

June 30, 2002

Concept for CBRN Full Facepiece Air Purifying Respirator Standard**(1) Goal:**

Develop a NIOSH, NPPTL, tight fitting, full facepiece, air purifying respirator standard that addresses CBRN materials identified as inhalation hazards and/or possible terrorist hazards using a minimum number of filters for emergency responders.

Target: Two (2) filters

	Short Duration	Long Duration
TIMs	15 minutes*	60 minutes*

* Indicated times are for illustration only. Actual times will be established from hazard modeling and developmental test results.

(2) Hazards:

NIOSH has been evaluating various lists of chemicals that could be deployed as a result of a terrorist incident. In an effort to reduce the number of certification tests necessary as part of a Chemical Biological Radiological Nuclear (CBRN) Air-Purifying Respirator (APR) standard, efforts have been underway to categorize potential respiratory hazards into families with a representative test agents identified for each family. The following information is a synopsis of this effort to date.

The current carbon technology used in canisters and cartridges were reviewed from existing certification standards. The current standards for gas masks in Europe and the U.S. (NIOSH) were reviewed. The military purchasing specification for ASZM-T carbon for C2A1 military canisters was also reviewed. The most common parameters identified from the review of the military specification and the certification standards were the middle range certification challenges. Some of the test chemicals were considered to be redundant, since other test chemicals would guarantee the carbon effectiveness against the chemicals in question (Chlorine, Hydrogen Chloride, Hydrogen Fluoride, Phosphine, CS & CN Tear Gases). Cyclohexane is the representative chemical for organic vapors. Meeting the organic vapor test for a cartridge will provide protection for all organic vapors having vapor pressures less than that of cyclohexane. From the CWA /TIC list, approximately 61 organic chemicals are cover by this logic, including GB and HD. The acid gases (32 chemicals) are covered by cyanogen chloride, hydrogen cyanide, hydrogen sulfide, and sulfur dioxide. Ammonia represents the base gases, and covers another 4 chemicals on the list. Formaldehyde, phosgene, phosphine and nitrogen dioxide are considered special case chemicals. Phosphine is a hydride and must be removed catalytically (copper⁺² and silver impregnates on carbon). Therefore, 108 of the 151 chemicals can be addressed through testing these 10 chemicals. Nine of the test chemicals are listed in ITF 25.

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Particulate Biological Agents and Particulate Radiological/Nuclear Agents have also been considered as part of the development of test representative agents. Thirteen biological agents are addressed as part of the standard. They include Anthrax, Brucellosis, Glanders, Pneumonic Plague, Tularemia, Q Fever, Smallpox, Venezuelan Equine Encephalitis, Viral Hemorrhagic Fevers, T-2 Mycotoxins, Botulism, Ricin, and Staphylococcus Enterotoxin B. Sixteen radiological/nuclear agents addressed as part of the standard include Hydrogen 3, Carbon 14, Phosphorous 32, Cobalt 60, Nickel 63, Strontium 90, Technetium 99m, Iodine 131, Cesium 137, Promethium 147, Thallium 204, Radium 226, Thorium 232, Uranium 235 & 238, Plutonium 239, Americium 241.

Chemicals	Organization Using as Test Agent
Ammonia	NIOSH & EN
Cyclohexane	Organic Vapor- EN
Cyanogen Chloride	Military
Formaldehyde	NIOSH
Hydrogen Cyanide	NIOSH, EN & Military
Hydrogen Sulfide	NIOSH & EN
Nitrogen Dioxide	NIOSH & EN
Phosgene	Military
Sulfur Dioxide	NIOSH & EN
Phosphine	NIOSH

Hazard mapping: Conduct modeling based on the ‘Most Credible Event’ (MCE) scenarios developed for the open-circuit SCBA CBRN standard to determine warm zone operational scenarios. Add or delete scenarios depending on the Toxic Industrial Material (TIM) being evaluated.

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(3) Respirator Use:

A. Warm Use: Less than IDLH concentrations, to REL; sustained warm zone support operations; long term use for decon, traffic control, rehabilitation, rescue and recovery; agent known & quantified.

