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DELTA Test Report

HALT product development of “Altitrack” altimeter

Performed for Larsen & Brusgaard ApS

Project no.: A506028

1 April 2009

DELTA
Danish Electronics,
Light & Acoustics

Venlighedsvej 4
2970 Hørsholm
Denmark

Tel. (+45) 72 19 40 00
Fax (+45) 72 19 40 01
www.delta.dk

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Title	HALT product development of “Altitrack” altimeter
Project no.	A506028
Test period	23 February - 18 March 2009
Client	Larsen & Brusgaard Ledreborg Allé 28 4000 Roskilde Denmark Tel.: +45 46 48 24 80
Contact person	Mr Mads Larsen E-mail: mads@l-and-b.dk
Test specimens	Two versions of “Altitrack” altimeter were tested: “Military version” and “Civil version”. The following 10 Military versions (prototypes) were tested: P05008, P09308, P07508, P03608, P08408, P09008, P08208, P09108, P07508, P10208. 3 Military versions were modified by the client after the first HALT run (23 and 24 February) and retested in the second HALT run (18 March): P08408, P09108, P09008. The following 9 Civil versions were tested (prototypes numbered by DELTA): 1, 2, 3, 4, 5, 6, 7, 8, 9. Civil version number “5” was modified by the client after the first HALT run (23 and 24 February) and retested in the second HALT run (18 March).
Purpose	In order to further improve the design of the Altitrack Military and Civil altimeters, a HALT (Highly Accelerated Life Testing) sequence, was carried out. HALT is known as a fast and efficient product development tool, using extreme stresses to pinpoint design weaknesses and defects. Used in the early stages of product development, HALT is an effective way to achieve maximum reliability from early stages in the product life cycle. Additionally, two altitude (low pressure) tests and two free fall tests were performed.

Specifications

As agreed with the client, the following HALT sequence was carried out:

First HALT run (23 and 24 February):

- Temperature characterisation to find lower and upper operational and destruct temperature limits (LOTL, LDTL, UOTL, and UDTL).
- Vibration (6-axis random) to find operational vibration level (OVL) and vibration destruct level (VDL).

Second HALT run (18 March), with modified test specimens:

- Vibration (6-axis random) to find operational vibration level (OVL) and vibration destruct level (VDL) for the modified versions of Altitrack.
- Combined exposure with vibration (6-axis random) and temperature variations of the modified versions of Altitrack.

Altitude tests (25 and 26 February):

- For Military version:
  Simulation of a complete 35000 feet (10680 m) jump sequence with test specimen constantly at -50°C.
- For Civil version:
  Simulation of a complete 11780 feet (3590 m) jump sequence with test specimen constantly at -20°C.

Free fall tests (18 March):

- Military and Civil versions:
  Free fall according to IEC 60068-2-32, Test Ec (2008):
  1.5 m on plywood (1 fall on each of 6 faces).
- Military and Civil versions:
  Free fall according to IEC 60068-2-32, Test Ec (2008):
  1.5 m on concrete (1 fall on each of 2 faces), Military & Civil version.

Functional tests and visual inspection

Functional tests were carried out by the client before, during and after all exposures. In general, the test specimens were operational in all tests, running special test software prepared by the client. Two different software versions were used:

- SW version 1.9.9:
  Simulates a “constant jump” with hand (motor) turning.
  On Military versions the OLED indicates altitude.
  Program constantly running.

- SW version 2.9.9:
  Simulates a “15 min. jump” with hand (motor) turning. On Military versions the OLED are always OFF.
  Program needs restart after 15 min.

For further details about the test software, we refer to the client.

Immediate visual inspections during the tests were carried out by DELTA and the client.

Furthermore, all tests were recorded on a video camera by the client.

Detailed visual inspections and modifications of test specimens between tests were carried out by the client.

Results

All testing was attended in part by the client: Mr Niels Brusgaard, Mr Steffen Kristensen and Mr Jacob Nielsen.

The tests were performed as specified.

The summarised results are given below:

First HALT run (23 and 24 February):

- Military and Civil versions stopped operating at -40 °C. According to the client, test SW version 1.9.9, consumed too much battery power for realistic functional testing. Further testing (on 23 February) was therefore omitted. All further testing was carried out with SW version 2.9.9.

- Lower Operational Temperature Limit (LOTL):
  Military version: -70 °C
  Civil version: -70 °C
  (Displays not readable below -30 °C)

- Lower Destruct Temperature Limit (LDTL):
  Military version: Not found
  Civil version: Not found

- Upper Operational Temperature Limit (UOTL):
  Military version: 100 °C
  Civil version: 80 - 100 °C

(Displays not operational above 100 °C)

- Upper Destruct Temperature Limit (UDTL):
  Military version: Not found
  Civil version: Not found

- Operational Vibration Level (OVL):
  Military version: 30 - 50 grms
  Civil version: 50 grms

- Vibration Destruct Level (VDL):
  Military version: 30 to 50 grms
  Civil version: 50 grms

Design weaknesses found during first HALT run:

- Two capacitors fall off PCB.
- Motor (for hand) suspension breaks.
- Fretting of battery contacts.
- Battery moves (rotates) in battery compartment.
- See Annex 2 for note from Client

Second HALT run (18 March), with modified test specimens:

- Operational Vibration Level (OVL):
  Military version: 50 grms
  Civil version: 50 grms

- Vibration Destruct Level (VDL):
  Military version: 50 grms (at -60 - 90 °C)
  Civil version: 50 grms (at -60 - 90 °C)

Design weaknesses found during second HALT run:

- Capacitors fall off PCB.
- Fretting of battery contacts.
- Battery moves (rotates) in battery compartment.
- Refer to client for further information.

Altitude tests (25 and 26 February):

- Military version:
  The 35000 feet (10680 m) jump sequence at -50 °C, was passed without errors. According to the client the correct pressure profile was logged in the test specimens.

- Civil version:
  The 11780 feet (3590 m) jump sequence at -20 °C, was passed without errors. According to the client the correct pressure profile was logged in the test specimens.

