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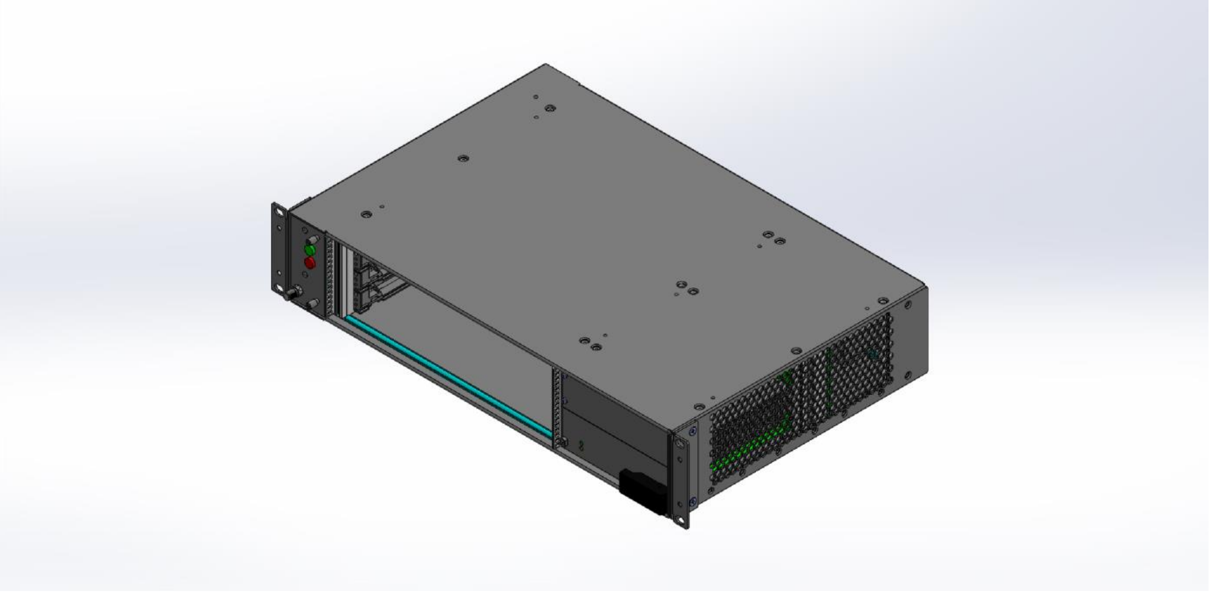
Thermal Flow Simulation Report

Project:

Thermal Study of different Fan Configurations for cooling a 2U Enclosure



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General Information

Objective of the simulation

The aim of this thermal study was to find the most efficient cooling solution for a new 4 slot 2U enclosure. The challenge was to find out the best compromise between a good cooling and an acceptable noise emission of the chosen solution. The study compares the state of the art of the enclosure with some alternative fan arrangements. It also compares a configuration where all 4 slots are equipped with cards with a configuration where only 2 slots are equipped.

Simulation Environment

Software Product:	Flow Simulation 2017 SP3.0. Build: 3794
CPU Type:	Intel(R) Xeon(R) CPU E3-1270 v5 @ 3.60GHz
CPU Speed:	3601 MHz
RAM:	32581 MB / 8388607 MB
Operating System:	Windows 7 Service Pack 1 (Version 6.1.7601)

Model Information

Model Name:	Slimbox 2U.SLDASM
Project Name:	Slimbox 2U 4x40

Project Information

Unit System:	SI (m-kg-s)
Analysis Type:	External (without Interior)
Coordinate System	Global Coordinate System

System Characterization

Initial Conditions

Thermodynamic Parameter

Static Pressure:	101325.00 Pa	
Temperature:	20.05 °C	

Velocity Parameter

Velocity Vector:	Velocity in X-Direction:	0 m/s
	Velocity in Y- Direction:	0 m/s
	Velocity in Z- Direction:	0 m/s

Solid Bodies Parameter

Default Material:	Aluminum
Initial Temperature for Solid Bodies:	20.05 °C

Simulation Model

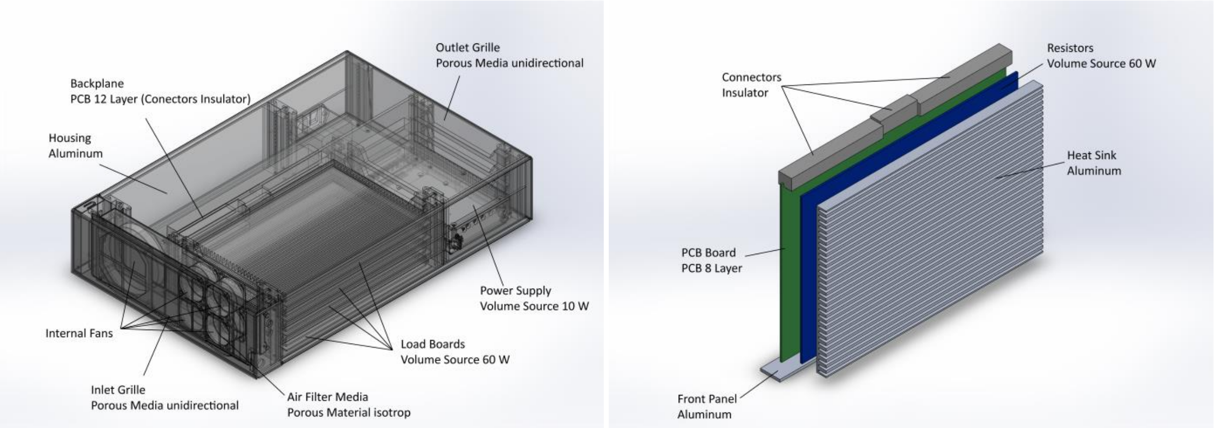


Figure 1: Simulation model of the enclosure and load board.

Figure 1 shows the how the simulation model of the enclosure and the simplified load boards.

The housing, fan tray, boards and power supply are modeled as solid parts with different materials (see chapter Materials). Heat sources are the resistors on the load boards and the power supply. They are modeled as volume sources with power loss. Also the heat sinks on the load boards are modelled as solid bodies. The fans, in- and outlets and the filter media are modelled as CFD-features. Air inlet and outlet are modeled as unidirectional porous media as well as the air filter media which is modeled as an isotropic porous media. For the fans the fan feature is used.

As another simplification because of missing information the equipment on the board of the power supply is only modelled as block, which fills 2/3 of the power supply interior volume. This should represent the flow resistance for the air flow through the power supply.

Also the resistor arrays on the load boards are not modelled in detail, they are combined to one single block which has the dimensions of the arrays envelope.

In the study the configurations listed in Table 1 were analyzed.

Configuration	Used Fans	Load Boards
Configuration A (Default)	Fan 1: SD 109R0812T4H101	Slot 1, Slot 2, Slot 3, Slot 4
Configuration B (Powerful Fans 80 x 80)	Fan 2: SD 9GV081P4J03	Slot 1, Slot 2, Slot 3, Slot 4
Configuration C (Modified Fan Panel Fans 40 x 40)	Fan 3: SD 109P0412B303	Slot 1, Slot 2, Slot 3, Slot 4
Configuration D (Default only two Fans)	Fan 1: SD 109R0812T4H101	Slot 1, Slot 2, Slot 3, Slot 4
Configuration E (One powerful plus one default fan)	Fan 1: SD 109R0812T4H101 Fan 2: SD 9GV081P4J03	Slot 1, Slot 2, Slot 3, Slot 4
Configuration F (Default half equipped)	Fan 1: SD 109R0812T4H101	Slot 1, Slot 3

Table 1: Analyzed configurations.

Simulation Parameters

Size of Computational Domain

X max:	0.350 m
X min:	0.050 m
Y max	0.150 m
Y min	-0.070 m
Z max	0.400 m
Z min	-0.400 m

Mesh Settings

All studies were simulated with the same mesh settings. The simulation mesh was generated with the automatic meshing method. The initial level for the mesh was set to 2. Additional the enhanced gab refinement was activated and the minimum gap size was set to 0.005 m. Also the small gap filling option was used with a minimum size for small gaps of 1 mm.

