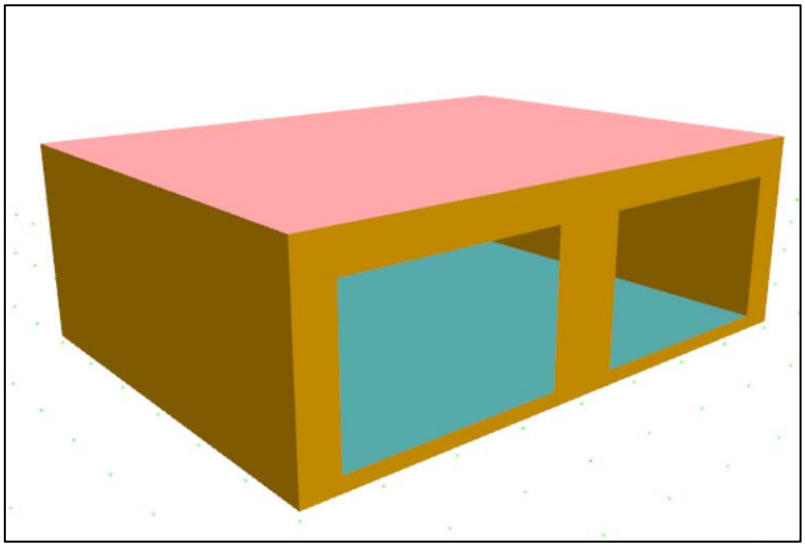
EDSL Tas 9.5.7 Compliance with BS EN 52016-1:2017

Six test cases were modelled. In each case a whole year simulation was carried out. Temperatures, heating loads, and cooling loads were compared to the target values from the standard. Other results, for which no target values exist, but which the standard requires to be reported, are also given in this document.

A. Input Data

A.1. Room Geometry



Geometry as seen in the Tas 3D modeller. The windows face south.

Element	Surface area (m^2)
External Wall (South)	9.6
Glazing (South	12.0
External Wall (West)	16.2
External Wall (North)	21.6
External Wall (East)	16.2
Floor	48.0
Roof	48.0

The volume of the room was 129.6m^3. The latitude of the building was 39.76°N.

A.2. Construction Details

Opaque constructions were set up in accordance with tables 23 and 24 of the standard. Details are given below in screenshots from Tas.

External wall (lightweight)

Layer	M-Code	Thickness (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Plasterboard	12.0	0.16	950.0	840.0
2	Fiberglass quilt	66.0	0.04	12.0	840.0
3	Wood Siding	9.0	0.14	530.0	900.0

Floor (lightweight)

Layer	M-Code	Thickness (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Timber flooring	25.0	0.14	650.0	1200.0
2	Insulation	1003.0	0.04	1.4e-045	1.4e-045

Roof

Layer	M-Code	Thickness (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Plasterboard	10.0	0.16	950.0	840.0
2	Fiberglass quilt	111.8	0.04	12.0	840.0
3	Roofdeck	19.0	0.14	530.0	900.0

The same roof was used for the lightweight and heavyweight buildings.

External wall (heavyweight)

Layer	M-Code	Thickness (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Concrete Block	100.0	0.51	1400.0	1000.0
2	Foam Insulation	61.5	0.04	10.0	1400.0
3	Wood Siding	9.0	0.14	530.0	900.0

Floor (heavyweight)

Layer	M-Code	Thickness (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Concrete slab	80.0	1.13	1400.0	1000.0
2	Insulation	1007.0	0.04	1.4e-045	1.4e-045

The solar absorption coefficient of all opaque surfaces was 0.6.

Note that the standard sets the heat capacity of the floor insulation as low as possible, and has very thick insulation, in order to “decouple the floor thermally from the ground”.

The glazing construction was set up in accordance with section 7.2.2.6 of the standard.
G-value 0.71 (reduced from 0.789) (EN 410)
U-value 2.984 W/m^{2}K (EN 673)
No solar radiation which entered the room was reflected back outside.

A.3. Weather

The weather data available from the link in section 7.2.2.12 of the standard was used.

A.4. System

Three different systems were used.

Continuous:
Constant heating setpoint of 20°C (operative temperature). Heat source 100% convective.
Constant cooling setpoint of 27°C (operative temperature). Cooling source 100% convective.
The heating and cooling had unlimited capacity.

Intermittent:
Heating setpoint of 20°C (operative temperature) from 7am-1pm. On other hours, heating setpoint is 10°C (operative temperature). Heat source 100% convective.
Constant cooling setpoint of 27°C (operative temperature). Cooling source 100% convective.
The heating and cooling had unlimited capacity.

Free-float:
No heating or cooling.

The operative temperature was calculated as the mean value of the room's dry bulb temperature and the mean radiant temperature of the room.

A.5. Other inputs

Floor

The floor of the building did not link to the ground, but instead to the outside air.

Internal gains

There was a constant heat gain of 200W in the space. This heat was 60% radiant, 40% convective.

Ventilation

There was a constant outside air flow equal to 0.411 air changes per hour.

Solar gains

10% of the solar heat entering the room through the window was added directly into the internal air.

The ground solar reflectance of the model was adjusted to match the total solar irradiation on a south-facing vertical surface given in Table 26a of the standard.

No solar radiation which entered the room was reflected back outside.

Solar gains were included in the calculation of the mean radiant temperature.

Heat transfer coefficients

Table 25 of the standard specifies 24.14 W/m^{2}K for the external surface heat transfer coefficient (convective plus long wave). In the Tas model the external surface emissivities were set to zero and the wind speed was set to a constant 5.035 m/s, to give a total external heat transfer coefficient of 24.14 W/m^{2}K (4 + 4*windspeed).

For internal surfaces, the convective heat transfer coefficient was set to 5 W/m^{2}K for the floor, 2.5 W/m^{2}K for the walls, and 0.7 W/m^{2}K for the floor.

Table 25 of the standard specifies 5.13 W/m^{2}K for the radiative heat transfer coefficient of the internal surfaces. Tas calculates long wave radiation exchange based on emissivities; these values were set to get as close as possible to the required 5.13 W/m^{2}K.

Sky temperature

Section 7.2.2.12 of the standard specifies that the apparent sky temperature will be fixed at 11°C below the air temperature for all hours of the year. Tas employs a sophisticated radiation back loss model that incorporates cloud data and humidity to predict a more accurate sky temperature. Because of good empirical agreement of this back loss model in the past, we prefer to retain it rather than model with the fixed sky temperature. On the Ashrae 140 models, the effect of Tas's sky temperature model was that the free-float temperatures for Tas tended to be lower than in other software.

A.6. Test Case Setup

Test	Ashrae 140 Equivalent	Constructions	System
1	600	Lightweight	Continuous
2	640	Lightweight	Intermittent
3	900	Heavyweight	Continuous
4	940	Heavyweight	Intermittent
5	600FF	Lightweight	Free-float
6	900FF	Heavyweight	Free-float

Note that there are significant differences between these tests and the Ashrae 140 tests which they were based on, and the target results differ significantly from the Ashrae 140 targets.

