**IVF Project Report 03/15**

# HALT Report

**Tadeusz Gruszecki**

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**Product tested:** Sensor

**Test dates:** 2003-03-18 -- 2003-03-20

**Report date:** 3 April 2003

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# Contents

# 1 Objective

The products were subjected to HALT to uncover design and/or process weaknesses. During the HALT process the products were exposed to progressively higher stress levels brought on by thermal step stress, vibration, rapid temperature transitions and combined environments. Throughout the HALT process, the intent was to subject the products to stimuli well beyond the expected field environment to determine the operating and destruct limits of the product. Failures, which typically show up in the field over a period of time at much lower stress levels, are quickly discovered while applying high stress conditions over a short period of time.

Each of the failures found during the HALT process (see section 2.0) need to be examined and the root cause of the failure determined. Once the root cause of each failure is determined, engineering judgment is used to determine whether corrective action should be taken to fix the problem. The products should then undergo verification HALT to ensure that the design margins have been increased to the fundamental limit of the technology and that the corrections made did not induce new failure modes. The ruggedization of the product will not be increased unless each of the failures found during the HALT process are taken to root cause and corrective action implemented when deemed necessary.

# 2 Executive summary

HALT was performed using 4 sets of samples. During the HALT process, the goal was to find the operating and destruct limits of the units tested using thermal step stress, vibration step stress, and combined environment stress of temperature and multi axis, 6-degree-of-freedom vibration. If once these limits were determined, the goal was to fix the weak links and stress even further to expand the limits as much as possible. The operating and destruct limits are summarized in Table 1. See section 5.0 for a detailed description of performed stresses.

*Table 1 Summary of operating and destruct limits for all products*

| Stress Type | Chamber Set point Level |
|---|---|
| Temp LOL | < -90°C |
| Temp LDL | Not detected |
| Temp UOL | > 100°C |
| Temp UDL | Not detected |
| Thermal Transitions | -70°C to 85°C @ 60°C/min. |
| Vibration OL | > 65 $G_{rms}$ |
| Vibration DL | Not detected |

Notes:

1. All temperature and vibration values are chamber set points. See Section 5 and the Appendix for product levels.
2. LOL/LDL=Lower Operating/Destruct Limit. UOL/UDL=Upper Operating/Destruct Limit. For vibration there is an upper limit only.
3. Operating limit is defined as the stress level prior to where one or more of the product's operating characteristics are no longer within specification and the product recovers when the stress is reduced (i.e. a soft failure).
4. Destruct limit is defined as the stress level where one or more of the product's operating characteristics are no longer within specification, the product is damaged and does not recover when the stress is reduced (i.e. a hard failure).
5. When the limit is preceded by a ">" or "<" sign it indicates that we stopped prior to a failure, either because of a limitation of the chamber, the test set-up or per customer request.
6. The limits shown are the worst-case limits. In other words, the limits for the product that had the lowest limits of all units under that stress. These limits reflect the product limits before any modifications.

# 3 HALT process

During HALT process functional tests were performed using artificial "mechanical finger" directly in the chamber. After each stress test fully functional test was performed.

# 4 HALT Set-up

## 4.1 Product identifiers and date of receipt

The serial numbers of the units subjected to the HALT process and the dates these units were received are shown in Table 2.

*Table 2 Product identifiers*

| Set | Unit number | Date received |
|---|---|---|
| 1 | 1 | 030318 |
| 2 | 2 | 030318 |
| 3 | 3 | 030318 |
| 4 | 4 | 030318 |

## 4.2 Fixturing and airflow

The products were tested 2 units at a time. Functional test was performed on the one unit, on the second only in the end of each stress. The sensors under vibration test were secured to the OVS table using aluminum holder clamped to the vibration table with threaded rods. Air from the chamber plenum was directed onto the unit using 100 mm aluminum ducting. The fixture and ducting was designed to maximize both transmission of energy from the vibration table to the product and thermal transition rates, as well as to help maintain consistent temperatures on all the components inside the test units. Pictures illustrating the fixture and arrangements of tested units in the test chamber are presented in Appendix A.

## 4.3 Description of test equipment

*Table 3A ARTC test equipment*

| Equipment | Manufacturer | Model | S/N | Cal. Date |
|---|---|---|---|---|
| Thermal and vibration Test Chamber | QualMark | OVS 2.5 HP | 2507990345 | N/A |
| Data logger | HP | 34970A+<br>34901A | US37023462+<br>US37025034 | 01-05-29 |
| Data logger thermocouples | Pentronic AB | B-10-T | EP817-A | 02-10-29 |
| Chamber thermocouples | QualMark | Type T | N/A | 02-11-07 |
| Spectrum analyser | OROS | OR254II | 99393498 | 02-02-15 |
| Chamber accelerometer | Dytran | 3030C1 | 7598 | 02-02-15 |
| Accelerometer-power supply | Kistler | 5134A | C91738 | 02-02-15 |
| Accelerometer channel 1 | Kistler | 8732A500 | C125366 | 02-02-15 |
| Accelerometer channel 2 | Kistler | 8732A500 | C125369 | 02-02-15 |
| Accelerometer channel 3 | Kistler | 8732A500 | C125372 | 02-02-15 |
| Accelerometer channel 4 | Kistler | 8732A500 | C135085 | 02-02-15 |
| Digital camera | Canon | P50 | - | N/A |

## 4.4 Data collection

Thermocouples were attached to various points on the devices under test using capton tape (Table 4A and Fig 1 appendix A). These thermocouples remained in place throughout thermal step stress and rapid thermal transitions. The product thermal response at each thermocouple location was recorded at each level of thermal stress. Because of the size, sensor tested functionally during the test was placed close to the one with thermocouple.

