Microphone HALT Report

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G.R.A.S.
SOUND & VIBRATION

G.R.A.S. HALT Report

Microphone HALT testing is about securing long term stability and robustness of the microphones.

This report presents the results of the G.R.A.S. Microphone Highly Accelerated Life Test (HALT) for the following G.R.A.S. microphones:

1) **½" externally polarized microphone sets (200V)**
2) **½" prepolarized microphone sets (CCP)**
3) **¼" externally polarized microphone sets (200V)**
4) **¼" prepolarized microphone sets (CCP)**

The tests involve prolonged exposures to extreme temperatures, levels of humidity, bi-axial vibrations and mechanical impulses.
The results are shown as variations in sensitivity and amplitude response.

The report contains an introduction and the protocol for each of the aforementioned tests. Then a detailed explanation of the results is provided, after which results for all four groups are presented individually.

Prepared February 2015
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1. Introduction

Microphone HALT testing is about securing long term stability and robustness of a given product.
It is a principle G.R.A.S. for years have relied on to develop products for both industry and laboratory as well as production environments.
Microphone HALT tests accelerate the lifetime and simulate the handling and use that a microphone is exposed to outside the laboratory, in real life conditions and beyond.
By stress testing the products to the limits where they break down, we are able to learn and develop the microphone design to give robust and stable solutions, thus precise measuring microphones.

The test results in this report are only an extract of the tests we do at G.R.A.S. However, the results show how resilient a G.R.A.S. microphone is to bumps, drops, vibration and environmental influence.

We randomly selected 5 samples from each of the 4 groups to be used in the tests.

		Polarization	
		200V	*CCP*
Size	*½"*	46AF (5 samples)	46AE (5 samples)
	¼"	46BP-1 (5 samples)	46BD (5 samples)

Table 1. Overview of the groups and the specific microphone sets used to represent each group

The microphone HALT testing reported here involves a series of stress tests aiming to simulate extreme storage, handling and operating conditions. These tests involve quantifying the effects due to the following factors: temperature (constant and cyclic), humidity, vibration, and mechanical impulse (shock and drop) – six in total. The individual tests are described in detail in Section 3.

Each microphone set is calibrated both prior to and following a given test. Calibration is performed in G.R.A.S.' calibration laboratory under the following ambient conditions:

- Ambient temperature: 23.5±1°C
- Ambient pressure: 1008±10mbar
- Ambient humidity: 40±10%RH

Calibration consists of a sensitivity recording at 250Hz using a G.R.A.S. 42AP pistonphone as well as a frequency response obtained, using the electrostatic actuator RA0014.

	Test					
	Temperature		Humidity	Vibration	Mech. Impulse	
	Constant	*Cyclic*	-	-	*Shock*	*Drop*
#	5	5	1	1	6	6

Table 2. The number of calibrations performed on each sample for a given test

2. Test protocol

In what follows, we describe the setup of each of the stress tests, in which we further justify the chosen range of test conditions.

2.1 Temperature Stress Test

Whether through storage or during operation, microphones may be subjected to extreme temperatures. The former case is typically constant in temperature, while the temperature of the latter may vary greatly – particularly if measuring far from large bodies of water.

Based on differing coefficients of thermal expansion, extreme temperatures may cause microphones to structurally distort, thus altering their frequency response. Deviations from room temperatures may equally influence the polarization of CCP microphones, changing their sensitivity.

The temperature stress tests herein have been conducted in an ASC Discovery climate chamber.

2.1.1 Constant Temperature

G.R.A.S. microphones are specified to withstand storage temperatures up to 85°C. In this Constant Temperature stress test, microphone sets are therefore periodically stored at 95°C. Four series of tests are conducted, each followed by a complete calibration.

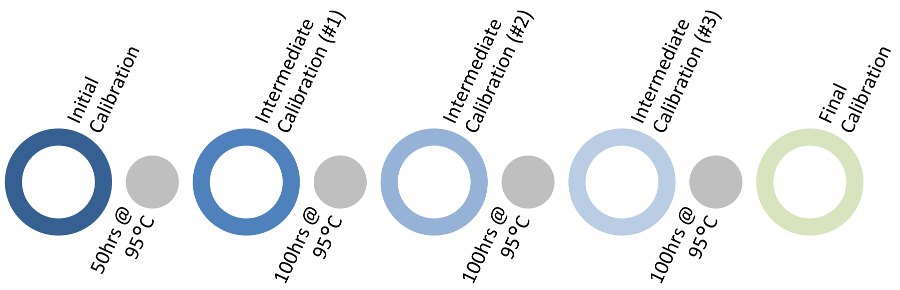


Figure 1. Protocol for the Constant Temperature stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

2.1.2 Cyclic Temperature

G.R.A.S. standard microphones are similarly specified to withstand operating temperatures in the range -30°C to 70°C. The microphone sets are consequently subjected to 100 temperature cycles in the range -40˚C to +95˚C. For every 25 cycles the microphone sets are calibrated. Each cycle has been defined to take four hours, consisting of (1) one hour at 95˚C; (2) one hour linearly decreasing in temperature at a rate of 135˚C/hour; (3) one hour at -40˚C; and (4) one hour linearly increasing in temperature, equally at a rate of 135˚C/hour.

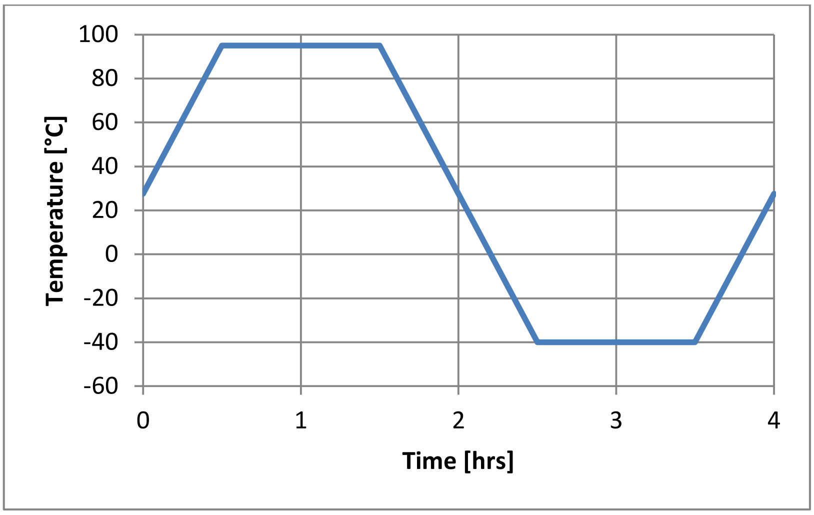


Figure 2. One period of a temperature cycle.

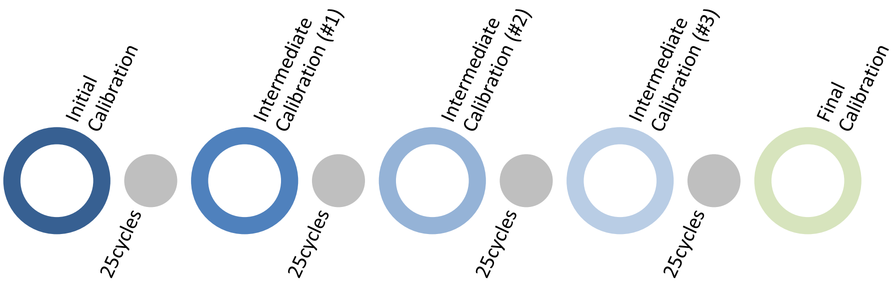


Figure 3. Protocol for the Cyclic Temperature stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

2.2 Humidity Stress Test

Humidity varies greatly with geography, as does it with the quality of HVAC systems. It may severely affect the internal dampening of a microphone. Moreover, long-term exposure to humid weather may lead to corrosion.

G.R.A.S. microphones are specified to withstand levels of relative humidity ranging from 0% to 95%, both during storage and operation. In this Humidity Stress test, the microphone sets are sequentially stored for 48 hours at 90% relative humidity at a temperature of 50°C. A Feutron KPK 200 Climate test chamber was utilized for the study.

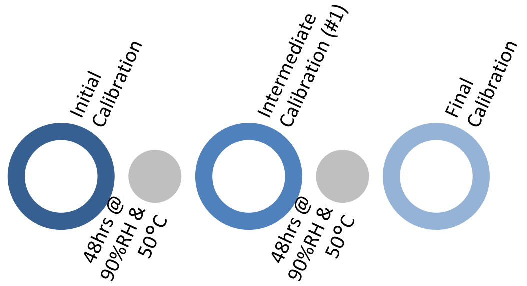


Figure 4. Protocol for the Humidity stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

2.3 Vibration Stress Test

Microphones may be vibrated both during transport and operation.

Prolonged exposures to severe vibrations may unsettle the critical elements, making up a measurement microphone, the important components being: the diaphragm, the backplate, the insulator, the outer casing, and the output contact. With a 2-5µm diaphragm suspended in parallel with the backplate at a distance of 10-20µm, there is little room for error.

In this Vibration stress test, conducted with a Brüel & Kjær Vibration Exciter Type 4808, the microphones are vibrated both along with and perpendicular to the axis of the microphone. In each direction, the microphones are subjected to the following two sequences:

a. 50 repetitions of a swept sine in the frequency range 20 Hz-10 kHz with 12 steps per octave and an acceleration of $8g_{rms}$, for a total test time of 15 hours.
b. 15 hours of broadband noise in the frequency range 20 Hz-10 kHz, equally at an acceleration of $8g_{rms}$.

We note that all four modes of vibration are conducted one after the other with calibrations performed only before and after.

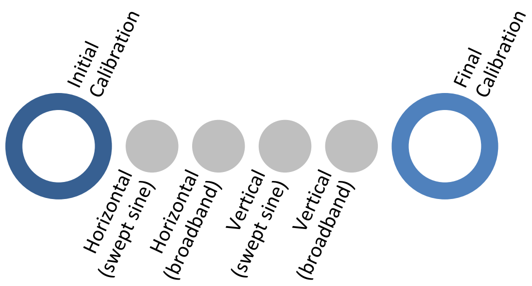


Figure 5. Protocol for the Vibration stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

2.4 Mechanical Impulse Stress Test

Impulse stresses may accidentally be imparted to a microphone set during transport and handling, often as a consequence of the microphone set or its container being dropped. Impulse stresses may similarly occur during operation, however, if mounted on vehicles that undergo significant accelerations.

A mechanical impulse may affect the internal workings of a microphone in a similar manner to that of vibrations, though with the additional possibility of large dents to the structure.

In what follows, we describe the protocols for both shock and drop testing.

2.4.1 Shock Test

The microphone set under test is mounted on the surface of a solid 2 kg steel block and dropped onto a steel surface such that the point of contact is between the steel block and surface. The system is dropped once from each of the following heights: 10 cm, 20 cm, 30 cm, 50 cm, 75 cm, and 100 cm. After each drop, the microphone set is calibrated.