B. Results

B.1. Target Results and Tas Results

In this section the results from the Tas models are shown next to the targets given in tables 28-34 of ISO 52016-1. There are no limits given for compliance or non-compliance. For context, the range of published results for the equivalent Ashrae 140 models are given here on the pages that follow.

Section 7.2.4 asks for further results for which no targets have been provided in the standard. These results are displayed in the next section, B.2.

Test Case	1 (600)	2 (640)	3 (900)	4 (940)
Monthly heating	Section B.1	Section B.1	Section B.2 *	Section B.1
Monthly cooling	Section B.1	Section B.1	Section B.1 *	Section B.1
Peak loads	Section B.1	Section B.1	Section B.1	Section B.1
Monthly temperatures	Section B.1	Section B.1	Section B.1	Section B.1
January 4th loads	Section B.1	Section B.1	Section B.1	Section B.1
July 27th loads	Section B.2	Section B.2	Section B.2	Section B.2

* Table 28: The heating figures quoted for case 900 are clearly wrong. These appear to be the cooling results. Table 29: The cooling figures quoted for case 900 are clearly wrong. They are also too small to make sense as the heating results.

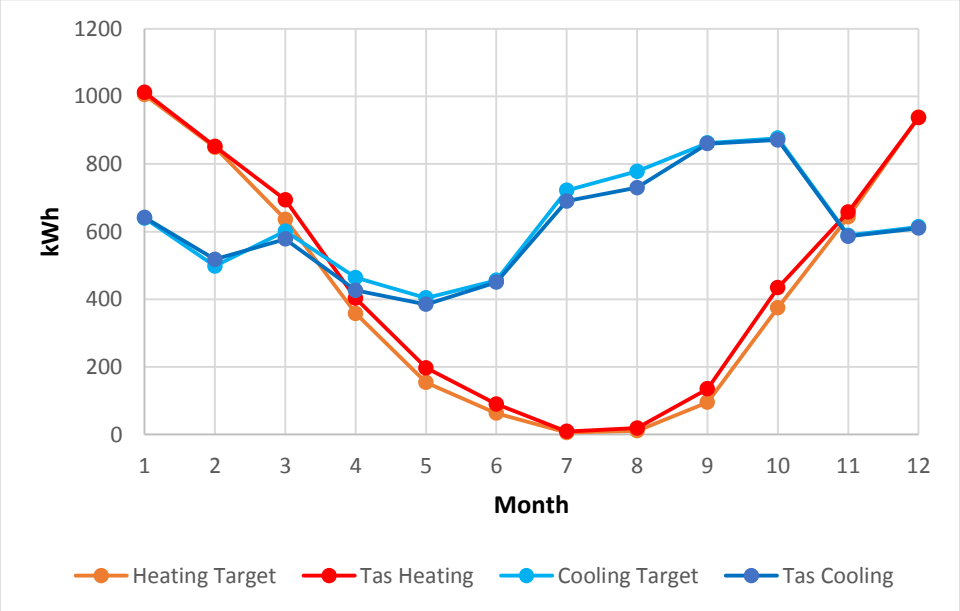
Test Case	5 (600FF)	6 (900FF)
Monthly temperatures	Section B.1	Section B.1
Peak temperatures	Section B.1	Section B.1
January 4th temperatures	Section B.1	Section B.1
July 27th temperatures	Section B.2	Section B.2

B.1.1. Test Case 1 (600)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual heating: Range is ± 14% from the median.
Annual cooling: Range is ± 13% from the median.
Peak heating: Range is ± 12% from the median.
Peak cooling: Range is ± 7% from the median.

Test Case 1 (600) Monthly heating and cooling (kWh)

Month	Heating Target	Tas Heating	Cooling Target	Tas Cooling
1	1005	1012	640	642
2	849	852	498	518
3	636	694	601	578
4	358	403	464	426
5	154	197	404	385
6	63	90	456	450
7	6	9	722	690
8	11	19	778	730
9	95	135	862	860
10	375	434	876	871
11	644	658	589	586
12	938	937	614	610
Total	**5133**	**5439**	**7503**	**7317**



The annual heating in Tas was 6% higher than the target.
The annual cooling in Tas was 2.5% lower than the target.

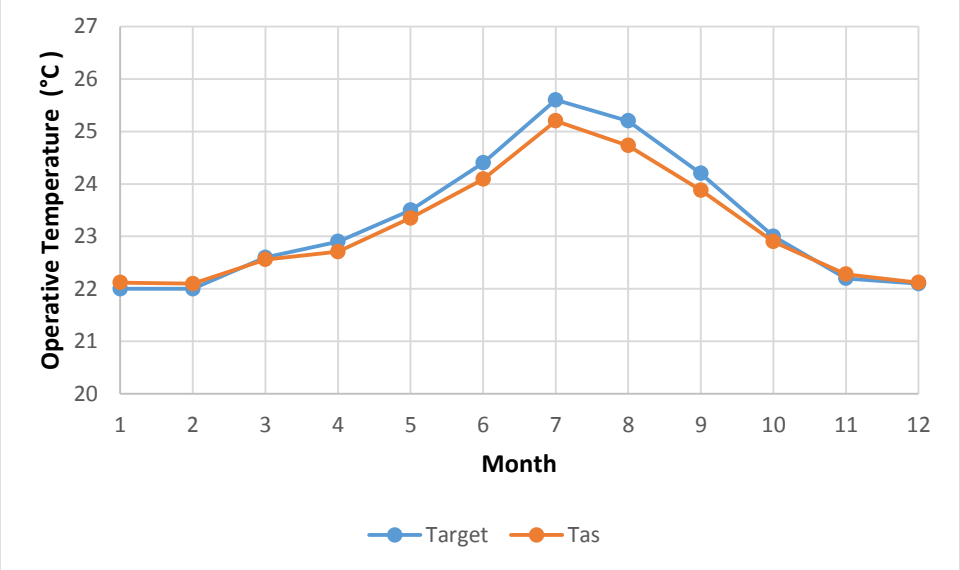
Test Case 1 (600) Peak Loads (kWh)

	Target	Tas
Heating	4351	4410
Cooling	6363	6776

The peak heating in Tas was 1.4% higher than the target.
The peak cooling in Tas was 6.5% higher than the target.