Accelerometers were placed at reference points next to the product during vibration step stress testing. The product vibration response was recorded at each level of vibration stress. The power spectral density (PSD) plots for the lowest and highest vibration levels are included in Appendix B. All measurements are in $G_{rms}$, and all accelerometers were mounted in the axis stated in the tables. The bandwidth used for all measurements is shown on the plots. The measured bandwidth for the chamber set point was from 0 to 10000Hz using a filter with 6dB per octave roll off starting at 3000Hz.

*Table 4A Data logger channel assignment*

| Channel | ID No. | Location or description |
|---|---|---|
| 1 | 101 | On the sensor plate |
| 2 | 102 | Air near tested sensor |
| 3 | 103 | Aluminum fixturing |
| 4 | 106 | Air in chamber |

*Table 4B OVS Control system thermocouple placement*

| Channel | Placement |
|---|---|
| Product/control | Sensor next to a tested sensor |
| Air | 50 mm below OVS chamber window |
| Eurotherm alarm | 50 mm over OVS chamber window |

*Table 4C Accelerometer placement*

| Channel | Axis | Location |
|---|---|---|
| 1 | z | Sensor |
| 2 | Z | Aluminum fixturing |
| 3 | Y | Chamber's plate |
| 4 | X | Chamber's plate |

### 4.5 Test routine

The device was functionally tested using an artificial "finger". (See Fig. 1, Appendix A).

All functional tests were performed and/or monitored by the customer.

# 5 HALT results

### 5.1 Thermal Step Stress

The test unit was subjected to cold thermal step stress beginning at 20°C, with the temperature decreasing in 10°C decrements (Diagram 1). After the thermocouples located on the unit had stabilized, the unit dwelled at that set point for 10 minutes plus the time for functional testing.

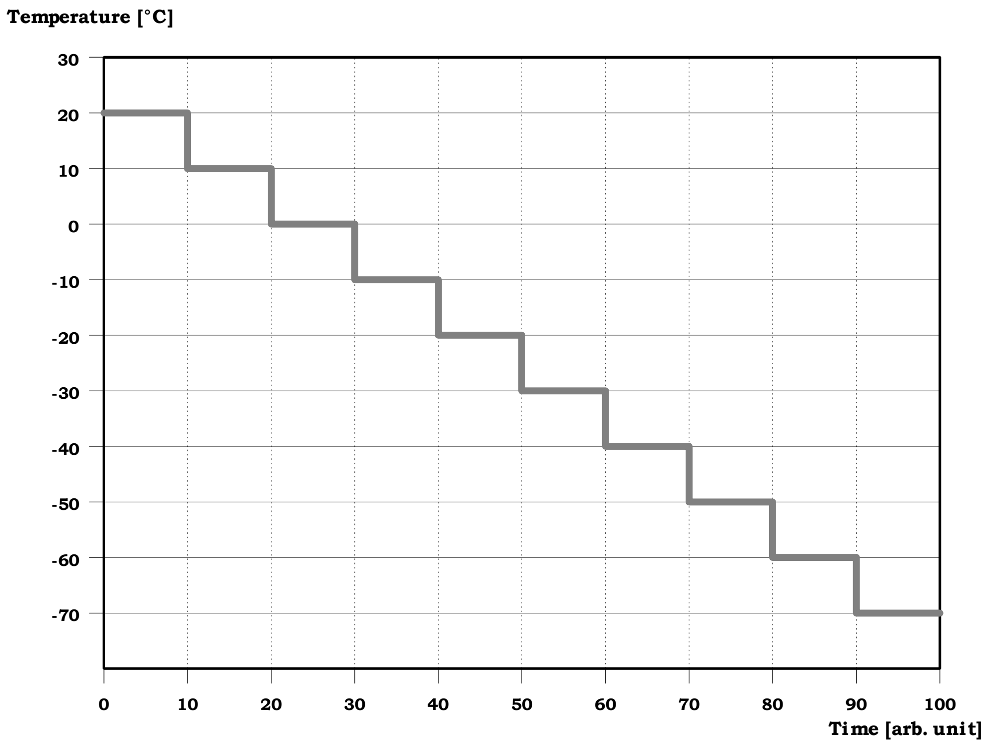



Diagram 1  Cold thermal stress step

When cold thermal step stress was completed, the unit was returned to 20°C and remained there until the thermocouples located on the unit stabilized. Once the unit reached 20°C, it was tested to ensure functionality. Hot thermal step stress began at a set point temperature of 30°C with the temperature increasing in 10°C increments (Diagram 2).