B. Crisis Provision: Contingency use for short duration, above IDLH concentrations and high physiological (flow) demand possible; Contingency for unforeseen factors such as secondary device or pockets of entrapped hazard.

Filter	Configuration	Long Duration Less Than IDLH	Crisis Panic Demand	Short Duration Less Than IDLH
Filter #1, TIMs	Full Facepiece Back or Chest Mounted	60 Minutes*	5 Minutes*	
Filter #2, TIMs	Full Facepiece Mask Mounted		5 Minutes*	15 Minutes*

* Indicated times are for illustration only. Actual times will be established from hazard modeling and developmental test results.

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(4) Filter Test Requirements:

Test Matrix for CBRN Air Purifying Respirators; June 12, 2002

Test Order	Penetration and Permeation Testing	Particulate Testing	Service Life Testing, 64 lpm flow	Service Life Testing, high flow	42 CFR Testing	Drop (not order specific)	Human Factors (not order specific)	Interchangeability
	6 APR systems (3 - GB and 3 - HD)	60 canister Units	60 canister units	12 canister units	TBD APR systems	6 Canister Units (2 per test)	APR Systems --TBD -- (2 APR systems per test)	APR Systems --TBD --
1.	Hot diurnal	Hot diurnal	Hot diurnal	Service Life Testing, 100 LPM	Canister in Parallel Resistance Requirements, 84.112	Major axis vertical, air inlet down	Hydration ⁽³⁾	EN 136 & EN 148 Mechanical Connector
2.	Cold constant	Cold constant	Cold constant		Breathing Tube, 84.115	Major axis vertical, air inlet up	Optical Haze	Breathing Resistance
3.	Humidity	Humidity	Humidity		Facepieces; eyepieces minimum requirements, 84.119	Major axis horizontal	Communications	Dimensions: Size & Weight
4.	Transportation vibration	Transportation vibration	Transportation vibration		Exhalation valve leakage test, 84.123 ⁽²⁾		Field of View	Facepiece Leakage
5.	System testing (GB or HD)	Initial breathing resistance, 84.122	Initial breathing resistance, 84.122		Determine CO ₂ levels ⁽⁴⁾		Donning	
6.		DOP Testing, 84.181	Service Life Testing, 64 LPM				Fogging	
7.		Final breathing resistance, 84.122	Final breathing resistance, 84.122				LRPL Testing	

Notes:

1. The six (6) APR systems may be used in the Penetration and Permeation test.
2. RCT-APR-STP-0004, Determination of Exhalation Valve Leakage Test, APR, STP, dated March 7, 2002 for HF Breathing Resistance: 3 Respirators.
3. RCT-APR-STP-0014, Determination of Leakage of Drinking Tube and Accessories for Respirator Facepieces STP, dated January 14, 2002, for HF Hydration/Drinking Tube: 3 Respirators.
4. RCT-APR-STP-0064, Determination of Facepiece Carbon Dioxide and Oxygen Concentration Levels of Tight Fitting Powered Air Purifying Respirators with the Blower Unit Off and Tight Fitting Non-Powered Gas Masks with a Tight Fitting Neck Seal STP, dated April 26, 2001 for HF CO₂ Test: 3 Respirators.

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	Warm Zone	Crisis ⁽¹⁾
	Non IDLH ⁽²⁾	Greater than IDLH ⁽²⁾
64 lpm flow	X	
high flow 100 lpm		X
Rough handling	X	X

(1) Crisis is a high use concentration at a high flow rate, 100 liters, per minute.

(2) Same test concentrations, different flow rates

(5) Special Test Requirements:

(5)(a) Chemical Agent Permeation and Penetration Resistance Against Distilled Mustard (HD) and Sarin (GB) Agent Requirement

The air purifying respirator system, including all components and accessories shall resist the permeation and penetration of distilled sulfur mustard (HD) and Sarin (GB) chemical agents when tested on an upper-torso manikin connected to a breathing machine operating at an air flow rate of 40 liters per minute (L/min), 36 respirations per minute, 1.1 liters tidal volume.

Test requirements for distilled sulfur mustard (HD) are shown in Table 1.