Test Case 1 (600) Average Monthly Operative Temperatures

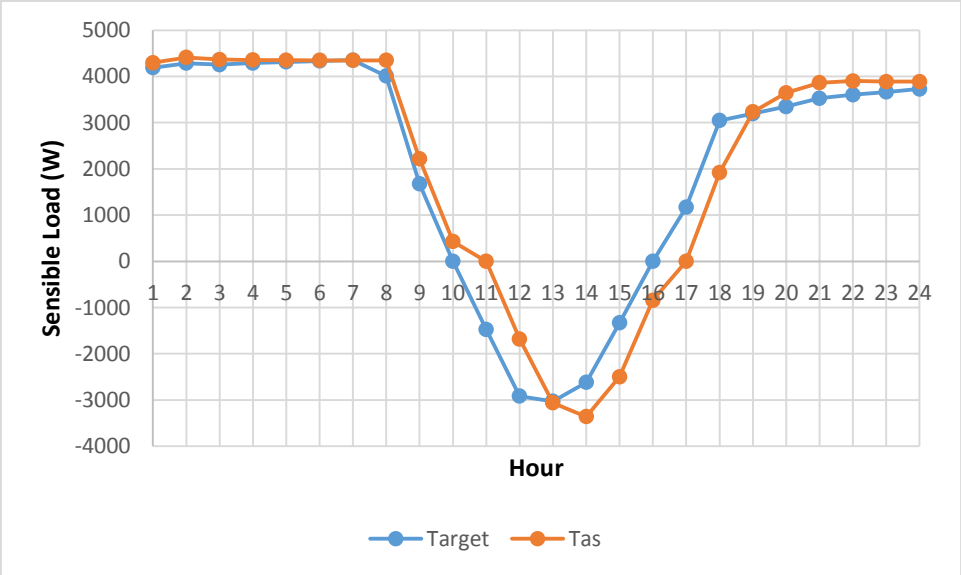
Month	Target	Tas
1	22	22.12
2	22	22.1
3	22.6	22.56
4	22.9	22.71
5	23.5	23.35
6	24.4	24.09
7	25.6	25.2
8	25.2	24.73
9	24.2	23.88
10	23	22.9
11	22.2	22.28
12	22.1	22.12
Yearly Average	**23.3**	**23.18**



The yearly average operative temperature in Tas was 0.12°C lower than the target.

Test Case 1 (600) January 4th sensible heating (+) and cooling (-) loads (W)

Hour	Target	Tas
1	4189	4295
2	4287	4410
3	4254	4364
4	4289	4355
5	4314	4352
6	4334	4350
7	4351	4350
8	4008	4347
9	1678	2220
10	0	427
11	-1478	0
12	-2916	-1681
13	-3028	-3064
14	-2620	-3360
15	-1330	-2499
16	0	-844
17	1170	0
18	3047	1922
19	3194	3233
20	3347	3646
21	3529	3863
22	3602	3901
23	3661	3887
24	3729	3886
Total Heating (Wh)	**60983**	**61806**
Total Cooling (Wh)	**11372**	**11448**



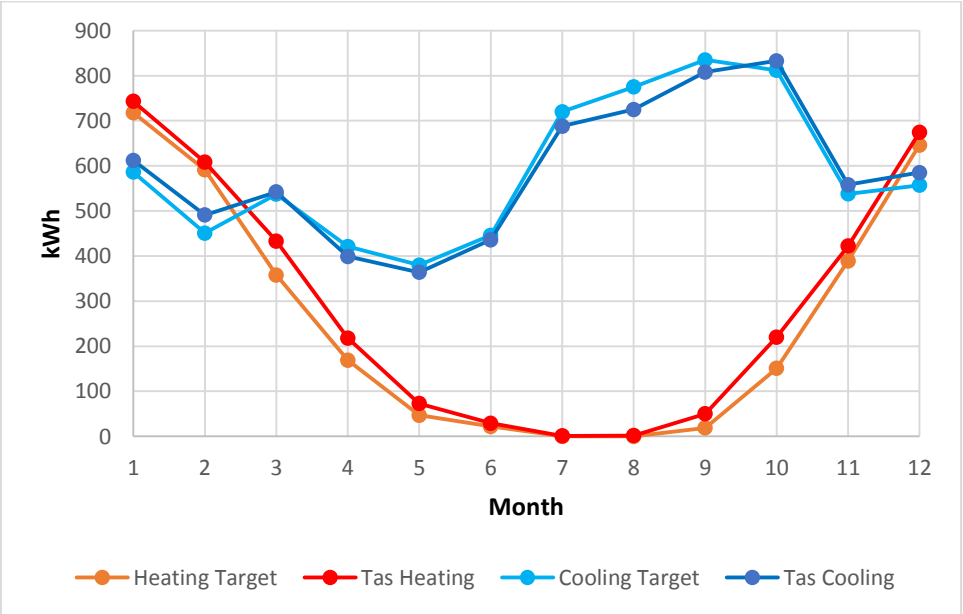
The day's heating in Tas was 1.3% higher than the target.
The day's cooling in Tas was 0.7% lower than the target.

B.1.2. Test Case 2 (640)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual heating: Range is ± 16% from the median.
Annual cooling: Range is ± 13% from the median.
Peak heating: Range is ± 14% from the median.
Peak cooling: Range is ± 7% from the median.

Test Case 2 (640) Monthly heating and cooling (kWh)

Month	Heating Target	Tas Heating	Cooling Target	Tas Cooling
1	718	743	586	612
2	591	608	451	491
3	358	433	537	542
4	169	218	421	399
5	47	73	380	364
6	22	29	446	436
7	0	1	720	688
8	0	2	775	725
9	19	50	835	808
10	151	220	812	833
11	389	422	538	558
12	646	674	557	585
Total	**3112**	**3473**	**7057**	**7041**



The annual heating in Tas was 11.6% higher than the target.
The annual cooling in Tas was 0.2% lower than the target.

Test Case 2 (640) Peak Loads (kWh)

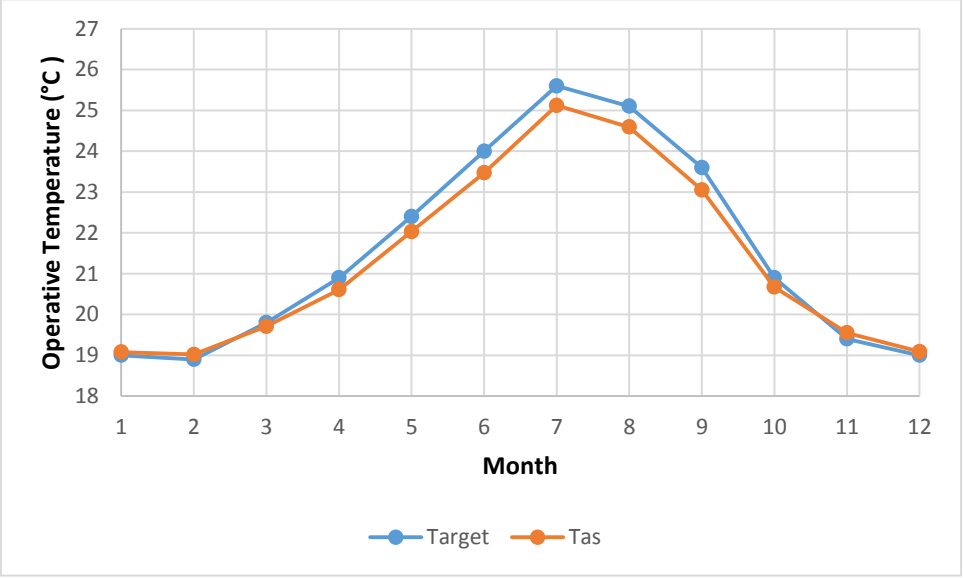
	Target	Tas
Heating	6690	7913
Cooling	6233	6730

The peak heating in Tas was 18.3% higher than the target.
The peak cooling in Tas was 8% higher than the target.