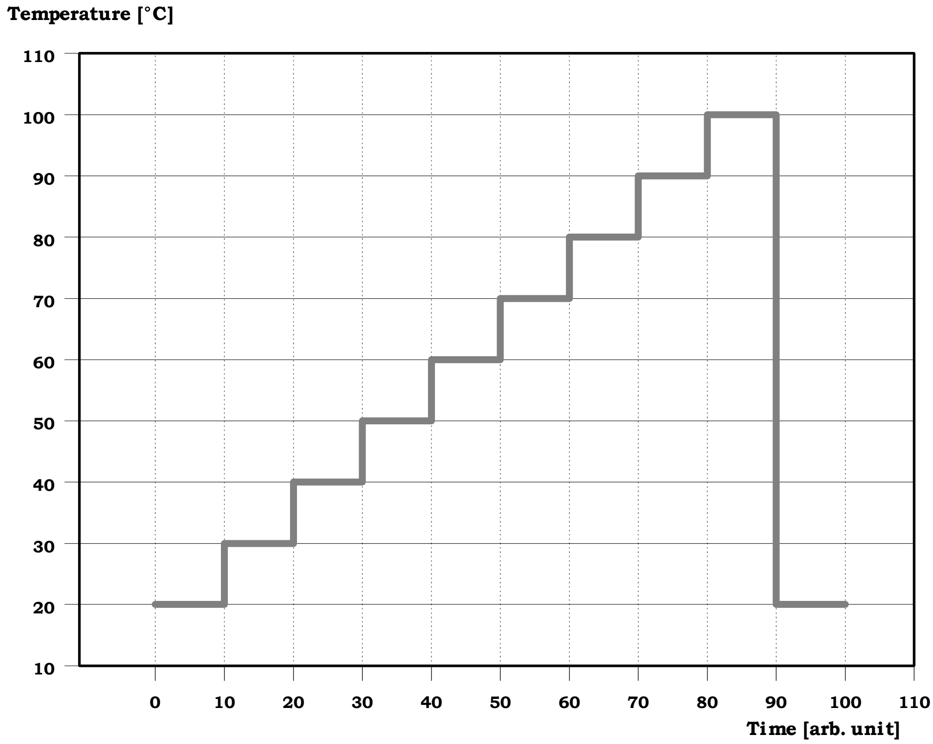



Diagram 2  Hot step thermal stress.

Once the thermocouples located on the unit reached the set point temperature, the unit dwelled at that temperature for 10 minutes. The results of thermal testing are summarized in Table 5.

*Table 5 Thermal step stress results. Set No. 1*

| Set point [°C] | Functional test results | Notes |
|---|---|---|
| 20 | OK | |
| 10 | OK | |
| 0 | OK | |
| -10 | OK | |
| -20 | OK | |
| -30 | OK | |
| -40 | OK | |
| -50 | OK | |
| -60 | OK | |
| -70 | OK | |
| 20 | OK | |
| 30 | OK | 1 |
| 40 | OK | |
| 50 | OK | |
| 60 | OK | |
| 70 | OK | |
| 80 | OK | |
| 90 | OK | |
| 100 | OK | |
| 20 | OK | |
| -80 | OK | 2 |
| -90 | OK | 2 |
| 20 | OK | 3 |

Notes:

1. New rubber artificial "finger" was installed. Allows reading and verification of the data. (See Figure 2, Appendix A)

2. Additional test at extreme low temperature.

3. Final test with real fingerprint test.

Temperatures were recorded at several points as stated in Table 4A on the test unit during testing. The temperatures recorded at each location on each set point during thermal step stress are stored in computer. To view temperatures at all times during testing consult the separate data files:

"Thermal cold step", "Thermal hot step", "Rapid thermal transitions step", "Combined step", "Chamber log file"

## 5.2 Rapid Thermal Transitions

The device under test was subjected to five temperature cycles from –70°C to 85°C at an average thermal transition rate of 60°C per minute. The average thermal transition rate is computed from the average transition of all the product temperature response thermocouples. The rate is computed through the center region of the entire transition, which discounts 20% at each end of the transition. Air temperature limits were set to –90°C and 105°C to prevent excessive overshoot.

*Table 6 Rapid thermal transition results. Set No. 1*

| Cycle | Set point [°C] | Functional test result | Notes |
|---|---|---|---|
| 1 | -70 | OK | 1 |
| 1 | 85 | OK | |
| 2 | -70 | OK | |
| 2 | 85 | OK | |
| 3 | -70 | OK | |
| 3 | 85 | OK | |
| 4 | -70 | OK | |
| 4 | 85 | OK | |
| 5 | -70 | OK | |
| 5 | 85 | OK | |
| - | 20 | OK | 2 |

Notes:

1. The functional tests were done at the end of each extreme.
2. Final test with real fingerprint test.

## 5.3 Vibration Step Stress

The device under test was subjected to vibration step stress beginning at a set point of 8 $G_{rms}$ with the vibration increasing in 5 $G_{rms}$ increments at 10-minute intervals plus the time for functional testing (Diagram 3).

