Heaters power sizing and AMS activation sequence

M.Capell; M.Cova; C.Vettore
Why do we need heaters?

1. To keep AMS above survival conditions during transfer from STS to ISS
2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit
3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)
Freezing could take place

- Transfer phase to the ISS
- Power outage during the nominal operating phase
- Cold environment during nominal operation
De-freezing is needed

- Ammonia freezing (in the heat pipes and in the LHP) is not a safety issue.
- But the start-up of a heat pipe from the frozen state may be a problem if heat input is concentrated in small portion of the pipe
  - So we need to de-freeze Zenith radiators before operating LHP (DE-FROST HEATERS on ZENITH RAD): $T > T_{\text{melting}}(NH_3)$
  - We need to de-freeze Tracker radiators before starting operating the Tracker loop (DE-FROST HEATERS on TRACKER RAD/CONDENSER): $T > T_{\text{melting}}(CO_2)$ => Q TBC by TTCS detailed analysis
Heater management

• Heaters are controlled thermostatically
• 12 pairs of heaters line are available from PDS
• Heaters can be en/disabled at PDS level to manage the total load to be less than 2KW
  – One of the heater line could be disabled when we decide to turn on the corresponding equipment
• Each of the heater line may even form a “bus” with multiple thermostats/heater circuit
• Individual thermostat status (ON/OFF) unknown
AMS 02 – Thermal Control
System Design

POWER DISTRIBUTION SYSTEM (PDS)

124V Input Section

124V Output Section

124V Output Section

28V Output Section

28V Consumers

ISS

ISS ARM

STS

UMA

EVA

PAS

BCS

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### AMS 02 – Thermal Control System Design

<table>
<thead>
<tr>
<th>Output lines</th>
<th>Description</th>
<th>Power A side [W]</th>
<th>Power B side [W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ram Tracker Radiator/Condenser</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Ram main radiator</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>3</td>
<td>E-crate+Lower HV bricks</td>
<td>10+60</td>
<td>10+60</td>
</tr>
<tr>
<td>4</td>
<td>Wake Tracker Radiator/Condenser</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>5</td>
<td>Wake main radiator</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>6</td>
<td>Zenith radiator (all 4 quarters)</td>
<td>100x4</td>
<td>100x4</td>
</tr>
<tr>
<td>7</td>
<td>Cryocoolers</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>Cryocoolers</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>Cryocoolers</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>Cryocoolers</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>TRD Gas Box+CAB</td>
<td>69+40</td>
<td>69+40</td>
</tr>
<tr>
<td>12</td>
<td>TTCB primary and secondary</td>
<td>50x2</td>
<td>50x2</td>
</tr>
<tr>
<td><strong>TOT</strong></td>
<td></td>
<td><strong>1879</strong></td>
<td><strong>1879</strong></td>
</tr>
</tbody>
</table>
Heater bus arrangement example for TTCB-P and -S boxes
How do we e/disable heaters?

- We can e/disable heaters according to the associated electronics and/or radiator temperature.
- We know the temperature of the electronics by means of the GTSN (= Global Temp Sensor Net) based on Dallas Temperature Sensors (DTS) and of the Zenith/Tracker radiators by means of PT100 (or PT1000):
  - DTS readout is done by USCM in J crate
  - Zenith rad. PT100 readout by CCEB
  - Tracker rad. PT100 readout by TT crate
AMS 02 – Thermal Control
System Design

PDS Heaters location 1/3

WAKE radiator

heaters

Baseplate

PDS Heaters located inside

Cover
PDS Heaters location 2/3
PDS Heaters location 3/3
CAB Heaters location
Zenith radiators De-frost Heaters location

OHB PROPOSAL

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Milano-Italy
Carlo Gavazzi Space

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Tracker rad. Heaters location

- Heaters on the radiator back (additional heaters on the condensers not needed)
Main rad. Heaters location

Remark: The heaters can not be placed underneath the boxes

AMS 02 – Thermal Control
System Design

RAM

From OHB detailed analysis

WAKE

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Carlo Gavazzi Space
10-11 March 2004
E-crates Heaters location

- Unlike the boxes on the main radiators, heaters are located directly on the E-crate.
HV bricks

- Ecal and RICH HV bricks heaters location to be defined with dedicated detailed analysis
- First iteration: heaters on outer sides
EHV bricks Heaters location (1\textsuperscript{st} iteration)

- Unlike the boxes on the main radiators heaters are located directly on the HV bricks.
RHV bricks Heaters location
(2-0-2-0) 1st iteration

- Unlike the boxes on the main radiators heaters are located directly on the HV bricks.
Cryo body heaters  
(substitution heaters)

- These heaters are located on the LHP evaporator
- Main functions:
  - Support the nominal cryo-cooler operation in order to avoid freezing on the zenith radiators under extreme cold conditions
  - Start-up the LHP operations and drive the temperature to the CRYO minimum switch-on temperature
Why do we need heaters?