Test Case 2 (640) Average Monthly Operative Temperatures

Month	Target	Tas
1	19	19.08
2	18.9	19.02
3	19.8	19.71
4	20.9	20.61
5	22.4	22.03
6	24	23.47
7	25.6	25.12
8	25.1	24.59
9	23.6	23.05
10	20.9	20.67
11	19.4	19.55
12	19	19.09
Yearly Average	**21.5**	**21.35**

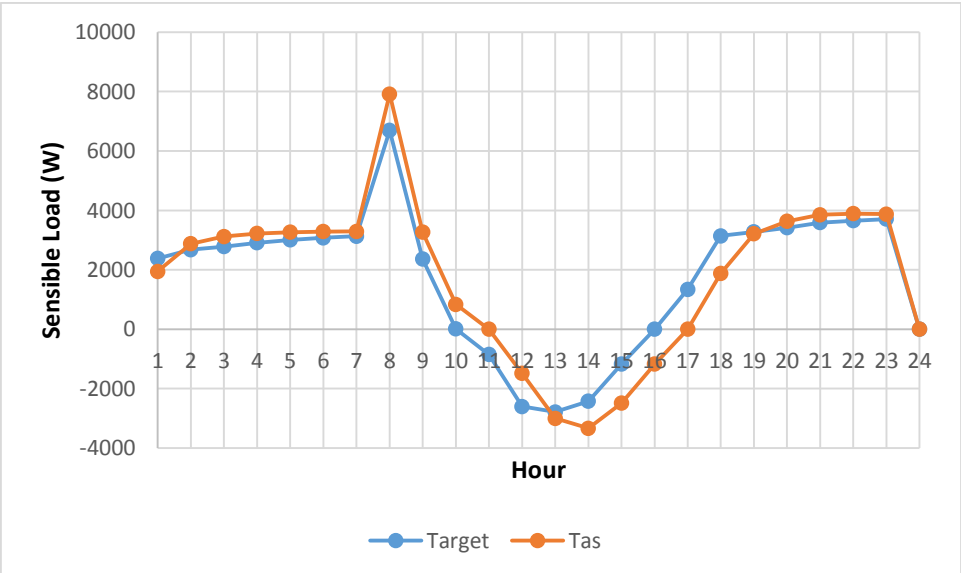
The yearly average operative temperature in Tas was 0.15°C lower than the target.



Test Case 2 (640) January 4th sensible heating (+) and cooling (-) loads (W)

Hour	Target	Tas
1	2380	1943
2	2677	2876
3	2779	3117
4	2910	3223
5	3004	3267
6	3076	3286
7	3131	3293
8	6690	7913
9	2360	3263
10	13	837
11	-849	0
12	-2601	-1486
13	-2783	-3003
14	-2426	-3335
15	-1173	-2488
16	0	-1173
17	1344	0
18	3143	1877
19	3275	3212
20	3416	3632
21	3588	3851
22	3654	3890
23	3707	3876
24	0	0
Total Heating (Wh)	**51147**	**53355**
Total Cooling (Wh)	**9832**	**11152**

The day's heating in Tas was 4.3% higher than the target.
The day's cooling in Tas was 13.4% higher than the target.

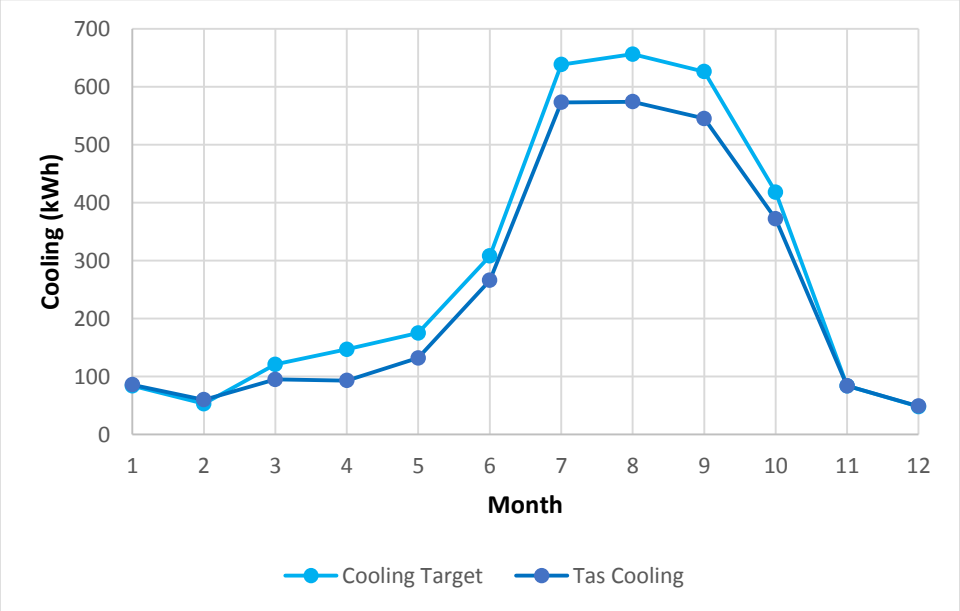


B.1.3. Test Case 3 (900)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual heating: Range is ± 27% from the median.
Annual cooling: Range is ± 23% from the median.
Peak heating: Range is ± 14% from the median.
Peak cooling: Range is ± 15% from the median.

Test Case 3 (900) Monthly cooling (kWh)

Month	Cooling Target	Tas Cooling
1	84	86
2	53	60
3	121	95
4	147	93
5	175	132
6	308	266
7	638	573
8	656	574
9	626	545
10	418	372
11	84	84
12	48	49
Total	**3360**	**2929**



The annual cooling in Tas was 12.8% lower than the target.

