

Performance of the Communication Enhancement and Protective System (CEPS) Under Sustained High and Low Temperatures

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14. ABSTRACT The USAARL conducted airworthiness testing on the Communication Enhancement and Protection System (CEPS). The test plan included conducting acoustic performance evaluations of the CEPS to determine if the CEPS would maintains clear and audible communications to the ear of the user and all its components would remain operational after exposure to sustained high and low temperatures conditions (Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests MIL-STD-810F). The CEPS met the test criteria after the high temperature operation test (49 °C) and the high temperature storage tests (52 °C). The device failed to meet the criteria after the maximum high temperature storage test (63 °C), possibly because of a component failure. The device met the test criteria after the low temperature operation test (-19° C) and after one iteration each of a 4-hr low temperature storage test conducted at -21 °C and -33 °C. The device failed the test criteria after one low temperature storage test (-46 °C), possibly because of component failure. (continued on next page)						
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In each case of component failure, the tube of the right microphone had become detached from the faceplate; measurements were erratic or could not be completed and testing was ended. It is recommended that the CEPS not be stored at temperatures higher than 52 °C longer than 6 hours or below -33 °C, and must be protected from condensation after exposure to low temperature operation and storage.

Acknowledgements

We acknowledge the assistance of Jeaneen Lesniak and Bruce Hall in the set up and operation of the Tenney walk-in controlled environmental chamber during the conduct of the study.

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Introduction

The Communication Enhancement and Protection System (CEPS) is a system designed to control the sound level that arrives at the ear and provide the user with dual radio communications. An expanding foam earplug attenuates ambient sounds that enter the occluded ear canal. The system integrates highly sensitive microphones, rapid response micro-circuitry that inputs the sound to the ear through the miniature earphone of the communications earplug (CEP) that is attached to the expanding foam earplug. The user can control the volume of the signal reaching the ear by contact switches. The device was designed to provide enhanced sound detection capability and localization in "recon" or "watch" modes; enhanced face-to-face communication for night, Mission Oriented Protective Posture (MOPP) or military operations on urban terrain (MOUT) operations; and two-way radio communications in stealth mode. It provides protection for both hazardous impulse and continuous noise environments and rapid cut-off and recovery protection for weapons firing.

The Aviation & Missile, Research, Development & Engineering Center, (AMRDEC), Product Manager Air Warrior (PM-Air Warrior) requested the U.S. Army Aeromedical Research Laboratory (USAARL) conduct airworthiness testing of the Communication Enhancement and Protection System (CEPS). Test requirements include environmental performance testing at sustained high and low temperatures in accordance with (IAW) Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests MIL-STD-810F, 1 January 2000 (MIL-STD-810F). This test report describes the results of partial execution of an environmental performance test plan for the CEPS, prepared for PM-Air Warrior.

USAARL developed a test plan to conduct acoustic performance testing in conjunction with conducting environmental performance testing of the CEPS. Portions of the test plan were completed but as noted in the report, testing was stopped and/or resumed when the device either failed to meet the test criteria or mechanical failure, after specific sections of the test plan were completed.

Specific tasks

Task A. Conduct Acoustic Output Limits testing, pre-environmental performance testing in IAW MIL-STD-810F; high temperature operation test, high temperature storage test, low temperature operation test, and low temperature storage test), to verify that the CEPS device maintains a maximum output that is not detrimental to hearing or safety of the wearer.

Task B. Conduct frequency response, sensitivity, and distortion tests pre-environmental performance testing, to verify that the CEPS will provide and maintain clear, audible communications to the ear of the wearer and is electrically compatible with the communications radio of the aircraft, and which will also serve as the pretest baseline for this testing.

Task C. Conduct frequency response tests, at 300 Hertz (Hz), 600 Hz, 1.0 kilohertz (kHz), 2.0 kHz, and 4.0 kHz, pre/post-high temperature storage tests. Conduct test, IAW MIL-STD-810F, Method 501.4, Procedure I (high temperature storage procedure).

Task D. Conduct frequency response tests, at 300 Hz, 600 Hz, 1.0 kHz, 2.0 kHz, and 4.0 kHz, pre/post-high temperature operation test. Conduct tests, IAW MIL-STD-810F, Method 502.4, Procedure II (high temperature operation procedure).

Task E. Conduct frequency response tests, at 300 Hz, 600 Hz, 1.0 kHz, 2.0 kHz, and 4.0 kHz, pre/post-low temperature storage tests. Conduct tests, IAW MIL-STD-810F, Method 502.4, Procedure I (low temperature storage procedure).

Task F. Conduct frequency response tests, at 300 Hz, 600 Hz, 1.0 kHz, 2.0 kHz, and 4.0 kHz, pre/post-low temperature operation tests. Conduct tests, IAW MIL-STD-810F, Method 501.4, Procedure II (low temperature operation procedure).

Test plan/methods

Baseline performance assessment

Objective

To determine if the equipment under test (EUT) is operational, IAW manufacturer's specifications.

Criteria

The EUT will meet susceptibility criteria: (1) altered acoustic performance from the manufacturer's specifications, (2) power failure, and (3) other unintended operations.

Test procedures

The EUT performance will be validated to ensure that all components are functional. The EUT will undergo frequency response, sensitivity, and distortion tests to verify the CEPS will provide and maintain clear, audible communications to the ear of the wearer. This will also serve as the pre-test baseline for the environmental testing.

High temperature

Objective

To determine the ability of the EUT to operate and be stored in high-temperature environments.

Criteria

The EUT will not experience the susceptibility criteria listed in the test plan, during the performance validation checks as outlined in the test procedures.

Procedure

Tests will be performed using MIL-STD-810F Method 501.4 as guidance. The test consists of two procedures:

Procedure II – High Temperature Operation. The EUT will be tested at 43 degrees Celsius (°C) and 49 °C. If the EUT meets the test criteria at 49 °C, repeat the procedure two more times for reliability. If the EUT does not meet the test criteria at 49 °C, repeat the procedure twice at 43 °C. Humidity will be set at 20%. The EUT will be turned on and exposed to the test conditions for 2hr.

