UNIVERSITÉ de Liège

Faculty of Applied Sciences
ArGEnCo Department (Architecture, Geology, Environment & Constructions) –
Sector Arkhê (Architecture)

Laboratory of Architecture: Performances & Techniques (LAP&T)
Director: Dr. Eng. Jean-Marie HAUGLUSTAINE, Associate Professor

Cold bridges on the building site of the European Bank of Investment at Luxemburg – Report 03

I the undersigned,

Jean-Marie HAUGLUSTAINE, civil engineer in architecture, doctor in applied sciences, Associate Professor at the ArGEnCo Department (Architecture, Geology, Environment and Construction) of the University of Liège,

Director of the Laboratory of Architecture: Performances & Techniques,

have been put in charge by the Joint venture CFE-VINCI, of assessing the cold bridges identified on the building site and of studying the ways to reduce their importance.

The present report is devoted to the three following cold bridges:

- 1. Search of an equilibrium temperature in the installation room;
- 2. Technical rooms located under the south access ramp and above the parking access ramp;
- 3. Search of condensation risks in the technical rooms.

This report includes this flyleaf and 48 pages of calculations and conclusions.

So written in LIEGE, the 19th of December 2007,

J.-M. HAUGLUSTAINE.

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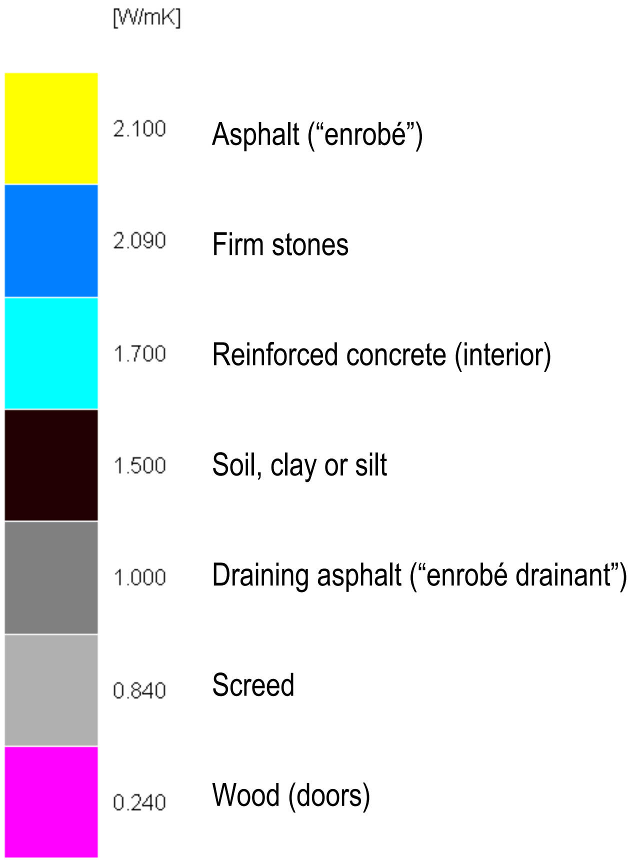
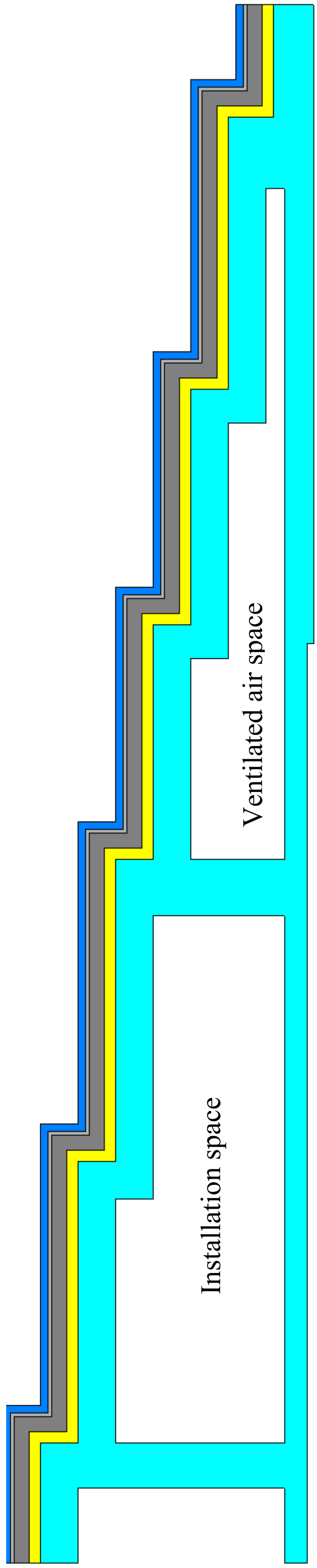
STUDY OF THERMAL BRIDGES – REPORT 03

1. SEARCH OF AN EQUILIBRIUM TEMPERATURE IN THE INSTALLATION ROOM

1.1 Input data:

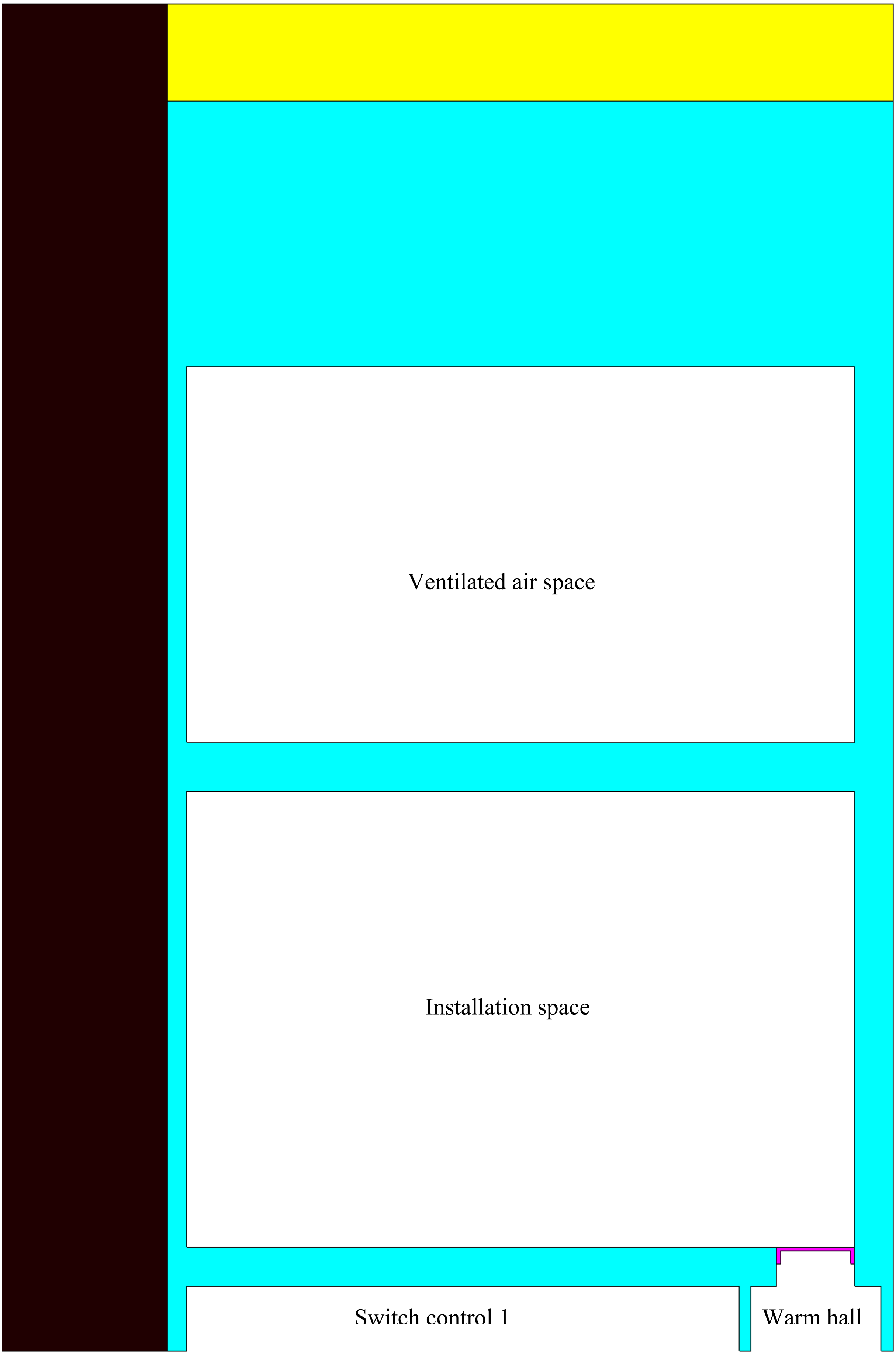
Vertical section (simulation)





Hypothesis:
- Trisco does not allow modeling a sloped structure. This, in consequence, obliged us to model a stair-shaped structure, to respect the inside volumes and to get as close as possible to the real external exchange surfaces.
- The lambda values used in this model are all coming from the Trisco data base (from the Belgian standard NBN B62-002 or from the Physibel data base).
- The temperatures used are 20°C inside (h = 8), and -12°C outside (h = 20).

Horizontal section (simulation)



TRISCO - Input Data

TRISCO data file: installation space equilibrium.trc

GRID of geometrical data

Grid unit = 0.01 m

No.	X	Y	Z
0-1	100.000	100.000	100.000
1-2	10.000	100.000	100.000
2-3	10.000	100.000	100.000
3-4	10.000	100.000	100.000
4-5	10.000	100.000	100.000
5-6	10.000	100.000	100.000
6-7	10.000	100.000	100.000
7-8	10.000	100.000	100.000
8-9	10.000	100.000	100.000
9-10	10.000	100.000	100.000
10-11	10.000	30.000	8.000
11-12	10.000	50.000	5.000
12-13	5.000	50.000	5.000
13-14	20.000	50.000	5.000
14-15	15.000	50.000	5.000
15-16	50.000	50.000	5.000
16-17	45.000	50.000	5.000
17-18	5.000	50.000	15.000
18-19	53.260	50.000	10.000
19-20	53.260	50.000	5.000
20-21	53.260	50.000	20.000
21-22	53.260	50.000	5.000
22-23	10.000	50.000	10.000
23-24	5.000	50.000	10.000
24-25	20.000	50.000	15.000
25-26	15.000	50.000	20.000
26-27	45.000	50.000	5.000
27-28	5.000	52.500	10.000
28-29	53.260	17.500	15.000
29-30	53.260	39.000	20.000
30-31	53.260	7.000	5.000
31-32	53.260	26.750	10.000
32-33	10.000	26.750	15.000
33-34	5.000	26.750	20.000
34-35	20.000	26.750	5.000
35-36	15.000	7.000	5.000
36-37	25.000	10.000	5.000
37-38	20.000	10.000	15.000
38-39	5.000	10.000	20.000
39-40	53.260	10.000	5.000
40-41	53.260	10.000	10.000
41-42	53.260	10.000	15.000
42-43	53.260	100.000	20.000
43-44	10.000		5.000
44-45	5.000		10.000
45-46	20.000		15.000
46-47	15.000		20.000
47-48	5.000		5.000
48-49	70.000		10.000
49-50	5.000		100.000
50-51	54.500		
51-52	54.500		
52-53	54.500		

53-54	54.500		
54-55	54.500		
55-56	10.000		
56-57	5.000		
57-58	20.000		
58-59	15.000		
59-60	50.000		
60-61	55.000		
61-62	55.000		
62-63	55.000		
63-64	55.000		
64-65	55.000		
65-66	10.000		
66-67	5.000		
67-68	20.000		
68-69	15.000		
69-70	5.500		
70-71	19.500		
71-72	35.000		
72-73	100.000		
Sum	2176.620	2220.000	1513.000

COLOURS of geometrical data

Col.	Type	CEN-rule	Name	lambda [W/mK]	eps [-]	t [°C]	h [W/m²K]	hc [W/m²K]
2	BC_SIMPL	NIHIL	EXTERIOR			-12.0	20.00	
3	BC_SIMPL	NIHIL	SWITCH CONTROL			21.0	8.00	
4	BC_SIMPL	NIHIL	WARM HALL			13.4	8.00	
5	MATERIAL		Reinforced concrete	1.700	0.90			
6	MATERIAL		Wood (doors)	0.240	0.90			
7	MATERIAL		asphalt (enrobé)	2.100	0.90			
8	MATERIAL		draining asphalt	1.000	0.90			
9	MATERIAL		screed	0.840	0.90			
10	MATERIAL		firm stones	2.090	0.90			
32	MATERIAL		soil, clay or silt	1.500	0.00			
155	BC_FREE	NIHIL	VENTILATED AIR SPACE					3.00
158	BC_FREE	NIHIL	INSTALLATION SPACE					3.00
180	BC_SIMPL	NIHIL	INSIDE ATRIUM			20.0	8.00	

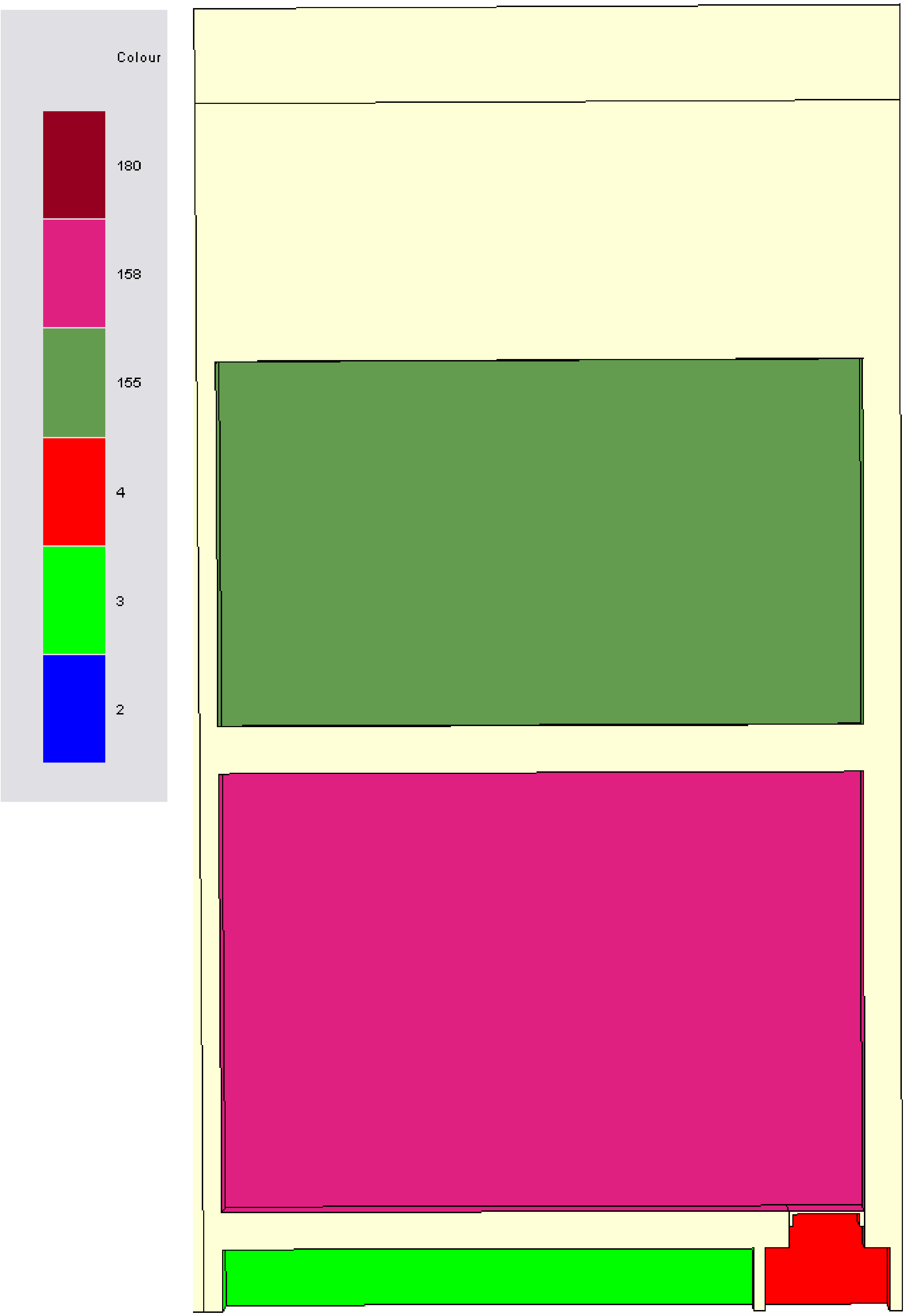
With :

- MATERIAL: material with fixed thermal conductivity (lambda)
- BC_SIMPL: simplified surface boundary condition, defined by a global surface heat transfer coefficient (h) and environmental temperature (t)
- BC_FREE: enclosure with unknown (free) air temperature
- hc [W/m²K]: convective heat transfer coefficient

Calculation parameters

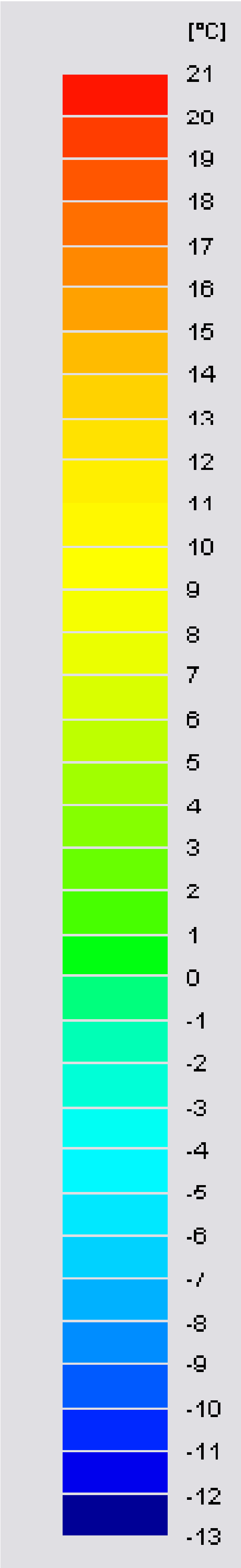
Maximum number of iterations = 10000
Maximum temperature difference = 0.0001°C
Heat flow divergence for total object = 0.001 %
Heat flow divergence for worst node = 1 %
Linear radiation
Smallest accepted view factor = 0.0001
Number of visibility rays between radiative surfaces = 100
Black radiation heat transfer coeff. = 5.25 W/(m².K)