Basic Mesh

Dimensions Basic Mesh

No. Of Cells X Direction:	6
No. Of Cells Y Direction:	6
No. Of Cells Z Direction:	12

Analysis Mesh

Total Cell count:	4645309
Fluid Cells:	2314827
Solid Cells:	2330482
Partial Cells:	1513195
Trimmed Cells:	7266
Irregular Cells	8
Auto Meshing	ON
Max. Refinement Level	6

The result of the meshing process is given in Figure 2 as a cut view parallel to the ground.

It can be seen, that the maximum refinement level is 6 which leads to 2 mm for the minimum edge length of the volumes. This means that the channels between two heat sink fins are parted into 3 cells.

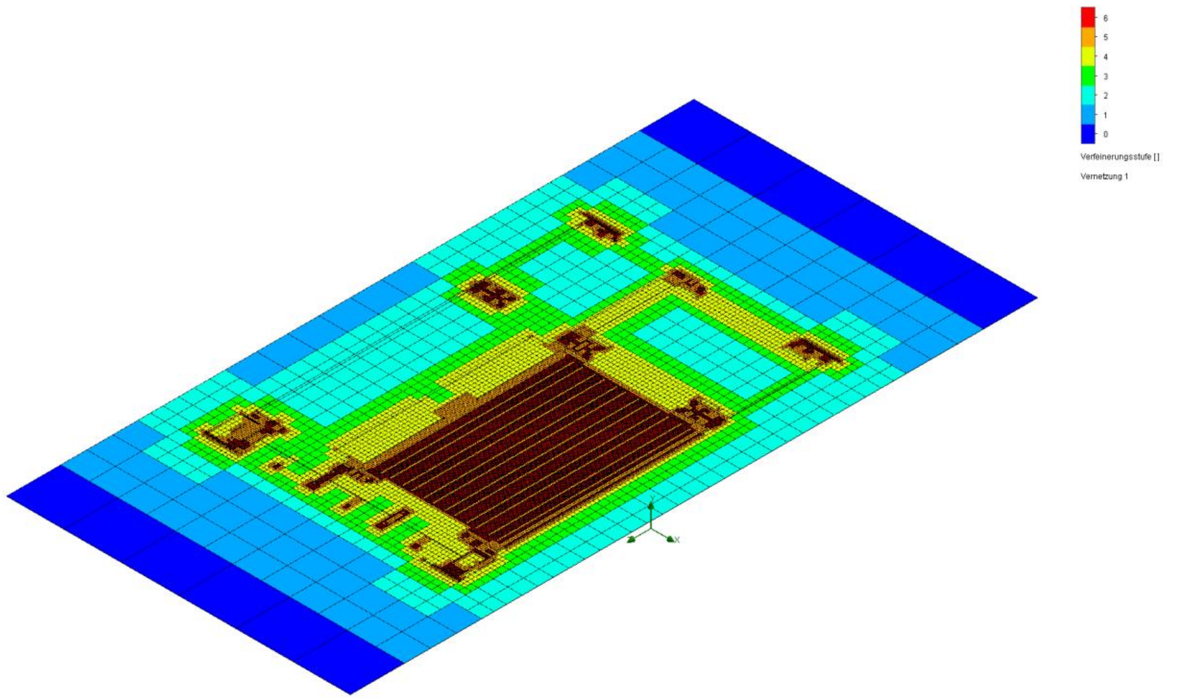


Figure 2: Cut view of the simulation mesh.

Input Data

Materials

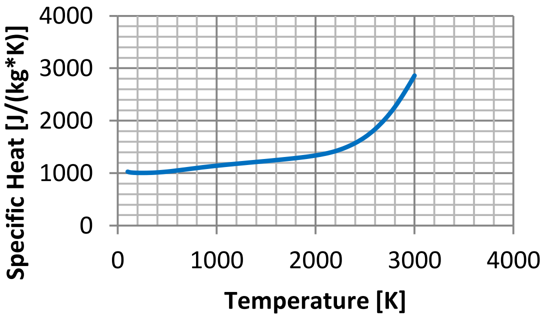
Fluids

Air

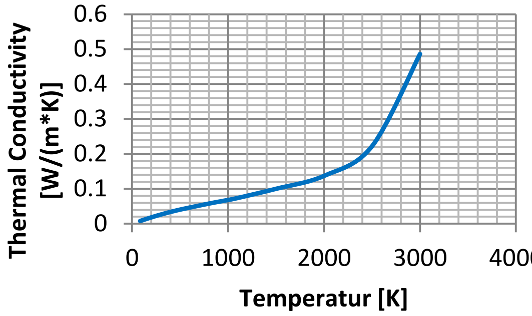
Isentropic Exponent cp/cv: 1.399

Molar Mass: 0.02896 g/mol

Specific Heat c_p:



Thermal Conductivity:

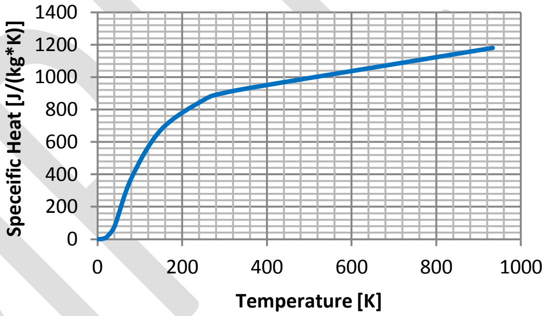


Solid Materials

Aluminum

Density: 2688.9 kg/m^3

Specific Heat c_p:



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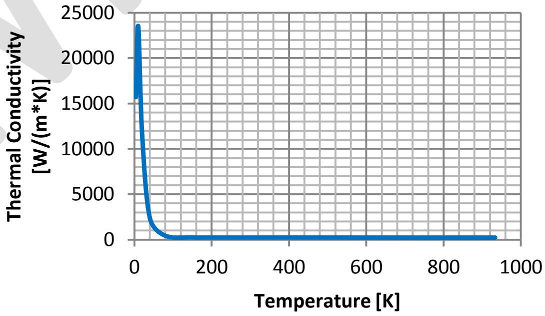
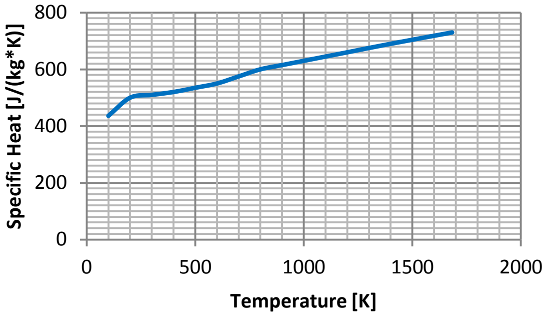


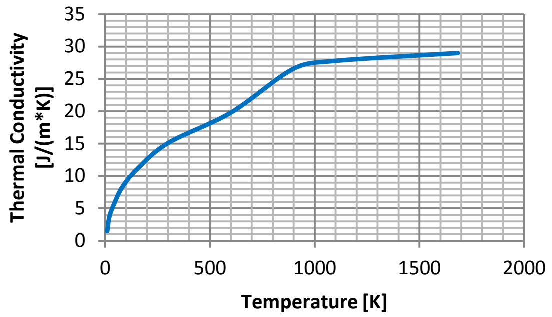
Structural Steel

Density: 2688.9 kg/m^3

Specific Heat c_p:



Thermal Conductivity:



PCB Board 12 Layer

Density: 2688.9 kg/m^3
Specific Heat c_p: 1039 J/(kg*K)
Thermal Conductivity Transversal: 0.29 W/(m*K)
Thermal Conductivity Lateral: 41.1 W/(m*K)

PCB Board 8 Layer

Density: 2391 kg/m^3
Specific Heat c_p: 1073 J/(kg*K)
Thermal Conductivity Transversal: 0.28 W/(m*K)
Thermal Conductivity Lateral: 32.7 W/(m*K)

Fans

Internal Fan 1

Type: Internal Fan
Specification SD 109R0812T4H12
Dimension (L x W x H): 80 mm x 80 mm x 25
RPM: 2900 min^{-1}
Sound Pressure: 29 dB(A)
Air Flow – Static Pressure Characteristics:

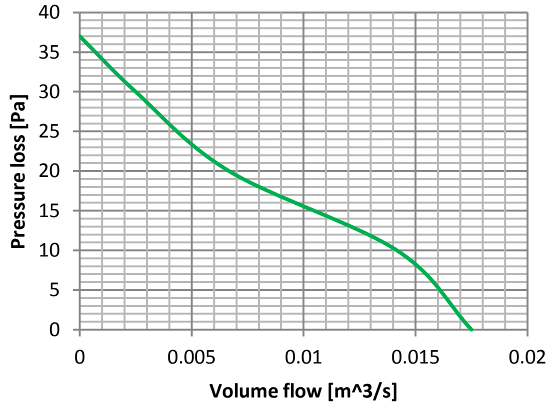


Figure 3: Flow chart internal fan 1.