Table 1: Simultaneous Liquid and Vapor Challenge of APR with Distilled Sulfur Mustard (HD)

Agent	Challenge Concentration	Duration of Challenge (min)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion (mg/m ³)	Maximum Breakthrough (concentration integrated over Minimum Service Life) (mg-min/m ³)	Number of Systems Tested	Minimum Service Life (hours)
HD-Vapor	300 mg/m ³	TBD ^{(1)**}	40	0.60 ⁽³⁾	TBD ⁽⁴⁾	3	TBD ^{(2)**}
HD-Liquid	TBD	TBD					

** Duration of challenge and minimum service life will be determined from hazard modeling and developmental test results.

⁽¹⁾ Vapor challenge concentration will start immediately after the liquid drops have been applied and the test chamber has been sealed.

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- (2) The test period begins upon start of initial vapor generation.
- (3) Three consecutive sequential test data points at or exceeding 0.6 mg/m³ will collectively constitute a failure where each test value is based on a detector sample time of approximately 2 minutes.
- (4) The cumulative Ct including all peak data points must not be exceeded for the duration of the test.

Test requirements for Sarin (GB) agent are shown in Table 2.

Table 2: Vapor Challenge of APR with Sarin (GB)

Challenge Agent	Vapor Concentration (mg/m ³)	Vapor Challenge Time (minutes)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion mg/m ³	Maximum Breakthrough (concentration integrated over Minimum Service Life) (mg-min/m ³)	Number of Systems Tested	Minimum Service Life (hours)
GB	2,000 mg/m ³	TBD ^{(1)**}	40	0.087 ⁽³⁾	TBD ⁽⁴⁾	3	TBD ^{(2)**}

** Duration of challenge and minimum service life will be determined from hazard modeling and developmental test results.

- (1) The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.
- (2) The test period begins upon initial generation of vapor concentration.
- (3) Three consecutive sequential test data points at or exceeding 0.087 mg/m³ will collectively constitute a failure where each test value is based on a detector sample time of approximately 2 minutes.
- (4) The cumulative Ct including all peak data points must not be exceeded for the duration of the test.

(5)(b) Laboratory Respiratory Protection Level (LRPL) Test Requirement:

The measured laboratory respiratory protection level (LRPL) for each full facepiece, air purifying respirator shall be 1000, when the APR facepiece is tested in a negative pressure mode in an atmosphere containing 20-40 mg/m³ corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers.

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(6) Design Requirements:

(6)(a) Filter Canister Test Challenge, Breakthrough Concentrations, and Filtration Efficiency

	Test Concentration (ppm) Draft	Breakthrough Concentration (ppm) Draft
Ammonia	2500	12.5
Cyanogen Chloride	300	2
Cyclohexane	3900	10
Formaldehyde	1000	1
Hydrogen Cyanide	940	4.7
Hydrogen Sulfide	1000	5.0
Nitrogen Dioxide	200	1
Phosgene	250	1.25
Phosphine	1500	5
Sulfur Dioxide	1500	5

The filter shall conform to the P100 filter requirements, as described in 42 CFR, Part 84

(6)(b) Interchangeable consumable filter cartridges and canisters

Interchangeable consumable filter cartridges and canisters are not required as part of CBRN APR certification. Optional approval requirements for manufacturers are identified in the following paragraphs.

(6)(b)(1) Mechanical Connector

The interface between the filter and the facepiece or respirator system shall use a standard thread in accordance with European Standard EN148.1. The filter shall be readily replaceable without use of special tools. The interface connector on the facepiece shall be the female thread and gasket-sealing gland as identified in EN148.1. The filter shall use a male thread in accordance with EN148.1. For respirators where the filter canister is not directly attached to the facepiece, (i.e., not mask mounted) a female thread and gasket sealing gland connector complying with EN 148.1 must be securely attached to a harness system to provide strain relief between the filter and the remaining respirator system.

(6)(b)(2) Performance Requirements for Interchangeability

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(6)(b)(2)(a) Breathing Resistance, Facepiece

The facepiece resistance to airflow shall be less than or equal to 10 mm water column when tested at 85 liters per minute.