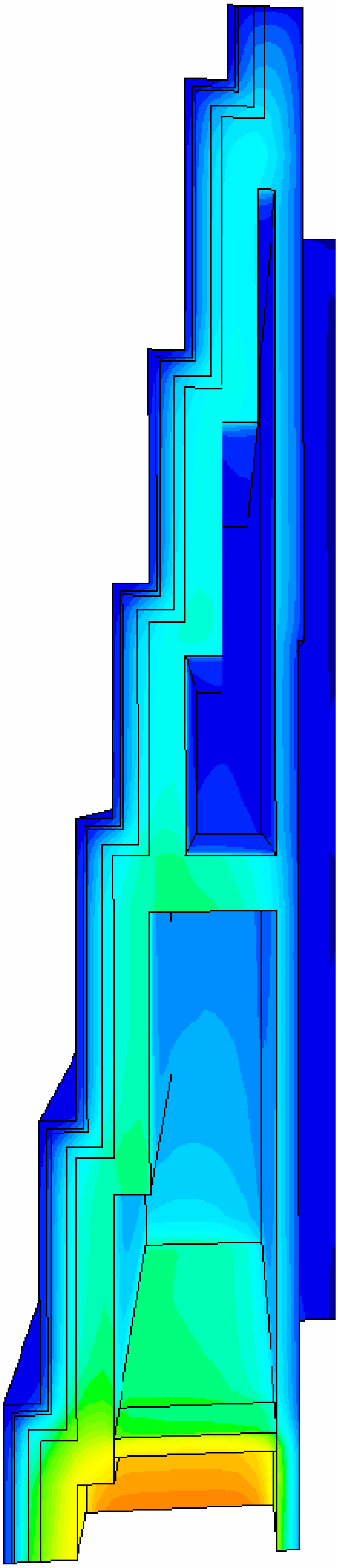
Boundary conditions

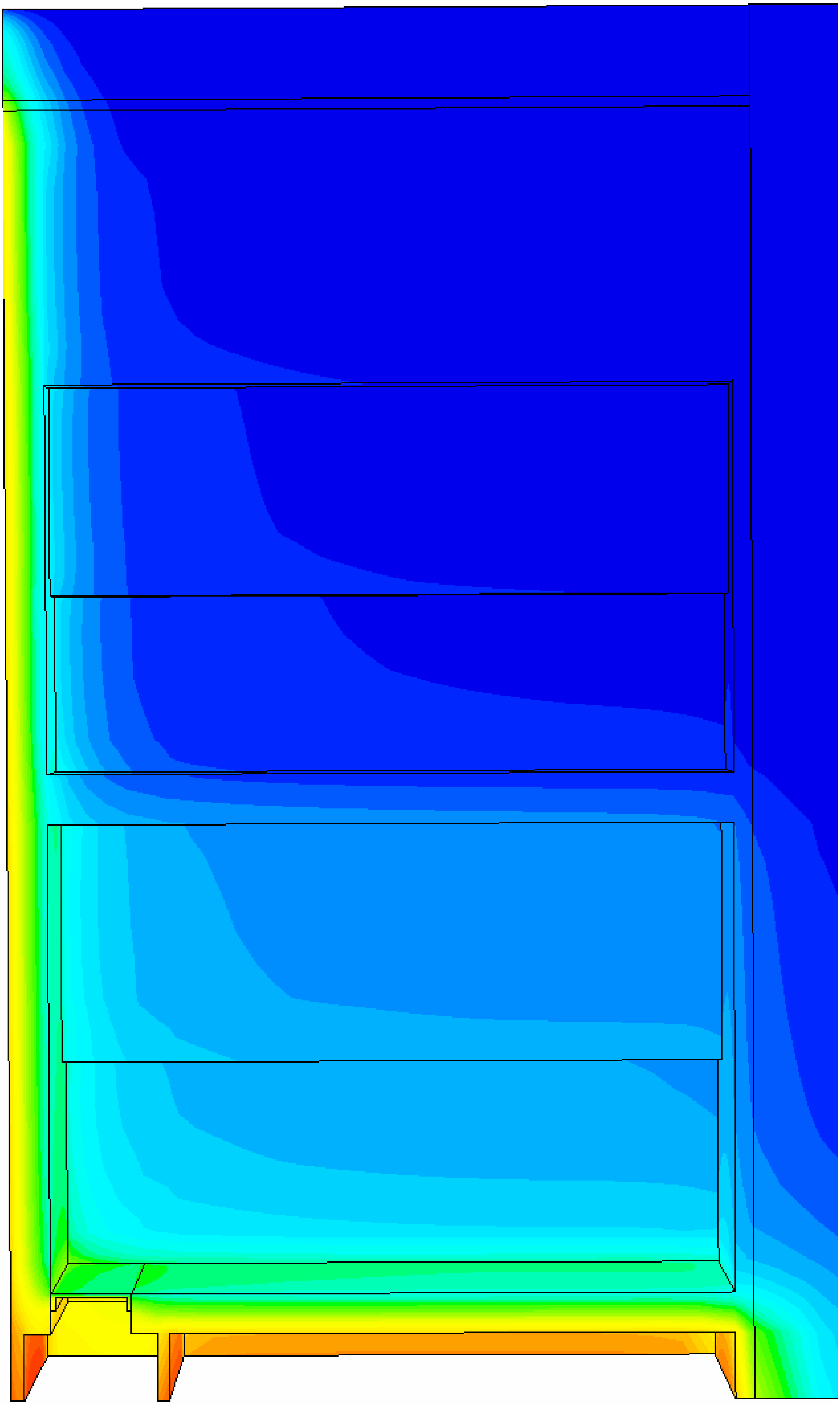


1.2 Graphical results:

General temperature in the model views







1.3 Numerical results:

TRISCO - Calculation Results

TRISCO data file: installation space equilibrium.trc

Number of nodes = 85792
Heat flow divergence for total object = 0.000120076
Heat flow divergence for worst node = 0.100238

Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
2	BC_SIMPL	EXTERIOR	-12.09	73	10	9	0.25	37	42	11
3	BC_SIMPL	SWITCH CONTROL 1	4.91	72	11	17	19.02	73	28	24
4	BC_SIMPL	WARM HALL	0.42	70	31	17	16.82	73	29	24
5	MATERIAL	Reinforced concrete	-12.00	1	10	10	20.19	73	42	29
6	MATERIAL	wood (doors)	-4.25	69	30	17	13.81	71	35	18
7	MATERIAL	asphalt (enrobé)	-12.00	1	10	20	12.63	69	42	41
8	MATERIAL	draining asphalt	-12.00	1	11	21	7.44	68	42	42
9	MATERIAL	screed	-12.00	1	11	22	-1.33	67	42	43
10	MATERIAL	firm stones	-12.00	1	11	23	-4.83	66	42	44
32	MATERIAL	soil, clay or silt	-12.09	73	10	9	11.57	73	10	30
155	BC_FREE	VENTILATED SPACE	-11.58	17	11	17	-1.81	47	36	28
158	BC_FREE	INSTALLATION SPACE	-9.93	49	11	17	4.60	69	36	37
180	BC_SIMPL	INSIDE ATRIUM	-6.19	1	42	10	20.19	73	42	29

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
2	BC_SIMPL	exterior		1.80	5770.55
3	BC_SIMPL	INTERIOR KNOWN		2798.14	0.00
4	BC_SIMPL	INTERIOR EXPECT		431.53	34.30
155	BC_FREE	INTERIOR SPACE	-10.64	470.42	470.42
158	BC_FREE	INTERIOR SPACE	-6.65	1738.25	1738.25
180	BC_SIMPL	INTERIOR KNOWN		2574.11	0.74

This temperature is the inside ambiance in the installation space.
Let's notice here, that these results are the final ones that we got after a number of iteration steps. Other models, which we will see after, have been created to get the right temperatures in the "switch control 1 room" and in the "warm hall". Iteration has then been set to allow a more precise equilibrium in this search.

TRISCO - Temperatures in corner nodes

TRISCO data file: installation space equilibrium.trc

X	Y	Z	t [°C]
1	0	0	-12.00
1	0	23	-12.00
1	10	0	-12.00
1	10	10	-12.00
1	42	10	-6.19
1	42	23	-11.84
11	0	23	-12.00
11	0	28	-12.00
11	42	23	-9.51
11	42	28	-11.87
17	11	17	-11.58
17	11	19	-11.54
17	36	17	-6.40

17	36	19	-4.99
22	0	28	-12.00
22	0	32	-12.00
22	42	28	-9.52
22	42	32	-11.85
27	11	19	-11.20
27	11	24	-11.33
27	36	19	-5.24
27	36	24	-3.87
32	0	32	-12.00
32	0	37	-12.00
32	42	32	-9.48
32	42	37	-11.84
37	10	10	-11.93
37	10	11	-11.87
37	42	10	-4.49
37	42	11	0.25
38	11	24	-11.08
38	11	28	-11.24
38	36	24	-4.37
38	36	28	-3.69
43	0	37	-12.00
43	0	41	-12.00
43	42	37	-9.40
43	42	41	-11.84
47	11	17	-11.13
47	11	28	-10.52
47	36	17	-6.50
47	36	28	-1.81
49	11	17	-9.93
49	11	32	-9.30
49	36	17	-5.43
49	36	32	-1.06
55	0	41	-11.99
55	0	45	-12.00
55	42	41	-9.29
55	42	45	-11.84
60	11	32	-7.73
60	11	37	-8.46
60	36	32	-1.10
60	36	37	-1.27
65	0	45	-11.99
65	0	49	-12.00
65	42	45	-9.01
65	42	49	-11.81
69	11	17	-6.36
69	11	37	-1.53
69	36	17	-1.68
69	36	37	4.60
70	31	17	0.42
70	31	36	6.94
70	35	17	1.62
70	35	36	8.74
71	30	17	1.15
71	30	37	6.84
71	31	17	3.02
71	31	36	11.88
71	35	17	3.98
71	35	36	12.79
71	36	17	3.53
71	36	37	10.48

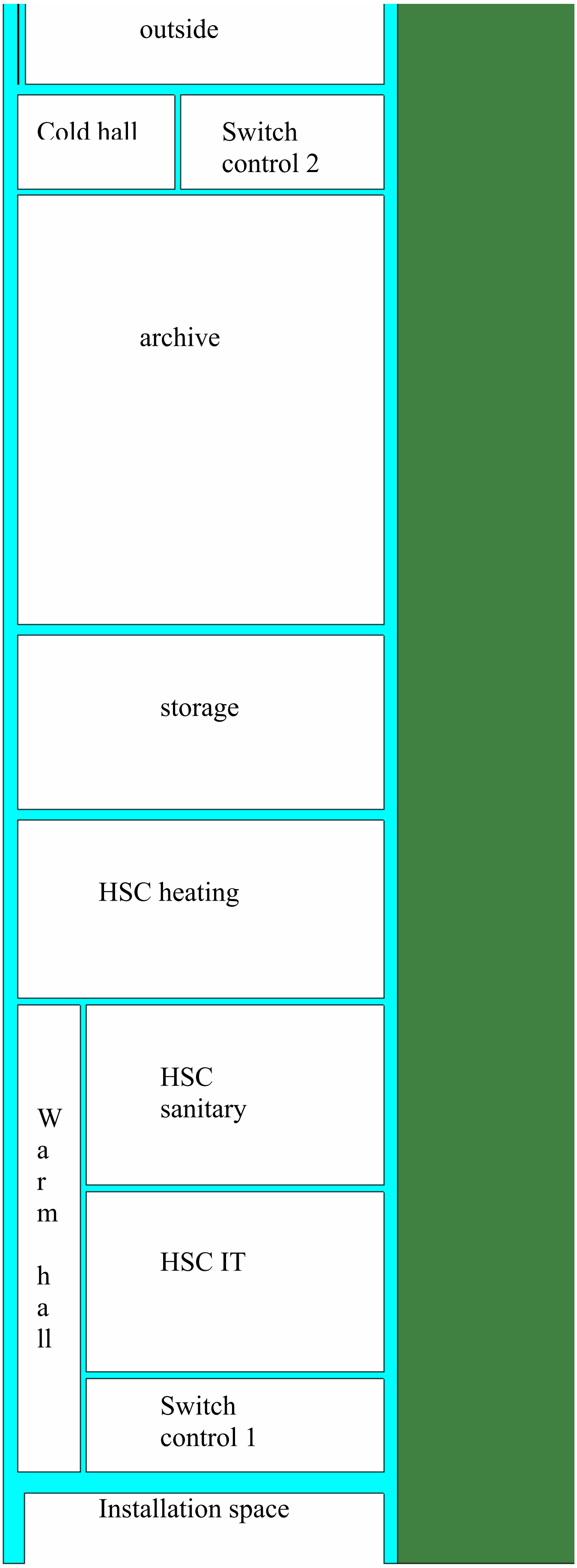
72	11	17	4.91
72	11	41	9.09
72	28	17	7.16
72	28	41	11.69
72	29	17	5.11
72	29	41	9.58
72	30	17	4.69
72	30	37	11.79
72	36	17	4.27
72	36	37	12.99
72	40	17	6.10
72	40	41	13.10
73	0	0	-11.79
73	0	49	-11.99
73	10	0	-12.00
73	10	11	-8.34
73	11	17	7.65
73	11	41	12.65
73	28	17	9.61
73	28	41	14.90
73	29	17	7.20
73	29	41	12.41
73	40	17	6.16
73	40	41	14.40
73	42	11	-1.28
73	42	49	-9.83

2. TECHNICAL ROOMS LOCATED UNDER THE SOUTH ACCESS RAMP AND ABOVE THE PARKING ACCESS RAMP

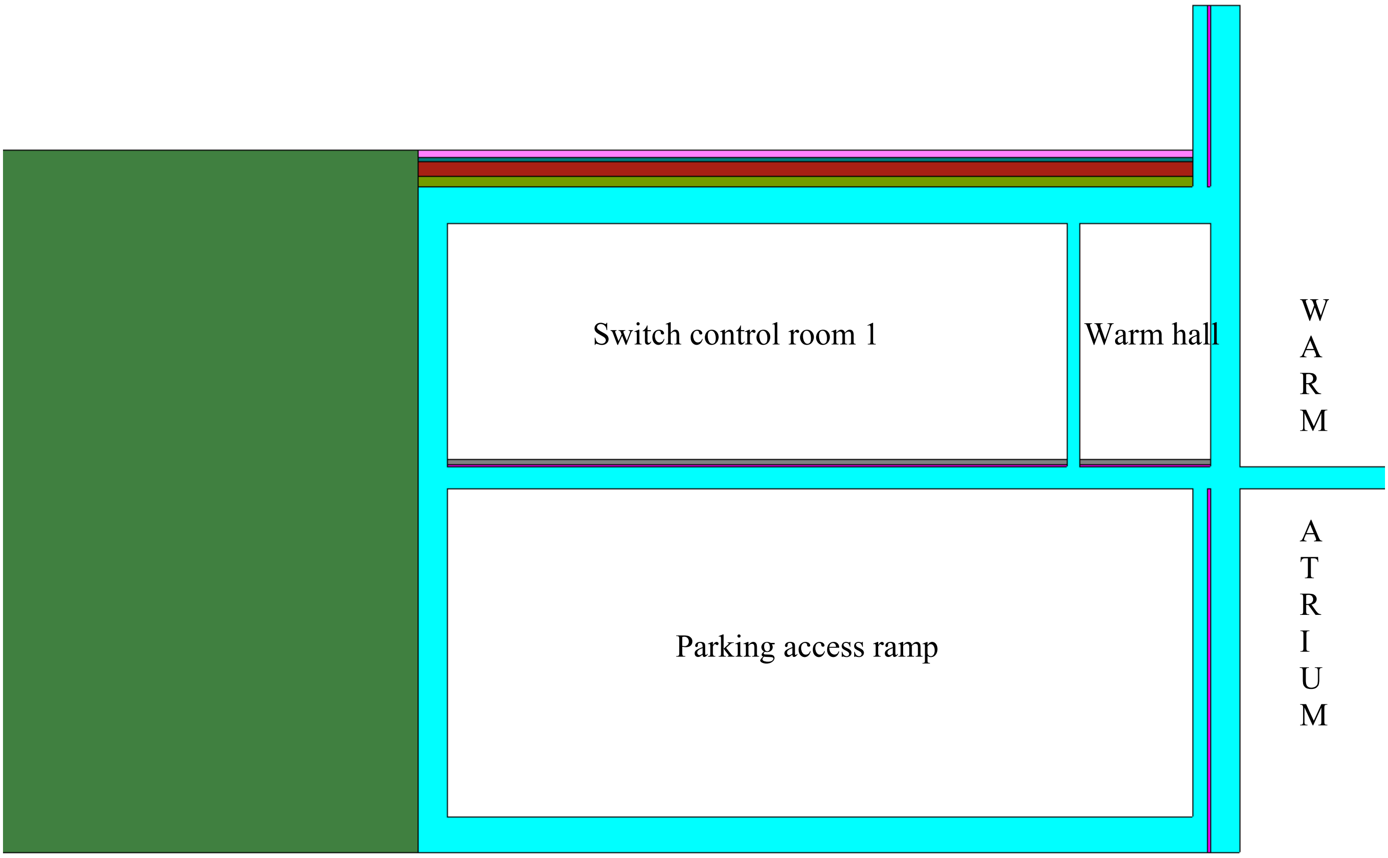
2.1 Input data

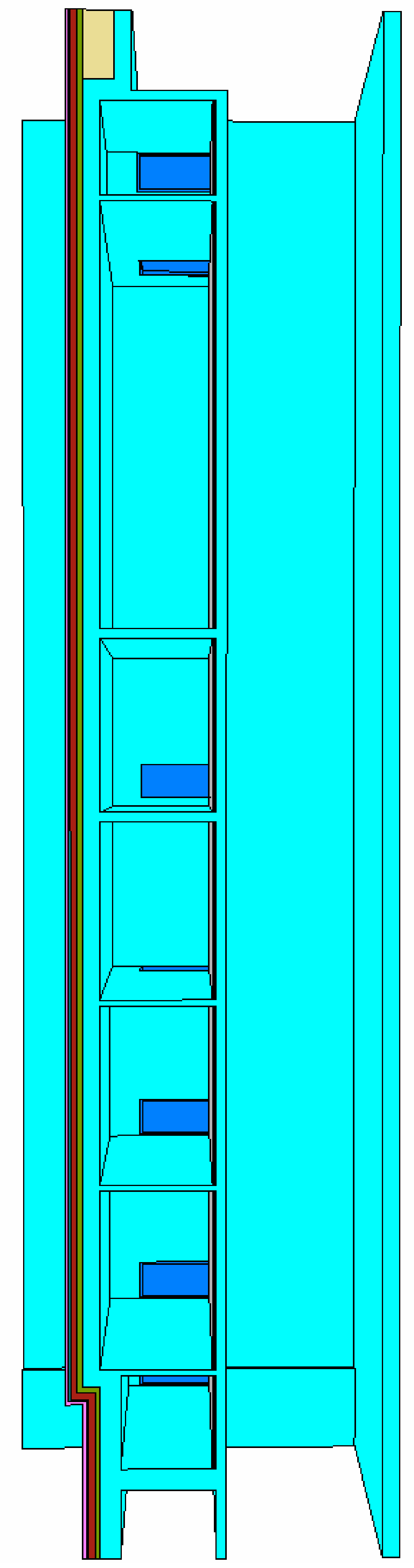
Vertical section (simulation)

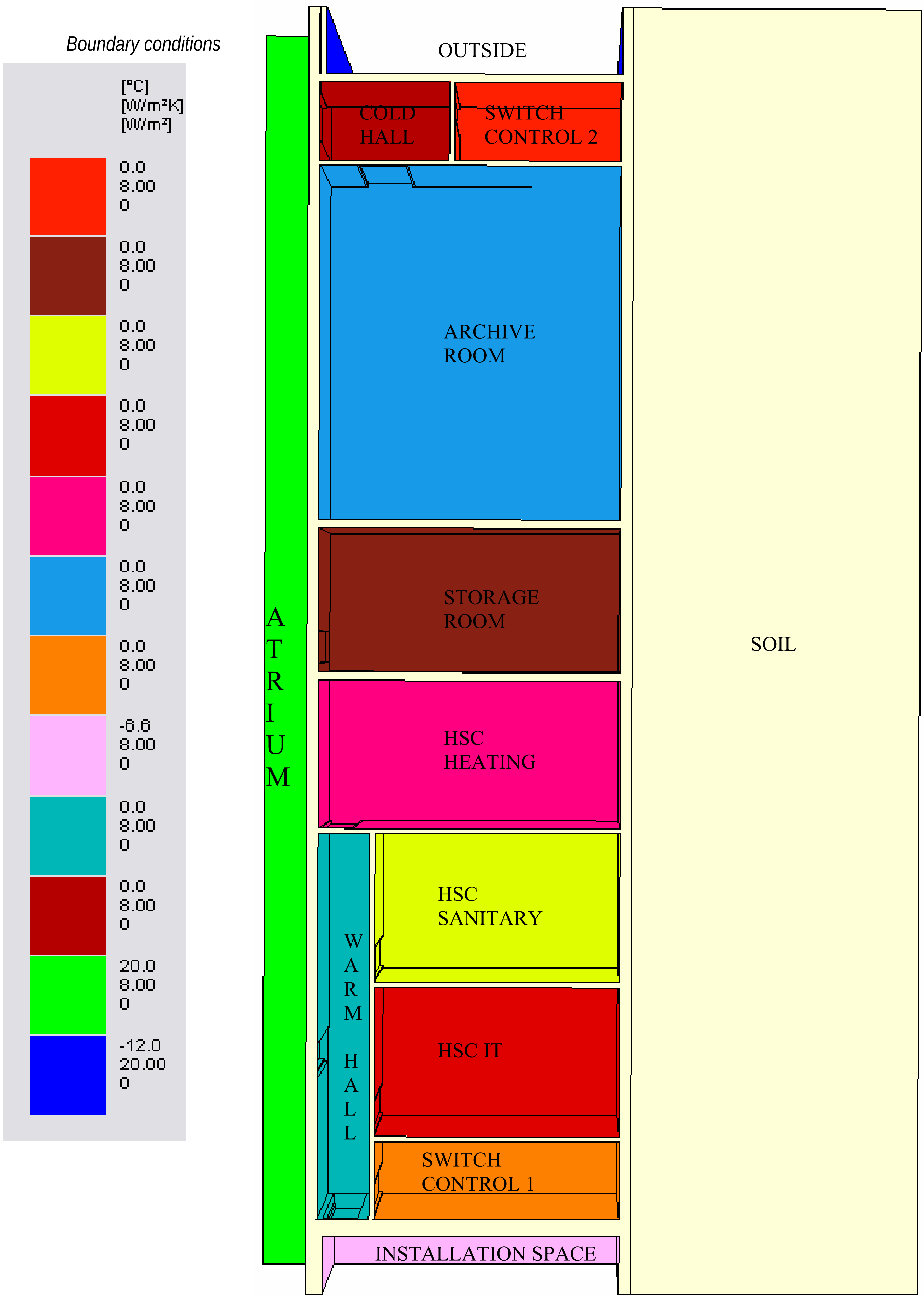
[W/mK]	
3.490	Heavy stones
2.100	Asphalt
2.090	Firm stones
1.700	Reinforced concrete
1.500	Soil, clay or silt
1.000	Drainig asphalt
0.840	Cement mortar
0.840	Floor coating
0.840	Anhydrite screed
0.240	Wood (doors)
0.200	Polyethylene
0.035	Polystyrene insulation



Vertical sections (simulation)






Boundary conditions
[°C]
[W/m²K]
[W/m²]
0.0
8.00
0
0.0
8.00
0
0.0
8.00
0
0.0
8.00
0
0.0
8.00
0
0.0
8.00
0
0.0
8.00
0
-6.6
8.00
0
0.0
8.00
0
0.0
8.00
0
20.0
8.00
0
-12.0
20.00
0
OUTSIDE
COLD HALL
SWITCH CONTROL 2
ARCHIVE ROOM
STORAGE ROOM
HSC HEATING
HSC SANITARY
HSC IT
SWITCH CONTROL 1
INSTALLATION SPACE
ATRIUM
WARM HALL
SOIL

Hypotheses:

- Trisco does not allow modeling a sloped structure. This, in consequence, obliged us to model a stair-shaped structure, to respect the inside volumes and to get as close as possible to the real external exchange surfaces.
- The lambda values used in this model are all coming from the Trisco data base (from the Belgian standard NBN B62-002 or from the Physibel data base).
- The temperatures used are 20°C inside (h = 8), and -12°C outside (h = 20). The other temperatures are obtained thanks to a special boundary condition in Trisco: the BC_FREE, which is an enclosure with an unknown (free) air temperature.