Procedure I – High Temperature Storage. The EUT will be tested at 63 °C and 71 °C. If the EUT meets the test criteria at 71 °C, the test will be repeated two more times for reliability. If EUT does not meet the test criteria at 71 °C, the procedure will be repeated two more times at 63 °C. Humidity will be set at 20%. The EUT will be turned on and exposed to the test conditions for 6 hr.

During the operation and storage procedures, the EUT will be placed inside the test chamber. Prior to testing, the EUT subject matter expert from USAARL's Acoustics Branch will validate the CEPS communication performance, as described in Task A. After the test cycle, the EUT will be returned to ambient conditions for post-test performance checks.

Low temperature

Objective

To determine the ability of EUT to operate and be stored in low-temperature environments.

Criteria

The EUT will not experience the susceptibility criteria listed in the test plan, during the performance validation checks as outlined in the test procedures.

Procedure

Tests will be performed using MIL-STD-810F method 502.4 as guidance. The test consists of two parts:

The first part will be the low temperature operation procedure. Testing will be conducted at the following temperatures: -19 °C, -31 °C, and -46 °C, as specified in MIL-STD-810F, Method

502.4. The EUT will be exposed to test conditions for 2 hr. Testing will be repeated twice at the lowest temperature where EUT meets the criteria.

The second part will be the low temperature storage procedure. Testing will be conducted at the following temperatures: -21°C, -33 °C, and -46 °C, as specified in MIL-STD-810F, Method 502.4. Test conditions will be maintained for 4 hr. The EUT will not be powered on during the tests. Testing will be repeated twice at the lowest temperature where EUT meets the criteria.

Prior to operation and storage testing, the EUT subject matter expert from USAARL's Acoustics Branch will validate the CEPS communication performance. After the test cycle, the EUT will be returned to ambient conditions for post-test performance checks.

Devices tested

The intent was to test one Communication Enhancement and Protective System (CEPS) device in this study. However, two devices were tested, CEPS #1 and CEPS #2, after mechanical failure of CEPS #1 during testing.

Instrumentation and equipment

The measurement instrumentation and equipment specifications are listed in the appendix. A USAARL closed-system test fixture was devised for measuring input and output levels to and from, respectively, the CEPS microphones (figure 1). The test fixture (figure 2) is spring-mounted and mass-loaded at the corners for best vibration and shock insulation, and has a two-port adapter for connecting the CEPS microphones to a Brüel & Kjær (B&K) 2-cubic centimeter (cc) coupler, Type DB0260. The two-port adapter is a small T-piece made from 1-millimeter (mm)-id steel tubing, largely embedded inside an aluminum disk (figure 3). The CEPS microphones have a small piece of tubing protruding from the faceplate, which fits the 1-mm-id coupler tubing. The total volume of the T-piece is very small compared with the volume of the 2-cc coupler. A ½-inch reference microphone, B&K Type 4192, was coupled to the threaded end of the B&K 2-cc coupler and to a B&K Measuring Amplifier, Type 2636, to monitor input reference levels. One earphone transducer of a Communications Earplug (CEP), used as an input sound source, was inserted into the open end of the 2-cc coupler (figure 4).

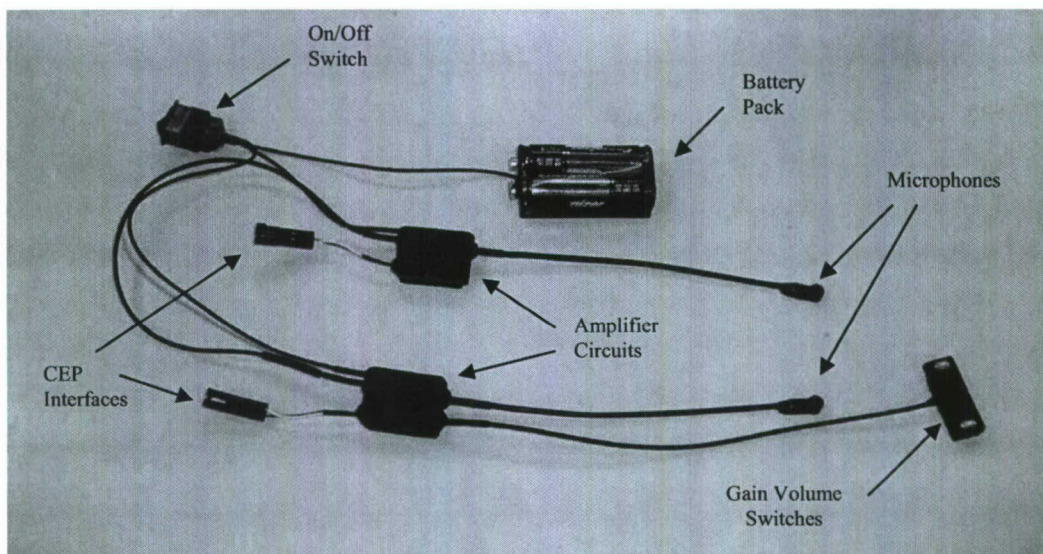


Figure 1. The Communication Enhancement and Protection System (CEPS).

