Designation: E2952 – 17 (Reapproved 2021)

Standard Specification for Air-Purifying Respiratory Protective Smoke Escape Devices (RPED)[1]

This standard is issued under the fixed designation E2952; 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 specification covers the minimum requirements for the design, performance, testing, and certification of air-purifying respiratory protective smoke escape devices for immediate emergency evacuation without entry/re-entry.

1.2 The purpose of this specification shall be to provide minimum requirements for respiratory protective escape devices that provide limited protection for 15 min for escape from the by-products of fire, including particulate matter, carbon monoxide, other toxic gases, and the effects of radiant heat.

1.3 The requirements of this specification specify an air-purifying respiratory protective escape device with a laboratory-tested 15-min service life intended to provide head, eye, and respiratory protection from particulate matter, irritants, and toxic gases and vapors commonly produced by fire.

1.4 Controlled laboratory tests that are used to determine compliance with the performance requirements of this specification shall not be deemed as establishing performance levels for all situations to which individuals can be exposed.

1.5 This specification shall not apply to the requirements for provision, installation, or use of air-purifying respiratory protective smoke escape devices.

1.6 This specification shall not apply to respiratory protective escape devices intended for use in circumstances in which an oxygen deficiency (oxygen less than 19.5 % by volume) exists or might exist.

1.7 This specification is not intended to be used as a detailed manufacturing or purchase specification, but shall be permitted to be referenced as a minimum requirement in purchase specifications.

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

1.9 *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.*

1.10 *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]

B117 Practice for Operating Salt Spray (Fog) Apparatus

D1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics

D4101 Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials

F1140 Test Methods for Internal Pressurization Failure Resistance of Unrestrained Packages

2.2 *ISO Standards:*[3]

ISO/IEC 17065 Conformity Assessment—Requirements for Bodies Certifying Products, Processes and Services

ISO 9001 Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

ISO 9002 Quality Systems—Model for Quality Assurance in Production, Installation, and Servicing.

2.3 *NFPA Standard:*[4]

NFPA 1981 Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service

3. Terminology

3.1 *Definitions:*

[1] This specification is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.04 on Personal Protective Equipment (PPE).

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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 International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.1.1 *air-purifying respiratory protective smoke escape device, RPED, n*—air-purifying respirator used to protect a person while escaping from a fire by removing certain contaminants of fire-generated products of combustion from the inhaled air.

3.1.2 *accessory, n*—item that may be provided with an RPED that does not affect its ability to meet the requirements of this specification.

3.1.3 *approved, adj*—acceptable to the authority having jurisdiction.

3.1.4 *authority having jurisdiction, n*—organization, office, or individual responsible for approving any equipment, an installation, or a procedure.

3.1.5 *basic plane, n*—plane through the centers of the external ear openings and the lower edges of the eye sockets.

3.1.6 *certification/certify, n/adj*—system whereby an organization determines that a manufacturer has demonstrated the ability to produce a product that complies with the requirements of this specification, authorizes the manufacturer to use a label on listed products that comply with the requirements of this specification, and establishes a follow-up program conducted by the organization as a check on the methods the manufacturer uses to determine continued compliance of labeled and listed products with the requirements of this specification.

3.1.7 *certification organization, n*—independent third-party organization that determines product compliance with the requirements of this specification with a labeling/listing/follow-up program.

3.1.8 *compliance/compliant, n/adj*—meeting or exceeding all applicable requirements of this specification.

3.1.9 *donning time, n*—time for equipment in hand to be placed over the head of the wearer and become functional. This time shall include the removal of an operational packaging.

3.1.10 *follow-up program, n*—sampling, inspections, tests, or other measures conducted by the certification organization on a periodic basis to determine the continued compliance of listed products that are being produced by the manufacturer to the requirements of this specification.

3.1.11 *gas, n*—fluid that has neither independent shape nor volume and tends to expand indefinitely.

3.1.12 *haze, n*—percent of incident light that is not transmitted in a straight line through the lens but forward scattered, greater than 2.5° diverging.

3.1.13 *identical respiratory protective escape device, n*—RPED that is produced to the same engineering and manufacturing specifications.

3.1.14 *labeled, adj*—equipment or material to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.1.15 *light transmission, n*—ratio of the luminous (approximately 380- through 760-mm) radiant power transmitted by an object to the incident luminous radiant power.

3.1.16 *listed, adj*—equipment, materials, or services included in a list published by the certification organization.

3.1.17 *melt, v*—to change from solid to liquid or become consumed by action of heat in a manner that could injure the user.

3.1.18 *model, n*—term used to identify an RPED, including all variants to its design.

3.1.19 *product label, n*—marking affixed to the RPED by the manufacturer containing general information, warnings, care, maintenance, or similar data.

3.1.19.1 *Discussion*—This product label is not the certification organization's label, symbol, or identifying mark; however, the certification organization's label, symbol, or identifying mark may be attached to it or be part of it. *See* **labeled**.

3.1.20 *ready-to-use configuration, n*—RPED in its final packaging state before use that, immediately upon opening or removing this operational package, allows the user to don the RPED.

3.1.21 *RPED, n*—a "short hand" acronym for Air-Purifying Respiratory Protective Smoke Escape Device.

3.1.22 *service life, n*—the manufacturer-declared duration of protection provided by the RPED for escape once the operational packaging is opened or removed from an RPED in a ready-to-use configuration.

3.1.23 *shall, v*—indicates a mandatory requirement.

3.1.24 *shelf life, n*—duration that an RPED can be stored under proper conditions in its ready-to-use configuration and remain suitable for use.

4. Performance Requirements

4.1 *Carbon Dioxide (CO_2) Inhalation*—RPED shall be tested for CO_2 levels in the inspired air stream as specified in 7.1 and shall not contain CO_2 concentration levels that exceed 2.5 %.

4.2 *Donning*—RPED shall be tested for donning ability as specified in 7.2. The time needed to don the RPED shall not exceed 30 s.

4.3 *Breathing Resistance:*

4.3.1 RPED shall be tested for resistance to breathing as specified in 7.3. The maximum inhalation resistance shall be 81.5-mm water column below ambient pressure from the beginning of the test until its conclusion.

4.3.2 RPED shall be tested for resistance to breathing as specified in 7.3. The maximum exhalation resistance shall be 30.6-mm water column above ambient pressure from the beginning of the test until its conclusion.

4.4 *Particulate Filtration*—RPED shall be tested for the filtration of particles as specified in 7.4. The minimum filtration efficiency shall be 95 % at any time during the test.

4.5 *Total Inward Leakage:*

4.5.1 RPED shall be tested for proper fit as specified in 7.5. The maximum total inward leakage of the challenge agent shall be an average of 2 % of the inhaled air for any of the test subjects in any of the test exercises.

4.5.2 The measured inward leakage shall include the exhalation valve leakage.

4.6 *Optical Properties:*

4.6.1 *Light Transmission*—The vision area of the RPED shall be tested for light transmission as specified in 7.6.1. The vision area shall have minimum light transmission of 20 % and the haze shall not exceed 15 %.

4.6.2 *Field of Vision*—The field of vision of the RPED shall be tested as specified in 7.6.2 and shall have a score of at least 70.

4.6.3 *Fogging*—The vision area of the RPED shall be tested for fogging as specified in 7.6.3. The test subject shall be capable of reading the Snellen eye chart at the 20/100 level.

4.6.4 *Ocular Leakage*—RPED shall be tested for ocular leakage as specified in 7.6.4. The maximum total ocular leakage of the challenge agent shall be an average of 20 % of the outside challenge environment for any of the test subjects in any of the test exercises.

4.7 *Operational Packaging Leakage:*

4.7.1 RPED shall be tested for leakage in its ready-to-use configuration as specified in 7.7.1.

4.7.2 After immersion, the exterior shall be immediately dried and weighed. There shall be no additional weight gain in excess of the tolerance of the scale.

4.7.3 RPED shall be tested for burst strength in its ready to use configuration as specified in 7.7.2.

4.7.4 The RPED in the ready-to-use configuration shall not experience a package burst until the internal pressure has been raised by at least 450 mbar (6.5 psi).

4.8 *Chemical Capacity*—The RPED shall be tested for gas breakthrough as specified in 7.8. The RPED shall have a minimum gas life of 15 min for the breakthrough conditions for each of the seven specific gases detailed herein.

4.9 *Inhalation Temperature*—RPED shall be tested for inspired air temperature as specified in 7.9. The inhalation temperature shall not exceed 90°C dry bulb or 50°C wet bulb when run at a cyclic flow.

4.10 *Soot Particulate:*

4.10.1 RPED shall be tested for increased inhalation breathing resistance as a result of soot particulate as specified in 7.10. The inhalation breathing resistance shall not exceed 204-mm water column.

4.10.2 RPED shall be tested for increased exhalation breathing resistance as a result of soot particulate as specified in 7.10. The exhalation breathing resistance shall not exceed 153-mm water column.

4.11 *Flammability:*

4.11.1 RPED shall be tested for heat and flame resistance as specified in 7.11. Components of the RPED shall not have any after flame after 5 s.

4.11.2 RPED shall be tested for heat and flame resistance as specified in 7.11. No RPED component shall drip, melt, or develop a hole that is visible to the unaided eye or be damaged in a manner that exposes eyes or lungs to gas or smoke.

4.11.3 After having been tested for heat and flame, the RPED shall be evaluated for vision as specified in 7.11.8. The 20/100 vision lines shall be legible.

4.12 *Molten Polymeric Drip Resistance:*

4.12.1 RPED shall be tested for resistance to molten drips as specified in 7.12. Any after flame shall not exceed 5 s.

4.12.2 RPED shall be tested for resistance to molten drips as specified in 7.12. The decrease in inhalation resistance shall not exceed 25 %.

4.12.3 RPED shall be tested for resistance to molten drips as specified in 7.12. No component shall drip, melt, or develop a hole that is visible to the unaided eye.

4.13 *Radiant Heat Resistance:*

4.13.1 RPED shall be tested for resistance to radiant heat as specified in 7.13. The temperature at the top of the head form and in the eyepiece shall not exceed 70°C.

4.13.2 RPED shall be tested for resistance to radiant heat as specified in 7.13. RPED shall not become damaged in a manner that exposes eyes or lungs to gas or smoke.

4.14 *Corrosion Resistance:*

4.14.1 RPED shall be tested for resistance to corrosion as specified in 7.14 and shall be evaluated for the proper use and function of all controls or operating features, as specified in the manufacturer's instructions.

4.14.2 Metals that are used in the RPED, storage containers, and accessories that are inherently resistant to corrosion including, but not limited to, stainless steel, brass, copper, aluminum, and zinc, shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metals.

4.14.3 Following the corrosion resistance testing in accordance with 7.14, RPED shall then be tested for resistance to breathing as specified in 7.3. The inhalation resistance shall not exceed 85-mm water column below ambient pressure from the beginning of the test until its conclusion.

4.14.4 Following the corrosion resistance testing in 7.14, RPED shall then be tested for resistance to breathing as specified in 7.3, Air Flow Resistance Test. The exhalation resistance shall not exceed 30.6-mm water column *above* ambient pressure from the beginning of the test until its conclusion.

5. Design Requirements

5.1 *General:*

5.1.1 The design of the RPED shall provide protection to the wearer's head, eyes, and respiratory system specified by this specification.

5.1.2 The RPED shall consist of at least a hood and a respiratory protection system.

5.1.3 All materials shall be free of sharp edges, burrs, and rough spots.

5.1.4 Materials containing latex shall be labeled as such.

5.1.5 The RPED shall not require the use of hands to maintain the RPED in place on the user or maintain the proper functioning of the RPED other than for donning and doffing.

5.1.6 The RPED shall have a tamper seal in its ready-to-use configuration. The tamper seal shall indicate whether the ready-to-use configuration of the RPED has been breached.

5.1.7 The tamper seal shall be secured against accidental opening but shall be able to be broken rapidly without the use of tools. Where the tamper seal has been broken, it shall be visually obvious.

5.1.8 The operational packaging seal required by 7.7 shall be permitted to be the same as the tamper seal.

5.2 *Hood:*

5.2.1 The RPED shall be designed as a hooded device. The hood shall cover the entire head of the wearer.

5.2.2 The RPED hood shall be available in not more than three separate and distinct sizes that fit all the anatomical dimensions specified in Table 1.

5.2.3 The RPED hood shall include an area for field of vision.

5.2.4 The hood shall be compatible with the wearing of eyeglasses.

5.3 *Respiratory Protection System:*

5.3.1 The respiratory protection system shall consist of an air-purifying element and a means of conveying the purified air to the wearer such that the RPED meets the performance requirements of 4.1 – 4.10 except 4.7.

5.3.2 The respiratory protection system shall be designed in such a manner that the air-purifying element(s) shall not be degraded by the CO_2 and humidity of the user's exhaled air.

5.3.3 The air-purifying element(s) shall be designed and installed so that the inhaled gas first passes through the particulate component before passing through the gas protection component.

5.4 *Accessories:*

5.4.1 Any accessories that are attached to an RPED shall not interfere with the function of the RPED or with the function of any of the RPED component parts.

5.4.2 Where an RPED is provided with an accessory or accessories that are attached to or integrated with the RPED, the RPED shall meet all of the design and performance requirements of this specification with the accessories installed. In all cases, such accessories shall not degrade the performance of the RPED.

6. Conditioning

6.1 *General:*

6.1.1 For the purpose of initial certification, a total of 43 RPED in the ready-to-use configuration shall be used as test specimens.

TABLE 1 Face, Neck, and Head Anatomical Dimensions

	Small (mm)	Medium (mm)	Large (mm)
Head Circumference	527–552	553–578	579–604
Neck Circumference	295–351	352–408	409–465
Face Length[A]	98.5–108.5	109–128.5	129–138.5
Lip Length	40–46	47–54	55–61

[A] Menton-nasal root depression length.

6.1.2 Ten of the RPED to be used for testing for the performance requirements specified in 4.5 shall be unconditioned.

6.1.3 The remaining 33 RPED shall be conditioned as specified in this section and in Table 2.

6.1.3.1 Thirty-one RPED shall be sequentially subjected to the conditioning procedures specified in 6.2 – 6.5 before testing for the performance requirements specified in 4.1, 4.3, 4.4, 4.6.1, 4.6.3, and 4.7 – 4.14.

6.1.3.2 Two RPED shall be subjected only to the conditioning procedure specified in 6.5 before testing for the performance requirements specified in 4.2 and 4.6.2

6.1.4 The conditioned or unconditioned state of the RPED shall be as specified in Table 2.

6.2 *Vibration Conditioning:*

6.2.1 Each RPED shall be placed into a compartment of the vibration equipment as specified in Fig. 1(a) and (b). Each RPED shall be conditioned in the ready-to-use configuration. The compartment shall be sized to allow horizontal movement in any direction of 7 ± 3 mm and free vertical movement.

6.2.2 The vibration equipment shall consist of a steel case affixed to a vertically moving piston that is attached to a rotating cam. The combined piston and case shall be raised by a rotating cam to a vertical height of 19 ± 1 mm and allowed to fall under its own weight onto a steel plate as the cam rotates at a rate of 100 ± 2 rpm.

6.2.3 Each RPED shall be vibrated for 10 000 cycles.

6.3 *Puncture and Tear Conditioning:*

6.3.1 The puncture and tear conditioning apparatus shall consist of the following six major parts as shown in Fig. 2:

6.3.1.1 A pointed striker of nonmalleable metal,

6.3.1.2 Removable weights on the striker,

6.3.1.3 A holder arm that supports the striker and weights,

6.3.1.4 A hinge of adjustable height with minimal friction,

6.3.1.5 A support arm, and

6.3.1.6 A base to which the support arm is attached and that holds the RPED in place.

6.3.2 The striker assembly, composed to the striker, holder arm, and weights, shall have a weight of 100 ± 0.5 g measured at the tip of the striker in a level orientation. The weight of the striker assembly shall be adjusted by adding weights to or removing weights from the striker.

6.3.3 The RPED shall be centered in its ready-to-use configuration under the striker, and the striker assembly shall be adjusted so that the distance between the bottom of the striker and the top of the RPED is 100 ± 2 mm.

6.3.4 The striker shall be held at a distance of 100 ± 2 mm above the RPED and then released onto the RPED.

6.3.5 While the striker is resting on the RPED, the RPED shall be pulled in a horizontal direction until the striker is free from the RPED.

6.3.6 The procedures specified in 6.3.2 – 6.3.5 shall be repeated using two other locations on the RPED 90° apart from the initial test location.