Test Case 3 (900) Peak Loads (kWh)

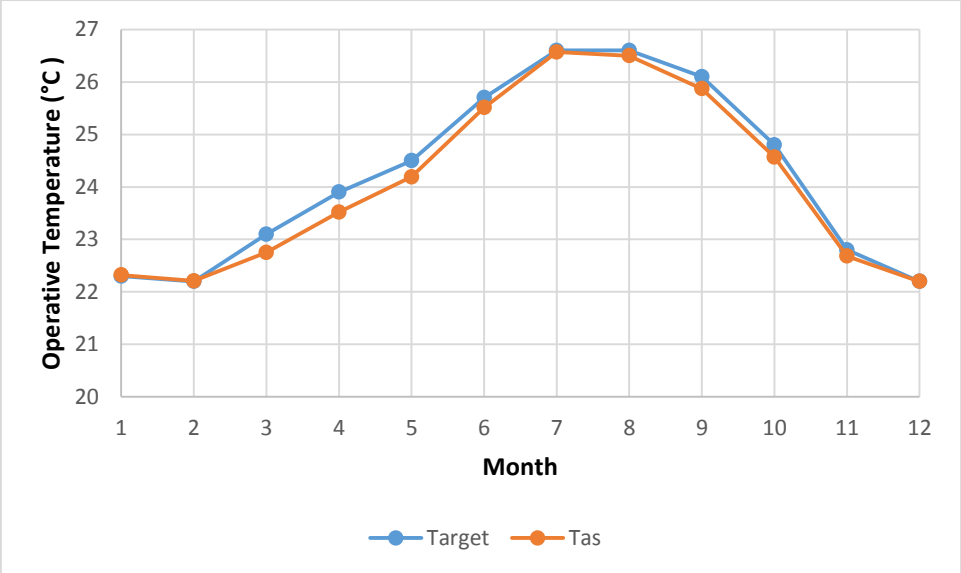
	Target	Tas
Heating	4067	4105
Cooling	4043	3831

The peak heating in Tas was 0.9% higher than the target.
The peak cooling in Tas was 5.2% lower than the target.

Test Case 3 (900) Average Monthly Operative Temperatures

Month	Target	Tas
1	22.3	22.32
2	22.2	22.21
3	23.1	22.75
4	23.9	23.52
5	24.5	24.19
6	25.7	25.51
7	26.6	26.57
8	26.6	26.5
9	26.1	25.87
10	24.8	24.57
11	22.8	22.68
12	22.2	22.2
Yearly Average	**24.2**	**24.09**

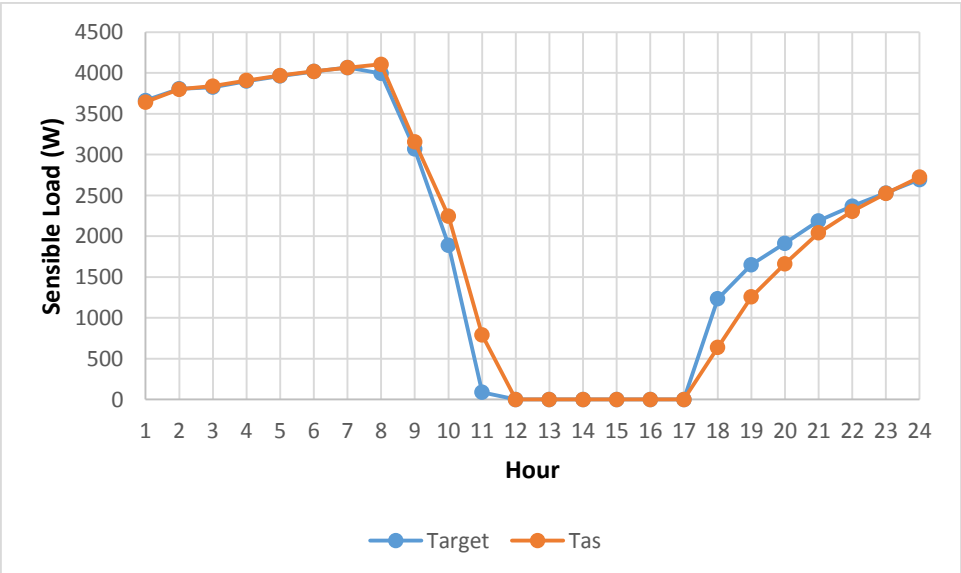
The yearly average operative temperature in Tas was 0.11°C lower than the target.



Test Case 3 (900) January 4th sensible heating (+) and cooling (-) loads (W)

Hour	Target	Tas
1	3663	3643
2	3805	3800
3	3826	3839
4	3900	3908
5	3962	3968
6	4017	4020
7	4067	4064
8	3994	4105
9	3069	3157
10	1890	2246
11	89	791
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	1233	637
19	1652	1257
20	1913	1662
21	2189	2041
22	2369	2306
23	2530	2523
24	2694	2723
Total Heating (Wh)	**50532**	**50688**
Total Cooling (Wh)	**0**	**0**

The day's heating in Tas was 0.3% higher than the target.
The day's cooling in Tas matches the target.

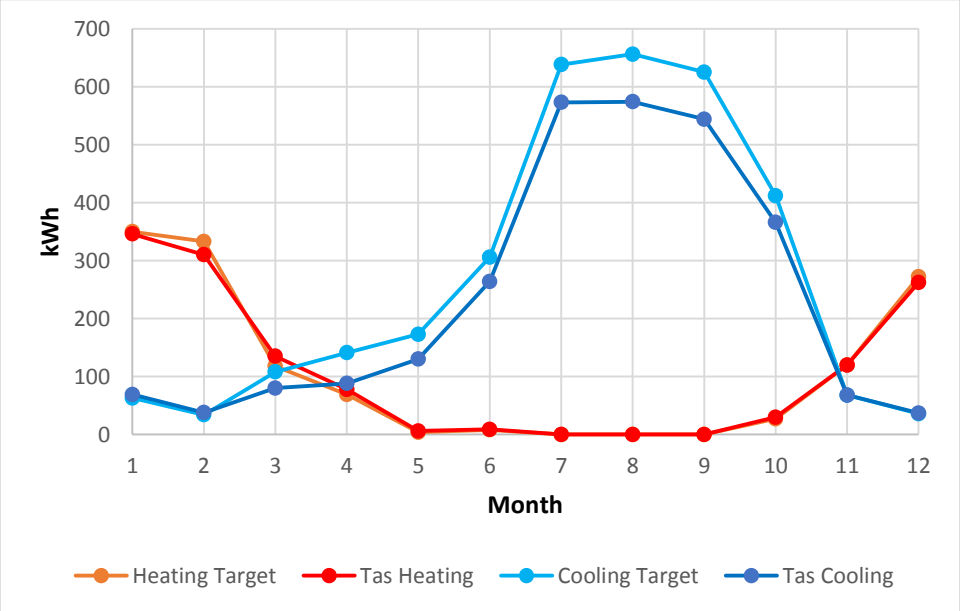


B.1.4. Test Case 4 (940)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual heating: Range is ± 14% from the median.
Annual cooling: Range is ± 22% from the median.
Peak heating: Range is ± 24% from the median.
Peak cooling: Range is ± 15% from the median.

Test Case 4 (940) Monthly heating and cooling (kWh)

Month	Heating Target	Tas Heating	Cooling Target	Tas Cooling
1	350	346	63	69
2	333	310	34	38
3	118	135	108	80
4	69	78	141	88
5	4	6	173	130
6	8	9	306	264
7	0	0	638	573
8	0	0	656	574
9	0	0	625	544
10	27	30	412	366
11	120	120	68	68
12	272	262	36	37
Total	**1303**	**1296**	**3261**	**2831**



The annual heating in Tas was 0.5% lower than the target.
The annual cooling in Tas was 13.2% lower than the target.

