ATLAS ATCA cooling tests

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Project motivations

**Vertical and horizontal air flow cooling tests on a standard LHC rack 52U**

- Cooling capabilities of the LHC rack need to be checked changing from VME Crates to ATCA shelves.

- Identify potential in-rack bottlenecks and airflow resistance sources. Propose possible alternatives/solutions to remove them and test any adaptations.

- Mechanical improvements on the rack to optimize the cooling performance (i.e.: removal of turbine chassis, fans trays, water flow in the cooling door, etc.)

- To compare different configurations (horizontal and vertical airflow), checking the possible failure modes and the relevant impact on the thermal performance.

- To evaluate thermal and safety aspects of the environment for the future installations in the ATLAS counting rooms (i.e.: noise, air conditioning, etc.)
Vertical cooling configuration

30 T sensors were installed. Their layout was changed according to the kind of tests we were carrying out.

- Air/water heat exchangers (1U), providing up to 3.8 kW of thermal capacity each
- Exchanged surface reduced (approx. 2/3)
- Plexiglas panel installed to improve the leak tightness
Inside the shelves

ASIS load blades: maximum power 600W

Comtel load blades: maximum power 350W

14 x Comtel blades: 6* Embedded Temperature sensors (green) + 6 air T sensors (blue)

14 x ASIS blades: 6 Temperature sensors (inlet and outlet)

3 x 3 fans on the top, 1 x 6 fans on the bottom. 96 W x fan (theoretical).
Vertical cooling performance (without bottom fans)

Equipment which is placed on the bottom of the rack has better cooling performance than the top one.
Horizontal cooling: equipment and sensors layout

The equipment that were used during the tests:

- ASIS ATCA horizontal cooled crate (16U), with ability to dissipate up to 600W on each slot,
- Schroff ATCA horizontal cooled crate (14U), with ability to dissipate up to 450W on each slot.
USA15 – Building 4 cooling performance comparison (1.8m³/h)

USA15 air inlet T: 18.5°C, Bldg 4 air inlet T: 21.4°C  \( \Delta T_{\text{air}} = 2.9K \)

Considering the air inlet temperature difference we can say that the performance are comparable.
Comparison between tests with and without bottom fans

- **ASIS Crate 14x450W**
  - Av. $\Delta T = WBF-BF = 3.6K$
- **ASIS Crate 14x350W**
  - Av. $\Delta T = WBF-BF = 1.4K$
- **Schroff Crate 14x350W**
  - Av. $\Delta T = WBF-BF = 1.5K$

- **ASIS crate performance with bottom fans working is better than with only top fans** (the average maximum temperature of the blades is 3.6K lower, while power dissipation is 450W per blade),
- **Schroff crate performance is poor in both cases although with only top fans working the airflow is much more homogeneous.**

Water inlet temperature
14.6°C ±0.3°C
Air and water inlet/outlet temperatures
(ATCA2 14x450W, ATCA1 14x350W, water flow 3m³/h)

Total power: 13.9kW

Q = \( mC_p (T_{out} - T_{in}) = 0.83 \times 4.18 \times 3.1 = 10.8 \text{ kW (78\% of the total power)} \)

Higher inlet temperature

Water inlet temperature 14.6°C ±0.3°C

\( \Delta T = 3.1°C \)
Repositioning of the crates (air outlet temperatures)

- ASIS crate 14x450W
- Schroff crate 14x350W

<table>
<thead>
<tr>
<th>Water flow 3m³/h</th>
<th>Water flow 2.4m³/h</th>
<th>Water flow 1.8m³/h (same as in USA15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIS top</td>
<td>ASIS bot</td>
<td>ASIS top</td>
</tr>
<tr>
<td>23.8°C</td>
<td>22.4°C</td>
<td>24.4°C</td>
</tr>
<tr>
<td>23.2°C</td>
<td>23.8°C</td>
<td>23.9°C</td>
</tr>
<tr>
<td>21.9°C</td>
<td>21°C</td>
<td>22.6°C</td>
</tr>
<tr>
<td>21.7°C</td>
<td>20.6°C</td>
<td>22.3°C</td>
</tr>
<tr>
<td>21.5°C</td>
<td>20.7°C</td>
<td>22.1°C</td>
</tr>
<tr>
<td>Av. outlet T</td>
<td>22.4°C</td>
<td>21.7°C</td>
</tr>
</tbody>
</table>

- The lower the water flow, the higher temperature of the air released to the environment,
- Placing the crate which produce more heat on the bottom of the rack causes more efficient distribution of the heat through the rack and decreases the temperature of the released air to the room.
## Repositioning of the crates (heat removal)

Water inlet temperature 14.6°C ±0.3°C

<table>
<thead>
<tr>
<th></th>
<th>Water flow 3m³/h</th>
<th>Water flow 2.4m³/h</th>
<th>Water flow 1.8m³/h (same as in USA15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASIS top</td>
<td>ASIS bot</td>
<td>ASIS top</td>
</tr>
<tr>
<td>ΔT of the water</td>
<td>3.1K</td>
<td>3.1K</td>
<td>3.8K</td>
</tr>
<tr>
<td>Power removed</td>
<td>10.8kW</td>
<td>10.8kW</td>
<td>10.6kW</td>
</tr>
<tr>
<td>% of the total power</td>
<td>78%</td>
<td>78%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Total power: 13.9kW

Putting the crate which generates more heat on the bottom of the rack, slightly improves the cooling performance due to efficient heat distribution on the cooling doors.
Comparison of heat removal for different water temperatures

