Environmental Stress:

Operating Absolute Laser Trackers in magnetic field environment

AT500, B-Probe\textsuperscript{plus} & ATS600

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Agenda

• Environmental Stress Tests
  • Norms
  • Scope
  • Special Tests

• Mechanical and Temperature Stress
  • Summary AT500 / AS1K

• Electromagnetic Compliance (EMC)
  • Summary AT500 / AS1K

• Magnetic Field Tests
  • Setup
  • Results
    • AT500
    • B-Probe plus
    • ATS600
Environmental Stress Tests

• Standard Tests to fulfil norms & internal expectations
  • ISO / (DIN ISO) / IEC / EN / CISPR / ASTM / …
  • Mechanical stress
  • Temperature stress
  • Electromagnetic compliance (EMC)

• Special Tests
  • Magnetic field tests
# Mechanical Stress

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Specification/Details</th>
</tr>
</thead>
</table>
| **Bump in transportation case**                       | [ISO 9022-31-05-1](https://example.com)  
25g; 6ms; ± 3 x 1000 at T_ambient                      |
| **Vibration in transportation case**                  | [ISO 9022-36-03-0](https://example.com)  
10-150Hz; 2g; ±0.15mm; 20 cycles at T_ambient           |
| **Drop in transportation case**                       | 0.75m; (internal specification) at T_ambient                                          |
| **Drop without case (if applicable)**                 | For hand-held devices:  
1.2m or 0.8 m loop handle; (internal specification) at T_ambient                     |
| **Handling shocks**                                  | Typical use cases (internal specification) at T_ambient                                |
| **IP 5x/ x4**                                         | Exposure to dust (sand) & water  
IEC 60529 / EN60529: 1989  
| **Paints and varnishes**                              | [ISO 2409](https://example.com)  
Cross-cut test and Abrasion                           |
| **Sound emission**                                   | Machinery 2006/42/EC 1.7.4.2 (u);  
SN EN ISO 11202                                         |
Example: Drop in Transportation Case AT500

Drop on all 6 faces of transportation case from 0.75m onto wooden plate on concrete floor
Example: Drop in Transportation Case AT500

Accuracy assessment

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Axes Check</td>
<td>61%</td>
<td>221%</td>
<td>73%</td>
</tr>
<tr>
<td>ADM Offset Check</td>
<td>27%</td>
<td>45%</td>
<td></td>
</tr>
</tbody>
</table>

Visual Assessment

- Aperture cover came off during
- Battery chargers moved slightly, but did not fall out
- Wear marks on ABS plate
- Wear marks on top of alidade, caused by contact with ABS plate

General functionality

<table>
<thead>
<tr>
<th>Component</th>
<th>System</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connections</td>
<td>Power / Mains</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>Network LAN /WLAN</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>Bluetooth</td>
<td>OK</td>
</tr>
<tr>
<td>External Temperature Sensor</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>MMI</td>
<td>Telescope Status LEDs</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>Side MMI LEDs</td>
<td>OK</td>
</tr>
<tr>
<td>Batteries</td>
<td>Charge</td>
<td>OK</td>
</tr>
<tr>
<td>Other</td>
<td>OVC</td>
<td>OK</td>
</tr>
<tr>
<td>Nivel</td>
<td></td>
<td>OK</td>
</tr>
<tr>
<td>Tilt sensor</td>
<td></td>
<td>OK</td>
</tr>
</tbody>
</table>
## Temperature Stress

<table>
<thead>
<tr>
<th>Condition</th>
<th>ISO Standard</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold operating</td>
<td>ISO 9022-10-01-2</td>
<td>0°C ±3°C; 16h&lt;br&gt;-15°C ±3°C; 16h (AT500)</td>
</tr>
<tr>
<td>Cold Storage</td>
<td>ISO 9022-10-05-0</td>
<td>-25°C ±3°C / 16h</td>
</tr>
<tr>
<td>Dry heat operating</td>
<td>ISO 9022-11-02-2</td>
<td>+40°C ± 2°C; 16h; &lt; 40% Humidity&lt;br&gt;+50°C ± 2°C; 16h; &lt; 40% Humidity (AT500)</td>
</tr>
<tr>
<td>Dry Heat Storage</td>
<td>ISO 9022-11-05-0</td>
<td>+70°C ±2°C; 6h; &lt; 40% Humidity</td>
</tr>
<tr>
<td>Humidity (non-condensing)</td>
<td>ISO 9022-12-01;</td>
<td>40°C ± 2°C; 90-95% rel. Humidity</td>
</tr>
<tr>
<td>Slow temperature change</td>
<td></td>
<td>+5°C / -5°C; min 2,5h; change rate: &gt;0.2K/min &lt;2K/min</td>
</tr>
<tr>
<td>Slow temperature change Cycles</td>
<td>ISO 9022-14-03-1</td>
<td>+70°C ±2°C/-25°C ±3°C; 5 Cycle; min 2.5h; change rate: &gt;0.2K/min &lt;2K/min</td>
</tr>
</tbody>
</table>
## Electromagnetic Compliance (EMC)