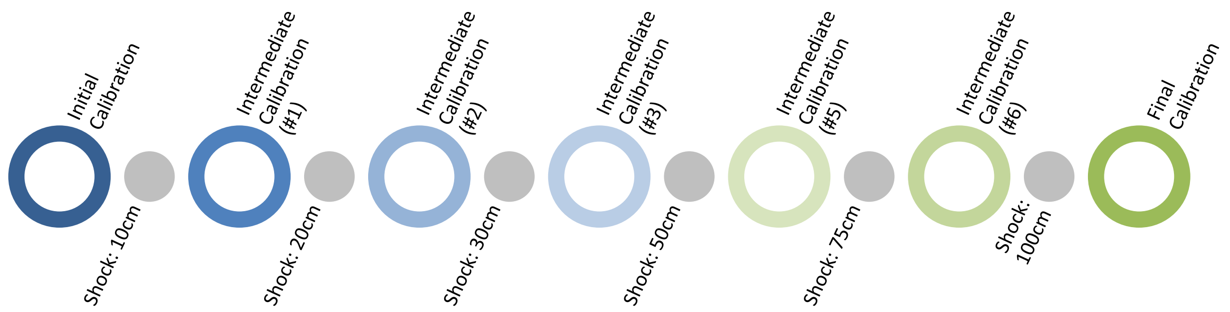


Figure 6. Protocol for the Mechanical Impulse Shock stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

2.4.2 Drop Test

The Mechanical Impulse Drop stress test is similar to its Shock test equivalent. Here, however, the steel block is removed and the microphone is instead dropped – grid first – from the following heights: 10cm; 20cm; 30cm; 50cm; 75cm; and 100cm. The microphones are dropped once from each height and calibrated after each drop, as before. Any change in sensitivity or amplitude response due to the impact is thus recorded and examined.

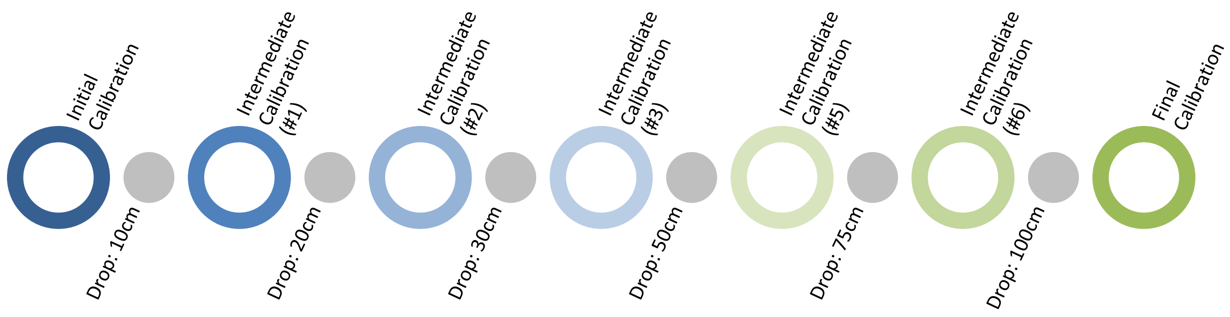


Figure 7. Protocol for the Mechanical Impulse Drop stress test. Large, colored and hollow circles mark points of calibration, while small, grey, filled circles represent test stages.

3. Description of Results

Results are provided both graphically and in tabular format for each combination of group and test. For the sake of brevity, however, the results are summarized as follows: for a given group (e.g. ½” CCP) and test (e.g. Constant Temperature stress test), a microphone set is selected at random from the sample set of five, whose results are displayed in full. Its amplitude response is displayed graphically as shown in Figure 8 and Figure 9, the latter of which has zoomed in on the region of interest. This, too, is the preferred view for the results to be provided. All curves are notably normalized to their respective response at 250Hz.

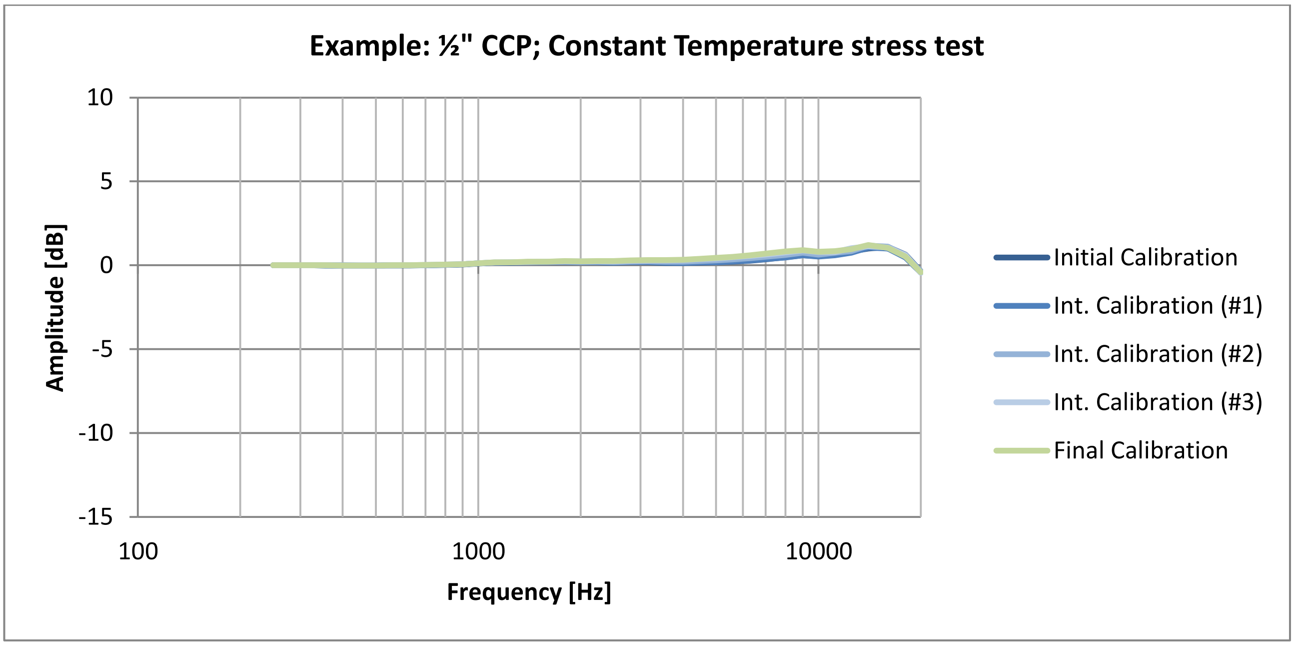


Figure 8. For a given combination of group and test – here, ½” CCP and the Constant Temperature stress test, respectively – a microphone set is chosen at random, whose calibration is tracked during the progress of the stress test.

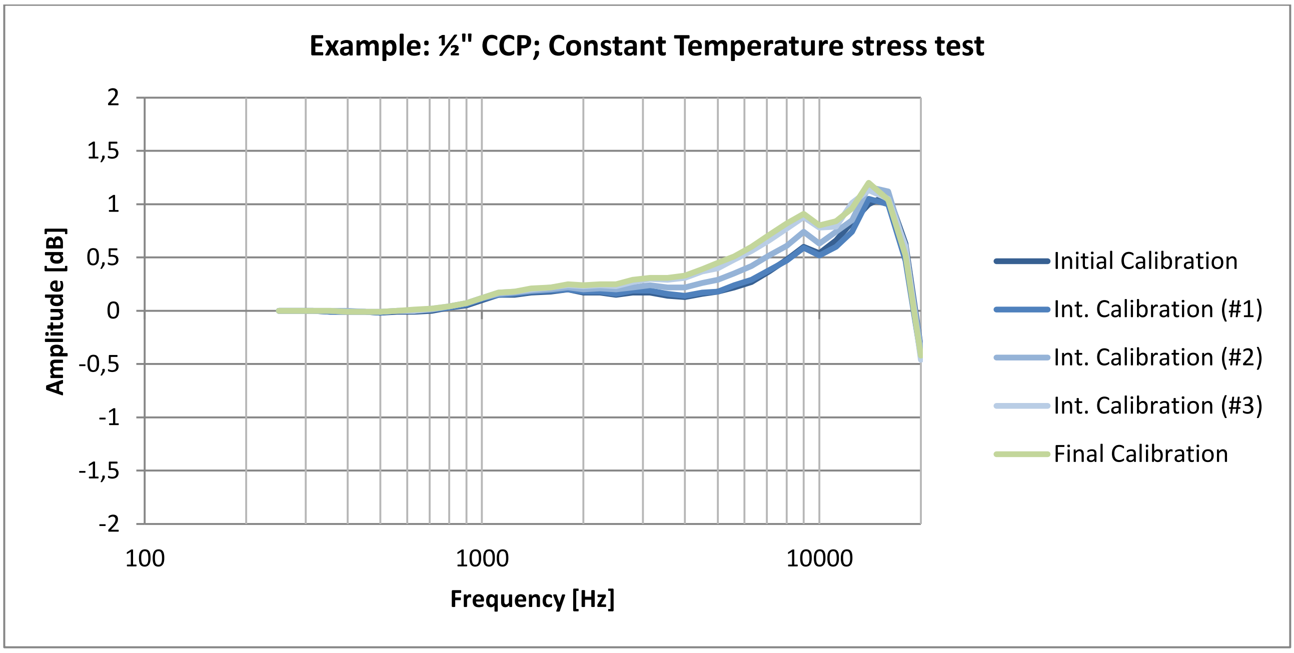


Figure 9. Is identical to Figure 8, having zoomed in on the region of interest.

The change in sensitivity at 250Hz is tracked as shown in Table 3.

	Initial Calibration	Int. Calibration (#1)	Int. Calibration (#2)	Int. Calibration (#3)	Final Calibration
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.95	-25.91	-25.84	-25.90	-25.69

Table 3. As with the amplitude response, the sensitivity at 250Hz of the microphone set is tracked during the progress of the stress test, stated in dB re. 1V/Pa.

Such data will give the reader an understanding of the sequential change in frequency response due to the given test conditions.

Following a complete stress test, statistics are collected on three metrics:

1) $\|\Delta\|_\infty$, the *maximum* deviation between the initial and final amplitude response
2) $\frac{1}{N}\|\Delta\|_1$, the *average* deviation between the initial and final amplitude response
3) δ, the change in sensitivity at 250Hz between the initial and final calibration

The former two metrics are visualized in Figure 10. $\|\Delta\|_\infty$ represents the largest of the dark lines and $\frac{1}{N}\|\Delta\|_1$ represents their mean length.

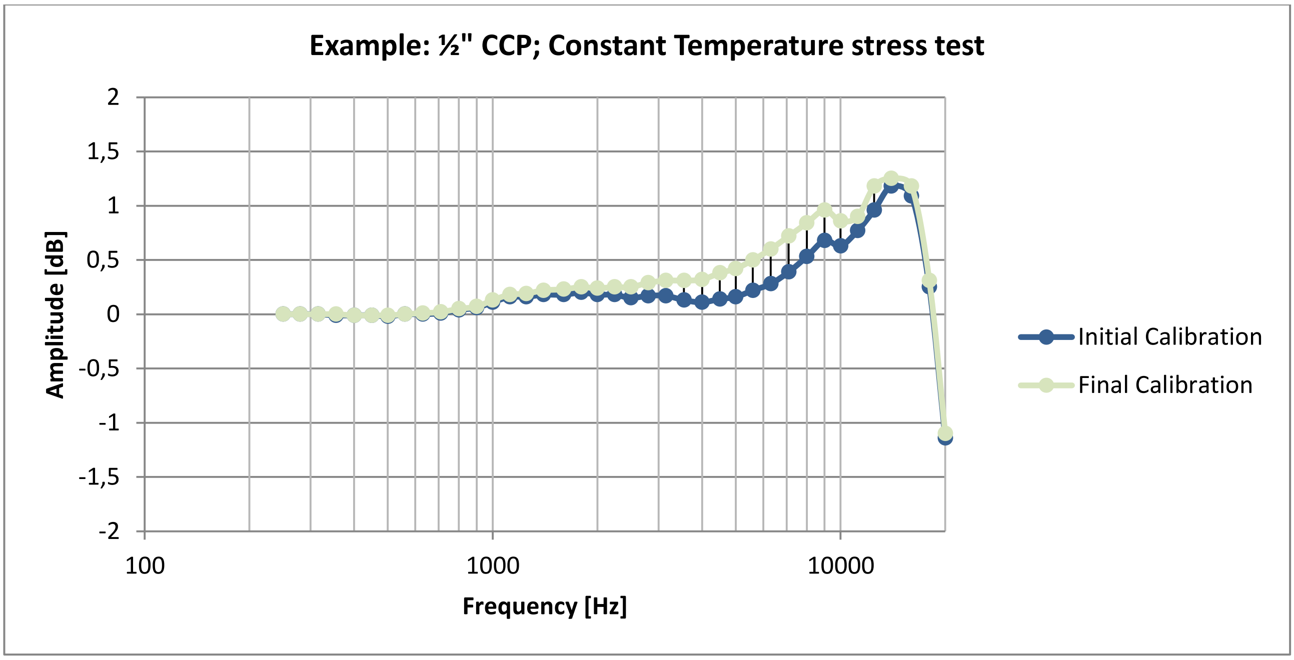


Figure 10. Clarification of the two metrics used in this study: the L_∞-norm (the maximum deviation between the initial and final amplitude response, e.g. the largest of the dark lines), and the L_1-norm (the average deviation between the initial and final amplitude response, e.g. the mean of the dark lines).

