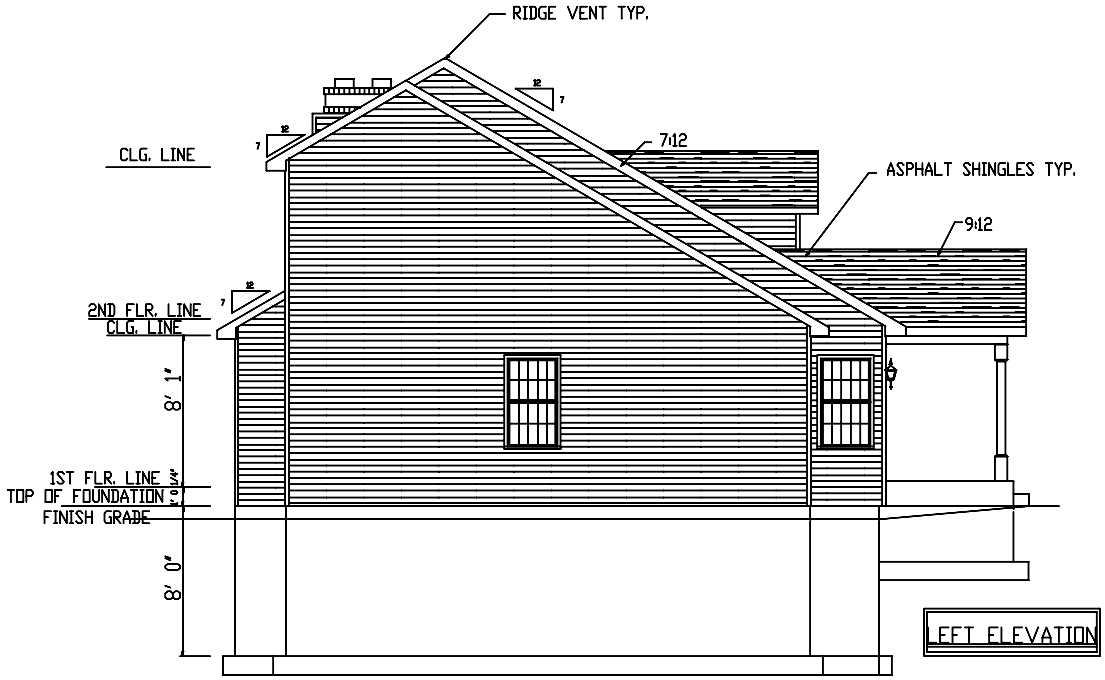
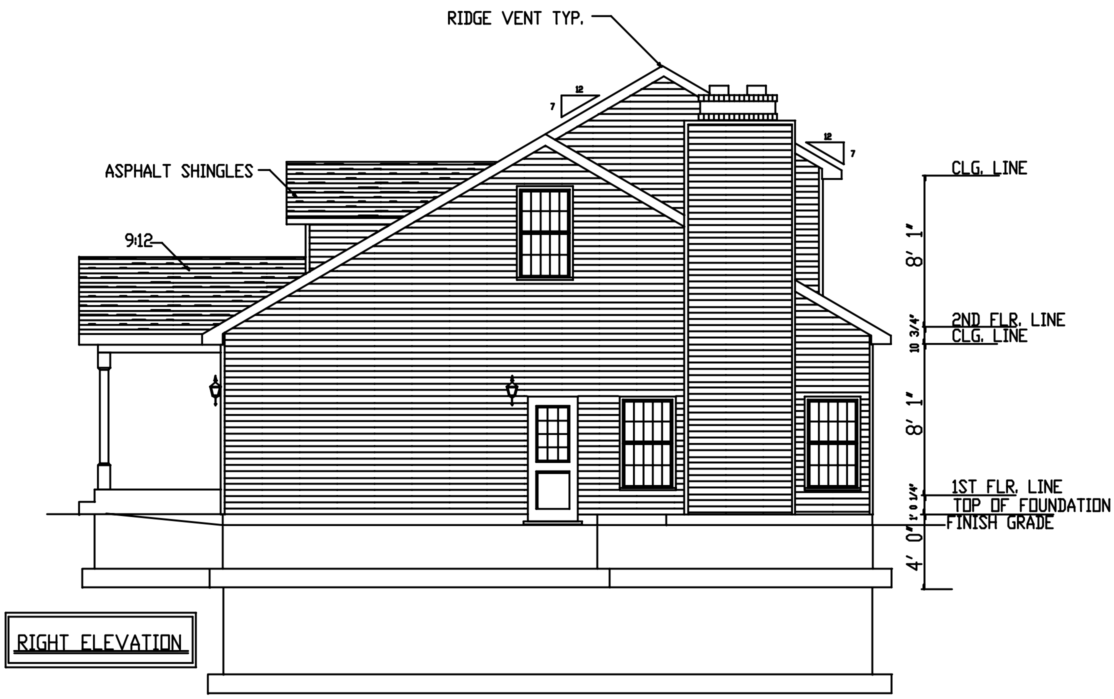
APPENDIX A