Internal Fan 2

Type:	Internal Fan
Specification:	SD 9GV081P4J03
Dimension (L x W x H):	80 mm x 80 mm x 25
RPM:	4500 min^{-1}
Sound Pressure:	46 dB(A)
Air Flow – Static Pressure Characteristics:	

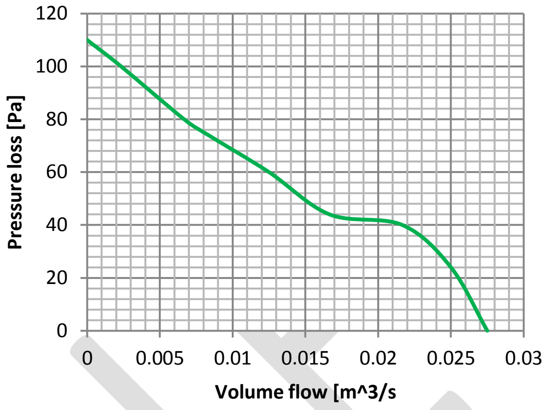


Figure 4: Flow chart internal fan 2.

Internal Fan 3

Type:	Internal Fan
Specification:	SD 109P0412B3013
Dimension (L x W x H):	40 mm x 40 mm x 28
RPM:	10300 min^{-1}
Sound Pressure:	40 dB(A)
Air Flow – Static Pressure Characteristics:	

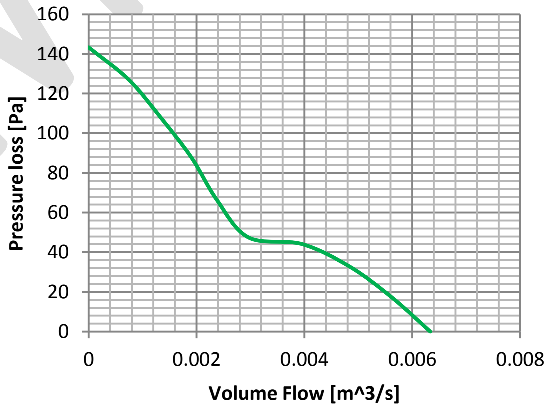


Figure 5: Flow chart internal fan 3.

Porous Media

Air inlet and outlet are modelled as unidirectional porous media features as well as the filter media between air inlet and the fans. The inlet and outlet is represented as a 6 mm hexagon perforation with a pitch of 7 mm. Its pressure loss velocity chart is given in Figure 6. For the filter media a typical ¼” 45 PPI quadrafoam was used (Figure 7).

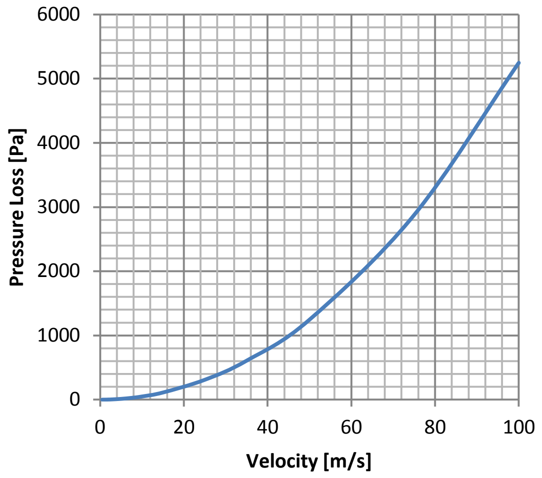


Figure 6: Pressure loss – velocity chart in/outlet.

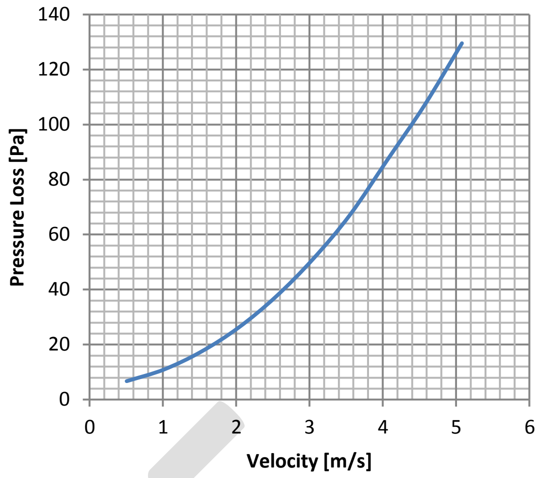


Figure 7: Pressure loss – velocity chart filter media.

Heat Sources

The thermal load of the system is caused by the load boards and the power supply. For the simulation the power supplies total power (minus its power loss) was uniformly distributed to the resistor blocks on the load boards. This results in four volumetric heat sources with a heat power of 60 W. The dimensions of the resistor blocks correspond with the envelope of the resistors on the real load boards.

The power supply was also modelled as volume source, represented by a block that fills 2/3 of the power supplies interior and produces 10 W heat power.

Solution

Additional Physical Calculation Options

Heat Transfer Analysis:	Heat Transfer in Solids:	OFF
	Only Heat Transfer in Solids:	OFF
Flow Type:	Laminar and turbulent	
Time-Dependent Analysis:	OFF	
Gravity:	ON	
Gravity Properties	X-Component	0 m/s^2
	Y-Component	9.81 m/s^2
	Z-Component	0 m/s^2
Rotation	OFF	
Radiation:	OFF	
Humidity:	OFF	
Default Wall Roughness:	0 Micrometer	

Simulation Goals

The most interesting results of the simulation are listed in Table 2. They are defined as simulation goals and were used for generating the convergence criteria for the solver.

Name	Unit	Progress [%]	Use for Convergence
Surface Goal Avg. Temperature (Fluid)	[°C]	100	YES
Surface Goal Max. Temperature (Fluid)	[°C]	100	YES
Heat Sink 1 Avg. Temperature (Solid)	[°C]	100	YES
Heat Sink 1 Max. Temperature (Solid)	[°C]	100	YES
Heat Sink 2 Avg. Temperature (Solid)	[°C]	100	YES
Heat Sink 2 Max. Temperature (Solid)	[°C]	100	YES
Heat Sink 3 Avg. Temperature (Solid)	[°C]	100	YES
Heat Sink 3 Max. Temperature (Solid)	[°C]	100	YES
Heat Sink 4 Avg. Temperature (Solid)	[°C]	100	YES
Heat Sink 4 Max. Temperature (Solid)	[°C]	100	YES
Volume Flow Rate Outlet	[m^3/s]	100	YES
Volume Flow Rate Inlet	[m^3/s]	100	YES

Table 2: Simulation goals for the study.

Convergence Charts

The convergence charts for the simulation goals of the four simulated configurations are given in Figure 8 to Figure 13.