<table>
<thead>
<tr>
<th>T° / Hygrométrie à la reprise</th>
<th>Régime d’eau (°C)</th>
<th>Puissance (kW)</th>
<th>Débit d’eau (m³/h)</th>
<th>T° / Hygrométrie au soufflage</th>
<th>Perte de charge batterie (mCE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33°C / 10 g/Kg air sec</td>
<td>13 / 18</td>
<td>14</td>
<td>2.4</td>
<td>22.5°C / 10 g/Kg air sec</td>
<td>2.13</td>
</tr>
<tr>
<td>33°C / 10 g/Kg air sec</td>
<td>14 / 19</td>
<td>13</td>
<td>2.24</td>
<td>23.2°C / 10 g/Kg air sec</td>
<td>1.87</td>
</tr>
<tr>
<td>37°C / 10 g/Kg air sec</td>
<td>13 / 18</td>
<td>18</td>
<td>3.09</td>
<td>23.5°C / 10 g/Kg air sec</td>
<td>3.39</td>
</tr>
<tr>
<td>37°C / 10 g/Kg air sec</td>
<td>14 / 19</td>
<td>17</td>
<td>2.93</td>
<td>24.2°C / 10 g/Kg air sec</td>
<td>3.06</td>
</tr>
</tbody>
</table>

Cooling doors specification

<table>
<thead>
<tr>
<th>Water flow 3m³/h</th>
<th>14.6°C</th>
<th>13.3°C</th>
<th>Water flow 2.4m³/h</th>
<th>14.6°C</th>
<th>13.3°C</th>
<th>Water flow 1.8m³/h (same as in USA15)</th>
<th>14.6°C</th>
<th>13.3°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔT of the water</td>
<td>3.1K</td>
<td>3.2</td>
<td>4°C</td>
<td>4.3</td>
<td></td>
<td>4.9°C</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Power removed</td>
<td>10.8kW</td>
<td>11.15kW</td>
<td>11.15kW</td>
<td>11.98kW</td>
<td></td>
<td>10.24kW</td>
<td>10.87kW</td>
<td></td>
</tr>
<tr>
<td>% of the total power</td>
<td>78%</td>
<td>80%</td>
<td>80%</td>
<td>86%</td>
<td>74%</td>
<td>78%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total heat removal in vertical configuration to be measured soon
Air and water inlet/outlet temperature

Water flow 2.4 m³/h

Water inlet temperature
14.6°C ±0.3°C

Average delta T of outlet/inlet water 4K

Average delta T of outlet/inlet air 0.7K
Av. outlet air T = 22.6°C, av. inlet air T = 21.9°C

The oscillations in the water temperature are caused by start/stop cycle of the water chiller.
Water inlet temperature 14.6°C ±0.3°C

The oscillations in the water temperature are caused by start/stop cycle of the water chiller.

Average delta T of outlet/inlet water 3.1K

Average delta T of outlet/inlet air 0.4K
Av. outlet air T = 21.7°C, av. inlet air T = 21.3°C
Water inlet temperature
13.3°C ±0.3°C

Average delta T of outlet/inlet water 3.4K

Average delta T of outlet/inlet air 0.5K
Av. outlet air T = 21°C, av. inlet air T = 20.5°C
Releasing heat to the working environment:
Warm air release under the rack

ATCA2 - 14x350W (top), ATCA1 – 14x450W (bot)
Air temperature under the rack

Average T: 23.2°C
Average T: 24.3°C
Releasing heat to the working environment: thermal camera pictures

As you can see on the pictures above, the rack is exchanging heat with the environment through radiation from all sides of the rack. The most heat is radiated to the environment through sides of the rack as well as the rear (surface of the cooling doors around the heat exchanger part).
Vertical - Horizontal cooling comparison in b4

Configuration (in both cases only top fans were working on maximum speed):
Vertical: Top – 14x450W Comtel LB in ASIS crate, Bottom – 14x450W ASIS LB in ASIS crate. Water temperature 13°C.
Horizontal: Top – 14x350W Comtel LB in Schroff crate, Bottom – 14x450W ASIS LB in ASIS crate. Water flow 2.4m³/h, water temperature 13°C.

The cooling performance are very similar
Noise reduction: noise measurements (horizontal shelves)

New sound suppression material: Masse lourde

Discussion with an external company is on-going in order to upgrade the counting rooms including a sound proof area for the ATCA racks.

Next steps: to insulate side (air gaps reduction) panels and rear door to check the noise reduction and how it affects the cooling efficiency.
As you can see on the charts above, closing the front doors has small influence on cooling performance. The average temperature on the ASIS blades while the doors are closed is higher by 2.2K and 0.8K on the Comtel blades.

**Schroff crate 14x350W**

**Water inlet temperature**

14.6°C ±0.3°C

**ASIS crate 14x450W**
Conclusions

• The tests carried out in B. 4 showed similar results to USA15.
• In both configurations the load boards temperature at the maximum power is very close and sometime above to 50C: the horizontal configuration looks slightly more efficient
• The push-pull configuration in horizontal configuration cooled the ASIS shelf better than only pull configuration (the fans system redundancy is preserved)
• With water flow between 2.4 - 3m³/h and water temperature of 13-14C, the air outlet/inlet ∆T=0.4 – 0.7K, and it looks stable in time. **Horizontal cooling is still in the game.**
• The cooling doors are removing up to 86% of the power dissipated in the rack, the thermal pictures showed as part of the heat is irradiated through the rack structure
• Equipping the rack with soundproofed front doors does not affect in significant way the cooling performance, in addition it lowers the noise by around 9dBA. More tests in vertical layout foreseen during next weeks to check the efficiency of the noise reduction and the effect of reducing the air gap to the cooling performance.
• A study is on-going to understand how we could soundproof USA15 counting rooms