Free fall tests (18 March):

- Military and civil versions:
  Free fall, 1.5 m on plywood (1 fall on each of 6 faces) was passed without damages or deteriorations.

- Military version:
  The free fall from 1.5 m on concrete damaged (cracked) the LCD of the test specimen. Test specimen remained operational.

- Civil version:
  The free fall from 1.5 m on concrete resulted in opening of the battery cover. Further, the test specimen opened along its edges ("unclicked"). Test specimen remained operational.

The tests and results are further documented on the following pages with photos and curves generally in the sequence of testing.

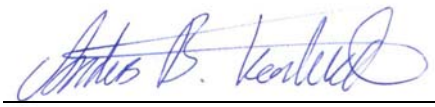
Results of any more detailed visual inspections and functional tests are separately reported at the responsibility of the client.

The test results apply to the tested specimens only.

Test personnel

Poul Terkelsen
Andreas H. Olsen
Anders B. Kentved
Kim A. Schmidt

Date 1 April 2009

Responsible 

Anders B. Kentved, B.Sc.E.E.
DELTA

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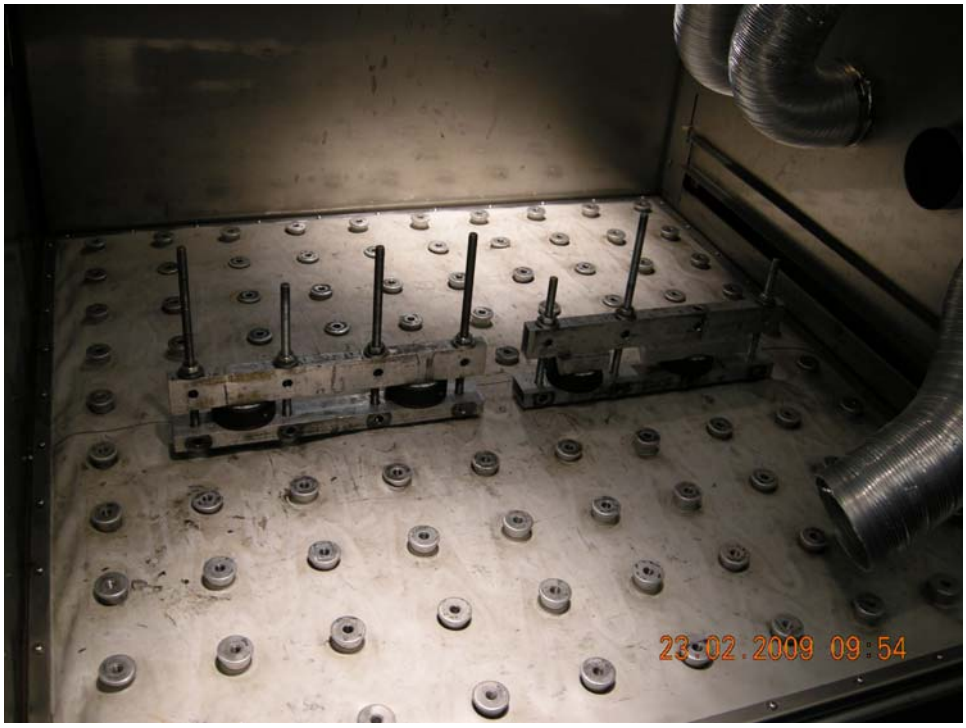
1. Detailed results and photos

1.1 First HALT run (23 and 24 February)

1.1.1 Cold (23 February)

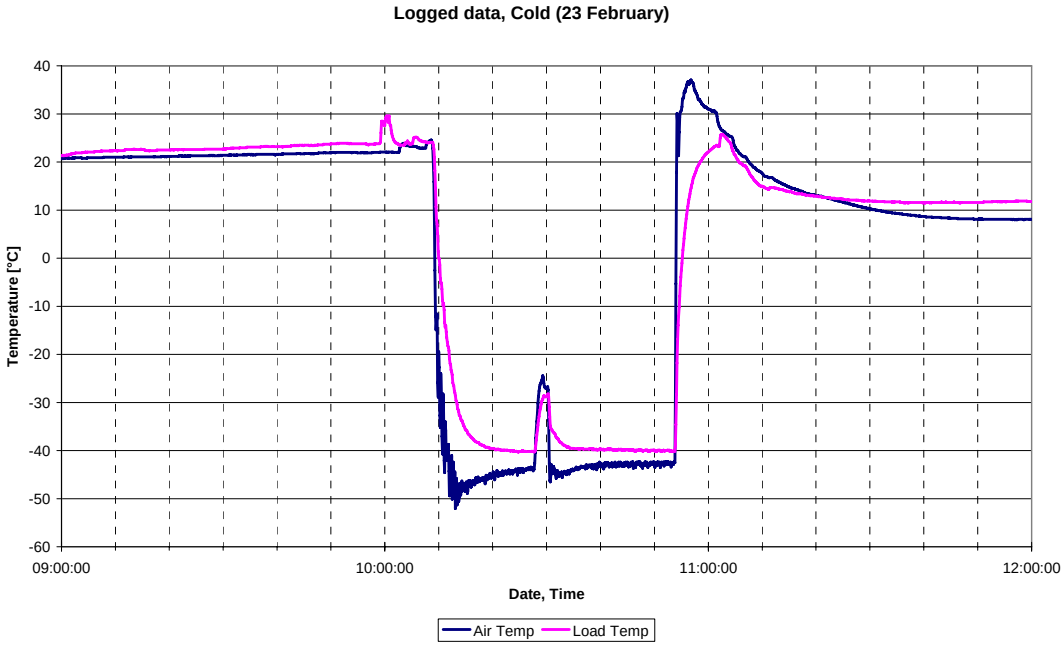
Military versions tested: P05008, P09308
Civil versions tested: 1, 2
Test SW version: 1.9.9



Test specimens in HALT chamber during cold.

NOTE: This fixture was only used on 23 February.

The test specimens were exposed to Cold as shown below.



