirator (9.1). Evaluators shall use their clinical judgment in the application of these

guidelines and require additional information or evaluation as necessary to permit certification or classification for respirator use.

4.2 *Shall and Should*—The provisions of this practice are mandatory in nature when the word "shall" is used and advisory in nature when the word "should" is used.

4.3 *Exceptions*—Users of this practice should be aware that regulatory agencies may have requirements that are different from this practice.

5. Respirator Characteristics

5.1 *Air-Purifying Respirators (APRs):*

5.1.1 *General*—APRs remove specific air contaminants by passing ambient air through an air-purifying filter, cartridge, or canister. APRs are either nonpowered or powered. APRs are not approved for firefighting efforts.

5.1.2 *Air-Purifying (Nonpowered) Respirators*—Inhalation through the filtering media and exhalation through the valve depend only on the breathing action of the lungs. The maximum allowed inhalation and exhalation resistance depends on the respirator type. For particulate-removing (particle filter) respirators, inhalation resistances are less than 35 mm H_2O and exhalation resistances are less than 25 mm H_2O. For gas/vapor-removing (chemical cartridge) respirators, including those with particle filters, inhalation resistances are less than 70 mm H_2O and exhalation resistances are less than 20 mm H_2O. For gas mask respirators, inhalation resistances are less than 85 mm H_2O and exhalation resistances are less than 20 mm H_2O. All resistances are measured at a maximum airflow of 85 L/min.

5.1.3 *PAPRs*—Powered units contain a blower to move the air through the filtering media. Inhalation and exhalation resistance are negligible similar to a continuous-flow air line device. The weight of the blower varies from approximately 2 to 7 kg.

5.2 *Atmosphere-Supplying Respirators:*

5.2.1 *General*—Atmosphere-supplying respirators are either self-contained or air line units. The SCBA is completely portable. The air line apparatus requires the trailing of an air hose from the wearer to the source of breathing air.

5.2.1.1 Atmosphere-supplying respirators operate in continuous-flow, demand, or pressure-demand modes. Continuous-flow respirators blow air continuously into the mask. Demand-type apparatus require the wearer to inhale and reduce the mask pressure below atmospheric pressure before the regulator will supply air. (This is similar to inhaling through an air-purifying device.) In a pressure-demand (positive pressure) device, a slight positive pressure is maintained in the face piece at all times by the regulator. More air is admitted to the mask as the positive pressure decreases during inhalation. Exhalation resistances are greater than for demand devices.

5.2.2 *Open-Circuit SCBA*—Open-circuit SCBA is available in demand or pressure-demand devices. In open-circuit devices, breathing air is supplied from a cylinder to the mask and then dumped into the atmosphere on exhalation. The nitrogen in the breathing air is excess weight that does not contribute to the wearer's metabolism. The maximum allowed weight is 16 kg, although modern half-hour units may weigh 4.5 kg less. Significant reduction (up to 20 %) in work capacity of the wearer can occur since the 16 kg load shall be carried. Heavy work rates may be required during firefighting and rescue situations while wearing SCBA.

5.2.2.1 Regulators on current SCBA may not meet the high instantaneous demand of wearers at heavy work rates and so may impair work output further. The increased exhalation resistance of pressure-demand units may also degrade the ability to perform heavy work.

5.2.3 *Closed-Circuit SCBA*—Closed-circuit SCBA is available in demand or pressure-demand devices. In closed-circuit units (also known as rebreathers), oxygen is supplied from a compressed gas, liquid, or chemical source. Exhaled air is scrubbed of carbon dioxide and returned to the face piece. Closed-circuit devices have a longer duration for their weight than do open-circuit equipment. Breathing is into and out of a bag rather than from a regulator. Oxygen concentrations may range from 21 to 90 %.

5.2.4 *Supplied-Air Respirators (SARs)*—Supplied-air or air line respirators are available as continuous-flow, demand, or pressure-demand devices. All SARs require a trailing air hose that limits movement about the workplace. Duration of use is limited only by the air source and the metabolic work rate. Exhalation resistance is equal to or lower than that of demand equipment since the exhalation valve is held open by the continuous outward flow of air. Demand and pressure-demand versions of air line units have physiological effects similar to the SCBA, except for the additional weight burden of the SCBA.

6. Medical Evaluation Rationale

6.1 The effects of physical work effort, protective clothing, temperature, humidity, and the physiological burden placed on a worker using a respirator shall be considered during the medical evaluation for respirator use. PLHCPs shall provide reasonable assurance that a worker can endure these stressors without adverse medical consequences and recommend any limitations on respirator use related to the medical condition of the employee or the workplace conditions in which the respirator will be used.

7. Qualifications of Persons Who Conduct Medical Evaluations to Determine Suitability to Use Respiratory Protective Devices

7.1 Medical evaluation shall be performed by a PLHCP.

7.2 PLHCPs are expected to consult with an appropriate physician when questions arise about an employee's physical condition and capability, such as those described in this practice.