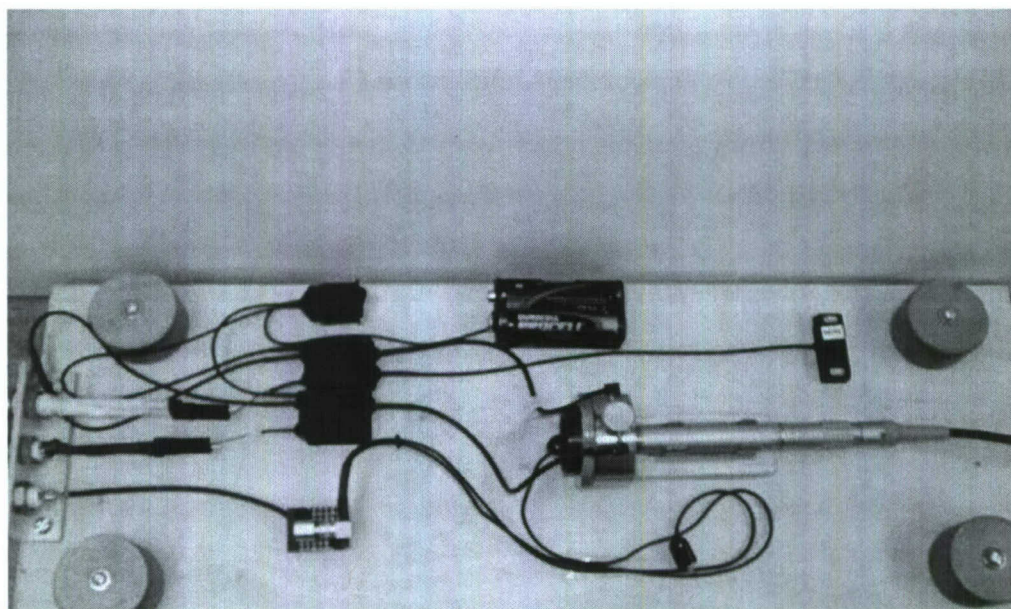


Figure 2. USAARL closed-system test fixture with CEPS and reference microphone connected.

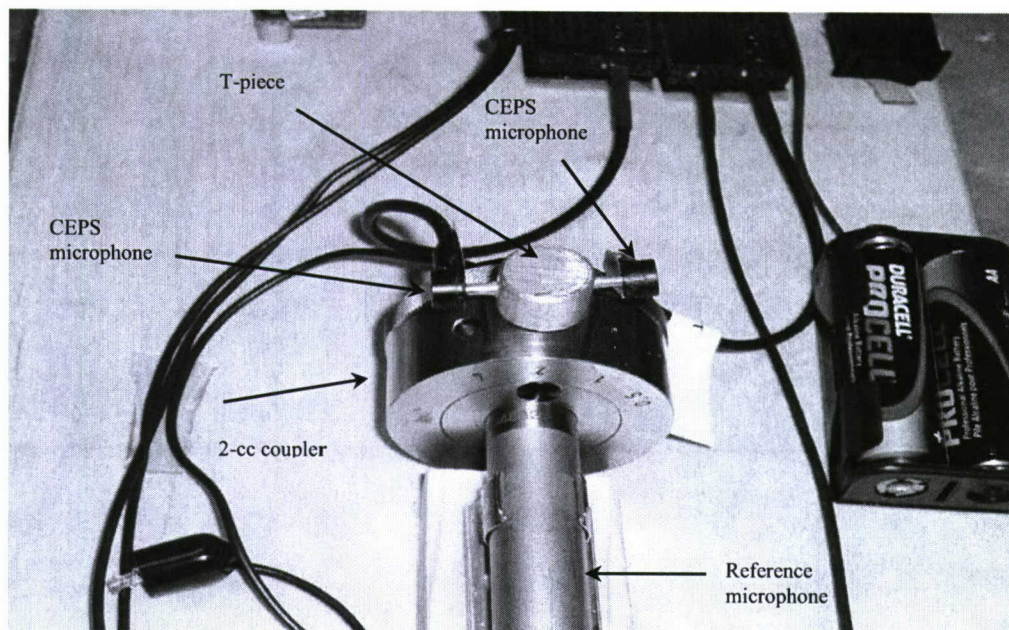


Figure 3. CEPS microphones connected to USAARL closed-system test fixture.

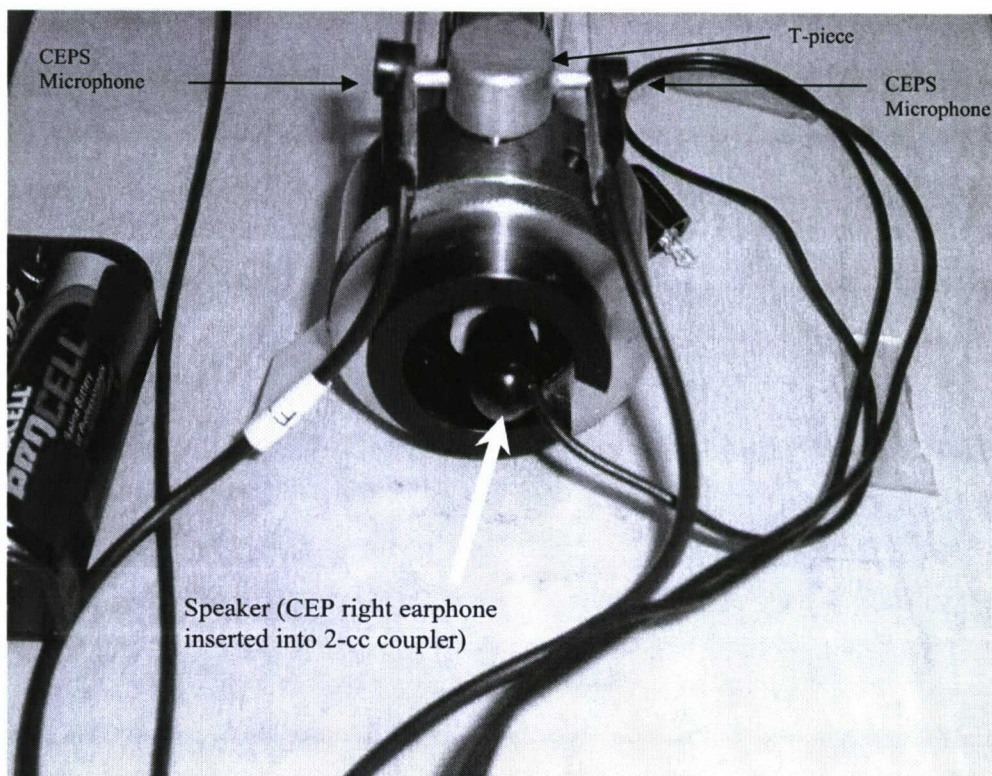


Figure 4. CEP right transducer, inserted in B&K 2-cc coupler, used as a speaker in the USAARL test fixture.