Observations

At -40 °C the following was observed:

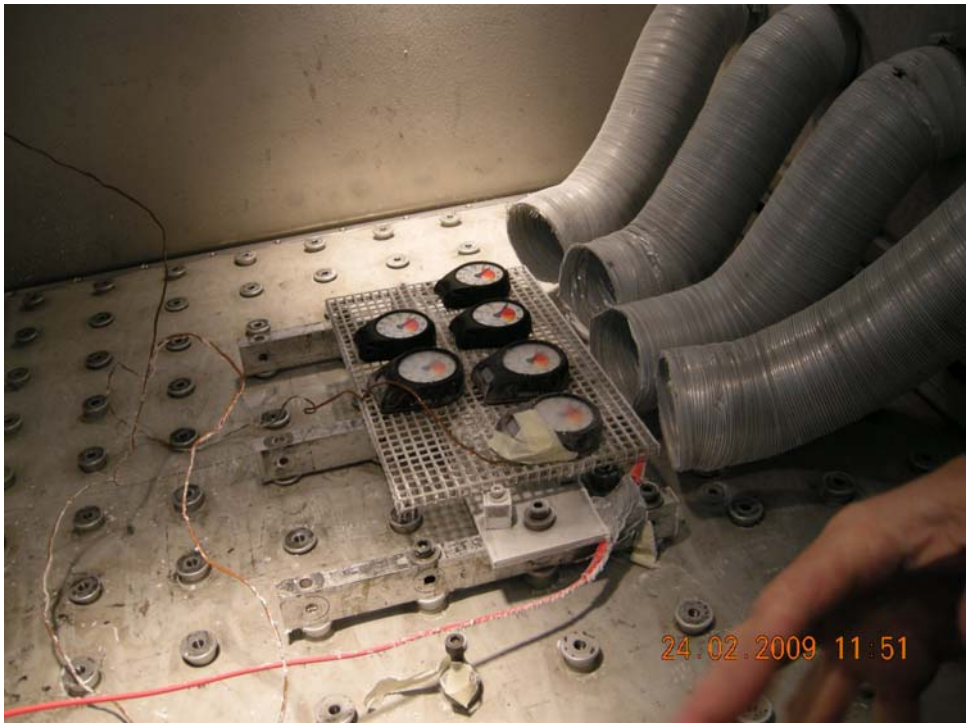
- Military versions, OLEDs were weak and then stopped along with the test specimen.
- Military and Civil versions stopped operating.
- On Military versions the light intensity of the OLEDs were significantly decreased.

Test were stopped and new test software in the test specimen were created

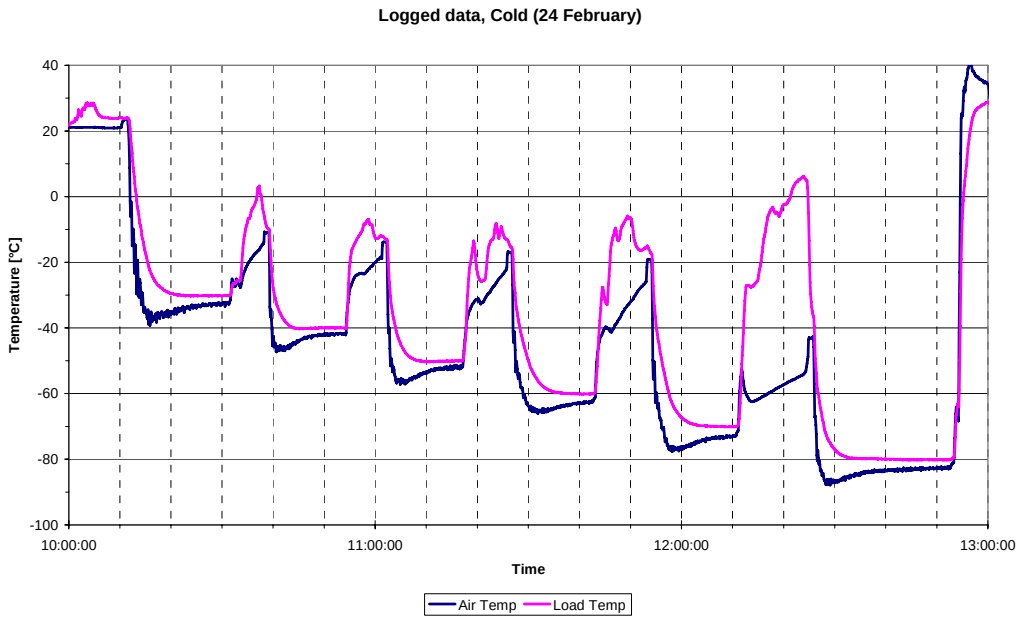
1.1.2 Cold (24 February)

Military versions tested: P09308, P07508, (P03608 from -50 °C and below)
Civil versions tested: 2, 3, (4 from -50 °C and below)
Test SW version: 2.9.9

The test specimens in HALT chamber during cold is shown below.



The test specimens were exposed to Cold as shown below.



Observations

- On Military and Civil versions, the display on the backside were not readable at low temperature (from -30 °C and down), but did resume operation after a short while at ambient conditions.

- At -70 °C:

    - P03608, hand showing the altitude, stopped in the middle of the functional test on test specimen. The LEDs were blinking after the 15 minutes test jump. Test specimen could be reset.

    - P07508, hand showing the altitude stopped in the middle of the functional check on test specimen. The LEDs were blinking after the 15 minutes test jump. Test specimen could NOT be reset - the motor turned the hand, but the hand could not find the zero position.

    - Civil 3, hand showing the altitude stopped in the middle of the functional check on test specimen. The LEDs were blinking after the 15 minutes test jump. Test specimen could be reset.

- At -80 °C:

    - Civil 2 completed the test jump.