Based on the data provided in Table 3 and Figure 10 for the particular microphone set, these three metrics translate to the following:

	[dB]		
	$\|\|\Delta\|\|_{\infty}$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.34	0.110	0.26

Table 4. We show the three metrics of interest following a complete stress test, based on the data provided in Table 3 and Figure 9 for the particular microphone set.

In general, however, results for a stress test will be presented as in Table 5. This table presents the sample mean and standard deviation of the three metrics across the sample set of five in a group.

	$\bar{\mathbf{x}} \pm \mathbf{s}$ **[dB]**		
	$\|\|\Delta\|\|_{\infty}$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.370 ± 0.135	0.119 ± 0.048	0.384 ± 0.083

Table 5. We provide the sample mean and standard deviation of the three metrics of interest, following a complete stress test. The statistics are collected across the five samples of the group.

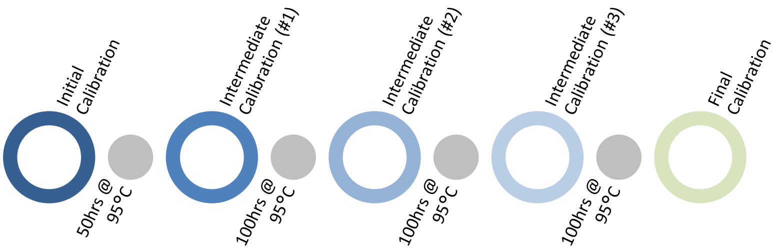
4. Results - ½" externally polarized microphone sets (200V)

This section presents the Microphone HALT results for the group of ½" externally polarized microphone sets based on measurements on 5 samples of 46AF. The conclusions drawn are valid for the following microphone sets: 46AC, 46AF, 46AG, 46AP, and 46AR.

4.1 Temperature Stress Test

4.1.1 Constant temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 11.

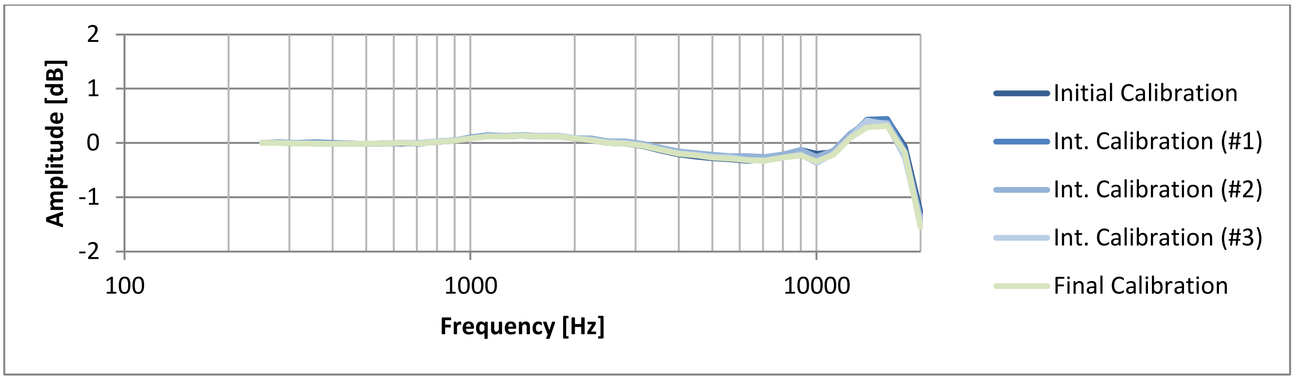


Figure 11. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Constant Temperature stress test.

The change in sensitivity of the same sample is tracked in Table 6.

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.8	-25.76	-25.71	-25.56	-25.41

Table 6. Tracking the change in sensitivity of the same sample as shown in Figure 11 during the progress of the Constant Temperature stress test.

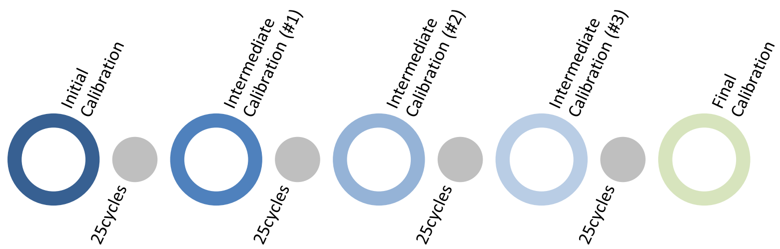
Table 7 summarizes the statistics of interest across the entire sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.242 ± 0.057	0.032 ± 0.010	0.316 ± 0.128

Table 7. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

4.1.2 Cyclic temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 12.

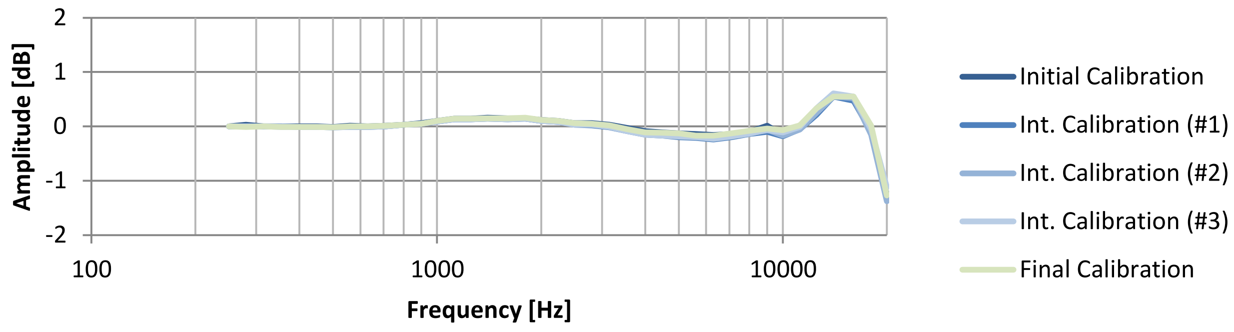


Figure 12. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Cyclic Temperature stress test.

The change in sensitivity of the same sample is tracked in Table 8.

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.38	-25.24	-25.22	-25.17	-25.15

Table 8. Tracking the change in sensitivity of the same sample as shown in Figure 12 during the progress of the Cyclic Temperature stress test.

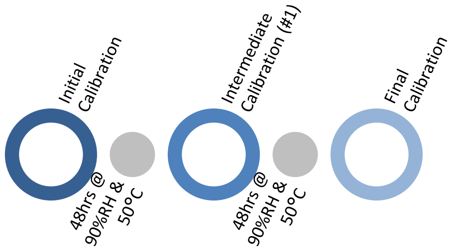
Table 9 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.136 ± 0.101	0.034 ± 0.036	0.172 ± 0.079

Table 9. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

4.2 Humidity Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 13.

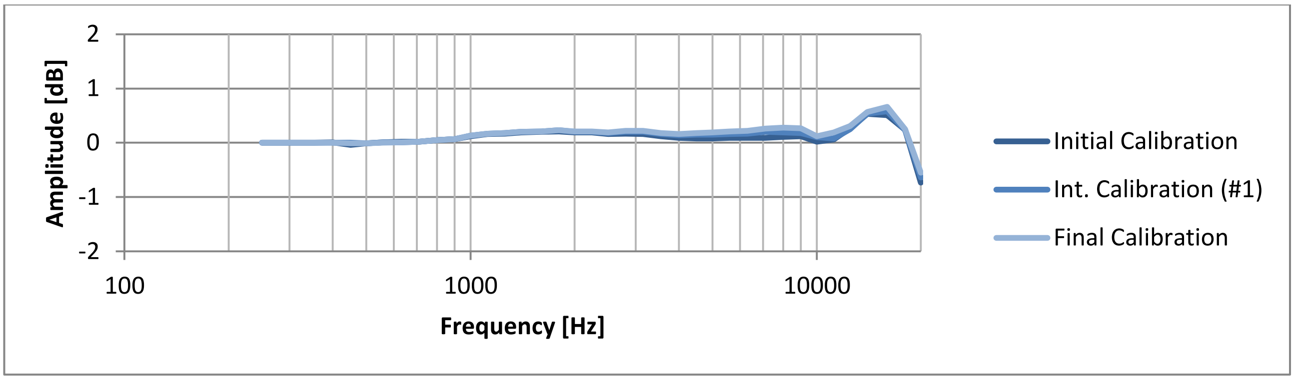


Figure 13. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Humidity stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.58	-25.45	-25.23

Table 10. Tracking the change in sensitivity of the same sample as shown in Figure 13 during the progress of the Humidity stress test.

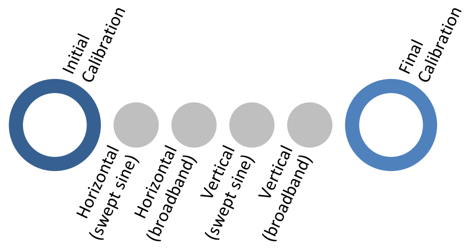
Table 11 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.160 ± 0.058	0.042 ± 0.025	0.166 ± 0.142

Table 11. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

4.3 Vibration Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 14.

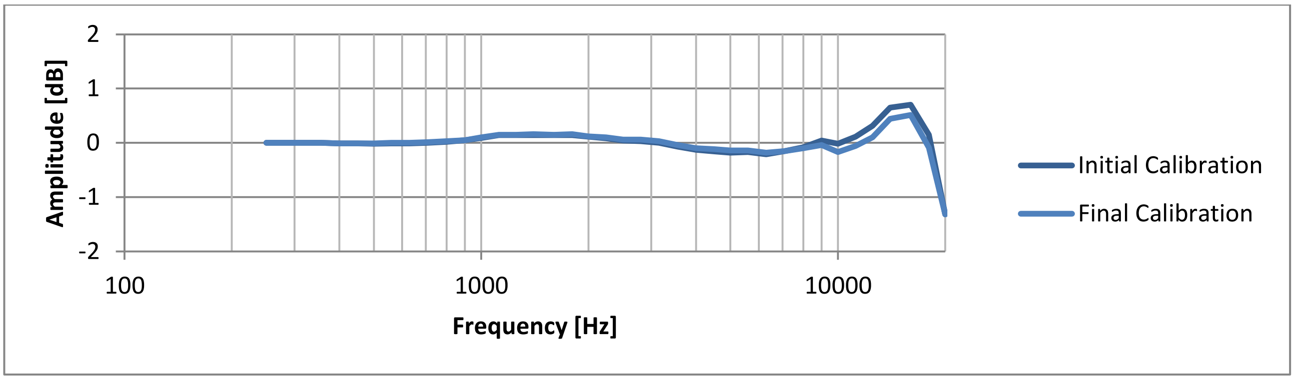


Figure 14. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Vibration stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.46	-25.34

Table 12. Tracking the change in sensitivity of the same sample as shown in Figure 14 during the progress of the Vibration stress test.

