ATLAS ATCA cooling tests

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Project motivations

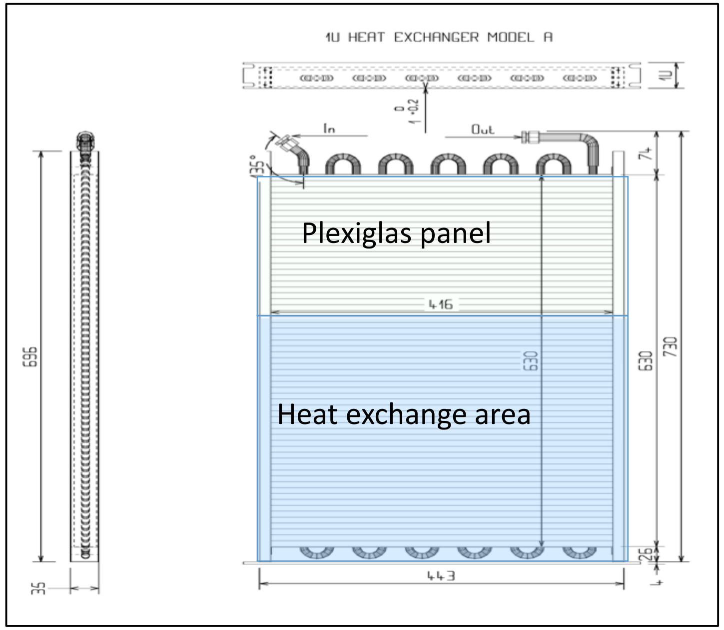
Vertical and horizontal air flow cooling tests on a standard LHC rack 52U

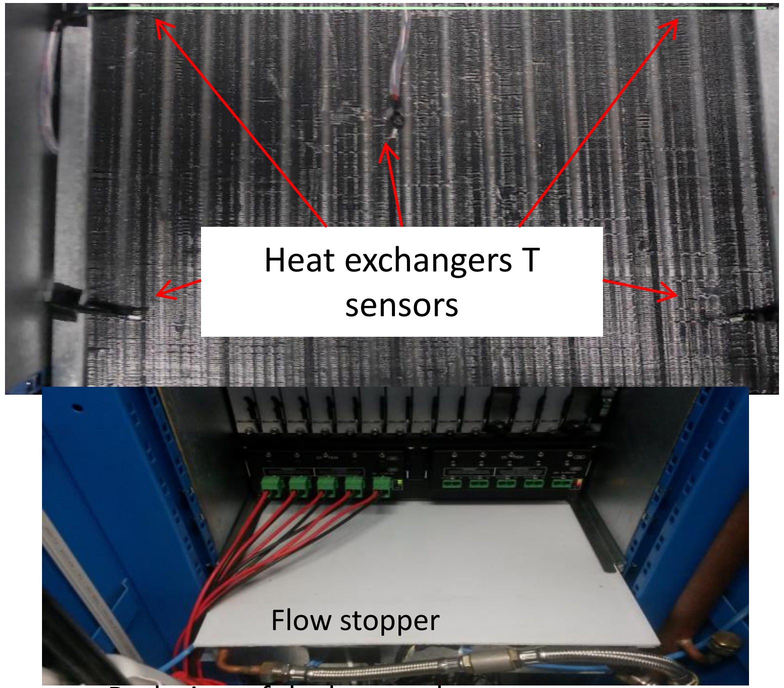
- Cooling capabilities of the LHC rack need to be checked changing from VME Crates to ATCA shelves.
- Identify potential in-rack bottlenecks and airflow resistance sources. Propose possible alternatives/solutions to remove them and test any adaptations.
- Mechanical improvements on the rack to optimize 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.)

Tdaq Lab
(b. 4)