Test Case 4 (940) Peak Loads (kWh)

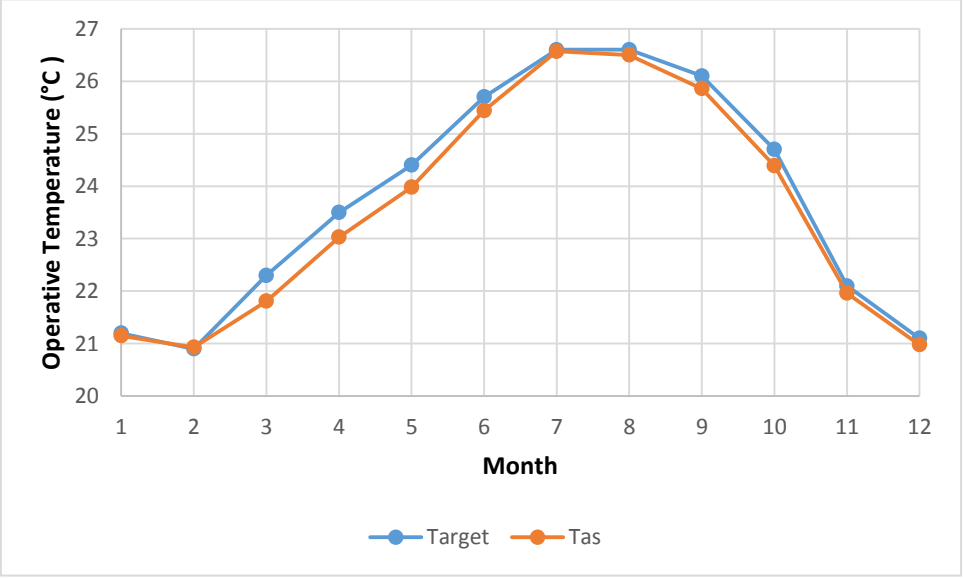
	Target	Tas
Heating	9793	8489
Cooling	4047	3831

The peak heating in Tas was 13.3% lower than the target.
The peak cooling in Tas was 5.3% lower than the target.

Test Case 4 (940) Average Monthly Operative Temperatures

Month	Target	Tas
1	21.2	21.15
2	20.9	20.93
3	22.3	21.81
4	23.5	23.03
5	24.4	23.98
6	25.7	25.44
7	26.6	26.57
8	26.6	26.5
9	26.1	25.86
10	24.7	24.39
11	22.1	21.96
12	21.1	20.98
Yearly Average	**23.8**	**23.57**

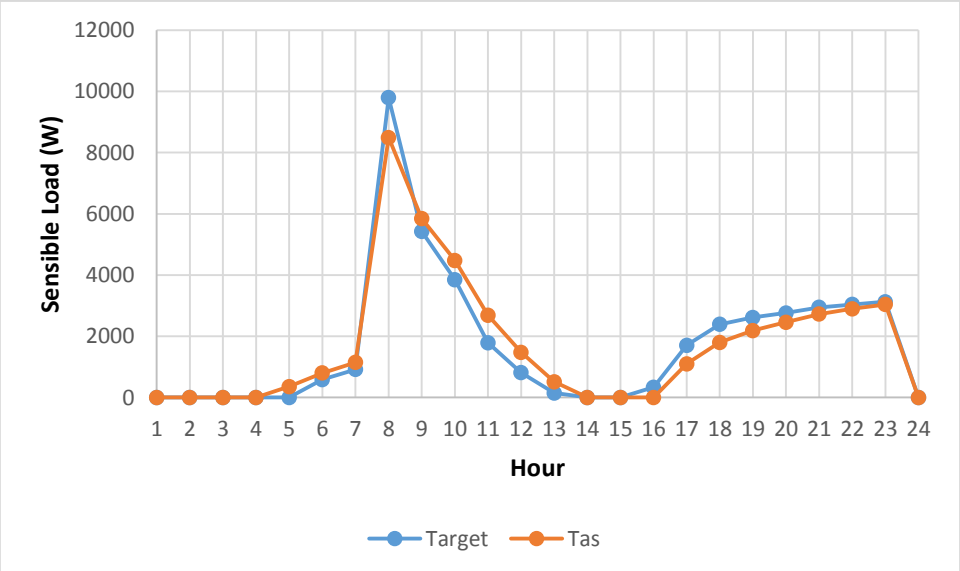
The yearly average operative temperature in Tas was 0.23°C lower than the target.



Test Case 3 (940) January 4th sensible heating (+) and cooling (-) loads (W)

Hour	Target	Tas
1	0	0
2	0	0
3	0	0
4	0	0
5	0	357
6	588	801
7	914	1146
8	9793	8489
9	5425	5847
10	3848	4476
11	1791	2686
12	810	1473
13	145	512
14	0	0
15	0	0
16	336	0
17	1705	1099
18	2391	1799
19	2614	2188
20	2762	2458
21	2943	2727
22	3040	2899
23	3128	3036
24	0	0
Total Heating (Wh)	**42233**	**41992**
Total Cooling (Wh)	**0**	**0**

The day's heating in Tas was 0.6% lower than the target.
The day's cooling in Tas matched the target.



B.1.5. Test Case 5 (600FF)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual Maximum Temperature: Range is ± 2.3°C from the median.
Annual Minimum Temperature: Range is ± 1.6°C from the median.
Annual Average Temperature: Range is ± 0.9°C from the median.

Test Case 5 (600FF) Average Monthly Operative Temperatures

Month	Target	Tas
1	17.3	17.49
2	16.7	17.28
3	22.1	21.11
4	24.3	22.99
5	26.7	25.71
6	29.6	28.81
7	35	33.86
8	35.2	33.79
9	34.6	32.99
10	29.7	28.54
11	21.4	21.33
12	17.9	17.97
Yearly Average	**25.9**	**25.21**