An important hypothesis had to be considered in this model: ventilation. Some of the rooms that are modelled here have an important heat power that could cause some serious overheating if we don't consider that this power can be largely diminished by a natural ventilation power which brings fresh air in the rooms.
For nearly each room, that resultant power (heating – ventilation) can be calculated this way:

- We will consider the total power in these rooms: internal heat power (given), heating power due to the fan heater (given), natural ventilation power, eventual fan coil power used for cooling system.
- First, we will consider a temperature supply, which is given on the drawings. It will provide us the temperature differential with the outside air (-12°C). That differential is of course supposed to change with the iteration that make the inside temperature evolve to an equilibrium;
- The internal volume will be calculated, on basis of the drawings.
- For each of those rooms, a ventilation rate (β) of 0.8 [vol/h] is considered
- the formula for the ventilation power is: P [W] = 0.34 [Wh/m²K] * β [vol/h] * V [m²] * ΔT[K]
- The resultant available power in each room is given by :
  Resultant Power = Heating Power + Internal Power – (Natural Ventilation Power + Fan coil used)
- Those results make it necessary to begin iteration, in order to reach an equilibrium between the inside temperature and the resultant power.

Here are the results obtained after iteration:

Room	T supply (°C)	T equilibrium (°C)	Heated V (m³)	β	ΔT (winter)	Ventilation P (W)
switch ctrl 1	18	23.18	63.03	0.8	35.18	603.13
archive	15	13.63	418.45	0.8	25.63	2917.17
HSC heating	26	26.6	174.52	0.8	38.6	1832.32
HSC IT	24	24.91	142.99	0.8	36.91	1435.55
HSC sanitary	18	22.37	142.99	0.8	34.37	1336.76
storage	24	25.55	170.1	0.8	37.55	1737.33
switch ctrl 2	18	17.88	51.29	0.8	29.88	416.85

Power (W) Room\	Heating capacity	Heating used	Internal	Total Heating	Natural Ventilation	Intensive Ventilation	Fan Coil Unit	Fan Coil used	Total Cooling	Resultant
switch ctrl 1	3090	3090	1000	4090	603.13	0	0	0	603.13	3486.87
archive	6180	6180	2836	9016	2917.17	0	0	0	2917.17	6098.83
HSC heating	0	0	8000	8000	13116.92	1832.32	0	0	1832.32	6167.68
HSC IT	3090	3090	7000	10090	1435.55	0	22500	3375	4810.55	5279.45
HSC sanitary	3090	3090	1950	5040	1336.76	0	0	0	1336.76	3703.24
storage	4090	0	14000	14000	1737.33	0	15000	6000	7737.33	6262.67
switch ctrl 2	3090	3090	1000	4090	416.85	0	0	0	416.85	3673.15

For the heating district, the IT room and the "storage" room, the situation is different. They are all submitted to a really high level of heating charge for their small dimensions, but also to an intensive ventilation or cooling system.
The inside heat charge of the "storage" room is 14 kW, and the tolerated temperature in this room is 24 to 26°C. It also contains 15 kW of ventilation power to cool that room. We can see here above that 6 kW of these 15 are enough to keep the room at nearly 25.5°C, in equilibrium with the others spaces, and with -12°C outside. Seeing that the cooling system power is superior to the heating power, there will be no need of the fan heaters (4kW).
As well, in the IT room, 15% of the total cooling power (or 30% of one fan coil power) is enough to keep the inside temperature at about 25°C.
Also, the heating district has a maximum of 8 kW heat charge, and the ventilation system can be divided into two sources: natural ventilation (1832.32 W), as in every other room, which cannot be stopped, and an intensive ventilation system that can provide up to 1000 m³ of fresh air every hour (1000 m³ = 0.34*1000*ΔT = 11284.6 W). The cooling power (13116.92 W) is superior to the heat charge: the natural 2 kW of ventilation should be enough to ensure 26°C in the room. A part of the intensive ventilation could be used (50% max) to make the temperature go down to 20°C, if necessary.

The results are quite satisfying: almost every room reaches the supply temperature that is asked. The only exception is the archive room, which should reach 15°C of equilibrium temperature, but fails to do so (13.5°C). We can notice that this is an extreme conditions situation. This shouldn't happen for most of the year, and the 15°C should be reached for most of the time. But we will prove hereunder that with only 2 cm of a polystyrene insulation on the ceiling, the target temperature will always be reached.

In Trisco, the BC_FRE_S boundary condition used for those room conditions is defined differently from the BC_FREE boundary condition previously explained here above. It is defined this way: "enclosure with unknown (free) internal temperature, fixed internal heat power, and simplified heat transfer (with fixed global surface heat transfer coefficient and fixed surface heat flux)".The resultant heat power obtained in the grid here above will be used as the "fixed internal heat power" of the room. Here again, these results are obtained after iteration.

TRISCO - Input Data

TRISCO data file: search of equilibrium temperature.trc

GRID
Grid unit = 0.01 m

No.	X	Y	Z
0-1	50.000	52.000	50.000
1-2	50.000	50.000	50.000
2-3	50.000	50.000	50.000
3-4	50.000	50.000	50.000
4-5	5.500	50.000	50.000
5-6	19.500	50.000	50.000
6-7	35.000	50.000	50.000
7-8	4.000	50.000	50.000
8-9	3.000	50.000	50.000
9-10	53.500	50.000	50.000
10-11	53.500	50.000	30.000
11-12	7.000	50.000	4.000
12-13	33.250	50.000	0.040
13-14	33.250	50.000	6.500
14-15	10.000	50.000	0.500
15-16	5.000	50.000	55.000
16-17	20.000	50.000	55.000
17-18	15.000	50.000	55.000
18-19	32.500	50.000	55.000
19-20	17.500	50.000	7.000
20-21	7.000	40.000	4.500

21-22	53.500	48.542	32.500
22-23	53.500	48.541	17.500
23-24	7.000	48.542	40.500
24-25	38.400	48.542	2.000
25-26	38.400	48.541	15.000
26-27	7.000	48.542	20.000
27-28	53.500	48.542	5.000
28-29	53.500	48.541	10.000
29-30	7.000	48.542	15.000
30-31	49.800	48.542	20.000
31-32	49.800	48.541	5.000
32-33	49.800	48.542	10.000
33-34	49.800	12.000	50.000
34-35	17.500	5.500	50.000
35-36	7.000	48.600	50.000
36-37	53.500	48.600	50.000
37-38	53.500	48.600	
38-39	7.000	7.000	
39-40	49.625	50.000	
40-41	49.625	50.000	
41-42	49.625	12.000	
42-43	49.625	5.500	
43-44	49.625	39.000	
44-45	49.625	7.000	
45-46	49.625	7.000	
46-47	49.625	6.000	
47-48	5.500	7.000	
48-49	12.000	43.500	
49-50	51.300	26.500	
50-51	51.300	17.000	
51-52	51.300	3.000	
52-53	51.300	4.000	
53-54	51.300	13.000	
54-55	51.300	3.000	
55-56	51.300	4.000	
56-57	51.300	15.000	
57-58	51.300	5.500	
58-59	51.299	14.000	
59-60	30.000	5.500	
60-61	31.201	50.000	
61-62	7.000	50.000	
62-63	48.500	50.000	
63-64	48.500	50.000	
64-65	7.000		
65-66	51.114		
66-67	51.115		
67-68	51.114		
68-69	51.114		
69-70	51.115		
70-71	51.114		
71-72	51.114		
72-73	30.000		
73-74	49.200		
74-75	49.200		
75-76	49.200		
76-77	49.200		
77-78	49.200		
78-79	49.200		
79-80	49.200		
80-81	49.200		
81-82	49.200		

82-83	49.200		
83-84	49.200		
84-85	49.200		
85-86	49.200		
86-87	49.200		
87-88	49.200		
88-89	49.200		
89-90	49.200		
90-91	49.200		
91-92	49.200		
92-93	49.200		
93-94	49.201		
94-95	49.199		
95-96	49.200		
96-97	49.201		
97-98	49.200		
98-99	12.000		
99-100	5.500		
100-101	4.000		
101-102	32.750		
102-103	32.750		
103-104	7.000		
104-105	37.000		
105-106	37.000		
106-107	6.999		
107-108	53.500		
108-109	53.500		
109-110	7.000		
110-111	30.000		
111-112	30.000		
112-113	50.000		
113-114	50.000		
114-115	50.000		
115-116	50.000		
Sum	4470.500	2332.300	1165.040

BLOCKS

No.	Col.	Xmin	Xmax	Ymin	Ymax	Zmin	Zmax
1	5	20	116	20	21	0	25
2	5	0	20	20	21	0	22
3	5	7	111	21	56	10	11
4	5	0	7	21	53	10	11
5	5	0	7	53	56	0	37
6	5	0	20	56	60	0	37
7	5	20	26	56	60	0	37
8	5	26	30	56	60	0	15
9	10	26	27	57	60	15	20
10	10	29	30	57	60	15	20
11	10	27	29	57	60	19	20
12	10	27	29	59	60	15	19
13	5	26	30	56	60	20	37
14	5	30	61	56	60	0	37
15	5	61	65	56	60	0	15
16	10	61	62	57	60	15	19
17	10	64	65	57	60	15	19
18	10	61	65	57	60	19	20
19	10	62	64	57	58	15	19
20	5	61	65	56	60	20	37
21	5	65	103	56	60	0	37
22	5	103	110	56	60	0	15
23	10	103	104	56	60	15	19

24	10	109	110	56	60	15	19
25	10	103	110	56	60	19	20
26	10	104	109	59	60	15	19
27	5	103	110	56	60	20	37
28	5	110	116	56	60	0	37
29	5	110	111	21	56	10	25
30	5	98	100	21	38	11	25
31	5	98	100	38	46	20	25
32	10	98	100	38	39	15	19
33	10	98	100	45	46	15	19
34	10	98	100	38	46	19	20
35	10	99	100	39	45	15	19
36	5	98	100	46	56	11	25
37	5	100	106	33	35	11	25
38	5	106	110	33	35	20	25
39	10	106	107	33	35	15	19
40	10	109	110	33	35	15	19
41	10	106	110	33	35	19	20
42	10	107	109	34	35	15	19
43	5	72	73	21	56	11	25
44	5	59	60	21	56	11	25
45	5	47	49	21	47	11	25
46	5	47	49	47	56	20	25
47	10	47	49	47	48	15	19
48	10	47	49	54	56	15	19
49	10	47	49	47	56	19	20
50	10	47	48	48	54	15	19
51	5	39	47	41	43	11	25
52	5	35	39	41	43	20	25
53	10	35	36	41	43	15	19
54	10	38	39	41	43	15	19
55	10	35	39	41	43	19	20
56	10	36	38	42	43	15	19
57	5	34	35	21	43	11	25
58	5	24	34	41	43	11	25
59	5	20	24	41	43	20	25
60	10	20	21	41	43	15	19
61	10	23	24	41	43	15	19
62	10	20	24	41	43	19	20
63	10	21	23	42	43	15	19
64	5	19	20	21	43	11	22
65	5	12	19	41	43	11	22
66	5	7	12	41	43	20	22
67	10	7	9	41	43	15	19
68	10	11	12	41	43	15	19
69	10	7	12	41	43	19	20
70	10	9	11	42	43	15	19
71	5	4	7	21	44	11	22
72	5	4	7	44	53	20	22
73	5	4	7	44	53	11	15
74	10	4	6	44	45	15	19
75	10	4	6	51	53	15	19
76	10	4	6	44	53	19	20
77	10	4	5	45	51	15	19
78	5	111	112	20	60	23	25
79	5	111	116	20	60	21	23
80	6	7	19	21	41	11	12
81	7	7	19	21	41	12	13
82	8	7	19	21	41	13	14
83	9	7	19	21	41	14	15
84	6	7	12	41	43	11	12

85	7	7	12	41	43	12	13
86	8	7	12	41	43	13	14
87	9	7	12	41	43	14	15
88	6	20	34	21	41	11	12
89	7	20	34	21	41	12	13
90	8	20	34	21	41	13	14
91	9	20	34	21	41	14	15
92	6	20	24	41	43	11	12
93	7	20	24	41	43	12	13
94	8	20	24	41	43	13	14
95	9	20	24	41	43	14	15
96	6	35	47	21	41	11	12
97	7	35	47	21	41	12	13
98	8	35	47	21	41	13	14
99	9	35	47	21	41	14	15
100	6	35	39	41	43	11	12
101	7	35	39	41	43	12	13
102	8	35	39	41	43	13	14
103	9	35	39	41	43	14	15
104	6	7	47	43	56	11	12
105	7	7	47	43	56	12	13
106	8	7	47	43	56	13	14
107	9	7	47	43	56	14	15
108	6	47	49	47	56	11	12
109	7	47	49	47	56	12	13
110	8	47	49	47	56	13	14
111	9	47	49	47	56	14	15
112	6	49	59	21	56	11	12
113	7	49	59	21	56	12	13
114	8	49	59	21	56	13	14
115	9	49	59	21	56	14	15
116	6	60	72	21	56	11	12
117	7	60	72	21	56	12	13
118	8	60	72	21	56	13	14
119	9	60	72	21	56	14	15
120	6	73	98	21	56	11	12
121	7	73	98	21	56	12	13
122	8	73	98	21	56	13	14
123	9	73	98	21	56	14	15
124	6	98	100	38	46	11	12
125	7	98	100	38	46	12	13
126	8	98	100	38	46	13	14
127	9	98	100	38	46	14	15
128	6	100	110	21	33	11	12
129	7	100	110	21	33	12	13
130	8	100	110	21	33	13	14
131	9	100	110	21	33	14	15
132	6	106	110	33	35	11	12
133	7	106	110	33	35	12	13
134	8	106	110	33	35	13	14
135	9	106	110	33	35	14	15
136	6	100	110	35	56	11	12
137	7	100	110	35	56	12	13
138	8	100	110	35	56	13	14
139	9	100	110	35	56	14	15
140	5	7	20	20	56	22	25
141	5	0	7	20	53	22	25
142	11	7	18	20	55	25	26
143	11	0	7	20	52	25	26
144	11	17	18	20	55	26	29
145	12	7	17	20	55	26	27

146	12	0	7	20	52	26	27
147	12	16	17	20	55	27	30
148	13	7	16	20	55	27	28
149	13	0	7	20	52	27	28
150	13	15	16	20	55	28	31
151	14	7	15	20	55	28	29
152	14	0	7	20	52	28	29
153	14	14	15	20	55	29	32
154	5	18	112	20	56	25	29
155	11	17	116	20	55	29	30
156	12	16	116	20	55	30	31
157	13	15	116	20	55	31	32
158	14	14	116	20	55	32	33
159	15	112	116	20	55	23	29
160	2	0	7	21	50	1	10
161	2	7	116	21	52	1	10
162	2	111	116	21	52	1	21
163	2	14	116	0	52	33	37
164	2	7	14	0	52	29	37
165	2	0	7	0	50	29	37
166	19	0	14	0	20	0	29
167	19	14	116	0	20	0	33
168	5	0	116	60	64	10	11
169	3	62	64	58	60	15	19
170	3	0	116	60	64	11	37
171	3	0	116	60	64	0	10
172	20	104	109	57	59	15	19
173	20	103	110	56	57	15	20
174	20	100	110	35	56	15	25
175	21	5	6	45	51	15	19
176	21	6	7	44	53	15	20
177	21	27	29	57	59	15	19
178	21	26	30	56	57	15	20
179	21	7	20	43	56	15	22
180	21	20	47	43	56	15	25
181	22	0	4	21	53	11	22
182	28	9	11	41	42	15	19
183	28	7	19	21	41	15	22
184	36	21	23	41	42	15	19
185	36	20	34	21	41	15	25
186	39	36	38	41	42	15	19
187	39	35	47	21	41	15	25
188	44	61	65	56	57	15	20
189	44	60	72	21	56	15	25
190	68	107	109	33	34	15	19
191	68	100	110	21	33	15	25
192	29	98	99	39	45	15	19
193	29	73	98	21	56	15	24
194	30	48	49	48	54	15	19
195	30	49	59	21	56	15	25
196	5	0	8	21	52	0	1
197	5	8	116	21	55	0	1
198	29	73	98	21	56	24	25
199	6	111	116	55	56	0	21
200	5	111	116	52	55	1	21
201	6	7	111	55	56	0	10
202	5	7	111	52	55	1	10
203	6	0	7	52	53	0	10
204	5	0	8	50	52	1	10
205	6	0	7	52	53	25	37
206	5	0	8	50	52	25	37

207	5	7	15	52	55	25	37
208	6	7	8	52	56	25	37
209	6	7	8	52	56	0	10
210	6	7	14	55	56	25	37
211	6	14	116	55	56	29	37
212	5	14	116	52	55	29	37

COLOURS

Col.	Type	CEN-rule	Name	lambda [W/mK]	eps [-]	t [°C]	h [W/m²K]	q [W/m²]
2	BC_SIMPL	NIHIL	EXTERIOR			-12.0	20.00	0
3	BC_SIMPL	NIHIL	INTERIOR ATRIUM			20.0	8.00	0
5	MATERIAL		Reinforced concrete	1.700				
6	MATERIAL		polystyrene insul.	0.035				
7	MATERIAL		polyethylene	0.200				
8	MATERIAL		anhydrite screed	0.840				
9	MATERIAL		floor coating	0.840				
10	MATERIAL		wood (doors)	0.240				
11	MATERIAL		asphalt	2.100				
12	MATERIAL		draining asphalt	1.000				
13	MATERIAL		cement mortar	0.840				
14	MATERIAL		heavy stones	3.490				
15	MATERIAL		firm stones	2.090				
19	MATERIAL		soil, clay or silt	1.500				
20	BC_FRE_S	NIHIL	COLD HALL				8.00	0
21	BC_FRE_S	NIHIL	WARM HALL				8.00	0
22	BC_SIMPL	NIHIL	INSTALLATION SPACE			-6.6	8.00	0
28	BC_FRE_S	NIHIL	SWITCH CONTROL 1				8.00	0
29	BC_FRE_S	NIHIL	ARCHIVE ROOM				8.00	0
30	BC_FRE_S	NIHIL	HSC HEATING				8.00	0
36	BC_FRE_S	NIHIL	HSC IT				8.00	0
39	BC_FRE_S	NIHIL	HSC SANITARY				8.00	0
44	BC_FRE_S	NIHIL	STORAGE ROOM				8.00	0
68	BC_FRE_S	NIHIL	SWITCH CONTROL 2				8.00	0