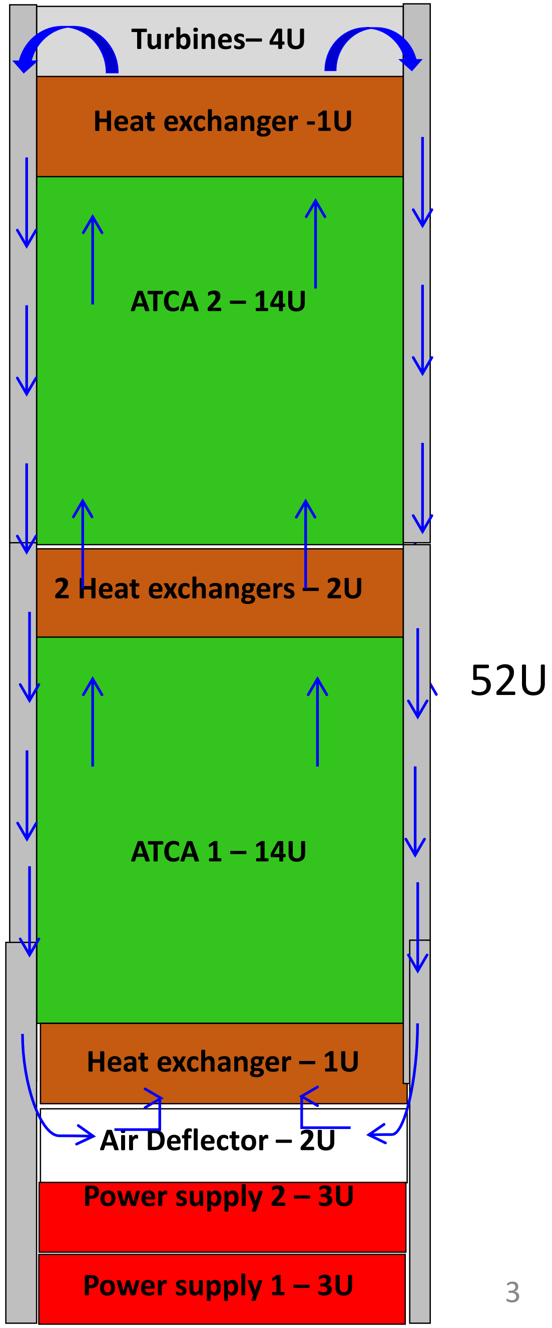
Vertical cooling configuration

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





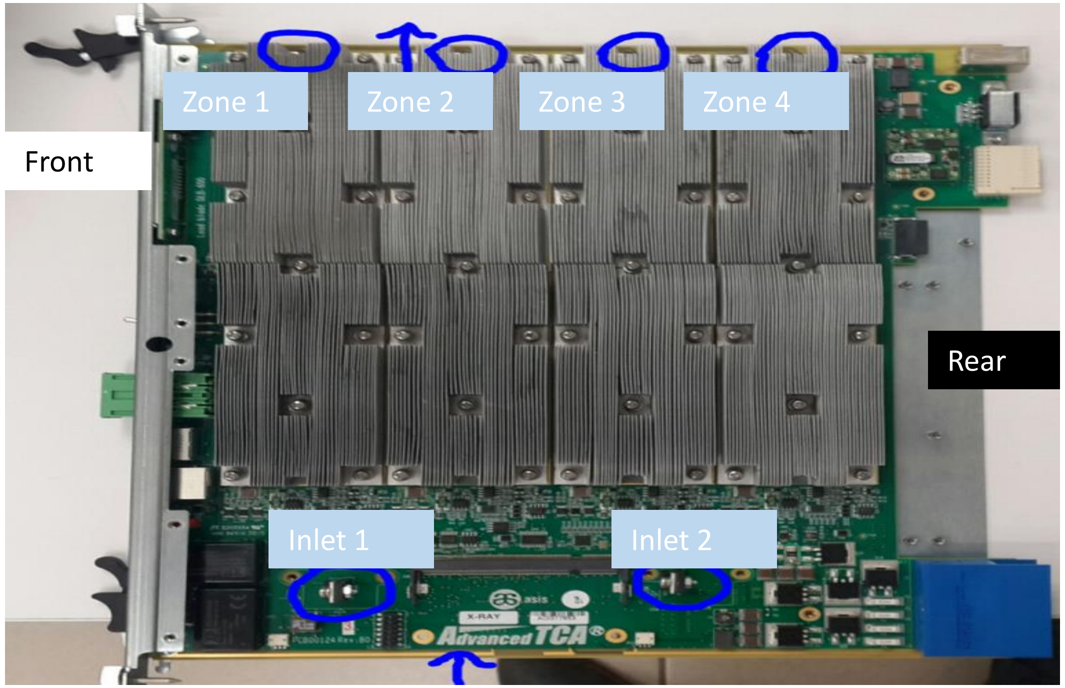
Back view of the heat exchanger



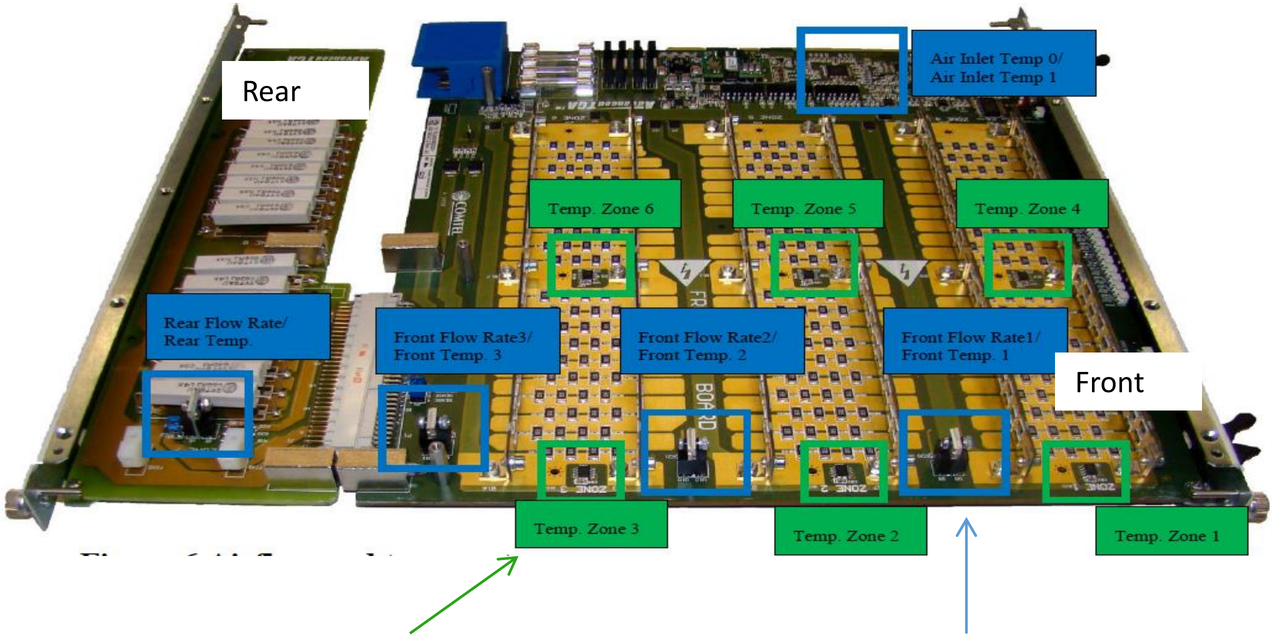
- Air/water heat exchangers (1U), providing up to 3.8 kW of thermal capacity each
- Exchanged surface reduced (approx. 2/3)
- Plexiglas panel installed to improve the leak tightness

Inside the shelves

ASIS load blades: maximum power 600W



Comtel load blades: maximum power 350W



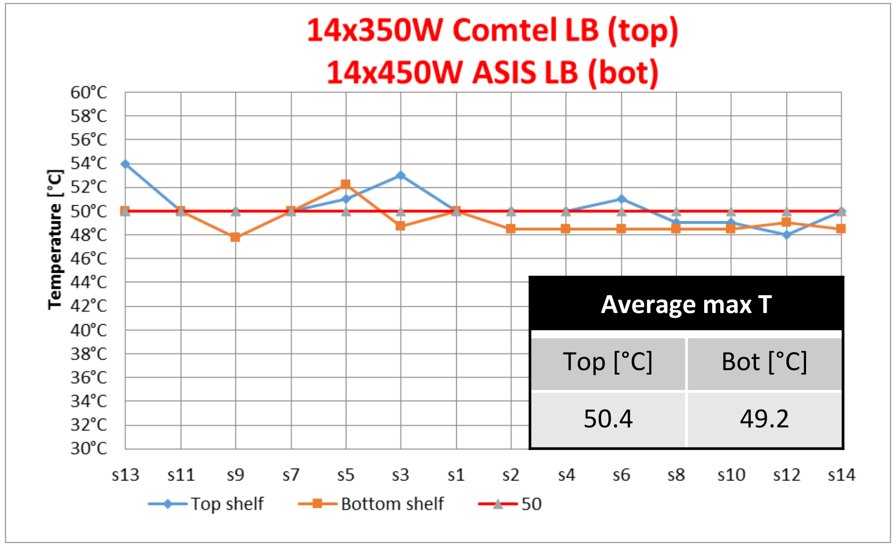
14 x Comtel blades: 6* Embedded Temperature sensors (green) + 6 air T sensors (blue)

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

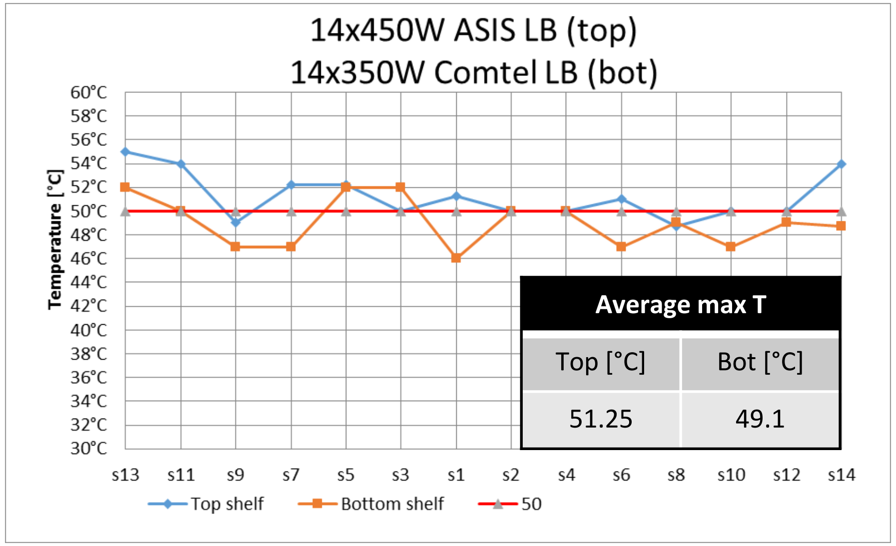
Model No.	PWM Duty Cycle [%] Note1)	Rated Current [A]	Rated Input [W]	Rated Speed [min⁻¹]	Max. Air Flow [m³/min]	Max. Air Flow [CFM]	Max. Static Pressure [Pa]	Max. Static Pressure [inchH2O]	SPL [dB(A)]
9HV1248P1G001	100	2.0	96	11,500	8.3	293	1,300	5.22	75
	0	0.23	11	3,800	2.7	95	161	0.65	46

3 x 3 fans on the top, 1 x 6 fans on the bottom. 96 W x fan (theoretical).

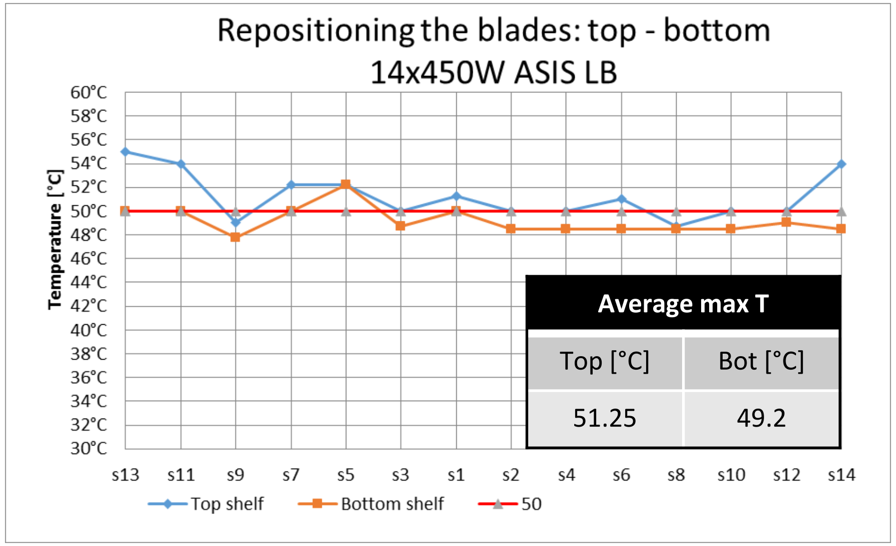
Vertical cooling performance (without bottom fans)