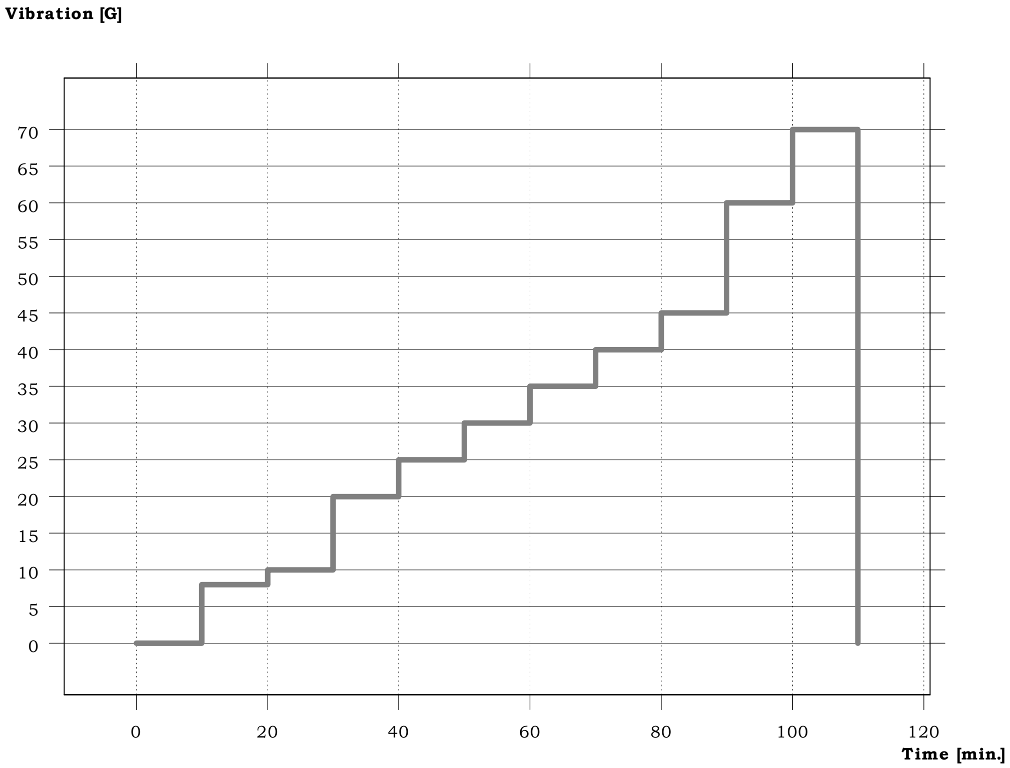



Diagram 3 Vibration step stress test.

The results are summarized in Table 7.

*Table 7 Vibration step stress results. Set No.1*

| **Set point** [$G_{rms}$] | **Functional test results** | **Notes** |
|---|---|---|
| 8 | OK | |
| 10 | OK | |
| 15 | OK | |
| 20 | OK | |
| 25 | OK | |
| 30 | OK | |
| 35 | OK | |
| 40 | OK | |
| 45 | OK | |
| 60 | OK | |
| 70 | OK | 1 |
| 0 | OK | 2 |

Notes:

1. The real measured vibration level was 65 $G_{rms}$.
2. Final test with real fingerprint test at 0 Grms.

Vibration levels in $G_{rms}$, were recorded at several points on the test unit during testing. The measured bandwidth for the chamber set point was from 2 to 3000 Hz using a filter with 6dB per octave roll-off starting at 3000 Hz. The bandwidth for product response measurements was from 2 to 10000 Hz using a digital filter at 10000 Hz. These measurements are summarized in table 8. The power spectral density plots showing the spectral distribution of energy over the measured frequency bands are included in Appendix B for the lowest and highest set point levels (8 $G_{rms}$ and 65 $G_{rms}$).

*Table 8 Vibration levels measured during vibration step stress [$G_{rms}$]*

| **Set point** [$G_{rms}$] | **Channel 1** [$G_{rms}$] **(Z-axis)** | **Channel 2** [$G_{rms}$] **(Z-axis)** | **Channel 3** [$G_{rms}$] **(Y-axis)** | **Channel 4** [$G_{rms}$] **(X-axis)** |
|---|---|---|---|---|
| 8 | 11,6 | 8,9 | 9,3 | 9,7 |
| 10 | 14,6 | 11,4 | 11,6 | 12,3 |
| 15 | 21,6 | 16,4 | 16,8 | 18,9 |
| 20 | 28,9 | 21,9 | 22,3 | 24,7 |
| 25 | 37,3 | 27,6 | 27,1 | 31,4 |
| 30 | 52,1 | 31,6 | 32,2 | 37,5 |
| 35 | 57,7 | 35,8 | 36,1 | 43,2 |
| 40 | 66,6 | 40,7 | 37,9 | 51,8 |
| 45[1] | - | 46,3 | 42,0 | 58,8 |
| 60 | 80,2 | 62,6 | 82,6 | 98,1 |
| 65 | 117 | 66,2 | 98,1 | 103 |

1. Accelerometer connected to channel 1 fell off.

Measurement uncertainty: ±0,1 g @80 Hz

## 5.4 Combined Environment

The test unit was subjected to five temperature cycles from -70°C to 85°C at an average transition rate of 60°C per minute combined with vibration. Vibration began at a set point of 14 $G_{rms}$ and was increased in 14 $G_{rms}$ increments at the end of each thermal cycle (Diagram 4).