6.4 *Pressure Conditioning:*

6.4.1 The RPED shall be placed in a pressure chamber and shall be subjected to 1000 cycles of differential pressure from

TABLE 2 RPED Initial Certification Testing Matrix

Test Section	Test Specimen Number				
	Conditioning Section				
	Vibration 6.2	Puncture/Tear 6.3	Pressure 6.4	Temperature 6.5	None
7.1 CO_2	43	43	43	43	
7.2 Donning				1-2	
7.3 Air Flow Resistance	3–4	3–4	3–4	3–4	
7.4 Particulate Filtration	4	4	4	4	
7.5 Inward Leakage Fit					5–14
7.6.1 Light Transmission	15	15	15	15	
7.6.2 Field of Vision				1	
7.6.4 Ocular Leakage					5–14
7.7.1 Pressure Test	16	16	16	16	
7.8 Capacity	17–37	17–37	17–37	17–37	
7.9 Inhalation Temperature	38	38	38	38	
7.10 Soot Particulate	39	39	39	39	
7.11 Flammability	40	40	40	40	
7.12 Molten Polymeric Drip	41	41	41	41	
7.13 Radiant Heat	42	42	42	42	
7.14 Corrosion Resistance	3	3	3	3	

Test Specimen Number	Test Section	Conditioning Requirements
1	7.6.2 Field of Vision	Temperature (6.5)
1–2	7.2 Donning	Temperature (6.5)
3	7.14 Corrosion Resistance	All
3–4	7.3 Air Flow Resistance	All
4	7.4 Particulate Filtration	All
5–14	7.5 Inward Leakage Fit	None
5–14	7.6.4 Ocular Leakage	None
15	7.6.1 Light Transmission	All
16	7.7.1 Pressure Test	All
17–37	7.8 Capacity	All
38	7.9 Inhalation Temperature	All
39	7.10 Soot Particulate	All
40	7.11 Flammability	All
41	7.12 Molten Polymeric Drip	All
42	7.13 Radiant Heat	All
43	7.1 CO_2	All

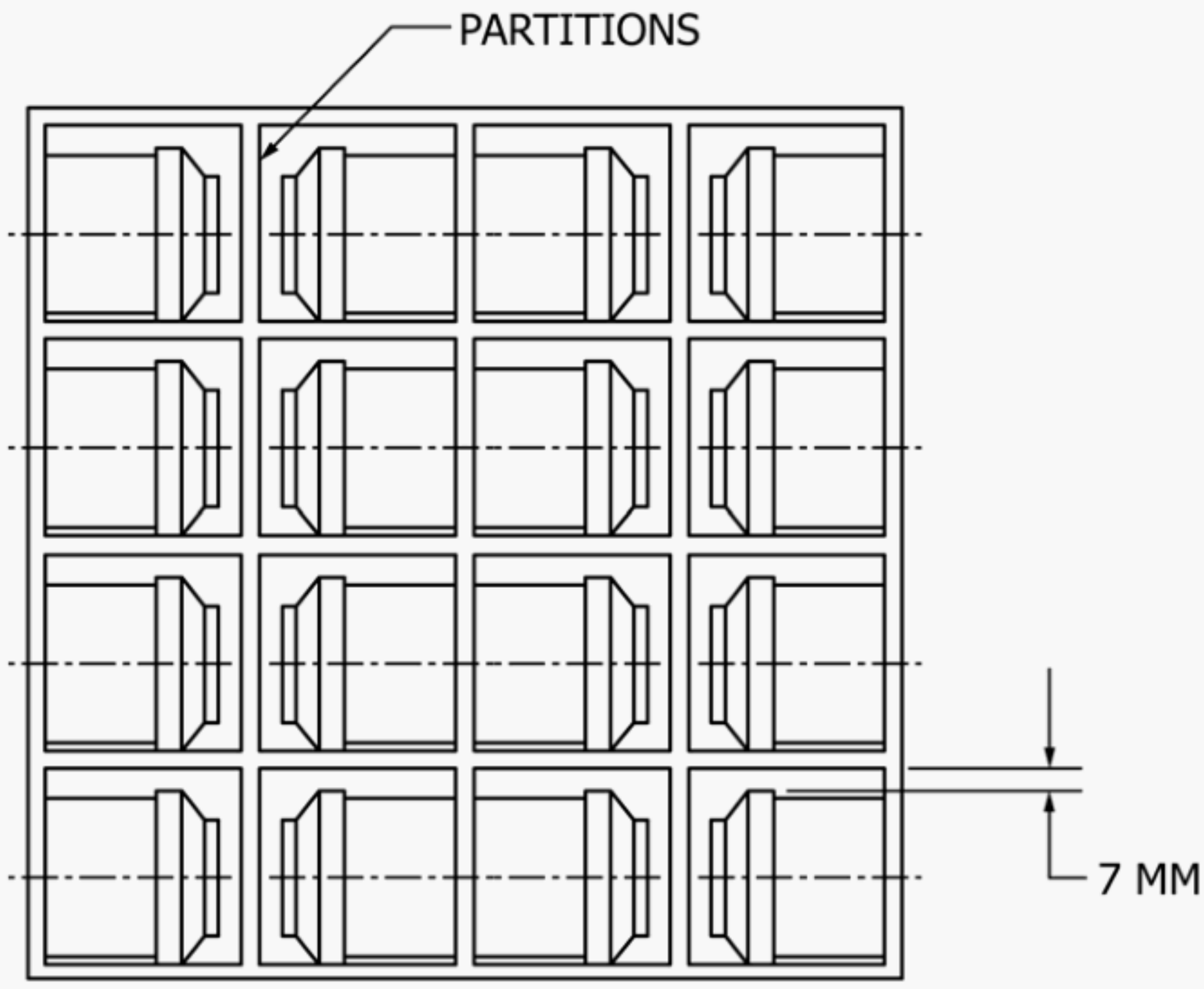

FIG. 1 (a) Vibration Test Device

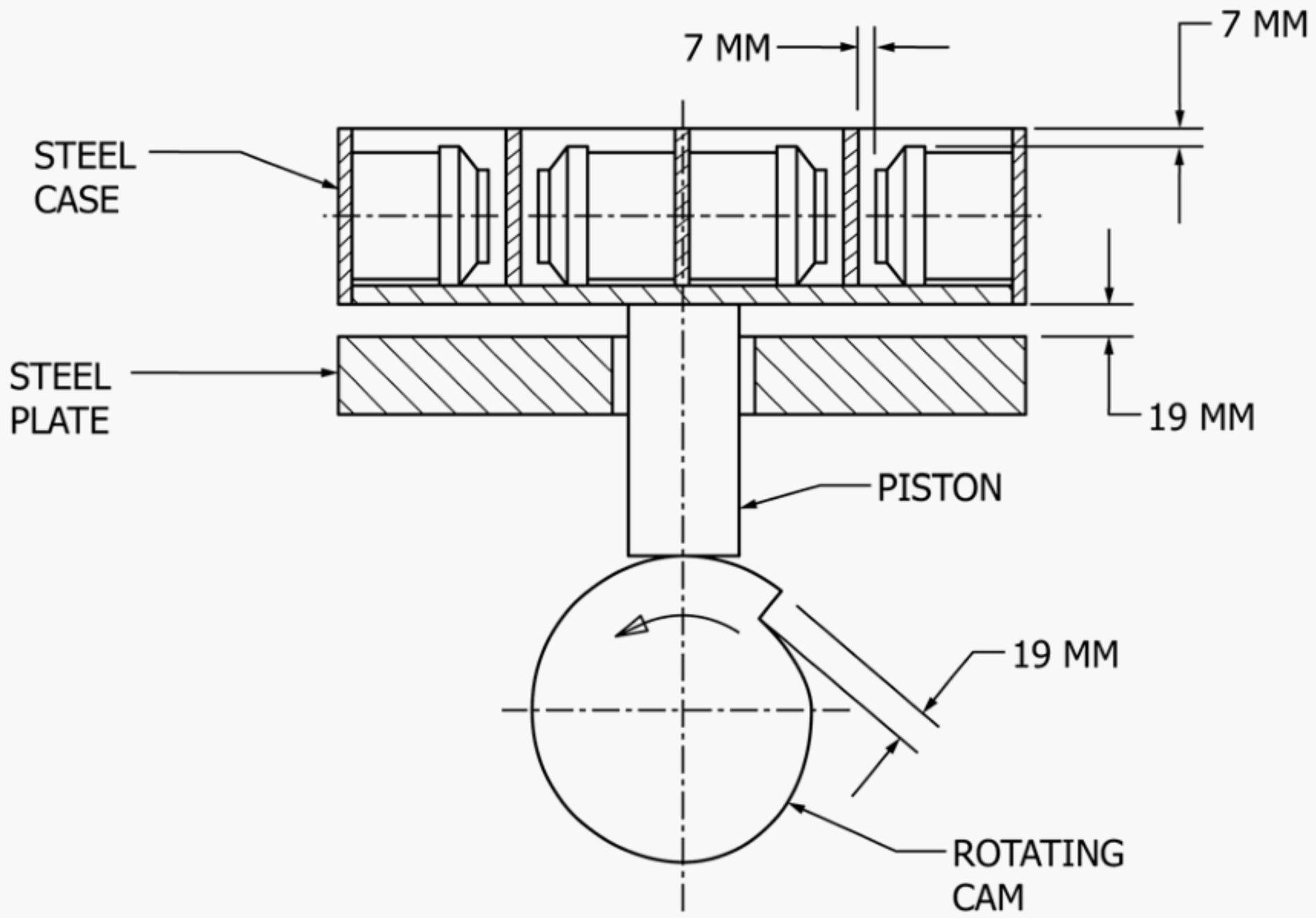

FIG. 1 (b) Vibration Test Device *(continued)*

ambient to 300 ± 10 mbar below ambient pressure in accordance with the following cycle sequence:

6.4.1.1 Sixty seconds at ambient pressure,

6.4.1.2 Twenty seconds from ambient pressure to 300 mbar below ambient pressure,

6.4.1.3 Sixty seconds at 300 mbar below ambient pressure, and

6.4.1.4 Twenty seconds from 300 mbar below ambient pressure to ambient pressure.

6.4.2 Where more than one RPED is placed in the chamber during the same conditioning, they shall be positioned so that no RPED comes into contact with another during testing.

6.5 *Temperature Conditioning:*

6.5.1 RPED shall be conditioned at 0 ± 2°C for 24 ± 1 h, followed by conditioning at 70 ± 2°C for 24 ± 1 h.

6.5.2 The transfer time of RPED between the elevated and low temperatures shall not exceed 5 min.

6.5.3 The low-temperature chamber recovery time after the door is closed shall not exceed 10 min.

6.5.4 After thermal conditioning, all but two of the RPED shall be conditioned at room temperature for a minimum of 24 h before testing begins.

6.5.5 The two remaining RPED shall be used for the testing required by 7.2.

7. Test Methods

NOTE 1—Unless otherwise specified, tolerances of ±0.1 mm shall be applied for dimensions of test fixtures.

7.1 *Carbon Dioxide Test:*

7.1.1 One RPED of each style or model of RPED shall be tested.

7.1.2 Testing shall be conducted as specified in the carbon dioxide test in EN 136.

7.2 *Donning Test:*

7.2.1 The donning test shall be performed within 1 h after the RPED has been removed from the conditioning specified in 6.5.4.

7.2.2 There shall be two test subjects who have not been trained in RPED use and have not previously donned an RPED. The test subjects shall be one female and one male. Neither test subject shall have any obvious mental or physical disabilities that prevent donning of the RPED.

7.2.3 The test subjects shall be given an RPED in the ready-to-use configuration. The test subjects shall be given 120 s to view the donning instructions that are supplied by the manufacturer or printed on the RPED.

7.2.4 After the 120 s required in 7.2.3 has passed, the test subjects shall be instructed to immediately don the RPED without any further instruction and the timer shall be started.

7.2.5 The test conductor shall confirm that the unit is positioned on the wearer's head consistent with the user information provided by the manufacturer.

7.3 *Air Flow Resistance Test:*

7.3.1 The RPED that is to be tested shall be secured to a temperature resistant full-face test head form. Where applicable, manufacturers shall supply fixtures to connect mouthpieces to the test head form.

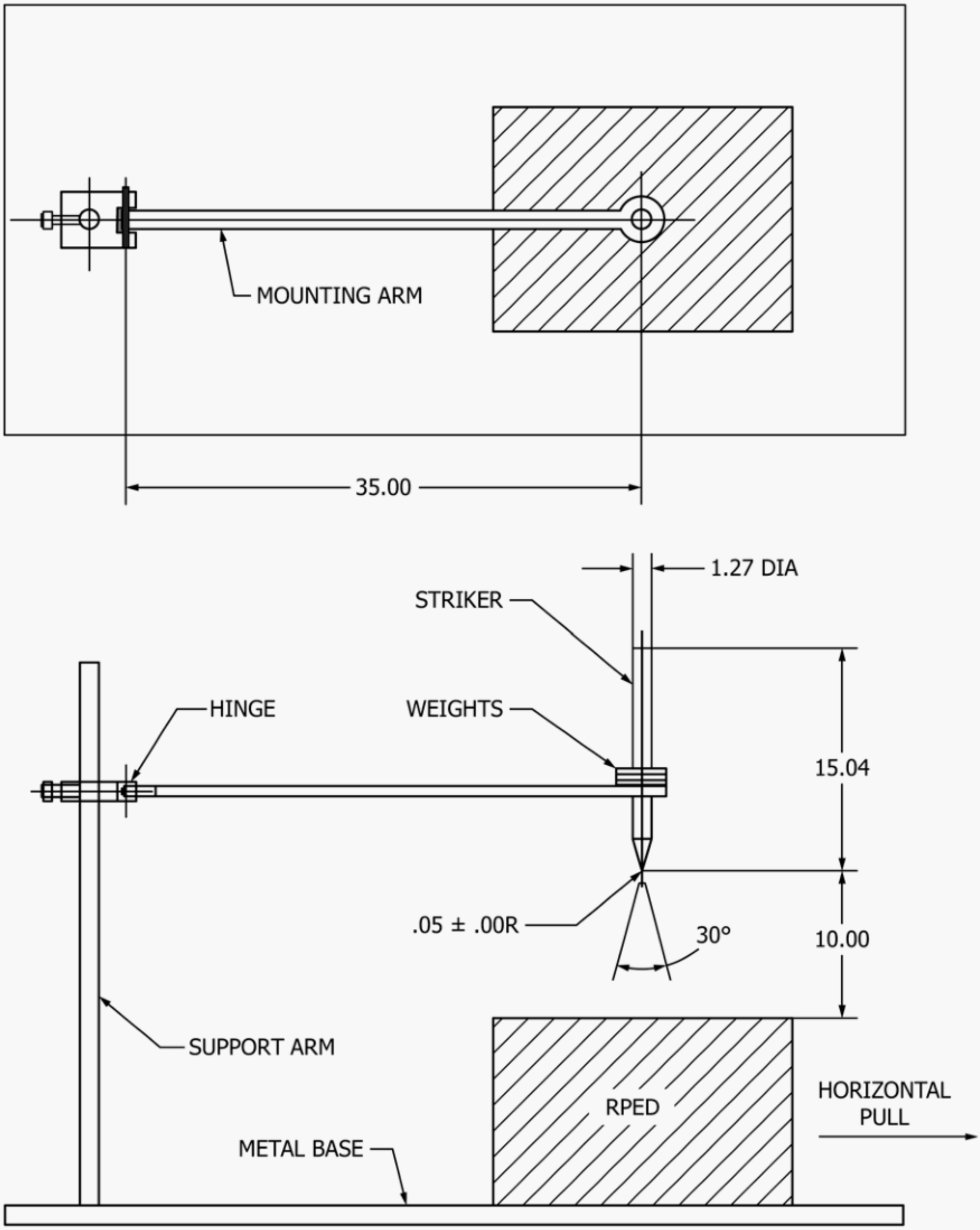

FIG. 2 Puncture Test Device

7.3.2 A pressure probe shall be attached to the test head form. The pressure probe shall be a 6-mm outside diameter (OD) with 2-mm wall thickness metal tube having one open end and one closed end. The closed end shall have four equally spaced holes, each 2 ± 0.1 mm and positioned 6 ± 0.5 mm from the end of the pressure probe.

7.3.3 The closed end of the pressure probe shall extend through the test head form and shall exit at the center of the

mouth. The pressure probe shall extend 13 ± 1.5/-0 mm outward from the surface of the center of the lips.

7.3.4 The open end of the pressure probe shall extend a maximum of 460 mm and a minimum of 25 mm outward from the back surface of the test head form.

7.3.5 A maximum 1.5-m length of nominal 5-mm inside diameter (ID) flexible smoothbore tubing with a nominal 2-mm wall thickness shall be permitted to be connected from the open end of the pressure probe to the inlet of the pressure transducer.

7.3.6 A differential pressure transducer that has the following characteristics shall be used:

7.3.6.1 *Range*—226 mm of water differential,

7.3.6.2 *Linearity*—±0.5 % full-scale (FS) best straight line,

7.3.6.3 *Line Pressure Effect*—Less than 1 % FS zero shift/68 bar,

7.3.6.4 *Output*—±2.5-V DC for ±FS,

7.3.6.5 *Output Ripple*—10-mV peak to peak,

7.3.6.6 *Regulation*—FS output shall not change more than ±0.1 % for input voltage change from 25 to 35 V DC,

7.3.6.7 *Operating Temperature*—From -54 to 121°C,

7.3.6.8 *Compensated Temperature*—From -18 to 71°C, and

7.3.6.9 *Temperature Effects*—Within 2 % FS/56°C error band.