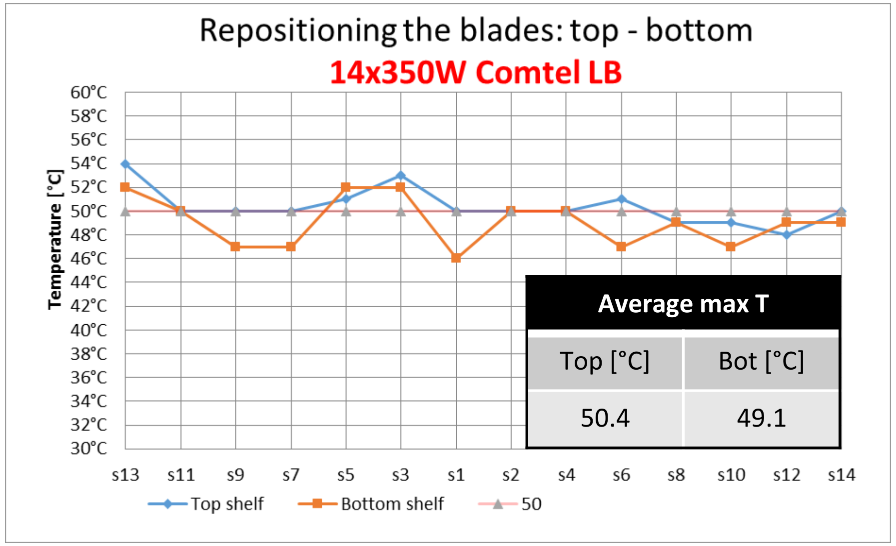
Average max T	
Top [°C]	Bot [°C]
50.4	49.2



Average max T	
Top [°C]	Bot [°C]
51.25	49.1



Average max T	
Top [°C]	Bot [°C]
51.25	49.2



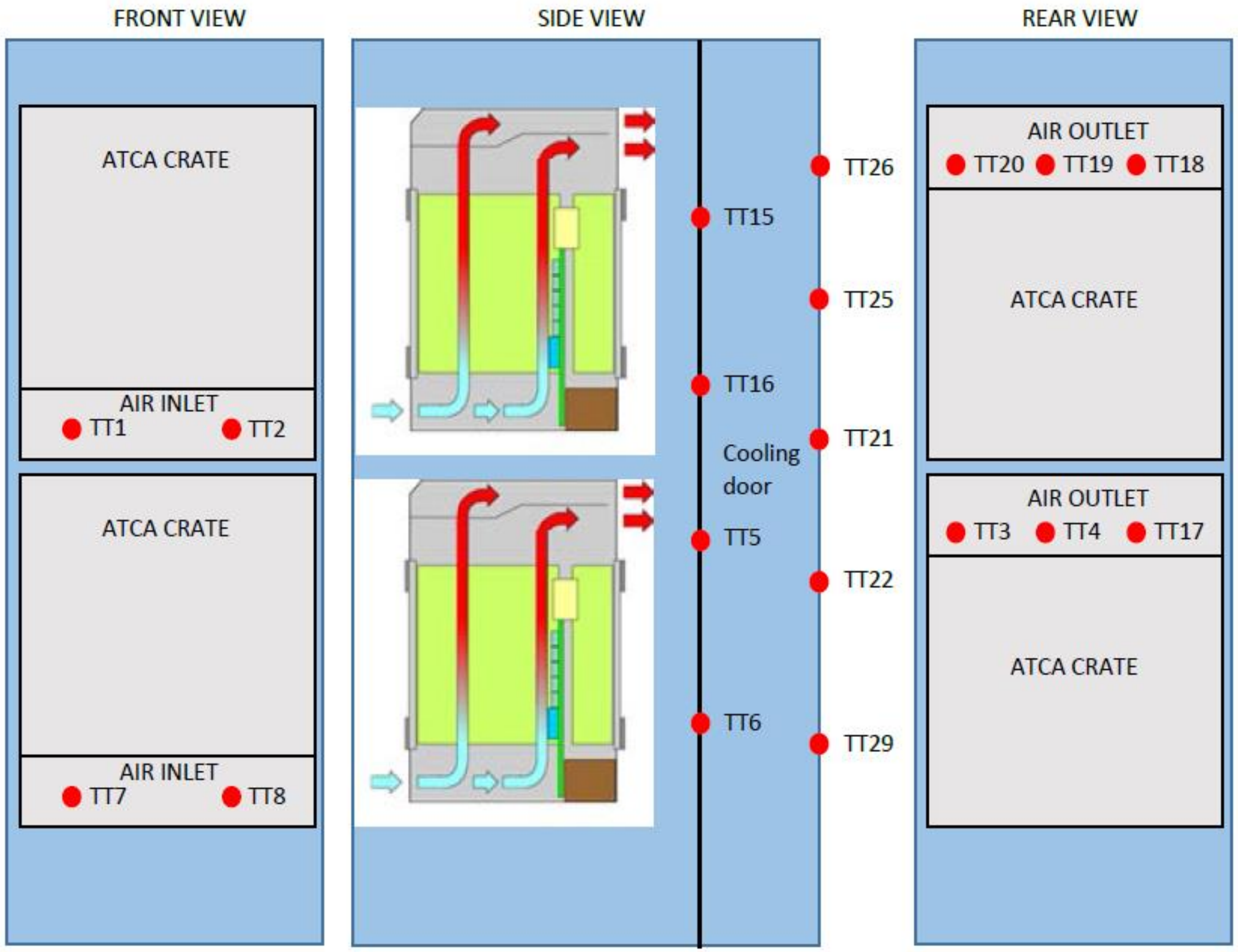
Average max T	
Top [°C]	Bot [°C]
50.4	49.1

Equipment which is placed on the bottom of the rack has better cooling performance than the top one

Horizontal cooling: equipment and sensors layout

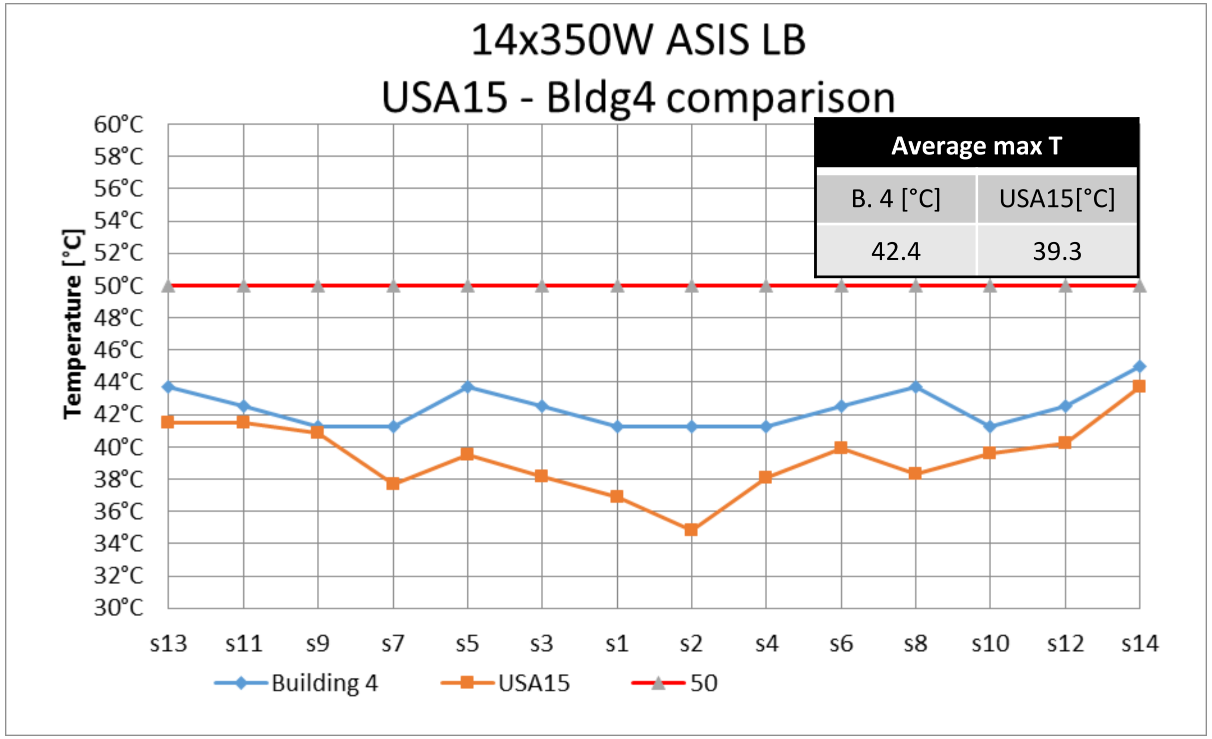
The equipment that were used during the tests:

- 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 **ΔT_{air}=2.9K**



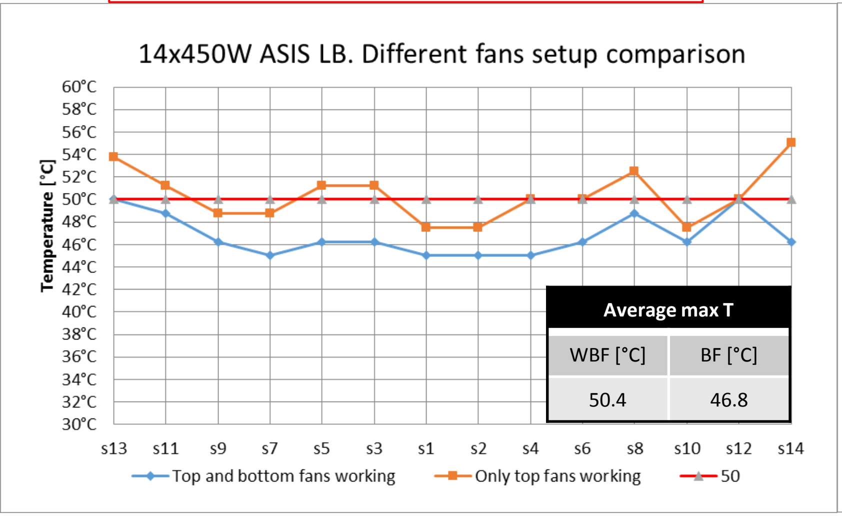
Average max T	
B. 4 [°C]	USA15[°C]
42.4	39.3

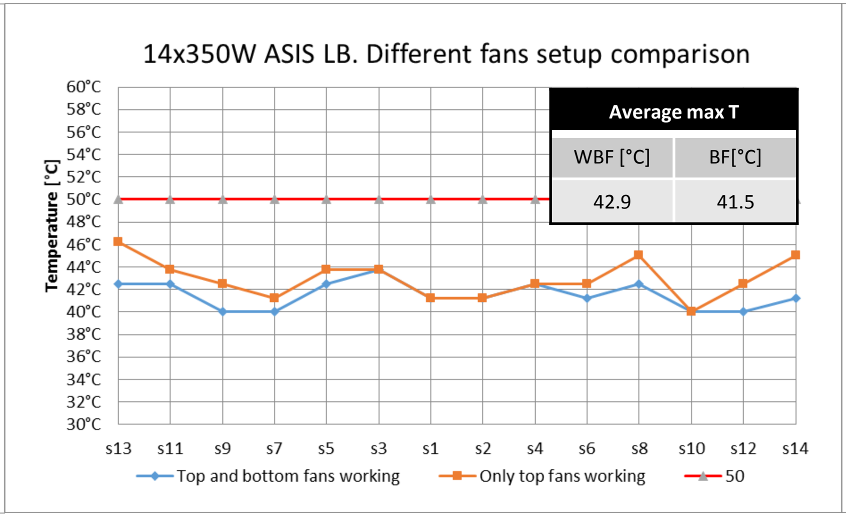
Considering the air inlet temperature difference we can say that **the performance are comparable.**

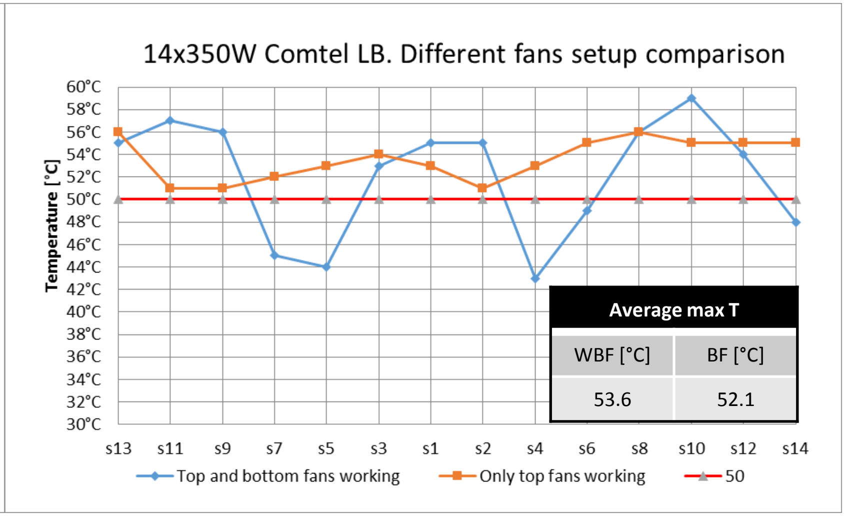
Comparison between tests with and without bottom fans

Water inlet temperature
14.6°C ±0.3°C

WBF – without bottom fans
BF – with bottom fans







ASIS Crate 14x450W

Av. ΔT = WBF-BF = 3.6K

ASIS Crate 14x350W

Av. ΔT = WBF-BF = 1.4K

Schroff Crate 14x350W

Av. ΔT = WBF-BF = 1.5K

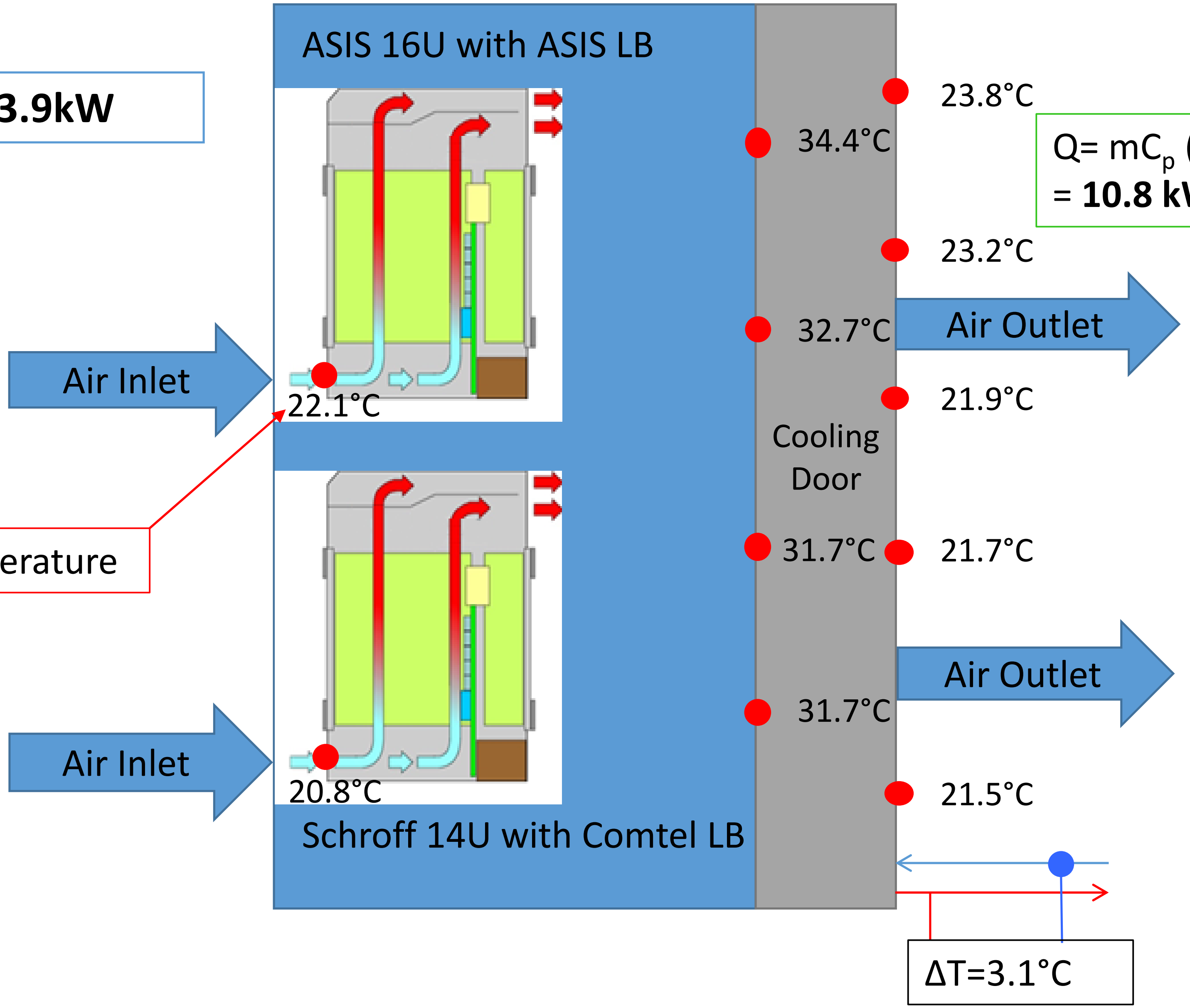
- ASIS crate performance with bottom fans working is better than with only top fans (the average maximum temperature of the blades is 3.6K lower, while power dissipation is 450W per blade),
- Schroff crate performance is poor in both cases although with only top fans working the airflow is much more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