Table 13 summarizes the statistics of interest across the sample set.

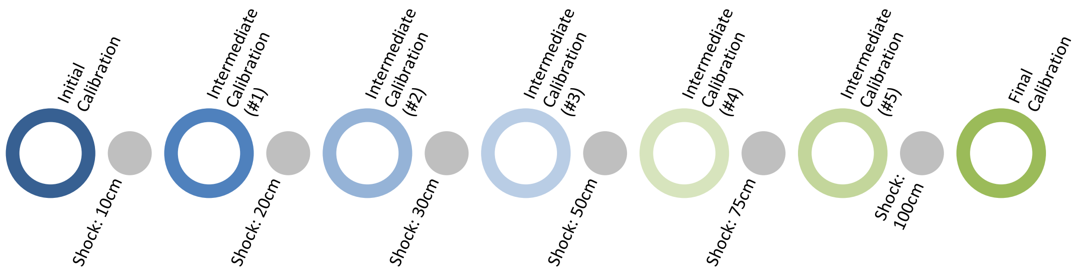
	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.230 ± 0.051	0.047 ± 0.027	0.138 ± 0.153

Table 13. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

4.4 Impulse Stress Test

4.4.1 Shock Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 15.

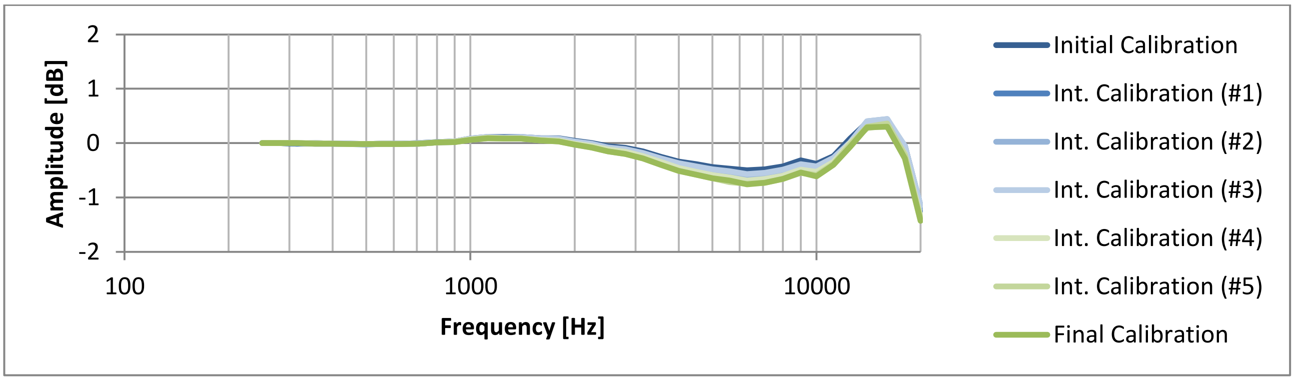


Figure 15. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Shock stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	***Int. Calibration (#1)***	***Int. Calibration (#2)***	***Int. Calibration (#3)***	***Int. Calibration (#4)***	***Int. Calibration (#5)***	***Final Calibration***
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.3	-25.24	-25.28	-25.27	-25.17	-25.15	-25.16

Table 14. Tracking the change in sensitivity of the same sample as shown in Figure 15 during the progress of the Mechanical Impulse Shock stress test.

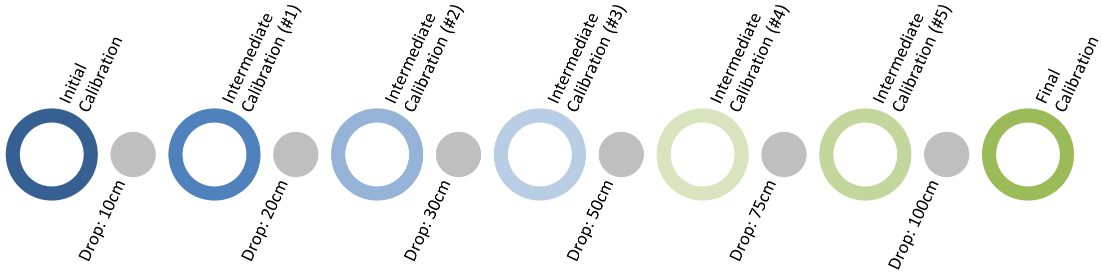
Table 15 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.322 ± 0.295	0.070 ± 0.050	0.064 ± 0.065

Table 15. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

4.4.2 Drop Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 16.

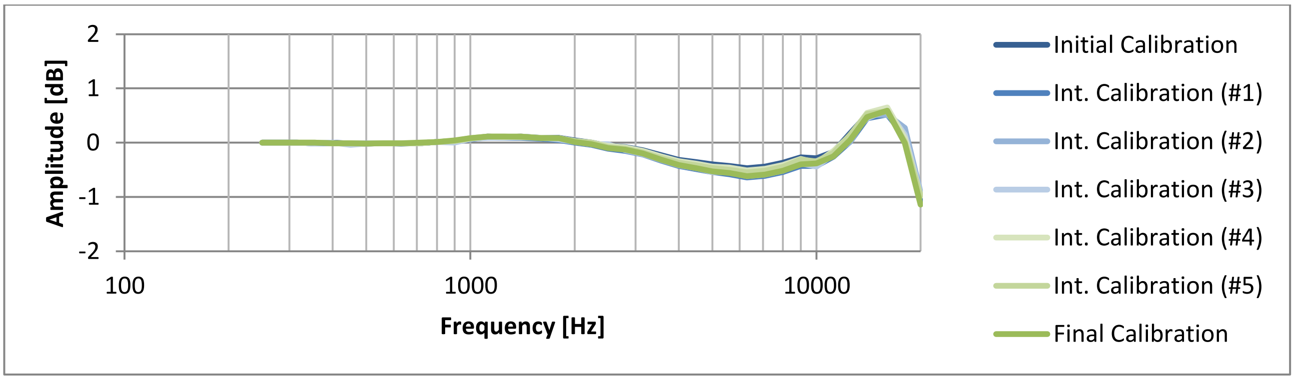


Figure 16. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Drop stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Int. Calibration (#4)*	*Int. Calibration (#5)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.28	-25.19	-25.26	-25.23	-25.24	-25.27	-25.21

Table 16. Tracking the change in sensitivity of the same sample as shown in Figure 16 during the progress of the Mechanical Impulse Drop stress test.

Table 17 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.235 ± 0.103	0.078 ± 0.040	0.135 ± 0.112

Table 17. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

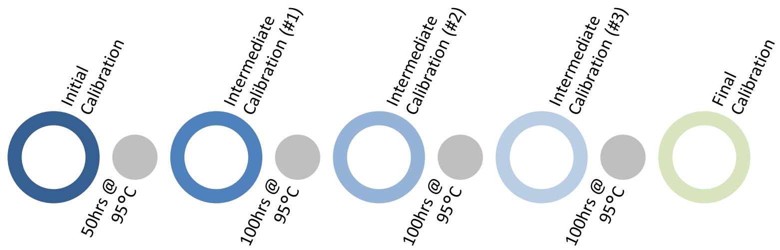
5. Results - ½" prepolarized microphone sets (CCP)

This section presents the HALT results for the group of ½" prepolarized microphone sets based on measurements on 5 samples of 46AE. The conclusions drawn are valid for the following microphone sets: 46AD, 46AE, 46AM, 46AO, and 46AQ.

5.1 Temperature Stress Test

5.1.1 Constant temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 17.

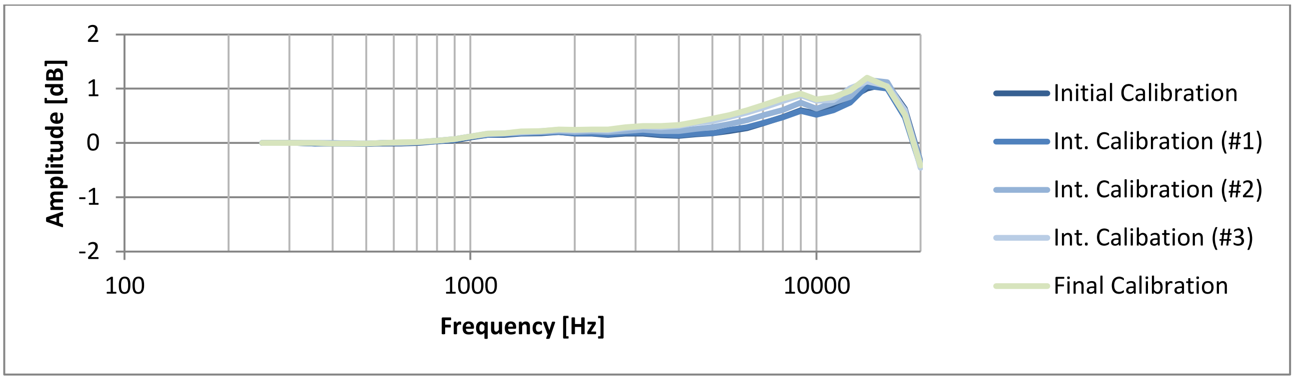


Figure 17. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Constant Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.95	-25.91	-25.84	-25.9	-25.69

Table 18. Tracking the change in sensitivity of the same sample as shown in Figure 17 during the progress of the Constant Temperature stress test.

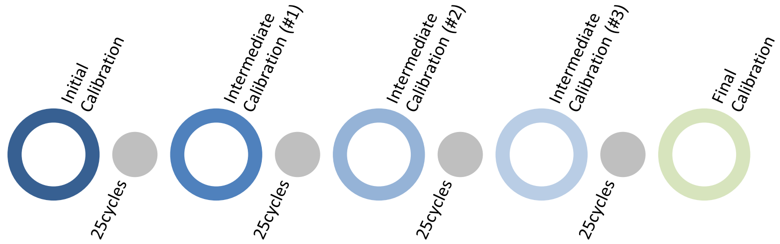
Table 19 summarizes the statistics of interest across the sample set following the final calibration.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.370 ± 0.135	0.119 ± 0.048	0.384 ± 0.083

Table 19. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

5.1.2 Cyclic temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 18.

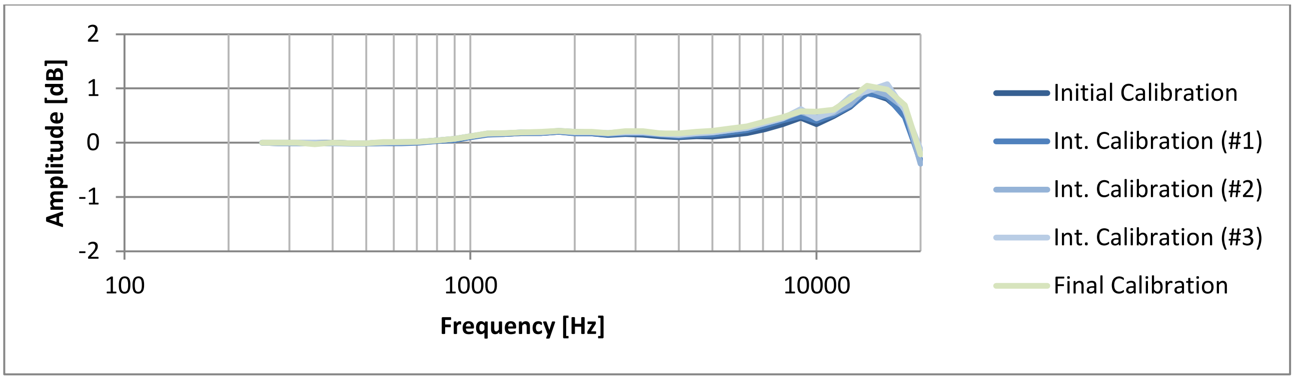


Figure 18. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Cyclic Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-26.16	-25.94	-25.91	-25.89	-25.83

Table 20. Tracking the change in sensitivity of the same sample as shown in Figure 18 during the progress of the Cyclic Temperature stress test.