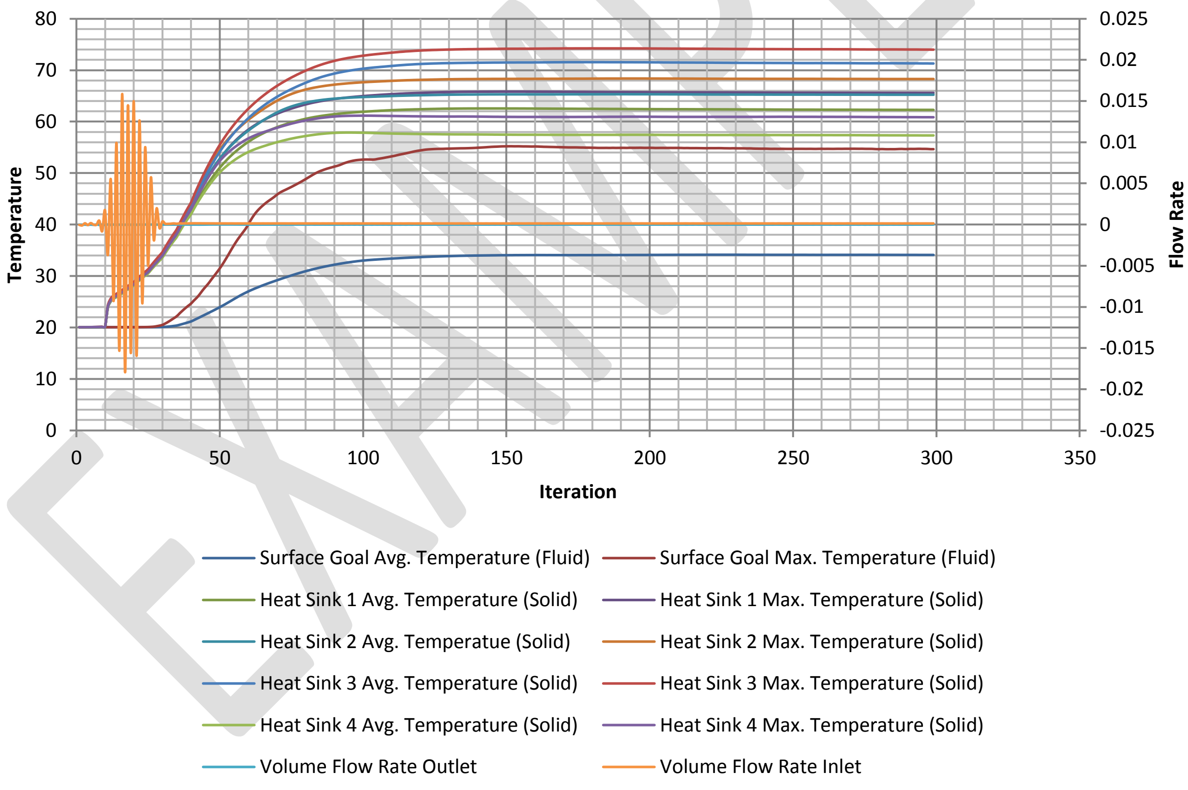


Figure 8: Convergence plot of configuration A.

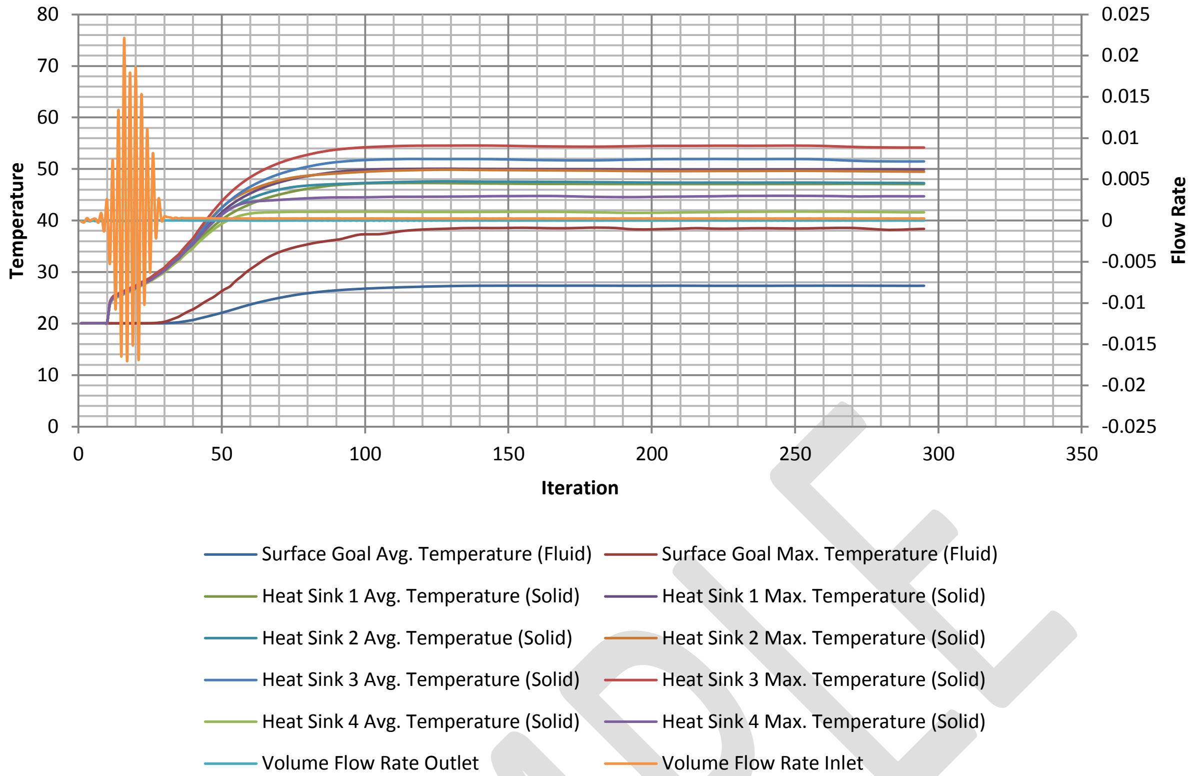


Figure 9: Convergence plot of configuration B.

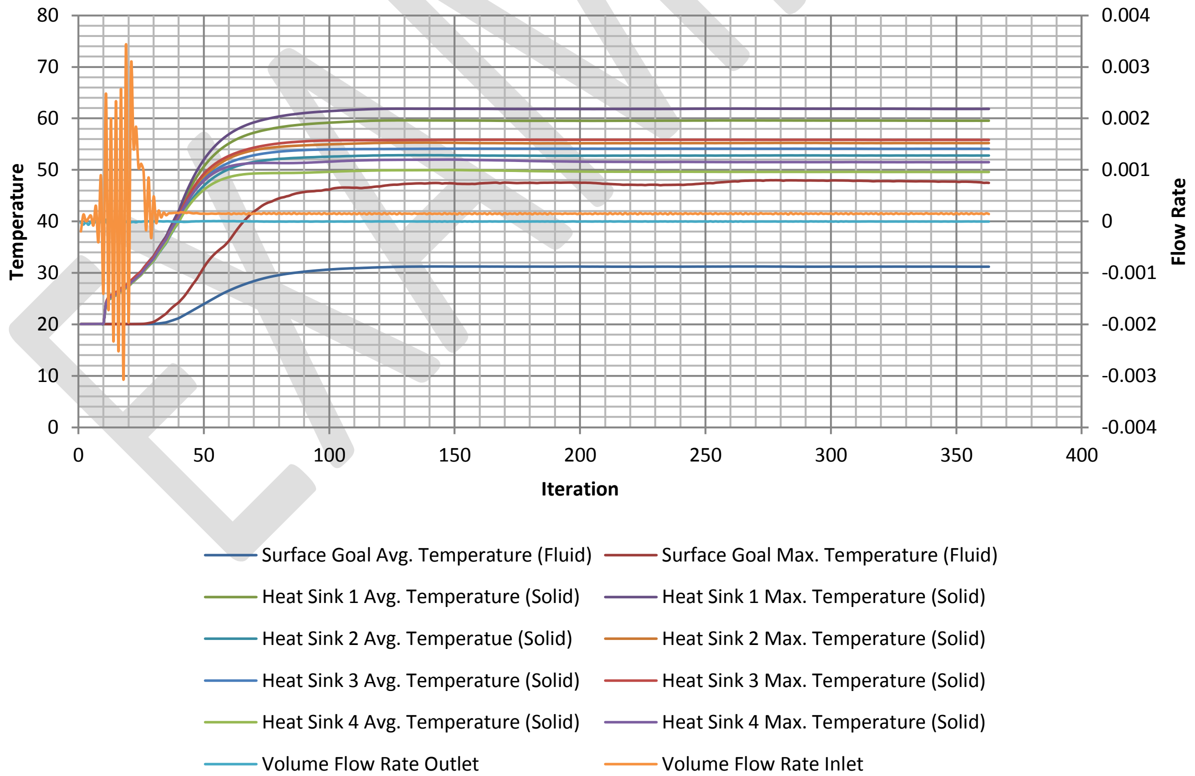


Figure 10: Convergence plot of configuration C.