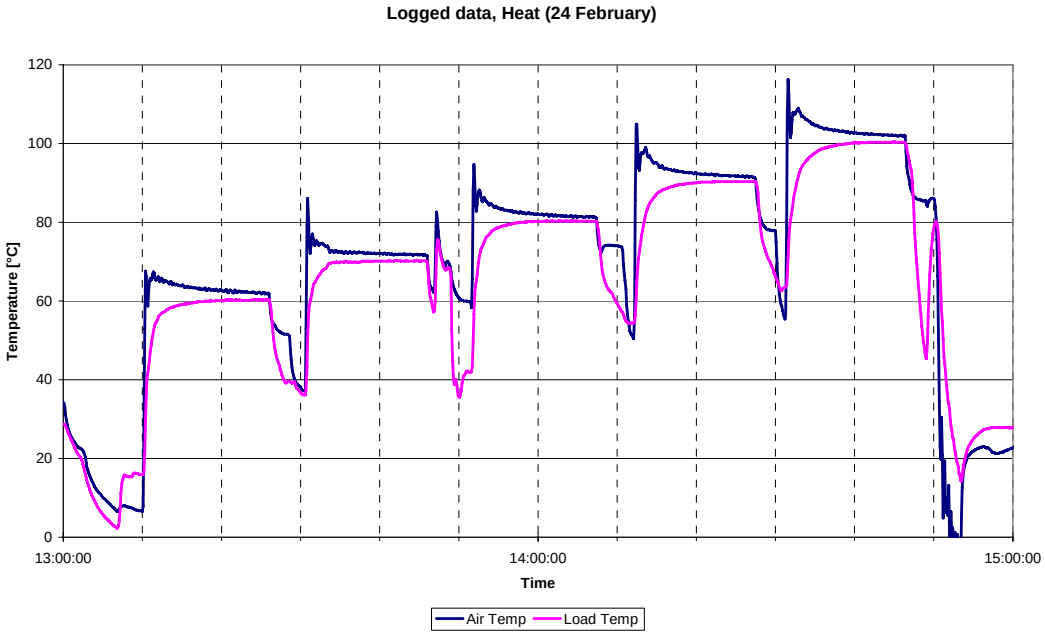
    - Civil 3 & 4 and MIL P03608 & P07508 & P09308) the hands stopped at wrong positions but the LEDs were blinking indicating that the test jump had finished (see photo below).

At ambient temperature a new test jump were run on the test specimens. All completed the jump satisfactory.

1.1.3 Heat (24 February)

Military versions tested: P05008, P08408
Civil versions tested: 1, 5
Test SW version: 2.9.9

The test specimens were exposed to Heat as shown below.



Observations

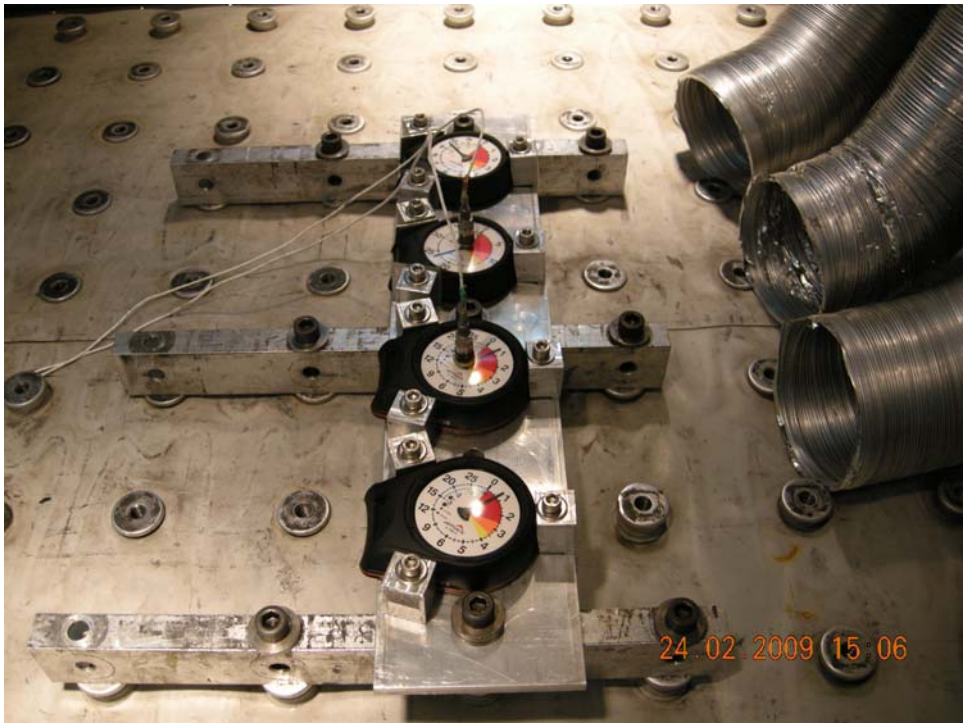
- At 80 °C:
  - Civil 5, the hand stopped at incorrect position. Civil 5 could be reset.
- At 90 °C:
  - Civil 5, the hand stopped at incorrect position. Civil 5 could be reset. Civil 5 was removed from the test.
- At 100°C:
  - Civil 1, the display on the backside stopped working.
  - P08408, display on backside stopped working. The test specimen reset spontaneously during the exposure, and the LEDs were not blinking after the test jump.
  - P05008, the display on the backside stopped working, the hand was stopped in an incorrect position and the LEDs were not blinking after the test jump.

At ambient after the test, it was possible to reset all three test specimens which also completed a test jump at ambient temperature.