Procedure

A Hewlett Packard (HP) function generator, Model 3314A, connected via coaxial cable to the speaker input, generated sine wave test signals. For frequency response measurements, a 50-kHz bandwidth pink-noise test signal was generated by a B&K noise generator, Type 1405, connected to the speaker by a coaxial cable. Output voltage levels of the CEPS microphones were measured by a HP 3456A, digital voltmeter. The reference microphone was calibrated using an acoustic reference signal from a B&K pistonphone, Type 4228.

The basic criterion in all tests was that output levels of each device were to remain within a range of ± 5 decibels (dB) for frequencies between 300 Hz and 4000 Hz and total harmonic distortion (THD) not to exceed 5 percent. A Tenney Engineering Walk-in Environmental chamber, Model ZWUL-1017D, was adjusted in accordance with MIL-STD-810F. The tests were conducted during September and October 2006.

Baseline tests

Baseline output sensitivity levels were measured at 300 Hz, 600 Hz, 1 kHz, 2 kHz, and 4 kHz. THD was calculated from the 1st and 2nd harmonic frequencies determined by the power spectrum measurements of the CEPS output. Frequency response output levels were analyzed at 315 Hz, 615 Hz, 1 kHz, 2 kHz, and 4 kHz. The CEPS microphones were measured with the gain volume switches set at each of three positions: maximum (Max Vol), middle (Mid Vol), and minimum (Min Vol) settings. The input drive level was set at 80 dB SPL at 2 kHz at some gain volume settings, because the microphones were found to have a resonance at that frequency, causing more than 5 percent THD. At Min gain Vol setting, the input drive level was increased to 100 dB SPL, except at 2 kHz, where it was set to 88 dB SPL. Output data was stored on a PC for later analysis. A Modular Precision Sound Analyzer, B&K Type 2260, was also used to analyze stored data.

High temperature operation test

The USAARL test fixture, with the B&K 4192 reference microphone and CEPS #1, were placed inside the test chamber. The output of the pink noise generator was set at 85 dB SPL. The other test instrumentation was set up outside the chamber and was connected to the test fixture, via coaxial cables, through a covered porthole in the chamber. The test chamber was adjusted IAW with MIL-STD-810F, Method 501.4, Procedure I, as guidance. The test article was powered on and exposed to test conditions for 2 hr. Thirty (30) minutes (min) after startup, the chamber stabilized at 43 °C (109 °F) and 20 percent relative humidity (RH). Measurements were conducted after 1 hr at temperature and were within the criteria. At the end of 2 hr, output voltage readings were measured. The test article was then tested at 49 °C (120 °F), met the criteria, was tested two more times at 49° C, for reliability, and met the criteria.

High temperature storage test

CEPS #1 was tested at high temperature storage at 63 °C (145° F) and 20 percent RH for 6 hr. The reference microphone and the test article's batteries were removed from the chamber prior to startup. The chamber temperature was ramped down at the end of the 6 hr and returned to ambient temperature; 23 °C (73 °F), after about 30 min. Output sensitivity and frequency response measurements were conducted after the chamber had returned to ambient temperature.

When CEPS #1 failed after the high temperature storage test, 6 hr at 63° C, a decision was made to test another device at a lower storage temperature, 52 °C (126 ° F). Testing was resumed, using a second device, CEPS #2, for the high temperature storage tests.

CEPS #2, was placed in the chamber and the chamber temperature was stabilized at 52 °C and 20 percent RH for 6 hr. At the end of 6 hr, the chamber temperature was ramped down to ambient temperature. Output measurements were conducted after an hr, when the chamber had reached ambient temperature. For reliability, 2 more iterations of the high temperature storage test, six-hr 52 °C and 20 percent RH were conducted.

Low temperature operation test

CEPS #2, was placed in the chamber and the temperature was stabilized at -19 °C (-2.2 °F) and 20 percent RH for 2 hr. At the end of 2 hr, the chamber temperature was ramped up to ambient temperature. When the chamber door was opened, there was extreme wetness, from condensation that saturated the test article, test fixture, and all other surfaces inside the chamber. Measured output levels were very erratic, due to the moisture, and measurements were discontinued. After several days of drying out, the test article was retested at ambient temperature and output levels met baseline criteria (table 7).

Low temperature testing was resumed. However, prior to each low temperature procedure, the test article and test fixture were enclosed in a sealed plastic bag to protect them from moisture. Before sealing the plastic bag, the suction tube of a suction pump was placed in the bag, to draw the air out of the bag and lower the humidity surrounding the test article and test fixture. The probe of a Fluke Thermo-Hygrometer, Model 5020, was also placed in the plastic bag before it was sealed, to monitor the humidity during tests.

Prior to startup of each test cycle, the reference microphone and connecting cables were removed from the chamber to protect them from moisture. To enhance removal of as much humidity as possible from the chamber, prior to starting each test, the humidity of the chamber was set at 20 percent and stabilized after about an hr. The chamber was then ramped down to the test temperature. At the end of the chamber's low temperature cycle, it was ramped up to ambient temperature. The reference microphone and connecting cables were then reconnected to the test fixture to conduct measurements.