(6)(b)(2)(b) Breathing Resistance, Mask Mounted (Chin Style) Filter

The filter resistance to airflow shall be less than or equal to 55 mm water column when tested at 85 liters per minute in the initial condition.

(6)(b)(2) (c) Breathing Resistance, Non-Facepiece Mounted Filter

The resistance to airflow for the respirator less facepiece shall be equal to or less than 60 mm water column height when tested at 85 liters per minute.

(6)(b)(2)(d) Dimensions and Weight, Mask Mounted (Chin Style) Filter

The maximum weight of a mask mounted (chin style) filter shall be 500 grams. The maximum size of a mask mounted (chin style) filter shall be such that the filter shall pass (with the threaded connector perpendicular to the diameter opening) through a 5-inch diameter opening.

(6)(b)(2)(e) Facepiece Leakage

The leakage of the facepiece shall not exceed that indicated by a change of 10 mm H₂O in 1 minute when tested with 95 to 100 mm H₂O negative pressure. The test shall be performed using a mannequin head and a pressure of negative 95 to 100 mm H₂O created in the cavity of the facepiece. The inhalation port of the mask shall be fitted with a test filter weighted to 500 grams and sized to the maximum permissible dimensions of (6)(b)(2)(d). The exhalation valve shall be moistened for the test.

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(6)(c) Rough handling (transportability, temperature range, survivability)

Test	Test Method	Test Condition	Duration	Pass / Fail Criteria ¹
Hot Diurnal	Mil-Std-810F, 501.4	71 °C max, cyclical	3 Weeks	Gas Life, System Permeation / Penetration
Cold Constant	Mil-Std-810F, 502.4	Basic Cold, -32 °C	3 Days	Gas Life, System Permeation / Penetration
Humidity	Mil-Std-810E, 507.3	Table 507.3-II, Natural Cycle, Cycle 1	5 Days, Quick Look	Gas Life, System Permeation / Penetration
Vibration	Mil-Std-810F, 514.5	US Highway Vibration, Unrestrained Figure 514.5C-1	12 Hours / Axis, 36 Hours Total (12,000 miles)	Gas Life, System Permeation / Penetration
Drop	3 foot drop onto concrete	Filter Only, 3 Axis	N/A	Gas Life, System Permeation / Penetration

(1) Pass / Fail Criteria is determined after APR has been subjected to Hot, Cold, Humidity and Vibration environmental exposure sequence order. Pass / Fail Criteria for Drop test is determined after 3 drops, 1 drop per axis, is completed.

(6)(d) Operational Characteristics (donning, field of view/acuity, flow, resistance, storage life, usage life)

(6)(d)(1) Full Facepiece Fogging

The respirator performance rating for resistance to fogging shall be greater than or equal to 70% when tested in accordance to the fogging test procedure, Appendix A:

(6)(d)(2) Communications

The respirator performance rating for communications shall be greater than or equal to 70% when tested in accordance with the communications test procedure, Appendix B.

(6)(d)(3) Breathing Resistance

Resistance to air flow shall be measured in the facepiece of a CBRN air purifying respirator mounted on a test fixture with air flowing at a continuous rate of 85 liters per minute both before and after each gas service life bench test. The maximum allowable resistance to air flow is as follows:

	Chin Style	Non Facepiece Mounted
Inhalation:		
Initial	65 mm H ₂ O	70 mm H ₂ O
Final ⁽¹⁾	80 mm H ₂ O	85 mm H ₂ O
Exhalation:	26 mm H ₂ O	26 mm H ₂ O

⁽¹⁾ Measured at end of service life

(6)(d)(4) Field of View

The full facepiece equipped with a single visor shall be designed so that the effective field of vision shall be not less than 70% related to the natural field of vision, and the overlapped field of vision related to the natural overlapped field of vision, shall not be less than 80%.

A full facepiece equipped with two eyepieces shall be designed so that the effective field of vision shall not be less than 70% related to the natural field of vision, and the overlapped field of vision, shall not be less than 20%.