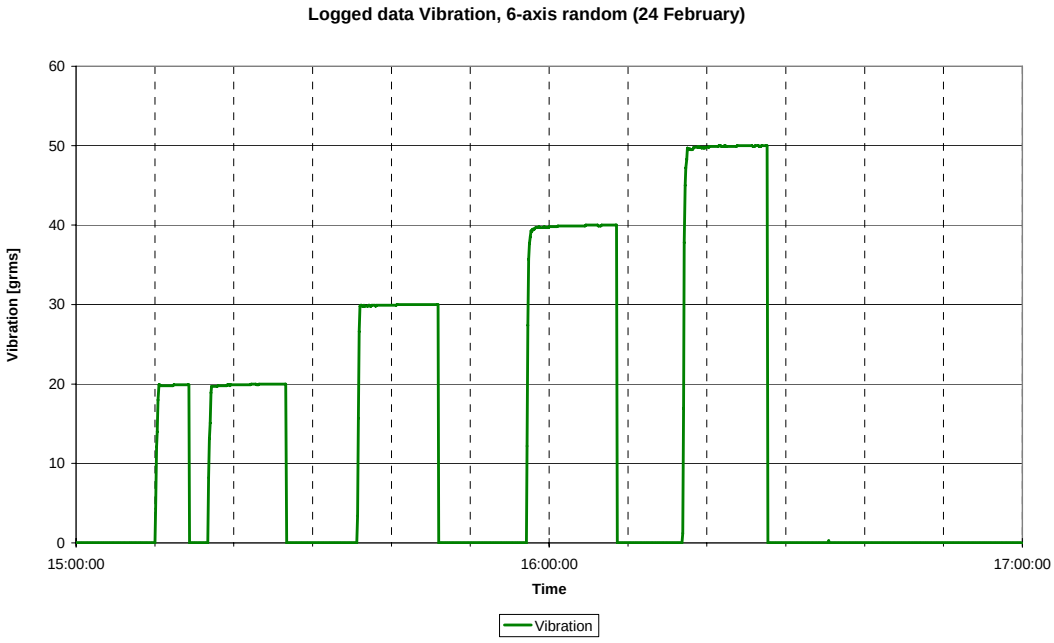
1.1.4 Vibration, 6-axis random (24 February)

Military versions tested: P09008, P08208, (P09108)
Civil versions tested: 6, 7
Test SW version: 2.9.9

The test specimens were placed in a fixture created by the client. See below.



The test specimens were exposed to 6-axis random vibration as shown below, the exposure were performed at room temperature.



Observations

- At 30 grms
    - P08208, Rattling sound came from the test specimen when shaking it. The test specimen was replaced with P09108.
- At 50 grms, (Vibration on for 10 minutes, then stopped for finishing 15 min test jump)
    - P09008, The hand was moving throughout the exposure but in a wrong way (according to the client). After the 15 minutes the P09008 stopped correctly
    - P09108, the hand stopped moving during vibration. After vibration the hand started moving again but stopped at an incorrect position. LEDs started blinking after 15 minutes. The display on the backside was blinking.
    - Civil 6, the hand stopped moving during vibration. After vibration the LEDs started blinking. Could not be reset.
    - Civil 7, the hand stopped moving during vibration. After vibration the LEDs started blinking. Could not be reset.

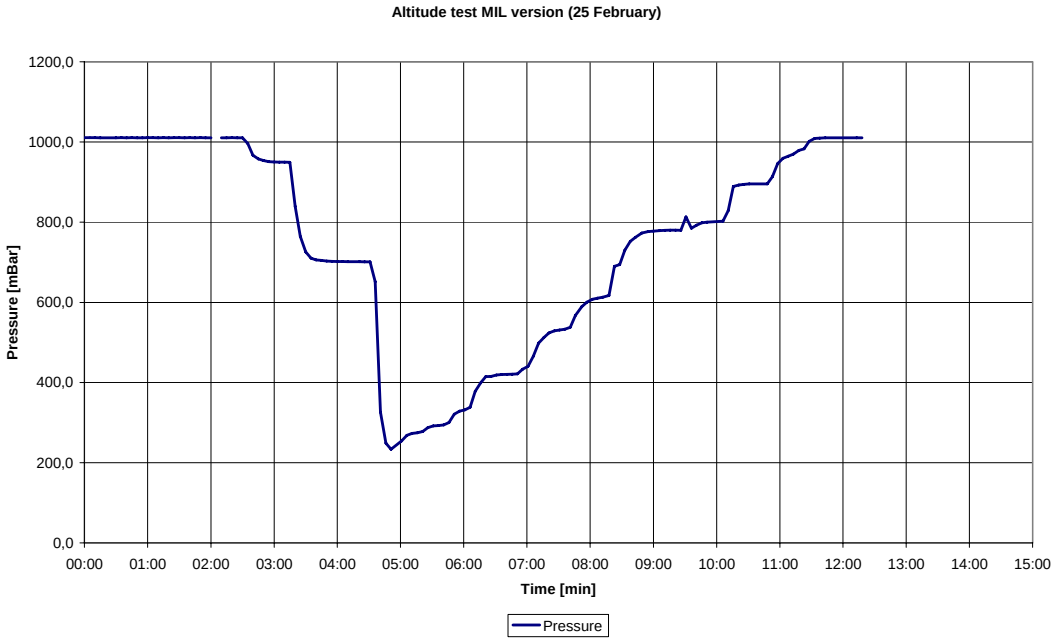
1.2 Altitude test (25 and 26 February)

1.2.1 Altitude test Military Versions

Military versions tested: P07508, P10208
Test SW version: X.X.X
The temperature was lowered until the surface of the vacuum chamber was -55 °C. The temperature on the surface of the test specimens was -51.2 °C

Photo of the vacuum chamber inside the HALT chamber is seen below.

When the test specimens were cooled down, the test specimens were exposed to low pressure as shown below.