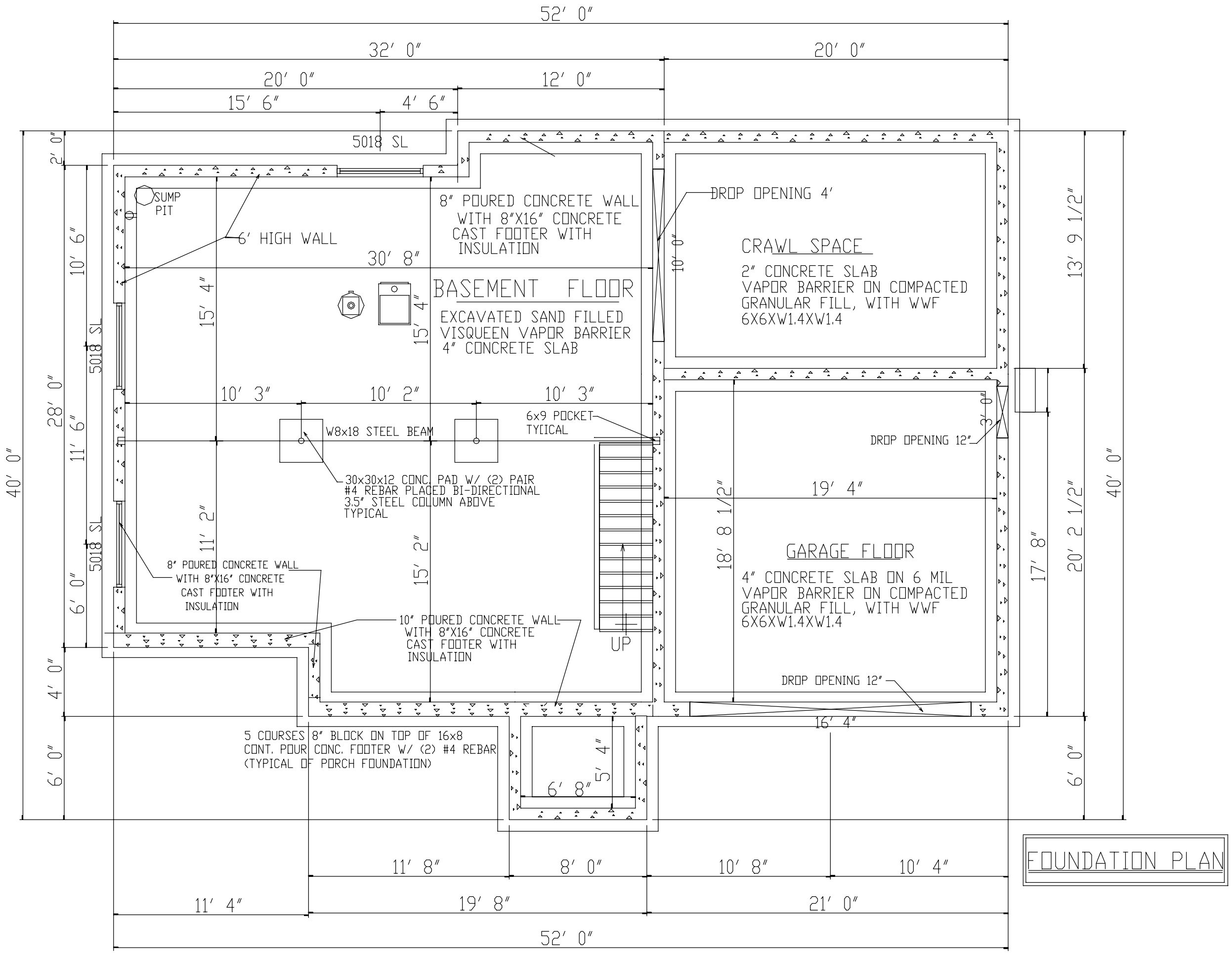
DEMONSTRATION HOME PLANS

Wood Demonstration Home

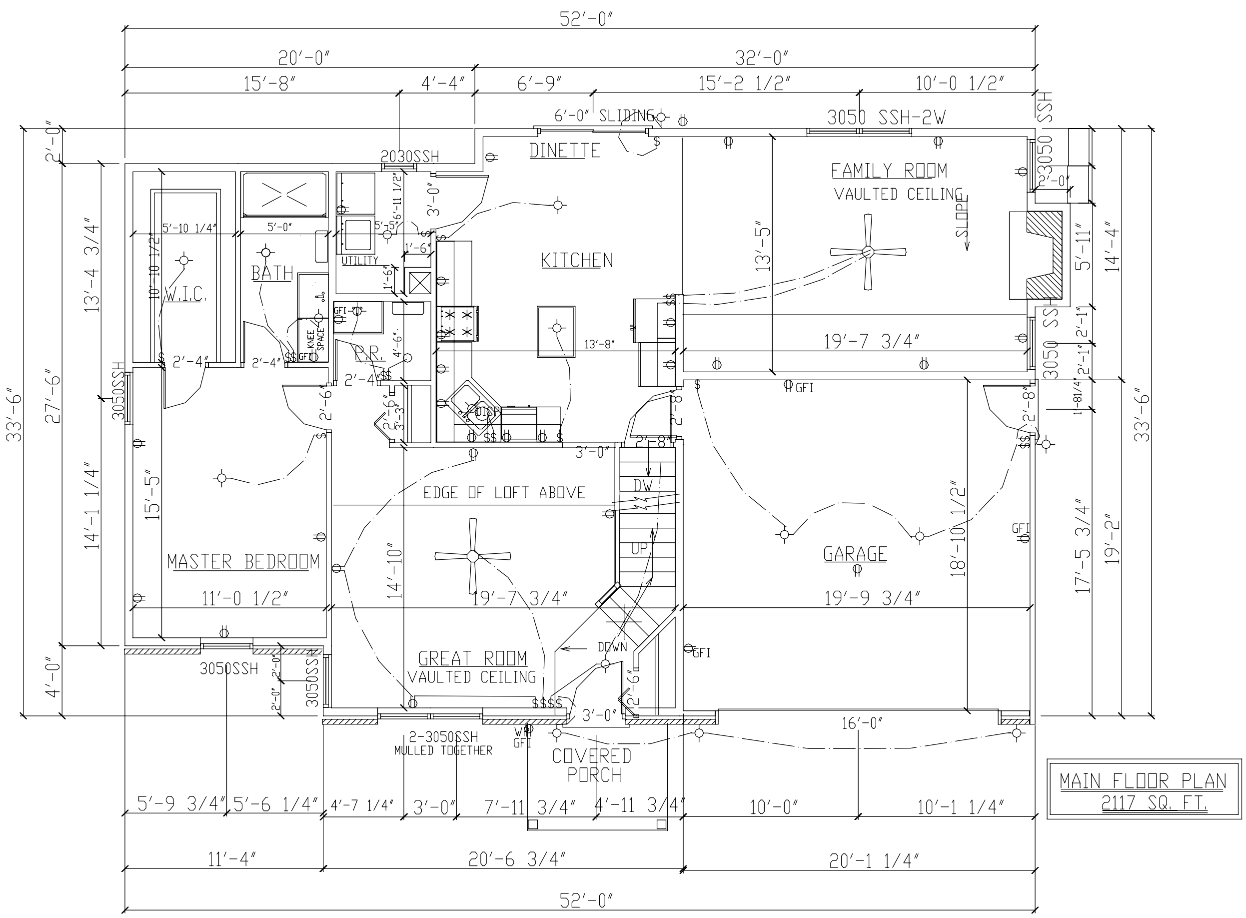




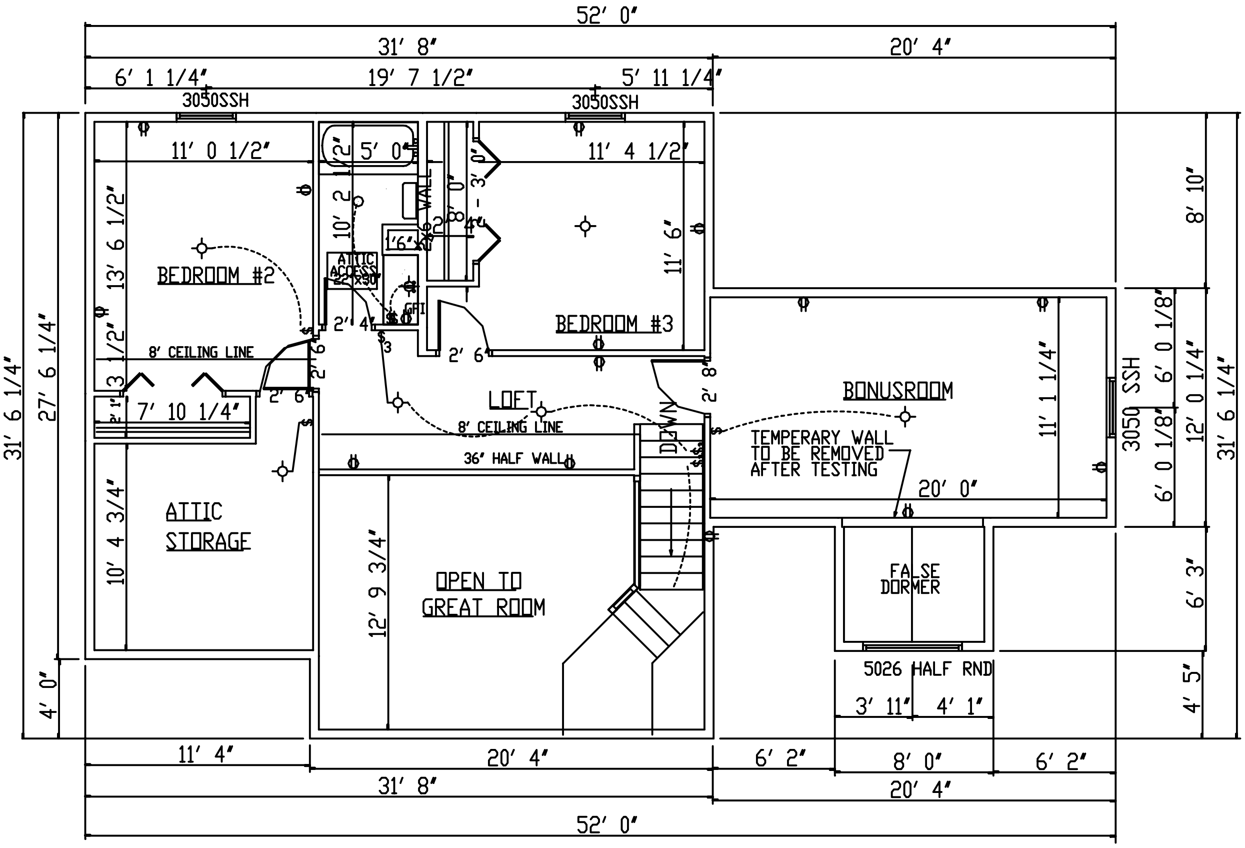
Wood Demonstration Home



Wood Demonstration Home



Wood Demonstration Home

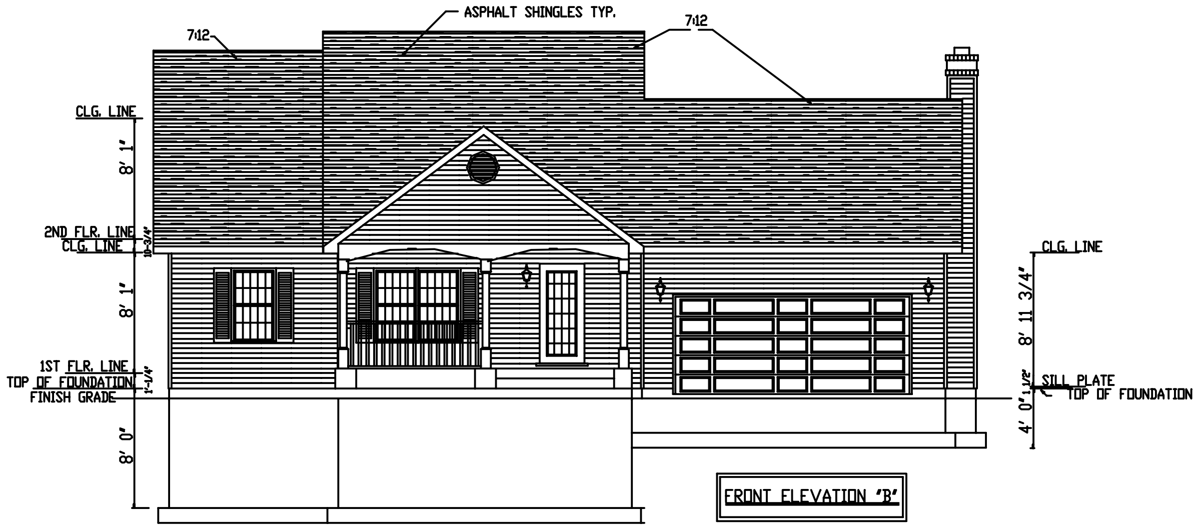


GENERAL NOTES:
1. ALL EXT. WALLS ARE 5 1/2" UNLESS OTHERWISE NOTED.

2. ALL INT. WALLS ARE 3 1/2" UNLESS OTHERWISE NOTED.

SECOND FLOOR PLAN

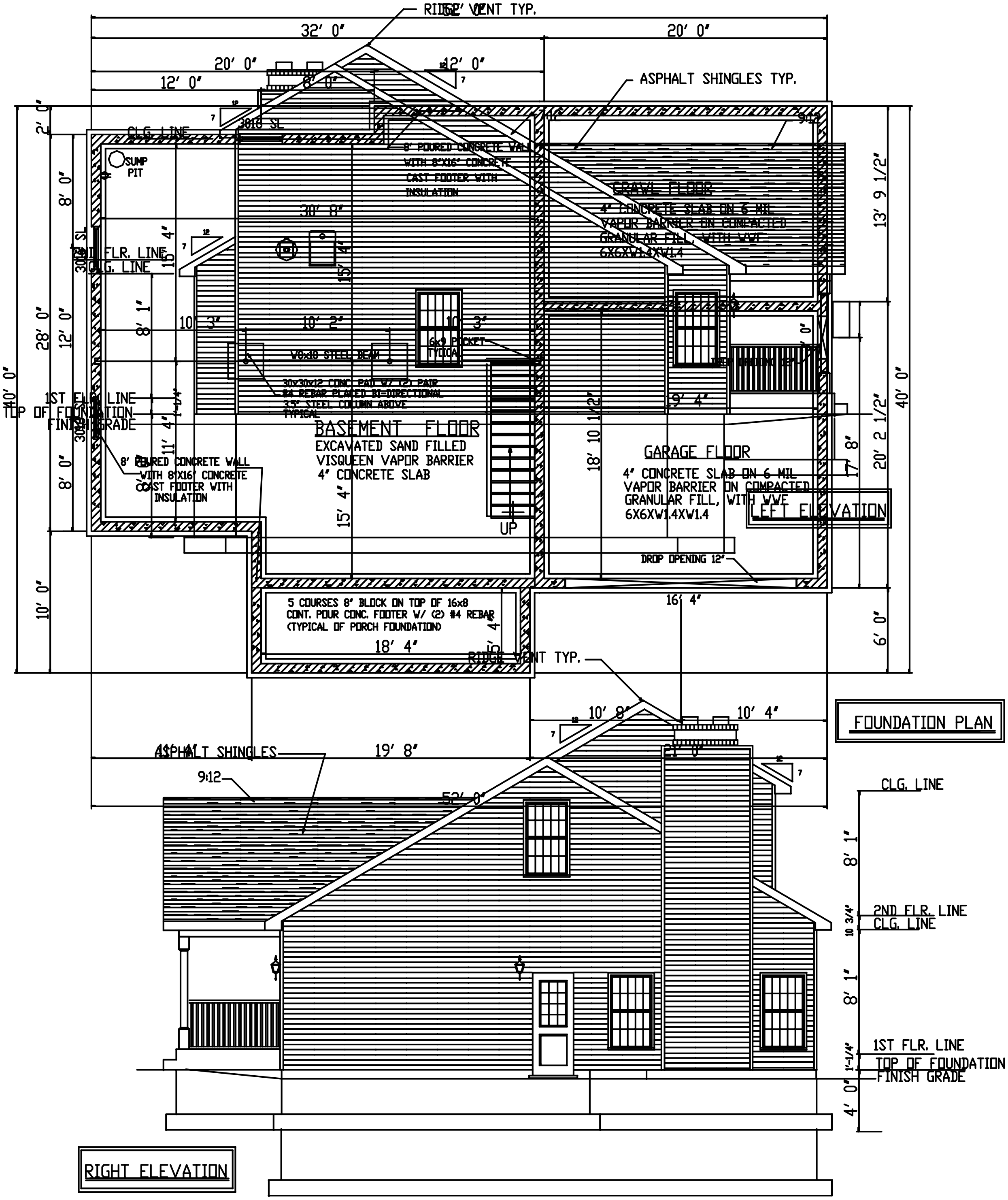
Wood Demonstration Home



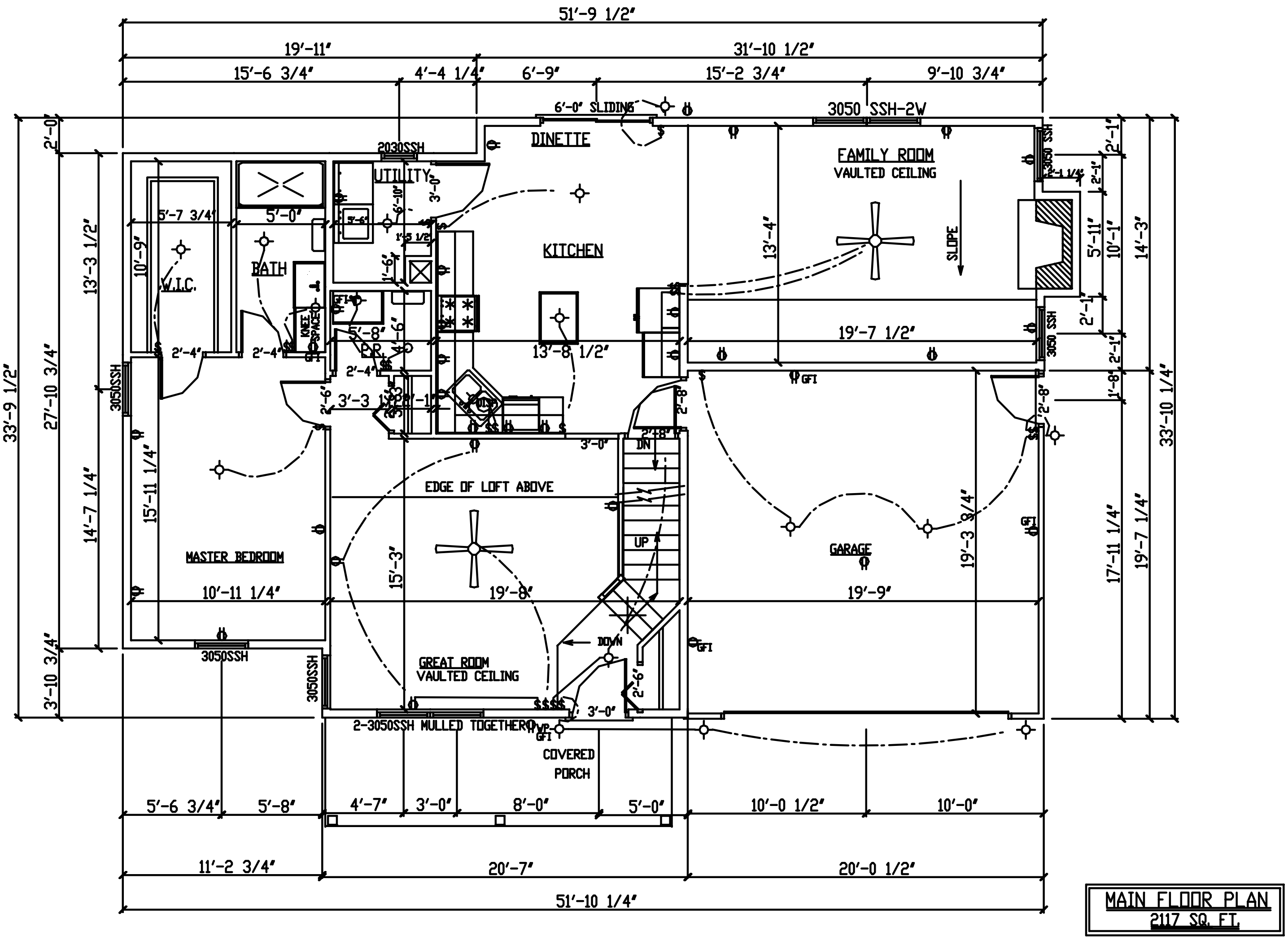
FRONT ELEVATION "B"