The field of view test procedure will be developed based on procedures of EN 136.

(6)(d)(5) Haze (Lens Abrasion)

Specimen CBRN APR facepiece lenses shall be tested for abrasion resistance and the average value of the tested specimens shall not exhibit a delta haze greater than 14%.

The abrasion resistance test procedure will be developed based on NFPA 1981 standard procedures.

(6)(d)(6) Carbon Dioxide

The maximum allowable average inhaled CO₂ concentration shall be less than or equal to 2%.

Test procedure RCT-APR-STP-0064 is used for carbon dioxide testing.

(6)(d)(7) Hydration

For CBRN APR respirators equipped with a hydration facility, the CBRN APR respirator shall meet all requirements of the CBRN APR standard with the hydration facility in place. In addition, dry drinking tube valves, valve seats, or seals will be subjected to a suction of 75mm water column height while in a normal operating position. Leakage between the valve and the valve seat shall not exceed 30 milliliters per minute.

Test procedure RCT-APR-STP-0014 shall be used to test the hydration facility for leakage.

(6)(e) Long term field auditing/maintenance procedures/ inspection

(6)(f) Extracts from 42 CFR, Part 84

(6)(f)(1) 42 CFR, Part 84 Subparts A, B, D, E, F and G apply in total:

Subpart A: General Provisions

Subpart B: Application For Approval

Subpart D: Approval and Disapproval

Subpart E: Quality Control

Subpart F: Classification of Approved Respirators

Subpart G: General Construction and Performance

(6)(f)(2) 42 CFR, Part 84 Subpart I; the following paragraphs apply:

84.110 Gas Masks; description.

84.111 Gas masks; required components

84.112 Canisters and cartridges in parallel; resistance requirements

84.113 Canisters and cartridges; color and markings; requirements

84.114 Filters used with canisters and cartridges; location; replacement

84.115 Breathing tubes; minimum requirements

84.116 Harnesses; installation and construction; minimum requirements

84.117 Gas mask containers; minimum requirements

84.118 Half-mask facepieces, full facepieces, and mouthpieces; fit; minimum requirements

84.119 Facepieces; eyepieces; minimum requirements

84.120 Inhalation and exhalation valves; minimum requirements

84.121 Head harnesses; minimum requirements

84.123 Exhalation valve leakage test

Appendix A – Full Facepiece Fogging

Two individuals with a visual acuity of 20/70 better shall perform each test while wearing the apparatus according to manufacturers directions. Test participants shall be assigned a properly sized and fitted test respirator for each environmental exposure condition. All participants shall be trained in the donning and usage of the respirator per manufacturer's instructions.

Prior to testing, visual acuity shall be recorded for each subject while wearing the respirator using Snellen Eye Test charts or an equivalent method.

Test 1

The APR shall be cold soaked in an environmental chamber at minus 21°C (-6°F) for 4 hours.

At the start of each cold temperature wear trial a test participant shall enter the test chamber (maintained at -21°C) and sit quietly for five minutes. Once the five minute rest period transpires, subjects shall self-don their assigned respirator.

A visual acuity test shall then be administered to quantify the impact of any lens fogging on vision.

The test participant shall then complete a 12-minute work-rest-work regimen comprised of five minutes of exercise, 2 minutes of rest, and an additional five minutes of exercise with the exercise periods consisting of treadmill walking at 4.8 km/hr (3 mph) on a level grade.

Visual acuity tests shall be repeated at the end of each walk period (i.e., after five minutes of walking and at the end of the 12 minute period immediately following the treadmill walk).

Test 2

The APR shall be conditioned in an environmental chamber at 15.5°C (60°F), 75% RH for 4 hours.

At the start of each cool/humid temperature wear trial a test participant shall enter the test chamber (maintained at 15.5 C) and sit quietly for five minutes. Once the five minute rest period transpires, subjects shall self-don their assigned respirator.

A visual acuity test shall then be administered to quantify the impact of any lens fogging on vision.

The test participant shall then complete a 12-minute work-rest-work regimen comprised of five minutes of exercise, 2 minutes of rest, and an additional five minutes of exercise with the exercise periods consisting of treadmill walking at 4.8 km/hr (3 mph) on a level grade.