Calculation parameters
Maximum number of iterations = 10000
Maximum temperature difference = 0.0001°C
Heat flow divergence for total object = 0.001 %
Heat flow divergence for worst node = 1 %

2.2 Numerical results

TRISCO - Calculation Results

TRISCO data file: search of equilibrium temperature.trc

Number of nodes = 188971
Heat flow divergence for total object = 1.85649e-012
Heat flow divergence for worst node = 0.647317

Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
2	BC_SIMPL	EXTERIOR	-12.20	8	50	9	-4.09	111	52	21
3	BC_SIMPL	INTERIOR ATRIUM	14.20	108	60	13	21.88	63	58	16
5	MATERIAL	reinforced concrete	-12.20	8	50	9	26.49	59	27	16
6	MATERIAL	polystyrene insul.	-11.06	8	52	9	23.46	58	22	12
7	MATERIAL	polyethylene	-5.65	110	40	12	23.51	58	22	13
8	MATERIAL	anhydrite screed	-5.64	110	40	13	25.58	58	22	14
9	MATERIAL	floor coating	-3.45	110	40	14	25.75	58	22	15
10	MATERIAL	wood (doors)	-2.73	4	44	15	26.94	49	48	16

11	MATERIAL	asphalt	-11.37	116	37	30	12.22	18	55	25
12	MATERIAL	draining asphalt	-11.74	116	37	31	8.58	17	55	26
13	MATERIAL	cement mortar	-11.85	116	37	32	1.18	16	55	27
14	MATERIAL	heavy stones	-11.91	116	37	33	-3.14	15	52	28
15	MATERIAL	firm stones	-11.30	116	37	23	5.33	112	55	24
19	MATERIAL	soil, clay or silt	-12.00	14	0	33	18.48	56	20	18
20	BC_FRE_S	COLD HALL	-3.30	110	40	15	10.67	104	59	15
21	BC_FRE_S	WARM HALL	3.40	6	44	15	20.23	47	43	16
22	BC_SIMPL	INSTALLATION SPACE	-8.56	3	44	11	3.53	4	53	17
28	BC_FRE_S	SWITCH CONTROL 1	7.08	7	21	15	24.53	19	22	16
29	BC_FRE_S	ARCHIVE	5.55	91	21	15	17.29	73	32	16
30	BC_FRE_S	HSC HEATING	14.38	50	21	15	26.94	49	48	16
36	BC_FRE_S	HSC IT	13.22	24	21	15	25.33	21	41	16
39	BC_FRE_S	HSC SANITARY	11.56	41	21	15	24.57	47	22	16
44	BC_FRE_S	STORAGE ROOM	11.86	72	21	15	26.05	60	32	16
68	BC_FRE_S	SWITCH CONTROL 2	1.73	110	33	15	18.02	107	33	16

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
2	BC_SIMPL	EXTERIOR		0.27	42670.63
3	BC_SIMPL	INTERIOR ATRIUM		9620.41	350.57
20	BC_FRE_S	COLD HALL	4.84	935.56	935.56
21	BC_FRE_S	WARM HALL	15.29	1347.46	1347.45
22	BC_SIMPL	INSTALLATION SPACE		335.32	1606.69
28	BC_FRE_S	SWITCH CONTROL 1	23.18	3593.74	106.86
29	BC_FRE_S	ARCHIVE	13.64	7540.34	1441.50
30	BC_FRE_S	HSC HEATING	26.60	6167.84	0.17
36	BC_FRE_S	HSC IT	24.91	5280.18	0.74
39	BC_FRE_S	HSC SANITARY	22.38	4167.77	464.53
44	BC_FRE_S	STORAGE ROOM	25.55	6327.71	65.04
68	BC_FRE_S	SWITCH CONTROL 2	17.89	3673.21	0.06

As we said before, this temperature is a bit too low for the target. Another calculation can be made, with 2 cm of insulation on the ceiling of the archive room, to ensure 15°C in that room every time:

Room	Tsupply (°C)	Téquilibre (°C)	Heated V (m³)	β	ΔT (winter)	Ventilation P (W)
switch ctrl 1	18	23.18	63.03	0.8	35.18	603.13
archive	15	16.19	418.45	0.8	28.19	3208.54
HSC heating	26	26.72	174.52	0.8	38.72	1838.02
HSC IT	24	24.92	142.99	0.8	36.92	1435.94
HSC sanitary	18	22.41	142.99	0.8	34.41	1338.32
storage	24	26.07	170.1	0.8	38.07	1761.39
switch ctrl 2	18	18.64	51.29	0.8	30.64	427.45

Room\Power	Heating capacity	Heating used	Internal	Total Heating	Natural Ventilation	Intensive Ventilation	Fan Coil Unit	Fan Coil used	Total Cooling	Resultant
switch ctrl 1	3090	3090	1000	4090	603.13	0	0	0	603.13	3486.87
archive	6180	6180	2836	9016	3208.54	0	0	0	3208.5	5807.46
HSC heating	0	0	8000	8000	13122.62	1838.02	0	0	1838	6161.98
HSC IT	3090	3090	7000	10090	1435.94	0	22500	3375	4810.9	5279.06
HSC sanitary	3090	3090	1950	5040	1338.32	0	0	0	1338.3	3701.68
storage	4090	4090	14000	14000	1761.39	0	15000	6000	7761.4	6238.61
switch ctrl 2	3090	3090	1000	4090	427.45	0	0	0	427.45	3662.55

TRISCO - Calculation Results

TRISCO data file: equilibrium with insulation archive.trc

Number of nodes = 189787
Heat flow divergence for total object = 4.21571e-010
Heat flow divergence for worst node = 0.693478

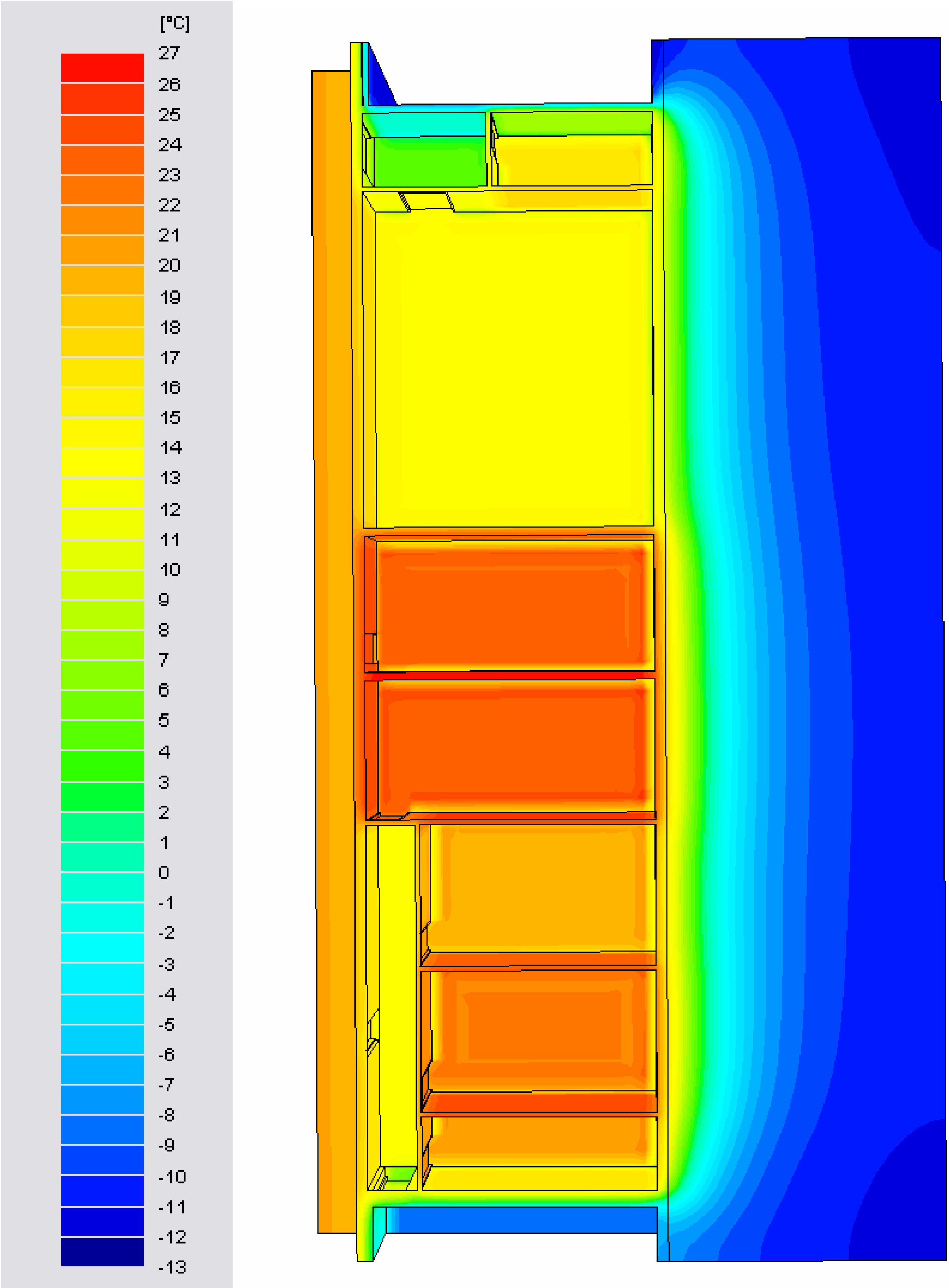
Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
2	BC_SIMPL	EXTERIOR	-12.20	8	50	9	-3.93	111	52	21
3	BC_SIMPL	INTERIOR ATRIUM	14.38	108	60	13	22.02	63	58	16
5	MATERIAL	reinforced concrete	-12.20	8	50	9	26.72	59	27	16
6	MATERIAL	polystyrene insul.	-11.06	8	52	9	23.56	58	22	12
7	MATERIAL	polyethylene	-5.39	110	40	12	23.61	58	22	13
8	MATERIAL	anhydrite screed	-5.38	110	40	13	25.68	58	22	14
9	MATERIAL	floor coating	-3.10	110	40	14	25.86	58	22	15
10	MATERIAL	wood (doors)	-2.72	4	44	15	27.06	49	48	16
11	MATERIAL	asphalt	-11.35	116	37	30	12.22	18	55	25
12	MATERIAL	draining asphalt	-11.73	116	37	31	8.58	17	55	26
13	MATERIAL	cement mortar	-11.85	116	37	32	1.18	16	55	27
14	MATERIAL	heavy stones	-11.90	116	37	33	-3.14	15	52	28
15	MATERIAL	firm stones	-11.28	116	37	23	5.46	112	55	24
19	MATERIAL	soil, clay or silt	-12.00	14	0	33	18.64	59	20	18
20	BC_FRE_S	COLD HALL	-2.94	110	40	15	11.41	100	56	21
21	BC_FRE_S	WARM HALL	3.40	6	44	15	20.28	47	43	16
22	BC_SIMPL	INSTALLATION SPACE	-8.56	3	44	11	3.53	4	53	17
28	BC_FRE_S	SWITCH CONTROL 1	7.08	7	21	15	24.54	19	22	16
29	BC_FRE_S	ARCHIVE ROOM	7.29	93	21	15	19.26	73	27	16
30	BC_FRE_S	HSC HEATING	14.46	50	21	15	27.06	49	48	16
36	BC_FRE_S	HSC IT	13.23	24	21	15	25.34	21	41	16
39	BC_FRE_S	HSC SANITARY	11.58	41	21	15	24.64	47	22	16
44	BC_FRE_S	STORAGE ROOM	12.57	72	21	15	26.46	60	27	16
68	BC_FRE_S	SWITCH CONTROL 2	2.10	110	33	15	18.78	107	33	16

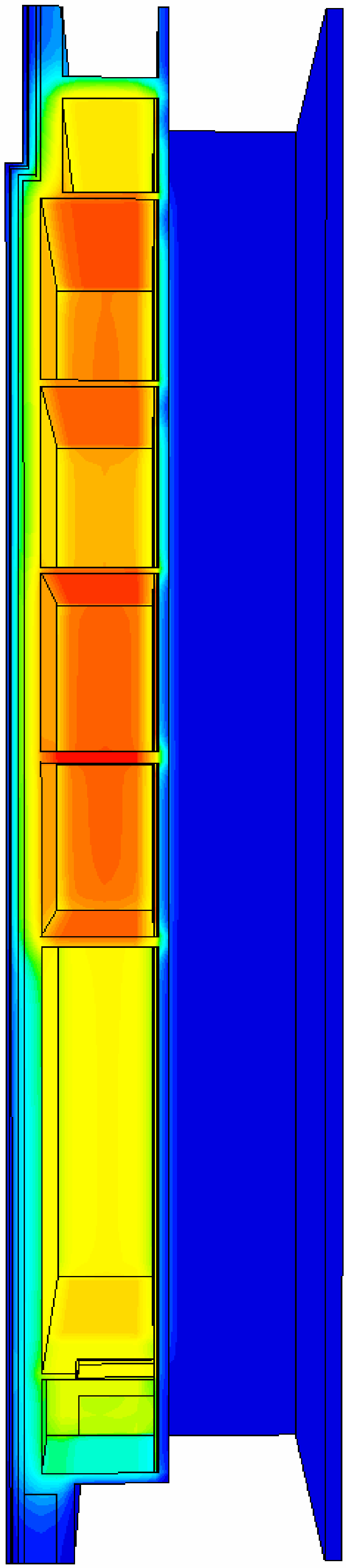
Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
2	BC_SIMPL	EXTERIOR		0.27	42086.54
3	BC_SIMPL	INTERIOR ATRIUM		9393.28	373.27
20	BC_FRE_S	COLD HALL	5.53	982.10	982.10
21	BC_FRE_S	WARM HALL	15.31	1348.42	1348.42
22	BC_SIMPL	INSTALLATION SPACE		335.30	1607.05
28	BC_FRE_S	SWITCH CONTROL 1	23.18	3593.97	107.10
29	BC_FRE_S	ARCHIVE ROOM	16.19	6832.06	1024.61
30	BC_FRE_S	HSC HEATING	26.71	6162.43	0.46
36	BC_FRE_S	HSC IT	24.92	5279.79	0.73
39	BC_FRE_S	HSC SANITARY	22.41	4170.40	468.72
44	BC_FRE_S	STORAGE ROOM	26.07	6280.12	41.52
68	BC_FRE_S	SWITCH CONTROL 2	18.64	3662.61	0.06

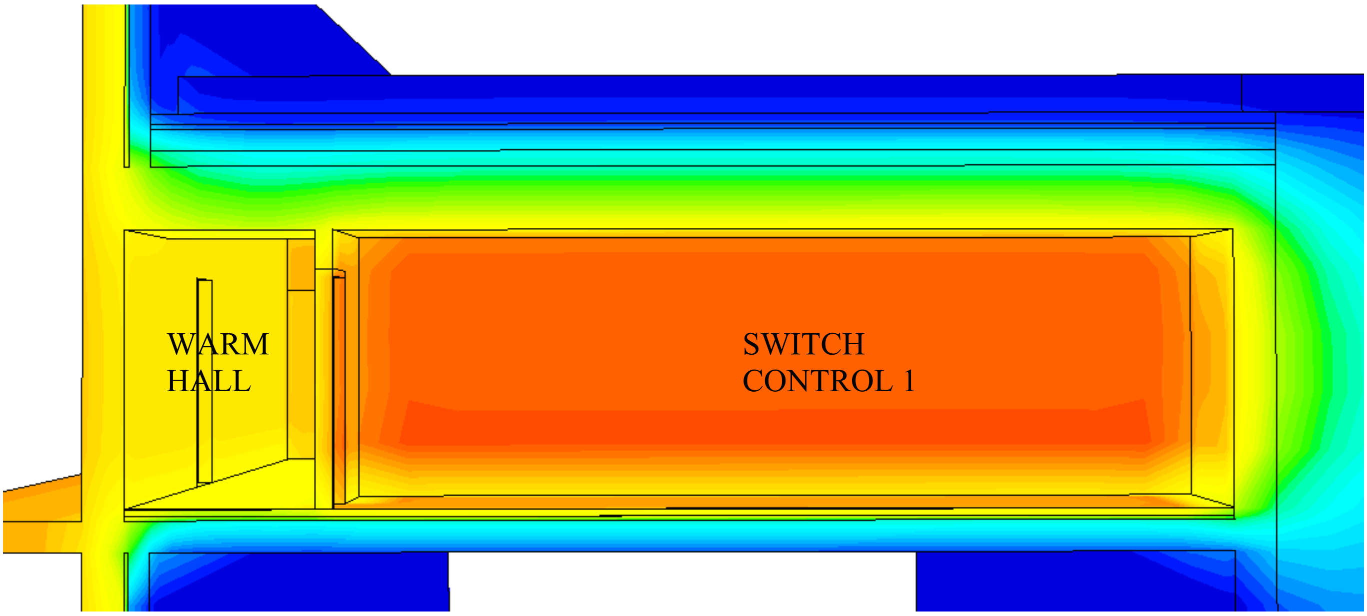
We will now only consider that last case (with the 2 cm insulation) for the following data and results. For information, a thickness of 1 cm for insulating material gives internal temperatures just lower than 15°C.