7.3.7 The differential pressure transducer shall be appropriately connected to a strip chart recorder or suitable data acquisition system that has the following characteristics:

7.3.7.1 A chart width of 250 mm,

7.3.7.2 A pen speed of at least 730 mm/s (0.333-s FS),

7.3.7.3 An accuracy of ±0.25 % FS,

7.3.7.4 An input voltage range of 0- to 1-V FS, and

7.3.7.5 A span set at 25 mm of chart per 25-mm water column.

7.3.8 The test head form shall be equipped with a stainless-steel breathing tube that has a 23-mm ID. The metal breathing tube shall be located on the centerline of the mouth and shall be flush with the test head form.

7.3.9 The metal breathing tube shall extend outward from the back or the base surface of the test head form a minimum of 203 mm and a maximum of 457 mm.

7.3.10 If flexible smoothbore tubing is run from the metal breathing tube to the inlet connection of the breathing machine, it shall have a minimum length of 1.2 m and an ID of 19 mm with a nominal 3-mm wall thickness.

7.3.11 A breathing machine as specified in NFPA 1981 shall be used. The breathing machine shall be calibrated before use.

7.3.11.1 The breathing machine shall use the lung breathing waveform for 40-L/min volume work rate but be set at 19 breaths per minute yielding a constant ventilation rate of 31.7 L/min and a peak inspiratory flow of 95 ± 1 L/min.

7.3.11.2 The test conditions shall be as follows:

(1) Ambient Temperature—22 ± 3°C,

(2) Relative Humidity—50 ± 25 %, and

(3) Barometric Pressure—750 + 50/-70 mm Hg.

7.3.11.3 The pressure shall be read from the strip chart recorder to determine pass/fail.

7.4 *Particulate Filtration Test:*

7.4.1 The RPED shall be mounted and sealed on a Scott Aviation model No. 803609-01 or 803606-02 test head form, or equivalent, and shall be tested at a continuous air flow rate of 85 ± 2.5 L/min.

7.4.2 The challenge aerosol shall be an unadulterated and undiluted sodium chloride with a purity level of 99 % or better. The temperature of the challenge aerosol during testing shall be maintained at 25 ± 5°C. The sodium chloride shall have a particle size distribution with a count median diameter of 0.075 ± 0.020 µm and a maximum standard geometric deviation of 1.86 at the specified test conditions as determined by a scanning mobility particle size or equivalent instrumentation.

7.4.3 The RPED shall be exposed to a maximum challenge aerosol concentration of 200 mg/m^3 that has been neutralized to the Boltzmann equilibrium state until the RPED has reached its minimum efficiency or an aerosol mass of at least 200 mg has contacted the filter, whichever occurs first.

7.4.4 The efficiency of the RPED shall be continuously monitored and recorded throughout the test period by a suitable forward-light-scattering photometer or equivalent instrumentation. Sampling shall be "downstream" of the mouth of the test head. The minimum efficiency shall be noted for each test.

7.5 *Total Inward Leakage Fit Test:*

7.5.1 *RPED Modifications:*

7.5.1.1 When an RPED is designed with a mouthpiece, it shall be modified by being equipped with a sampling probe that is located between the mouthbit and the filtering element, but as close to the mouth as practical. The probe shall be leak tight.

7.5.1.2 When an RPED is designed without a mouthpiece, it shall be modified by being equipped with a sampling probe that is located approximately 0.6 cm from the skin at a point midway between the nose and upper lip as close to the center line of the face as possible. The probe shall extend into the oral/nasal cup if present. The exact final position of the sample probe will depend on the design of the RPED. The probe shall be leak tight.

7.5.2 *Test Subjects:*

7.5.2.1 The inward leakage test shall be performed using ten RPED on test subjects. The manufacturer shall provide RPED with size categories that fit ten test subjects whose facial, head, and neck dimensions are provided in Table 1.

7.5.2.2 When the manufacturer requests certification for one size of RPED that fit all three head size categories of Table 1, the RPED shall be apportioned among test subjects in the following manner:

(1) Two test subjects that meet all dimensions of the small size category of Table 1 shall each be total inward leakage tested with one RPED,

(2) Two test subjects that meet all dimensions of the large size category of Table 1 shall each be total inward leakage tested with one RPED, and

(3) The six remaining subjects that meet any combination of the dimensions specified in Table 1 shall each be total inward leakage tested with one of the six remaining RPED.

7.5.2.3 When the manufacturer requests certification for an RPED of only two different sizes that meet all three size categories of Table 1, the RPED shall be apportioned among test subjects in the following manner:

(1) Two test subjects that meet all the dimensions of the small size category of Table 1 shall each be fit tested with one RPED designed to fit the small/medium size categories,

(2) Two test subjects that meet all the dimensions of the large size category of Table 1 shall each be fit tested with one RPED designed to fit the medium/large size categories,

(3) Three test subjects that meet any combination of the dimensions specified in Table 1 for the small size or medium size category shall be fit tested with one RPED designed to fit the small/medium size categories, and

(4) Three test subjects that meet any combination of the dimensions specified in Table 1 for the medium size or large size category shall be each fit tested with one RPED designed to fit the medium/large size categories.

7.5.2.4 When the manufacturer requests certification for an RPED of three different sizes that meet all three size categories of Table 1, the RPED shall be apportioned among test subjects in the following manner:

(1) Three test subjects that meet all the dimensions of the small size category of Table 1 shall each be total inward leakage tested with three RPED designed to fit the small size category,

(2) Four test subjects that meet all the dimensions of the medium size category of Table 1 shall be each total inward leakage tested with one RPED designed to fit the medium size categories, and

(3) Three test subjects that meet all the dimensions of the large size category of Table 1 shall each be total inward leakage tested with one RPED designed to fit the large size category.

7.5.3 *Procedure:*

7.5.3.1 If specified by the manufacturer's instructions in 9.2.6, test subjects shall position their hair so that it does not interfere with any seal of the RPED that is intended to protect the wearer.

7.5.3.2 Test subjects shall not have significant facial hair, scarring in the area of the face seal, significant dental abnormalities, or other condition that interferes with the seal of the RPED that is intended to protect the wearer.

7.5.3.3 Test subjects shall don the RPED as specified by the manufacturer's instructions in accordance with 9.2.6. The test supervisor shall ensure that the test subject has read the RPED instructions.

7.5.3.4 All instruments and equipment shall be calibrated before use in accordance with the manufacturer's instructions.

7.5.3.5 The RPED sampling probe shall be connected to an instrument to measure the concentration inside and outside the face piece. Such instrumentation shall:

(1) Use a condensation nuclei counter;

(2) Measure aerosol only in the approximate (mass median aerodynamic diameter) size range of 0.02 to 0.06 μm; and

(3) Respond linearly, within ±5 %, over the approximate concentration range of 0.1 to 10 000 particles/cm^3.

7.5.3.6 The test subject shall perform the exercises specified in 7.5.3.6 *(1)* – *(5)* for 30 s each while walking on a treadmill that operates at a rate of approximately 5 km/h. The total test time shall be 2½ min. The exercises shall be performed in the following order:

(1) Normal breathing,

(2) Deep breathing,

(3) Turning head side to side,

(4) Moving head up and down

(5) Bending movement, and

(6) Normal breathing.

7.5.3.7 The average concentration of the challenge particles within the probed space shall be obtained for each exercise. The average value for all five average concentrations shall be calculated. The instrumentation described in 7.5.3.5 shall measure the C_i and C_O.

7.5.3.8 Total inward leakage shall be calculated as:

$$C_i / C_o \quad (1)$$

Where:

C_i = Average concentration as calculated in 7.5.3.7, and
C_O = Average concentration outside the RPED.

7.5.3.9 The total inward leakage for all ten test subjects shall be calculated to determine pass/fail as specified in 4.5.

7.6 *Optical Properties Test:*

7.6.1 *Light Transmission Test:*

7.6.1.1 A 25-mm-diameter sample shall be cut from the vision area of the RPED.

7.6.1.2 The light transmission and haze of the sample shall be determined in accordance with Test Method D1003.

7.6.2 *Field of Vision Test:*

7.6.2.1 An Apertometer head form as show in Fig. 3 shall be used.

7.6.2.2 The RPED hood shall be mounted and the hood vision area shall be located on the Apertometer head form according to the manufacturer's instructions.

7.6.2.3 The effective field of vision shall be measured in an Apertometer apparatus as shown in Fig. 4.

7.6.2.4 The effective field of vision shall be transferred to the field of vision scoring grid overlay as shown in Fig. 5.

7.6.2.5 The effective field of vision shall be determined by counting the dots within the effective field of vision for the RPED being tested, as shown in Fig. 4.

7.6.3 *Fogging Test:*

7.6.3.1 The test subject shall have a minimum visual acuity of 20/20 in each eye, uncorrected or corrected, as determined by a visual acuity test or doctor's examination.

7.6.3.2 The temperature of the test environment shall be measured and should be 22 ± 2°C.

7.6.3.3 Visual acuity testing shall be conducted using a standard 6.1-m Snellen eye chart, with normal lighting range of 1076 to 1615 lux at the chart.

7.6.3.4 Within 30 s after completion of the total inward leakage test, the test subject shall exit the chamber if necessary to be positioned 6.1 m in front of a standard 6.1-m Snellen eye chart illuminated at 1076 to 1615 lux. The test subject shall then attempt to read the Snellen eye chart at the 20/100 line to determine pass/fail.

7.6.4 *Ocular Leakage Test:*

7.6.4.1 RPED shall be modified to allow connection through all necessary layers to connect the ocular sampling probe to the test fixture. All connections shall be leak tight.

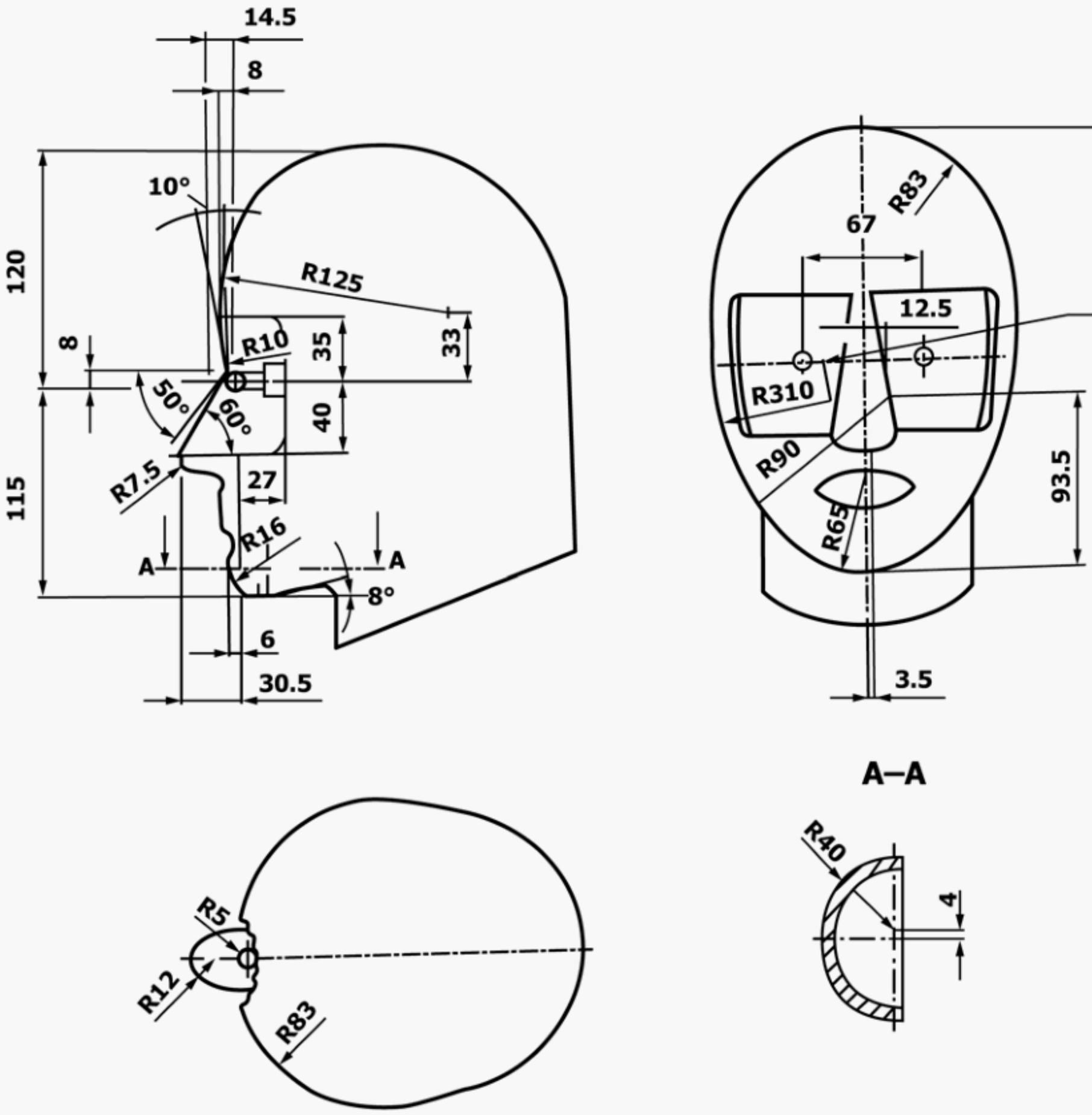

FIG. 3 Apertometer Head Form (Dimensions in mm)

7.6.4.2 The ocular leakage test fixture shall be adjusted such that the fixture sample ports are located in-line with each test subjects' center of pupil.

7.6.4.3 Using the same test subjects in 7.5.2 and following the same test procedure in 7.5.3, samples shall be drawn from each port. Caution should be taken to avoid contact between the eye and the test fixture.

7.7 *Operational Packaging Leakage Test:*

7.7.1 *Pressure Test (to be conducted for initial and year five recertification testing):*

7.7.1.1 Before testing, the RPED shall be weighted on a gram scale calibrated to tenths. Record the initial weight.

7.7.1.2 A tub that is 600 mm long by 600 mm wide by 750 mm deep or larger shall be filled with water to a depth of at least 600 mm. The water shall be maintained at a temperature of 70 ± 3°C throughout the test.

7.7.1.3 The RPED in the ready-to-use configuration shall be completely immersed, without interfering with the operational packaging seal integrity, until it is firmly positioned at the bottom of the tub.

7.7.1.4 Once firmly in position, the RPED in the ready-to-use configuration shall remain in the water for 5 min.

7.7.1.5 Pass/fail shall be determined in accordance with 4.7.

7.7.2 *Burst Test (to be conducted for annual testing)*

7.7.2.1 The RPED in the ready-to-use configuration shall be pressurized until it bursts open in response to pressurization.

7.7.2.2 Pressurization shall be in accordance with the Standard Test Methods for Internal Pressurization Failure Resistance of Unrestrained Packages described in Test Methods F1140.