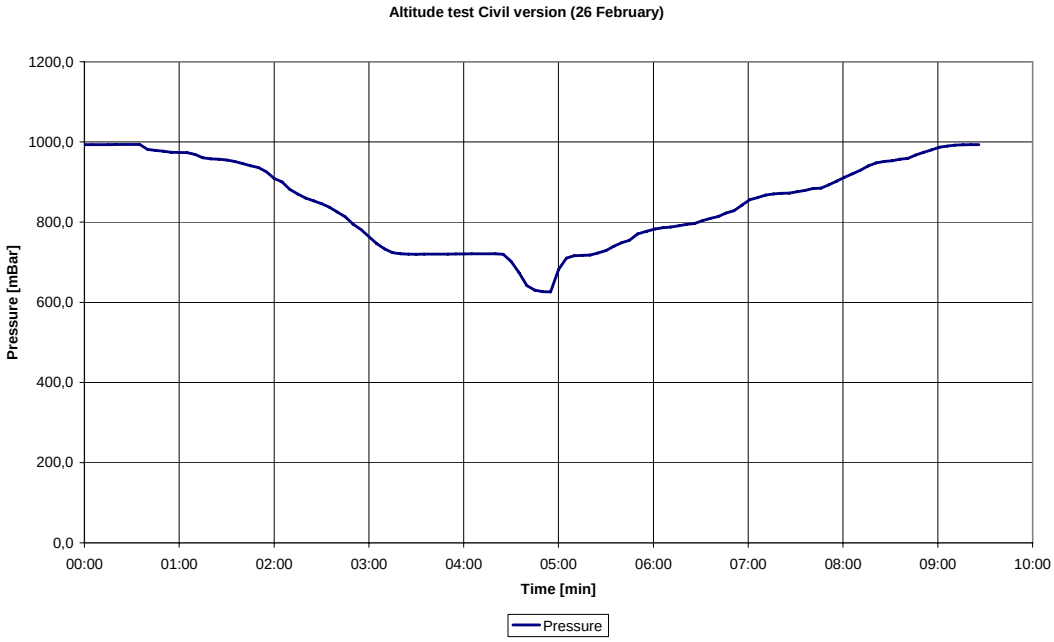
Observation

The 35000 feet (10680 m) jump sequence at -50 °C, was passed without errors. According to the client the correct pressure profile was logged in the test specimens.

1.2.2 Altitude test Civil Versions

Civil versions tested: 1, 8
Test SW version: X.X.X
The temperature was lowered until the surface of the vacuum chamber was -22° C. The temperature on the surface of the test specimens was -19 °C

When the test specimens were cooled down, the test specimens were exposed to low pressure as shown below.



Observations

The 11780 feet (3590 m) jump sequence at -20 °C, was passed without errors. According to the client the correct pressure profile was logged in the test specimens.

1.3 Modifications

Weaknesses found in the first run are described in a note from the client. The note is included in Annex 2. According to the client the following modifications have been implemented in test specimens used for the second HALT run (see also Annex 3).

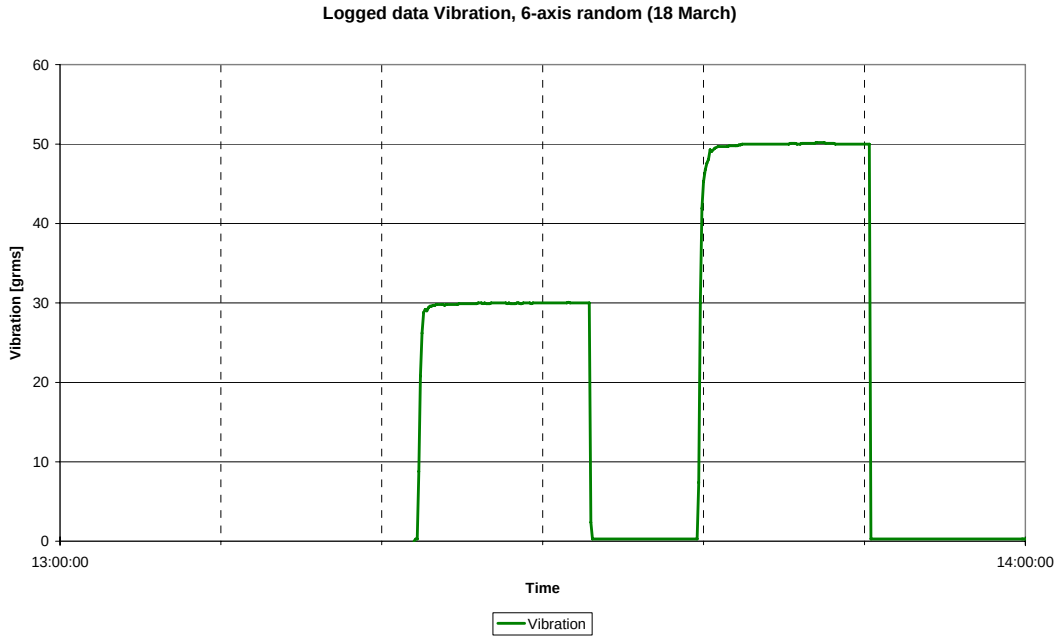
- Military version no. P08408
    - Motor fixated with two plastic pellets
    - Battery fixated with self adhesive foam.
    - Capacitor fixated with Loctite
- Military version no. P09108
    - Motor fixated with plastic pins through the PCB
    - Battery fixated with self adhesive foam
    - Capacitor NOT fixated
    - Test specimen is not operational.
- Military version no. P09008
    - Motor fixated with self cutting screws through PCB
    - Battery fixated with self adhesive foam
    - Capacitor NOT fixated.
    - Test specimen is not operational
- Civil version no. 5
    - Motor fixated with self cutting screws through PCB
    - Battery NOT fixated
    - Capacitor fixated with Loctite

1.4 Second HALT run (18 March)

1.4.1 Vibration, 6-axis random (18 March)

Military versions tested: P09008, P08408, P09108
Civil versions tested: 5
Test SW version: x.x.x

The test specimens were exposed to 6-axis random vibration as shown below, the exposure were performed at room temperature.