Air and water inlet/outlet temperatures

(ATCA2 14x450W, ATCA1 14x350W, water flow 3m^3/h)

Total power: 13.9kW

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



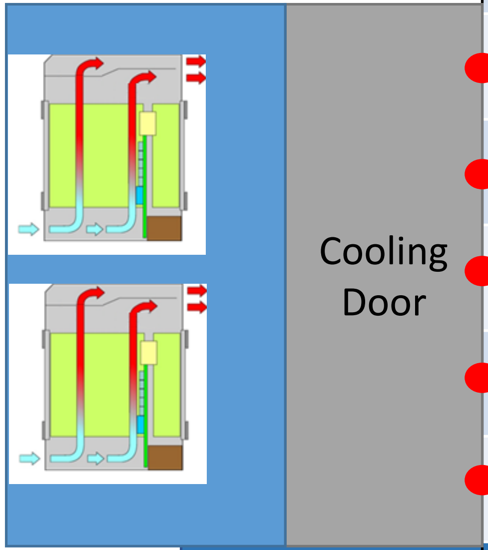
Higher inlet temperature

Water inlet temperature
14.6°C ±0.3°C

Repositioning of the crates (air outlet temperatures)

Water inlet temperature 14.6°C ±0.3°C

- ASIS crate 14x450W
- Schroff crate 14x350W



	Water flow $3 m^3/h$		Water flow $2.4 m^3/h$		Water flow $1.8 m^3/h$ (same as in USA15)	
	ASIS top	**ASIS bot**	**ASIS top**	**ASIS bot**	**ASIS top**	**ASIS bot**
	23.8°C	22.4°C	24.4°C	23.4°C	25.1°C	24°C
	23.2°C	23.8°C	23.9°C	24.8°C	24.5°C	25.4°C
	21.9°C	21°C	22.6°C	21.9°C	22.1°C	22.2°C
	21.7°C	20.6°C	22.3°C	21.6°C	21.8°C	22°C
	21.5°C	20.7°C	22.1°C	21.4°C	22.6°C	21.7°C
Av. outlet T	22.4°C	21.7°C	23.1°C	22.6°C	23.2°C	23.1°C

- 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)

Total power: 13.9kW

Water inlet temperature 14.6°C ±0.3°C

	Water flow 3m³/h		Water flow 2.4m³/h		**Water flow 1.8m³/h (same as in USA15)**	
	ASIS top	**ASIS bot**	**ASIS top**	**ASIS bot**	**ASIS top**	**ASIS bot**
ΔT of the water	3.1K	3.1K	3.8K	4K	4.7K	4.9K
Power removed	10.8kW	10.8kW	10.6kW	11.15kW	9.82kW	10.24kW
% of the total power	78%	78%	76%	80%	71%	74%

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

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

Cooling doors specification

Total power: 13.9kW

	Water flow $3m^3/h$		Water flow $2.4m^3/h$		Water flow $1.8m^3/h$ (same as in USA15)	
	14.6°C	**13.3°C**	**14.6°C**	**13.3°C**	**14.6°C**	**13.3°C**
ΔT of the water	3.1K	3.2	4°C	4.3	4.9°C	5.2
Power removed	10.8kW	11.15kW	11.15kW	11.98kW	10.24kW	10.87kW
% of the total power	78%	80%	80%	86%	74%	78%

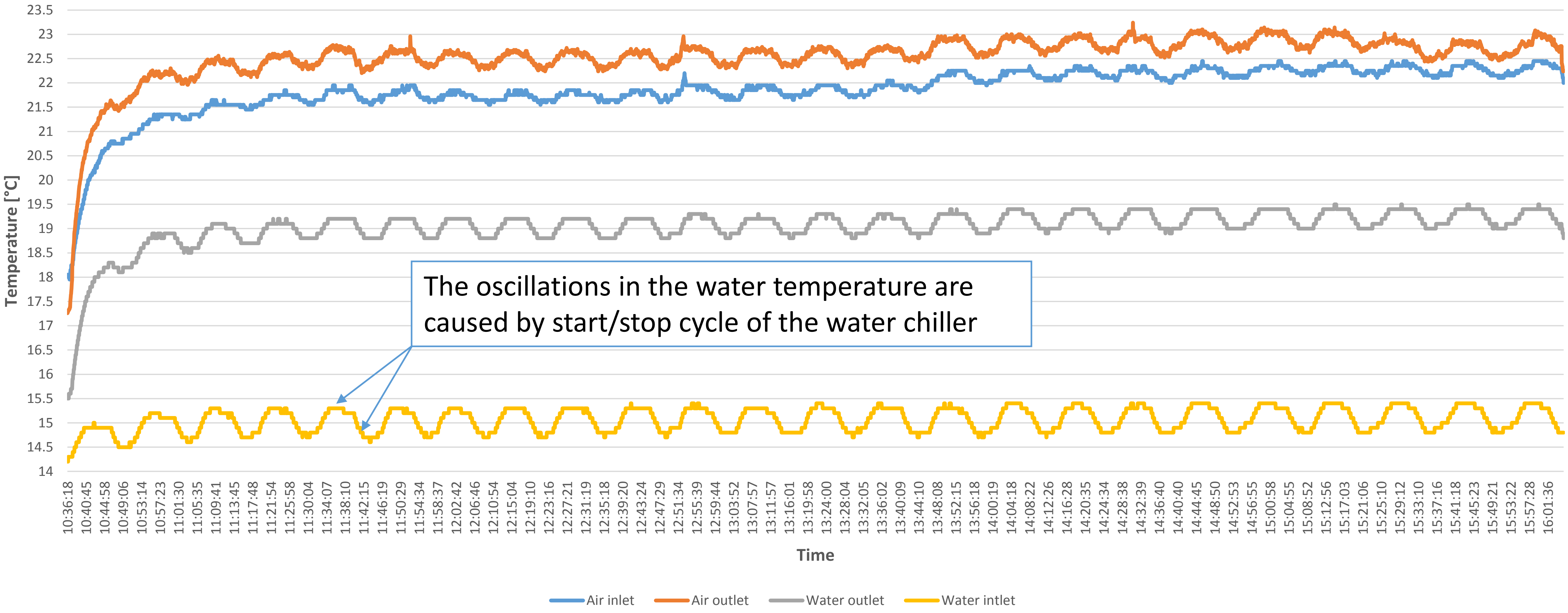
Total heat removal in vertical configuration to be measured soon

Air and water inlet/outlet temperature

Water flow 2.4m³/h

ATCA2 - 14x350W (top), ATCA1 – 14x450W (bot)
Air and water inlet/outlet temperature