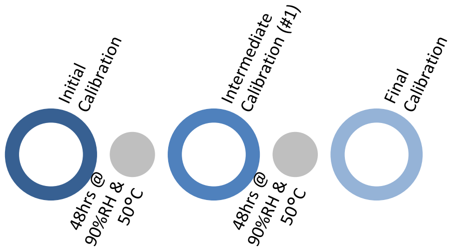
Table 21 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.246 ± 0.077	0.068 ± 0.030	0.324 ± 0.080

Table 21. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

5.2 Humidity Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 19.

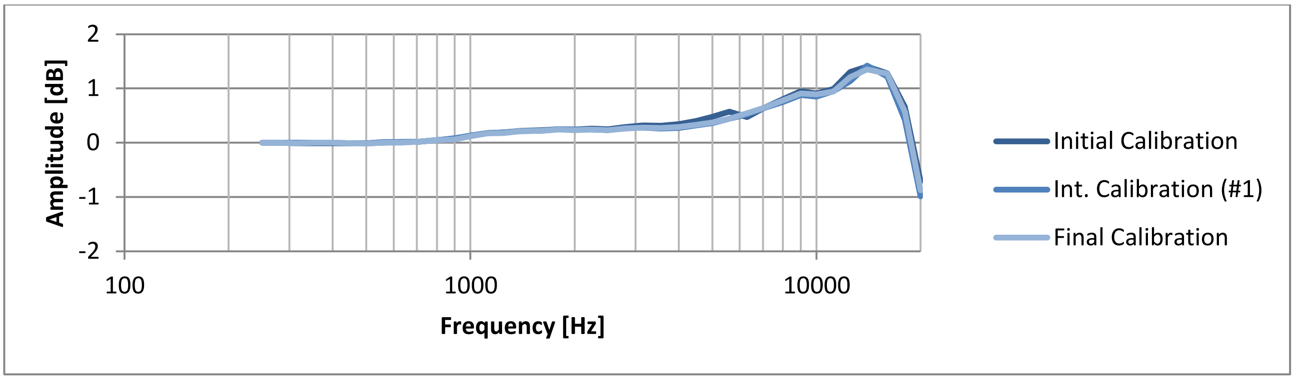


Figure 19. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Humidity stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	***Int. Calibration (#1)***	***Final Calibration***
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-27.38	-27.25	-27.29

Table 22. Tracking the change in sensitivity of the same sample as shown in Figure 19 during the progress of the Humidity stress test.

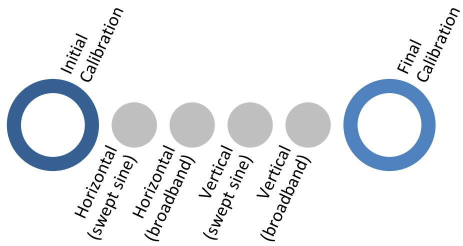
Table 23 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.184 ± 0.050	0.043 ± 0.017	0.124 ± 0.067

Table 23. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

5.3 Vibration Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 20.

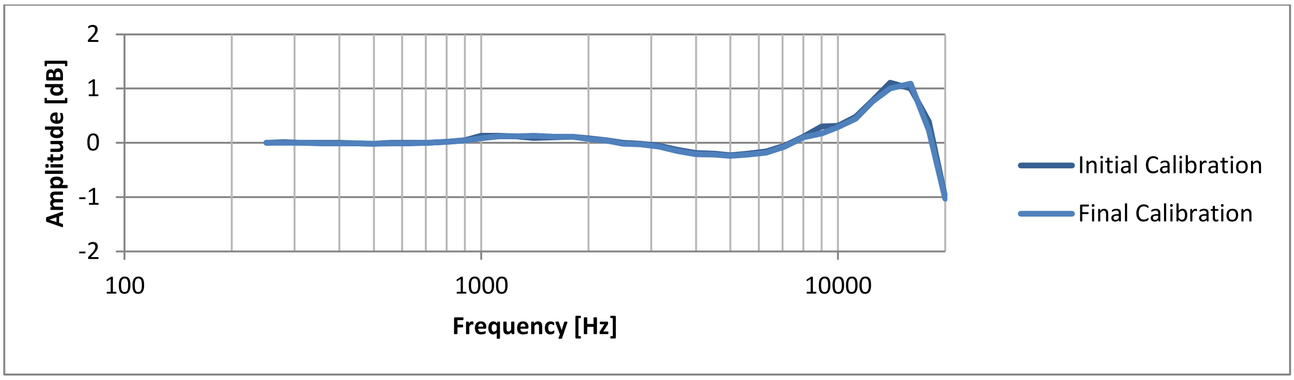


Figure 20. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Vibration stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.23	-25.11

Table 24. Tracking the change in sensitivity of the same sample as shown in Figure 20 during the progress of the Vibration stress test.

Table 25 summarizes the statistics of interest across the sample set.

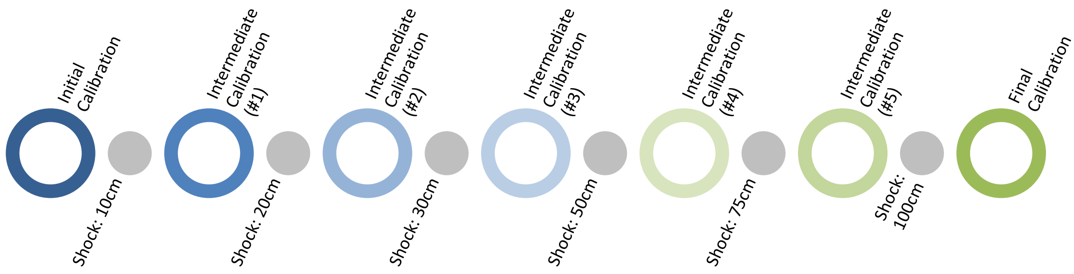
	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.180 ± 0.090	0.041 ± 0.013	0.114 ± 0.066

Table 25. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

5.4 Impulse Stress Test

5.4.1 Shock Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 21.

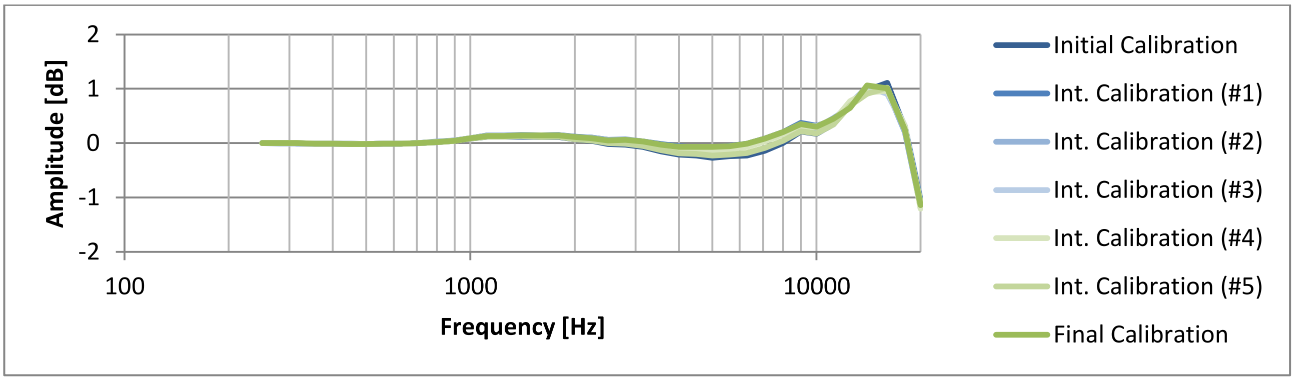


Figure 21. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Shock stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Int. Calibration (#4)*	*Int. Calibration (#5)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.03	-24.95	-24.97	-24.96	-24.97	-24.93	-24.93

Table 26. Tracking the change in sensitivity of the same sample as shown in Figure 21 during the progress of the Mechanical Impulse Shock stress test.

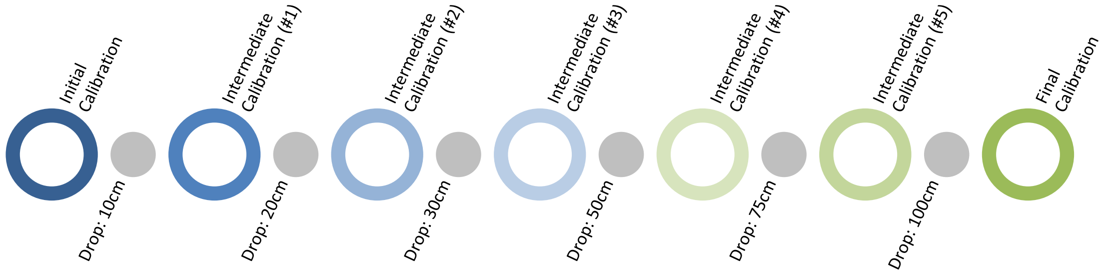
Table 27 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.210 ± 0.070	0.067 ± 0.032	0.098 ± 0.100

Table 27. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

5.4.2 Drop Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 22.

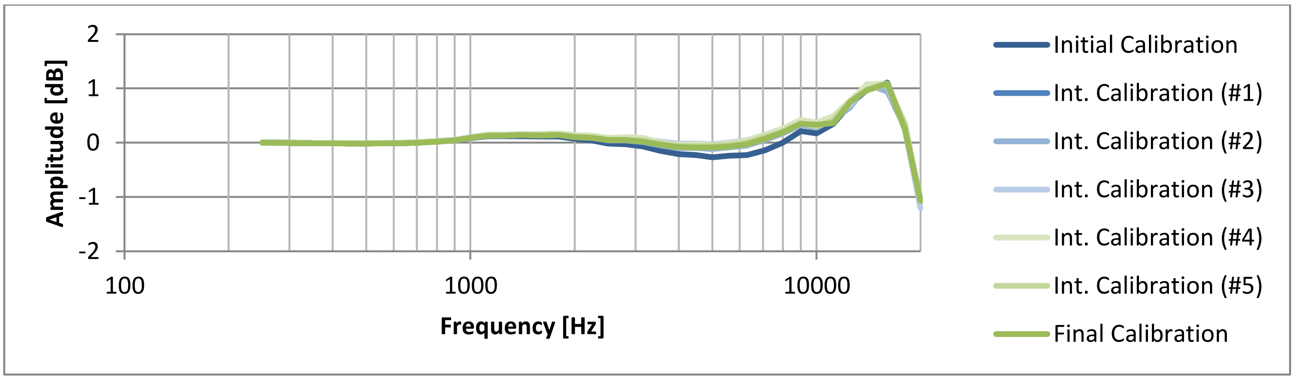


Figure 22. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Drop stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Int. Calibration (#4)*	*Int. Calibration (#5)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-25.03	-24.91	-24.95	-24.96	-24.92	-24.96	-24.98

Table 28. Tracking the change in sensitivity of the same sample as shown in Figure 22 during the progress of the Mechanical Impulse Drop stress test.