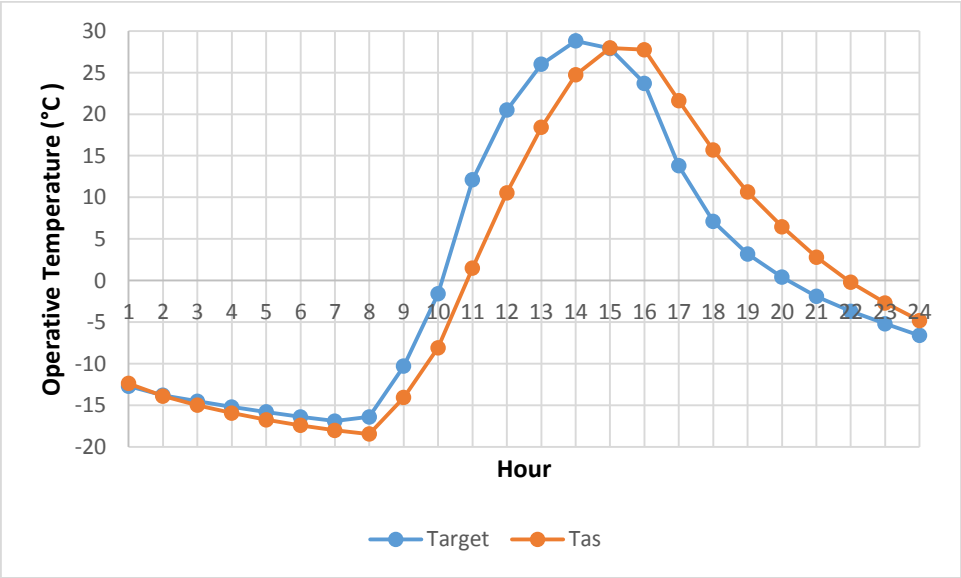
The yearly average operative temperature in Tas was 0.69°C lower than the target.

Test Case 5 (600FF) Annual Maximum, Minimum, and Average Operative Temperatures

	Target	Tas	Difference
Maximum	63.5	62.35	1.15
Minimum	-16.9	-18.45	1.55
Average	25.9	25.21	0.69

Test Case 5 (600FF) Hourly Operative Temperatures, January 4th

Hour	Target	Tas
1	-12.7	-12.37
2	-13.8	-13.89
3	-14.5	-14.99
4	-15.2	-15.93
5	-15.8	-16.73
6	-16.4	-17.41
7	-16.9	-18
8	-16.4	-18.45
9	-10.3	-14.07
10	-1.6	-8.08
11	12.1	1.51
12	20.5	10.55
13	26	18.41
14	28.8	24.72
15	27.9	27.96
16	23.7	27.74
17	13.8	21.63
18	7.1	15.69
19	3.2	10.65
20	0.4	6.46
21	-1.9	2.81
22	-3.7	-0.21
23	-5.2	-2.69
24	-6.6	-4.81



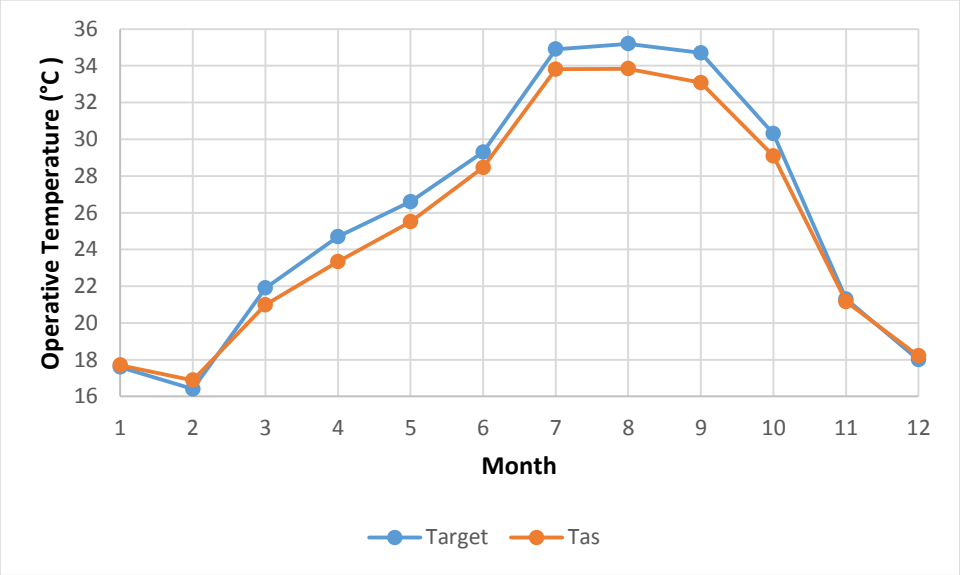
B.1.6. Test Case 6 (900FF)

Spread of results in published Ashrae 140 results for the equivalent test case:
Annual Maximum Temperature: Range is ± 1.5°C from the median.
Annual Minimum Temperature: Range is ± 2.4°C from the median.
Annual Average Temperature: Range is ± 0.7°C from the median.

Test Case 5 (600FF) Average Monthly Operative Temperatures

Month	Target	Tas
1	17.6	17.7
2	16.4	16.88
3	21.9	20.99
4	24.7	23.34
5	26.6	25.51
6	29.3	28.46
7	34.9	33.81
8	35.2	33.84
9	34.7	33.08
10	30.3	29.09
11	21.3	21.16
12	18	18.21
Yearly Average	**25.9**	**25.22**

The yearly average operative temperature in Tas was 0.68°C lower than the target.

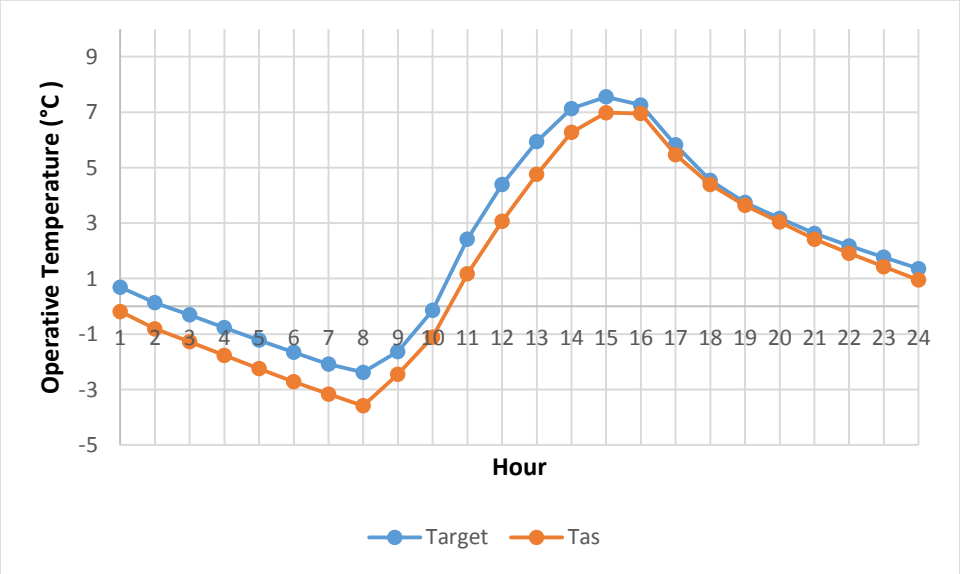


Test Case 6 (900FF) Annual Maximum, Minimum, and Average Operative Temperatures

	Target	Tas	Difference
Maximum	44.4	42.57	1.83
Minimum	-2.4	-3.59	1.19
Average	26	25.23	0.77