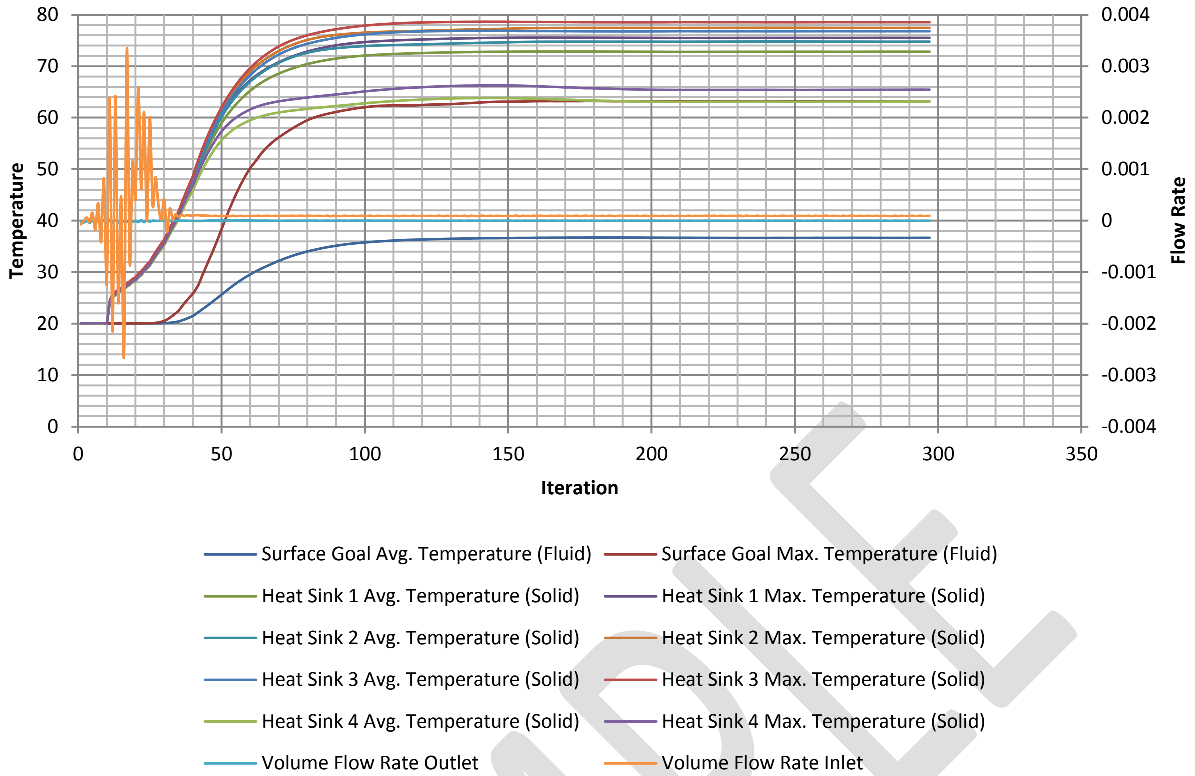


Figure 11: Convergence plot of configuration D.

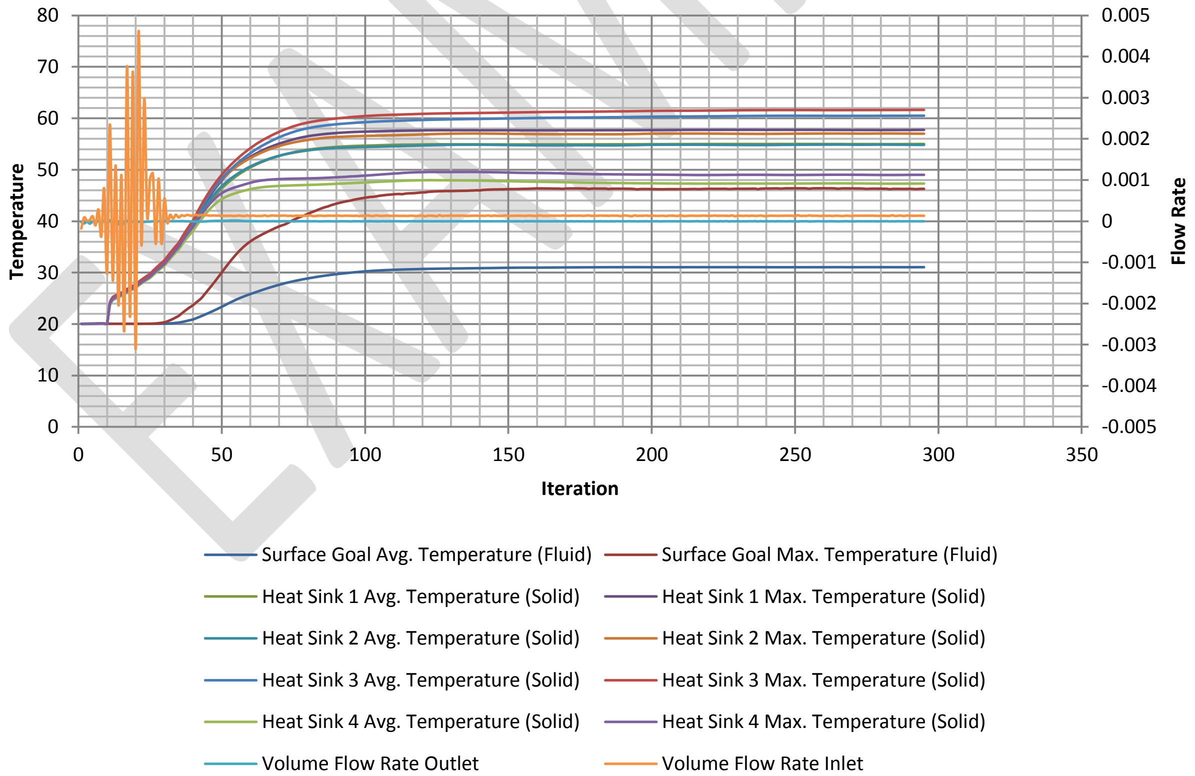


Figure 12: Convergence plot of configuration E.