Water inlet temperature
14.6°C ±0.3°C

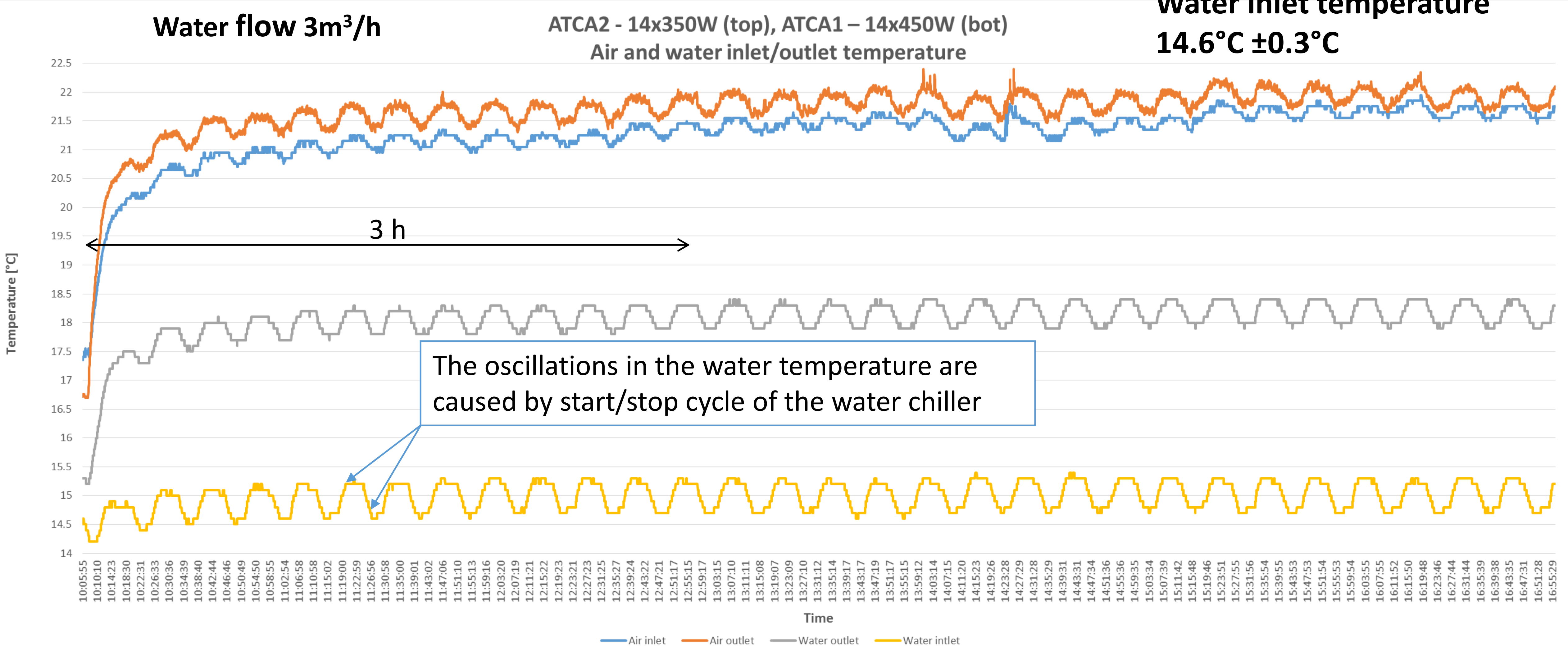


Average delta T of outlet/inlet water 4K

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

Air and water inlet/outlet temperature

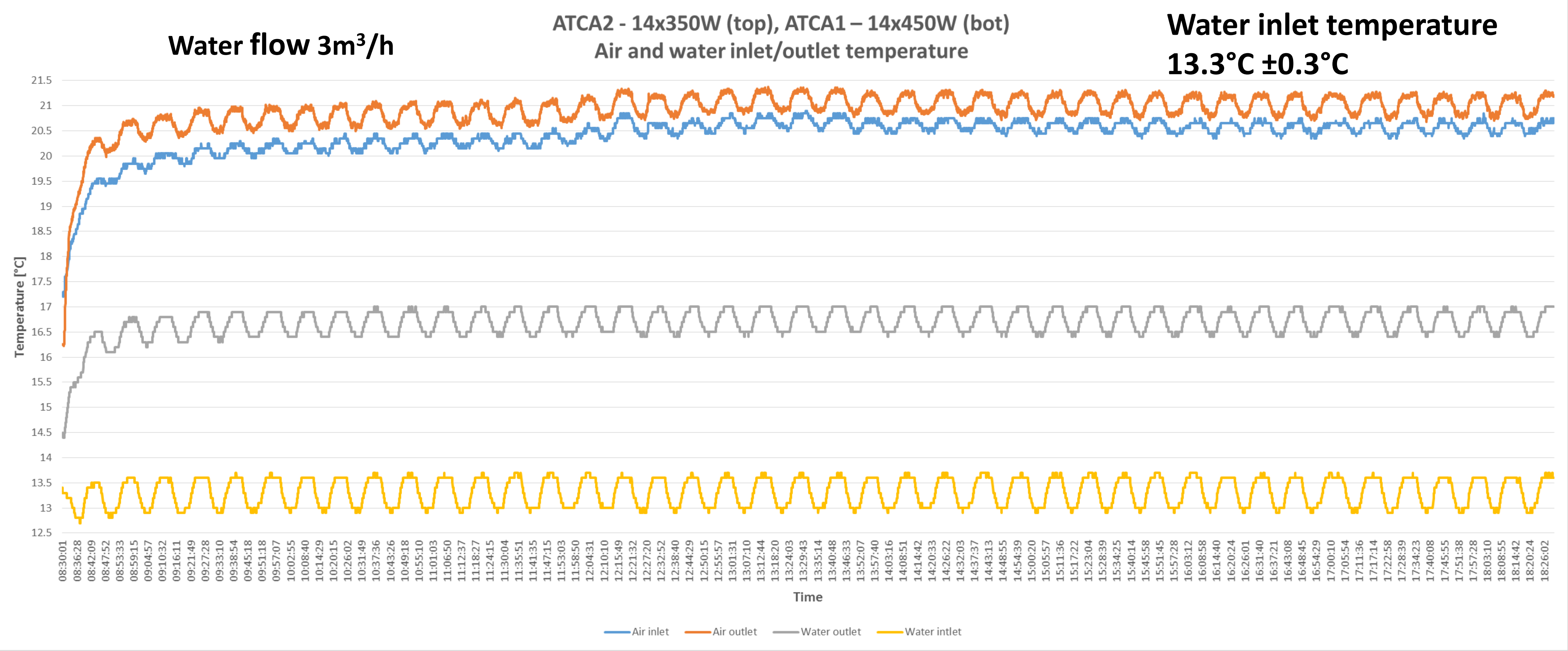
Water inlet temperature
14.6°C ±0.3°C



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

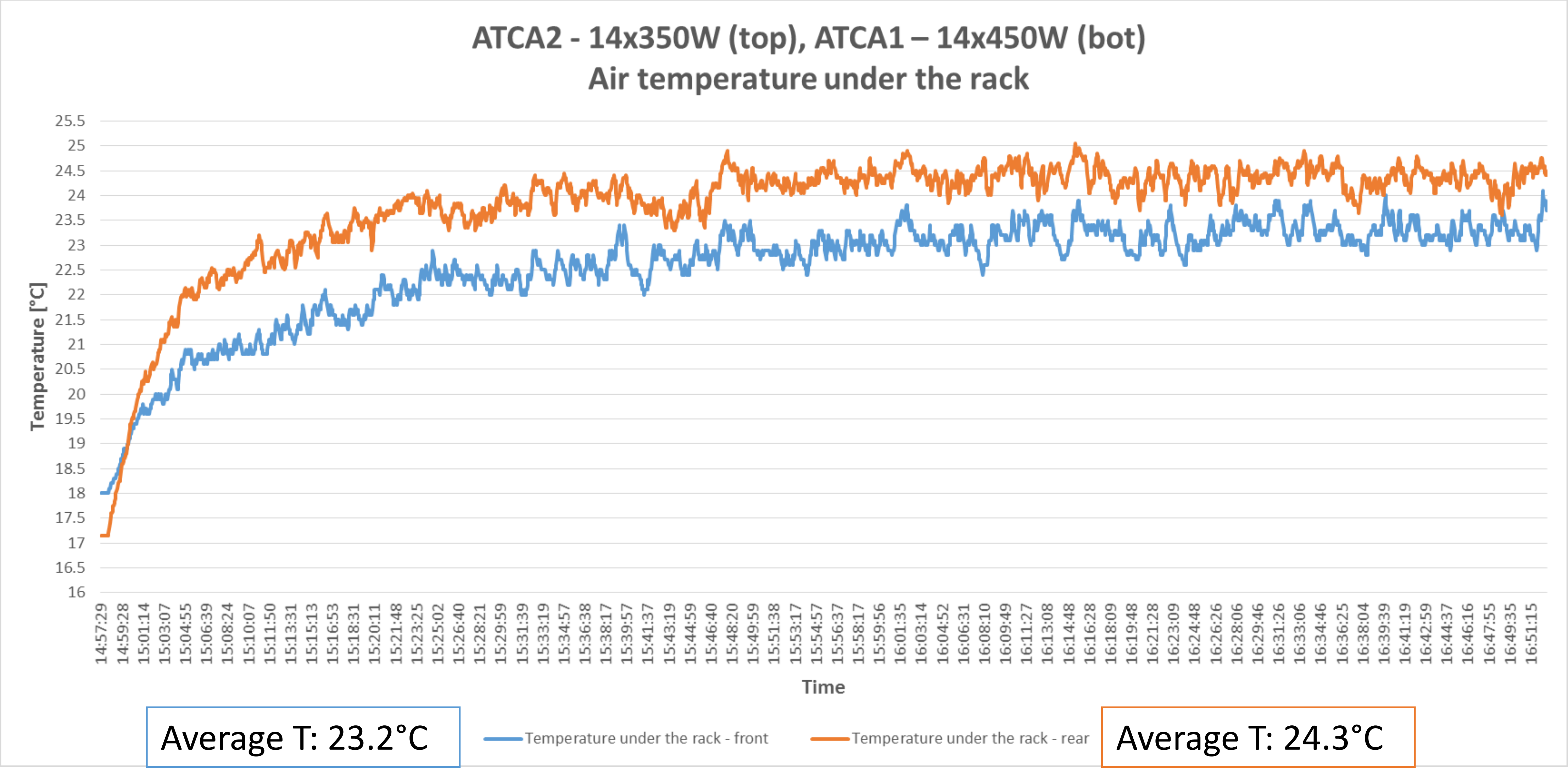
Air and water inlet/outlet temperature