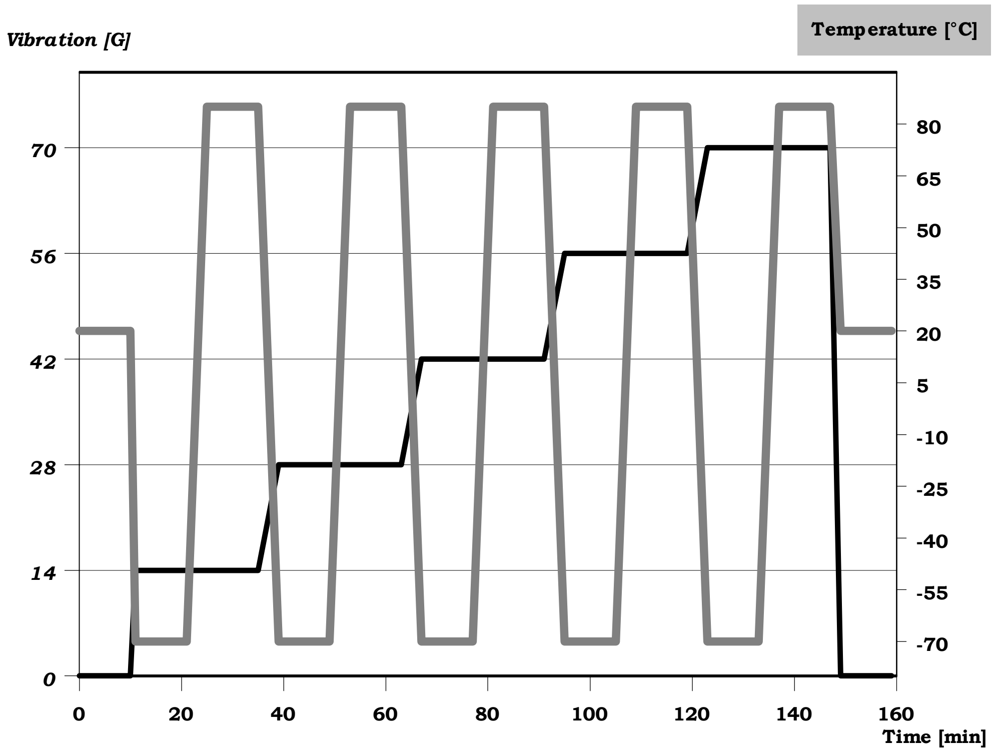



Diagram 4  Combined stress step.

The dwell at each extreme was 10 minutes plus the time for functional testing. The results are shown in Table 9.

*Table 9 Combined environment results. Set No 3*

| Cycle | Temp [°C] | Vibration [$G_{rms}$] | Functional test results | Notes |
|---|---|---|---|---|
| 1 | -70 | 14 | OK | 1 |
| 1 | 85 | 14 | OK | |
| 2 | -70 | 28 | OK | |
| 2 | 85 | 28 | OK | |
| 3 | -70 | 42 | OK | |
| 3 | 85 | 42 | OK | |
| 4 | -70 | 56 | OK | |
| 4 | 85 | 56 | OK | |
| 5 | -70 | 70 | Not done | 2 |
| 5 | 85 | 70 | ND | 3 |

Notes:

1. Functional tests were done at the end of each extreme temperature.
2. The real measured vibration level was 66 $G_{rms}$. Because the artificial "finger" failed, it was unable to do a functional test.
3. After this stress level positive functional test was done at 20°C with sensors No. 3 and 4.

# 6 HALT and HASS

HALT is a margin discovery process. A HALT test will yield the widest possible margin between product capabilities and the environment in which it will operate, thus increasing the products reliability.

The operating and destruct limits discovered during HALT on these units can be used to develop an effective Highly Accelerated Stress Screen (HASS) for manufacturing which will quickly detect any process flaws or new week links without taking significant life out of the product. The HASS process will ensure that the reliability gains achieved through HALT will be maintained in future production.