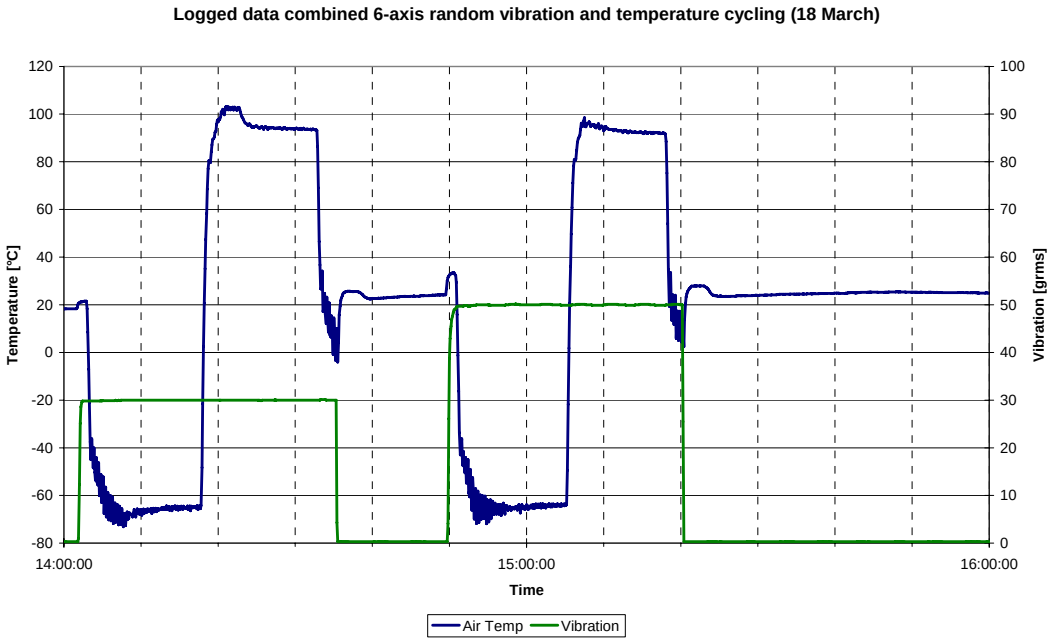
Observations

- At 30 grms
    - P09108, Rattling sound came from the test specimen when shaking it (capacitor was NOT fixated in this test specimen).

1.4.2 Combined vibration, 6-axis random and temperature cycling (18 March)

Military versions tested: P09008, P08408, P09108
Civil versions tested: 5.
Test SW version: 2.9.9

The test specimens were exposed to 6-axis random vibration and temperature cycling as shown below.



Observations

- At 30 grms
  - P08408, stopped turning hand. At visual after exposure fretting on the battery contacts was observed. A new battery was inserted and the test specimen was OK.
  - Civil 5, stopped turning hand. At visual after exposure fretting on the battery contacts was observed. The fretting residues on the battery were scraped off with a scalpel, the battery was inserted and the test specimen was OK.
- At 50 grms
  - P08408, hand was moving at random during the vibration. After the exposure battery fretting is seen. With a new battery the test specimen is slow to reset and cannot find zero.
  - P09108, at a visual inspection after the exposure the test specimen is rattling (capacitor was not fixated in this test specimen).

- P09008, at a visual inspection after the exposure the test specimen is rattling. (Capacitor was not fixated in this test specimen)

- Civil 5, At a visual after the exposure the test specimen is rattling and not working. The battery spring was broken.

1.5 Free fall tests (18 March)

Military versions tested: P08208 (tested without wrist mount)
Civil versions tested: 9 (tested without wrist mount, but with flat rubber edge)
Test SW version: x.x.x

The test specimens were exposed to Free fall as shown below.

- Both versions Free fall, 1.5 m on plywood (1 fall on each of 6 faces).
    - No damages or deteriorations observed.
- Military version, Free fall 1.5 m on concrete in carry bag (1 fall on top and bottom).
    - No damages or deteriorations observed.
- Both versions Free fall, 1.5 m on concrete (1 fall on bottom and top).
    - P08208, LCD screen cracked - Function OK.
    - Civil 9, Battery cover opened. Unit opened (clicks unclicked) - Function OK

Annex 1

DELTA test facilities

DELTA test facilities

USE	REF.	INSTRUMENT	MANUFACTURER	TYPE
	EVFGT-42	HALT CHAMBER	THERMOTRON	AST-35
		PRESSURE GAUGE	WENZEL	
		VACUUM PUMP		
		FREE FALL SIMULATOR	DELTA	

Annex 2

DELTA HALT test (from Client)

1

DELTA HALT TEST

Der er fundet 4 ting der skal forbedres efter HALT test hos Delta.

1. Motorfiksering
2. Batterifiksering
3. Batterifjeder forbedring
4. Kondensatorlimning

1. Motorfiksering:

Motoren klipper sine egne ben over ved vedvarende g påvirkning, enten ryst eller drop, når den ikke er fikseret ved andet end lodning.

Der gøres følgende tiltag mht. at fiksere motoren:

1. stag tilføjes i støbeværktøj for at fiksere motor fra oven

2. Motoren skrues fra bunden gennem print og bliver fikseret.

De 2 ovennævnte tiltag er gjort og fundet gode ved ryste og drop test.

Batterifiksering:

Batteriets horisontale bevægelse i batteriholderen er for stor og batterifjederen knækker eller bliver slap.

Der gøres følgende tiltag for at fiksere batteriet:

1. 2 små vægge tilføjes i støbeværktøjet for at forhindre batteriets horisontale bevægelse

Batterifjeder forbedring:

Batterifjederen kan knække ved ryst eller drop.

Der gøres følgende tiltag for at forbedre batterifjederen:

1. Batterifjederen skal laves i berylliumkobber.

Dette vil forbedre fjederevnen og også forbedre holdeevnen på batteriet. Til start vil fjederen blive produceret i samme dimensioner som i dag.

2

Kondensatorlimning:

De 2 store 470µF kondensatorer falder af når de kun er fikseret ved lodning.

Der gøres følgende tiltag for at forhindre dette:

1. Kondensatorene limes hos printbestykningsfirmaet.

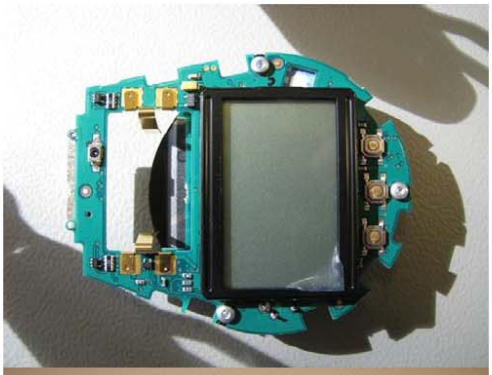
Ved test hos Delta, hvor kondensatorerne var limet, opnåede vi at kondensatorerne kunne klare både ryste og droptest.

Billededokumentation:

På side 3,4,5 og 6 er der billeder til illustration.