Test Case 6 (900FF) Hourly Operative Temperatures, January 4th

Hour	Target	Tas
1	0.69	-0.19
2	0.13	-0.81
3	-0.31	-1.28
4	-0.77	-1.77
5	-1.22	-2.25
6	-1.66	-2.72
7	-2.09	-3.17
8	-2.38	-3.59
9	-1.63	-2.45
10	-0.15	-1.11
11	2.42	1.17
12	4.39	3.06
13	5.94	4.76
14	7.13	6.27
15	7.55	6.98
16	7.26	6.95
17	5.82	5.47
18	4.54	4.39
19	3.74	3.64
20	3.17	3.04
21	2.63	2.42
22	2.18	1.91
23	1.77	1.43
24	1.36	0.95



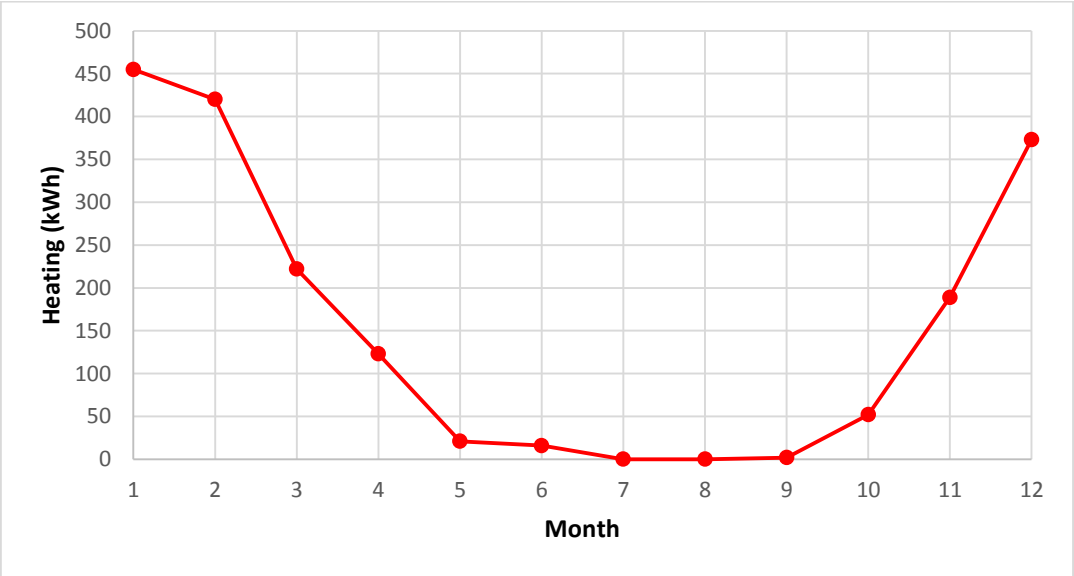
B.2. Further Tas Results

This section contains the results requested by section 7.2.4 of the standard but for which no target result is given in the standard.

Test Case 3 (900) Monthly heating (kWh)

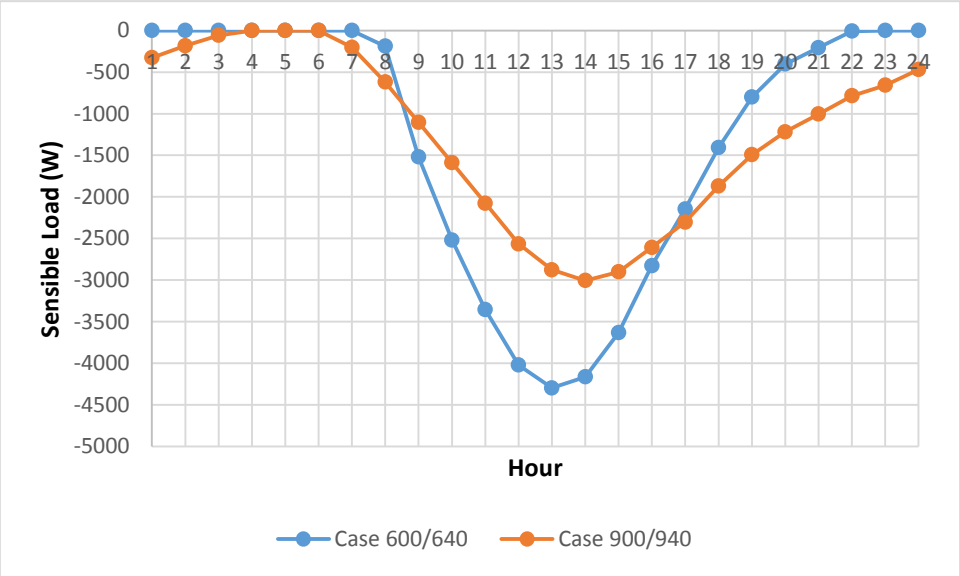
Table 28: The heating figures quoted for case 900 are clearly wrong. These appear to be the cooling results. Table 29: The cooling figures quoted for case 900 are clearly wrong. They are also too small to make sense as the heating results.

Month	Tas
1	455
2	420
3	222
4	123
5	21
6	16
7	0
8	0
9	2
10	52
11	189
12	373
Annual	**1874**



Test 1-4 July 27th sensible heating (+) and cooling (-) loads (W)

Hour	Case 1 (600)	Case 2 (640)	Case 3 (900)	Case 4 (940)
1	0	0	-328	-328
2	0	0	-184	-184
3	0	0	-59	-59
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	-203	-203
8	-188	-188	-619	-619
9	-1519	-1519	-1102	-1102
10	-2518	-2518	-1590	-1590
11	-3356	-3356	-2077	-2077
12	-4021	-4021	-2565	-2565
13	-4296	-4296	-2877	-2877
14	-4164	-4164	-3005	-3005
15	-3633	-3633	-2901	-2901
16	-2827	-2827	-2607	-2607
17	-2145	-2145	-2303	-2303
18	-1407	-1407	-1868	-1868
19	-801	-801	-1494	-1494
20	-424	-404	-1219	-1219
21	-207	-207	-1005	-1005
22	-8	-8	-785	-785
23	0	0	-659	-659
24	0	0	-469	-469
Total Heating (Wh)	**0**	**0**	**0**	**0**
Total Cooling (Wh)	**31514**	**31494**	**29919**	**29919**



Tests 5 (600FF) and 6 (900FF) operative temperatures, July 27th

Hour	Case 5 (600FF)	Case 6 (900FF)
1	34	36.44
2	32.09	36.01
3	30.4	35.61
4	28.87	35.2
5	27.58	34.83
6	27.06	34.71
7	28.05	35.12
8	29.99	35.69
9	32.78	36.46
10	36.33	37.31
11	40.37	38.25
12	44.59	39.25
13	48.27	40.09
14	50.87	40.67
15	52.01	40.89
16	51.59	40.75
17	50.35	40.51
18	48.19	39.98
19	45.56	39.39
20	42.99	38.92
21	40.66	38.53
22	38.42	38.1
23	36.53	37.77
24	34.66	37.34