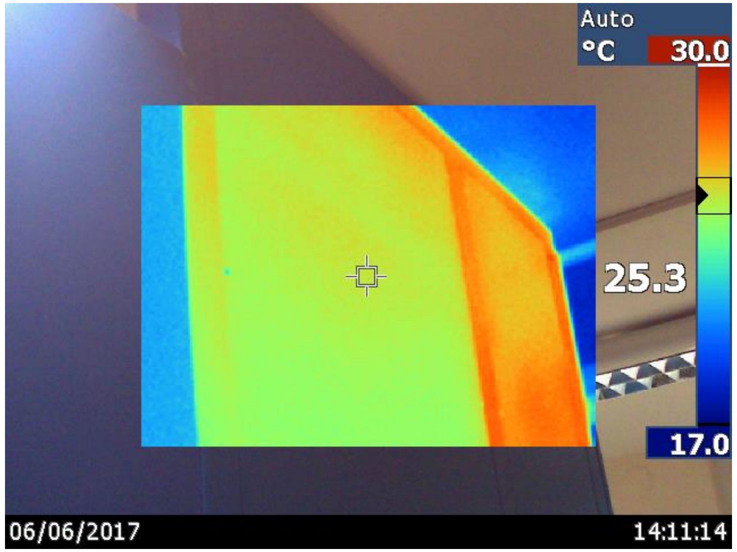
Average delta T of outlet/inlet water 3.4K

Average delta T of outlet/inlet air 0.5K
Av. outlet air T = 21°C, av. inlet air T = 20.5°C

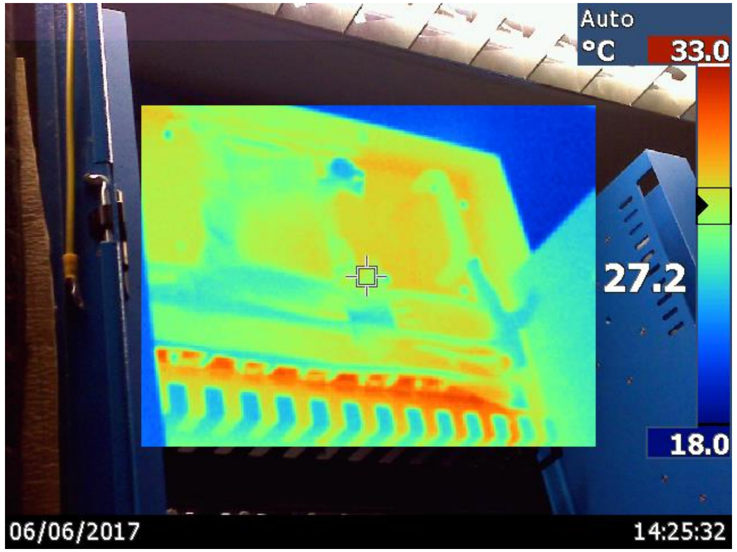
Releasing heat to the working environment: Warm air release under the rack



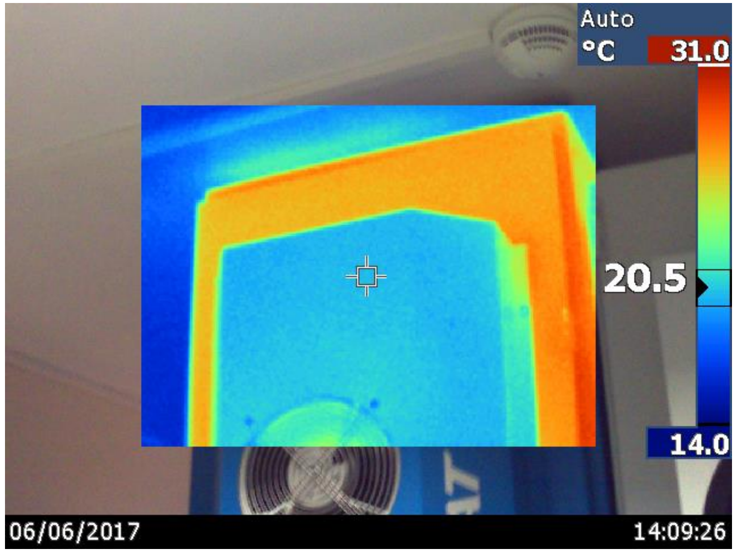
Releasing heat to the working environment: thermal camera pictures



Side of the rack



Front of the rack – turbine unit (switched off)