1. **To keep AMS above survival conditions during transfer from STS to ISS**

2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit

3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)
AMS/02 transfer preliminary results

1. AMS in the STS docked at the ISS
2. AMS in hand-off position
3. AMS on the ISS truss
Selected Case

<table>
<thead>
<tr>
<th>Beta angle</th>
<th>Yaw</th>
<th>Pitch</th>
<th>Roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>+25°</td>
<td>0°</td>
<td>+20°</td>
<td>0°</td>
</tr>
</tbody>
</table>

COLDEST CASE DURING THE HANDOFF

The environment is the worst cold, characterized by:

- Altitude= 270 Nautical miles
- Albedo=20%
- Earth temperature=245.5K
- Solar flux=1300 W/m²
1. AMS in the STS
# 1. AMS in the STS

## Power dissipation

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>input feed APCU</td>
<td>2000</td>
</tr>
<tr>
<td>max power PDS bus B</td>
<td>204</td>
</tr>
<tr>
<td>Nominal users</td>
<td></td>
</tr>
<tr>
<td>Cryocooler</td>
<td>480 @ 120V (4A)</td>
</tr>
<tr>
<td>J-CRATE</td>
<td>50 @ 28V (1.8A)</td>
</tr>
<tr>
<td>CAB</td>
<td>30 @ 28V (1A)</td>
</tr>
<tr>
<td>POWER HEATERS AVAILABLE</td>
<td>1156,0W</td>
</tr>
<tr>
<td>TRD Gas Box</td>
<td>69</td>
</tr>
<tr>
<td>Crates RAM radiator</td>
<td>350</td>
</tr>
<tr>
<td>Crates WAKE radiator</td>
<td>350</td>
</tr>
<tr>
<td>TTCS boxes</td>
<td>100</td>
</tr>
<tr>
<td>HV bricks</td>
<td>60</td>
</tr>
<tr>
<td>E crate</td>
<td>10</td>
</tr>
<tr>
<td>Tot</td>
<td>939</td>
</tr>
</tbody>
</table>

CCEB has been considered ON = 80W
2. AMS in the HAND-OFF position

- The precise set of time-dependent positions of AMS during the transfer phase from STS to ISS is not available yet.
- The only available information is the intermediate position, when both STS and ISS robotic arms will be attached to AMS.
- This is a position where AMS could stay for:
  - 1 orbit w/o power
  - 1 orbit with power from ISS arm
AMS 02 – Thermal Control
System Design

2. AMS in the HAND-OFF position
2a). One orbit with AMS completely unpowered
2b). One orbit with the following power applied

<table>
<thead>
<tr>
<th>input feed</th>
<th>PVGF 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>max power</td>
<td>2100W</td>
</tr>
<tr>
<td>PDS active bus</td>
<td>A</td>
</tr>
<tr>
<td>PDS</td>
<td>204W</td>
</tr>
<tr>
<td>Nominal users</td>
<td></td>
</tr>
<tr>
<td>Cryocooler Heaters</td>
<td>200W @ 120V (0,53Ax4)</td>
</tr>
<tr>
<td>Zenith radiator</td>
<td>4 x 50 W</td>
</tr>
<tr>
<td>J-CRATE</td>
<td>100W @ 28V (3,57AX2)</td>
</tr>
<tr>
<td>POWER HEATERS AVAILABLE</td>
<td>1316W</td>
</tr>
</tbody>
</table>

CCEB has been considered ON = 80W
3. AMS on the ISS

<table>
<thead>
<tr>
<th>input feed</th>
<th>MAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>max power</td>
<td>2100W</td>
</tr>
<tr>
<td>PDS active bus</td>
<td>A</td>
</tr>
<tr>
<td>PDS</td>
<td>204W</td>
</tr>
<tr>
<td>Nominal users</td>
<td></td>
</tr>
<tr>
<td>Cryocooler</td>
<td>200W @ 120V (0.53Ax4)</td>
</tr>
<tr>
<td>Heaters</td>
<td>200W @ 120V (0.53Ax4)</td>
</tr>
<tr>
<td>Zenith radiator</td>
<td>4 x 50 W</td>
</tr>
<tr>
<td>J-CRATE</td>
<td>100W @ 28V (3.57AX2)</td>
</tr>
<tr>
<td>POWER HEATERS</td>
<td></td>
</tr>
<tr>
<td>AVAILABLE</td>
<td>1316W</td>
</tr>
<tr>
<td>TRD Gas Box</td>
<td>69W</td>
</tr>
<tr>
<td>Crates RAM radiator</td>
<td>350W</td>
</tr>
<tr>
<td>Crates WAKE radiator</td>
<td>350W</td>
</tr>
<tr>
<td>TTCS boxes</td>
<td>100 W</td>
</tr>
<tr>
<td>CAB</td>
<td>40W</td>
</tr>
<tr>
<td>HV bricks</td>
<td>60 W</td>
</tr>
<tr>
<td>E crate</td>
<td>10 W</td>
</tr>
<tr>
<td>Tot</td>
<td><strong>979 W</strong></td>
</tr>
</tbody>
</table>

CCEB has been considered ON = 80W

(same as before)
Transfer Analysis Results
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Time (orbits)

Temperature [°C]

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Carlo Gavazzi Space
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Why do we need heaters?