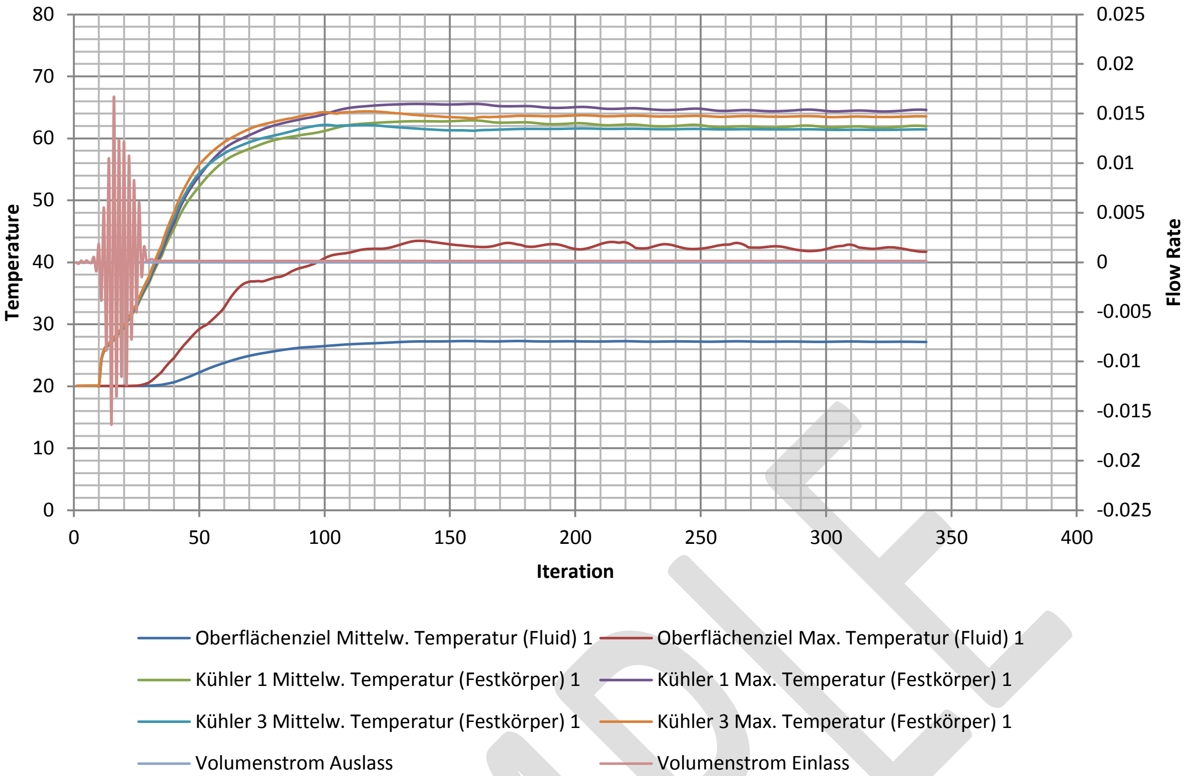


Figure 13: Convergence plot of configuration F.

Results

First the results of the three different fan arrangements should be discussed. Therefore the temperatures and the steam lines of each configuration were analyzed. The simulation showed that for the configurations A and B the hot spot is located on resistor block of the load board in the third slot (counted from bottom) for configuration C and D the hot spot is located on resistor block of the load board in the first slot. Figure 14 to Figure 16 are showing the temperature fields and the steam lines for each configuration in the plane 5 mm above the hot spot. This is done, because the resistor block is a solid body and there will be no information about the air flow, a cut view through the heat sink of the resistor block contains this information and the temperature is nearly the same. A comparison of the temperature results on the resistor blocks is given in Table 3.

	Config. A	Config. B	Config. C	Config. D	Config. E	Config. F
Temperature						
Min	20.04 [°C]	20.04 [°C]	20.04 [°C]	20.04 [°C]	20.04 [°C]	20.04
Max	74.0 [°C]	54.1 [°C]	61.8 [°C]	78.5 [°C]	61.8 [°C]	64.6

Table 3: Comparison of calculated temperatures.

As you can see from the table the best cooling is achieved with the 80 mm high flow rate fans. But it is remarkable that the maximum temperature with 40 mm fans, which are positioned more central relative to the load boards and cover a smaller area, is only about 7 °C higher. This fact leads to two more studies with configuration D and E with 80 mm fans in this location.

A comparison of the steam lines of configuration B and C in the figures shows, that the 80 mm fans of configuration B (also on A), which cover the full side area, are generating a swivel in the lower left region of the enclosure. The swivel is caused by the profile in this region, which is essential needed due to mechanical reasons. Contrary to configuration B the swivel does not exist in the steam lines of configuration C. This leads to the conclusion that the air flow through the heat sinks is blocked by the swivel. Although the high flow rate fans are leading to the lowest temperature, this configuration is not the most efficient. It seems that there is a massive loss in cooling because of the swivel which is generated by them.

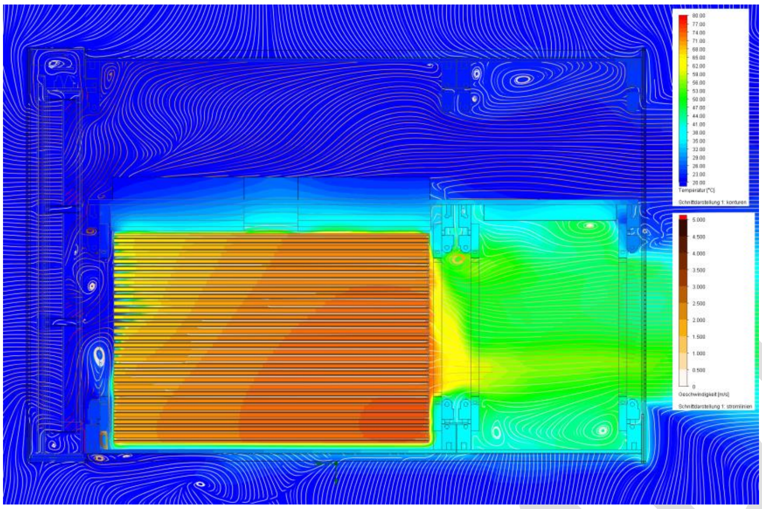


Figure 14: Cut view of temperature field with steam lines configuration A.

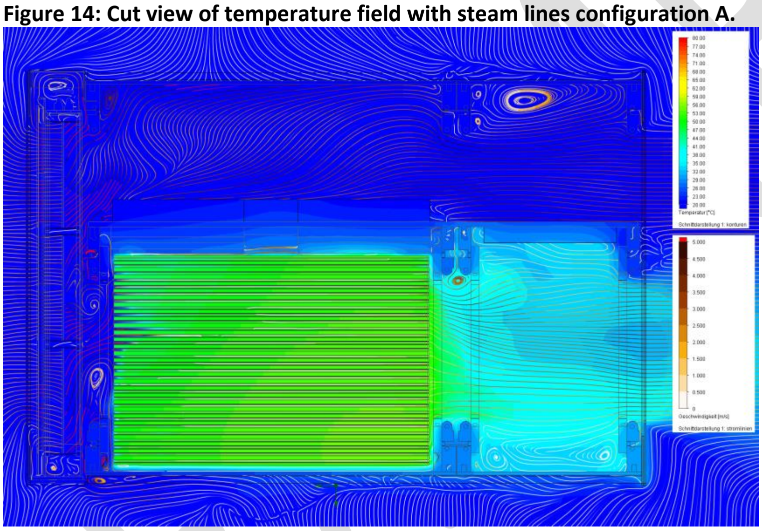


Figure 15: Cut view of temperature field with steam lines configuration B.

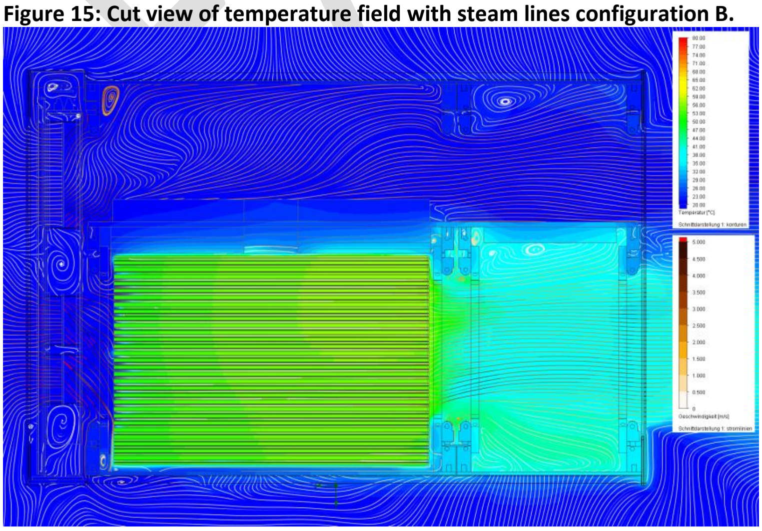


Figure 16: Cut view of temperature field with steam lines configuration C.

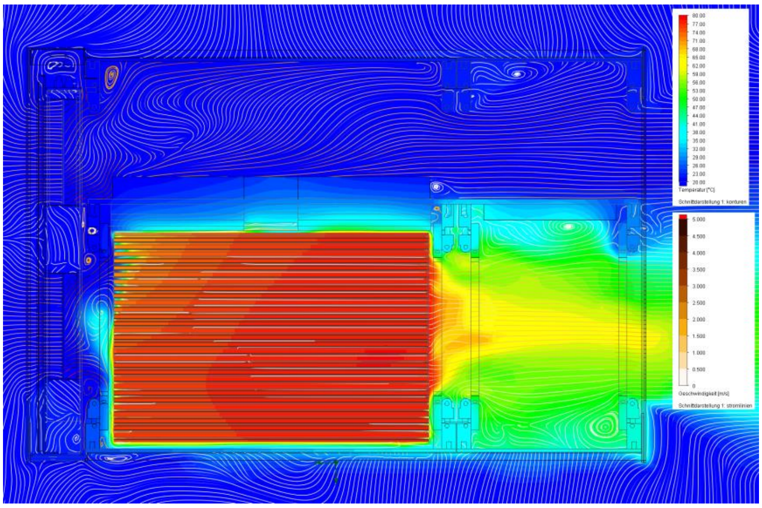


Figure 17: Cut view of temperature field with steam lines configuration D.