Table 29 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.212 ± 0.092	0.069 ± 0.036	0.078 ± 0.091

Table 29. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

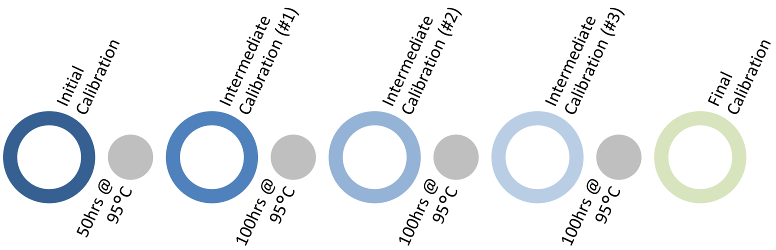
6. Results – ¼" externally polarized microphone sets (200V)

This section presents the HALT results for the group of ¼" externally polarized microphone sets based on measurements on 5 samples of 46BP-1. The conclusions drawn are valid for the following microphone sets: 46BF-1, 46BH-1, and 46BP-1.

6.1 Temperature Stress Test

6.1.1 Constant temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 23.

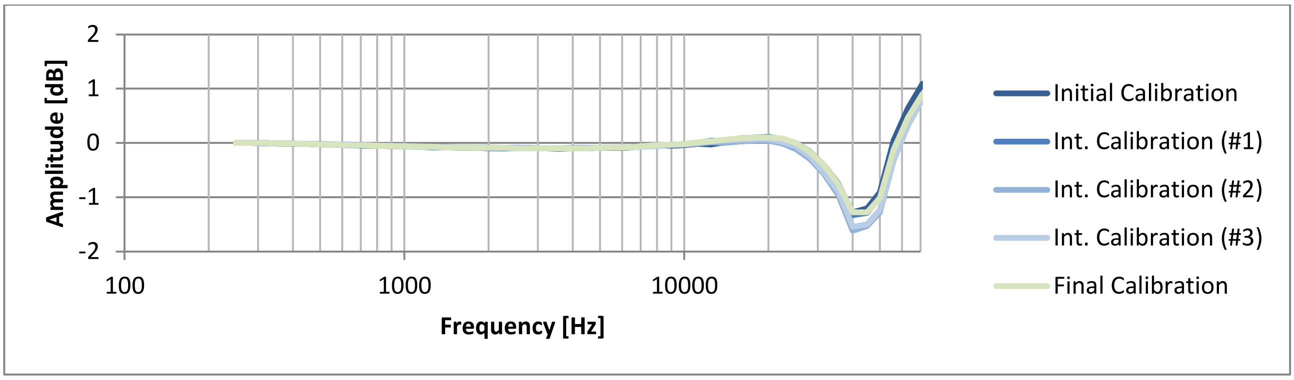


Figure 23. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Constant Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.61	-56.59	-56.61	-56.51	-56.59

Table 30. Tracking the change in sensitivity of the same sample as shown in Figure 23 during the progress of the Constant Temperature stress test.

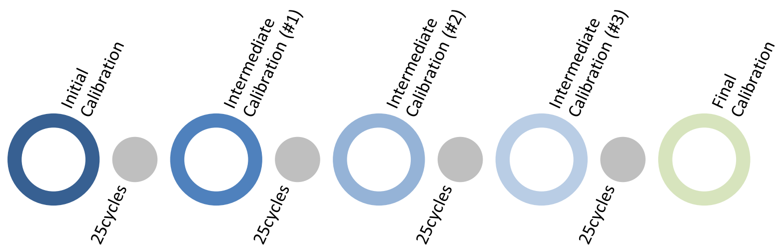
Table 31 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.228 ± 0.045	0.031 ± 0.010	0.030 ± 0.014

Table 31. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

6.1.2 Cyclic temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 24.

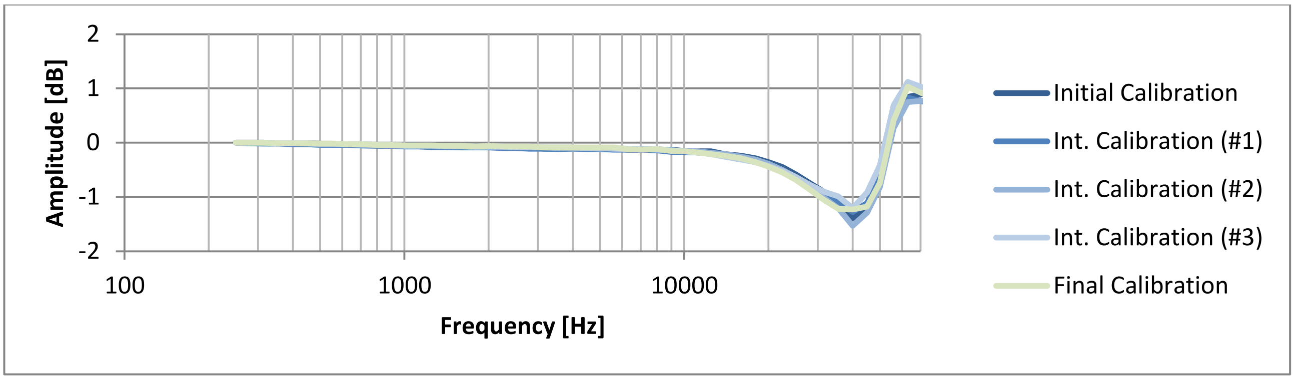


Figure 24. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Cyclic Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.63	-56.62	-56.59	-56.59	-56.6

Table 32. Tracking the change in sensitivity of the same sample as shown in Figure 24 during the progress of the Cyclic Temperature stress test.

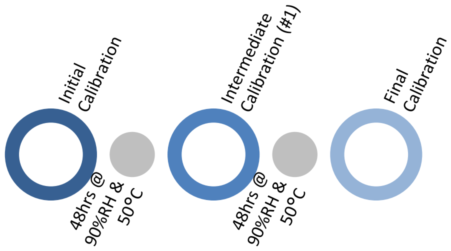
Table 33 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.254 ± 0.127	0.047 ± 0.023	0.082 ± 0.067

Table 33. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

6.2 Humidity Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 25.

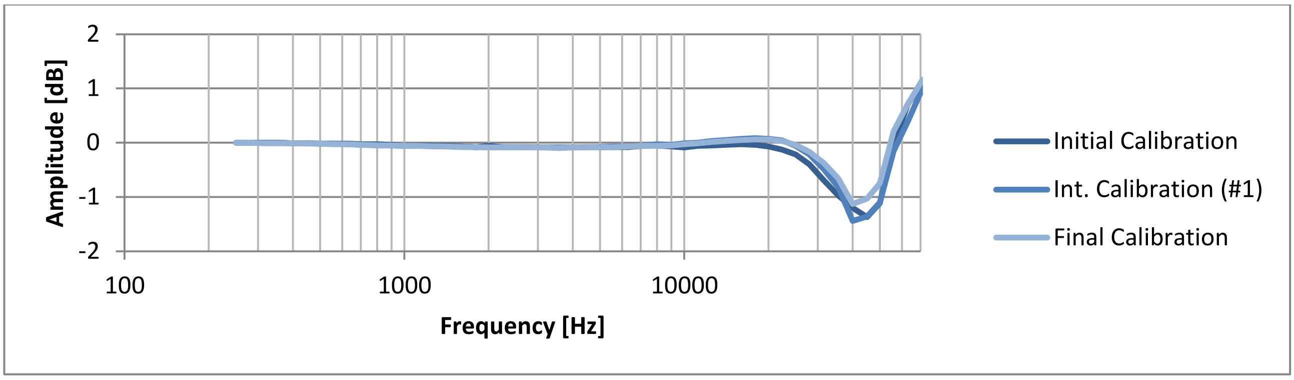


Figure 25. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Humidity stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.86	-56.85	-56.81

Table 34. Tracking the change in sensitivity of the same sample as shown in Figure 25 during the progress of the Humidity stress test.

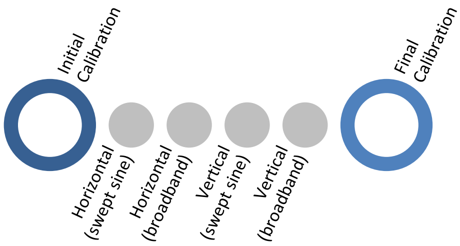
Table 35 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.370 ± 0.127	0.052 ± 0.024	0.100 ± 0.037

Table 35. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

6.3 Vibration Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 26.

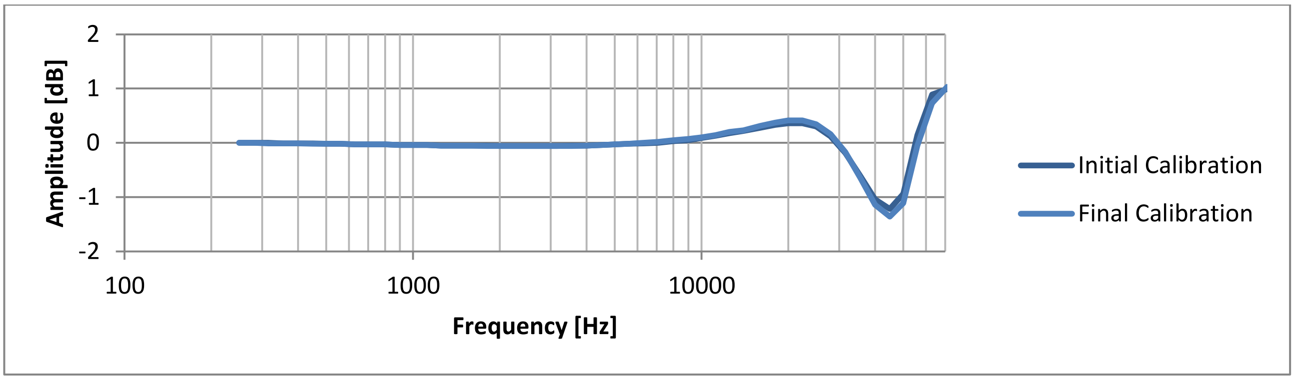


Figure 26. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Vibration stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-57.69	-57.65

Table 36. Tracking the change in sensitivity of the same sample as shown in Figure 26 during the progress of the Vibration stress test.

Table 37 summarizes the statistics of interest across the sample set.