Test CEPS #2 was tested three more times at -19 °C, for reliability, and met the criteria after each test., in accordance with (IAW) Department of Defense Test Method Standard for

Environmental Engineering Considerations and Laboratory Tests MIL-STD-810F, 1 January 2000 (MIL-STD-810F) The change in output level at the exposure temperature was less than 2 dB from baseline measurements. Humidity levels inside the sealed plastic bag varied during each iteration of testing (table 16).

Low temperature storage test

CEPS #2 was placed in the chamber and the temperature was stabilized at -21 °C (-5.8 °F) and 20 percent RH for 4 hr. At the end of the 4-hr cycle, the chamber temperature was ramped up to ambient temperature. Low temperature storage testing was completed at -33 °C (-27 °F). Low temperature storage testing was also conducted at -46 °C (-51 °F).

Results

The baseline test results for CEPS #1, converted to Decibel reference 1 Volt/Pascal (dB re 1 V/Pa), are shown in table 1 and baseline frequency response and THD are shown in table 2. The change in output level after the first high temperature operation exposure temperature at 43 °C was less than 2 dB from baseline measurements (table 3). The change in output level after each of the three high temperature operation exposures at 49 °C was less than 2 dB from baseline measurements (table 3). The frequency response of CEPS #1 after each iteration of high temperature operation exposure is shown in tables 4 through 7. In some instances, the frequency response output at 315 Hz, at Min Vol, was greater than 5 dB.

CEPS #1 failed to meet the criteria after high temperature storage exposure, 6 hr at 63 °C. The change in output voltage levels and frequency response, after exposure, exceeded the criteria, was greater than 5 dB (tables 8 and 9). During post-test sensitivity measurements, it was noted that the tip on the right microphone of the test article had broken off and the testing on test CEPS #1 had to be terminated.

Baseline measurements conducted on CEPS #2 are shown in table 10. CEPS #2 met the criteria after high temperature storage exposure at 52 °C and 20 percent RH for 6 hr. The change in output voltage levels was less than 1 dB. The change in output level after each exposure at 52 °C was less than 1 dB from baseline measurements (table 11). Microphone output levels were less than 4 dB from baseline measurements after the first and second iterations (tables 12 and 13). However, after the third iteration, relative output differences at Min Vol exceeded 5 dB (table 14). Post-test output sensitivity levels at Min Vol exceeded the criteria. Analysis of the data was done after testing was completed, thus the output levels that exceeded the criteria were not known at the time of completion of high temperature storage testing.

After the low temperature operation tests, CEPS #2 met the criteria. The change in output level at the exposure temperature was less than 2 dB from baseline measurements. Humidity levels inside the sealed plastic bag varied during each iteration of testing (table 16).

After the low temperature storage tests, CEPS #2 met the criteria. The change in output levels at -21 °C and -33 °C was less than 4 dB from baseline measurements (table 17). As post-tests were being conducted on test article #2, output levels were erratic and it was discovered that the tube of the right microphone had become detached from the faceplate. Testing of CEPS #2 was terminated.

Discussion

The CEPS met the test criteria after the 2-hr, 49 °C maximum high temperature operation tests, but failed the 6-hr high temperature storage test at 63 °C, possibly because of a component failure, the tube of the right microphone became detached from the faceplate. Testing was resumed using a new device, CEPS #2. After three iterations of 6-hr high temperature storage tests at 52 °C, CEPS #2 met the test criteria.

When protected from condensation, the CEPS met the test criteria at the 2-hr low temperature operation tests at -19° C. The device met the test criteria after one iteration of the 4-hr low temperature storage test was conducted at -21 °C and -33 °C. The device failed the test criteria after one 4-hr low temperature storage test at -46 °C, possibly because of a component failure; the tube of the right microphone detached from the faceplate.

It is recommended that the CEPS not be stored at temperatures higher than 52 °C longer than 6 hours. The CEPS must be protected from potential damage from condensation during and after exposure to low temperature operation and storage. Additional low temperature operation and storage testing of the CEPS should be repeated to determine the reliability of the device under sustained low temperature operation and storage.

Table 1.

CEPS #1 – Baseline output sensitivity levels and total harmonic distortion, at ambient temperature and humidity, at the frequencies, input reference levels, and volume gain settings shown.

<u>Left microphone</u>				<u>Right microphone</u>	
<u>Frequency</u> <u>(Hz)</u>	<u>Input</u> <u>(dB SPL)</u>	<u>Output</u> <u>(dB re 1 V/Pa)</u>	<u>THD (%)</u>	<u>Output</u> <u>(dB re 1 V/Pa)</u>	<u>THD (%)</u>
<u>Max Vol</u>				<u>Max Vol</u>	
300	88.0	-10.3	0.6	-9.7	0.7
600	88.0	-8.3	1.2	-8.3	1.1
1000	88.0	-5.6	1.3	-4.6	1.5
2000	80.0	8.8	1.4	9.8	1.9
4000	88.0	-1.4	1.0	-0.8	1.2
<u>Mid Vol</u>				<u>Mid Vol</u>	
300	88.0	-18.4	1.4	-17.7	1.3
600	88.0	-16.4	1.1	-15.4	1.2
1000	88.0	-13.7	1.3	-12.7	1.4
2000	80.0	8.4	4.3	9.4	4.9
4000	88.0	-9.3	1.1	-8.8	1.3
<u>Min Vol</u>				<u>Min Vol</u>	
300	100.0	-46.0	1.9	-46.0	2.3
600	100.0	-43.7	2.5	-42.5	2.7
1000	100.0	-40.9	5.0	-40.0	5.6
2000	88.0	-26.8	3.9	-25.7	5.0
4000	100.0	-36.8	5.3	-36.2	5.7

Table 2.