8. Evaluation Requirements

8.1 The industrial hygienist, safety professional, or other employer representative shall provide the PLHCP with supplemental information before the PLHCP makes a recommendation concerning an employee's ability to use a respirator. The following supplemental information shall be provided (see Fig. A2.2):

8.1.1 The type and weight of the respirator to be used by the employee, and this should include effort of breathing and special features such as size, shape, bulk, full face, hood, and so forth;

8.1.2 The duration and frequency of respirator use (including use for rescue and escape);

8.1.3 The expected physical work effort;

8.1.4 Additional protective clothing and equipment to be worn;

8.1.5 Temperature and humidity extremes that may be encountered;

8.1.6 A copy of the written respiratory protection program; and

8.1.7 A copy of 29 CFR Part 1910.134.

8.2 Extent of usage should be defined as:

8.2.1 On a daily basis (if so, state maximum hours a day of expected use);

8.2.2 Occasionally, but probably more than once weekly (as in maintenance worker); if so state maximum hours per week of expected use;

8.2.3 Rarely (if so, state maximum hours per year of expected use); and

8.2.4 For emergency situations only.

8.3 Special responsibilities should be defined, such as individuals who have responsibility for the safety of others and consequently may be expected to have special physical capabilities. This would include rescue workers, firefighters, security personnel, and the like.

8.4 The estimated frequency for each type of "emergency situation" that may pose an IDLH risk should be provided.

8.5 Other special environmental conditions (that is, excessive heat, confined space usage, and hyperbaric or hypobaric environments) should be identified. Additional requirements for protective clothing should also be listed.

8.6 The above supplemental information need not be provided for subsequent medical evaluations if the information remains the same and is transferred to the new evaluator.

8.7 The agents to which a worker will be exposed should be identified for regularly scheduled work and during emergencies when possible.

8.8 Based on this medical evaluation and the information provided, the PLHCP shall certify whether the individual is permitted to use a respirator under the circumstances described. The physical demands of the work shall be the limiting factor. The special characteristics of the respirator(s) to be used for this work insofar as they significantly increase the work demands while in use shall be considered.

8.8.1 In addition to the classification for respirator use, the report to the employer representative should include any other work limitations or restrictions found during evaluation, even if they are not necessarily related specifically to respirator use.

8.8.2 The PLHCP shall classify the examinee in a category as follows (see Fig. A2.1).

8.8.2.1 Class 1—No restriction on respirator use.

8.8.2.2 Class 2—Conditional respirator use permitted subject to specific use restrictions, medical evaluations, or treatments. These work restrictions should be identified to permit a decision by the supervisor or safety representative to determine suitability for a specific task. Restrictions may include moderate/light work only, no SCBA use, PAPR only, annual medical evaluation, or age-specific medical evaluation.

8.8.2.3 Class 3—Permanent restriction from respirator use. No respirator use permitted (permanently) under any circumstances. The reason should not be identified on the report to the supervisor or the safety department or other groups responsible for the respirator program.

8.8.2.4 Class 4—Temporary restriction from respirator use. No respirator use permitted (temporary). Worker requires additional medical evaluation or treatment, or both, and physician evaluation.

8.8.2.5 Class 5—Additional temporary or permanent non-respirator work restrictions (for example, no heavy lifting, no climbing, and no heat stress).

8.9 A written respiratory protection program shall include a written worksite-specific procedure describing the medical evaluation process for respirator users.

9. Medical History

9.1 A medical history (respirator questionnaire) should be used to identify (see Fig. A2.3 for example):

9.1.1 Previously diagnosed diseases, particularly known cardiovascular or respiratory diseases;

9.1.2 Psychological problems or symptoms including claustrophobia;

9.1.3 Problems associated with breathing during normal work activities;

9.1.4 Past problems with respirator use;

9.1.5 Past and current usage of medication;

9.1.6 Any known physical deformities or abnormalities, including those that may interfere with respirator use; and

9.1.7 Known current pregnancy.

9.2 The PLHCP shall review the medical questionnaire. Conditions that may possibly disqualify personnel for respirator use, as identified by a positive response on the respirator questionnaire, shall be followed by an interview with a PLHCP.

9.2.1 If indicated, following an interview, the PLHCP shall refer or perform an evaluation of the individual (see Fig. A2.1). The PLHCP will determine the scope of the evaluation and what testing, if any, shall be required to determine medical suitability to use a respirator.

9.2.2 In certain cases following an evaluation, additional medical tests, consultation, or diagnostic procedures (such as, a cardiac EST, spirometry, an audiogram, and an ophthalmology consultation) may be necessary to make a final determination (see Annex A1 and Fig. A2.1). Only the PLHCP's determination shall be communicated to the supervisor/manager; no medical information shall be communicated.