# Appendix A Photographs

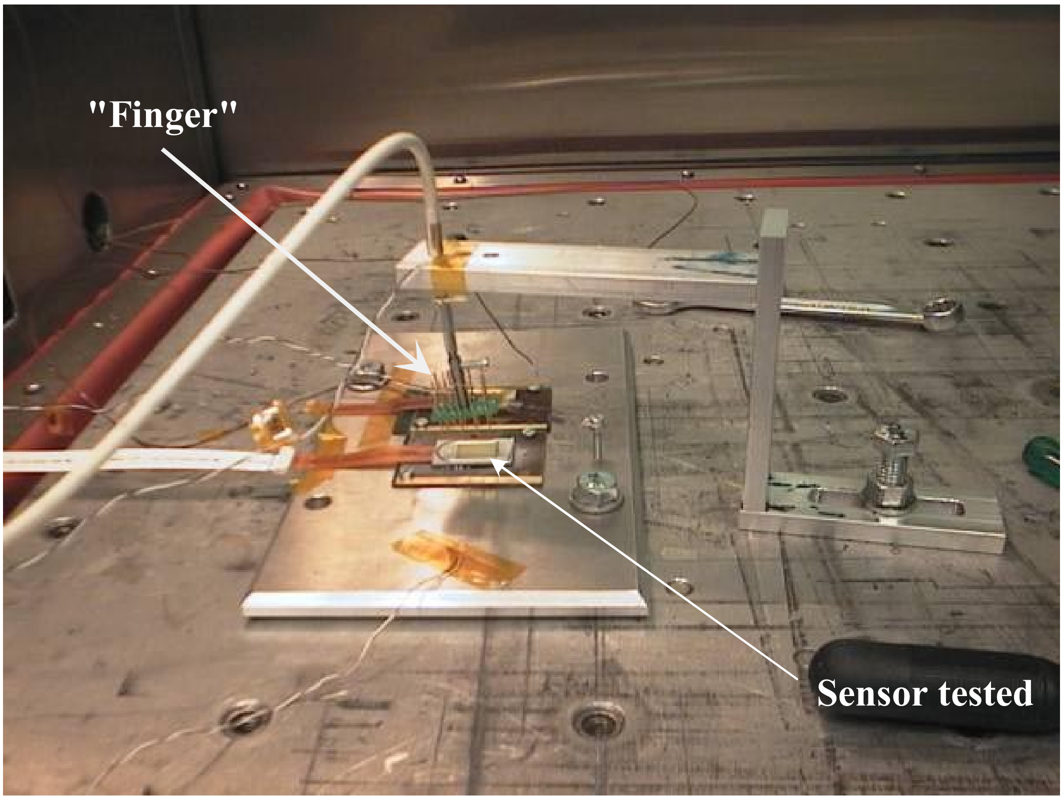



**Figure 1 Fixturing prior to thermal step stress**

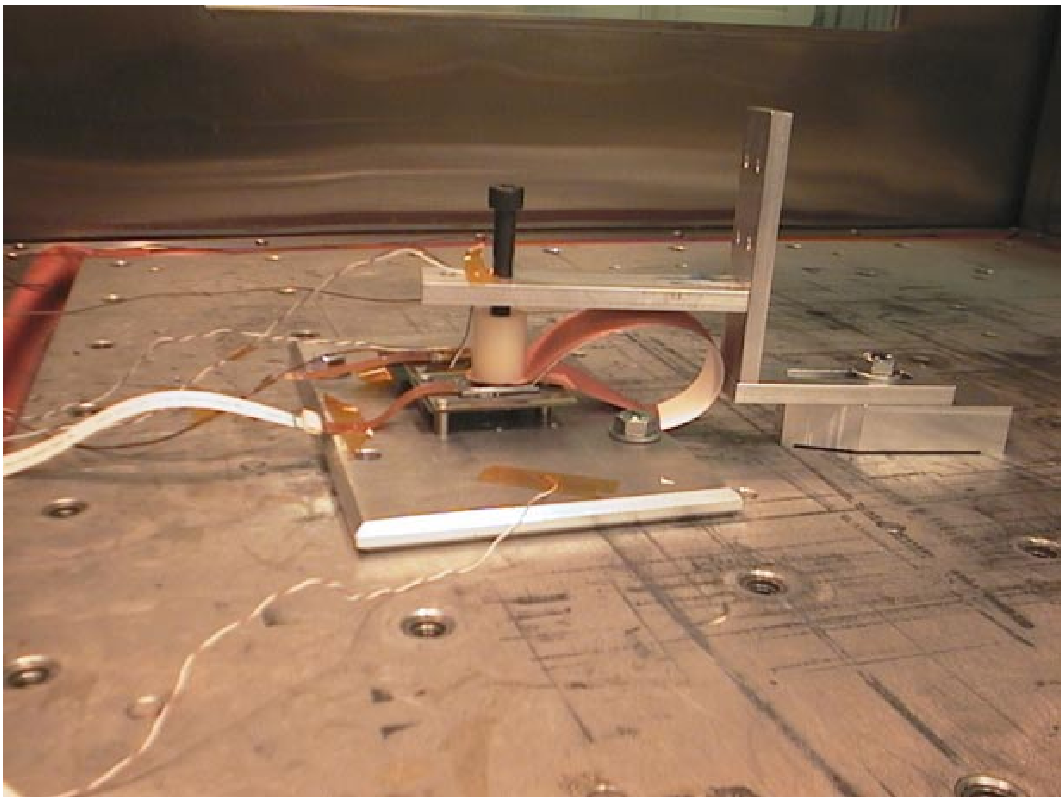
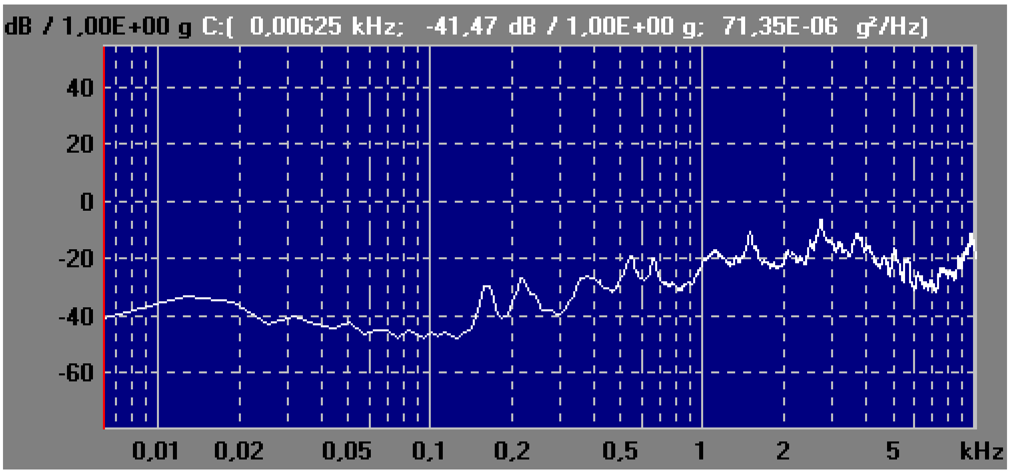