Visual acuity tests shall be repeated at the end of each walk period.

Interpretation of Results

Visual acuity scores obtained during each environmental test with the respirator shall be divided by a subject's visual acuity score obtained with the mask prior to testing to calculate a *performance rating* using the following equation:

$$\text{Performance Rating (\%)} = \text{VA}_{\text{CHAMBEREX}} / \text{VA}_{\text{INITIAL}} \times 100 \quad (1)$$

where $\text{VA}_{\text{chamber } x}$ = visual acuity score during chamber test at time x and $\text{VA}_{\text{initial}}$ = visual acuity score obtained with the mask prior to testing.

Visual acuity performance ratings calculated from measurements taken post-donning and at the end of each treadmill walk shall be averaged for each individual subject to obtain an average visual acuity performance rating for each subject based on the environmental condition.

Average *performance rating* for each test participant shall be greater than or equal to 70% for both Test 1 and Test 2 to meet the fogging requirement.

Appendix B—Communication

- 1) Speech intelligibility testing shall be accomplished through the use of the Modified Rhyme Test (MRT), which evaluates a listener’s ability to comprehend single words and provides an indication of speech transmission of the selected words. The MRT consists of multiple lists of 50 monosyllabic, phonetically balanced words each. A sample word list is provided in Table 1.

Table 1. Sample MRT stimulus word list

1. lick	11. same	21. pad	31. pip	41. name
2. beat	12. peal	22. din	32. seen	42. soil
3. puff	13. kit	23. sit	33. way	43. fin
4. cook	14. sat	24. win	34. west	44. cuff
5. tip	15. sin	25. teak	35. pace	45. heal
6. rave	16. gold	26. dent	36. bat	46. hark
7. hang	17. buff	27. sub	37. mop	47. heat
8. till	18. lay	28. led	38. big	48. then
9. math	19. nun	29. tot	39. tab	49. law
10. sale	20. must	30. dub	40. case	50. bean

- 2) Three test listeners consisting of two males and one female shall comprise the subject test panel. All participants shall be tested for “normal” hearing prior to testing by a qualified individual.
- 3) An additional five individuals (four males and one female) without obvious speech defects or strong regional accents shall serve as MRT speakers.
- 4) All participants shall be trained in the donning and usage of the respirator per manufacturer’s instructions and all shall pass a qualitative facepiece-to-face fit check according to the manufacturer’s instructions.
- 5) Procedure:
 - a. The three test listeners shall be seated opposite a single test speaker for each MRT trial at a distance of 3 meters (10 ft), and they shall be facing one another. Each listener shall be given a multiple choice answer sheet or positioned before a computer and monitor that will be used to input his or her responses.
 - b. Data for the MRT will be collected with a steady background noise of 60 dBA consisting of a broadband “pink” noise. A Brüel and Kjaer Type 1405 Noise Generator or equivalent will be used to produce the background noise. Background noise levels will be monitored at a position near the listening panel using a Type 2 digital sound level meter and recorded at the beginning, middle, and end of each MRT session.

- c. The test speaker shall present each stimulus word using the carrier phrase “The word is _____.”
- d. Speakers will be instructed and trained to maintain a constant output volume at 75 dBA to 85 dBA for all presented words. A Type 2 digital sound level meter will be positioned in front of the speaker within his or her sight to provide feedback concerning the loudness of their voice during testing. Speaker output levels will be recorded at the beginning, middle, and end of each MRT session for verification.
- e. Listeners will select the word that was perceived to be spoken from a list of six response words presented on the computer monitor by clicking a button on the monitor that corresponds to the perceived word. If given a paper answer form, subjects will circle their selection. A sample answer sheet is provided in Figure 1.
- f. Test listeners shall then provide a thumbs-up hand signal to the speaker to cue him or her to say the next word.
- g. An individual speaker will present a total of 50 stimulus words to complete one MRT trial. A different speaker shall then be used to present the next MRT trial. Test speakers will continue to rotate among the speaker test panel until all trials have been complete. A sample test matrix is provided in Table 2.
- h. Data will be obtained without the respirator and with the respirator worn and operated per the manufacturer’s instructions by both speakers and listeners. All conditions shall be randomly assigned and a different word list shall be used for each test. Again, an example of a test matrix is provided in Table 2.