10. Medical Evaluation

10.1 *Frequency*—An initial medical evaluation shall be performed using a medical history (respirator questionnaire, see Fig. A2.3) or interview and examination that obtain the same information as the medical questionnaire. Additional evaluations shall be required if: (*1*) the employee reports

medical signs or symptoms that are related to the ability to use a respirator; (*2*) a PLHCP, supervisor, or the respirator program administrator informs the employer that an employee needs to be reevaluated; (*3*) information from the respiratory protection program including observations made during fit testing and program evaluation indicates a need for employee reevaluation; or (*4*) a change occurs in workplace conditions (for example, physical work effort, protective clothing, and temperature) that may result in a substantial increase in the physiological burden placed on an employee.

10.1.1 In addition, a follow-up questionnaire or interview should be used periodically to identify medical conditions that develop after the initial evaluation. This questionnaire could be administered before an annual fit test (see Fig. A2.4). The frequency of this follow-up could be age specific, for example, every five years up to age 35, then every two years until age 45, and annually thereafter.

10.1.2 Annual evaluations for SCBA users of all ages shall be required.

10.1.3 Following review of the periodic questionnaire, interview, and/or limited medical testing, the PLHCP may determine that certain individuals require additional evaluation (such as all or part of the physical examination and testing described in Fig. A2.1) and/or medical testing, consultation, or diagnostic procedures.

10.2 *General Considerations*—The PLHCP's evaluation of suitability of the individual examinee for respirator use shall be based on the unique medical status of the individual (regarding the workload to be performed while wearing the respirator).

10.2.1 Following the initial or a subsequent evaluation, the PLHCP may determine that periodic medical reevaluation (examination, testing, or consultation) is appropriate for a certain individual.

10.2.2 The PLHCP shall provide the worker/employee and the employer with a written recommendation regarding the worker's medical ability to use a respirator (see Fig. A2.2). The PLHCP shall also notify the worker/employee of any medical conditions, actions recommended, and the frequency of necessary periodic evaluations (see Fig. A2.5).

10.2.3 The following conditions shall be considered temporarily disqualifying for most respirator use. These conditions may require medical evaluation or treatment and may result in permanent restriction from respirator use. Additional communication with the PLHCP and monitoring of health status may help to disposition workers with these conditions.

10.2.3.1 Facial conditions such as deformities or facial hair that prevent tight-fitting respirators from making an acceptable seal may disqualify the applicant from wearing a tight-fitting respirator. A fit test is performed to determine whether facial deformity will affect the respirator fit. A fit test shall not be conducted if there is any hair growth between the skin and the face piece sealing surface, such as stubble beard growth, beard, mustache, or sideburns that cross into the respirator sealing surface.

10.2.3.2 Acute respiratory diseases that are anticipated to resolve (including acute pneumonia, acute bronchitis, and acute asthma) may prevent respirator use.

10.2.3.3 "Moderate to severe" restrictive or obstructive pulmonary disease or perfusion disorders may require further evaluation. The worker's medical history, physical examination, and spirometry results may be used as a basis for temporary disqualification pending further medical evaluation (see Fig. A2.1). Spirometry may also be useful for medical surveillance purposes with certain workplace exposures.

10.2.3.4 Symptomatic CAD, significant arrhythmias (for example, PVCs, tachycardia, or bradycardia), or a history of myocardial infarction may require further evaluation. If an EKG is performed, it should be interpreted using informed clinical judgment with consideration of the worker's overall health status.

10.2.3.5 The PLHCP, using clinical judgment, shall decide if individuals with treated or untreated hypertension, individuals using cardiovascular medications, and individuals with multiple risk factors or a single extreme risk factor require further medical evaluation.

10.2.3.6 Workers with an SBP greater than or equal to 180 or a DBP greater than or equal to 110, treated or untreated, shall be temporarily restricted from respirator use. Workers with an SBP greater than or equal to 140 or a DBP greater than or equal to 90 shall be referred for physician evaluation. The PLHCP will disposition the worker after consideration of the medical information provided and the work effort anticipated.

10.2.3.7 In cases in which the PLHCP has concerns about a worker's ability to use respiratory protective devices because of abnormal pulmonary function testing (11.1 and Annex A3), a history of CAD, obesity (BMI of greater than 35), or a combination of these or other medical problems, the worker may be medically cleared for respirator use at a known level of work (light, moderate, or heavy) by use of an EST. The demonstration of greater than or equal to 10 METs functional capacity absent ischemia, arrhythmia, or abnormal BP response on a physician-supervised EST is considered adequate for clearance to perform most heavy physical work and to work in heat stress environments (see 11.1 and Annex A1).