REAR ELEVATION

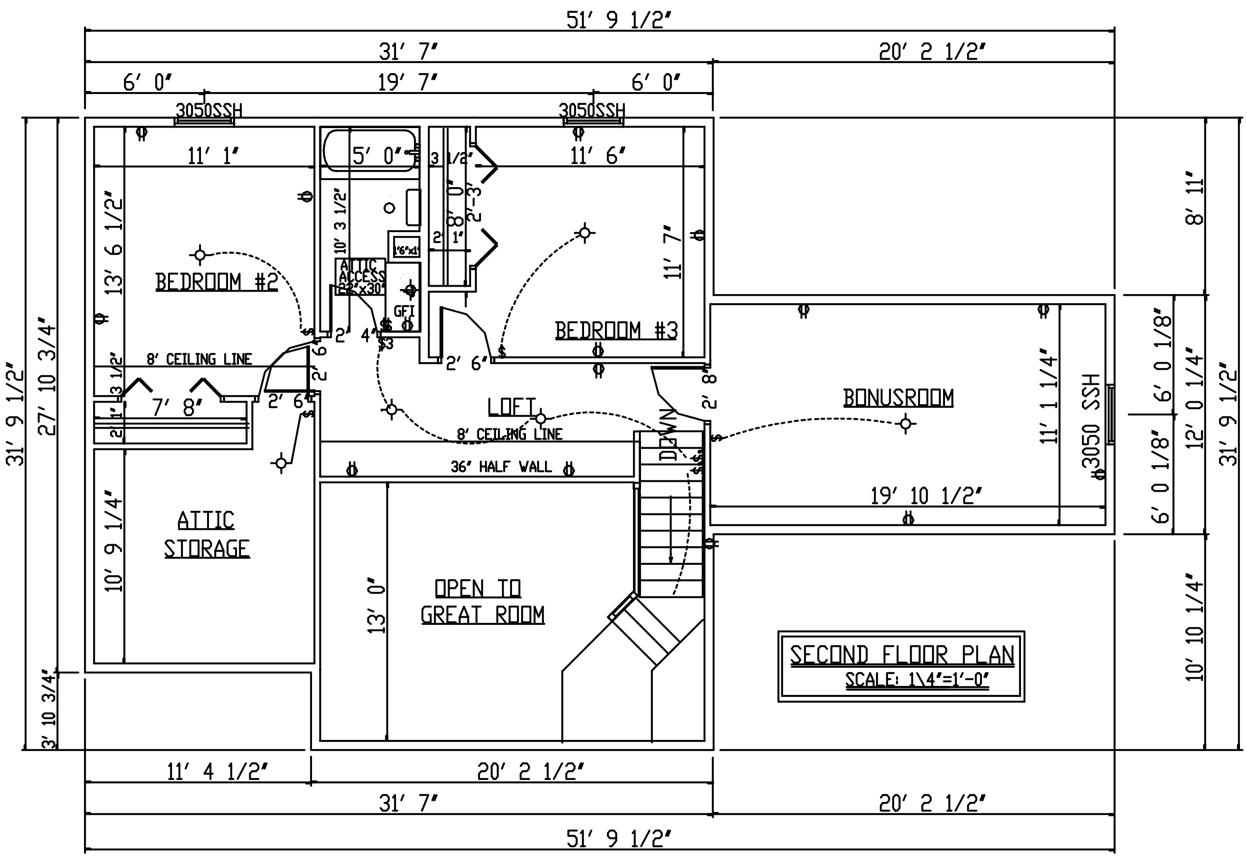
Steel Demonstration Home



Steel Demonstration Home



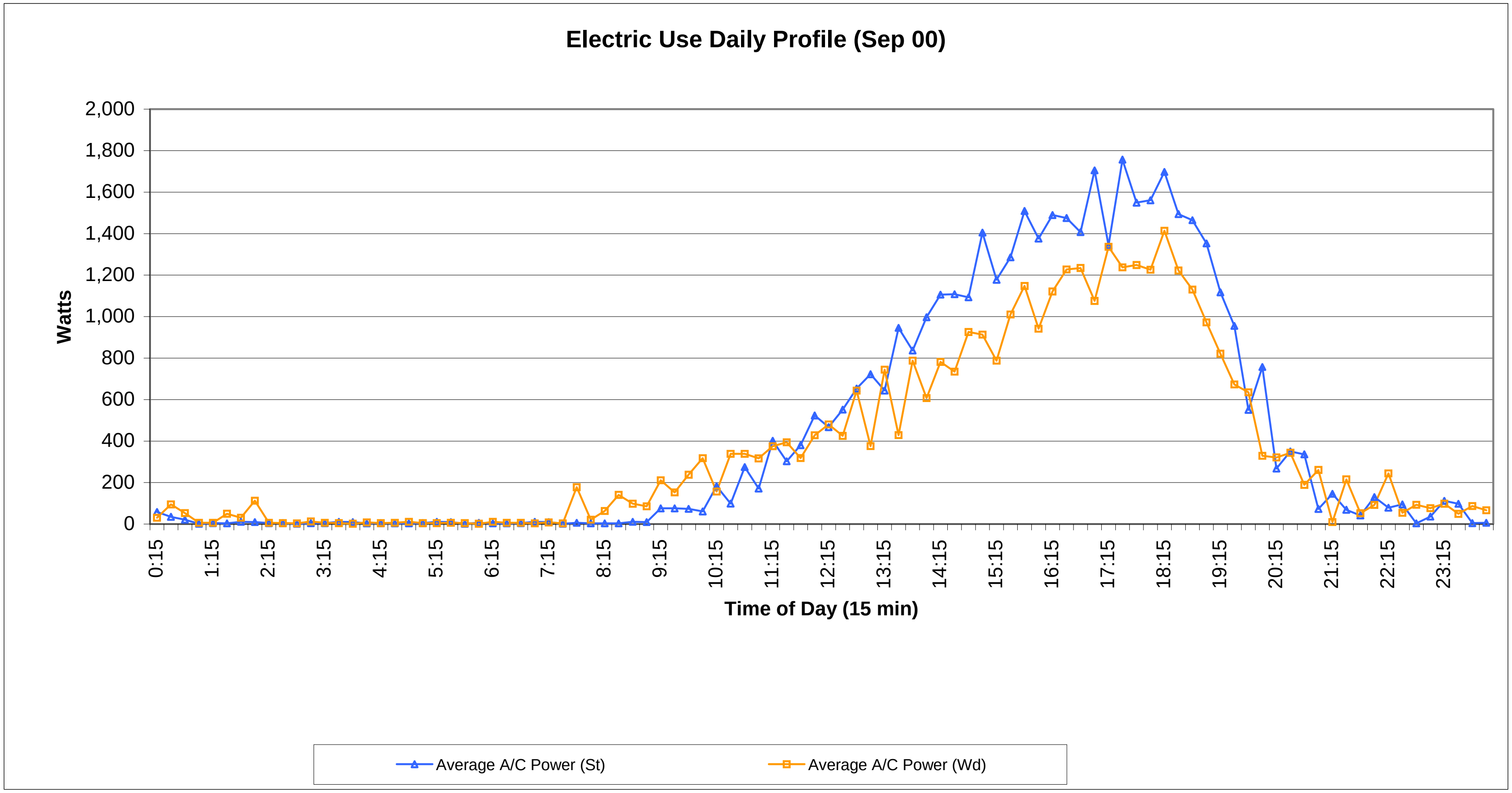
Steel Demonstration Home

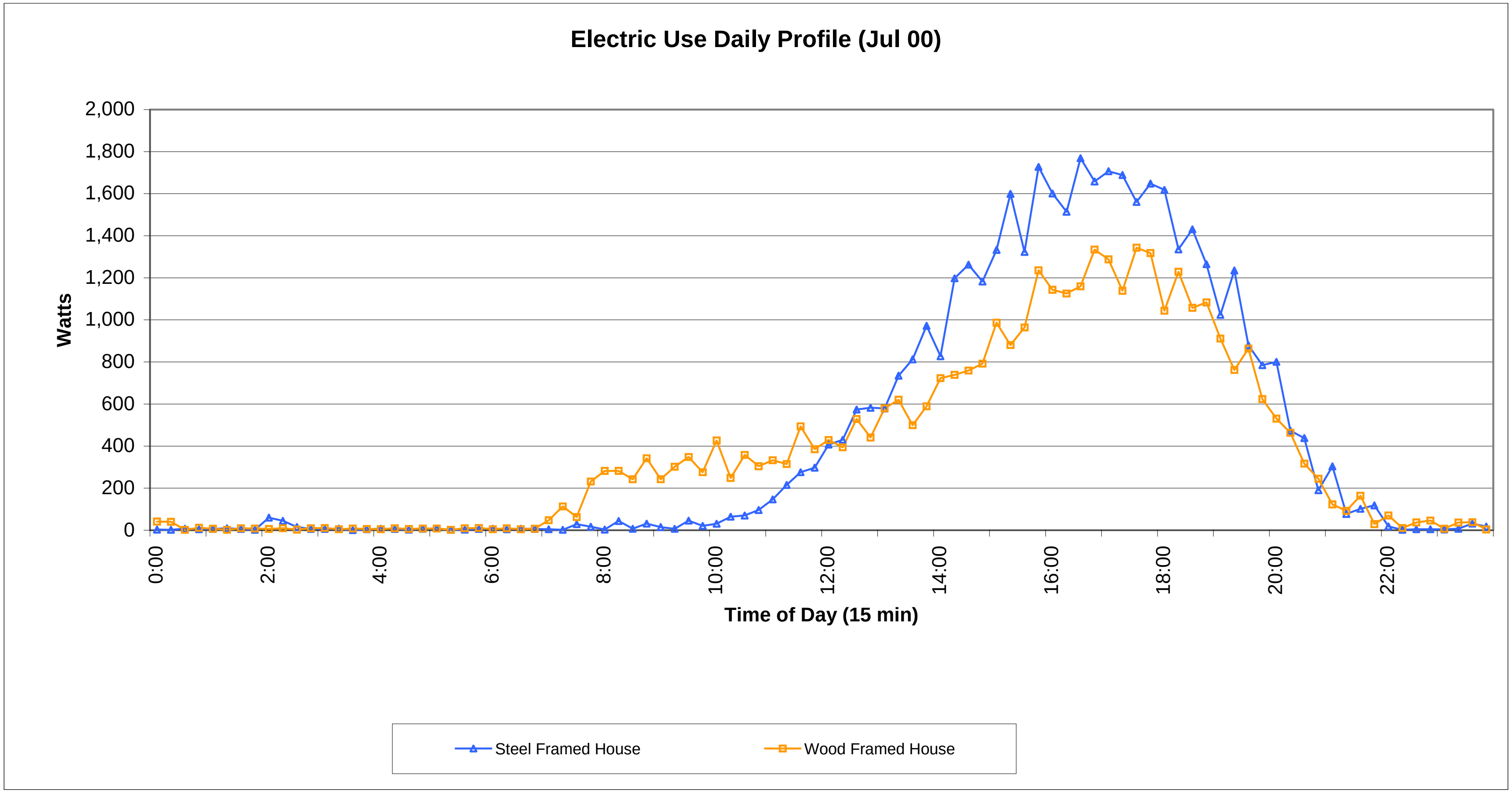

51' 9 1/2"
31' 7"
20' 2 1/2"
6' 0"
19' 7"
6' 0"
3050SSH
3050SSH
11' 1"
5' 0"
11' 6"
13' 6 1/2"
BEDROOM #2
ATTIC ACCESS
GFI
BEDROOM #3
11' 7"
8' 11"
8' CEILING LINE
7' 8"
2' 6"
LOFT
8' CEILING LINE
36" HALF WALL
DOWN
BONUSROOM
11' 1 1/4"
3050 SSH
19' 10 1/2"
6' 0 1/8"
12' 0 1/4"
31' 9 1/2"
27' 10 3/4"
ATTIC STORAGE
10' 9 1/4"
OPEN TO GREAT ROOM
13' 0"
10' 10 1/4"
3' 10 3/4"
SECOND FLOOR PLAN
SCALE: 1\4"=1'-0"
11' 4 1/2"
20' 2 1/2"
31' 7"
20' 2 1/2"
51' 9 1/2"