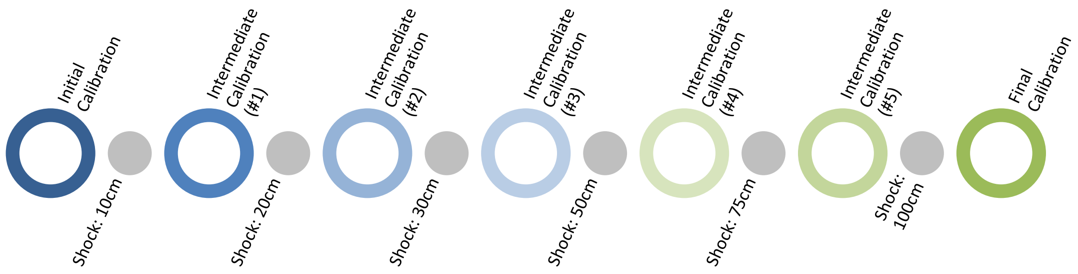
	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.234 ± 0.117	0.030 ± 0.014	0.028 ± 0.033

Table 37. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

6.4 Impulse Stress Test

6.4.1 Shock Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 27.

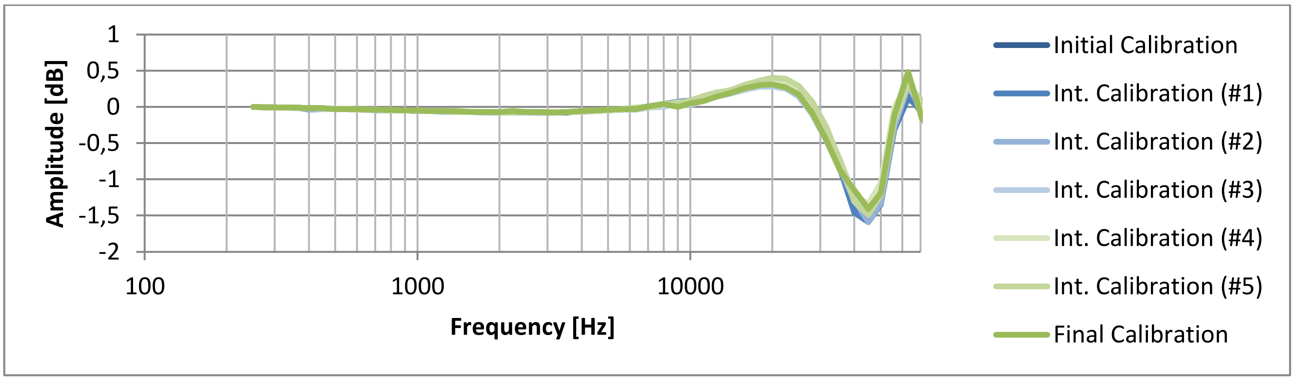


Figure 27. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Shock stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	***Int. Calibration (#1)***	***Int. Calibration (#2)***	***Int. Calibration (#3)***	***Int. Calibration (#4)***	***Int. Calibration (#5)***	***Final Calibration***
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-57.16	-57.06	-57.15	-56.99	-57.1	-57.08	-57.06

Table 38. Tracking the change in sensitivity of the same sample as shown in Figure 27 during the progress of the Mechanical Impulse Shock stress test.

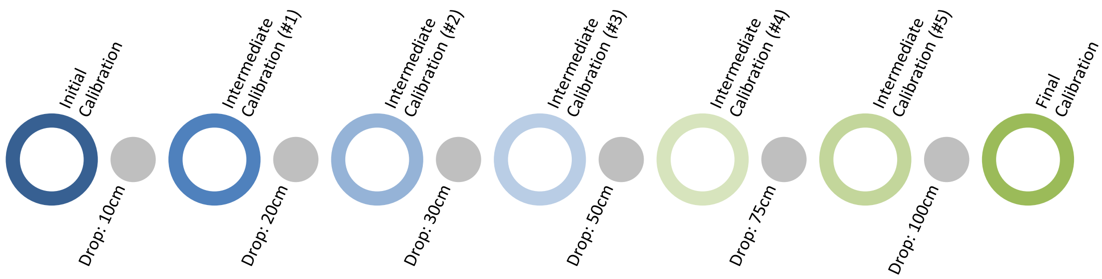
Table 39 summarizes the statistics of interest across the sample set.

	$\bar{\mathrm{x}} \pm \mathrm{s}$ **[dB]**		
	$\lVert\Delta\rVert_\infty$ *(max. dev.)*	$\frac{1}{N}\lVert\Delta\rVert_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.302 ± 0.104	0.032 ± 0.009	0.048 ± 0.043

Table 39. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\lVert\Delta\rVert_\infty$ (max. dev.); (2) $\lVert\Delta\rVert_1/N$ (avg. dev.); and (3) δ.

6.4.2 Drop Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 28.

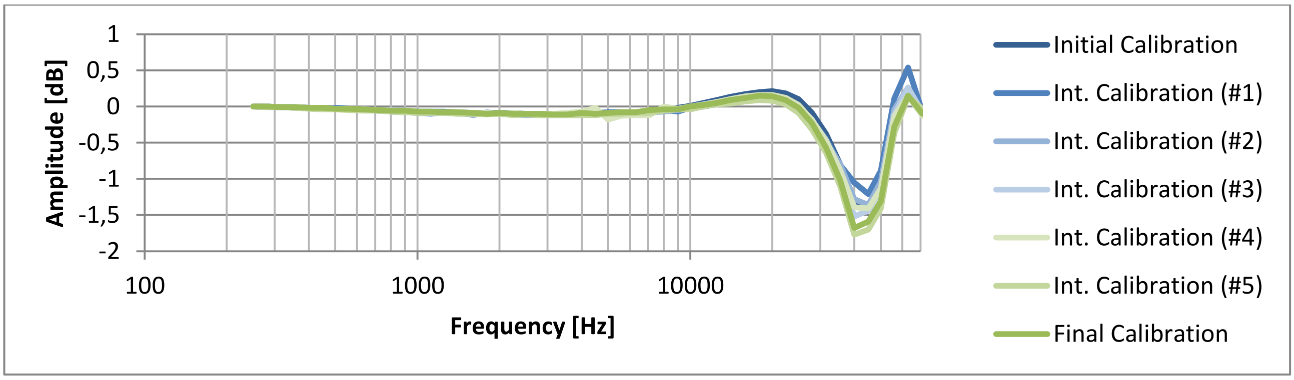


Figure 28. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Drop stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Int. Calibration (#4)*	*Int. Calibration (#5)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.36	-56.35	-56.36	-56.36	-56.34	-56.34	-56.33

Table 40. Tracking the change in sensitivity of the same sample as shown in Figure 28 during the progress of the Mechanical Impulse Drop stress test.

Table 41 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.440 ± 0.403	0.047 ± 0.022	0.164 ± 0.165

Table 41. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

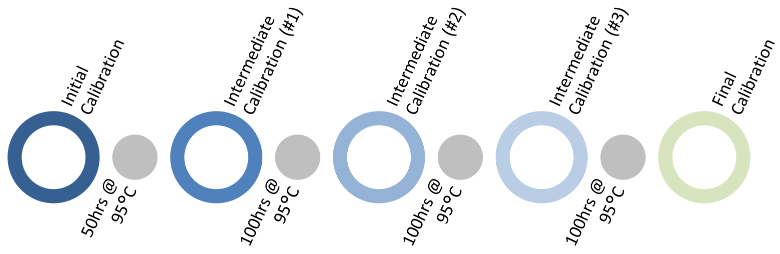
7. Results – ¼" prepolarized microphone sets (CCP)

This section presents the HALT results for the group of ¼" prepolarized microphone sets based on measurements on 5 samples of 46BD. The conclusions drawn are valid for the following microphone sets: 46BD, 46BD-S1, 46BD-S2, 46BE, and 46BG.

7.1 Temperature Stress Test

7.1.1 Constant temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 23.

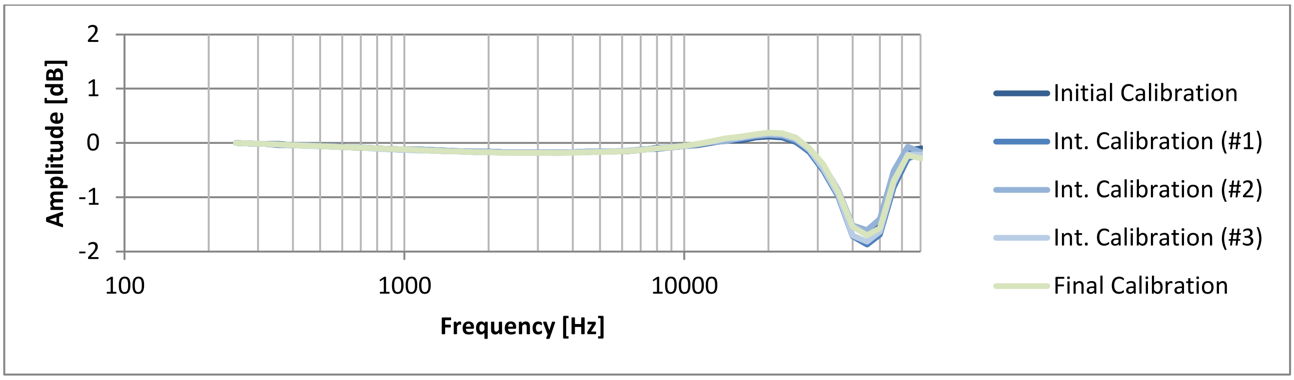


Figure 29. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Constant Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.99	-56.88	-56.75	-56.81	-56.61

Table 42. Tracking the change in sensitivity of the same sample as shown in Figure 29 during the progress of the Constant Temperature stress test.

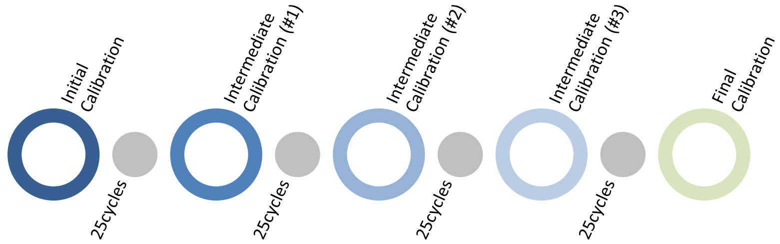
Table 43 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.184 ± 0.015	0.032 ± 0.006	0.760 ± 0.305

Table 43. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

7.1.2 Cyclic temperature

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 24.

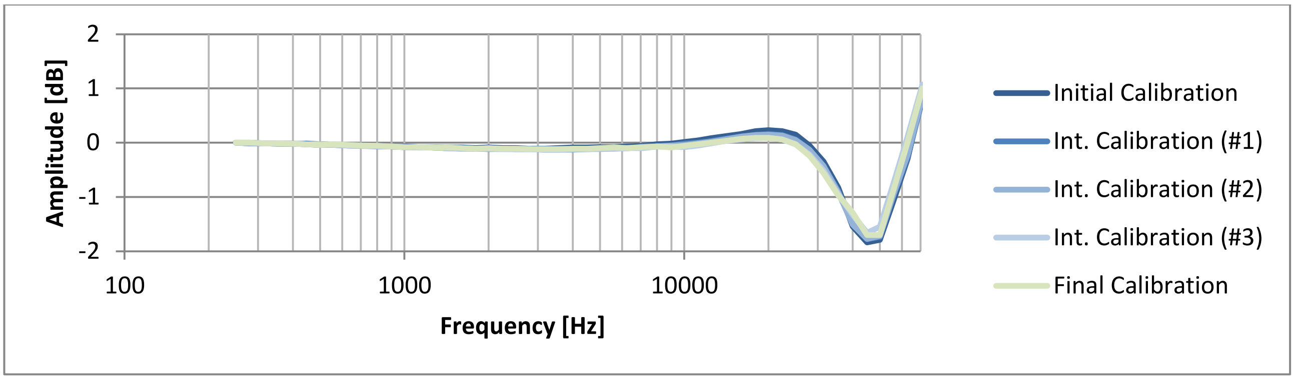


Figure 30. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Cyclic Temperature stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-55.37	-55.29	-55.28	-55.28	-55.24

Table 44. Tracking the change in sensitivity of the same sample as shown in Figure 30 during the progress of the Cyclic Temperature stress test.