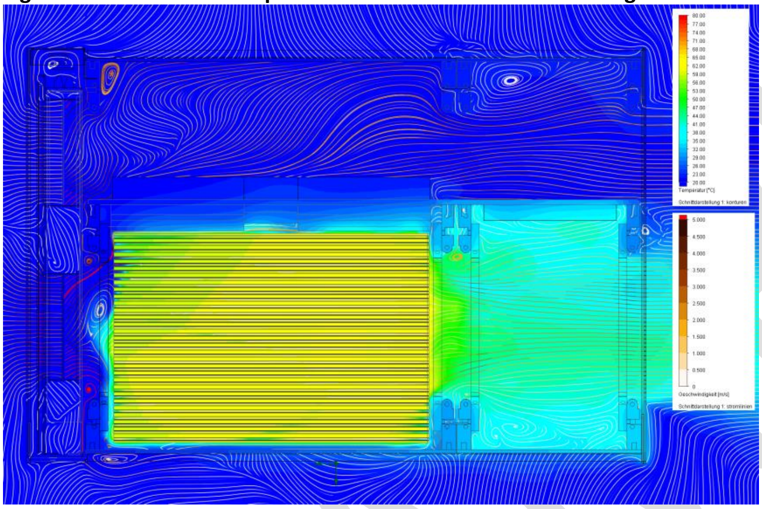


Figure 18: Cut view of temperature field with steam lines configuration E.

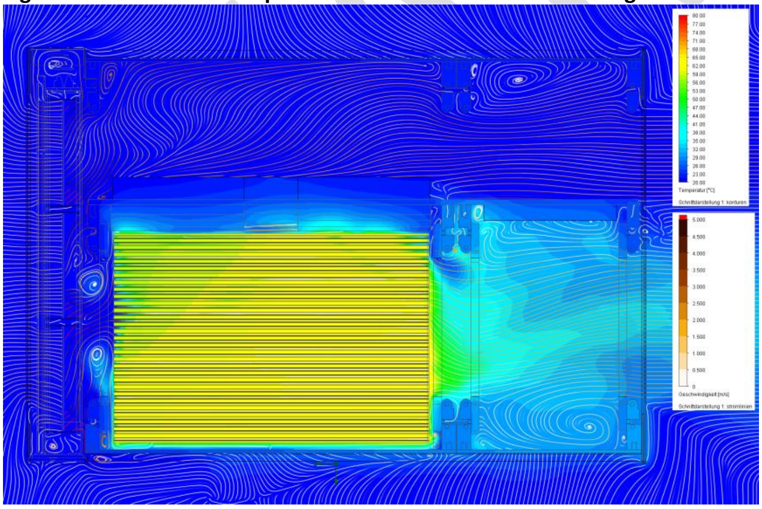
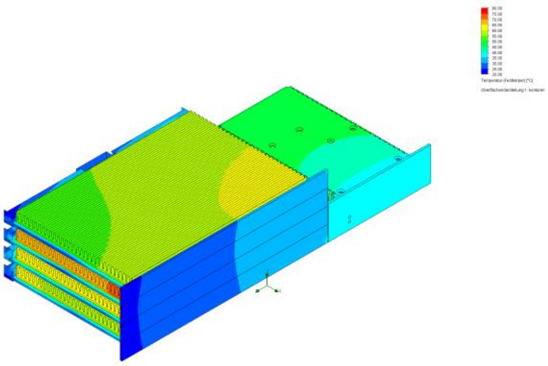
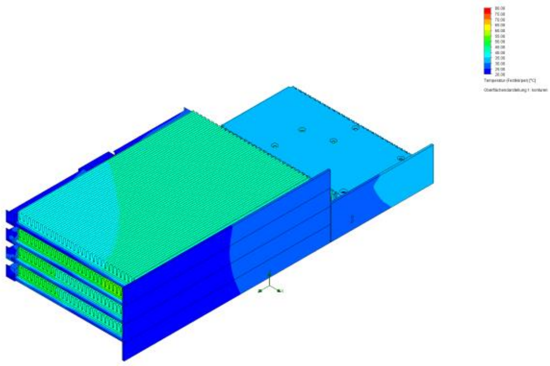


Figure 19: Cut view of temperature field with steam lines configuration F.

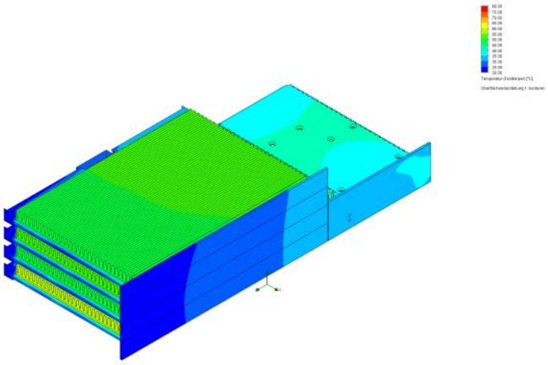
The following pictures are showing the temperature distribution on the interior.