7.7.2.3 The pressure required to burst the package shall be recorded.

7.7.2.4 Pass/fail shall be determined in accordance with 4.7.4.

7.8 *Chemical Capacity Test:*

7.8.1 *Overview*—Paragraph 7.8 is intended to provide a description of chemical capacity test methods sufficient to allow a technician skilled in the art to perform laboratory testing to determine conformance with the chemical capacity requirements of this specification as outlined in 4.8. Each

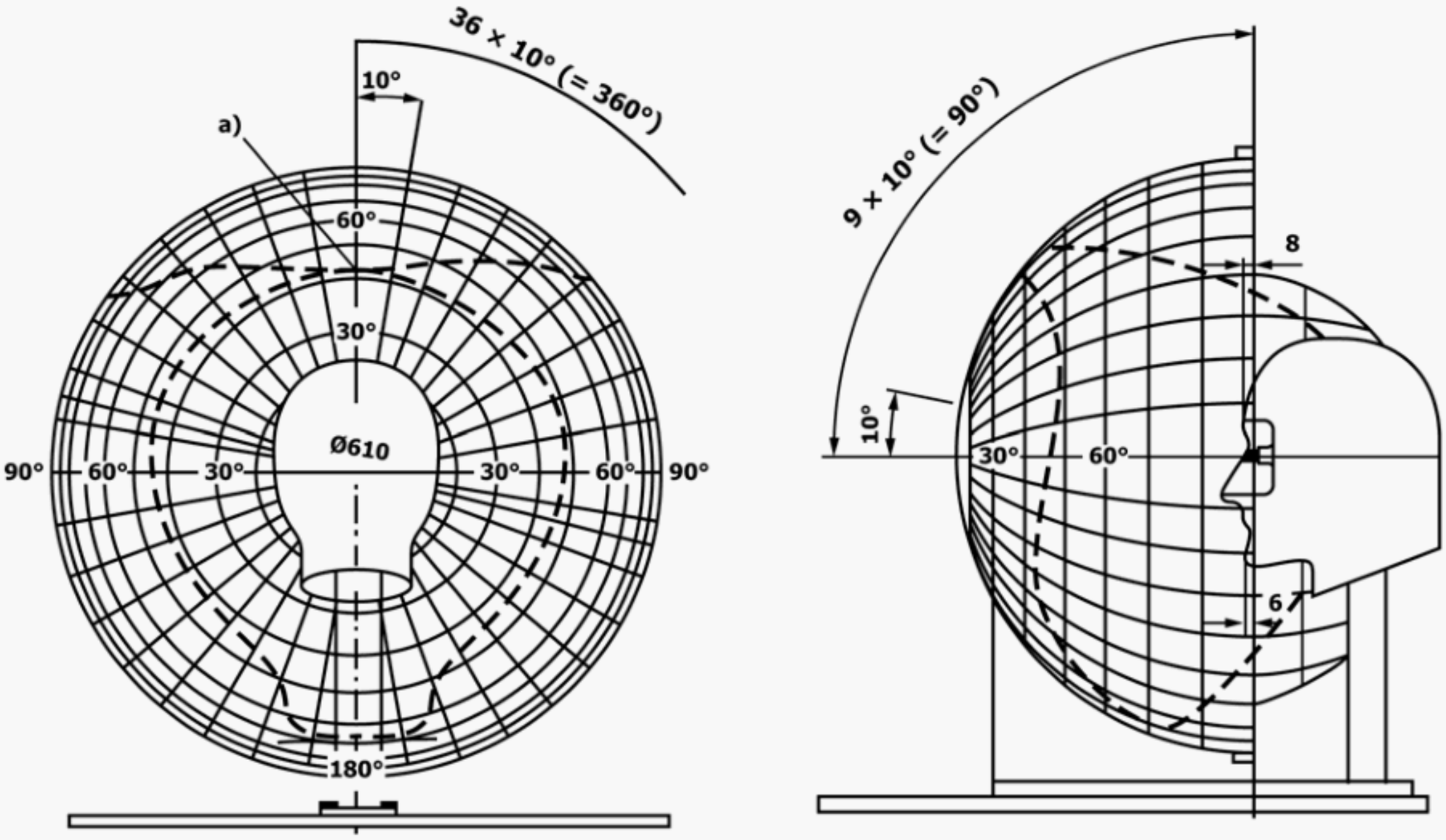

FIG. 4 Field of Vision in Apertometer Apparatus

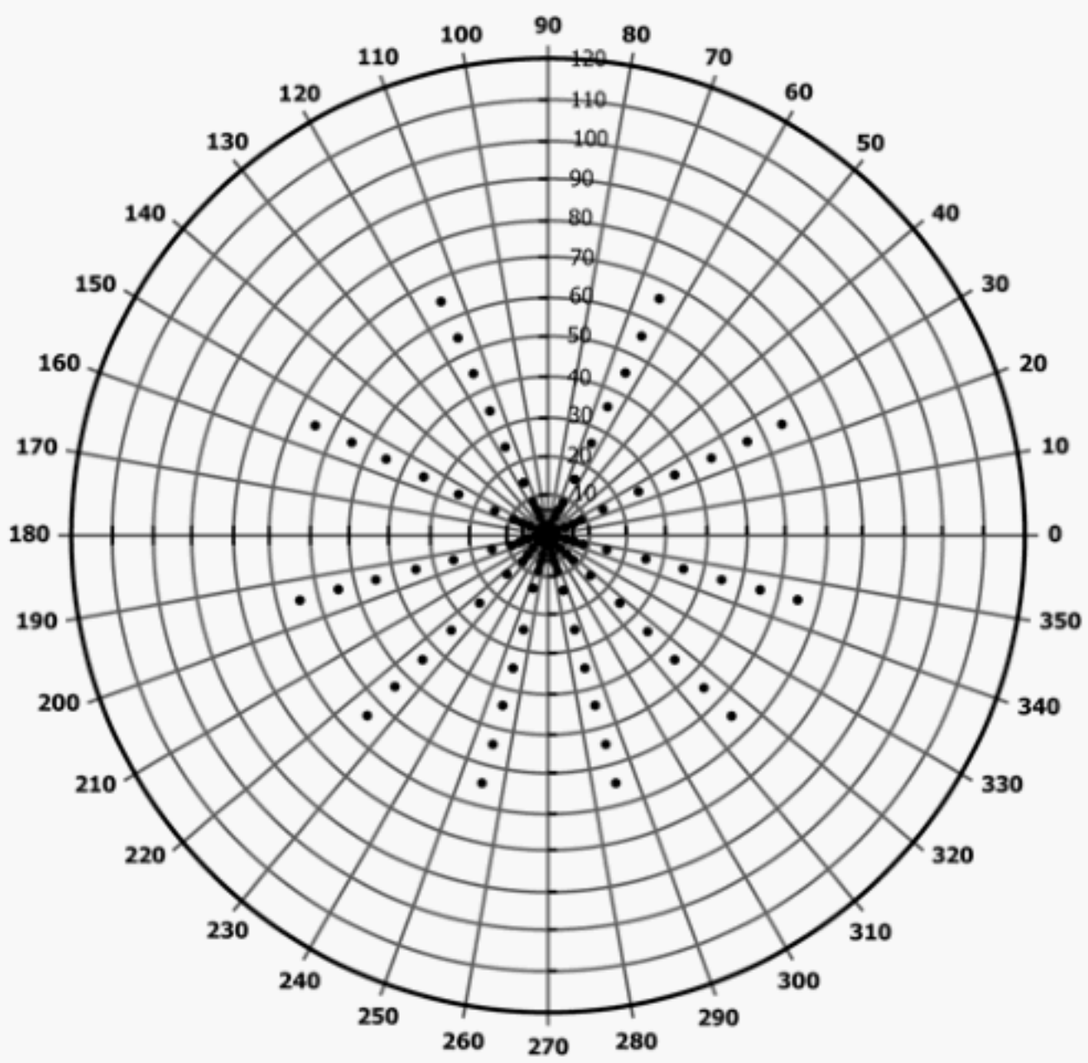

FIG. 5 Vision Scoring Grid Overlay

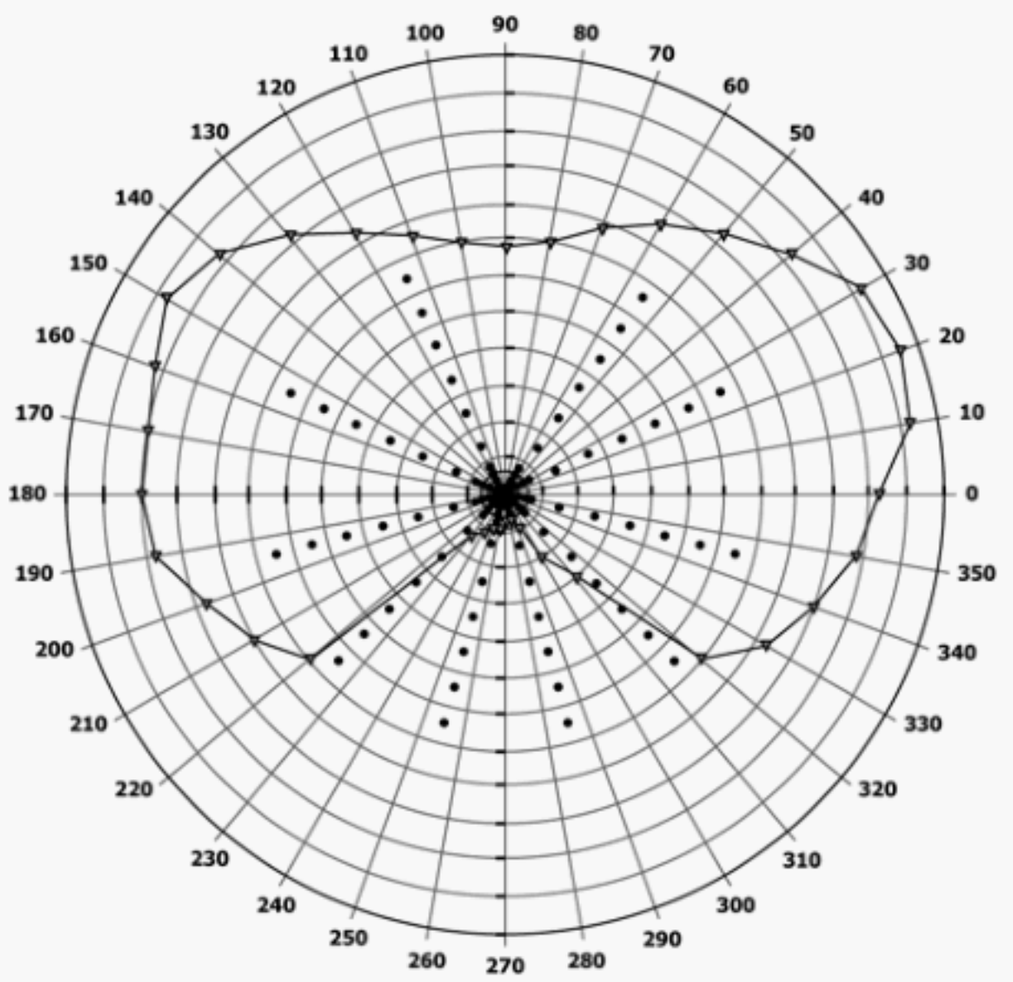

FIG. 6 Typical Effective Field-of-Vision Scoring

chemical challenge test shall be conducted within the general method guidelines outlined in 7.8.

7.8.2 *Challenge Gases and Conditions*—Random samples of RPED that are representative of the production process shall be tested against the challenge gases, concentrations, and conditions listed in Table 3 in accordance with the testing matrices in 8.3 and the test methods described herein.

7.8.3 *Challenge Test Flow Path:*

7.8.3.1 Delivery tubing, sample tubing, fittings, valves, chambers, and components in the challenge test flow path shall be designed to minimize pressure drop and shall be constructed of material that neither affects nor is affected by the challenge agent (for example, polyolefin, polytetrafluoroethylene [PTFE], glass, or stainless steel).

7.8.3.2 A typical schematic diagram for the challenge test flow path for constant flow tests (cyclohexane, acrolein, hydrogen chloride, sulfur dioxide, and hydrogen cyanide) is depicted in Fig. 7, but other flow paths meeting the requirements of this specification may be acceptable.

7.8.3.3 The test flow path and setup for carbon monoxide performance involves the use of a breathing machine and will differ from the constant flow setups. There shall be an outer

TABLE 3 Challenge Gases and Test Conditions

	Challenge Agent	Challenge Concentration (ppm)	Breakthrough Concentration (ppm)	Air Flow Rate Through RPED (L/min)	Temperature (°C)	Relative Humidity (%)
1.	Cyclohexane	500 ± 15	5	30 ± 1	25 ± 2	50 ± 5
2.	Acrolein	100 ± 3	0.5	30 ± 1	25 ± 2	50 ± 5
3.	Hydrogen Chloride	1000 ± 30	5	30 ± 1	25 ± 2	50 ± 5
4.	Sulfur Dioxide	100 ± 3	3	30 ± 1	25 ± 2	50 ± 5
5.	Hydrogen Cyanide	400 ± 12	10[A]	30 ± 1	25 ± 2	50 ± 5
6.	Carbon Monoxide	3000 ± 90	200[B]	30 ± 1 cyclic[C]	25 ± 2	80 ± 3
7.	Carbon Monoxide	5000 ± 150	200[B]	30 ± 1 cyclic[C]	0 ± 2	80 ± 3

[A] Total of HCN and C_2N_2.
[B] 5-min moving time weighted average.
[C] 20 respirations/min with a sinusoidal wave form.

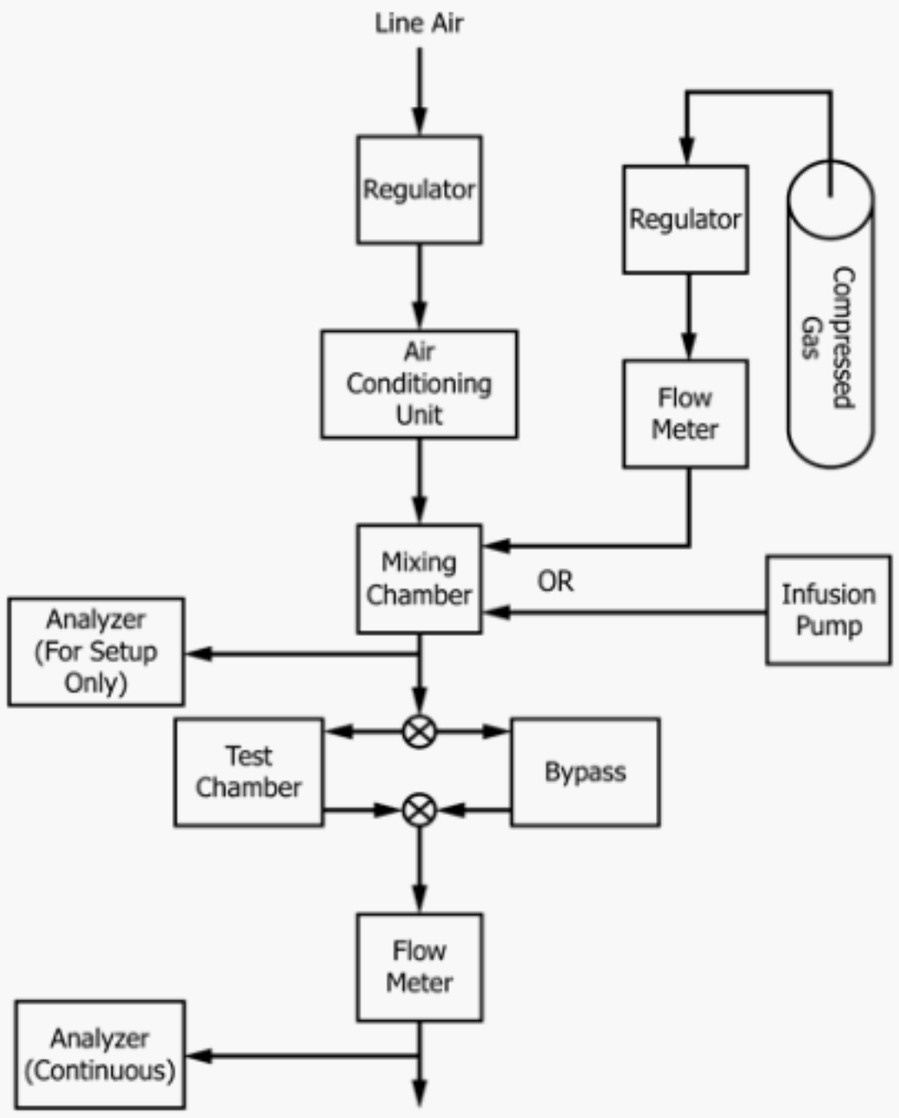

FIG. 7 Constant Flow Gas Diagram

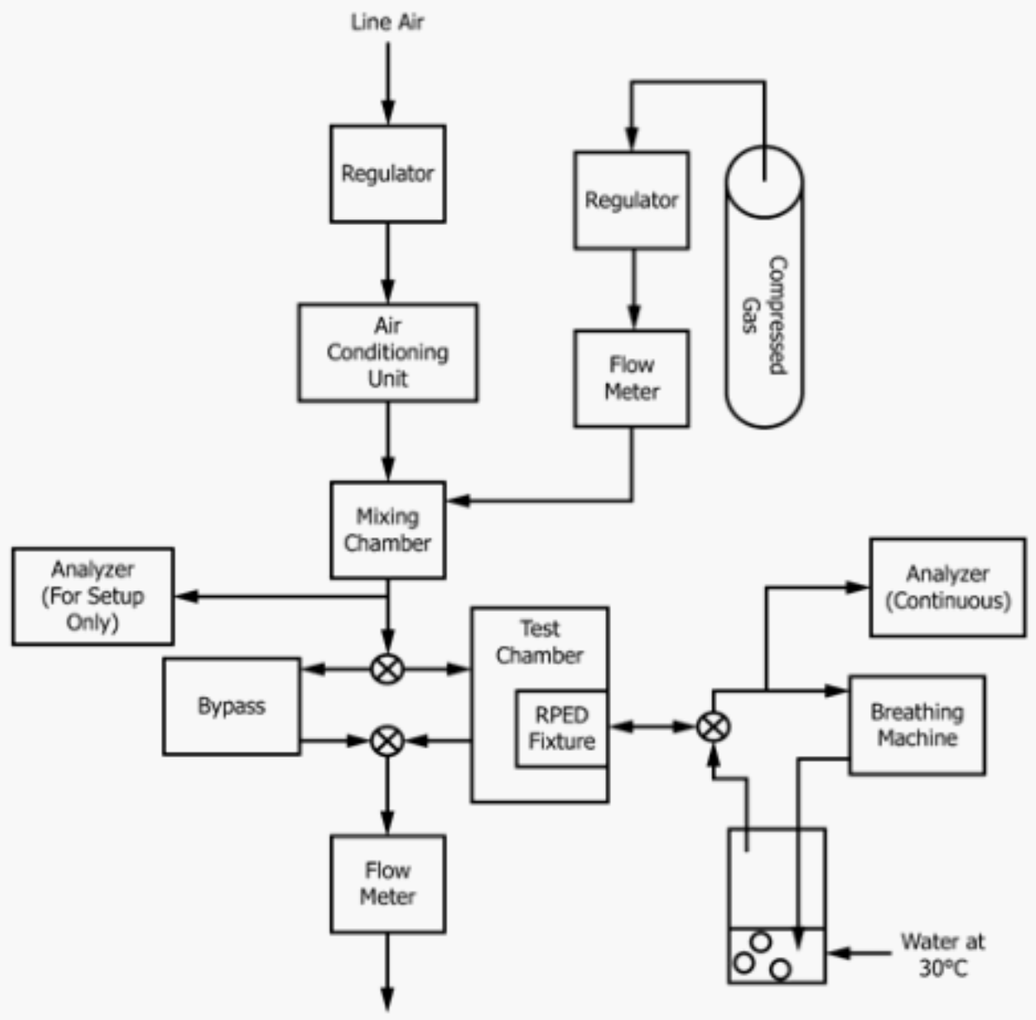

FIG. 8 Carbon Monoxide Gas Test Diagram

chamber, with its own outlet, from which challenge air is drawn through the RPED or its active element during the breathing cycle. Challenge air flow shall be directed through the RPED or its active element during both the "inhalation" and "exhalation" portions of the breathing cycle. Check valves shall be used to isolate as much of the "inhalation" and "exhalation" legs of the test flow path as is practical. The breathing machine shall be capable of operating at an airflow rate of 30 ± 1 L/min with a respiration rate of 20 respirations/min and a breathing wave form that is sinusoidal in shape. "Exhalation" air shall be humidified to simulate exhalation by a user by bubbling the "exhaled" air through water maintained at a temperature of 30 ± 1°C.