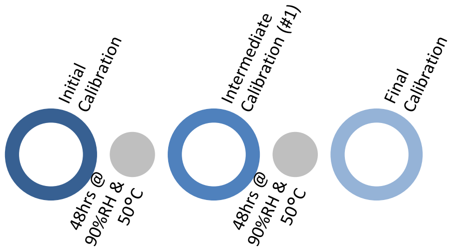
Table 45 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.280 ± 0.082	0.059 ± 0.008	0.088 ± 0.029

Table 45. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

7.2 Humidity Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 25.

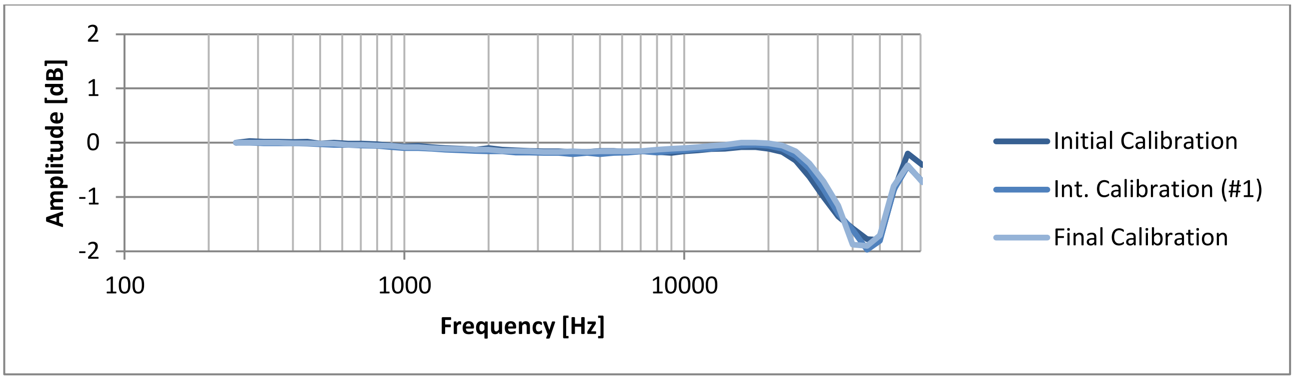


Figure 31. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Humidity stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-56.98	-56.96	-56.96

Table 46. Tracking the change in sensitivity of the same sample as shown in Figure 31 during the progress of the Humidity stress test.

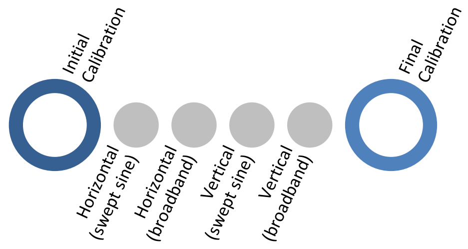
Table 47 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.350 ± 0.075	0.051 ± 0.012	0.018 ± 0.005

Table 47. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

7.3 Vibration Stress Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 26.

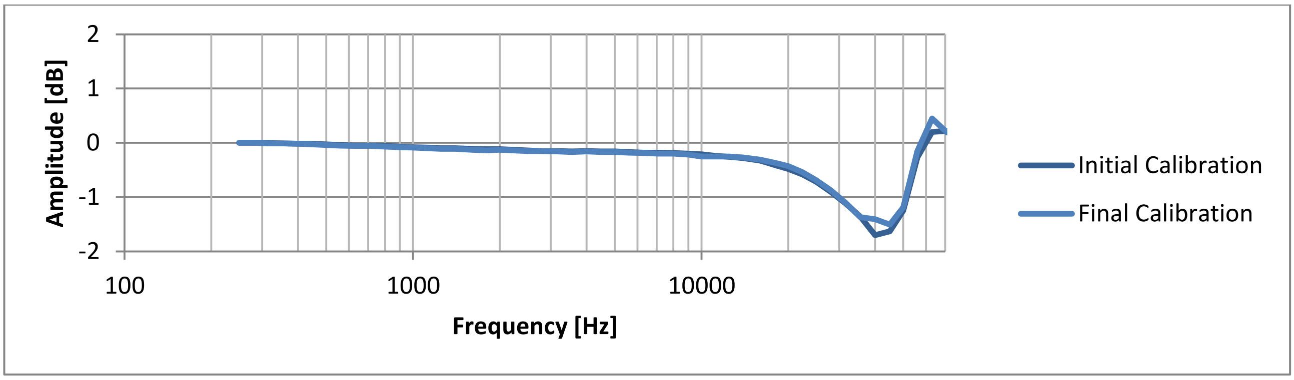


Figure 32. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Vibration stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-57.25	-57.18

Table 48. Tracking the change in sensitivity of the same sample as shown in Figure 32 during the progress of the Vibration stress test.

Table 49 summarizes the statistics of interest across the sample set.

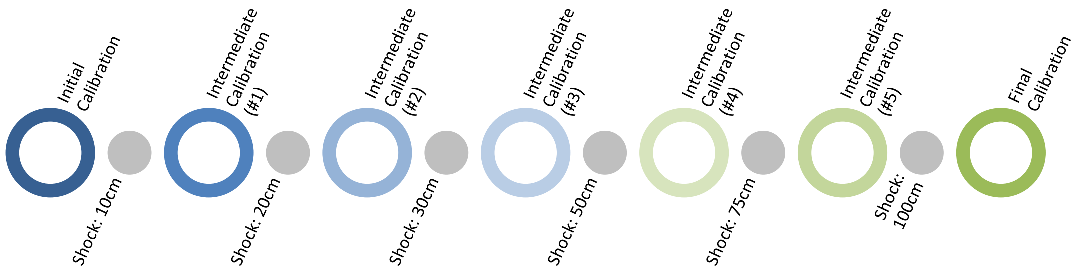
	$\bar{x} \pm s$ [dB]		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.276 ± 0.149	0.037 ± 0.023	0.036 ± 0.022

Table 49. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.

7.4 Impulse Stress Test

7.4.1 Shock Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 27.

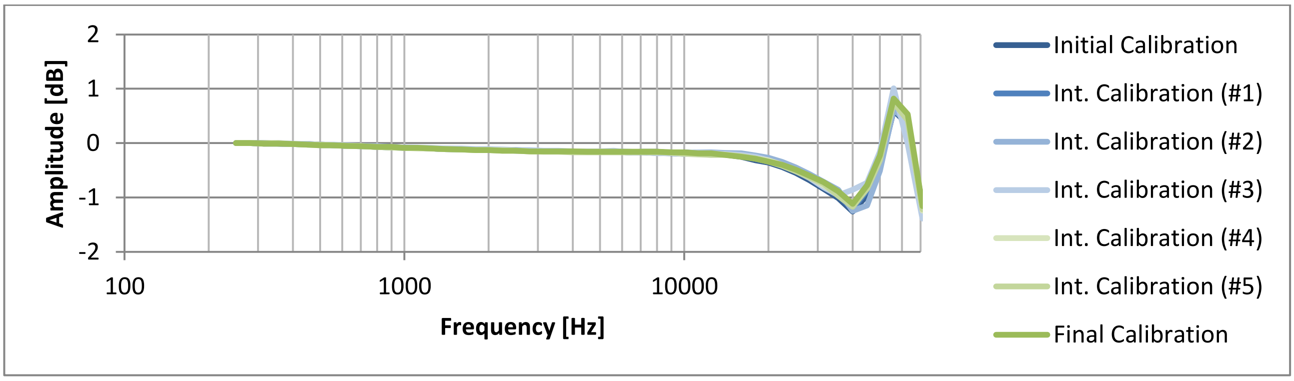


Figure 33. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Shock stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	*Int. Calibration (#1)*	*Int. Calibration (#2)*	*Int. Calibration (#3)*	*Int. Calibration (#4)*	*Int. Calibration (#5)*	*Final Calibration*
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-54.1	-54.08	-54.08	-54.09	-54.08	-54.09	-54.09

Table 50. Tracking the change in sensitivity of the same sample as shown in Figure 33 during the progress of the Mechanical Impulse Shock stress test.

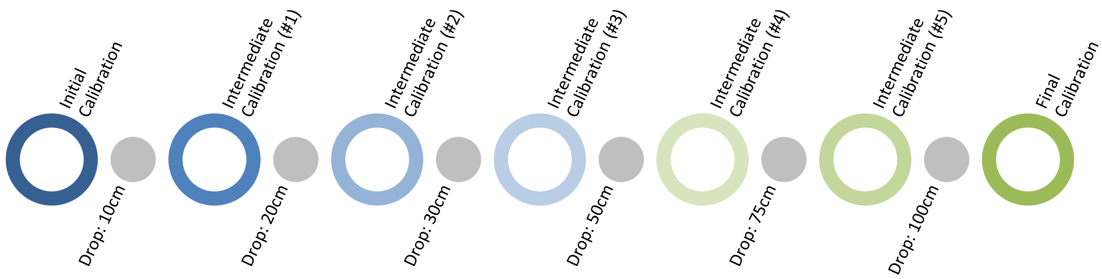
Table 51 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ [dB]		
	$\|\|\Delta\|\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\|\Delta\|\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.252 ± 0.098	0.036 ± 0.010	0.106 ± 0.160

Table 51. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $||\Delta||_\infty$ (max. dev.); (2) $||\Delta||_1/N$ (avg. dev.); and (3) δ.

7.4.2 Drop Test

The test protocol was as follows:



with calibrated results of an arbitrary sample as shown in Figure 28.

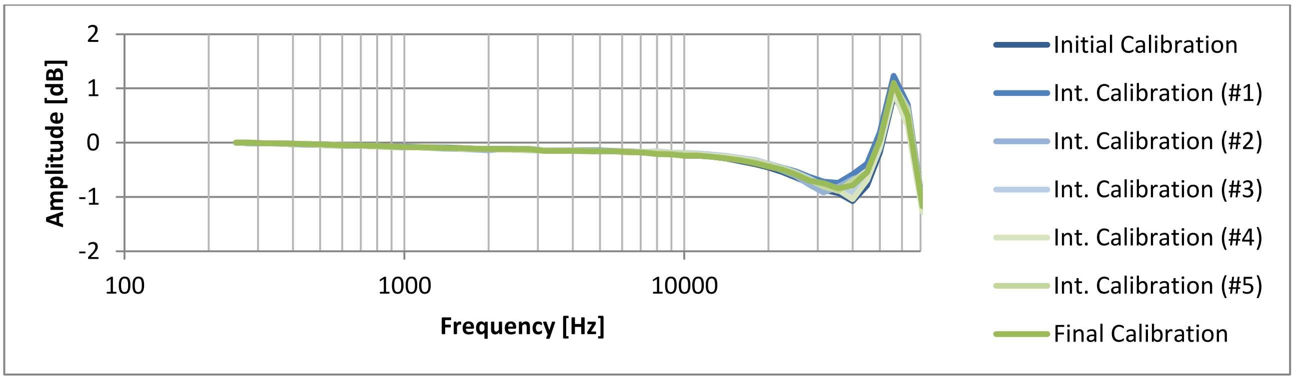


Figure 34. Tracking the change in frequency response of an arbitrary sample in the group during the progress of the Mechanical Impulse Drop stress test.

The change in sensitivity across the stress test for the same sample is tracked in

	Initial Calibration	***Int. Calibration (#1)***	***Int. Calibration (#2)***	***Int. Calibration (#3)***	***Int. Calibration (#4)***	***Int. Calibration (#5)***	***Final Calibration***
Sensitivity @ 250Hz [dB re. 1V/Pa]:	-58.6	-58.58	-58.57	-58.57	-58.59	-58.58	-58.58

Table 52. Tracking the change in sensitivity of the same sample as shown in Figure 34 during the progress of the Mechanical Impulse Drop stress test.

Table 53 summarizes the statistics of interest across the sample set.

	$\bar{x} \pm s$ **[dB]**		
	$\|\Delta\|_\infty$ *(max. dev.)*	$\frac{1}{N}\|\Delta\|_1$ *(avg. dev.)*	δ
Final Calibration re. Initial Calibration	0.282 ± 0.191	0.044 ± 0.018	0.074 ± 0.106

Table 53. Providing the mean, $\bar{x}$, and standard deviation, s, of (1) $\|\Delta\|_\infty$ (max. dev.); (2) $\|\Delta\|_1/N$ (avg. dev.); and (3) δ.