CEPS #1 – Baseline microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85dB SPL input level, at ambient temperature and humidity, at the gain volume settings shown.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>					
Max Vol	64.6	62.9	63.1	82.7	60.9	85.2
Mid Vol	64.6	62.8	63.1	82.6	60.7	85.2
Min Vol	60.6	59.1	59.2	78.5	57.1	81.1
<u>Right microphone</u>	<u>dB SPL</u>					
Max Vol	data lost					
Mid Vol	65.0	63.8	64.2	83.6	61.3	86.1
Min Vol	60.9	59.7	60.0	79.3	57.4	81.8

Table 3.

CEPS #1 – Output sensitivity at baseline and after high temperature operation tests at 85dB, SPL input level at the gain volume settings and temperatures shown.

	<u>Baseline</u>	<u>43 °C</u>	<u>1st iteration</u>	<u>2nd iteration</u>	<u>3rd iteration</u>
<u>Left microphone</u>	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>	<u>49 °C</u>	<u>49 °C</u>	<u>49 °C</u>
Max Vol	-2.7	-3.4	-3.8	-3.4	-3.8
Mid Vol	-10.2	-11.0	-11.9	-11.9	-11.9
Min Vol	-37.7	-38.7	-39.0	-39.0	-39.0
<u>Right microphone</u>					
Max Vol	-1.5	-2.7	-2.7	-2.7	-2.7
Mid Vol	-9.4	-10.2	-11.0	-11.0	-10.6
Min Vol	-37.0	-37.9	-37.9	-38.3	-38.3

Table 4.

CEPS #1 – Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85dB SPL input level – High temperature operation test, 2 hr at 43 °C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	63.6	61.9	62.1	81.8	60.2	84.8	1.0	1.0	1.0	0.9	0.7	0.4
Mid Vol	66.3	63.1	63.0	82.4	60.8	85.6	-1.7	-0.3	0.1	0.2	-0.1	-0.4
Min Vol	69.7	64.6	63.8	81.6	60.7	85.8	-9.1	-5.5	-4.6	-3.1	-3.6	-4.7
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	64.6	63.2	63.5	83.2	61.1	86.1	baseline data lost					
Mid Vol	66.4	63.5	63.5	82.9	60.8	86.0	-1.4	0.3	0.7	0.7	0.5	0.1
Min Vol	data lost											

Table 5.

CEPS #1 – Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband, (dBC) at 85dB SPL input level – 1st iteration high temperature operation test, 2 hr at 49 °C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	62.7	60.8	60.8	80.6	59.0	83.6	1.9	2.1	2.3	2.1	1.9	1.6
Mid Vol	66.1	63.1	62.5	81.7	60.4	85.2	-1.5	-0.3	0.6	0.9	0.3	0.0
Min Vol	68.4	63.2	62.2	79.4	58.8	84.0	-7.8	-4.1	-3.0	-0.9	-1.7	-2.9
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	63.0	61.5	61.9	81.5	59.5	84.5	baseline data lost					
Mid Vol	66.8	63.6	63.6	82.7	60.9	86.0	-1.8	0.2	0.6	0.9	0.4	0.1
Min Vol	68.9	63.8	62.9	80.7	59.3	84.9	-8.0	-4.1	-2.9	-1.4	-1.9	-3.1

Table 6.

CEPS #1 – Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband, (dBC), at 85dB SPL input level – 2nd iteration high temperature operation test, 2 hr at 49 ° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	63.5	62.1	62.3	81.8	60.6	84.9	1.1	0.8	0.8	0.9	0.3	0.3
Mid Vol	64.1	62.9	63.1	82.7	61.4	85.8	0.5	-0.1	0.0	-0.1	-0.7	-0.6
Min Vol	62.3	61.0	61.2	80.7	59.8	83.8	-1.7	-1.9	-2.0	-2.2	-2.7	-2.7
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	64.0	63.0	63.0	82.8	61.0	85.9	baseline data lost					
Mid Vol	63.7	62.5	62.7	82.4	60.7	85.4	1.3	1.3	1.5	1.2	0.6	0.7
Min Vol	62.6	62.0	62.3	81.7	60.5	84.8	-1.7	-2.3	-2.3	-2.4	-3.1	-3.0

Table 7.

CEPS #1 – Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband, (dBC), at 85dB SPL input level – 3rd iteration high temperature operation test, 2 hr at 49 ° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	62.3	60.5	60.6	80.1	58.7	83.2	2.3	2.4	2.5	2.6	2.2	2.0
Mid Vol	64.6	61.5	61.0	80.1	58.8	83.6	0.0	1.3	2.1	2.5	1.9	1.6
Min Vol	67.4	61.7	60.5	77.7	57.0	82.5	-6.8	-2.6	-1.3	0.8	0.1	-1.4
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	63.2	61.8	61.7	81.5	59.5	84.6	baseline data lost					
Mid Vol	64.9	62.0	62.0	81.0	59.3	84.4	0.1	1.8	2.2	2.6	2.0	1.7
Min Vol	67.2	62.6	61.6	78.9	57.8	83.4	-6.3	-2.9	-1.6	0.4	-0.4	-1.6

Table 8.

CEPS #1 – Output sensitivity at baseline and after high temperature storage test, 6 hr at 63° C, at 85dB SPL input level, at the gain volume settings shown.

	<u>Baseline</u>	<u>63° C</u>
<u>Left microphone</u>	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>
Max Vol	-2.7	-11.0
Mid Vol	-10.2	-18.5
Min Vol	-37.7	-23.0
<u>Right microphone</u>		
Max Vol	-1.5	-5.9
Mid Vol	-9.4	-33.5
Min Vol	-37.0	-37.0

Table 9.