<table>
<thead>
<tr>
<th>Category</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiated Emissions</td>
<td></td>
</tr>
<tr>
<td>Conducted Emissions at Mains Power Ports</td>
<td>EN 55032</td>
</tr>
<tr>
<td>Conducted Emissions at Communication Ports</td>
<td>EN 55035</td>
</tr>
<tr>
<td>Harmonic current emission</td>
<td></td>
</tr>
<tr>
<td>Flicker</td>
<td></td>
</tr>
<tr>
<td>Enclosure Port - Power-frequency magnetic field</td>
<td>EN 61326-1</td>
</tr>
<tr>
<td>Enclosure Port - Radio-frequency electromagnetic field</td>
<td>EN 61000-3-2</td>
</tr>
<tr>
<td>Enclosure Port - Radio-frequency continuous conducted</td>
<td>EN 61326-1</td>
</tr>
<tr>
<td>Enclosure Port - Electrostatic discharge</td>
<td>EN 61000-3-3</td>
</tr>
<tr>
<td>Signal Port - Radio-frequency continuous conducted</td>
<td>EN 61000-4-2</td>
</tr>
<tr>
<td>Signal Port - Electrical fast transient</td>
<td>EN 61000-4-4</td>
</tr>
<tr>
<td>AC Power Port - Radio-frequency continuous conducted</td>
<td>EN 61000-4-5</td>
</tr>
<tr>
<td>AC Power port - Voltage dips</td>
<td></td>
</tr>
<tr>
<td>AC Power port - Voltage interruptions</td>
<td></td>
</tr>
<tr>
<td>AC Power Port – Surges</td>
<td></td>
</tr>
<tr>
<td>AC Power Port - Electrical fast transient</td>
<td></td>
</tr>
</tbody>
</table>
Magnetic field tests: Test Setup

- Copper Coil
- 160 Windings
- $\bar{D} = 0.482$ m
- Height of coil cylinder $l = 0.1$ m
- Copper cable diameter: 5 mm
- Resistance $R_{DC} @22^\circ C$: 0.21 $\Omega$
- Inductance $L$ (100Hz) @22°C: 16.7 mH (measured)
- Magnetic flux density $B$: 4.2 Gauss / A

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Measured Magnetic Field [Gauss] vs. Current applied to coil [A]

- Black dots: Measured Magnetic Field at Sensor Envelope - Coil in horizontal position
- Dashed line: Nominal Magnetic Field
Magnetic field tests Setup – Coil in horizontal Position

- Observation of Target at 7.5m / slightly up
- Short time magnetic fields (~ 5-7 sec)
Magnetic field tests Setup – Coil in vertical Position

- Observation of Target at 3m / tilting axis height
- 4 orientations of instrument with respect to coil
- Short time magnetic fields (~ 5-7 sec)
AT500 – 3D Continuous measurements (100Hz) – coil in horizontal position

- Continuous Measurements to 1.5” CCR
- Short time magnetic fields (~5 sec)
- Significant effects in angles observed from 400G for the time of active field
- No effects on distance (ADM)
- Increasing overall noise level with heating up of magnetic field inducing coil

~7.5m
AT500 – 3D Continuous measurements (100Hz) – coil in vertical position – Orientation#1

- Continuous Measurements to 1.5° CCR
- Short time magnetic fields (~5-8 sec)
- Significant effects in Vt angle and distance observed from 200G for the time of active field
- No drop out, errors or damage up to 400G (experiment not continued for higher fields)
AT500 – 3D Continuous measurements (100Hz) – coil in vertical position – Orientation #2 - 4

Orientation #2

- Some effect seen in Hz angle from 300G
- No effects observed on ADM distances

Orientation #3

- Some effect seen in Vt angle and ADM distances from 200G

Orientation #4

- Some effect seen in Hz angle from 300G
- No effects observed on ADM distances
AT500 – Continuous measurements to B-Probe\textsuperscript{plus} (in magnetic field) – coil in vertical position

- Continuous Measurements to B-Probe\textsuperscript{plus} CCR & 6Dof Geometry (development mode)
- Short time magnetic fields (~ 5-8 sec)
- No significant effect seen on 3D measurements or 6Dof information, some single higher Image RMS (6Dof image information), without impact on 6Dof rotational angles
- No drop out, errors or damage up to 400G (experiment not continued for higher fields)
ATS600 – 3D Continuous measurements (100Hz) – coil in horizontal position

- Continuous Measurements to 1.5” CCR
- Short time magnetic fields (~5 -7 sec)
- Some effects seen on distance from 200G, at 400G some outliers at maximum change of field
- Increasing overall noise level with heating up of magnetic coil
ATS600 – 3D Continuous measurements (100Hz) – coil in vertical position – Orientation #4

• Continuous Measurements to 1.5” CCR
• Short time magnetic fields (~ 4 - 7 sec)
• Effects on angle measurements observed from small magnetic fields, starting at ~120G.
• From ~300G distance measurements system drops out, but recovers instantly after magnetic field is deactivated
• From 400G erratic angular measurements occur
• Reason found to be moving components sensitive to magnetic field. Mechanical noise audible
• Damage could occur when exposing system to persisting strong magnetic fields (above 200G).
ATS600 – 3D Continuous measurements (100Hz) – coil in vertical position – Orientation #1-3

Orientation #1
- Effects seen on distance from 200G, more significant for higher fields
- Effects on angles from 200G
- No drop outs or damages observed

Orientation #2
- Small effects seen on angles from 300G
- No effect seen on distances up to 400G -> drop outs (as for Position#4)

Orientation #3
- Effects seen on vertical angles and distances from 300G
- No drop outs or damages observed
Magnetic Field Tests: Conclusion for User Application

≤ 200 G:
- Full functionality
- Full accuracy
- No damage expected

200 - 400 G:
- Full functionality
- Accuracy begins to decrease
- Probably no damage

ATS600

B-Probe\textsuperscript{plus}
- Unaffected by magnetic fields up to 400G

≤ 200 G:
- Full functionality
- Possibly decreased accuracy
- No damage expected

≥ 200 G:
- Drop-outs possible
- Accuracy decreased
- Damage possible (listen for mechanical noise)
Thank you!

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