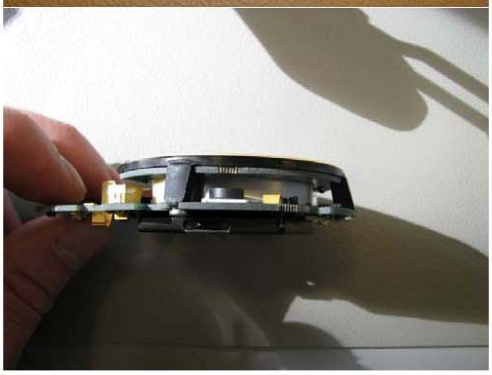
3

GENERELLE BILLEDER



Bagside

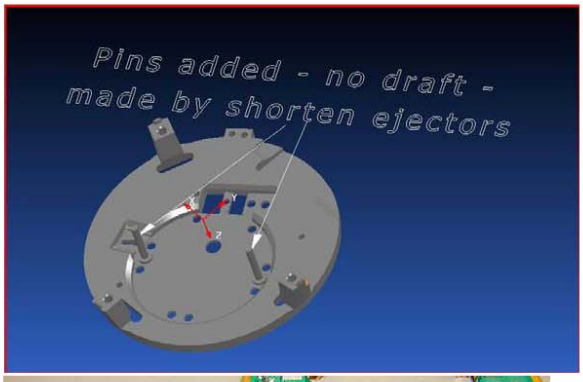
Skilt ad, indvendigt



Side

4

MOTORFIKSERING

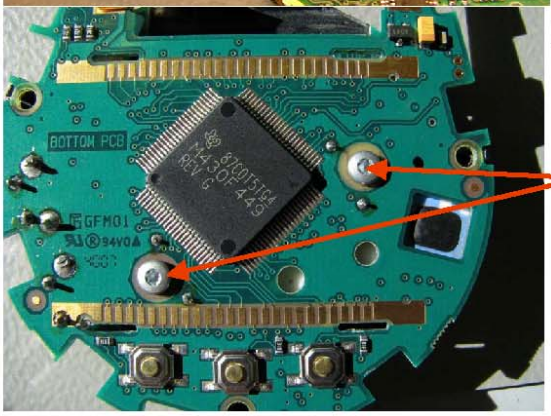


1

2 fikseringspinde tilføjet i værktøjet til at fiksere motoren

2

Motoren klipper sine egne ben over når den ikke er fikseret. Efter test hos Delta er det blevet besluttet at ændre støbeværktøj og skrue motoren fast med selvskærende skruer



3

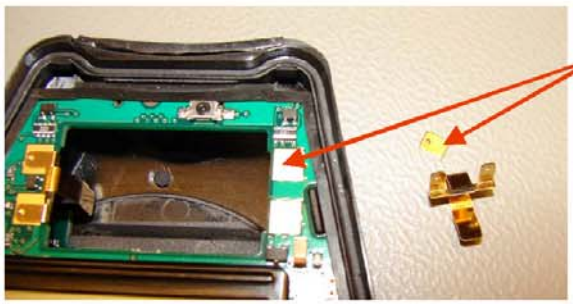
Skruer til at fiksere motoren

5

BATTERIHOLDER OG BATTERIFJEDER

2 vægge tilføjet i værktøjet til batteriholder for at forhindre horisontal bevægelse af batteri

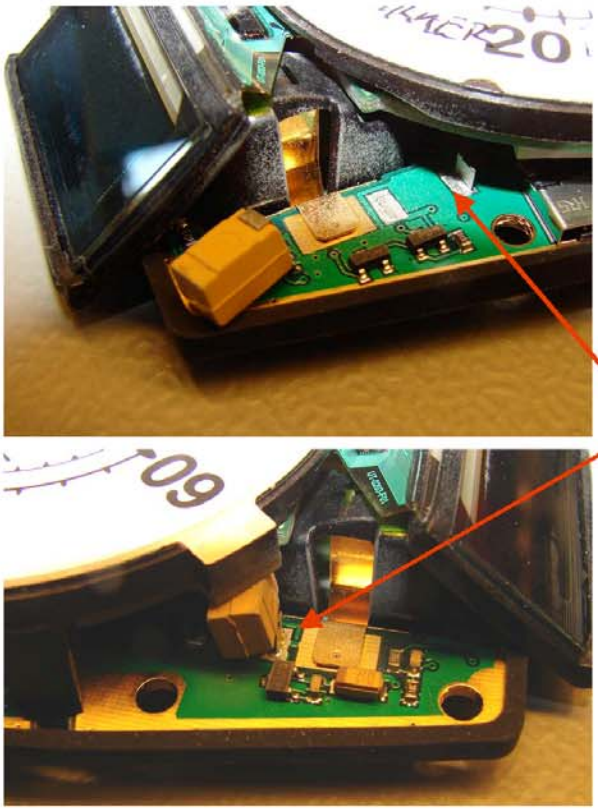
Batteriets horisontale bevægelse ved 30G og opefter gør at det lille stykke synlige print gnaver i batteriet.



Batterifjederen knækker under stress pga. den horisontale bevægelse. Det er besluttet at få fjederen i berylliumkobber

6

KONDENSATORLIMNING



De 2 store kondensatorer bliver rystet løs og skal limes Printbestykningsfirmaet er blevet kontaktet.

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Annex 3

Test hos DELTA 18-03-2009 (from Client)

Test hos DELTA 18-03-2009

1. NO. P08408
   Motor fixeret med 2 stk. Plast brikker.
   Batteri fixeret med selvklæb-skum
   Kondensatorer fixeret med cyanolim (Loctite super attak)

2. NO. Plast 5
   Motor fixeret med 2 selskærende skruer igennem print.
   Batteri ikke fixeret
   Kondensatorer fixeret med cyanolim

3. NO. P09108
   Motor fixeret med plaststifter igennem print.
   Batteri fixeret med selvklæb-skum
   Kondensatorer ikke fixeret
   Denne måler virker ikke.

4. NO. P09008
   Motor fixeret med selvskærende skruer igennem print.
   Batteri fixeret med selvklæb-skum
   Kondensatorer ikke fixeret
   Denne måler virker ikke.

Reserve: NO. P08208
Motor fixeret med 2 stk. Plast brikker.
Batteri fixeret med selvklæb-skum
Kondensatorer fixeret med cyanolim (Loctite super attak)