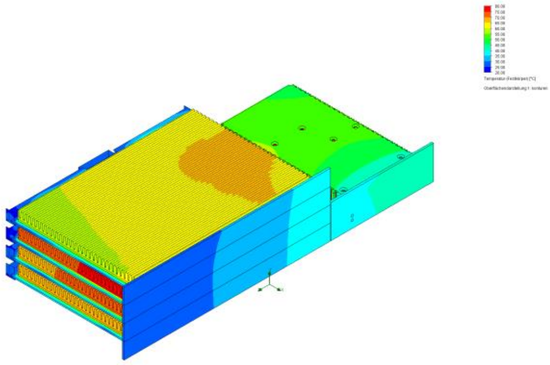
Configuration A



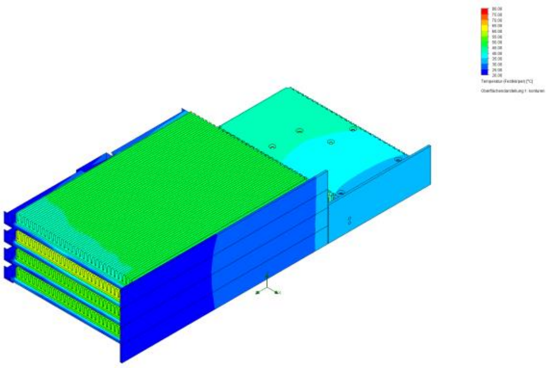
Configuration B



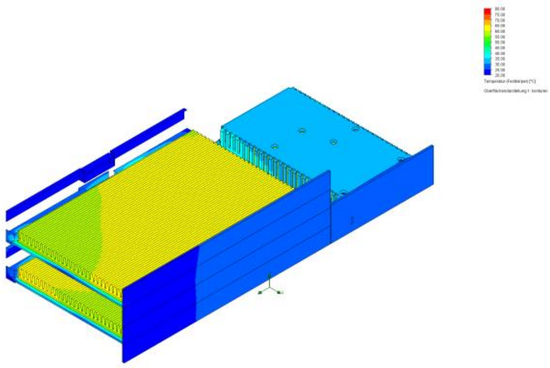
Configuration C



Configuration D

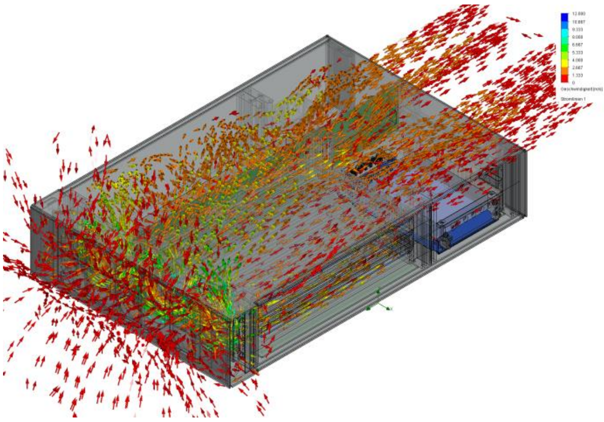


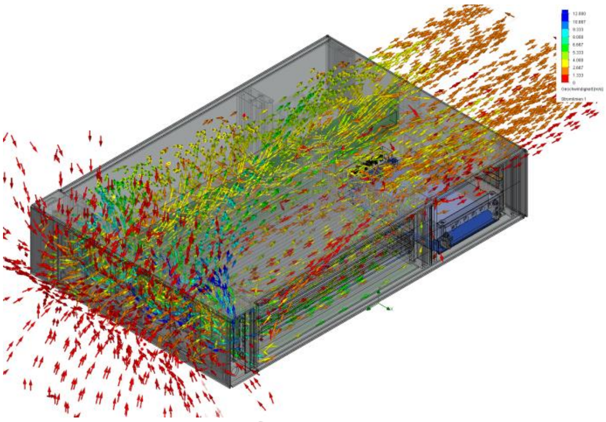
Configuration E

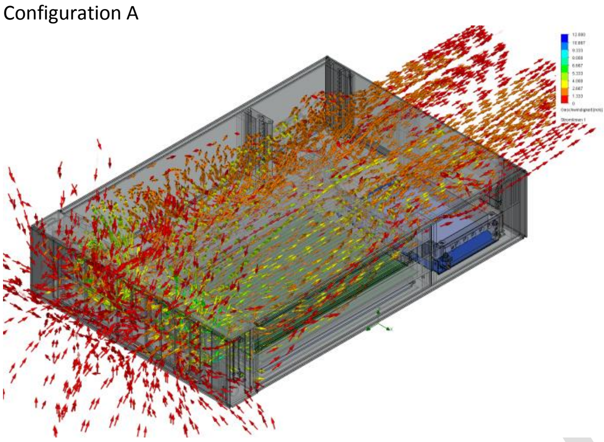


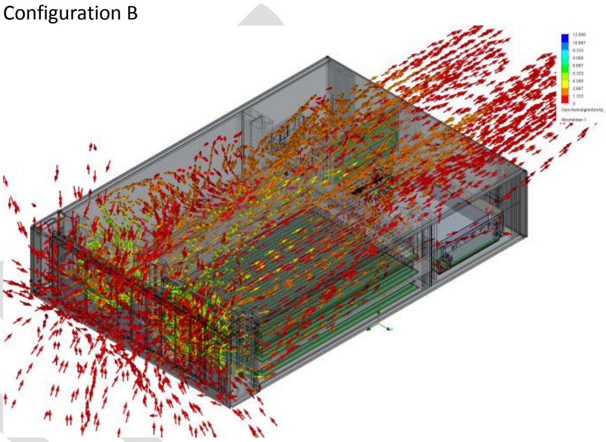
Configuration F

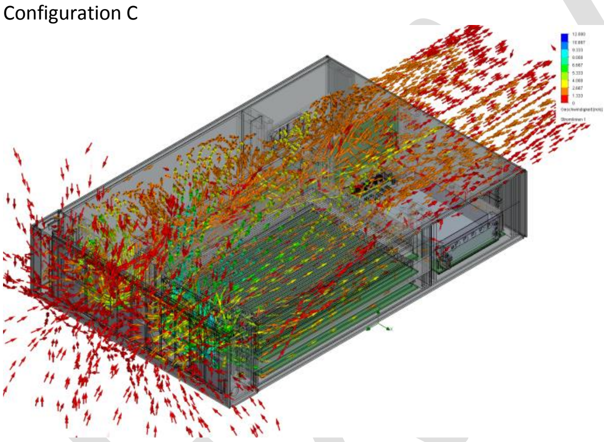
Figure 20: Temperature distribution on interior.


Configuration A


Configuration B


Configuration C


Configuration D


Configuration E

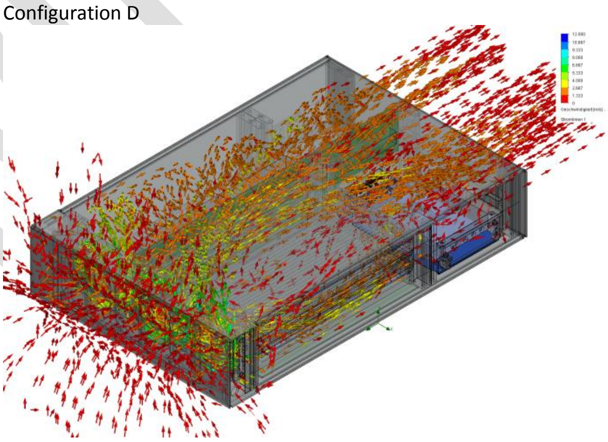

Configuration F

Figure 21: Flow trajectories.

The comparison of configuration A and D (full and half equipped) shows that the swivel is not only caused by the profile of the enclosure but also by the height of the flow channels between the load boards. There is a temperature difference of about 10 °C between configuration A and D. So it can be said that the swivel behind the fans has to be avoided to get the most efficient cooling.

Another goal of the study was to achieve a cooling solution with moderate noise emission. In Table 4 the total sound pressure level caused by the fans is listed.

	Config. A	Config. B	Config. C	Config. D	Config. E	Config. F
Sound Pressure	33 dB(A)	49 dB(A)	46 dB(A)	32 dB(A)	45 dB(A)	33 dB(A)

Table 4: Sound pressure level for each configuration.

All configurations produce an acceptable noise emission. Nevertheless configuration B generates the highest noise emission.

Summary

The study showed that the best cooling results are reached with the high flow rate of the high flow rate 80 mm fans (Configurations B and E). But regarding the noise emission and the cooling efficiency configuration C with 40 mm fans seems to be also recommendable.

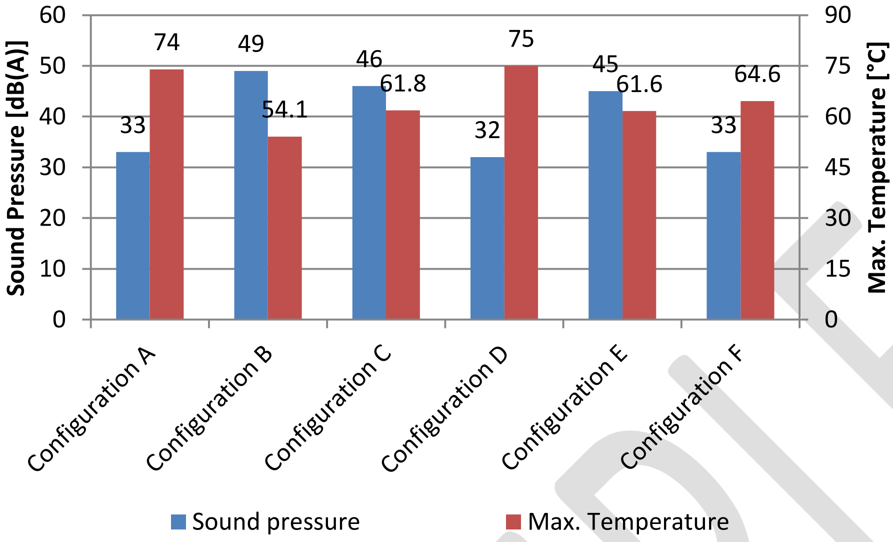


Figure 22: Summary of the simulation results.

The configuration E with one high flow rate 80 mm fan and C with four 40 mm fans combine a good cooling behavior and an acceptable noise emission. These configurations are nearly identical from the point of cooling efficiency and noise emission. Why to prefer configuration C is the reason that there is still a reserve in cooling if one fan has a failure. This is an advantage against the solution with one high flow rate fan which provides no cooling reserve in case of a fan failure.

The acknowledgement that not only high flow rates lead to good cooling results, but also a optimized flow field should give impulses for further studies of a more detailed investigation of positioning fans in enclosures.