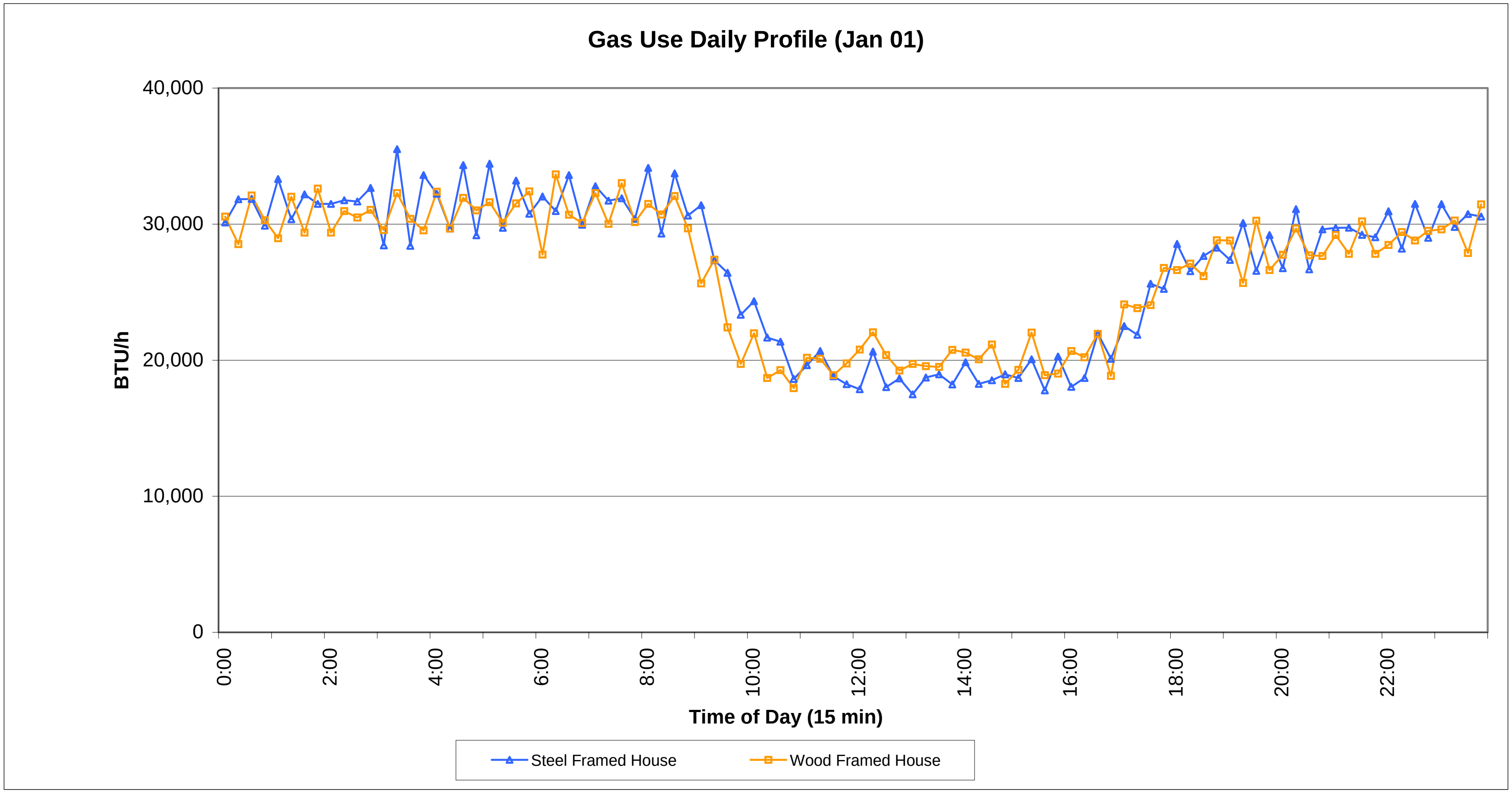
APPENDIX B

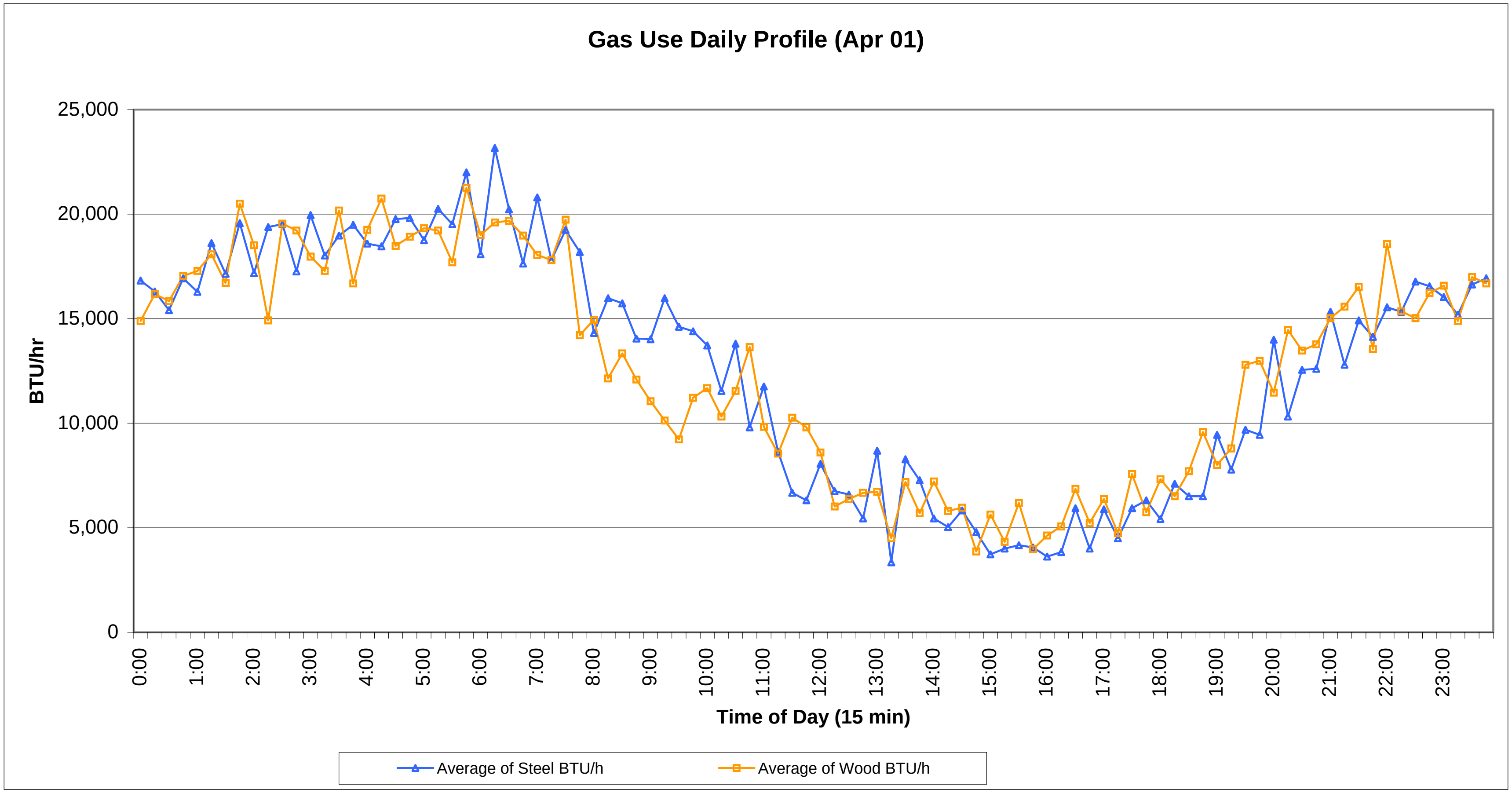
ENERGY USE GRAPHS

The Energy Graphs have been divided into actual winter natural gas usage and actual summer electric usage. Representative months (July, September, January, April) were chosen to show daily average heating or cooling utility usage.

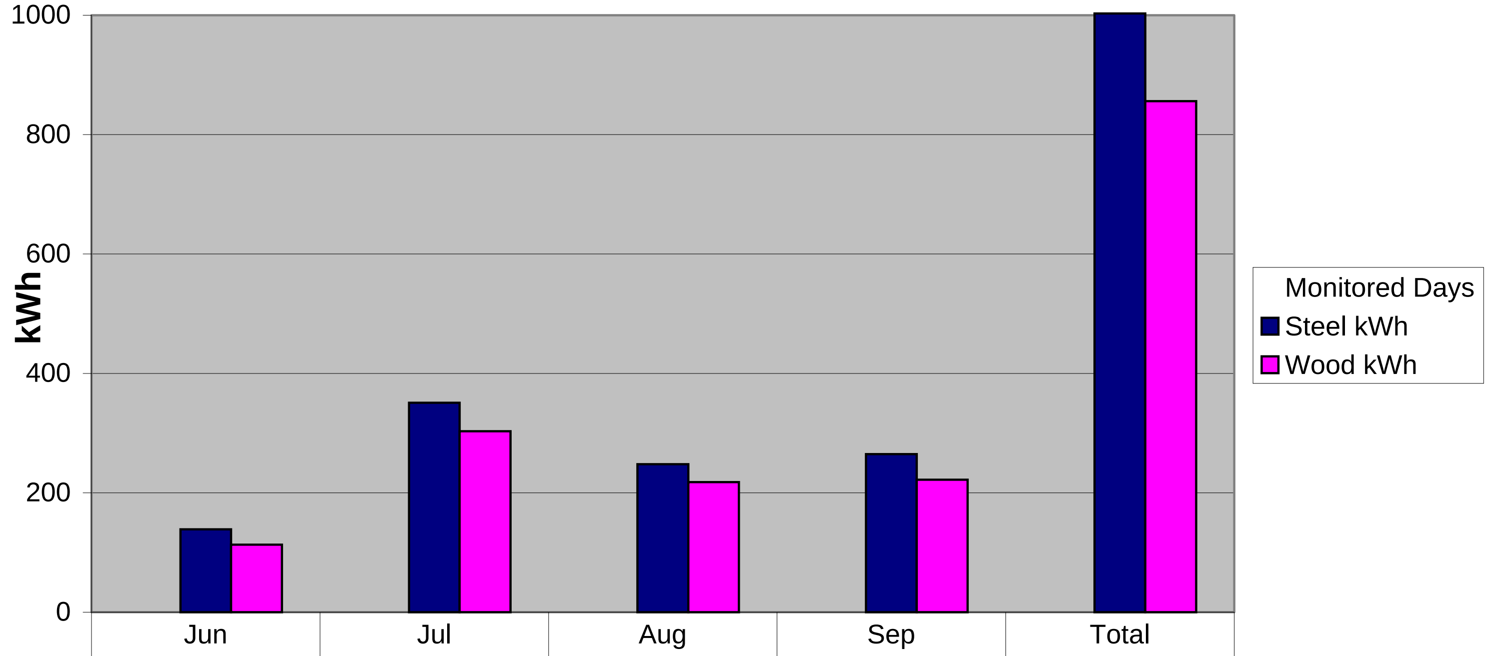

Electric Use Daily Profile (Sep 00)
Watts
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Average A/C Power (St)
Average A/C Power (Wd)


Electric Use Daily Profile (Jul 00)
Watts
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time of Day (15 min)
Steel Framed House
Wood Framed House


Gas Use Daily Profile (Jan 01)
40,000
30,000
20,000
10,000
0
BTU/h
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time of Day (15 min)
Steel Framed House
Wood Framed House