1. To keep AMS above survival conditions during transfer from STS to ISS

2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit

3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)
AMS is operating under extreme cold case:

<table>
<thead>
<tr>
<th>Item</th>
<th>Power (W)</th>
<th>Calculated by</th>
<th>Orbital case (β, YPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRD Gas Box</td>
<td>69</td>
<td>LMSO</td>
<td>0 –15 +15 –15</td>
</tr>
<tr>
<td>HV bricks</td>
<td>60W (TBC)</td>
<td>CGS</td>
<td></td>
</tr>
<tr>
<td>Cryocoolers</td>
<td>50 each = 200W</td>
<td>OHB</td>
<td>+75 –15 +15 +15</td>
</tr>
<tr>
<td>RICH</td>
<td>TBD (depending on ongoing tests)</td>
<td>CGS</td>
<td>TBD</td>
</tr>
<tr>
<td>TTCB P or S</td>
<td>50W + 50W</td>
<td>Proposed by CGS</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>429W</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Why do we need heaters?

1. To keep AMS above survival conditions during transfer from STS to ISS
2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit
3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)
AMS-02 re-activation after Power outage
Extreme cold case for WAKE(*)

<table>
<thead>
<tr>
<th>Beta angle</th>
<th>Yaw</th>
<th>Pitch</th>
<th>Roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>+75°</td>
<td>-15°</td>
<td>-20°</td>
<td>+15°</td>
</tr>
</tbody>
</table>

The environment is characterized by:

• Altitude = 270 Nautical miles
• Albedo = 20%
• Earth temperature = 245.5K
• Solar flux = 1300 W/m²

(*): PDS radiator
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System Design

Step sequence

1. AMS is operating
2. AMS is suddenly shut down
3. FIRST TASK: define how long we can remain un-powered?
4. As soon as one of the sub-detectors/sub-system is going under the minimum storage temperature we have to restore power to make the activation sequence start. NO TEMPERATURE MONITORING AT ALL.
5. PDS minimum switch-on conditions have to be restored
6. PDS HEATERS ON (230W)
7. As soon as T=-25°C is reached at PDS TRP, PDS is turned ON and PDS heaters are switched OFF by a thermal interlock device (TBD)
8. STILL NO TEMPERATURE MONITORING AT ALL
Step sequence

9. If PDS is ON we can turn ON all the heaters we need: which ones?
   ✓ MAIN RADIATORS
   ✓ CAB + TRDGB
   ✓ TTCB
   ✓ HV BRICKS + E-CRATE

10. We can NOT turn ON heaters on:
    ✓ CRYO-BODY ----- zenith radiators could be frozen

11. We have both the choices (ON/OFF) for the heaters on:
    ✓ ZENITH RADIATORS
    ✓ TRACKER RADIATORS
12. Finally thanks to the heaters on the main wake radiators J+JPD boxes reach their minimum switch-on temperature and the JPD can be powered up. This is done controlling the power input line from PDS in a thermostatic way.

13. As soon as J-crate is operating we can start (via JMDC) to monitor temperatures via GTSN.

14. DTS MONITORING AVAILABLE

15. LOW TEMPERATURE MONITORING (zenith and tracker radiators) DONE IN CCEB AND TT CRATE NOT AVAILABLE

16. CCEB and TT Crate ON as soon as they reach switch on temperature

17. Readout of zenith and tracker temperature available

18. Unfrozen heaters ON on zenith/tracker

19. Substitution heaters ON on cryos when zenith is unfrozen
20. LHP starts working
21. Cryo reach minimum switch on
22. Cryocoolers ON
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PDS switch on temp = -20°C

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Crates on RAM radiator

![Graph showing temperature over time for different crates and sensors.]

- **Temperature** [°C]
- **Time** [hr]
- **Crates**: 1, 2/3, 4/5/6

**Sensors and Components**:
- CCEB
- JT
- M
- SRPD1
- TPD1
- TPD2
- TSPD1
- TSPD2
- SHV1
- SHV2
- GPS

AMS 02 – Thermal Control
System Design

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10-11 March 2004
# AMS 02 – Thermal Control System Design

<table>
<thead>
<tr>
<th>@-15°C ON</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U1</strong></td>
<td>18 hr 40min</td>
</tr>
<tr>
<td><strong>UPD1</strong></td>
<td>28 hr 47min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>@-15°C ON</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1</strong></td>
<td>14 hr 38min</td>
</tr>
<tr>
<td><strong>TPD1</strong></td>
<td>8 hr 8min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>@-15°C ON</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T4</strong></td>
<td>16 hr 18min</td>
</tr>
<tr>
<td><strong>S2</strong></td>
<td>17 hr 37min</td>
</tr>
<tr>
<td><strong>TSPD1</strong></td>
<td>16 hr 18min</td>
</tr>
<tr>
<td><strong>SHV2</strong></td>
<td>6 hr 27 min</td>
</tr>
</tbody>
</table>

![Graph showing temperature and time]
AMS 02 – Thermal Control
System Design

RAM

WAKE

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Conclusions

• A preliminary heater power sizing has been performed at system level
• Confirmation shall be provided by sub-system according to their detailed thermal analysis
• Power budget has to be checked