10.2.3.8 *Neurological Disability*—Certain neurological disorders that affect movement or consciousness or both may be aggravated by the work environment associated with respirator use (heat, humidity, protective clothing, and strenuous work). Workers with such a disorder shall be temporarily disqualified pending physician evaluation.

10.2.3.9 *Medications*—PLHCPs shall use clinical judgment to determine if an individual should be denied use of a respirator because of medication use (including prescription and non-prescription drugs) that may affect an employee's ability to perform his or her job. This decision may involve communication with the PLHCP.

10.2.3.10 *Psychological Conditions*—The PLHCP shall decide if an employee with a psychological condition that may impair judgment or reliability should be disqualified (for example, claustrophobia or severe anxiety). The decision may involve communication with the PLHCP. The PLHCP may recommend observed fit testing for the examinee.

10.2.3.11 Hearing should be adequate to ensure response to instructions and alarm systems, or hearing deficiencies should be otherwise accommodated. In certain work environments,

olfaction may be an important sense to warn respirator users of poor face seal or other causes of respirator failure. Workers who report trouble smelling odors may require work restriction or additional medical evaluation (which may include olfactory testing), and these workers may be unsuitable for fit testing methods that rely on odor detection. Workers shall have adequate vision to perform their assigned job duties.

10.2.3.12 If a worker has suffered a sudden loss of consciousness or response capability, a physician shall determine if the employee may use a respirator.

11. Special Testing

11.1 Spirometry or EST may be used if the PLHCP needs information in addition to a history and physical. Spirometry results do not in themselves indicate fitness or lack of fitness to use a respirator. For accurate assessment, spirometry should be performed in accordance with the most recent recommendations of the American Thoracic Society/European Respiratory Society (ATS/ERS) and the American College of Occupational and Environmental Medicine (see Annex A3).

12. Keywords

12.1 physician or other licensed healthcare professional; PLHCP; respirator user; respiratory protection program

ANNEXES

(Mandatory Information)

A1. EXERCISE STRESS TESTING

A1.1 Clinical exercise testing, or the EST, is a useful test for evaluating the functional capacity (work capacity) of users of industrial respirators, as respiratory reserve is normally greater than circulatory system reserve and cardiac disease is common in working populations (**1**).[4] Cardiac disease is a common cause of sudden incapacity and decreased functional capacity. For normal humans, it appears there is no single exercise-limiting factor; the heart with contributions of muscle, rather than lungs and blood, is largely responsible for exercise limitations, training effects, and differences in exercise capacity between people (**2**).

A1.2 The EST is a convenient means of determining exercise tolerance and precipitating symptoms and signs in a controlled environment using a standard protocol. Standardized protocols, reduced equipment costs, and computerized interpretations have greatly enhanced the practicality and availability of this testing. Observations of heart rate are easily available data to compare performance on an EST with demands of job activities. At submaximal workloads, the relationship between heart rate and oxygen uptake (workload) is almost linear (**3**).

A1.3 Maximal testing with the aim of establishing safe levels of exercise or work performance can be performed on any person and aerobic capacity reported as METs (1 MET = metabolic equivalent = energy expended at rest = 3.5 mL O_2/kg/min) (**3**).

A1.4 It is prudent to perform selectively supervised EST in respirator users who are expected to engage in heavy work if the evaluating PLHCP suspects deconditioning or coronary disease on the basis of signs, symptoms, or risk factors. EST for cardiovascular fitness may be necessary, especially if the work requires strenuous exertion, heat stress will be present, or a clinical indication of a cardiovascular abnormality is present. The use of respirators in conjunction with water-impermeable protective clothing can impose significant thermal stress. Such situations occur in the hazardous waste, nuclear, and other industries. EST may also be advisable in the first two situations for workers older than 45 years of age regardless of clinical status. Resting EKGs are not predictive of risk from respirator use during exertion (**4**).

A1.5 EST requires the active cooperation and informed consent of the participant. Stress testing may not detect significant coronary disease, especially in asymptomatic workers (**5**). And in young, healthy individuals false positives may occur. In such cases, there should be a way to quickly obtain confirmation using a technique such as a radionuclide stress imaging. Although EST cannot reliably identify all persons at risk of an acute event, it may increase the margin of safety. Workers should be evaluated on an individual basis and additional testing such as imaging studies may also be recommended for those considered to be at higher risk (**3**).

A1.6 Supervision during EST should be provided by a physician with appropriate training and experience (**6**).

A1.7 Many protocols and types of equipment (treadmill, cycle ergo meter) are available to perform EST. The choice of equipment and protocol should be the decision of the testing physician.

A1.8 Workers are less likely to have clinically significant CAD if they achieve a level of 10 METs functional capacity (**7**) with absence of arrhythmia, abnormal blood pressure response, or ischemia and are usually capable of performing heavy physical work and work in high-heat stress situations (**8**).

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.