7.8.3.4 A typical schematic diagram for the test flow path for carbon monoxide performance is depicted in Fig. 8, but other flow paths meeting the requirements of this specification may be acceptable.

7.8.4 *RPED Test Fixture and Chamber:*

7.8.4.1 For tests requiring constant flow, the RPED, or its active element (cartridge or canister), shall be installed in a test fixture in such a way that 100 % of the flow from the test flow path is directed through the RPED's active element or diverted through a bypass path (during test setup and parameter verification). This may be accomplished by installing a three-way valve or other switch in the test flow path to direct flow either through the bypass path or the RPED active element. Care shall be taken to ensure the pressure drop across both paths is approximately equal through the use of the cartridges or flow restriction devices to provide stable flow and concentration.

7.8.4.2 For tests requiring cyclical flow (for example, breathing machine), the RPED, or its active element (cartridge or canister), shall be installed in a test chamber such that 100 % of the flow from the test flow path is directed to the surrounding chamber or diverted through a bypass path (during test setup and parameter verification). This may be accomplished by installing a three-way valve or other switch in the test flow path to direct flow either through the bypass path or the surrounding chamber. The RPED, or its active element, shall be installed in a test fixture so that challenge air is drawn from the surrounding chamber through the device by the breathing machine. Challenge air flow to the surrounding chamber shall be sufficient to prevent negative pressure within the surrounding chamber at any point during the breathing cycle.

7.8.5 *Supply Air System:*

7.8.5.1 Supply air for each test setup shall be free of oil or contaminants that would affect the performance of the RPED or interfere with monitoring of the challenge gas for that test setup. Total gaseous contaminants in the supply air shall be less than 1 % of the intended challenge concentration. Contamination of the supply air by the particular challenge gas or contaminants that interfere with monitoring shall be less than 0.5 % of the intended challenge concentration.

7.8.5.2 The supply air for each constant flow test setup shall be maintained at the target humidity ±5 % relative humidity (RH) or ±3 % RH for cyclical flow CO tests as a time-weighted average throughout the test duration. The humidity measuring device shall have an accuracy and precision of ±1.0 % RH or better.

7.8.5.3 The supply air for each test setup shall be maintained at the target temperature ±2°C noted in Table 3 throughout the test duration. The temperature measuring device shall have an accuracy and precision of 0.2°C or better.

7.8.5.4 The supply air for each test setup shall be maintained at the target flow rate ±1 L/min throughout the test duration. The flow rate measuring device shall have an accuracy and precision of 0.5 L/min or better. The supply air target flow rate shall be set to ensure that the total air flow through the RPED is maintained at the flow rate specified in Table 3 (see Note 4).

NOTE 2—For carbon monoxide testing, it will be necessary to provide >100 L/min of supply air to the test fixture to sustain 30 L/min through the RPED using the breathing machine without developing negative pressure as a result of the high instantaneous flow rates generated by the breathing cycle.

7.8.5.5 The supply air system shall be calibrated regularly according to the manufacturer's recommendations.

7.8.6 *Challenge Air Temperature and Humidity Monitoring:*

7.8.6.1 Temperature and humidity of the challenge air stream shall be monitored periodically during the test by a device placed as near to the RPED cartridge as is practical on the upstream side. Temperature and relative humidity measurement devices shall be calibrated according to manufacturer's recommendations. The challenge air for each constant flow test setup shall be maintained at the target humidity ±5 % RH or ±3 % RH for cyclical flow CO tests as a time-weighted average throughout the test duration. The humidity measuring device shall have an accuracy and precision of ±1.0 % RH or better.

NOTE 3—Temperature and humidity monitors should not be continuously placed in the flow path downstream from the point where challenge agent is introduced because of corrosive effects of agents and the heat produced by their interaction with the RPED cartridge.

7.8.6.2 Flow rate of the total challenge air shall be monitored downstream from the test fixture. The flow rate shall be maintained at the target from Table 3 ±1 L/min throughout the test duration. The flow rate measuring device shall have an accuracy and precision of 0.5 L/min or better.

7.8.7 *Challenge Contamination Generation:*

7.8.7.1 Where the contaminant is a gas (that is, hydrogen chloride, sulfur dioxide, carbon monoxide, hydrogen cyanide), challenge concentrations shall be generated by adding a metered flow of gaseous contaminant at a known purity into the test flow path upstream from the RPED test fixture at a distance sufficient to provide uniform mixing with the supply air flow.

NOTE 4—This may be achieved by dispensing pure or diluted contaminant from a pressurized, regulated cylinder through a flowmeter which has been periodically cleaned and calibrated. Metered flow rate can be calculated from the following equation:

$$Q_C = (C_{CH} \times Q_T) / (P_C \times 10) \quad (2)$$

Where:

Q_C = Flow rate of contaminant stream, mL/min,
C_{CH} = Desired challenge concentration of contaminant, ppm,
Q_T = Flow rate of challenge air supplied to test fixture, L/min, and
P_C = Purity of contaminant stream, %.

NOTE 5—If Q_C is >300 mL/min, then the supply air flow rate shall be reduced by the same amount to ensure that the total challenge flow supplied to the test fixture remains within the specified range. Supply air humidity may also need to be adjusted to compensate for this addition of dry air.

7.8.7.2 Where the challenge agent is a liquid (that is, cyclohexane, acrolein), challenge concentrations shall be generated by adding a metered flow of pure liquid into the test flow path downstream from the supply air conditioning system and upstream from the entry to the RPED test fixture. Addition of liquid contaminant shall occur a sufficient distance upstream from the RPED test fixture to provide complete mixing of the challenge agent in the air stream and dissipation of excess cooling arising from the vaporization of the liquid. Care shall be taken that the addition of liquid provides a smooth, constant challenge concentration within the air stream (that is, not a "pulsed" challenge).

NOTE 6—A metered flow of liquid contaminant may be achieved by delivery of pure liquid from a precision, gas-tight syringe mounted in a calibrated syringe pump through inert tubing and a needle that penetrates a gas-tight rubber septum mounted in the test flow path. A minimal amount of heat may be directed at the point of liquid addition by heating mantle, tape, or heat gun to completely vaporize the liquid or minimize evaporative cooling, or both. Metered flow rate can be calculated from the following equation:

$$M_C = (C_{CH} \times Q_T \times M\ W) / (24.45 \times 1000) \quad (3)$$

Where:

M_C = Mass flow rate of pure liquid contaminant, mg/min,
C_{CH} = Desired challenge concentration of contaminant, ppm,
Q_T = Flow rate of challenge air supplied to test fixture, L/min,
MW = Molecular weight of contaminant, g/mole, and
24.45 = Litres/mole according to ideal gas law at 25°C and 1 atmosphere.

7.8.8 *Upstream Challenge Concentration Monitoring*—Upstream challenge contaminant concentration shall be measured near the RPED test fixture using an in-line instrument (for example, calibrated infrared spectrophotometer) or by a wet-chemical analysis (see Appendix X1 for examples) of an air sample performed before beginning the test. The laboratory shall document that an appropriate instrument or analytical method has been chosen that has the necessary accuracy to ensure the challenge concentration is within the specified range. In-line analyzing instruments shall be calibrated according to the manufacturer's recommendations at the intended challenge concentration.

7.8.9 *Downstream Monitoring for Breakthrough:*

7.8.9.1 The contaminant breakthrough concentration shall be monitored in the test flow path directly downstream from the RPED test fixture using a continuous monitoring instrument that has been calibrated at or near the breakthrough concentration according to the manufacturer's recommendations. The downstream monitor shall be incorporated in the test flow path only when flow has been switched to the RPED test fixture via the test shunt.

7.8.9.2 The downstream monitoring instrument shall have an accuracy and lower detection limit less than or equal to 20 % of the contaminant breakthrough concentration.

7.8.9.3 The sample point for the downstream monitoring instrument shall be placed so that the sample is representative of the overall flow from the RPED or its active element. For carbon monoxide, the downstream monitoring sample point shall be placed so that only the inhalation portion of the breathing cycle is sampled.

7.8.10 *Procedure:*

7.8.10.1 The test apparatus and test flow path shall be assembled according to the laboratory's procedures for the contaminant to be tested. The test flow path shall be tested to ensure that no leaks are present. The test flow path shall be directed through the bypass path during the setup and equilibration.

7.8.10.2 The supply air system shall be turned on and adjusted to the specified flow rate, temperature, and relative humidity. Before the first test, the supply air system shall be allowed to stabilize for 30 min.

7.8.10.3 The contaminant generation system shall be turned on and adjusted to provide the specified concentration of contaminant to the supply air. The contaminant generation system shall be allowed to equilibrate for 15 min to ensure uniform concentration. After equilibration time, the challenge concentration shall be verified and adjustments made if required to achieve the specified level.

7.8.10.4 The RPED or its active element shall be mounted in the appropriate fixture and chamber. Precautions shall be taken to ensure the RPED or its active element is sealed to prevent inward leakage of the challenge contaminant that bypasses the active element.

7.8.10.5 The test flow path shall be switched to direct the challenge air flow through the RPED test fixture and chamber. If the test contaminant is carbon monoxide, the breathing pump shall be turned on and the timing device actuated simultaneously.

7.8.10.6 The flow of effluent shall be continuously sampled using the downstream monitoring instrument for at least 15 min at a sampling rate of at least one measurement per 6 s for CO and no less than one measurement per 1 min for other test gases. The maximum downstream concentration during the 15-min test shall be recorded to determine pass/fail as specified in 4.8. For carbon monoxide, the individual measurements shall be used to calculate a moving 5-min, time-weighted average to determine pass/fail as specified in 4.8. In the event that the downstream concentration reaches the breakthrough concentration before the end of the 15-min test, the test laboratory should record the time that this occurred to aid the manufacturer.

7.8.10.7 The test apparatus shall be shut down according to the laboratory's standard procedures.

7.9 *Inhalation Temperature Test:*

7.9.1 This test shall be conducted simultaneously with the test specified in 7.8 for carbon monoxide testing.

7.9.2 The RPED shall be challenged with 5000 ± 150 ppm CO at a temperature of 25 ± 2°C.

7.9.3 A calibrated thermocouple that is connected to a digital thermometer or strip chart recorder shall be placed in the airstream that exits the fixture base. The thermocouple shall be centered within the airstream and 508 ± 6 mm from the exit of the fixture base.

7.9.4 The temperature of the air that exits the fixture base shall be continuously recorded to determine pass/fail as specified in 4.9.

7.10 *Soot Particulate Test:*

7.10.1 *Equipment:*

7.10.1.1 The following equipment and supplies shall be used for soot testing. Where applicable, manufacturers shall supply fixtures to connect mouthpieces to the test head form:

(1) Soot test chamber,

(2) Compressed acetylene gas in a concentration of greater than or equal to 99.6 %,

(3) A flow meter with a flow range of 50 to 4960 cm^3/min and an accuracy of ±5 % full scale,

(4) Two Fisher 03-900 burners or equivalent,

(5) Filter paper with an efficiency of at least 99.97 % against 0.3 μ 1 diethylhexyl phthalate particles and a diameter of 84 ± 13 mm,

(6) Filter paper holder (see Fig. 9), and

(7) Modified Model 327-6 breathing machine, as defined by NFPA 1981, or equivalent.

7.10.1.2 The soot test chamber specified in 7.10.1.1 (*1*) shall consist of a 970 ± 25-L metal box that is equipped with an opening through which room air and soot are introduced, an exhaust fan to pull air through the chamber, and openings on which test devices can be mounted. The test setup shall be as shown in Fig. 10.

7.10.1.3 The air shutters on the burners specified in 7.10.1.1 (*4*) shall be completely closed and taped shut to prevent air from mixing with acetylene gas.

7.10.1.4 The breathing machine specified in 7.10.1.1 (*7*), or equivalent, shall be modified to use two of its pneumatic cylinders and shall yield a tidal volume of 1.7 L. At 18.8 cycles per minute, the breathing machine shall produce 32 ± 2 L/min.

7.10.2 *Procedures:*

7.10.2.1 The exhaust fan shall be turned on and adjusted to pull air through the test chamber at a rate of 500 to 1000 L/min.

7.10.2.2 The acetylene gas shall be turned on and the flow rate of the acetylene to the burners shall be adjusted to 0.75 L/min per burner.