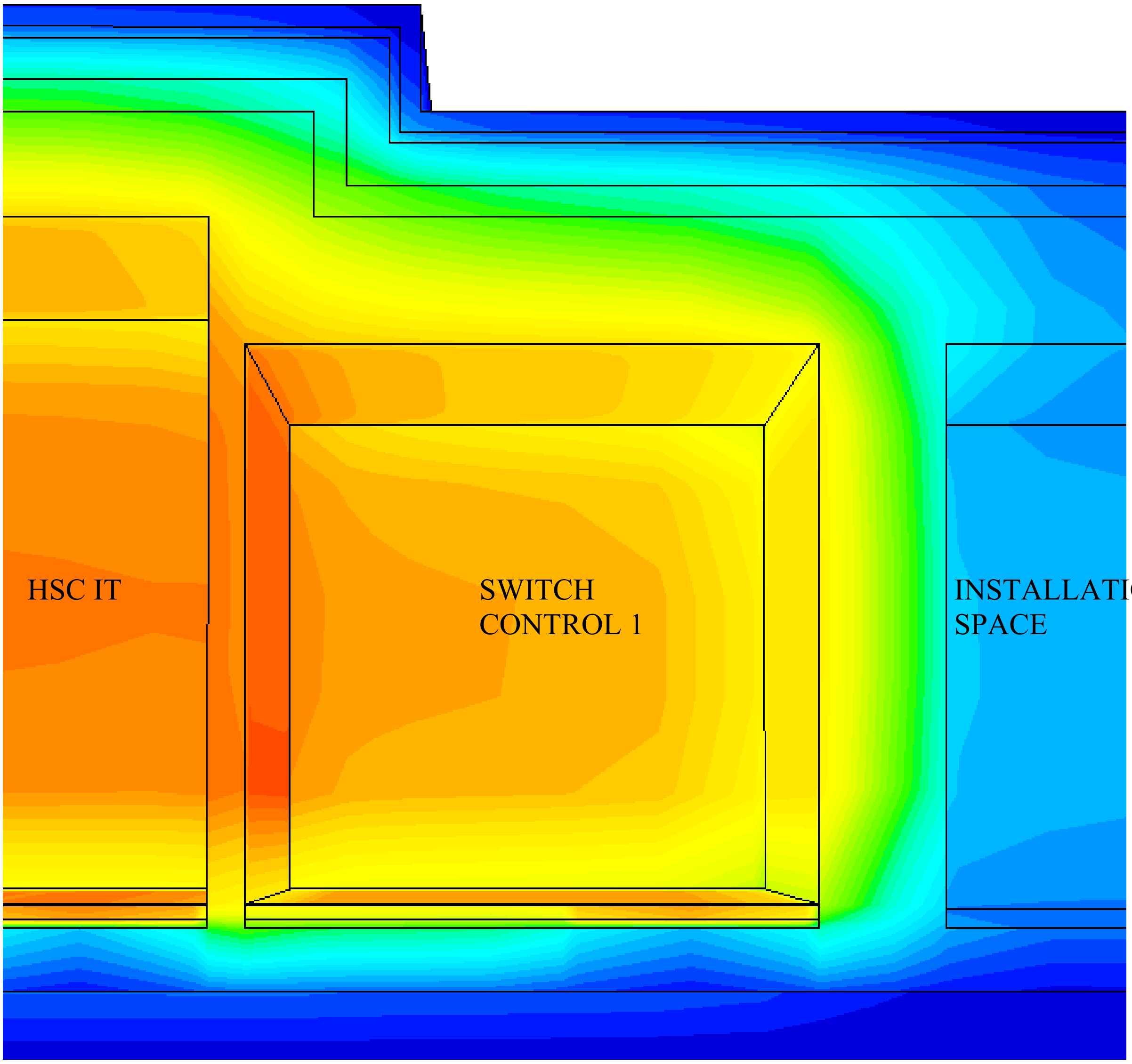
2.3 Graphical results:

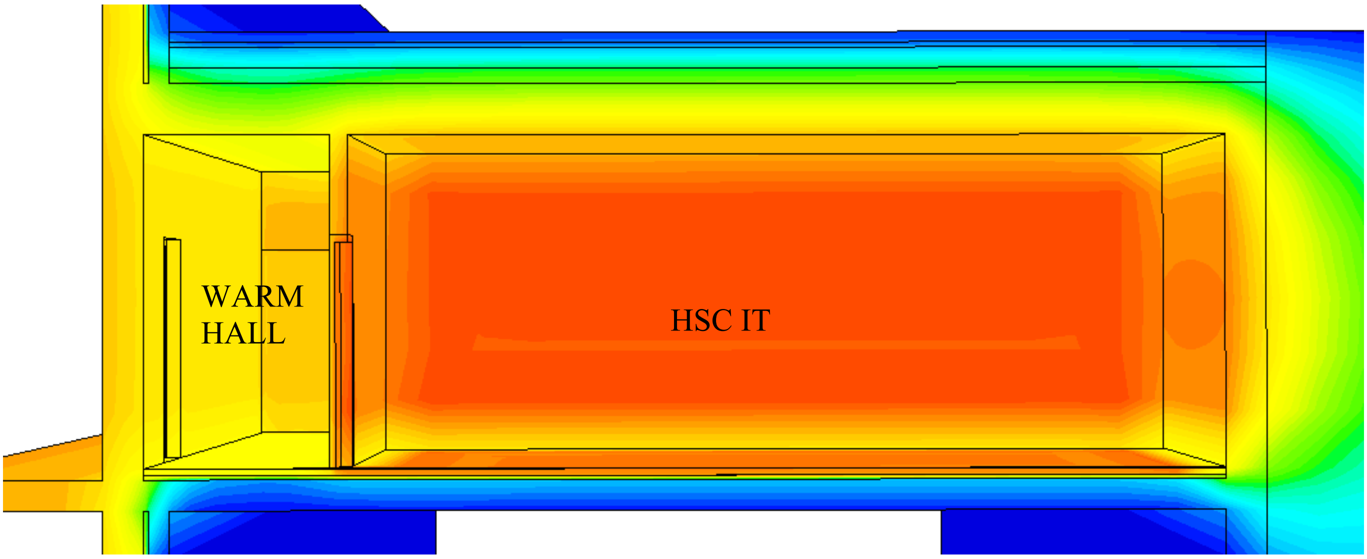
Global temperature profile in the model and temperatures on the inside face