CEPS #1 – Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85dB SPL input level – after high temperature storage test, 6 hr at 63° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>dBC</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	70.7	64.2	62.7	75.7	73.8	83.9	-6.1	-1.3	0.4	7.0	-12.9	1.3
Mid Vol	71.3	64.8	63.3	75.9	74.1	84.1	-6.7	-2.0	-0.2	6.7	-13.4	1.1
Min Vol	72.7	65.5	64.0	77.5	75.8	85.6	-12.1	-6.4	-4.8	1.0	-18.7	-4.5
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	70.5	64.4	62.9	72.5	67.9	81.2	baseline data lost					
Mid Vol	62.0	58.8	58.2	62.9	58.2	72.9	3.0	5.0	6.0	20.7	3.1	13.2
Min Vol	71.7	63.9	61.7	73.9	69.7	82.3	-10.8	-4.2	-1.7	5.4	-12.3	-0.5

Table 10.

CEPS #2 - Baseline output sensitivity levels, at ambient temperature and humidity, at the frequencies, input reference levels, and volume settings shown.

<u>Frequency (Hz)</u>	<u>Input dB SPL</u>	<u>Left microphone</u>	<u>Right microphone</u>
		<u>dB re 1 V/Pa</u>	<u>dB re 1 V/Pa</u>
		<u>Max Vol</u>	<u>Max Vol</u>
300	88.0	-13.2	-10.7
600	88.0	-10.6	-8.4
1000	88.0	-7.7	-5.7
2000	80.0	7.3	9.3
4000	88.0	-2.9	-0.7
		<u>Mid Vol</u>	<u>Mid Vol</u>
300	88.0	-20.4	-18.4
600	88.0	-18.4	-15.9
1000	88.0	-15.1	-13.2
2000	88.0	-0.4	1.6
4000	88.0	-10.1	-8.2
		<u>Min Vol</u>	<u>Min Vol</u>
300	88.0	-48.0	-44.5
600	88.0	-45.7	-34.9
1000	88.0	-42.0	-40.0
2000	88.0	-28.0	-26.0
4000	88.0	-38.4	-20.0

Table 11.
CEPS #2 - Output sensitivity at baseline and after three 2-hr iterations of high temperature storage tests at 52°C, at 85dB SPL input level.

	<u>Baseline</u> <u>Ambient/23°C</u> <u>dB re 1V/Pa</u>	<u>1st iteration</u> <u>52°C</u> <u>dB re 1V/Pa</u>	<u>2nd iteration</u> <u>52°C</u> <u>dB re 1V/Pa</u>	<u>3rd iteration</u> <u>52°C</u> <u>dB re 1V/Pa</u>
<u>Left microphone</u>				
Max Vol	-4.6	-5.0	-5.0	-5.0
Mid Vol	-12.3	-12.3	-12.9	-12.7
Min Vol	-39.9	-40.1	-40.7	-40.1
<u>Right microphone</u>				
Max Vol	-2.4	-2.7	-2.7	-2.7
Mid Vol	-10.2	-11.0	-10.2	-11.0
Min Vol	-37.7	-38.3	-38.1	-38.1

Table 12.
CEPS #2 - Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85dB SPL input level – 1st iteration of 6-hr high temperature storage test at 52° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>
<u>Left microphone</u>							<u>Difference relative to Baseline (dB)</u>					
			<u>dB SPL</u>									
Max Vol	65.1	63.4	63.8	84.3	62.6	86.3	-0.2	0.4	0.5	0.2	0.3	0.1
Mid Vol	68.0	67.2	67.1	86.3	62.2	88.4	-1.4	-1.8	-1.2	-0.5	1.9	-0.7
Min Vol	70.7	65.4	64.5	81.4	60.9	85.5	-3.7	1.1	2.4	4.5	3.8	2.4
<u>Right microphone</u>							<u>Difference relative to Baseline (dB)</u>					
			<u>dB SPL</u>									
Max Vol	67.1	65.5	65.8	86.2	64.7	88.3	-0.1	0.4	0.5	0.5	0.2	0.3
Mid Vol	67.0	65.8	65.7	85.1	60.8	87.1	-1.2	-1.3	-0.8	-0.1	2.5	-0.1
Min Vol	71.5	66.2	65.7	83.9	65.3	87.3	-2.9	2.0	2.7	4.0	1.4	2.6

Table 13.

CEPS #2 - Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85dB SPL input level – 2nd iteration of 6-hr high temperature storage test at 52° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	62.3	61.4	61.7	82.4	60.4	84.3	2.6	2.4	2.6	2.1	2.5	2.1
Mid Vol	63.0	61.8	62.2	82.5	60.6	84.5	3.6	3.6	3.7	3.3	3.5	3.2
Min Vol	63.9	63.5	63.8	82.7	61.9	84.9	3.1	3.0	3.1	3.2	2.8	3.0
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	65.1	64.0	64.2	84.9	62.9	86.9	1.9	1.9	2.1	1.8	2.0	1.7
Mid Vol	64.4	63.5	63.8	84.0	62.0	86.1	1.4	1.0	1.1	1.0	1.3	0.9
Min Vol	65.7	64.8	65.1	84.9	63.3	87.0	2.9	3.4	3.3	3.0	3.4	2.9

Table 14.

CEPS #2 - Microphone output, in dB SPL, at five 1/3-Octave band frequencies and broadband (dBC) at 85 dB SPL input level – 3rd iteration of 6-hr high temperature storage test at 52° C.

<u>Frequency (Hz)</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>	<u>315</u>	<u>630</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>C</u>
<u>Left microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	65.4	64.9	64.9	85.5	62.8	87.5	-0.5	-1.1	-0.6	-1.0	0.1	-1.1
Mid Vol	65.7	64.9	64.9	85.2	62.6	87.2	0.9	0.5	1.0	0.6	1.5	0.5
Min Vol	62.1	61.5	61.4	80.7	59.0	82.8	4.9	5.0	5.5	5.2	5.7	5.1
<u>Right microphone</u>	<u>dB SPL</u>						<u>Difference relative to Baseline (dB)</u>					
Max Vol	66.9	66.0	66.1	86.6	63.8	88.6	0.1	-0.1	0.2	0.1	1.1	0.0
Mid Vol	68.2	66.8	67.3	87.5	64.7	89.5	-2.4	-2.3	-2.4	-2.5	-1.4	-2.5
Min Vol	66.9	66.0	66.1	86.6	63.8	88.6	4.9	5.3	5.3	5.2	6.1	5.1

Table 15.