**Figure 2 New rubber "finger" used during the hot step thermal stress**

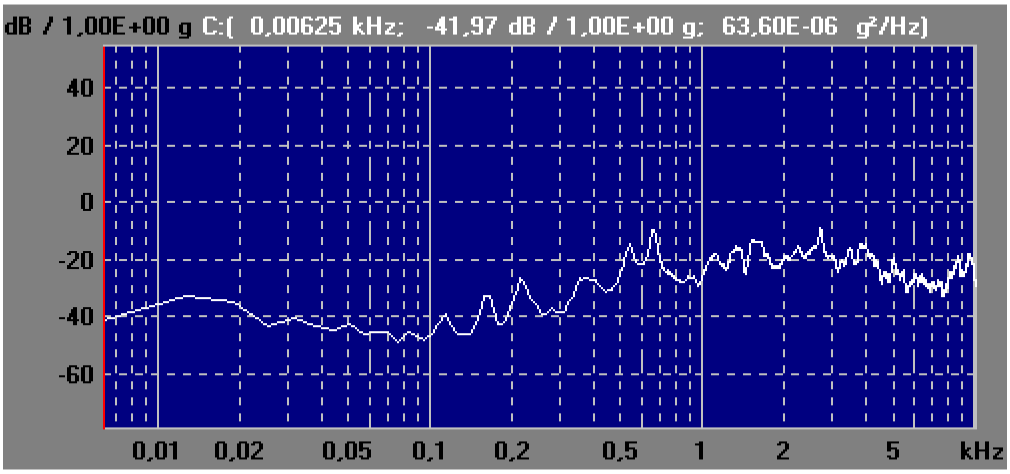
# Appendix B Vibration plots

8 $G_{rms}$ set point

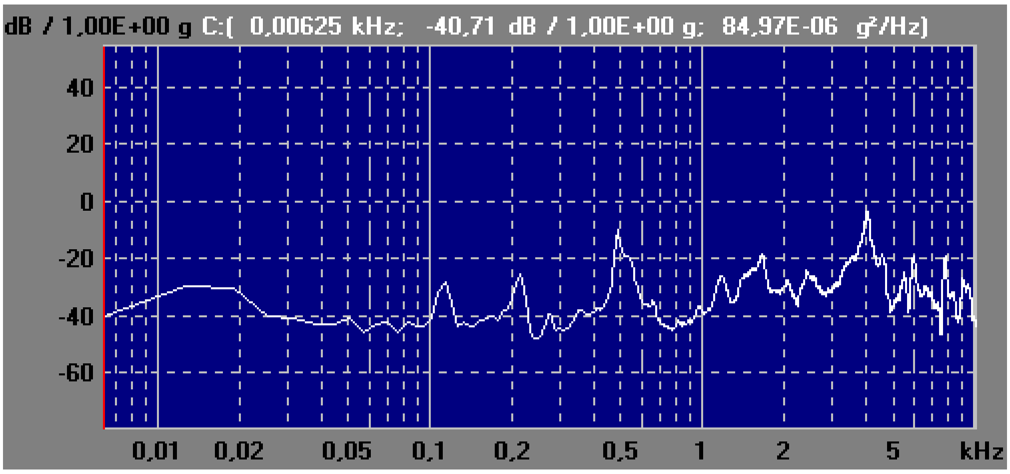
Channel 1:



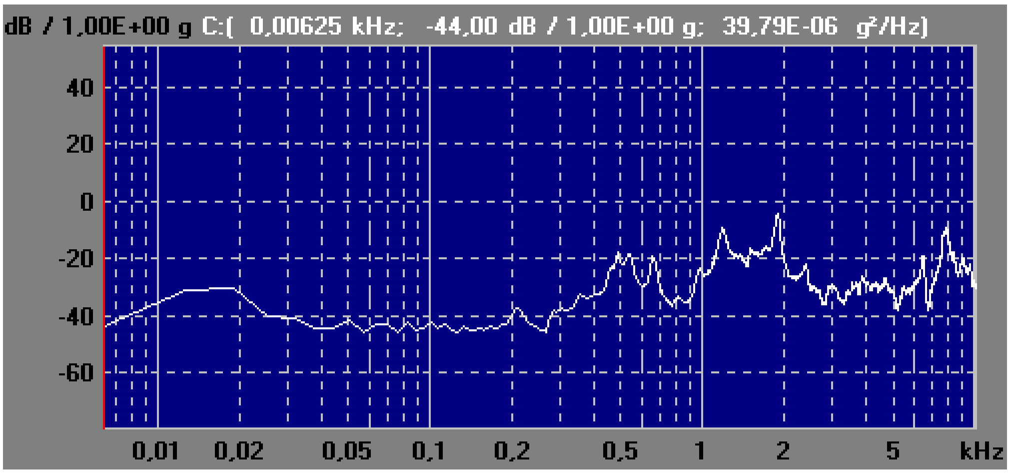

Channel 2:



Channel 3:

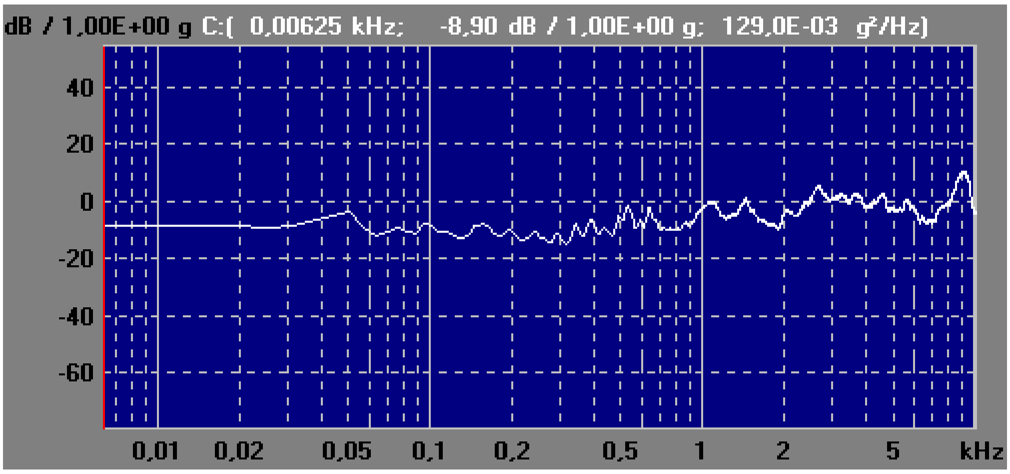



Channel 4:

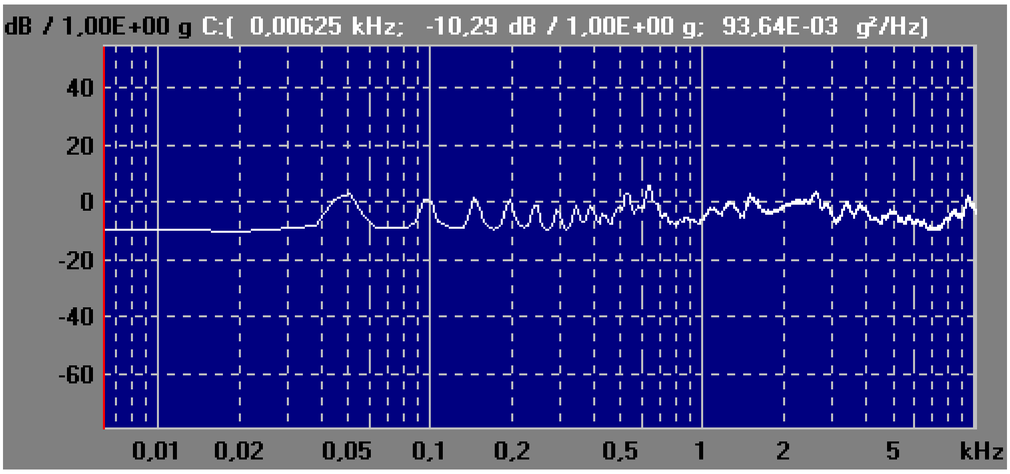


70 $G_{rms}$ set point

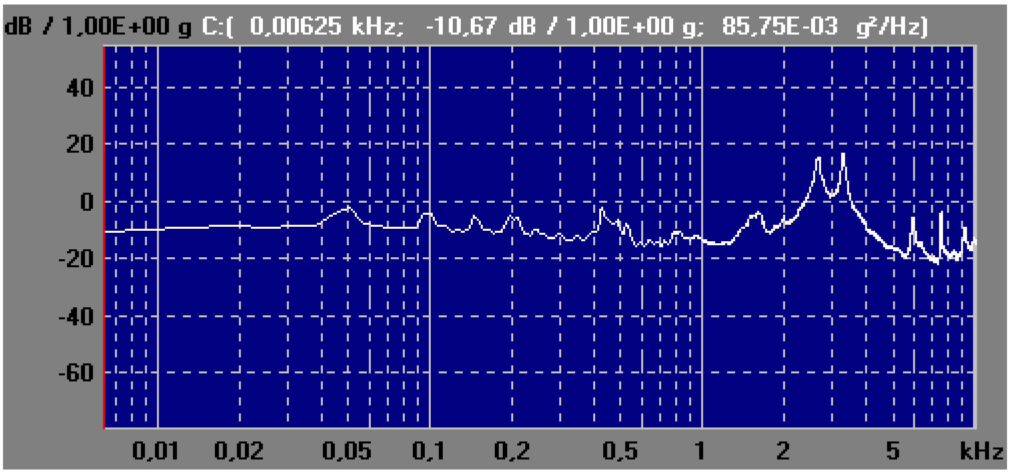
Channel 1:



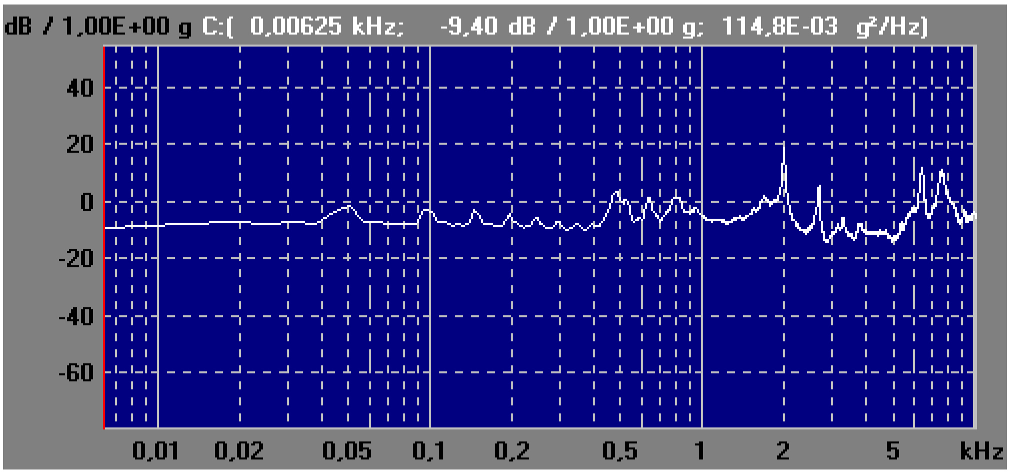

Channel 2:




Channel 3:



Channel 4:


dB / 1,00E+00 g C:( 0,00625 kHz; -9,40 dB / 1,00E+00 g; 114,8E-03 g²/Hz)
40
20
0
-20
-40
-60
0,01
0,02
0,05
0,1
0,2
0,5
1
2
5
kHz