Table 2. Sample MRT test matrix

Speaker	Speaker Condition	Listeners’ Condition	Word list
1	No mask	No mask	1
2	No mask	No mask	3
3	Masked	Masked	5
4	Masked	Masked	7
5	No mask	No mask	9
2	Masked	Masked	2
4	No mask	No mask	4
1	Masked	Masked	6
5	Masked	Masked	8
3	No mask	No mask	10

- i. A total of 10 MRT trials shall be performed. The 10 trials will result in a total of 15 MRT scores (five per listener) for the unworn mask condition and 15 scores for the worn condition.
- j. Listener performance on the MRT shall be scored in terms of the percentage of words correctly identified using the equation:

$$\% \text{ correct} = (\text{number correct} - (\text{number incorrect}/5)) * 2 \quad (1)$$

The equation accounts for chance or guessing made possible by the multiple-choice form of the answer sheet (*Human Engineering Guide to Equipment Design*, American Institutes for Research, Washington, DC, 1972).

- k. Individual listeners' scores for the unworn and worn respirator conditions shall be averaged for each condition.
- l. Each individual listener's average score with the respirator shall be divided by their average unmasked MRT score to calculate a *performance rating* (ref equation (2)). (Because the listening subjects serve as their own controls, the performance rating allows the effect of the respirator condition to be isolated from the effect of the individual).

$$\text{Performance rating (\%)} = \left(\frac{\text{MRT \%correct with respirator}}{\text{MRT \%correct without respirator}} \right) \times 100 \quad (2)$$

- m. The communications requirement shall be met if the average *performance rating* is greater than or equal to 70%.

MRT Listener Response Sheet Date: _____ Listener Position: _____ TP#: _____

Scenario: _____ Speaker: TP#: _____ Mask Condition: _____

**** 1-A ****

1	kick tick	lick wick	sick pick	14	sack sag	sad sat	sap sass	27	sup sum	sub sun	sud sung	40	cake cane	came case	cave cape
2	neat meat	beat feat	seat heat	15	sit sick	sip sin	sill sing	28	wed led	fed shed	bed red	41	tame same	came name	fame game
3	pun pub	puff pus	pup puck	16	fold hold	sold cold	gold told	29	pot not	hot tot	lot got	42	toil coil	boil oil	foil soil
4	hook took	shook cook	book look	17	but buff	bug bun	bus buck	30	duck dun	dud dug	dung dub	43	fig fib	fizz fin	fit fill
5	lip sip	hip rip	dip tip	18	late lame	lake lane	lay lace	31	pit pill	pin pick	pig pip	44	cuss cut	cud cub	cup cuff
6	rake raze	rate race	ray rave	19	run sun	bun nun	fun gun	32	seethe seed	seek seep	seen seem	45	heel feel	peel eel	keel reel
7	fang sang	bang gang	hang rang	20	dust bust	gust just	must rust	33	say gay	pay way	may day	46	mark lark	bark hark	dark park
8	will bill	hill fill	kill till	21	path pat	pack pad	pass pan	34	best vest	west test	nest rest	47	heath heat	heave heal	heap hear
9	map mad	mat mass	math man	22	dip dill	dim did	din dig	35	page pave	pane pale	pace pay	48	then pen	den hen	ten men
10	pale gale	sale male	bale tale	23	fit sit	hit kit	bit wit	36	bash back	bat bath	ban bad	49	law jaw	saw raw	paw thaw
11	sane save	sake same	safe sale	24	tin win	fin pin	sin din	37	hop mop	cop pop	shop top	50	beat beam	beak bean	beach bead
12	peak peal	peach peace	peas peat	25	tear team	teal tease	teak teach	38	dig fig	wig pig	big rig	Score			
13	kin king	kid kit	kick kill	26	dent went	tent sent	rent bent	39	tack tang	tan tam	tab tap				