CEPS #2 - Output sensitivity after three 6-hr iterations of high temperature storage tests at the frequencies, input reference levels, and volume settings shown.

Freq	<u>Input/Ref Mic (dB)</u>	<u>Left microphone</u>	<u>Right microphone</u>
		<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>
		<u>Max Vol</u>	<u>Max Vol</u>
300	88.0	-14.0	-11.1
600	88.0	-11.1	-8.9
1000	88.0	-8.9	-6.4
2000	80.0	5.6	8.0
4000	88.0	-0.2	2.1
		<u>Mid Vol</u>	<u>Mid Vol</u>
300	88.0	-21.1	-18.9
600	88.0	-18.6	-16.5
1000	88.0	-15.9	-14.0
2000	88.0	-2.0	0.2
4000	88.0	-8.0	-6.0
		<u>Min Vol</u>	<u>Min Vol</u>
300	88.0	-48.9	-48.0
600	88.0	-46.8	-48.0
1000	88.0	-43.9	-44.5
2000	88.0	-29.9	-41.7
4000	88.0	-36.0	-34.0

Table 16.

CEPS #2 – Output sensitivity at baseline and after three iterations of the 2-hr low temperature operation test at -19 °C, at 85 dB SPL input level, measured humidity, and volume settings shown.

10/11/2006	<u>Baseline Retest</u>	^{1st} Iteration	^{2nd} Iteration	^{3rd} Iteration
	<u>Ambient/23 °C</u>	<u>-19 °C</u>	<u>-19 °C</u>	<u>-19 °C</u>
	<u>20 % RH</u>	<u>39 % RH</u>	<u>44 % RH</u>	<u>50.4% RH</u>
	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>
<u>Left microphone</u>				
Max Vol	-4.6	-5.4	-4.6	-4.6
Mid Vol	-12.7	-12.6	-11.9	-11.9
Min Vol	-40.4	-40.6	-39.4	-39.6
<u>Right microphone</u>				
Max Vol	-2.4	-3.4	-2.7	-2.7
Mid Vol	-10.4	-11.0	-10.2	-11.0
Min Vol	-37.7	-38.7	-37.4	-37.9

Table 17.

CEPS #2 - Output sensitivity at baseline and after two 4-hr low temperature storage tests at -21 °C and -33 °C, at 85dB SPL input level, at the measured humidity and gain volume settings shown.

	<u>Baseline Retest</u>		
	<u>Ambient/23 °C</u>	<u>-21 °C Storage</u>	<u>-33 °C Storage</u>
	<u>20 % RH</u>	<u>20.4 % RH</u>	<u>20.8 % RH</u>
	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>	<u>dB re 1V/Pa</u>
<u>Left microphone</u>			
Max Vol	-4.6	-2.1	-2.1
Mid Vol	-12.7	-9.4	-9.4
Min Vol	-40.4	-37.4	-37.2
<u>Right microphone</u>			
Max Vol	-2.4	0.4	-0.1
Mid Vol	-10.2	-8.1	-8.1
Min Volume	-37.7	-35.7	-35.4

Reference

Department of Defense. Test Method Standard for Environmental Engineering Considerations and Laboratory Tests MIL-STD-810F.

Appendix.

Measurement equipment and instrumentation

<u>Item #</u>	<u>Cycle</u>	<u>Last Calibration</u>	<u>Description</u>	<u>Manufacturer</u>	<u>Model/Type #</u>	<u>Range</u>	<u>Accuracy</u>
1	12 Mo.	05/06	Microphone	Brüel & Kjær	4192	3.15 Hz to 20 kHz, -30° to +150 °C operating temp (up to +300° C, with permanent sensitivity change of typically +0.4 dB, -30° to +70 °C storage temp	± 2 dB
2	N/A	N/A	Microphone Preamplifier	Brüel & Kjær	2669	3 Hz to 200 kHz, -25° to 60 °C operating temp (+150 °C with increase in noise), -25° to 70 °C storage temp	± 0.5 dB
3	12 Mo.	09/05	Pistonphone	Brüel & Kjær	4228	Nominal Sound Pressure Level: 124 dB re 20 µPa at reference conditions	± 0.2 dB
4	12 Mo.	07/06	Measuring Amplifier	Brüel & Kjær	2636	1 Hz up to 200 kHz, 10 µV to 30 V FSD, selectable in 10 dB steps, Direct, plus Mic. Preamp.	± 0.5 dB
5	12 Mo.	07/06	Noise Generator	Brüel & Kjær	1405	Pink noise – 20 Hz to 50 kHz	± 1 dB
6	24 Mo.	08/05	Function Generator	Hewlett Packard	3314A	1 Hz to 100 kHz	Variable, ± 0.5% of period
7	12 Mo.	04/06	Digital Voltmeter	Hewlett Packard	3456A	AC RMS Voltage Input: 1.0V to 1000.0 V	± (% of Reading + Number of Counts), Auto- zero on > 1% of full scale, and DC components < 10% of AC component.
8	N/A	N/A	Modular Precision Sound Analyzer	Brüel & Kjær	2260	Max. Input voltage: 4.5 Peak full scale, Gain: 0 to 50 dB in 10 dB steps, Max Output: 4.5 V peak full scale, 1 Hz (-3 dB) to 20 kHz	+0.2V -0.25V , ± 0.1 dB
9	N/A	N/A	2 CC Coupler	Brüel & Kjær	DB 0260	N/A	N/A
10	N/A	N/A	CEPS Test Fixture	USAARL	N/A	N/A	N/A
11	N/A	N/A	Walk-in controlled environmental chamber	Tenney Engineering	ZWUL- 1017D	N/A	N/A