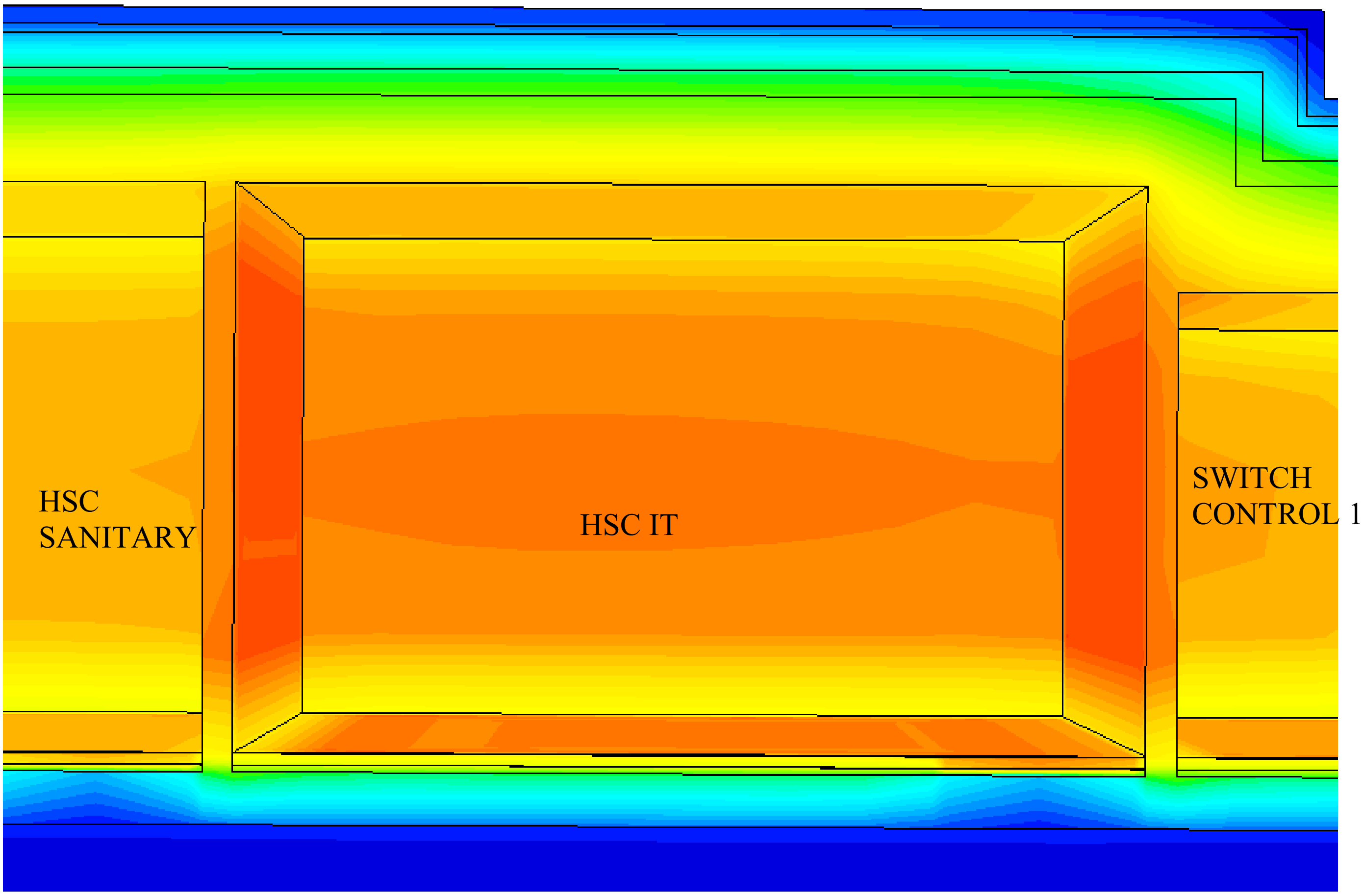


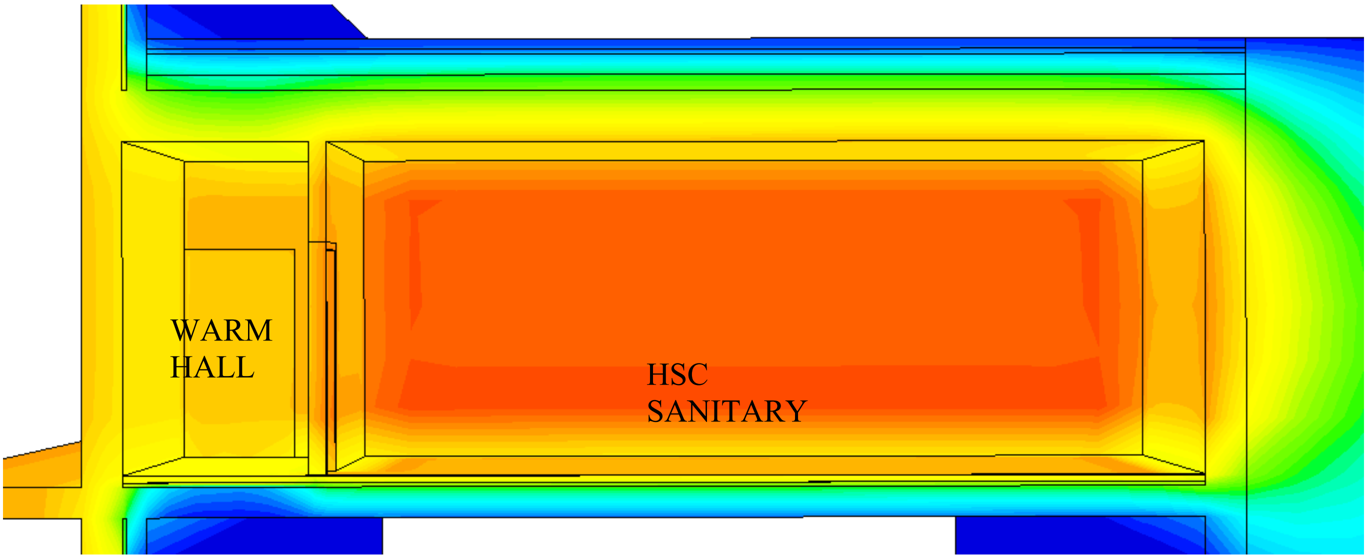


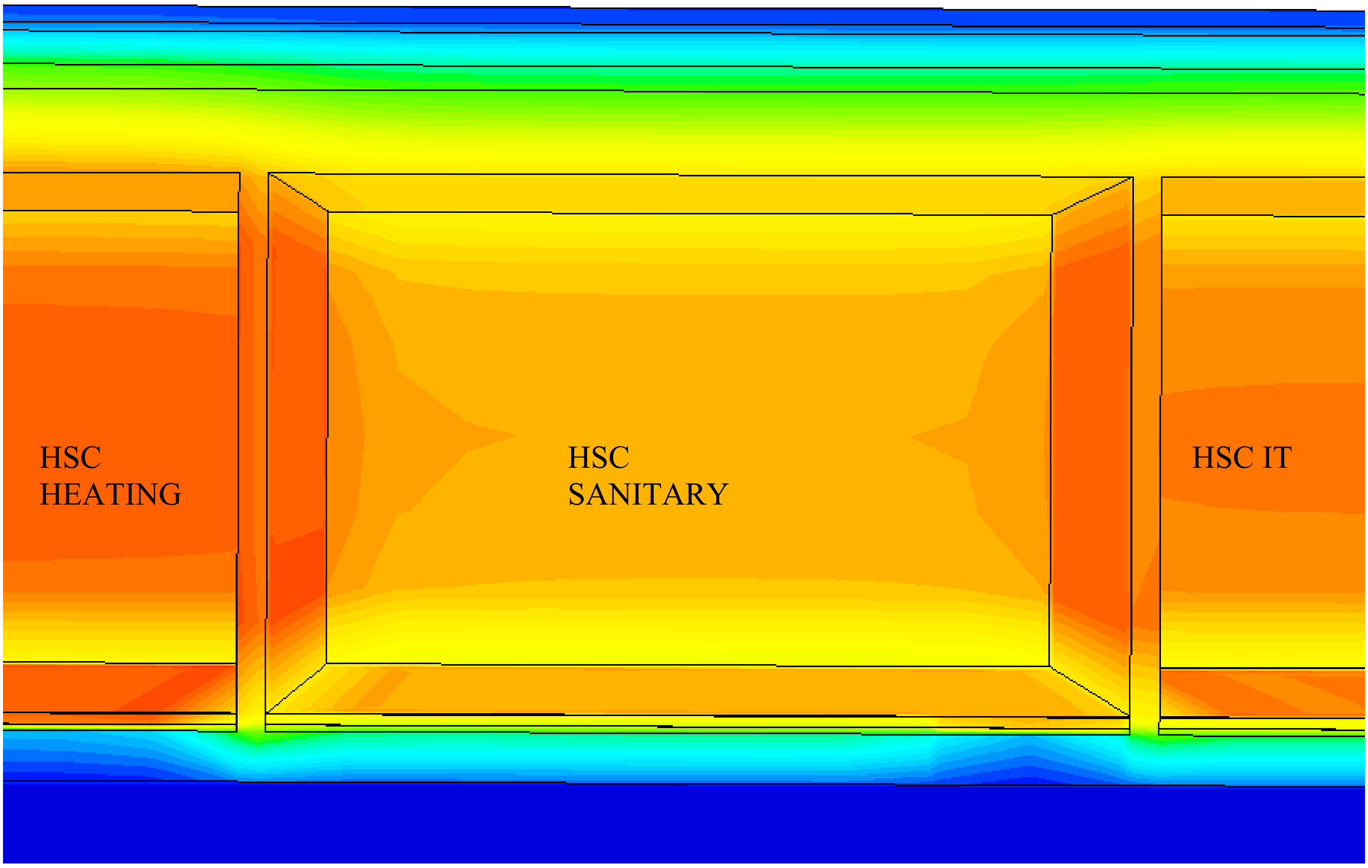

WARM
HALL
SWITCH
CONTROL 1

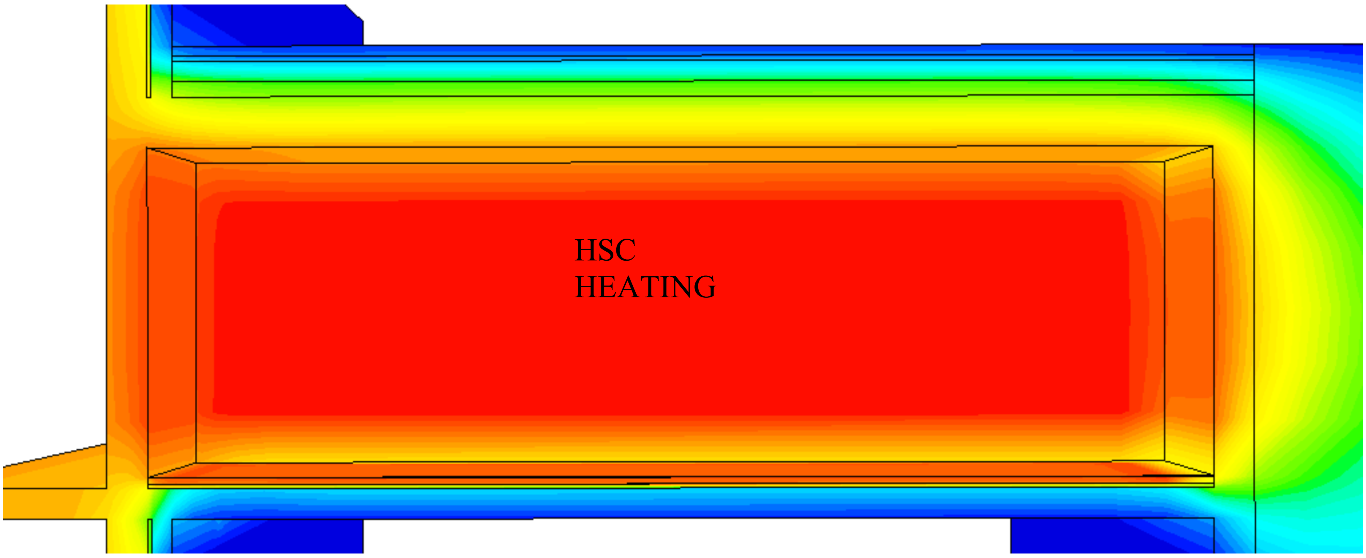

HSC IT
SWITCH
CONTROL 1
INSTALLATION
SPACE

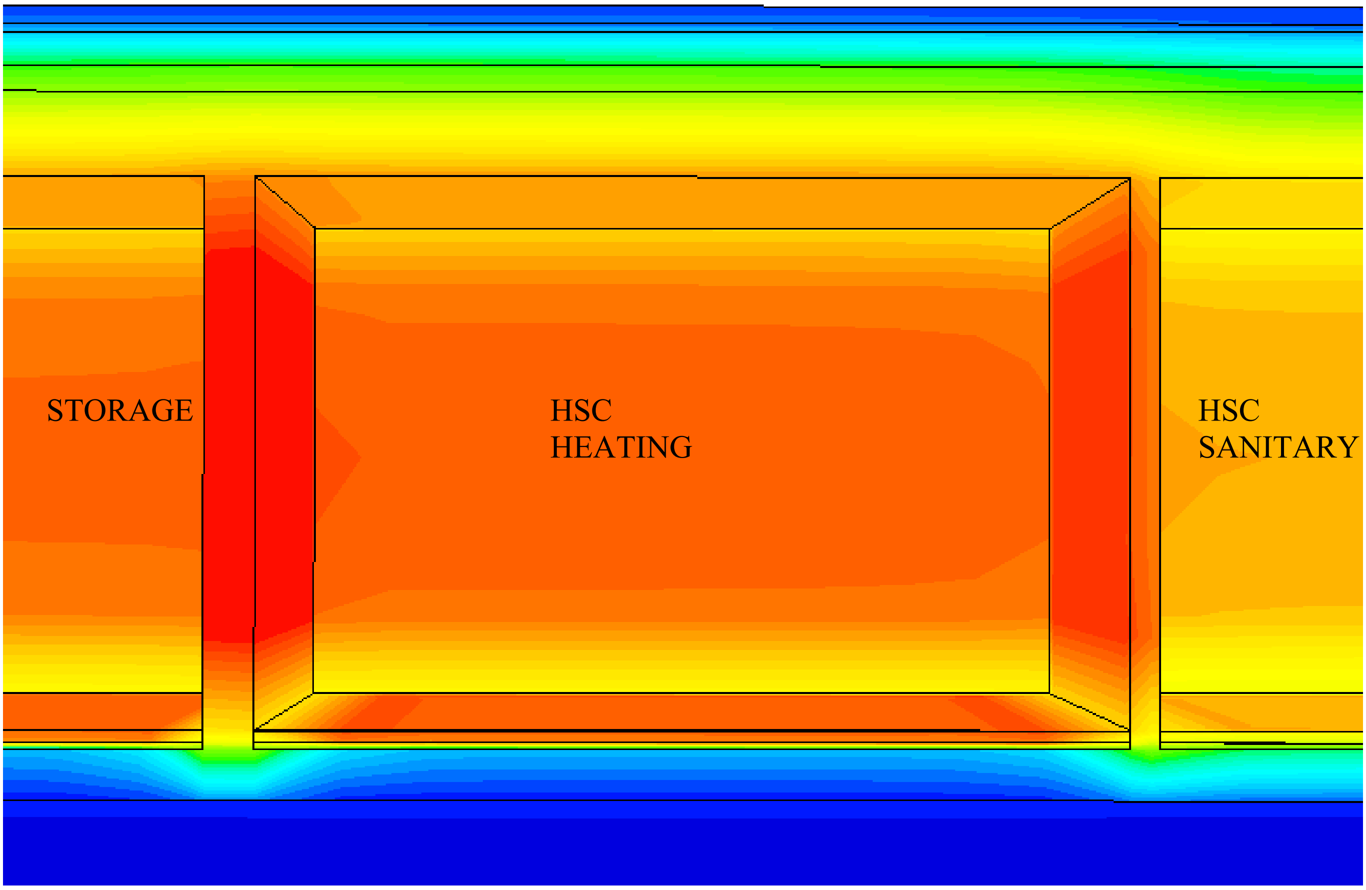

WARM
HALL
HSC IT

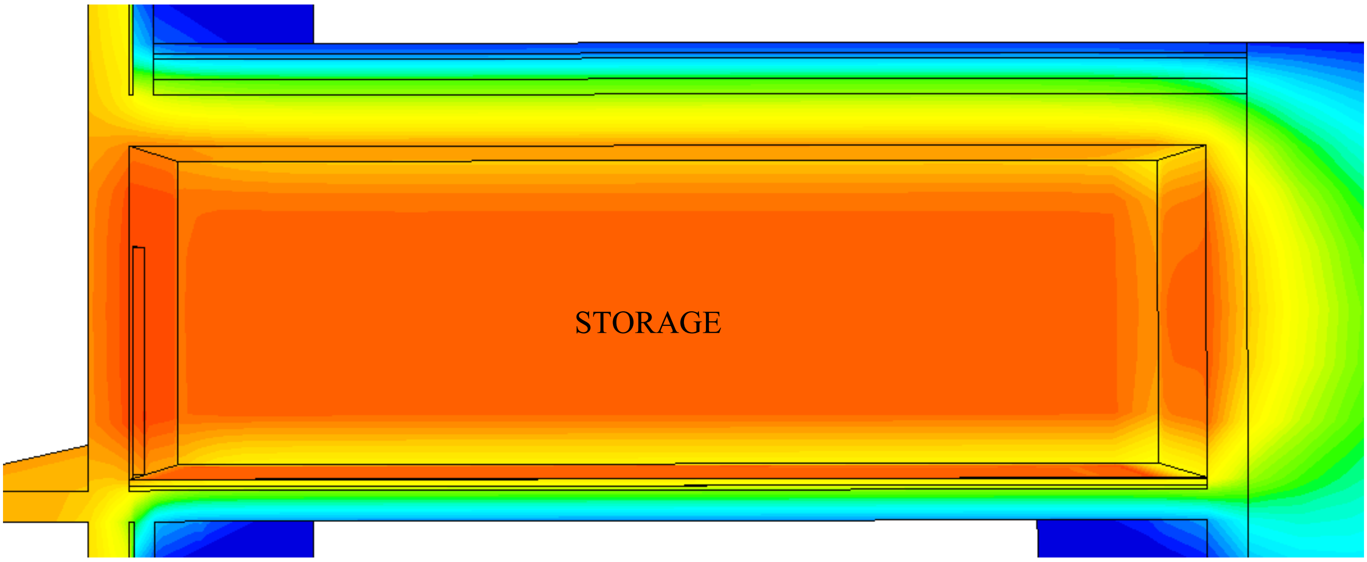

HSC
SANITARY
HSC IT
SWITCH
CONTROL 1

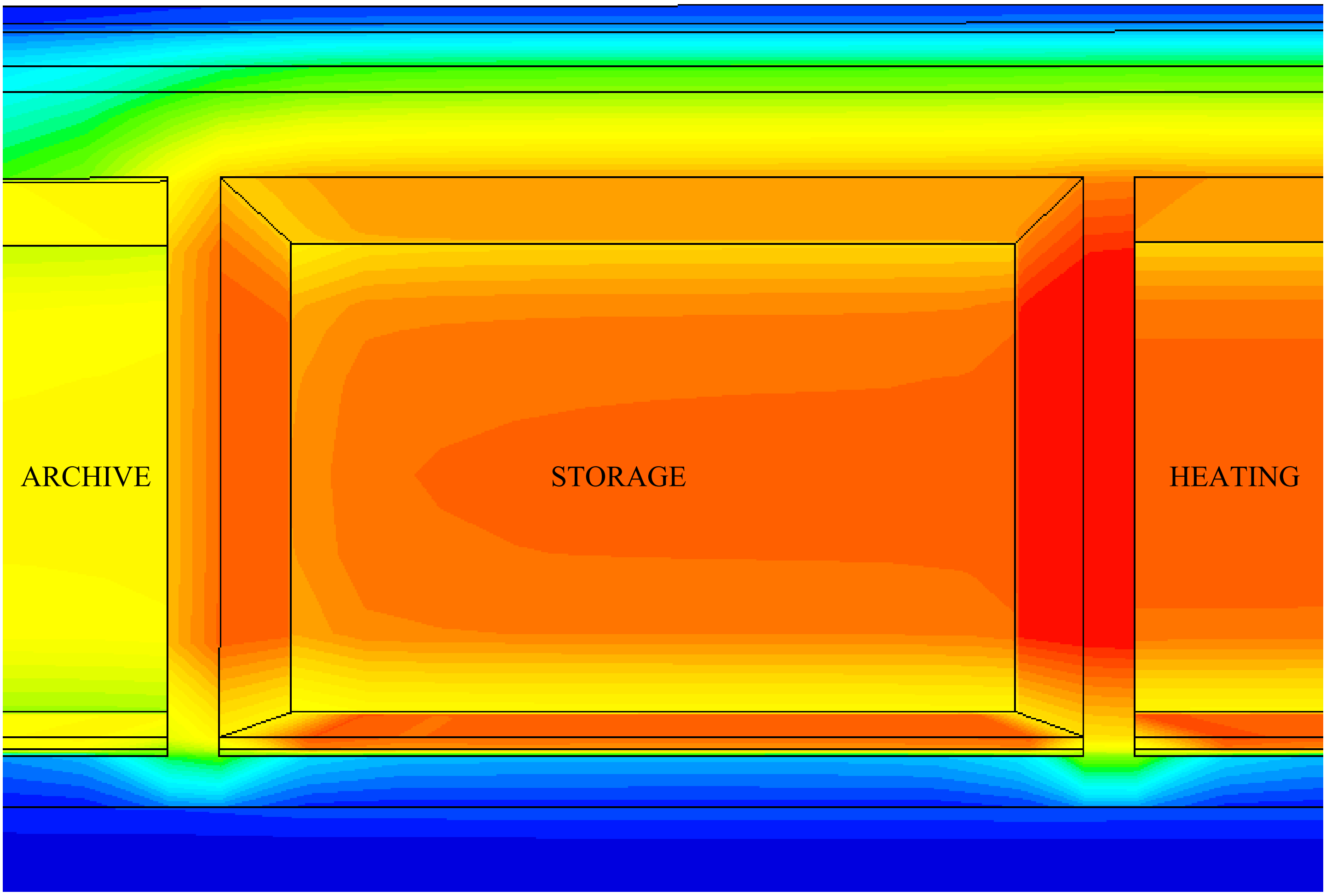

WARM
HALL
HSC
SANITARY

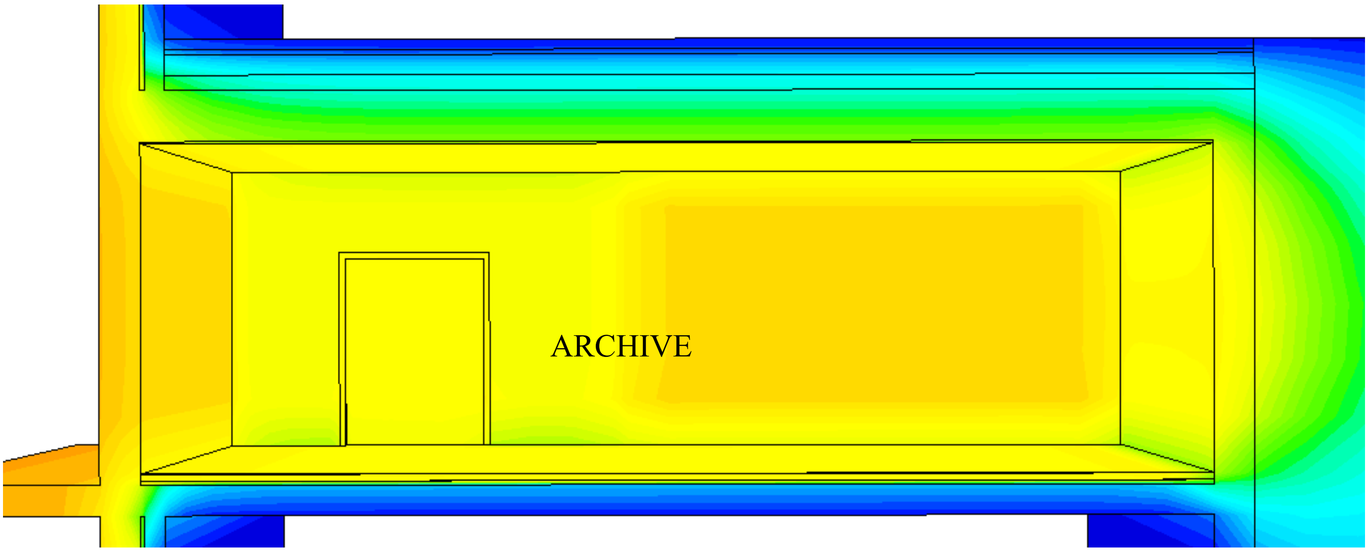

HSC
HEATING
HSC
SANITARY
HSC IT

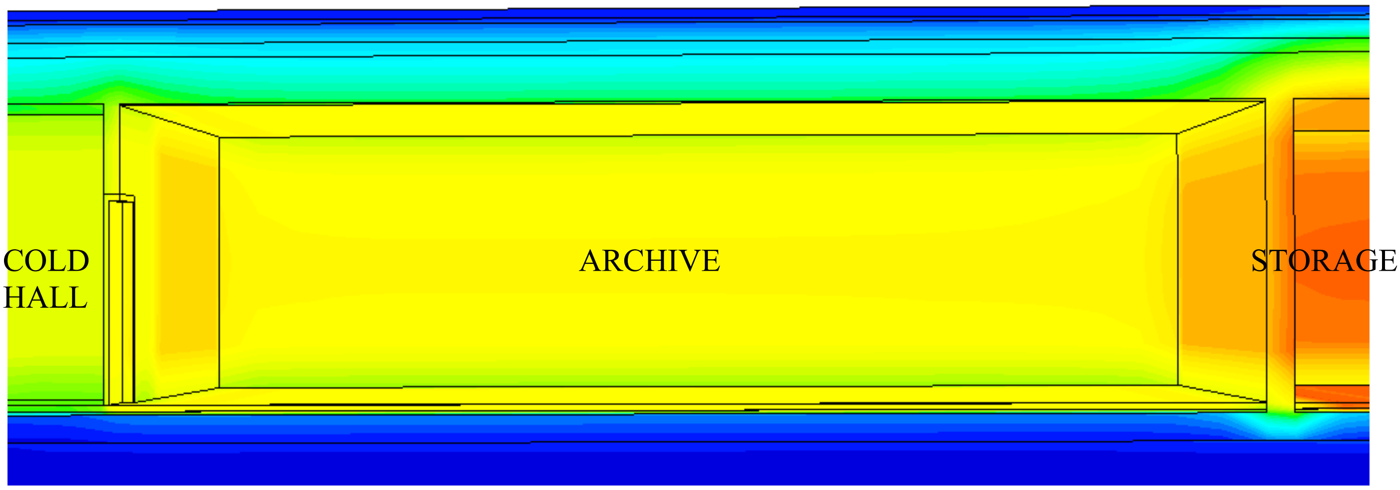

HSC
HEATING

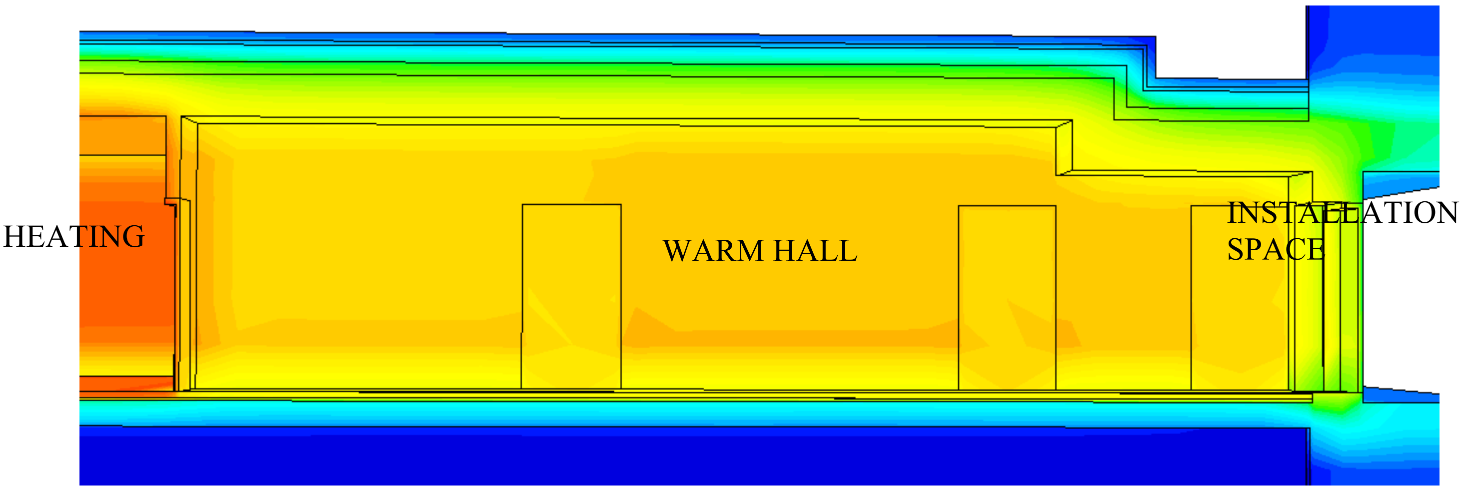

STORAGE
HSC
HEATING
HSC
SANITARY

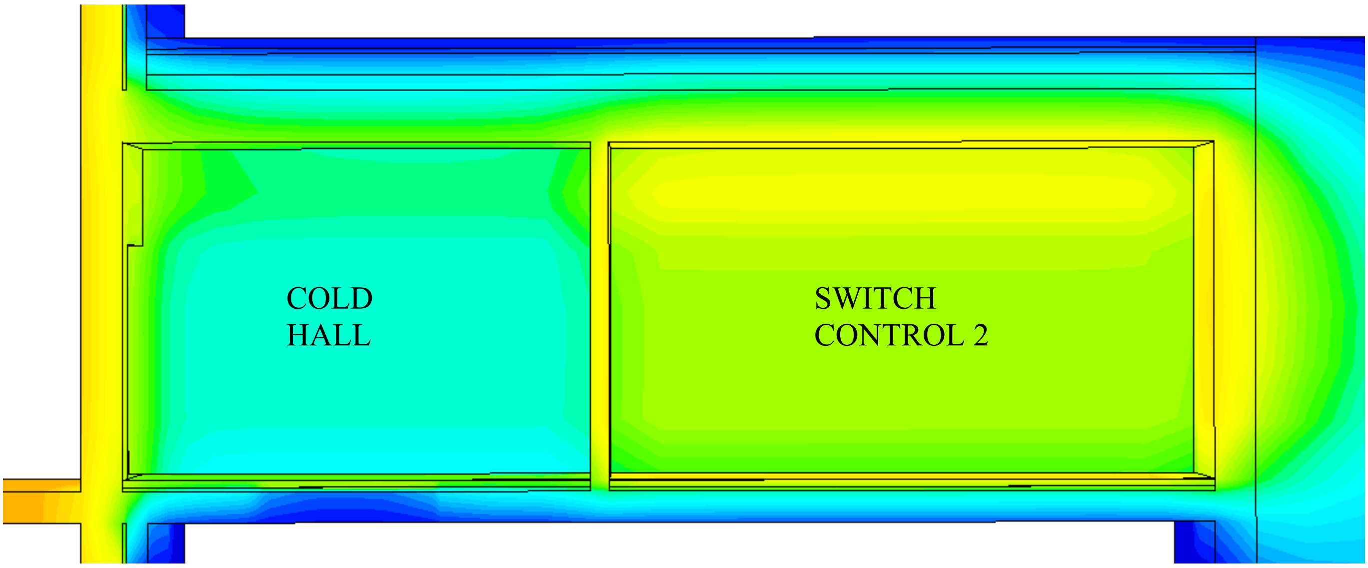

STORAGE

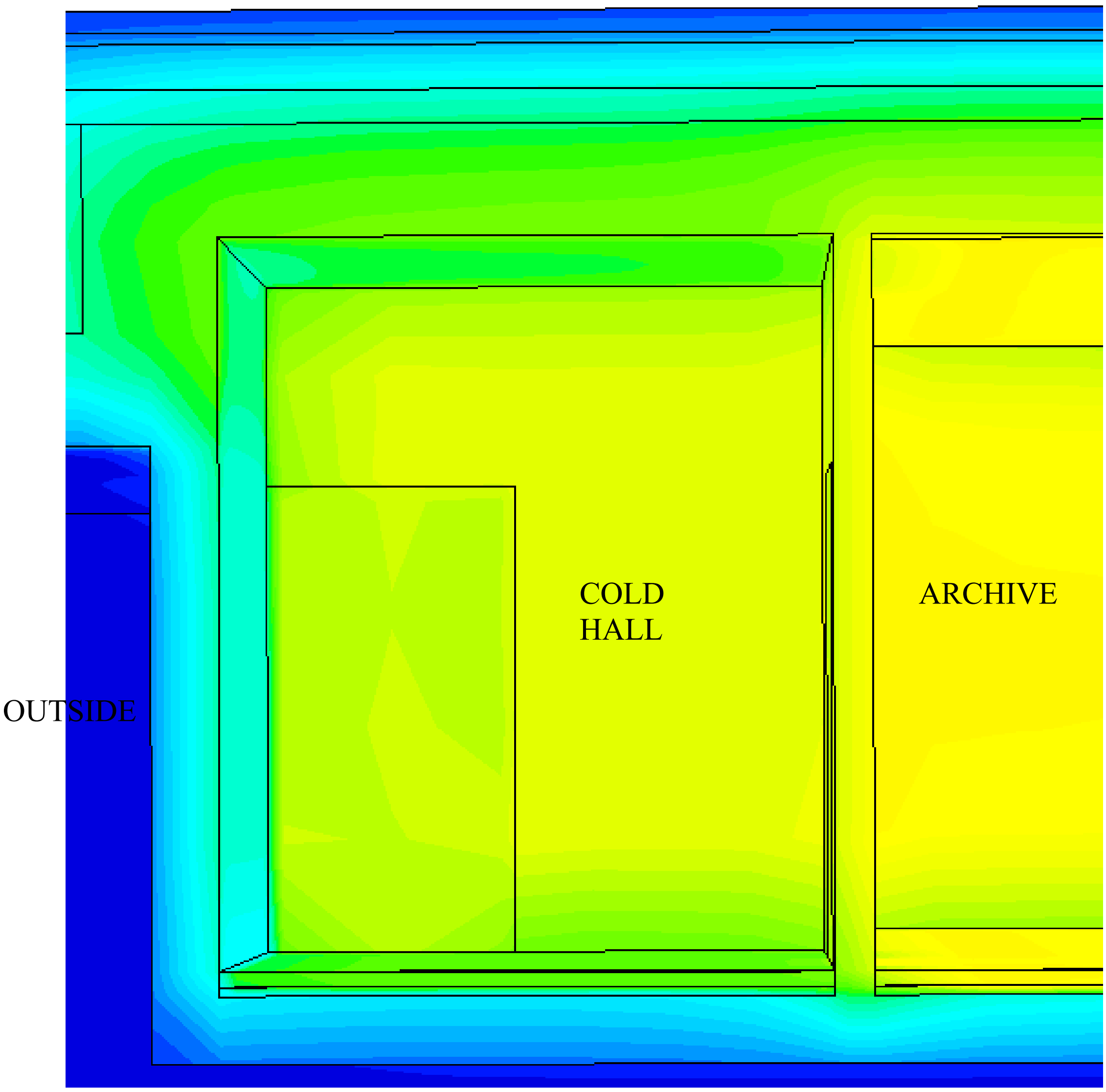

ARCHIVE
STORAGE
HEATING

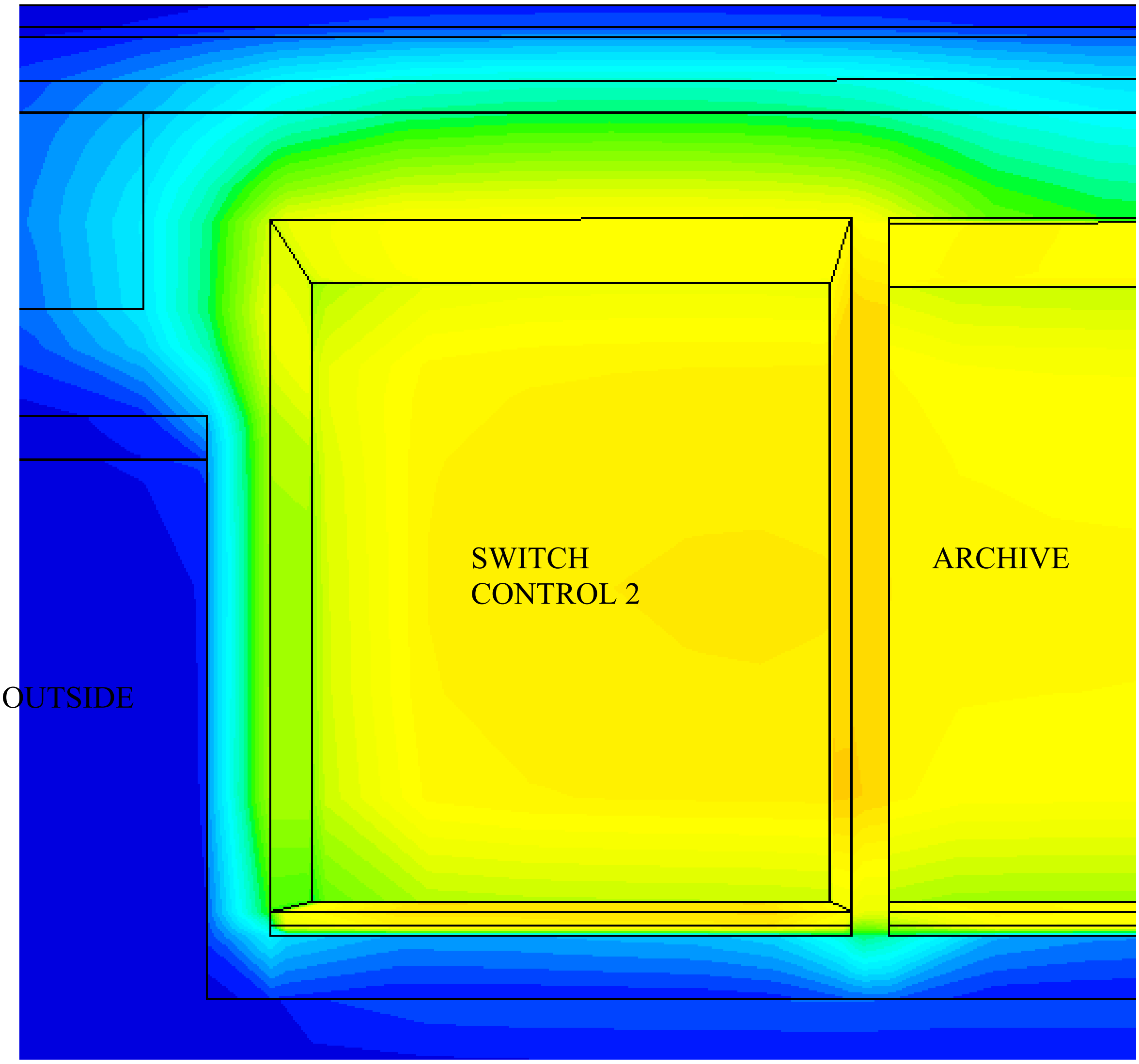

ARCHIVE


COLD
HALL
ARCHIVE
STORAGE


HEATING
WARM HALL
INSTALLATION
SPACE


COLD
HALL
SWITCH
CONTROL 2


COLD
HALL
ARCHIVE
OUTSIDE


SWITCH
CONTROL 2
ARCHIVE
OUTSIDE

3. SEARCH OF CONDENSATION RISKS IN THE TECHNICAL ROOMS

3.1 Analysis of the results and observations

TRISCO data file: equilibrium with insulation archive.trc

Number of nodes = 189787
Heat flow divergence for total object = 4.21571e-010
Heat flow divergence for worst node = 0.693478

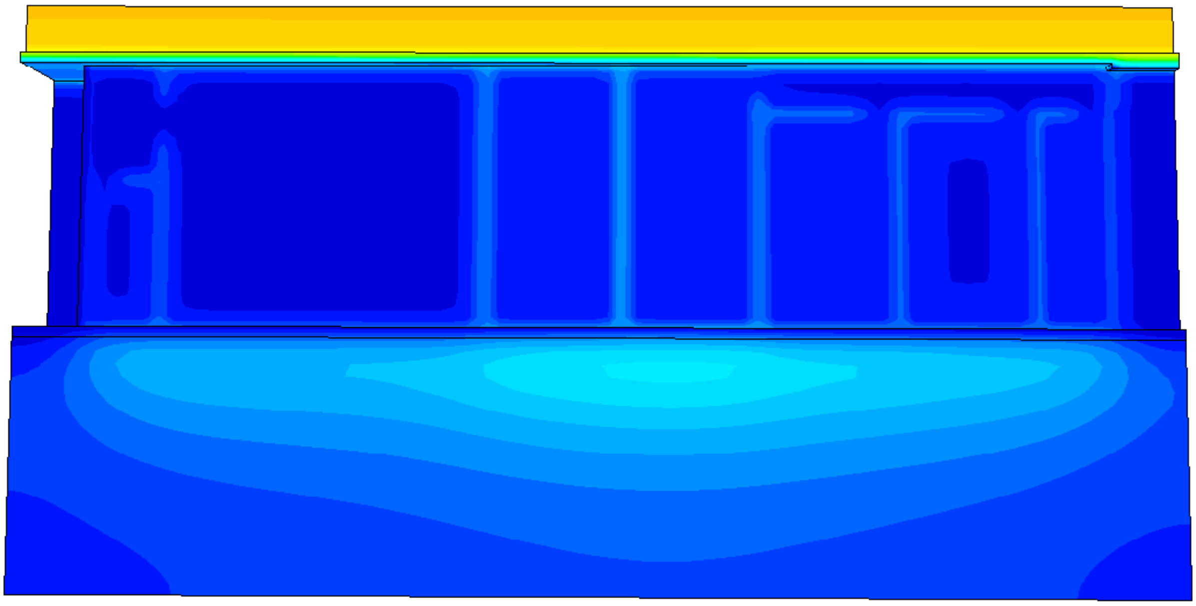
Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
2	BC_SIMPL	EXTERIOR	-12.20	8	50	9	-3.93	111	52	21
3	BC_SIMPL	INTERIOR ATRIUM	14.38	108	60	13	22.02	63	58	16
5	MATERIAL	reinforced concrete	-12.20	8	50	9	26.72	59	27	16
6	MATERIAL	polystyrene insul.	-11.06	8	52	9	23.56	58	22	12
7	MATERIAL	polyethylene	-5.39	110	40	12	23.61	58	22	13
8	MATERIAL	anhydrite screed	-5.38	110	40	13	25.68	58	22	14
9	MATERIAL	floor coating	-3.10	110	40	14	25.86	58	22	15
10	MATERIAL	wood (doors)	-2.72	4	44	15	27.06	49	48	16
11	MATERIAL	asphalt	-11.35	116	37	30	12.22	18	55	25
12	MATERIAL	draining asphalt	-11.73	116	37	31	8.58	17	55	26
13	MATERIAL	cement mortar	-11.85	116	37	32	1.18	16	55	27
14	MATERIAL	heavy stones	-11.90	116	37	33	-3.14	15	52	28
15	MATERIAL	firm stones	-11.28	116	37	23	5.46	112	55	24
19	MATERIAL	soil, clay or silt	-12.00	14	0	33	18.64	59	20	18
20	BC_FRE_S	COLD HALL	-2.94	110	40	15	11.41	100	56	21
21	BC_FRE_S	WARM HALL	3.40	6	44	15	20.28	47	43	16
22	BC_SIMPL	INSTALLATION SPACE	-8.56	3	44	11	3.53	4	53	17
28	BC_FRE_S	SWITCH CONTROL 1	7.08	7	21	15	24.54	19	22	16
29	BC_FRE_S	ARCHIVE ROOM	7.29	93	21	15	19.26	73	27	16
30	BC_FRE_S	HSC HEATING	14.46	50	21	15	27.06	49	48	16
36	BC_FRE_S	HSC IT	13.23	24	21	15	25.34	21	41	16
39	BC_FRE_S	HSC SANITARY	11.58	41	21	15	24.64	47	22	16
44	BC_FRE_S	STORAGE ROOM	12.57	72	21	15	26.46	60	27	16
68	BC_FRE_S	SWITCH CONTROL 2	2.10	110	33	15	18.78	107	33	16

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
2	BC_SIMPL	EXTERIOR		0.27	42086.54
3	BC_SIMPL	INTERIOR ATRIUM		9393.28	373.27
20	BC_FRE_S	COLD HALL	5.53	982.10	982.10
21	BC_FRE_S	WARM HALL	15.31	1348.42	1348.42
22	BC_SIMPL	INSTALLATION SPACE		335.30	1607.05
28	BC_FRE_S	SWITCH CONTROL 1	23.18	3593.97	107.10
29	BC_FRE_S	ARCHIVE ROOM	16.19	6832.06	1024.61
30	BC_FRE_S	HSC HEATING	26.71	6162.43	0.46
36	BC_FRE_S	HSC IT	24.92	5279.79	0.73
39	BC_FRE_S	HSC SANITARY	22.41	4170.40	468.72
44	BC_FRE_S	STORAGE ROOM	26.07	6280.12	41.52
68	BC_FRE_S	SWITCH CONTROL 2	18.64	3662.61	0.06

Most of these temperatures are too low for the inside temperatures of the associated rooms, which means that for the given conditions (-12°C outside), condensation might appear.
But some important points have to be cleared:

- First, as we said before, -12°C is an extreme condition. It will eventually be reached a couple of days, some years.
- Condensation is not to be avoided if it is in small quantities of water and if it can be dried, especially in these technical areas, so that no water is remaining for one year observation.

- Given that this part of the building is not insulated and cannot be insulated from the outside, it seems difficult to eliminate all the thermal bridges that appear in the model. Every wall (see below) is a thermal bridge at its connections with the horizontal slabs, and trying to insulate those edges will just report the thermal bridge a few centimetres further.



- As we cannot predict precisely the rate of relative humidity in any of those rooms (inside air is mixed with outside air, in quantities that we don't know…), we cannot know exactly at what superficial temperature that condensation will appear.

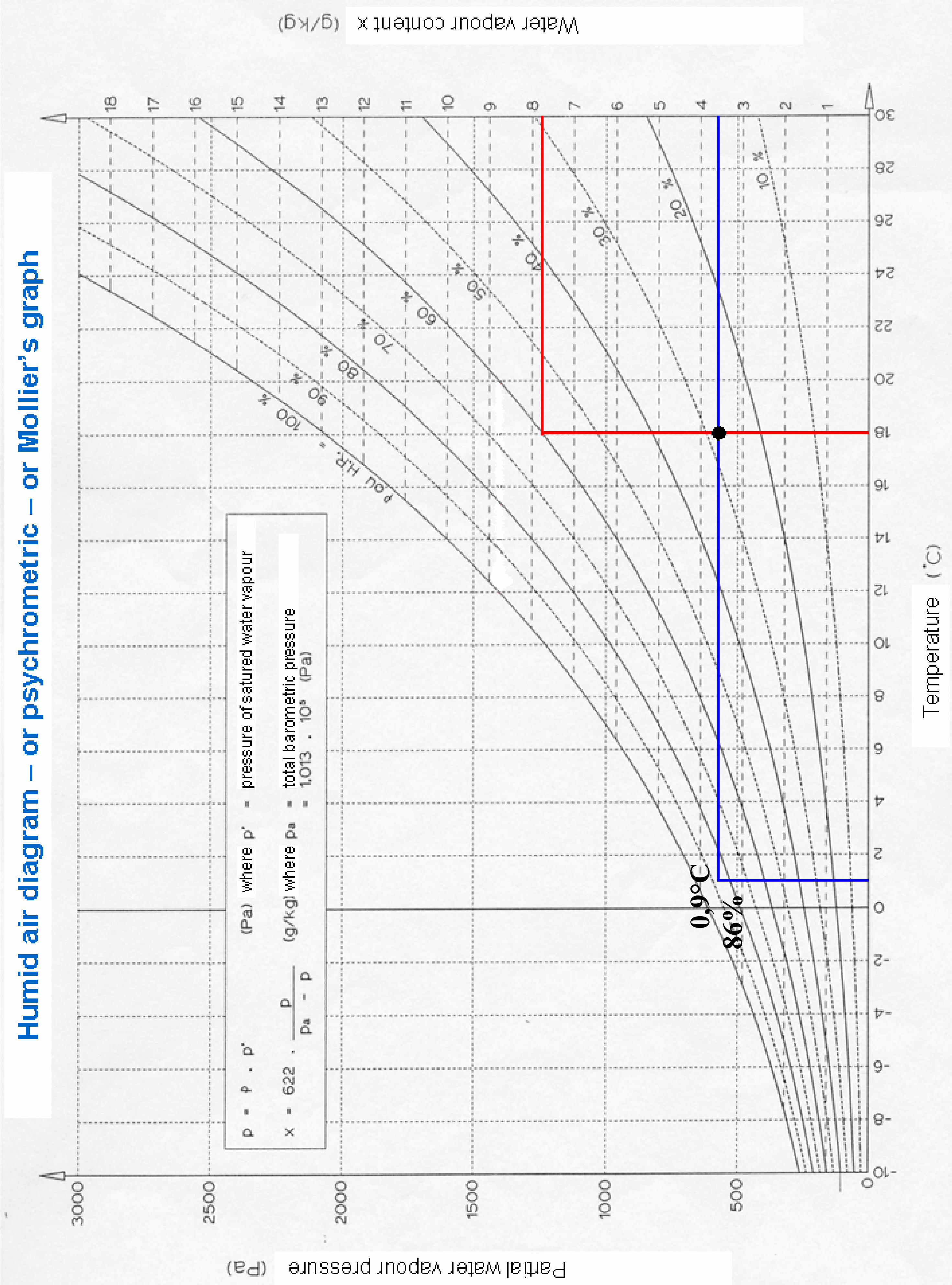
3.2 Hypothesis of the new model

Here is an average climate for Luxembourg City, available on the web site www.climatology.lu.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AVERAGE TEMPERATURE	0.9	1.92	4.85	8.22	12.55	15.69	17.27	16.86	13.59	9.43	4.75	2.07
AVERAGE RELATIVE HUMIDITY	86	80	76	71	70	71	71	73	78	83	86	88

January seems to be the coldest month of the year. We will use its characteristics to evaluate the risk of condensation in the technical rooms.
We can see that for this period, an average temperature of 0.9°C can be accepted: it has been calculated over the last 50 years.