7.10.2.3 The burners shall be ignited carefully.

7.10.2.4 The system shall warm up for at least 15 min.

7.10.2.5 The challenge concentration shall be measured using the following procedure:

(1) Weigh the filter paper to the nearest 0.01 mg;

(2) Place the filter paper into the filter holder;

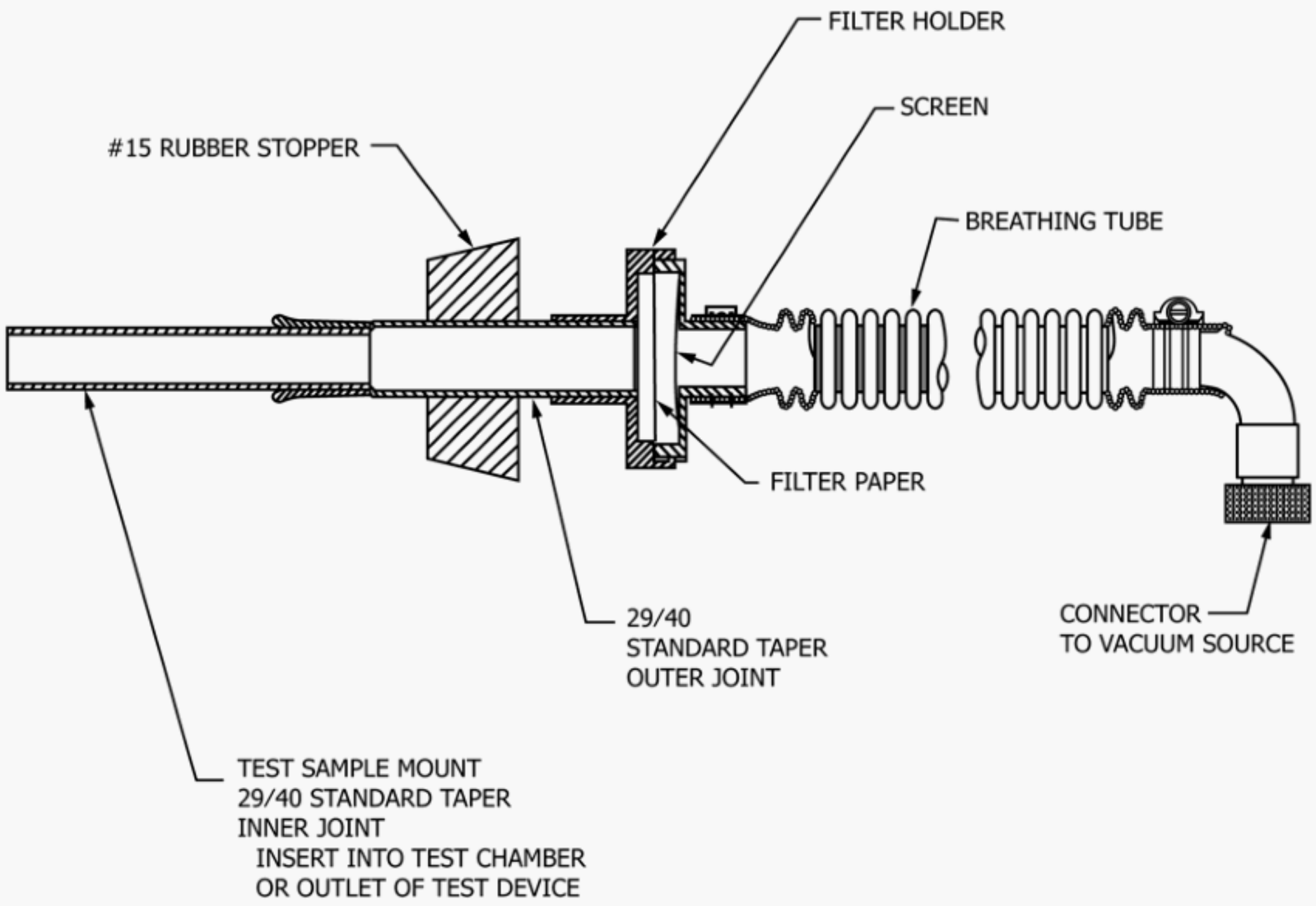

FIG. 9 Schematic of Filter Paper Holder

(3) Connect the outlet of the concentration test fixture to the vacuum pump;

(4) Place the inlet of the concentration test fixture into soot test chamber;

(5) Use the breathing machine to pull soot-laden air through the filter paper via the head form opening;

(6) Remove the filter paper from the filter holder of the concentration test fixture and reweigh the filter paper to the nearest 0.01 mg;

(7) Calculate the concentration of the soot-laden air using:

$$\text{Soot concentration (mg/ m}^3\text{)} = \frac{\text{final weight (mg)} - \text{initial weight (mg)}}{32\ \text{L/min} \times 5\ \text{min}} \times 1000 \quad (4)$$

(8) If the concentration of the soot is too low, increase the flow rate of acetylene to the burners. Conversely, if the concentration is too high, reduce the flow of acetylene to the burners.

7.10.2.6 An RPED mounted on the temperature resistant full-face headform shall be positioned within the soot chamber such that the center of RPED filter media shall be located within 12.5 mm of the opening of the previous fixture location used within 7.10.2.5 soot challenge calibration.

(1) After it has been established that the soot concentration is within the desired range of 200 ± 25 mg/m^3, the oral/nasal cup or mouthpiece, as applicable, shall be connected to the end of the metal tube of the apparatus test fixture with appropriate fixtures as shown in Fig. 11.

7.10.2.7 The hose of the apparatus test fixture as shown in Fig. 11 shall be connected to the modified Model 327-6 breathing machine.

7.10.2.8 The RPED shall be placed in the soot chamber and the breathing machine shall be started.

7.10.2.9 After 5 min, the breathing machine shall be turned off and the test RPED shall be removed.

7.10.2.10 The breathing resistance of the RPED shall be measured in accordance with 7.3 to determine pass/fail as specified in 4.10.

7.11 *Flammability Test:*

7.11.1 The RPED shall be fitted on the test head. If the RPED is not equipped with a head harness, the material in an appropriate clamping device shall be included such that the material is horizontal.

7.11.1.1 Testing shall be conducted using the test equipment as specified in 6.5.2 and EN 136.

7.11.2 The distance between the outer surface of the RPED and the burner tips shall be adjusted to 250 ± 6.4 mm.

7.11.3 The temperature of the flame positioned 250 ± 6.4 mm above the burner tip shall be 800 ± 50°C.

7.11.4 The RPED shall be rotated once through the flame at a linear speed measured at the flame position of 6 ± 0.5 cm/s.

7.11.5 When components such as valves and filters are arranged on other parts of the RPED, the test shall be repeated with these components at the appropriate height of 250 ± 6.4 mm above the flame.

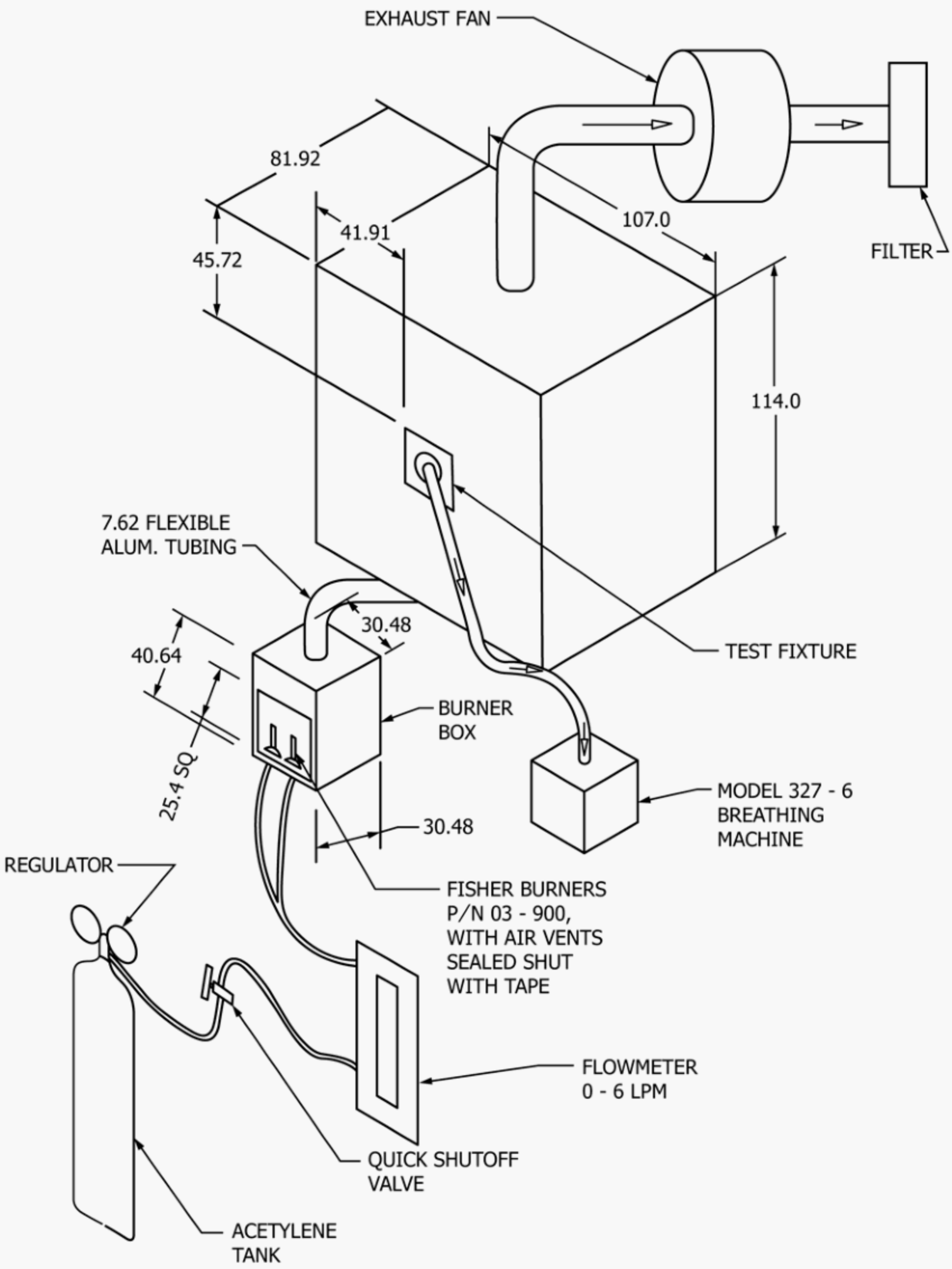

FIG. 10 Schematic of Soot Particulate Test System

7.11.6 The RPED shall be observed for any after flame, and the after flame duration shall be recorded to determine pass/fail as specified in 4.11.1.

7.11.7 To determine pass/fail as specified in 4.11.2, the RPED shall be observed for any dripping, melting, or hole development and shall be evaluated for any damage to components that exposes eyes and lungs to gas or smoke.

7.11.8 A test subject having visual acuity of 20/20 in each eye, corrected or uncorrected, shall don the hood. The test subject shall be positioned at a distance of 6.1 m in front of a

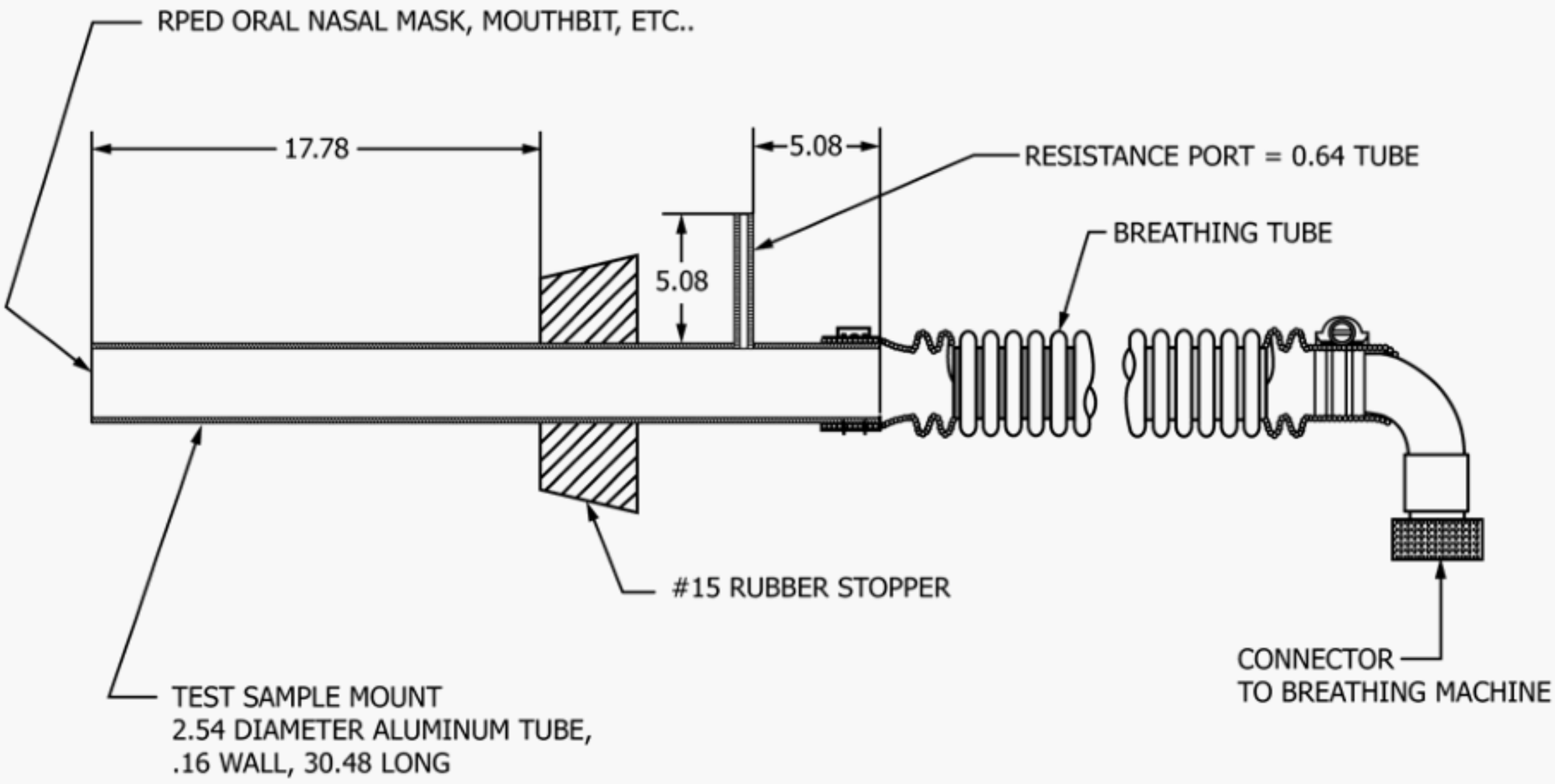

FIG. 11 Schematic of Soot Particulate Apparatus Test Fixture

standard Snellen eye chart illuminated at 1076 to 1615 lux. The test subject shall then attempt to read the 20/100 line to determine pass/fail.

7.12 *Molten Polymeric Drip Test:*

7.12.1 *Equipment*—The testing apparatus shall consist of the following components:

7.12.1.1 Test fixture to support the head form that meets the requirements shown in Fig. 12;

7.12.1.2 Breathing machine specified in 7.3.11 or equivalent;

7.12.1.3 A 5-mm diameter polypropylene rod that meets Specification D4101, Class 1, Group 1, Grade 1-3 (general purpose, homopolymer) of a minimum length of 102 ± 6 mm; and

7.12.1.4 Stopwatch.

7.12.2 *Procedure:*

7.12.2.1 Each RPED shall be tested in accordance with the procedure specified in 7.12.2.2 – 7.12.2.4.

7.12.2.2 The test fixture that supports the head form in the vertical (upright) position shall be capable of being moved forward and backward, and left to right, to ensure access to different RPED test locations.

7.12.2.3 The RPED test locations that are chosen for evaluation shall include each material and material interface that is exposed during escape.

7.12.2.4 The test fixture with head form in the vertical position shall be capable of rotating in such a manner that the head form can be positioned horizontally, 90° from its original

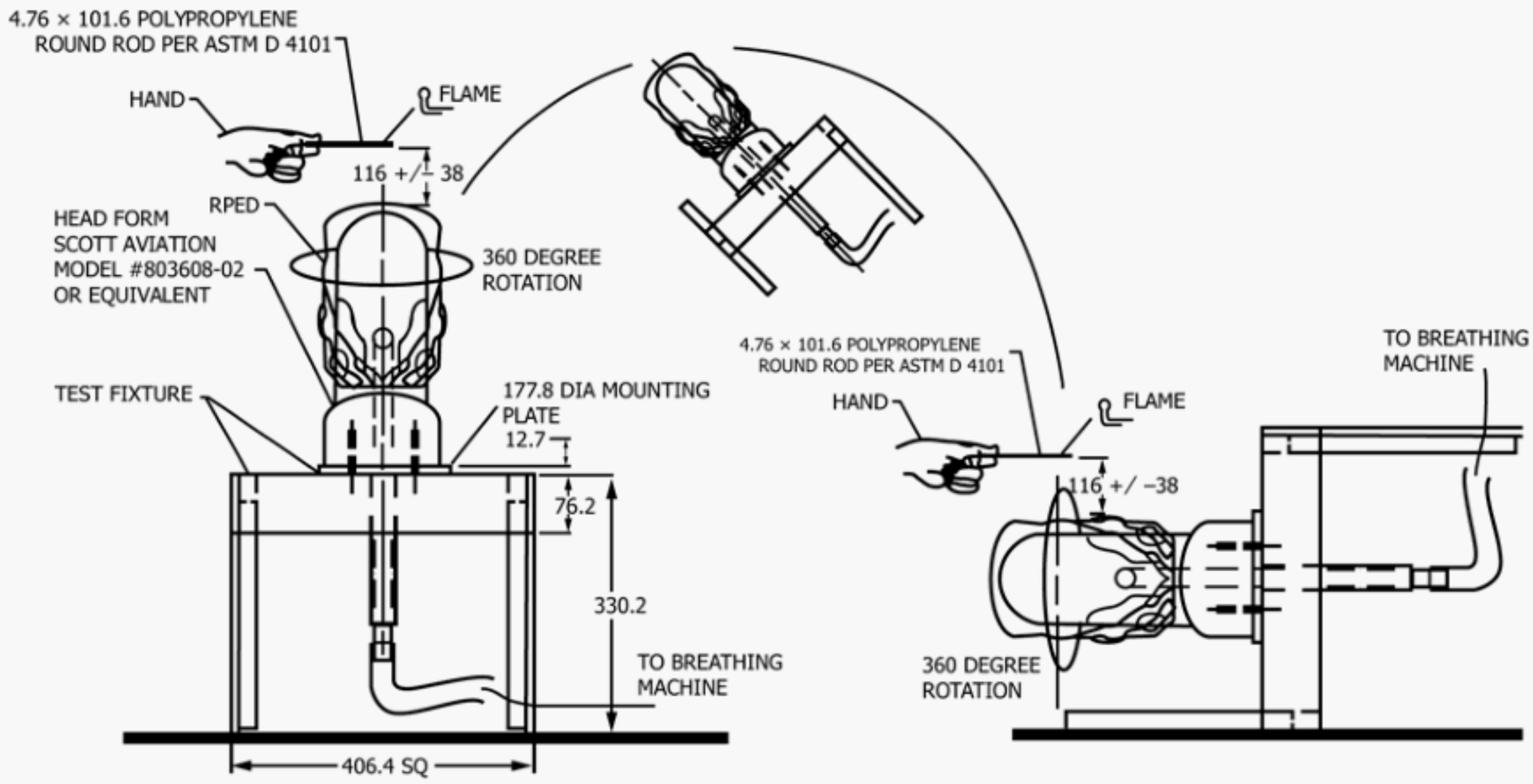

FIG. 12 Molten Polymeric Drip Test Setup

vertical position. The head form in its horizontal position shall be capable of rotation 360° around the horizontal axis to ensure access to different RPED test locations.