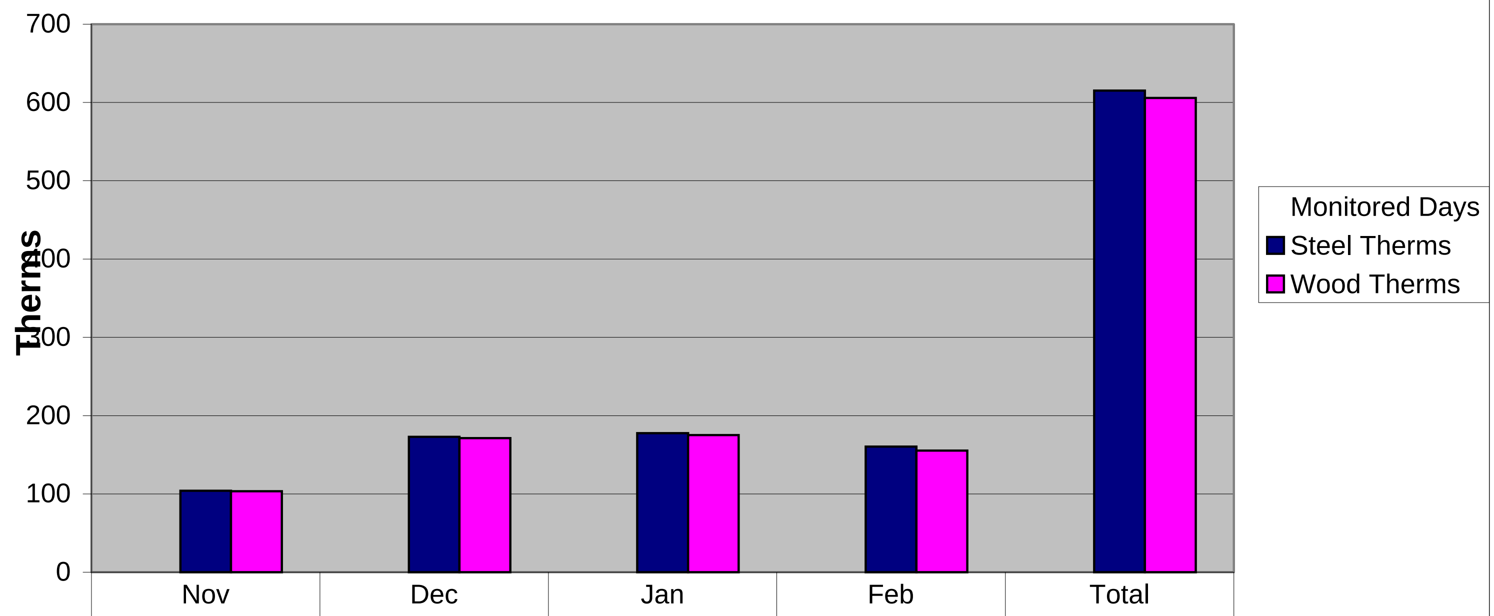

Gas Use Daily Profile (Apr 01)
25,000
20,000
15,000
10,000
5,000
0
BTU/hr
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day (15 min)
Average of Steel BTU/h
Average of Wood BTU/h

Actual Summer Electric Usage



	Jun	Jul	Aug	Sep	Total
Monitored Days	30	33	25	25	113
Steel kWh	139	351	248	265	1003
Wood kWh	113	303	218	222	856

Actual Winter Gas Usage



	Nov	Dec	Jan	Feb	Total
Monitored Days	23	23	27	26	99
Steel Therms	104.08641	172.87356	177.64899	160.40355	615.01251
Wood Therms	103.54749	171.36159	175.25379	155.50836	605.67123

APPENDIX C

TEMPERATURE GRAPHS

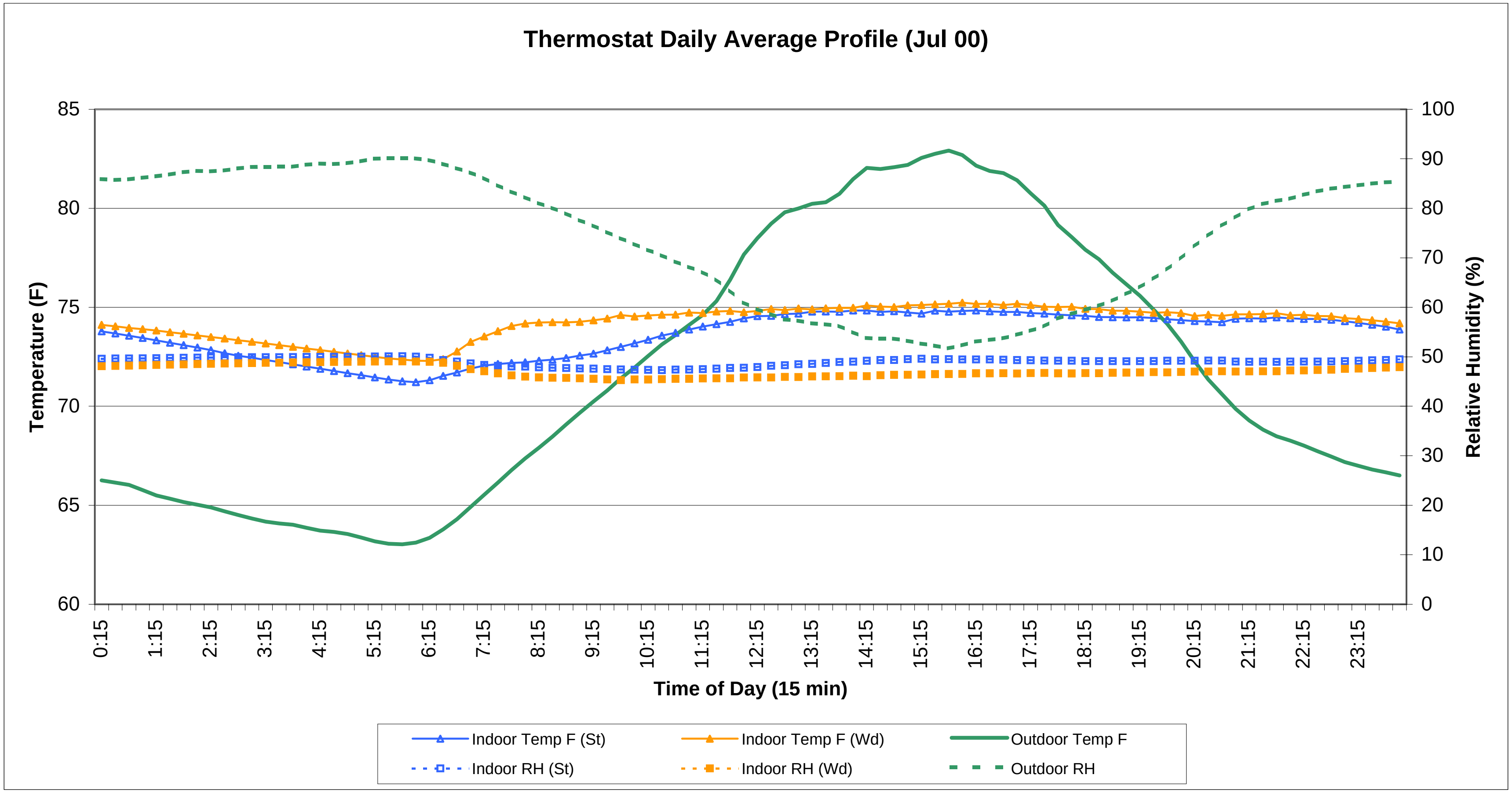
Four representative months were chosen (July, September, January, April) to reflect the performance of the houses in the different seasons. For the extreme months (January and July) the extreme monthly temperature was included in the selected time period.

Each graph focused on a different area of the house. Below is a list of the different types of graphs:

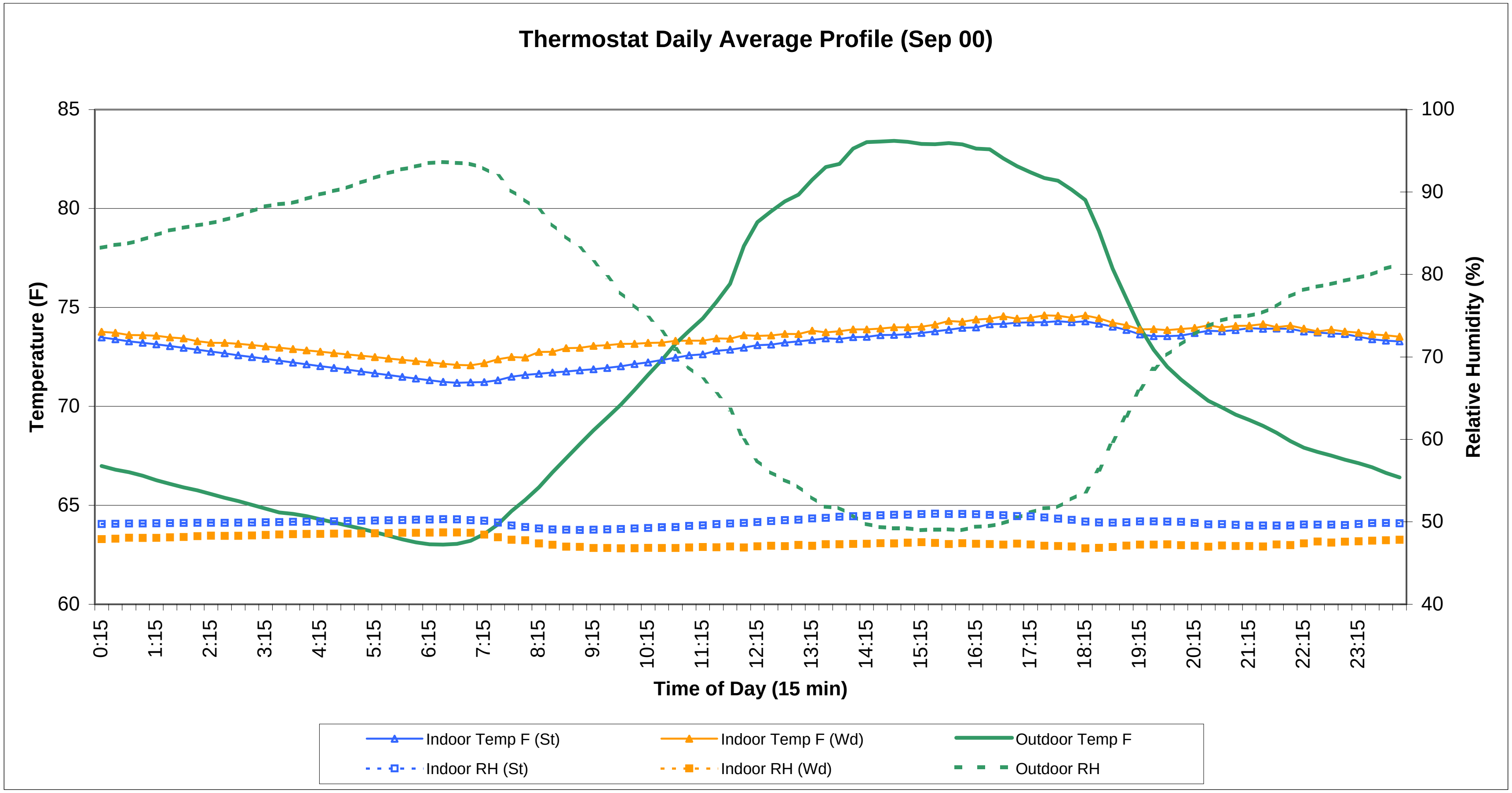
- Conditioned Space
- Wall Temperature
- Wall Relative Humidity
- Ceiling/Attic Temperatures
- Thermostat/Outdoor Temperature and Humidity
- Basement Temperature

Temperature Graphs were split into two different types, the first is a five-day profile charting the temperature changes over a five-day period of time in 15-minute increments. The second type, Average Daily Profile, included the entire month's data averaging each 15-minute period and reflecting a normal day for that month.