For the very same month, an average 86% of relative humidity is calculated on the same basis.

We can do the hypothesis that, in particular in the hot rooms, with an intensive ventilation system, the air of the room is replaced every 20 minutes or so by external air. We could consider that the air in those rooms contains the same quantity of water vapour as the external air at its equilibrium point.
If we look at the Mollier's graph (see figure next page), we can see that the air that ventilates the rooms contains about 3.5 grams of water vapour in each kilogram of dried air.
We know that in the rooms, the very same air will be heated until the target temperature, but will keep the same content of water vapour. This means that the relative humidity of the room will diminish, until 20 to 35%, according to room temperature arising 15°C to 25°C.
On those results, we can notice that condensation will only appear in January if the minimal temperature on an internal face is inferior to -1°C and doesn't appear in other month or with higher external temperatures.


Humid air diagram – or psychrometric – or Mollier's graph
Water vapour content x (g/kg)
Partial water vapour pressure (Pa)
Temperature (°C)
p = φ . p' (Pa) where p' = pressure of satured water vapour
x = 622 . p / (pa − p) (g/kg) where pa = total barometric pressure = 1,013 . 10⁵ (Pa)
φ ou H.R. = 100 %
0,9°C
86%

Other hypotheses:

- We have used the same model than the first one of this report to obtain an equilibrium temperature of 4°C for the installation space.
- The temperature inside the atrium is still 20°C, and the outside temperature is now 0.9°C.
- The boundary conditions used in the rooms are now the one called "BC_SIMPL": "simplified surface boundary condition, defined by a global surface heat transfer coefficient (h) and environmental temperature (t)". This means that we have imposed the target temperature upon each room (18°C for the "switch control 1 and 2" and for the "HSC sanitary", 15°C for the "archive room" 24°C for the "IT room" and the "storage room", and 26°C for the heating district); for the cold and warm halls, we still have the boundary conditions "BC_FRE_S", as we don't know their equilibrium temperatures.
- Trisco does not allow modeling a sloped structure. This, in consequence, obliged us to model a stair-shaped structure, to respect the inside volumes and to get as close as possible to the real external exchange surfaces.
- The lambda values used in this model are all coming from the Trisco data base (from the Belgian standard NBN B62-002 or from the Physibel data base).

3.2 Input data

TRISCO - Input Data

TRISCO data file: condensation risks.trc

GRID

Grid unit = 0.01 m

No.	X	Y	Z
0-1	50.000	52.000	50.000
1-2	50.000	50.000	50.000
2-3	50.000	50.000	50.000
3-4	50.000	50.000	50.000
4-5	5.500	50.000	50.000
5-6	19.500	50.000	50.000
6-7	35.000	50.000	50.000
7-8	4.000	50.000	50.000
8-9	3.000	50.000	50.000
9-10	53.500	50.000	50.000
10-11	53.500	50.000	30.000
11-12	7.000	50.000	4.000
12-13	33.250	50.000	0.040
13-14	33.250	50.000	6.500
14-15	10.000	50.000	0.500
15-16	5.000	50.000	55.000
16-17	20.000	50.000	55.000
17-18	15.000	50.000	55.000
18-19	32.500	50.000	55.000
19-20	17.500	50.000	7.000
20-21	7.000	40.000	4.500
21-22	53.500	48.542	32.500
22-23	53.500	48.541	17.500
23-24	7.000	48.542	40.500
24-25	38.400	48.542	2.000
25-26	38.400	48.541	15.000
26-27	7.000	48.542	20.000
27-28	53.500	48.542	5.000
28-29	53.500	48.541	10.000
29-30	7.000	48.542	15.000
30-31	49.800	48.542	20.000
31-32	49.800	48.541	5.000
32-33	49.800	48.542	10.000

33-34	49.800	12.000	50.000
34-35	17.500	5.500	50.000
35-36	7.000	48.600	50.000
36-37	53.500	48.600	50.000
37-38	53.500	48.600	
38-39	7.000	7.000	
39-40	49.625	50.000	
40-41	49.625	50.000	
41-42	49.625	12.000	
42-43	49.625	5.500	
43-44	49.625	39.000	
44-45	49.625	7.000	
45-46	49.625	7.000	
46-47	49.625	6.000	
47-48	5.500	7.000	
48-49	12.000	43.500	
49-50	51.300	26.500	
50-51	51.300	17.000	
51-52	51.300	3.000	
52-53	51.300	4.000	
53-54	51.300	13.000	
54-55	51.300	3.000	
55-56	51.300	4.000	
56-57	51.300	15.000	
57-58	51.300	5.500	
58-59	51.299	14.000	
59-60	30.000	5.500	
60-61	31.201	50.000	
61-62	7.000	50.000	
62-63	48.500	50.000	
63-64	48.500	50.000	
64-65	7.000		
65-66	51.114		
66-67	51.115		
67-68	51.114		
68-69	51.114		
69-70	51.115		
70-71	51.114		
71-72	51.114		
72-73	30.000		
73-74	49.200		
74-75	49.200		
75-76	49.200		
76-77	49.200		
77-78	49.200		
78-79	49.200		
79-80	49.200		
80-81	49.200		
81-82	49.200		
82-83	49.200		
83-84	49.200		
84-85	49.200		
85-86	49.200		
86-87	49.200		
87-88	49.200		
88-89	49.200		
89-90	49.200		
90-91	49.200		
91-92	49.200		
92-93	49.200		
93-94	49.201		

94-95	49.199		
95-96	49.200		
96-97	49.201		
97-98	49.200		
98-99	12.000		
99-100	5.500		
100-101	4.000		
101-102	32.750		
102-103	32.750		
103-104	7.000		
104-105	37.000		
105-106	37.000		
106-107	6.999		
107-108	53.500		
108-109	53.500		
109-110	7.000		
110-111	30.000		
111-112	30.000		
112-113	50.000		
113-114	50.000		
114-115	50.000		
115-116	50.000		
Sum	4470.500	2332.300	1165.040