7.12.2.5 The RPED shall be mounted on the head form to simulate the correct wearing position on an adult as specified by the RPED manufacturer's instructions.

7.12.2.6 The modified Model 327-6 breathing machine shall be turned on and breathing resistance shall be recorded.

7.12.2.7 The test shall commence with the head in the vertical position.

7.12.2.8 The polypropylene rod shall be held in a horizontal position so that the end of the rod is 116 ± 38 mm from the RPED test location.

7.12.2.9 The rod shall be ignited, and one flaming drip shall be allowed to fall onto each RPED test location until all accessible RPED test locations have been tested.

7.12.2.10 The time taken for after flame to begin shall start to be recorded when the drip hits the RPED test location.

7.12.2.11 The head form and the test fixtures that support the head form shall be rotated 90° to the horizontal position. The head form shall be rotated around the horizontal axis as necessary to access the RPED test locations, and the remaining test locations shall be tested in accordance with 7.12.2.8 – 7.12.2.11.

7.12.2.12 The breathing machine shall be turned off after the last RPED test location has been evaluated.

7.12.2.13 The RPED shall be observed, and test data shall be reviewed to determine pass/fail as specified in 4.12.3.

7.13 *Radiant Heat Test:*

7.13.1 *Equipment:*

7.13.1.1 The test apparatus shown in Fig. 13 and described in 7.13.1.2 – 7.13.1.7 shall be used to conduct the radiant heat test.

7.13.1.2 The radiant heat source shall consist of two quartz lamps that are mounted at an angle of 120° to one another. Each lamp shall be at least 150 by 255 mm. The spectral radiant emittance curve of the radiant panel shall be that of a black body at a temperature between 800 and 1200°K.

7.13.1.3 The radiant heat chamber shall be insulated on all but one side to provide easy access to the test sample and hardware.

7.13.1.4 A nonconductive head form shall be used. It shall be connected to a remotely located modified Model 327-6 breathing machine.

7.13.1.5 The breathing machine shall be set to the specifications of 7.3.11.

7.13.1.6 Thermocouples that are capable of accurately measuring at least 100°C shall be affixed to the back of the dome-shaped aluminum fixture that is illustrated in Fig. 14. The dome-shaped fixture subsequently shall be attached to the crown and right eye of the head form. The thermocouple voltage shall be connected to the strip chart recorder specified in 7.3.7.

7.13.1.7 Pyroheliometers that are capable of accurately measuring at least 0.12 cal/cm^2/s shall be affixed to the crown and right eye of the head form.

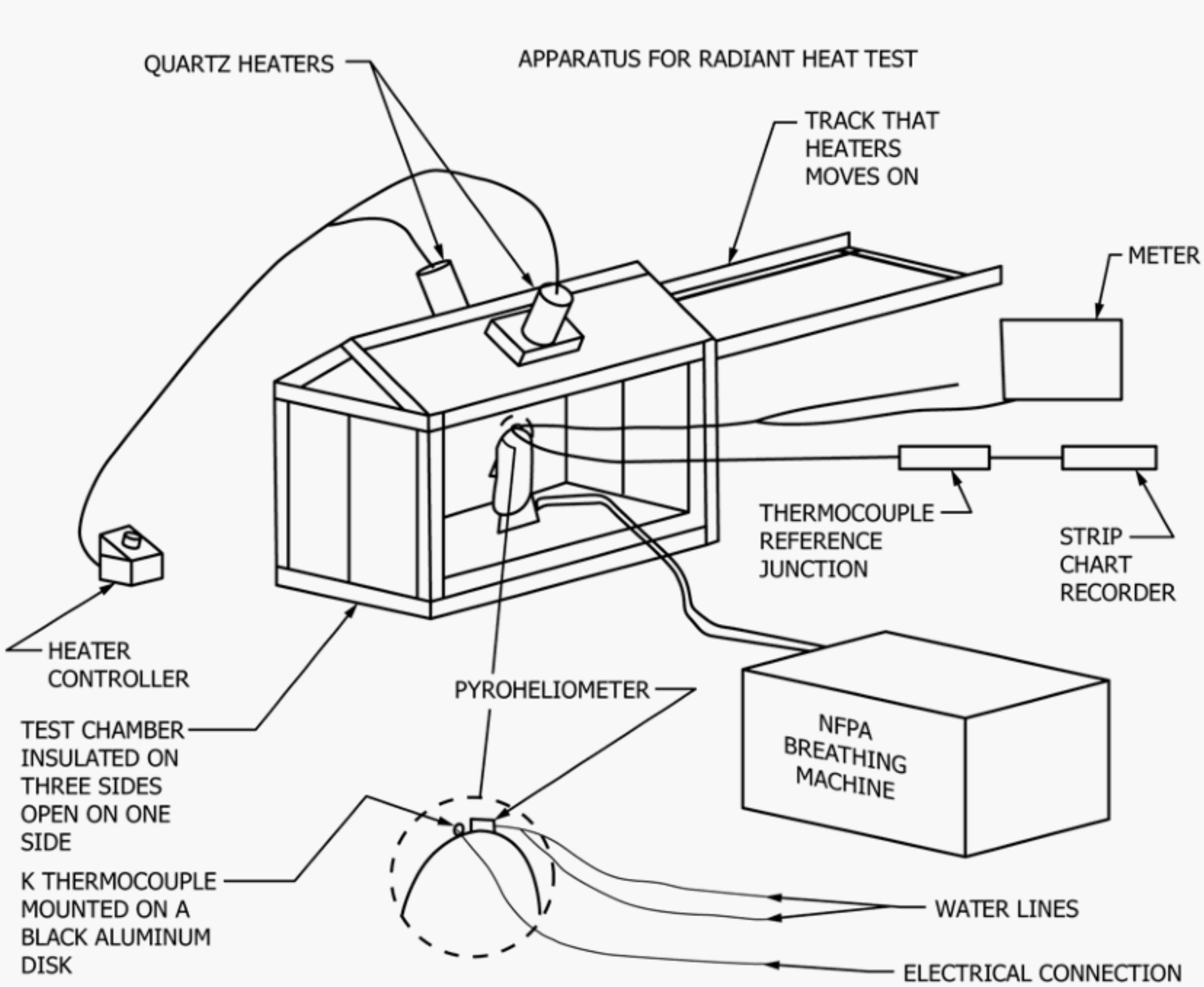

FIG. 13 Radiant Heat Test Setup

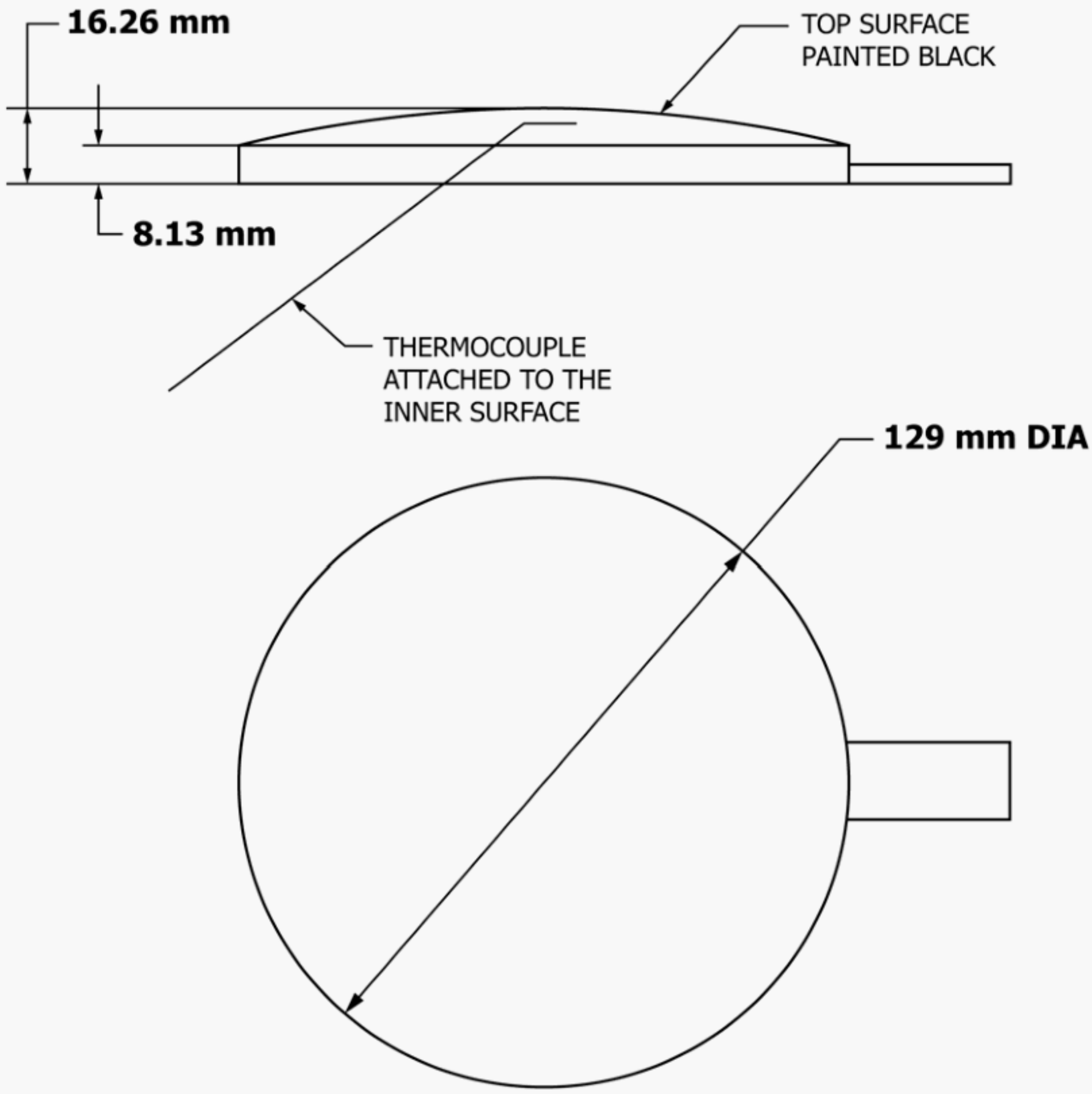

FIG. 14 Thermocouple Mounting

7.13.2 *Procedure:*

7.13.2.1 A pyroheliometer shall be placed on the top center of the head form. The head form shall be relocated so that the pyroheliometer is 240 mm from the heat lamps as shown in Fig. 15. The voltage to the radiant heat panels shall be set so that a constant heat flux of 0.12 ± 0.003 cal/cm^2/s reaches the pyroheliometer.

7.13.2.2 The radiant heat panels shall be removed from the chamber, the pyroheliometer shall be removed from the test head, and the test head shall cool for at least 15 min. The RPED shall be placed on the test head, and the test head form shall be returned to the test chamber and positioned at the distance specified in 7.13.2.1.

7.13.2.3 The radiant heat panel shall be turned on at the voltage specified in 7.13.2.1 and shall stabilize for at least 3 min.

7.13.2.4 The breathing machine shall be turned on. The hood shall be inflated before turning on the breathing machine or breath shall be used to inflate the hood.

7.13.2.5 The radiant heat panel shall be rolled back into the test chamber. The time taken to place the heat panel in the final test position shall be less than 2 s. The exposure to the heat lamps shall last 15 ± 1 s after the heat panels are in the final test position. The temperature at the top of the head shall be continuously recorded.

7.13.2.6 After completing the procedure specified in 7.13.2.5, the heat panel shall be removed from the test chamber within 2 s. The breathing machine shall remain on and the temperature shall continue to be recorded. After 30 s, the RPED shall be observed to determine pass/fail as specified in 4.13.1 and 4.13.2.

7.13.2.7 The RPED shall be removed and the test head form shall cool for 15 min.

7.13.2.8 The test head form shall be placed in the position shown in Fig. 16 so that the pyroheliometer in the eye is 240 mm from the heat panels. The voltage shall be set at the radiant head panels so that a constant heat flux of 0.12 ± 0.003 cal/cm^2/s reaches the pyroheliometer.

7.13.2.9 The radiant heat panels shall be removed from the chamber, the pyroheliometer shall be removed, and the test head form shall cool for at least 15 min. A new RPED shall be

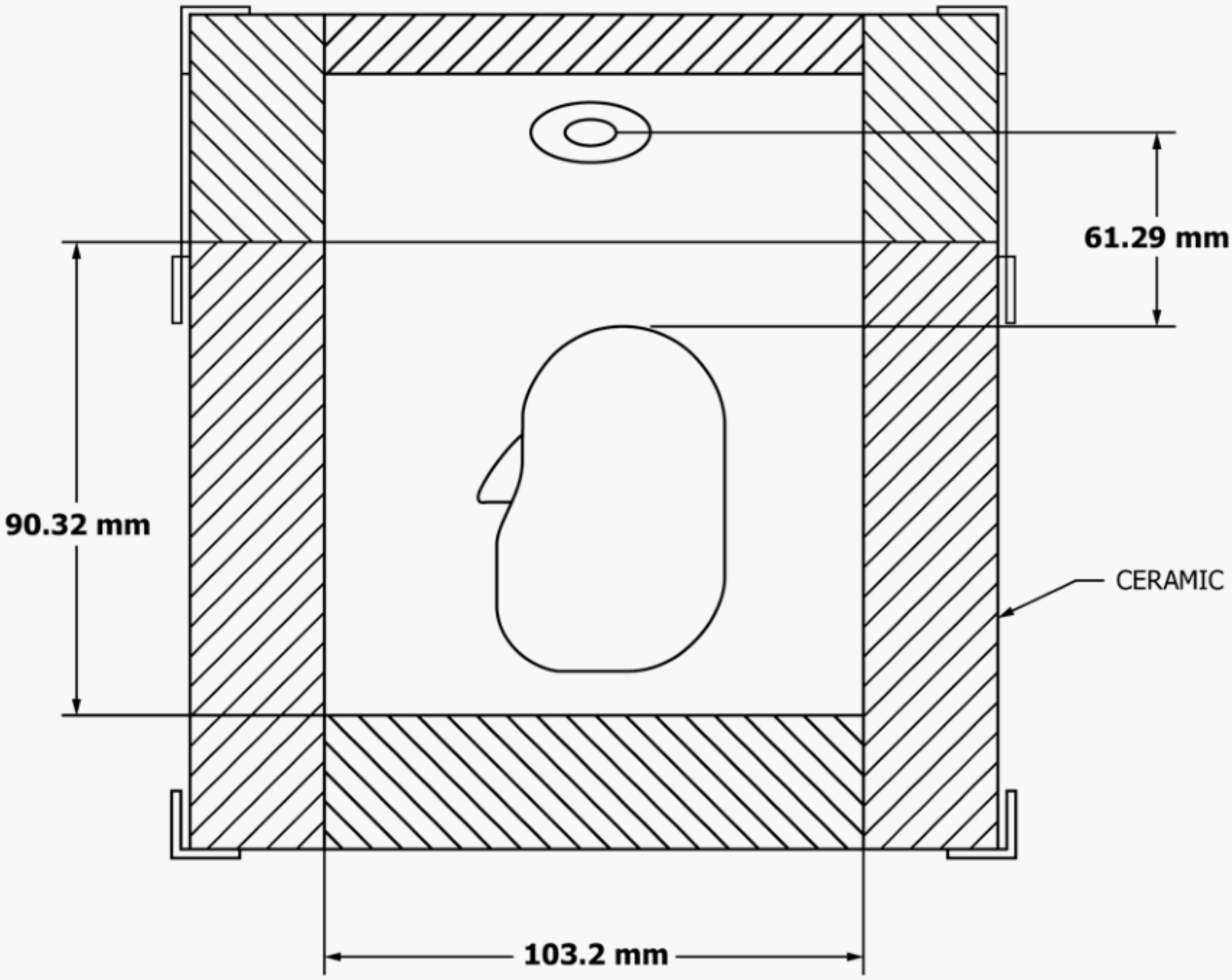

FIG. 15 Pyroheliometer Setup

placed on the test head form, and the test head form shall be returned to the test chamber and positioned at the distance specified in 7.13.2.8.