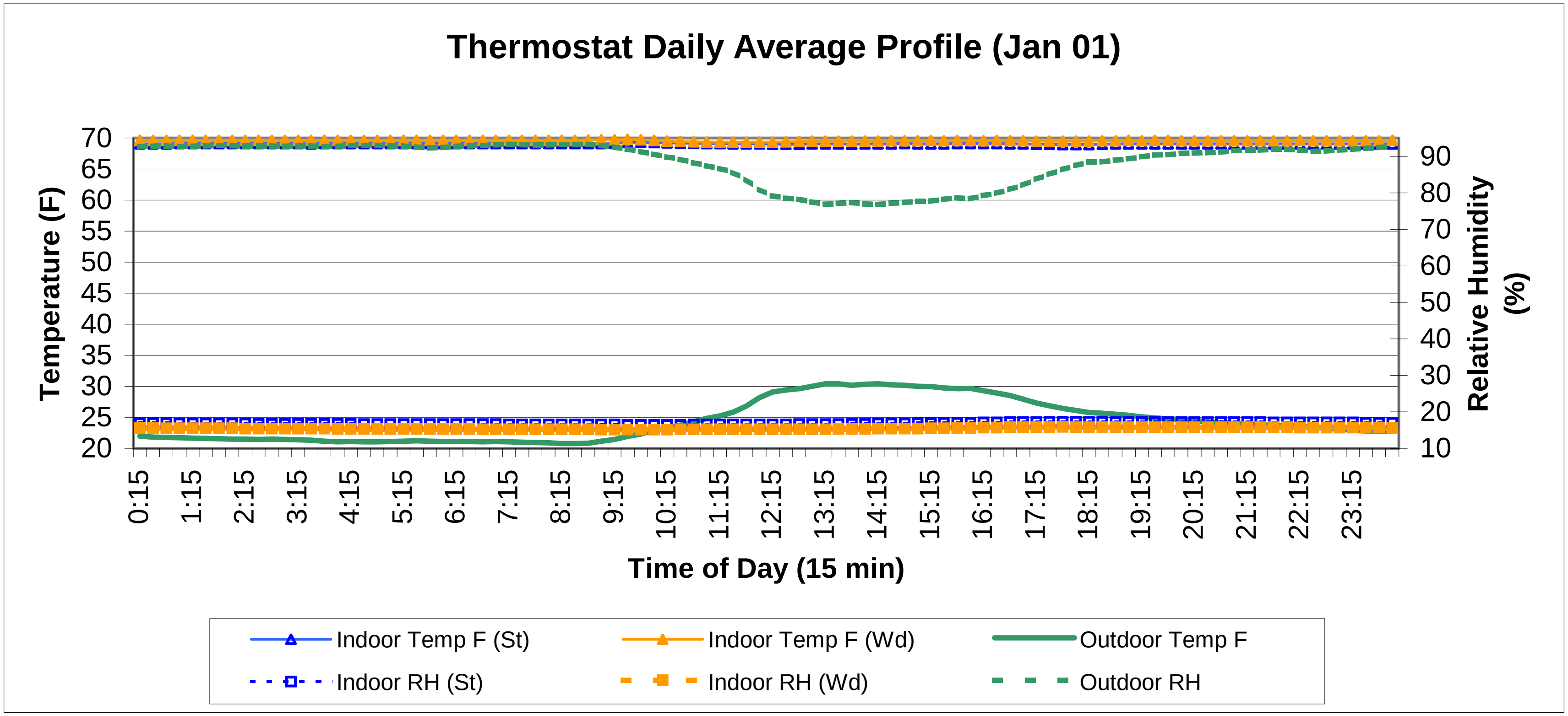
Most of the following graphs are not referenced in the text of the report. They do reflect the some of the important conclusions made and could also address some specific concerns not covered in the discussion.

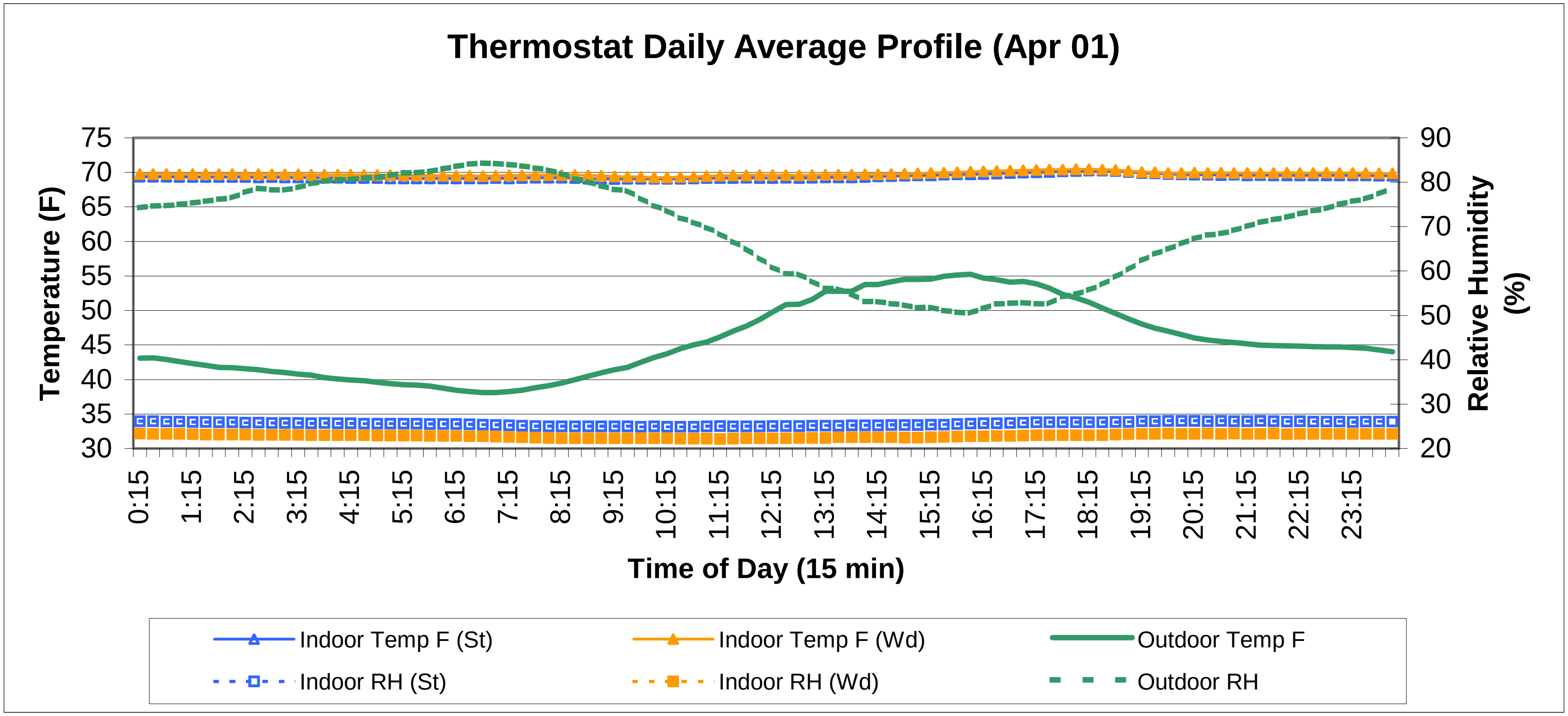


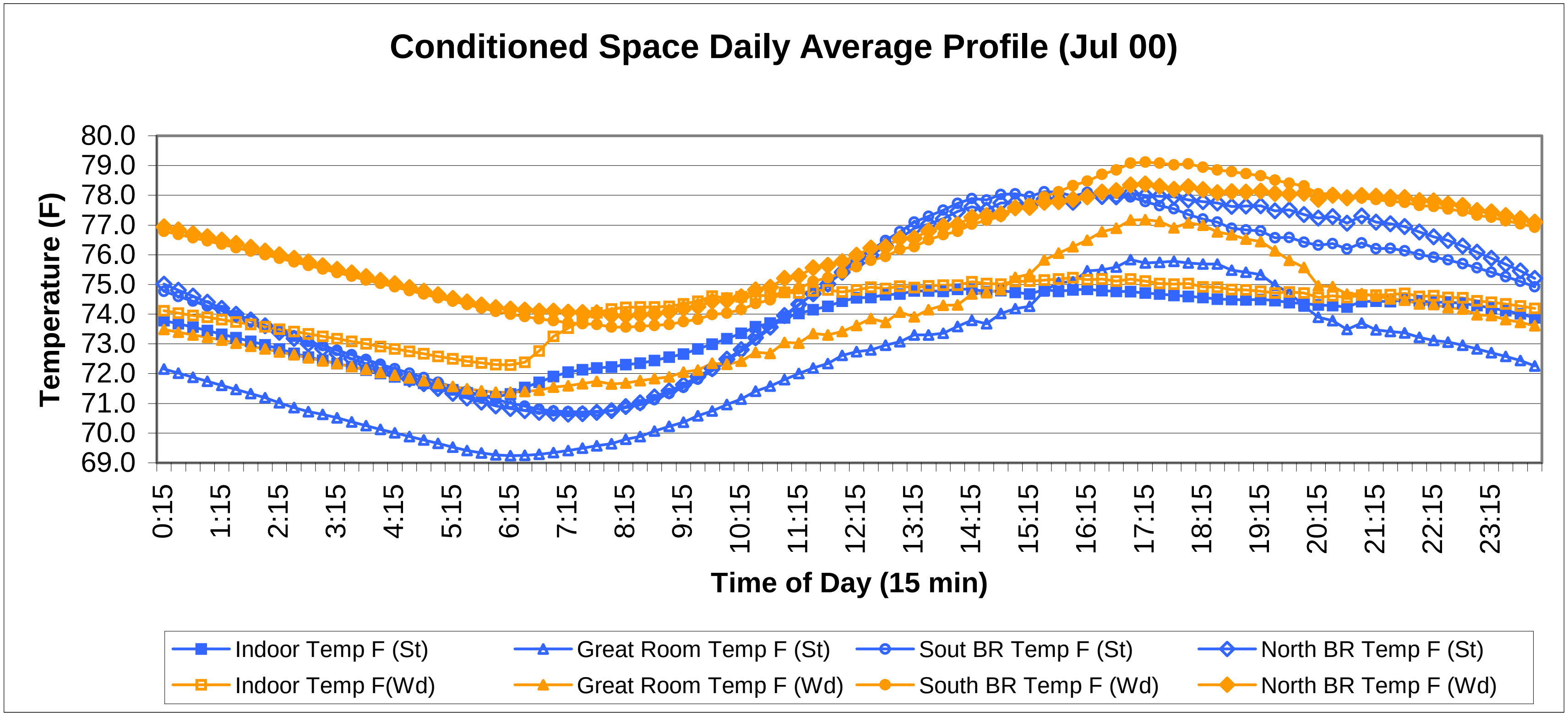
Thermostat Daily Average Profile (Jul 00)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
85
80
75
70
65
60
100
90
80
70
60
50
40
30
20
10
0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Indoor Temp F (St)
Indoor Temp F (Wd)
Outdoor Temp F
Indoor RH (St)
Indoor RH (Wd)
Outdoor RH



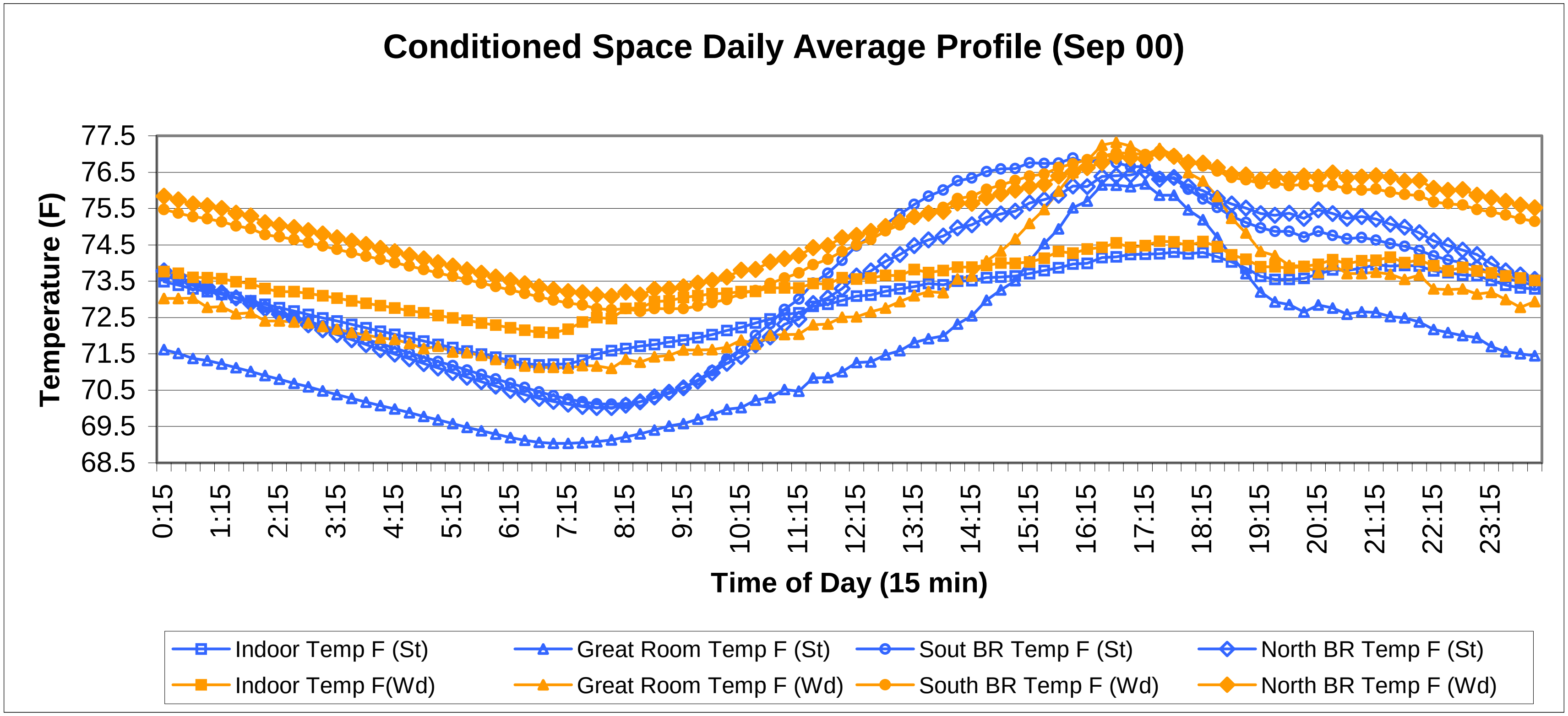
Thermostat Daily Average Profile (Sep 00)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
85
80
75
70
65
60
100
90
80
70
60
50
40
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Indoor Temp F (St)
Indoor Temp F (Wd)
Outdoor Temp F
Indoor RH (St)
Indoor RH (Wd)
Outdoor RH