COLOURS

Col.	Type	CEN-rule	Name	lambda [W/mK]	eps [-]	t [°C]	h [W/m²K]	q [W/m²]
2	BC_SIMPL	NIHIL	EXTERIOR			0.9	20.00	0
3	BC_SIMPL	NIHIL	INTERIOR ATRIUM			20.0	8.00	0
5	MATERIAL		reinforced concrete					
6	MATERIAL		polystyrene insul.	0.035				
7	MATERIAL		polyethylene	0.200				
8	MATERIAL		anhydrite screed	0.840				
9	MATERIAL		floor coating	0.840				
10	MATERIAL		wood (doors)	0.240				
11	MATERIAL		asphalt	2.100				
12	MATERIAL		draining asphalt	1.000				
13	MATERIAL		cement mortar	0.840				
14	MATERIAL		heavy stones	3.490				
15	MATERIAL		firm stones	2.090				
19	MATERIAL		soil, clay or silt	1.500				
20	BC_FRE_S	NIHIL	COLD HALL				8.00	0
21	BC_FRE_S	NIHIL	WARM HALL				8.00	0
22	BC_SIMPL	NIHIL	INSTALLATION SPACE			4.0	8.00	0
28	BC_SIMPL	NIHIL	SWITCH CONTROL 1			18.0	8.00	0
29	BC_SIMPL	NIHIL	ARCHIVE ROOM			15.0	8.00	0
30	BC_SIMPL	NIHIL	HSC HEATING			26.0	8.00	0
36	BC_SIMPL	NIHIL	HSC IT			24.0	8.00	0
39	BC_SIMPL	NIHIL	HSC SANITARY			18.0	8.00	0
44	BC_SIMPL	NIHIL	STORAGE ROOM			24.0	8.00	0
68	BC_SIMPL	NIHIL	SWITCH CONTROL 2			18.0	8.00	0

Calculation parameters

Maximum number of iterations = 10000
Maximum temperature difference = 0.0001°C
Heat flow divergence for total object = 0.001 %
Heat flow divergence for worst node = 1 %

3.3 Results

TRISCO - Calculation Results

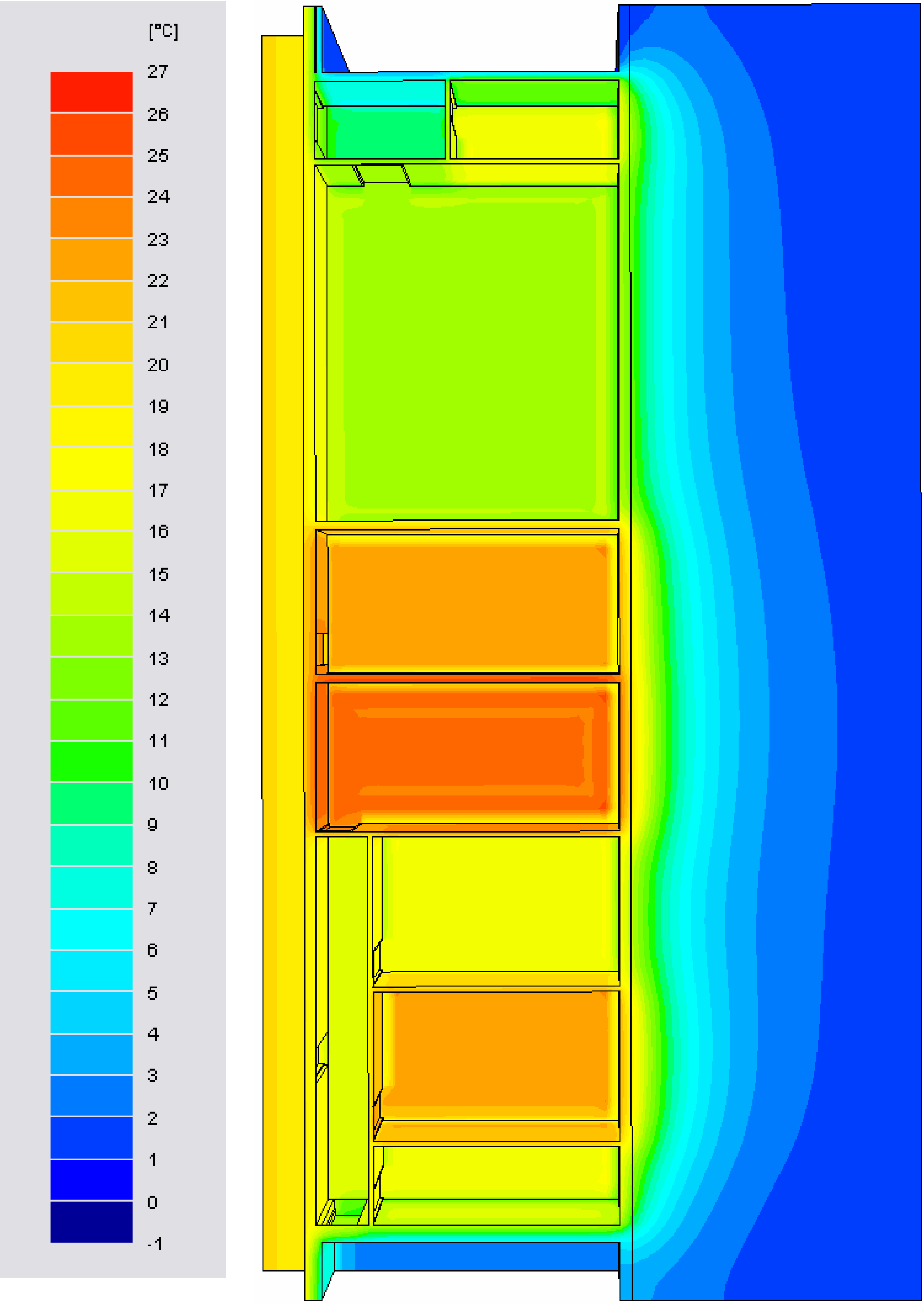
TRISCO data file: condensation risks.trc

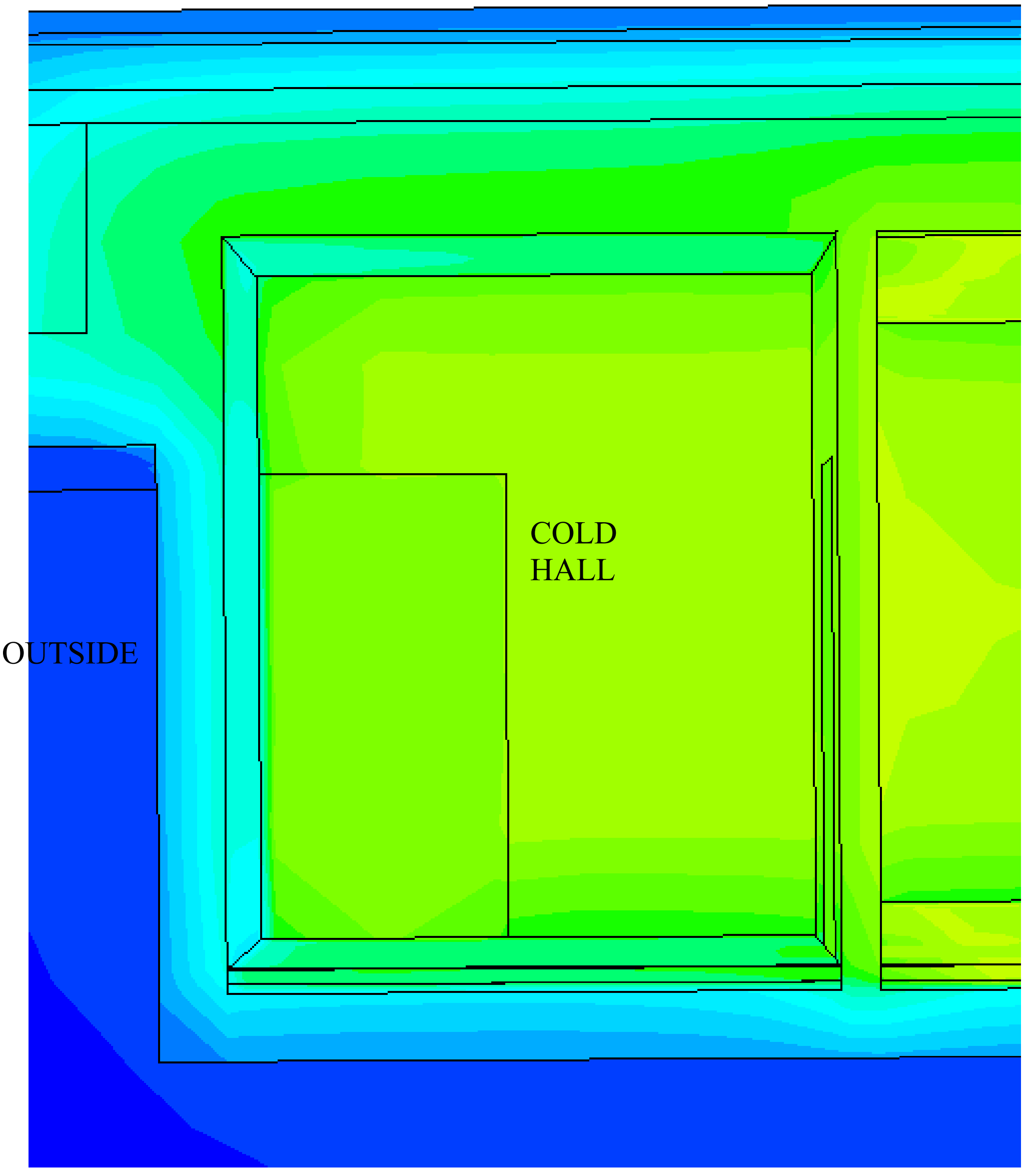
Number of nodes = 189780
Heat flow divergence for total object = 1.82906e-012
Heat flow divergence for worst node = 0.926411

Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
2	BC_SIMPL	EXTERIOR	0.78	8	50	9	5.51	111	52	21
3	BC_SIMPL	INTERIOR ATRIUM	16.41	108	60	13	21.54	54	60	18
5	MATERIAL	reinforced concrete	0.78	8	50	9	25.54	59	30	16
6	MATERIAL	polystyrene insul.	1.46	8	52	9	23.99	50	22	12
7	MATERIAL	polyethylene	4.51	110	40	12	24.02	50	22	13
8	MATERIAL	anhydrite screed	4.52	110	40	13	25.40	50	22	14
9	MATERIAL	floor coating	5.76	110	40	14	25.51	50	22	15
10	MATERIAL	wood (doors)	6.22	4	44	15	26.18	49	48	16
11	MATERIAL	asphalt	1.26	116	37	30	15.14	18	55	25
12	MATERIAL	draining asphalt	1.05	116	37	31	12.98	17	55	26
13	MATERIAL	cement mortar	0.99	116	37	32	8.64	16	55	27
14	MATERIAL	heavy stones	0.95	116	37	33	6.09	15	52	28
15	MATERIAL	firm stones	1.30	116	37	23	11.15	112	55	24
19	MATERIAL	soil, clay or silt	0.90	14	0	33	20.65	55	20	18
20	BC_FRE_S	COLD HALL	5.84	110	40	15	14.17	104	59	15
21	BC_FRE_S	WARM HALL	9.70	6	44	15	20.40	47	46	16
22	BC_SIMPL	INSTALLATION SPACE	2.88	3	44	11	10.00	4	53	17
28	BC_SIMPL	SWITCH CONTROL 1	10.25	7	21	15	20.54	19	22	16
29	BC_SIMPL	ARCHIVE ROOM	10.55	90	21	15	17.77	73	56	18
30	BC_SIMPL	HSC HEATING	17.08	49	21	15	26.18	49	48	16
36	BC_SIMPL	HSC IT	15.82	20	21	15	24.18	23	41	16
39	BC_SIMPL	HSC SANITARY	12.65	41	21	15	21.24	47	22	16
44	BC_SIMPL	STORAGE ROOM	15.29	72	21	15	24.71	60	26	16
68	BC_SIMPL	SWITCH CONTROL 2	8.75	110	33	15	18.07	107	33	16

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
2	BC_SIMPL	EXTERIOR		0.15	24052.75
3	BC_SIMPL	INTERIOR ATRIUM		5925.40	298.15
20	BC_FRE_S	COLD HALL	10.47	534.95	534.95
21	BC_FRE_S	WARM HALL	16.66	793.46	793.46
22	BC_SIMPL	INSTALLATION SPACE		201.98	812.76
28	BC_SIMPL	SWITCH CONTROL 1		1580.76	356.88
29	BC_SIMPL	ARCHIVE ROOM		3215.54	1100.06
30	BC_SIMPL	HSC HEATING		4704.16	0.07
36	BC_SIMPL	HSC IT		4133.12	0.08
39	BC_SIMPL	HSC SANITARY		1754.65	962.41
44	BC_SIMPL	STORAGE ROOM		4046.32	127.41
68	BC_SIMPL	SWITCH CONTROL 2		2148.67	0.03

The cold hall is obviously the coldest room here again. We can check this out on the following pictures:


[°C]
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1



TRISCO - Temperatures in corner nodes

TRISCO data file: condensation risks.trc

X	Y	Z	t [°C]
0	0	0	2.26
0	0	29	0.92
0	21	1	0.94
0	21	10	1.44
0	21	11	2.92
0	21	22	3.44
0	50	1	1.68
0	50	10	2.76
0	50	29	2.14
0	50	37	1.43
0	53	11	7.25
0	53	22	7.85
0	60	0	18.71
0	60	10	17.51
0	60	11	17.49
0	60	37	18.66

this list of all the corner nodes of the model shows us that there is no point where the temperature is under -1°C. Condensation should not then be a problem in the rooms.

0	64	10	20.00
0	64	11	20.00
4	21	11	3.85
4	21	22	5.33
4	53	11	9.18
4	53	22	9.70
5	45	15	10.15
5	45	19	12.49
5	51	15	12.08
5	51	19	13.41
6	44	15	9.70
6	44	20	11.65
6	45	15	11.50
6	45	19	15.92
6	51	15	13.68
6	51	19	16.53
6	53	15	13.84
6	53	20	14.33
7	21	15	10.25
7	21	22	11.51
7	41	15	11.03
7	41	22	13.15
7	43	15	10.87
7	43	22	12.87
7	44	15	12.42
7	44	20	15.22
7	53	15	14.85
7	53	20	16.27
7	56	15	15.46
7	56	22	16.01
8	50	1	1.32
8	50	10	2.62
8	50	29	2.20
8	50	37	1.00
8	52	1	2.09
8	52	10	4.97
8	52	29	3.00
8	52	37	1.68
9	41	15	15.47
9	41	19	17.57
9	42	15	15.71
9	42	19	17.18
11	41	15	16.12
11	41	19	17.93
11	42	15	16.22
11	42	19	17.55
14	0	29	0.94
14	0	33	0.90
14	52	29	3.83
14	52	33	1.67
14	55	25	14.04
14	55	29	5.87
14	56	25	15.32
14	56	29	16.50
18	55	25	15.14
18	55	29	11.62
18	56	25	15.56
18	56	29	14.42
19	21	15	14.35
19	21	22	17.96
19	41	15	14.99

19	41	22	18.41
20	21	15	15.82
20	21	25	16.26
20	41	15	16.72
20	41	25	17.31
20	43	22	18.09
20	43	25	15.32
20	56	22	17.33
20	56	25	16.33
21	41	15	20.88
21	41	19	23.60
21	42	15	19.99
21	42	19	21.74
23	41	15	21.07
23	41	19	23.70
23	42	15	20.06
23	42	19	21.84
26	56	15	15.76
26	56	20	17.22
26	57	15	16.27
26	57	20	17.75
27	57	15	15.86
27	57	19	16.76
27	59	15	17.48
27	59	19	17.65
29	57	15	15.87
29	57	19	16.76
29	59	15	17.48
29	59	19	17.65
30	56	15	15.77
30	56	20	17.24
30	57	15	16.28
30	57	20	17.77
34	21	15	16.07
34	21	25	17.47
34	41	15	16.98
34	41	25	18.45
35	21	15	14.49
35	21	25	15.95
35	41	15	15.45
35	41	25	16.88
36	41	15	16.43
36	41	19	18.16
36	42	15	16.46
36	42	19	17.77
38	41	15	16.10
38	41	19	17.95
38	42	15	16.23
38	42	19	17.60
47	21	15	14.83
47	21	25	16.32
47	41	15	16.08
47	41	25	17.84
47	43	15	15.64
47	43	25	17.43
47	56	15	17.23
47	56	25	18.46
48	48	15	21.37
48	48	19	23.27
48	54	15	21.63
48	54	19	23.09

49	21	15	17.08
49	21	25	18.51
49	48	15	22.95
49	48	19	25.65
49	54	15	23.18
49	54	19	25.57
49	56	15	20.35
49	56	25	21.06
59	21	15	17.85
59	21	25	19.76
59	56	15	20.87
59	56	25	22.30
60	21	15	17.10
60	21	25	19.08
60	56	15	20.14
60	56	25	21.63
61	56	15	21.03
61	56	20	23.28
61	57	15	20.31
61	57	20	22.60
62	58	15	19.83
62	58	19	21.16
62	60	15	19.64
62	60	19	20.10
64	58	15	19.72
64	58	19	21.14
64	60	15	19.60
64	60	19	20.10
65	56	15	20.80
65	56	20	23.19
65	57	15	20.04
65	57	20	22.46
72	21	15	15.29
72	21	25	16.65
72	56	15	18.90
72	56	25	19.96
73	21	15	12.18
73	21	24	13.69
73	56	15	15.78
73	56	24	17.00
98	21	15	11.52
98	21	24	12.71
98	39	15	13.20
98	39	19	14.82
98	45	15	13.31
98	45	19	14.81
98	56	15	14.20
98	56	24	14.82
99	39	15	12.71
99	39	19	13.68
99	45	15	12.43
99	45	19	13.58
100	21	15	12.31
100	21	25	13.25
100	33	15	12.85
100	33	25	13.50
100	35	15	10.56
100	35	25	11.43
100	56	15	12.87
100	56	25	13.57
103	56	15	11.39

103	56	20	12.09
103	57	15	12.87
103	57	20	13.62
104	57	15	11.91
104	57	19	10.78
104	59	15	14.17
104	59	19	13.36
107	33	15	15.66
107	33	19	17.69
107	34	15	14.41
107	34	19	15.77
109	33	15	14.76
109	33	19	17.15
109	34	15	13.69
109	34	19	15.17
109	57	15	11.74
109	57	19	10.71
109	59	15	14.08
109	59	19	13.24
110	21	15	8.90
110	21	25	11.18
110	33	15	8.75
110	33	25	11.47
110	35	15	6.66
110	35	25	9.50
110	56	20	11.04
110	56	25	12.60
110	57	15	12.33
110	57	20	12.90
111	21	10	1.30
111	21	21	4.81
111	52	10	2.67
111	52	21	5.51
112	55	23	10.97
112	55	29	9.61
112	56	23	11.88
112	56	29	13.45
116	0	0	1.97
116	0	33	0.92
116	21	1	0.93
116	21	21	1.08
116	52	1	1.76
116	52	21	3.58
116	52	33	1.81
116	52	37	1.47
116	55	23	9.30
116	55	29	4.55
116	56	23	11.60
116	56	29	17.37
116	60	0	18.64
116	60	10	18.83
116	60	11	18.87
116	60	37	18.57
116	64	10	20.00
116	64	11	20.00

3.4 Conclusions

The heating power that has been installed in the different rooms seems to be enough to ensure the target temperatures in each room. However, an external temperature of -12°C showed a weakness: the archive room is quite huge, and the heating power installed (2836 W of internal power and 2*3090 W of fan heater power) is not enough to ensure 15°C in the room with this extreme outside conditions. We have proved that 2 centimetres thickness of polystyrene insulation (λ = 0.035 W/mK) is enough to solve the problem. But here again, we could argue that -12°C is a temperature that won't be reached often during a year.

Condensation should not be a major problem in these rooms, seeing that:

- -12°C is an extreme condition. It will eventually be reached a couple of days for some years.
- Condensation is not dangerous if it is in small quantities and if it can be dried, so that no condensate water is remaining.
- These are technical rooms, not living rooms of offices.

Here are the faces, or parts of faces, that could be considered as the coldest walls:

- Obviously, the ceiling of the archive room, a hypothesis that have been made in the previous models.
- The wall of the "cold hall" and the "switch control 1 room" which is directly submitted to external conditions: it is only composed of 30 centimetres of reinforced concrete, with no insulation.

110	21	15	8.90	
110	33	15	8.75	
110	35	15	6.66	These are the lowest temperature at a corner of
110	35	25	9.50	this wall.

- All the edges of the wall against the soil: they are also directly connected to the external conditions and are not insulated.
- The wall of the "switch control 1" room which is directly connected to the installation room, and especially all the connections of this wall with the horizontal slabs.