7.13.2.10 The radiant heat panel shall be turned on as specified in 7.13.2.8 and shall stabilize for at least 3 min.

7.13.2.11 The breathing machine shall be turned on. The hood shall be inflated before turning on the breathing machine or breath shall be used to inflate the hood.

7.13.2.12 The radiant heat panel shall be rolled back into the test chamber. The time taken to place the heat panel in the final test position shall be less than 2 s. The exposure to the heat lamps shall last 15 ± 1 s after the heat panels are in the final test position. The temperature at the eyes shall be continuously recorded.

7.13.2.13 After completing the procedure specified in 7.13.2.12, the heat panel shall be removed from the test chamber within 2 s. The breathing machine shall remain on and the temperature shall continue to be recorded. After 30 s, the RPED shall be observed to determine pass/fail as specified in 4.13.1 and 4.13.2.

7.14 *Corrosion-Resistance Test:*

7.14.1 The test chamber temperature shall be adjusted to 35 ± 2°C. The specimens shall be placed in the chamber for 2 h before the introduction of the salt solution.

7.14.2 RPED shall be tested in accordance with Practice B117. Salt spray shall be 5 % saline solution and test exposure shall be 48 h + 30/-0 min.

7.14.3 RPED shall then be stored in an environment that has a temperature of 22 ± 3°C and an RH of 50 ± 5 % for a minimum of 48 h.

7.14.4 Following the test exposure and storage, and before examination, RPED shall be permitted to be rinsed under warm, running tap water and dried with compressed air.

7.14.5 All controls or operating features of the RPED shall operate in accordance with the manufacturer's instructions to determine pass/fail as specified in 4.14.1. Specimens shall also be examined visually with the unaided eye to determine pass/fail in accordance with 4.14.2.

7.14.6 The RPED specimens shall then be tested as specified in 7.3, and the results reviewed to determine pass/fail as specified in 4.14.3 and 4.14.4.

8. Certification

8.1 *General:*

8.1.1 Each RPED model shall be certified to the standard. RPED's that are labeled as certified with this specification shall meet all applicable requirements of this specification. The certification program shall meet at least the criteria specified in

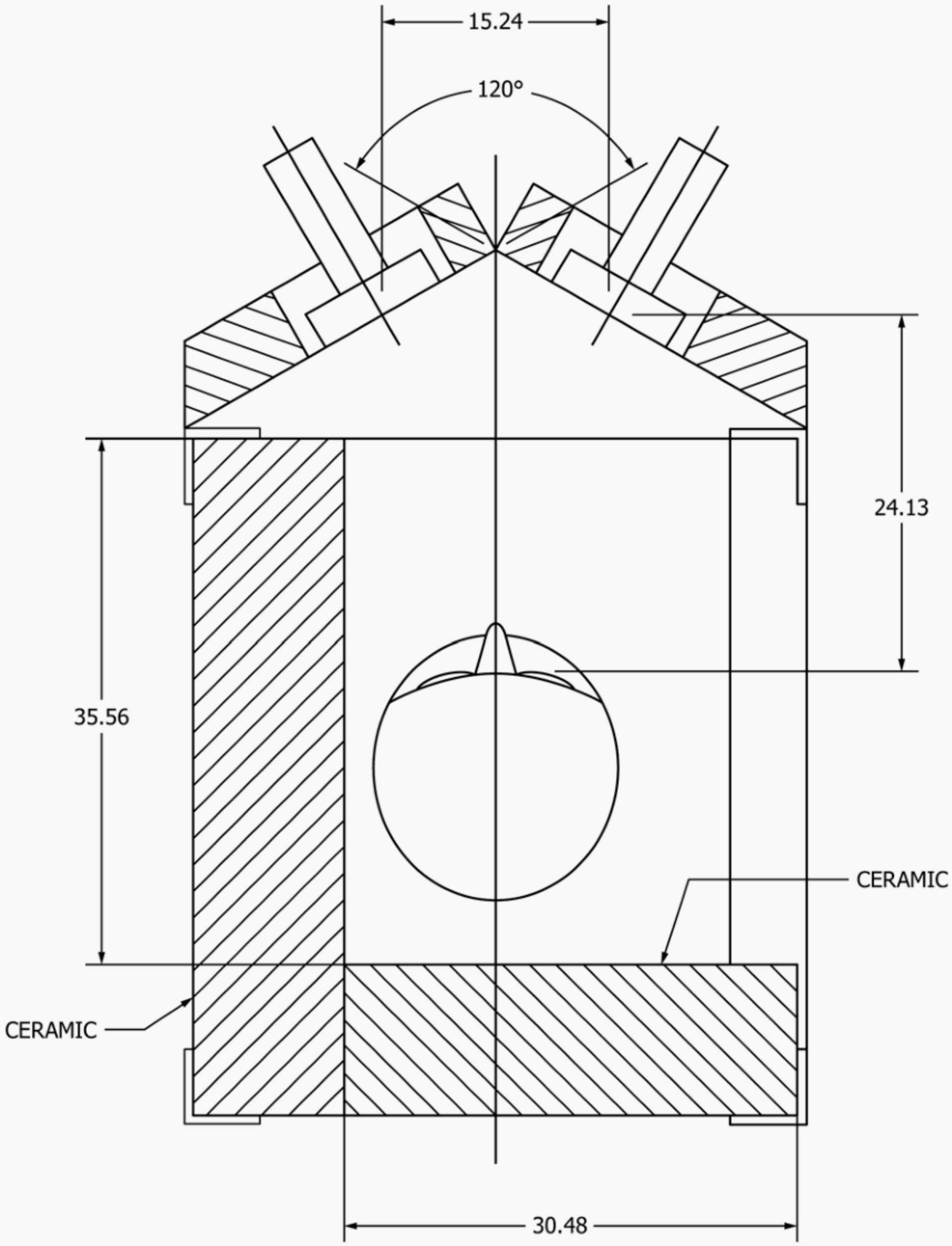

FIG. 16 Head Form Positioning (Dimensions in mm)

8.2. Manufacturers shall not claim compliance with any part of the requirements of this specification and shall not use the name or identification of this specification in any statements regarding their respective products unless the product is certified to this specification.

8.1.2 Each compliant RPED model that has been labeled and has entered the stream of commerce shall maintain its certification status throughout its shelf life.

8.1.3 A compliant RPED shall be labeled and listed. Such RPED shall also have a product label that meets the requirements specified in 9.1.

8.1.4 All certification shall be performed by a certification organization that meets at least the requirements specified in 8.2 and that is accredited for personal protective equipment in accordance with ISO/IEC 17065.

8.1.5 The RPED shall be tested with all accessories.

8.1.6 The RPED shall meet all of the performance requirements of this specification with the accessories installed. The accessories alone shall be required to meet only the requirements of 4.11 – 4.13.

8.2 *Certification Program:*

8.2.1 For both the initial certification and annual conformance testing of the RPED, the certification organization shall be responsible for all inspection, evaluation, conditioning, and testing as specified in this specification.

8.2.2 The certification organization shall refuse to certify products that do not comply with all applicable requirements of this specification.

8.2.3 The contractual provisions between the certification organization and the manufacturer shall specify that certification is contingent on compliance with all applicable requirements of this specification. There shall be no conditional, temporary, or partial certifications. Manufacturers shall not be authorized to use any label or reference to the certification organization on products that are not manufactured in compliance with all applicable requirements of this specification.

8.2.4 The certification organization and the manufacturer shall identify each model for approval and the variants within each model.

8.2.5 The certification organization shall require the manufacturer to establish and maintain a program of production inspection and testing that at least meets the requirements specified in 8.3. The certification organization shall audit the manufacturer's quality assurance program to ensure that the quality assurance program provides continued product compliance with this specification.

8.2.6 The certification organization shall have a follow-up inspection program of the manufacturing facilities of the certified product with at least one visit per twelve-month period. As part of the follow-up inspection program, the certification organization shall select four samples at random from the manufacturer's production line, the manufacturer's in-house stock, or the open market. These samples shall be inspected and tested by the certification organization to verify the product's continued compliance.

8.2.7 The certification organization shall require the manufacturer to have a product recall system as part of the manufacturer's quality assurance program.

8.2.8 The certification organization's name and label shall be registered and legally defendable.

8.3 *Inspection and Testing:*

8.3.1 The inspection by the certification organization to determine compliance with the design requirements specified in Section 5 shall be performed on RPED in the ready-to-use configuration.

8.3.2 RPED's shall be tested for certification to this specification and shall meet the performance requirements of one test series as specified in Table 2.

8.3.3 After initial certification to this edition, random RPED's from production shall be tested annually as specified in Table 4 and shall meet all the applicable performance requirements as specified in Section 4.

8.3.4 Any change in the design, construction, or material of a certified RPED shall necessitate new inspection and testing to verify compliance to all applicable requirements of this specification that the certification organization determines can be affected by such change. Inspection and testing shall be conducted before labeling the modified RPED as compliant with this specification.

8.3.5 For evaluation and testing for certification, the certification organization shall accept from the manufacturer only RPED or RPED components that are identical in every respect to the final product or component. The certification organization shall not permit the substitution, repair, or modification of any RPED or any RPED component during testing.

8.4 *ISO Registration for Manufacturers:*

8.4.1 The manufacturer shall provide and operate a quality assurance program that meets the requirements of this section and includes a documented product recall system as specified in 8.2.7.

8.4.2 The manufacturer shall be registered to ISO 9001 or another equivalent quality assurance system that is acceptable to the third-party certification organization.

8.4.3 The RPED shall be assembled in a facility that is registered at least to ISO 9002.

9. Labeling and Information

9.1 *Product Labeling Requirements:*

9.1.1 Each RPED shall have a product label(s) that is permanently and conspicuously attached to the outside of the ready-to-use configuration.

9.1.2 More than one label piece shall be permitted to carry all statements and information that are required to appear on the product label. Label pieces that comprise the product label shall be located adjacent to each other.

9.1.3 At a minimum, the following statement shall be legibly printed on the product label(s) in letters at least 2 mm high:

"THIS ESCAPE DEVICE MEETS THE REQUIREMENTS OF ASTM E2952, STANDARD ON AIR-PURIFYING RESPIRATORY PROTECTIVE SMOKE ESCAPE DEVICES AS A 15-MINUTE SERVICE LIFE DEVICE."

9.1.4 At a minimum, the following information shall also be legibly printed on the product label(s). All letters shall be at least 2 mm high.

9.1.4.1 Certification organization's label, symbol, or identifying mark;

9.1.4.2 Manufacturer's name, identification, or designation;

9.1.4.3 Manufacturer's product identification number, lot number, or serial number;

9.1.4.4 Month and year of manufacture (not coded);

9.1.4.5 Model name, number, or design; and

9.1.4.6 Expiration date.

TABLE 4 RPED Annual Conformance Testing Matrix

NOTE 1—Testing series repeats after Annual 5 Test Section.

Test Section	Year 1				Year 2				Year 3			Year 4				Year 5
	7.3	7.4	Table 3 Line 1	Table 3 Line 5	7.3	7.4	Table 3 Line 2	Table 3 Line 6	7.3	7.4	Table 3 Line 3	7.3	7.4	Table 3 Line 4	Table 3 Line 7	Recertification
	Test Specimen Number				Test Specimen Number				Test Specimen Number			Test Specimen Number				
Conditioning Section																
Vibration (6.2)	1	2			1	2			1	2		1	2			
Puncture/Tear (6.3)	1	2			1	2			1	2		1	2			
Temperature (6.5)	1	2			1	2			1	2		1	2			
Burst (7.7.2)	1	2			1	2			1	2		1	2			
None			3	4			3	4			3			3	4	

9.1.5 Each RPED product and product label shall contain the words "for one time use only" in letters at least 2 mm high.

9.1.6 All worded portions of the required product label shall be printed at least in English.

9.1.7 Symbols and other pictorial graphic(s) shall be permitted to be used to supplement the text on product labels.

9.2 *User Information:*

9.2.1 With each RPED, the RPED manufacturer shall provide, as a minimum, the user information that is specified in 9.2.5 and 9.2.6.

9.2.2 The user information shall clearly state that the RPED cannot be used in an oxygen-deficient atmosphere.

9.2.3 The RPED manufacturer shall attach the required user information, or the packaging that contains the user information, to the RPED or the storage container in a conspicuous location.

9.2.4 The RPED manufacturer shall provide notice that the user information is to be removed only by the end user. The user shall have access to the instructions and information without breaking the packaging seal.

9.2.5 The RPED manufacturer shall provide at least the following with each RPED:

9.2.5.1 Pre-use information:

(1) Safety considerations;

(2) Limitations of RPED, including clear direction that the RPED is intended for escape only;

(3) Oxygen-deficient atmosphere warning in 9.2.2;

(4) A statement that increased resistance to breathing is expected when using RPED;

(5) A statement that the temperature of inspired air may be hot;

(6) A statement that the RPED cannot be tested by the user; and

(7) A statement do not use if tamper seal is broken.

9.2.5.2 Recommended storage practices;

9.2.5.3 Instructions for donning and use;

9.2.5.4 Periodic checks or inspections;

9.2.5.5 Whether maintenance and cleaning instructions are required, if so, describe;

9.2.5.6 Service life; and

9.2.5.7 Shelf-life and instructions for removal from availability for use.

9.2.6 The RPED manufacturer shall also provide instructions with each RPED that cover the removal of the RPED from the ready-to-use configuration packaging and all preparations necessary to operate the RPED. Such preparations shall include placing the RPED over the head and face, tightening the straps, securing the mouth bit, nose clip, oral/nasal cup, as applicable, and adjusting the seals.

10. Keywords

10.1 air-purifying; escape devices; respiratory protection

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF WET TITRATION TO DETERMINE CHALLENGE CONCENTRATION

X1.1 Hydrogen Chloride (HCl)

X1.1.1 The concentration of HCl in the challenge gas/air stream mixture can be determined by sampling 10.0 L of challenge gas/air mixture at a rate of 1.0 L/min via a vacuum pump through a bubbler that contains 20 mL of distilled water and 10.0 mL of 0.10 *N* sodium hydroxide.

X1.1.2 Add five drops of methyl purple indicator solution to the bubbler.

X1.1.3 Titrate with 0.10 *N* HCl until the solution changes from green to purple.

X1.1.4 Calculate the concentration of the HCl in the challenge gas/airstream mixture using:

$$\text{ppm HCl} = [1.00 - (0.10 \times V_{HCl})] \times 1000 / 0.409 \quad \text{(X1.1)}$$

Where:

V_{HCl} = Volume of 0.10 *N* HCl, in millilitres, used in the titration, and

0.409 = Calculated number of milliequivalents of HCl in a 10-L sample of 1000-ppm HCl.

X1.2 Sulfur Dioxide (SO_2)

X1.2.1 The concentration of SO_2 in the challenge gas/air stream mixture can be determined by sampling 10.0 L of challenge gas/air mixture at a rate of 1.0 L/min via a vacuum pump through a bubbler that contains 20 mL of distilled water and 10.0 mL of 0.01 *N* iodine.

X1.2.2 Titrate the bubbler solution with 0.01 *N* sodium thiosulfate ($Na_2S_2O_3$) until the solution changes to a light straw color. Add approximately 0.1 g of thyodene and continue the titration until the solution becomes clear.

X1.2.3 Calculate the concentration of the SO_2 in the challenge gas/air stream mixture using the following equation:

$$\text{ppm } SO_2 = [0.1 - (0.01 \times V_{thio})] \times 100 / 0.0819 \quad \text{(X1.2)}$$

Where:

V_{thio} = Volume of 0.01 *N* sodium thiosulfate, in millilitres, used in the titration, and

0.0819 = Calculated number of milliequivalents of SO_2 in a 10-L sample of 100-ppm SO_2.

X1.3 Hydrogen Cyanide (HCN)

X1.3.1 The concentration of HCN in the challenge gas/air stream mixture can be determined by sampling 1.2 L of challenge gas/air mixture at a rate of 1.0 L/min via a vacuum pump through a bubbler that contains 30 mL of a 10 % sodium bicarbonate solution.

X1.3.2 Add 0.1 ± 0.05 g thyodene to the bubbler solution.

X1.3.3 Titrate with 0.01 *N* iodine until the solution becomes blue.

X1.3.4 Calculate the concentration of HCN in the challenge gas/air stream mixture using:

$$\text{ppm HCN} = V_i \times 20\,375 \times 0.005 \qquad \text{(X1.3)}$$

Where:

V_i = Volume of 0.01 *N* iodine, in millilitres, used in the titration,

0.005 = Number of millimoles/millilitre in 0.01 *N* iodine, and

20 375 = Conversion factor for millimoles of HCN to ppm HCN in a 1.2 L sample of 400 ppm HCN.