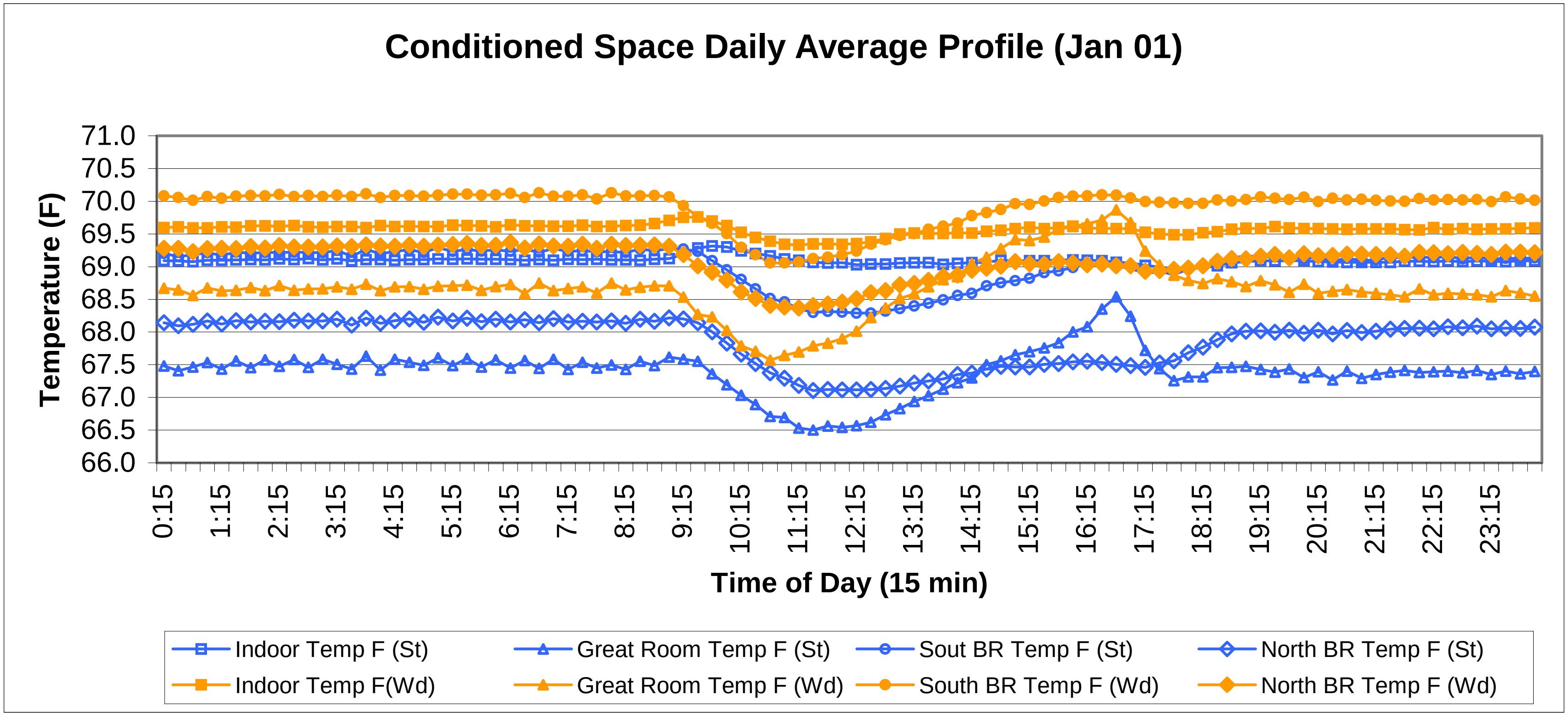

Thermostat Daily Average Profile (Jan 01)
Temperature (F)
70
65
60
55
50
45
40
35
30
25
20
Relative Humidity (%)
90
80
70
60
50
40
30
20
10
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Indoor Temp F (Wd)
Outdoor Temp F
Indoor RH (St)
Indoor RH (Wd)
Outdoor RH

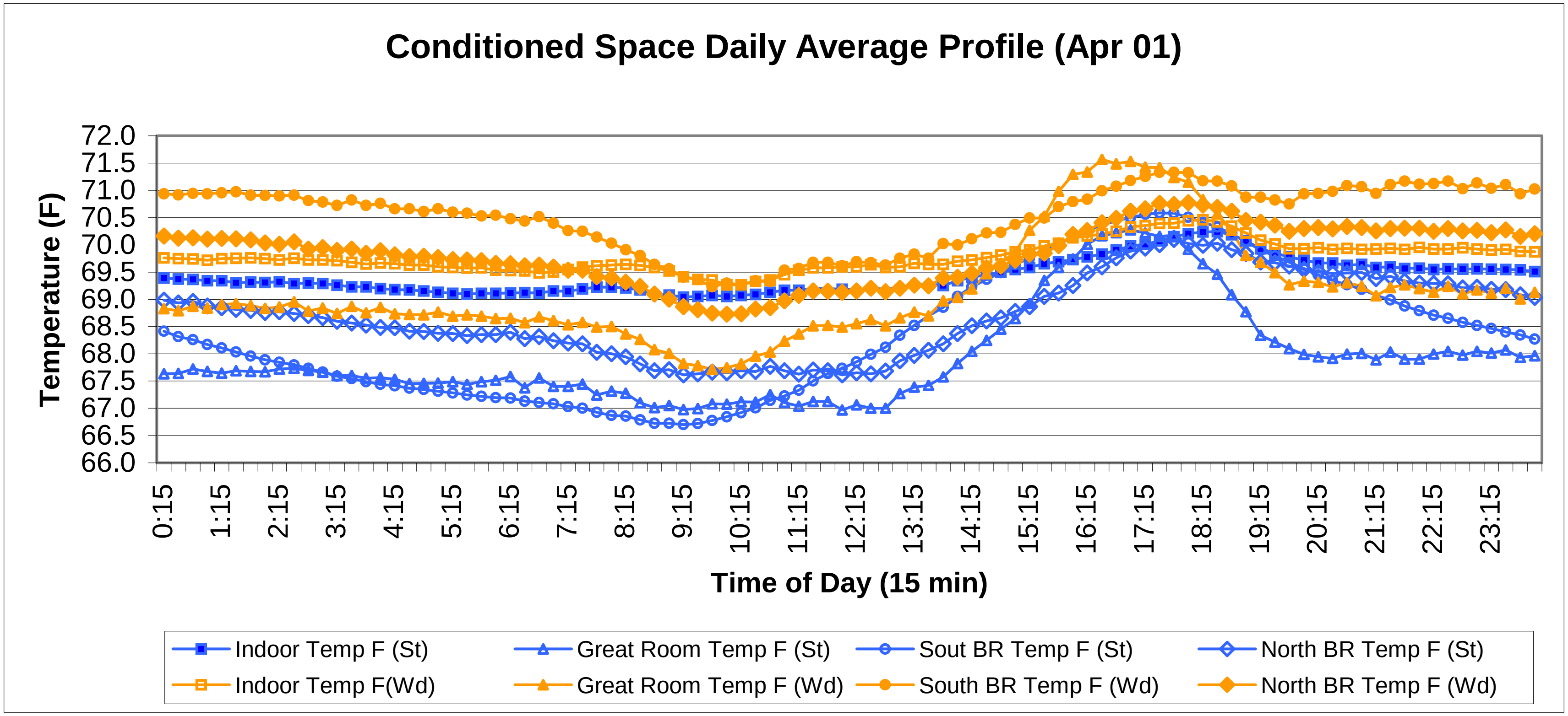

Thermostat Daily Average Profile (Apr 01)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
75
70
65
60
55
50
45
40
35
30
90
80
70
60
50
40
30
20
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Indoor Temp F (St)
Indoor Temp F (Wd)
Outdoor Temp F
Indoor RH (St)
Indoor RH (Wd)
Outdoor RH

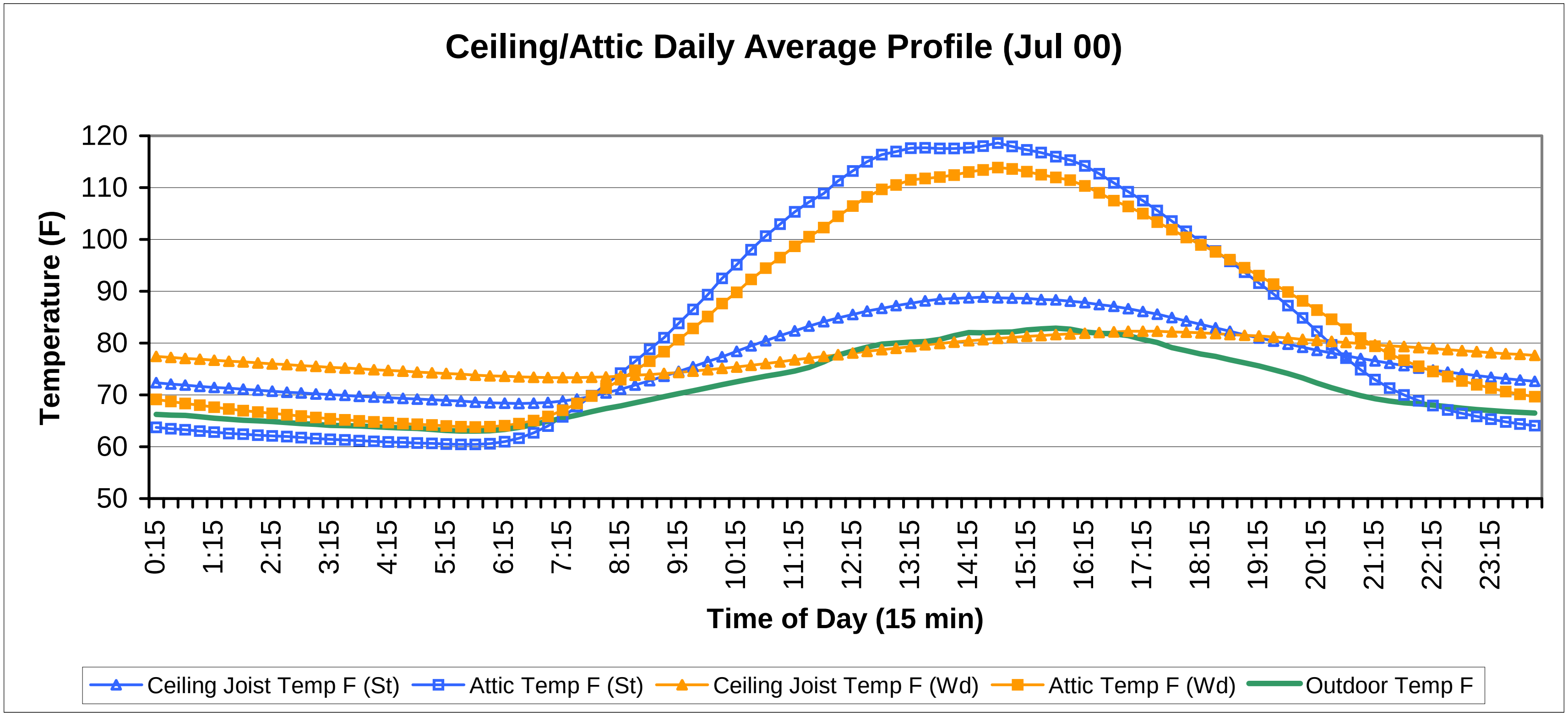


Conditioned Space Daily Average Profile (Jul 00)
Temperature (F)
80.0
79.0
78.0
77.0
76.0
75.0
74.0
73.0
72.0
71.0
70.0
69.0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Great Room Temp F (St)
Sout BR Temp F (St)
North BR Temp F (St)
Indoor Temp F(Wd)
Great Room Temp F (Wd)
South BR Temp F (Wd)
North BR Temp F (Wd)