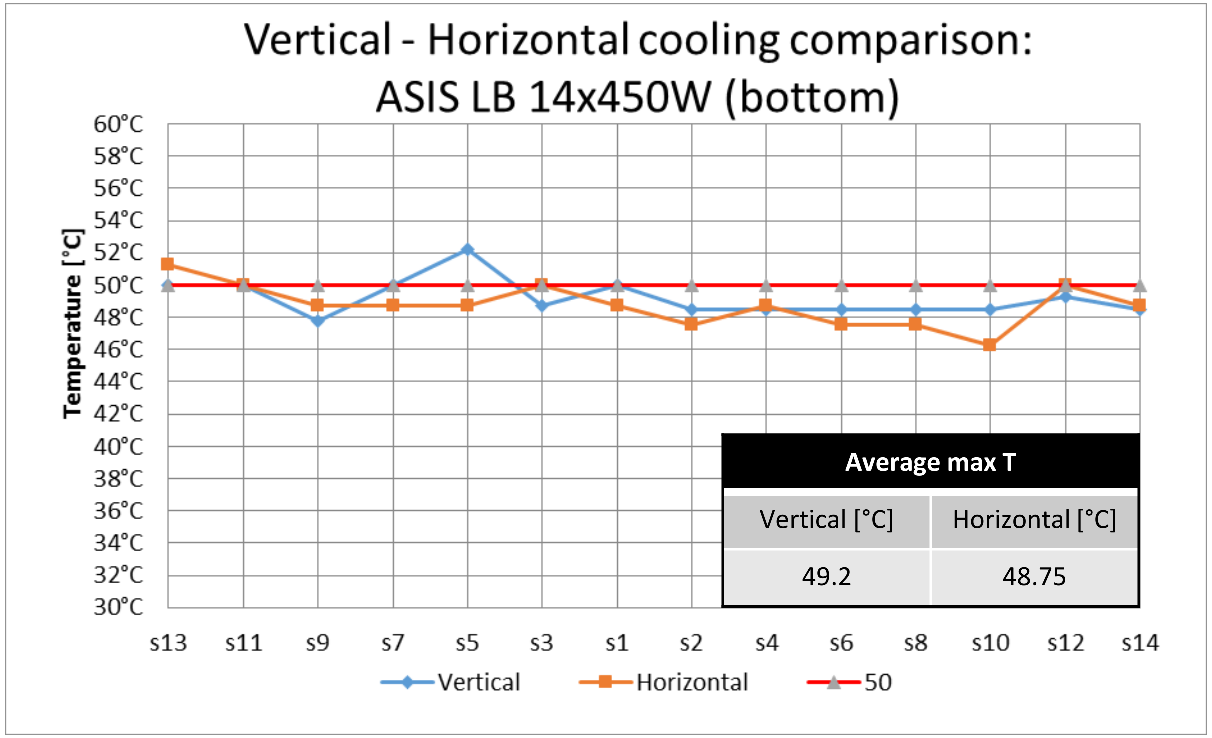


Rear of the rack – cooling doors

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 **<u>Comtel LB in Schroff crate</u>**, Bottom – 14x450W ASIS LB in ASIS crate. Water flow 2.4m^3/h, water temperature 13°C.



<u>The cooling performance are very similar</u>

Noise reduction: noise measurements (horizontal shelves)

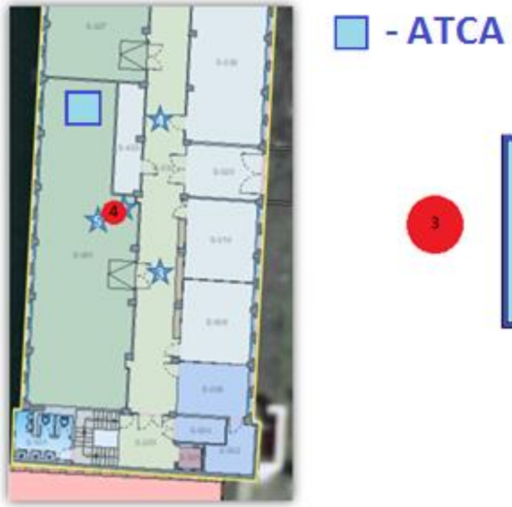
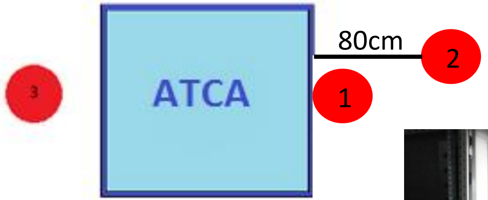


Figure 2 Lieux des mesures

All values in dBA



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.

Noise suppression material: Acoustic foam

	1	2	3
Doors open	97.2	92.7	92.4
Doors closed	85	83.1	92.4
Delta dBA	12.2	9.6	0

Fig.1. Test with only top fans working at maximum speed.

	1	2	3
Doors open	99.4	96.4	94.2
Doors closed	86.9	85.7	94.2
Delta dBA	12.5	10.7	0

Fig.2. Test with top and bottom fans working at maximum speed.

Noise suppression material: Masse lourde

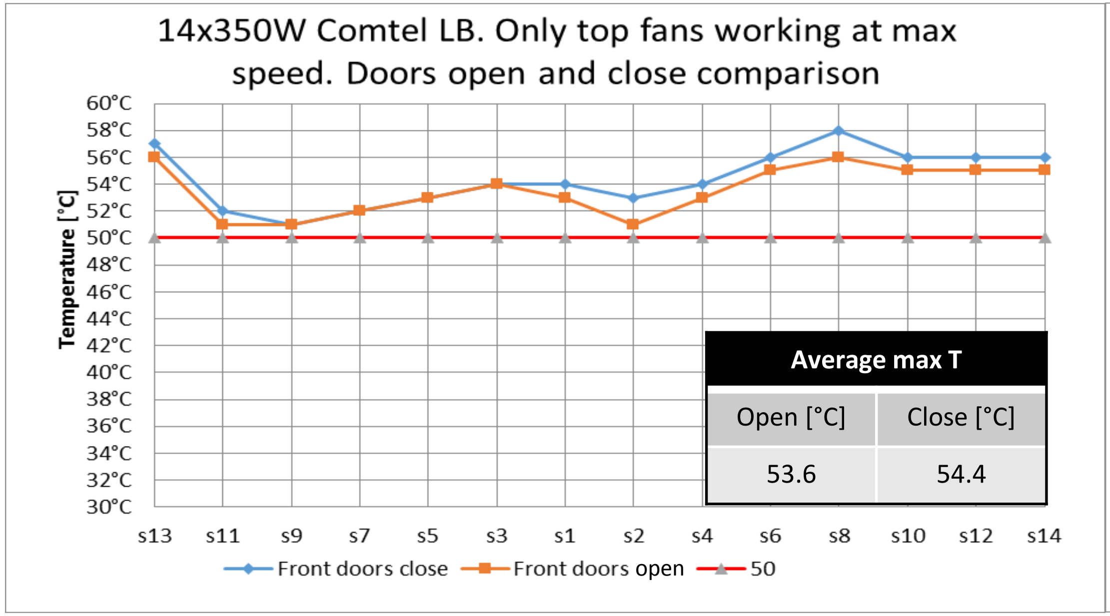
	1	2	3
Doors open	97.2	92.7	92.4
Doors closed	87.8	84.1	92.4
Delta dBA	9.4	8.6	0

Fig.3. Test with only top fans working at maximum speed.

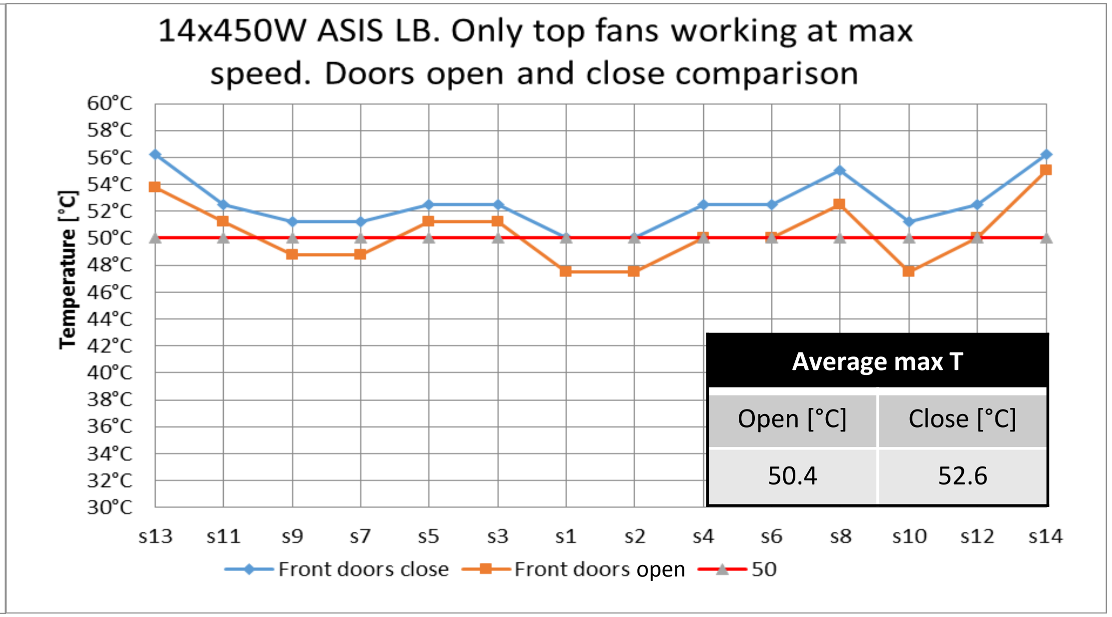
	1	2	3
Doors open	99.4	97.4	94.3
Doors closed	90.1	87.8	94.3
Delta dBA	9.3	9.6	0

Fig.4. Test with top and bottom fans working at maximum speed.

Noise reduction: Influence of closing the doors on the cooling performance



Schroff crate 14x350W



ASIS crate 14x450W

Water inlet temperature
14.6°C ±0.3°C

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.

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 - 3m^3/h and water temperature of 13-14C, the air outlet/inlet ΔT=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