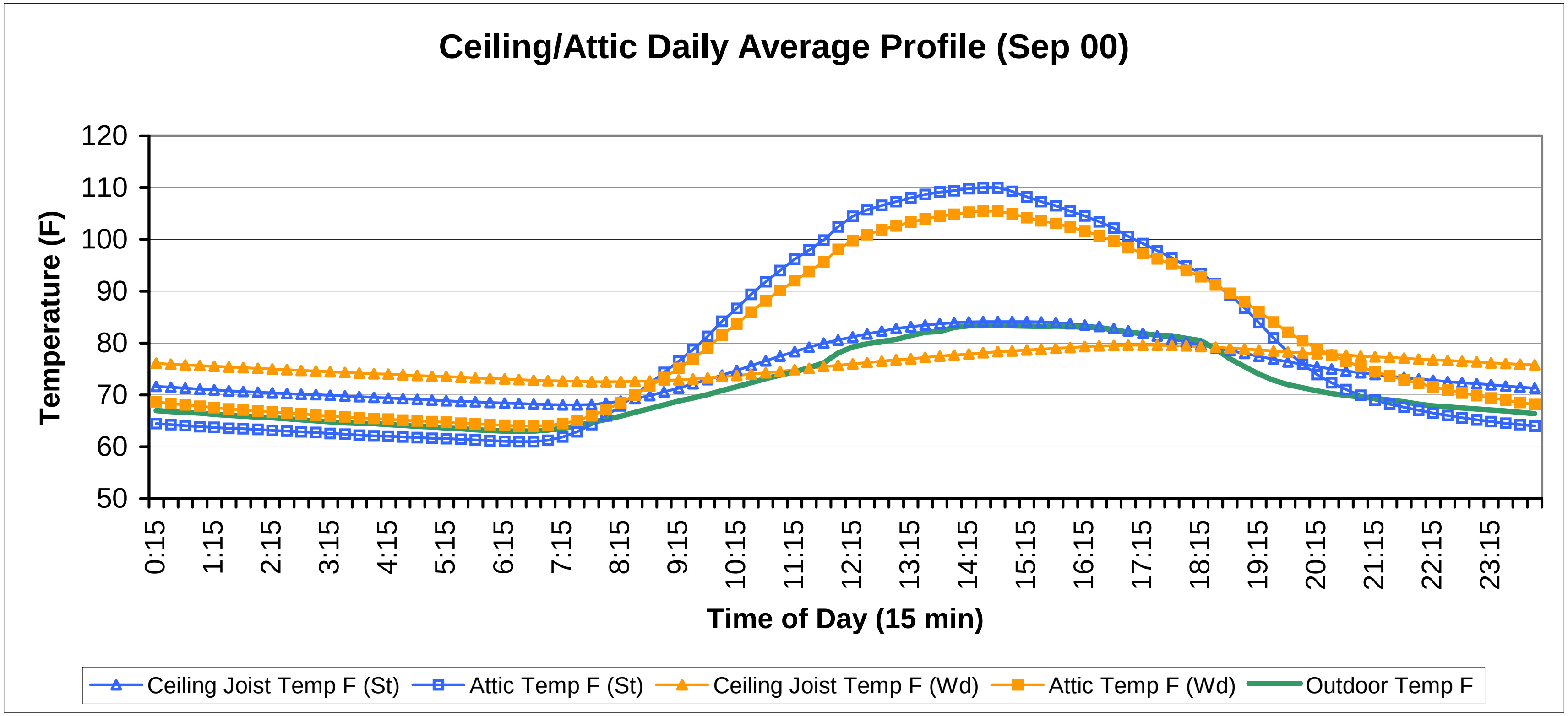

Conditioned Space Daily Average Profile (Sep 00)
Temperature (F)
77.5
76.5
75.5
74.5
73.5
72.5
71.5
70.5
69.5
68.5
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Great Room Temp F (St)
Sout BR Temp F (St)
North BR Temp F (St)
Indoor Temp F(Wd)
Great Room Temp F (Wd)
South BR Temp F (Wd)
North BR Temp F (Wd)


Conditioned Space Daily Average Profile (Jan 01)
Temperature (F)
71.0
70.5
70.0
69.5
69.0
68.5
68.0
67.5
67.0
66.5
66.0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Great Room Temp F (St)
Sout BR Temp F (St)
North BR Temp F (St)
Indoor Temp F(Wd)
Great Room Temp F (Wd)
South BR Temp F (Wd)
North BR Temp F (Wd)

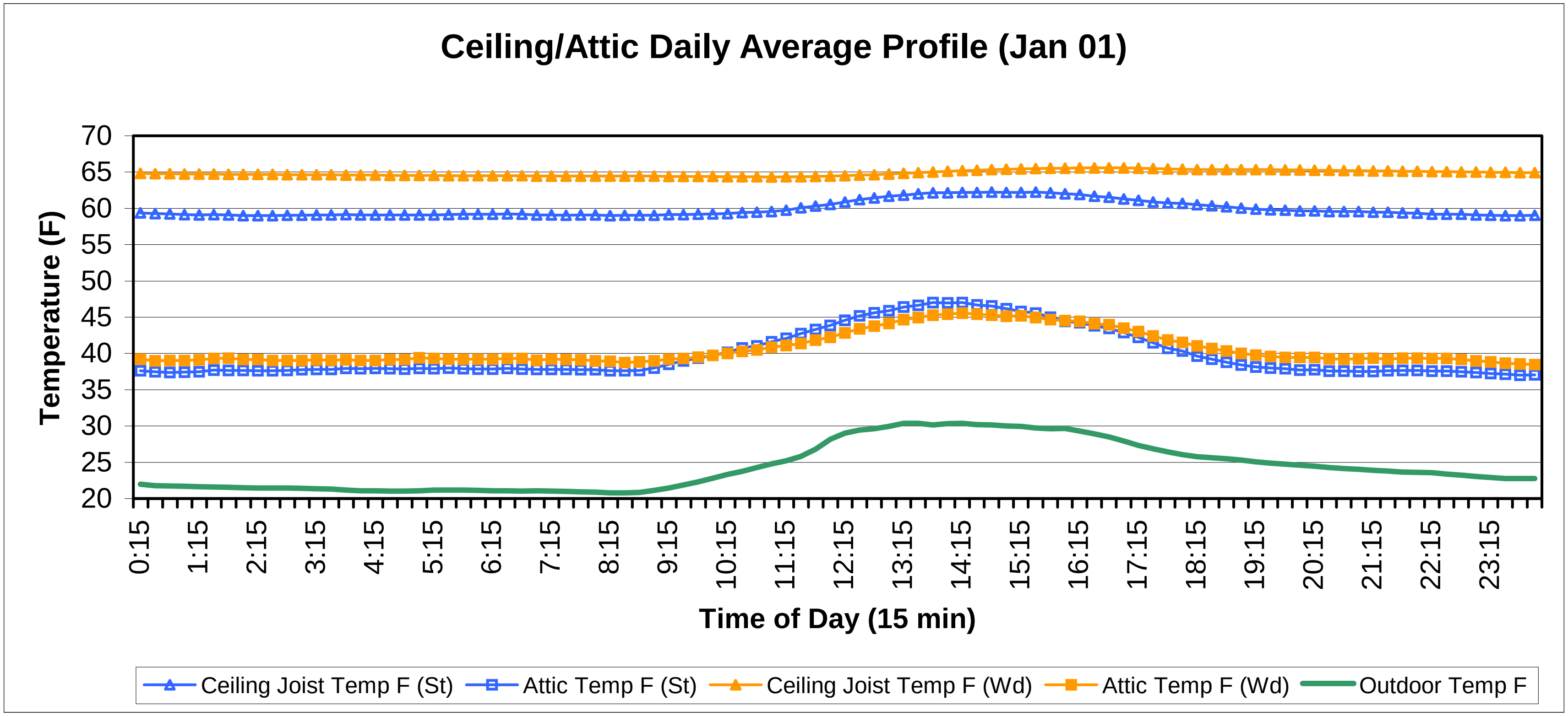

Conditioned Space Daily Average Profile (Apr 01)
Temperature (F)
72.0
71.5
71.0
70.5
70.0
69.5
69.0
68.5
68.0
67.5
67.0
66.5
66.0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Great Room Temp F (St)
Sout BR Temp F (St)
North BR Temp F (St)
Indoor Temp F(Wd)
Great Room Temp F (Wd)
South BR Temp F (Wd)
North BR Temp F (Wd)

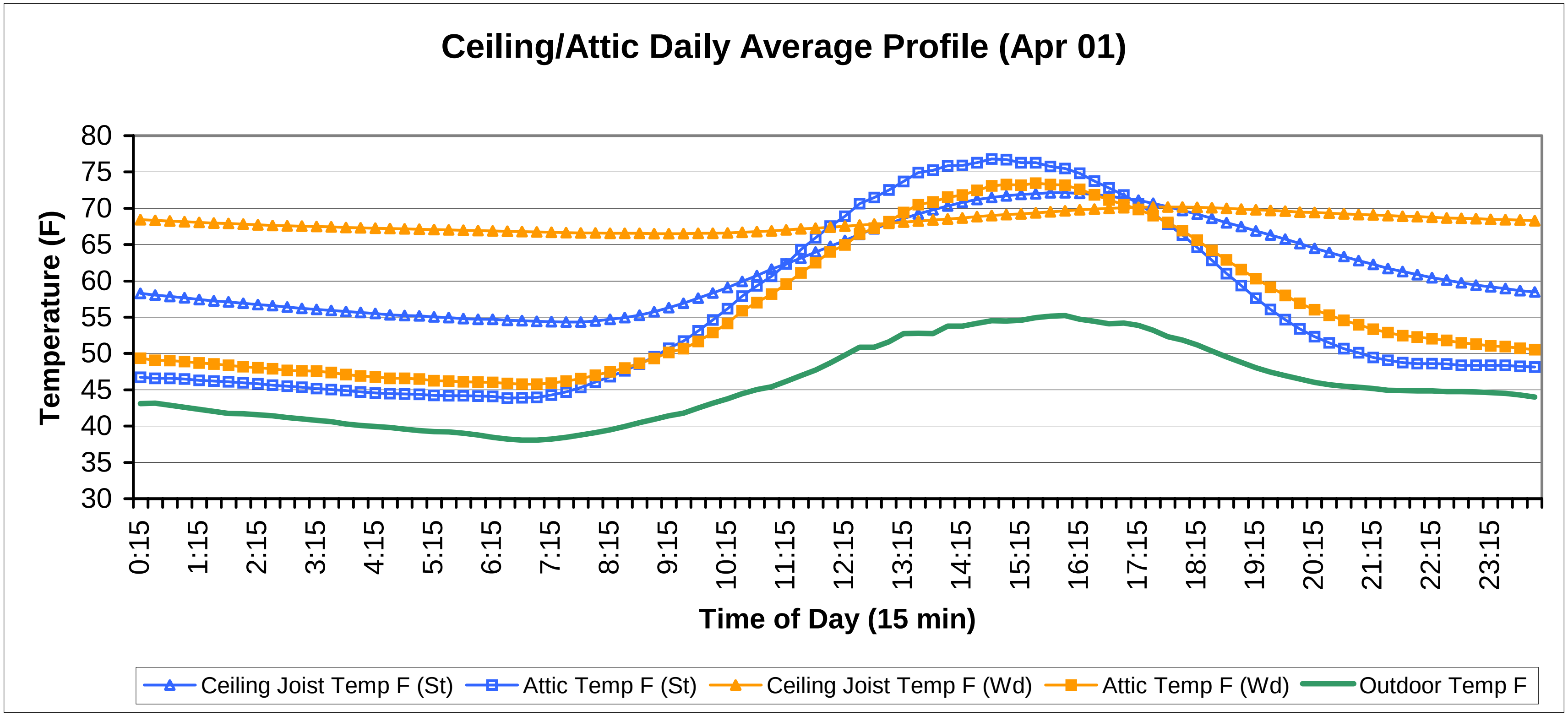


Ceiling/Attic Daily Average Profile (Jul 00)
Temperature (F)
120
110
100
90
80
70
60
50
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Ceiling Joist Temp F (St)
Attic Temp F (St)
Ceiling Joist Temp F (Wd)
Attic Temp F (Wd)
Outdoor Temp F

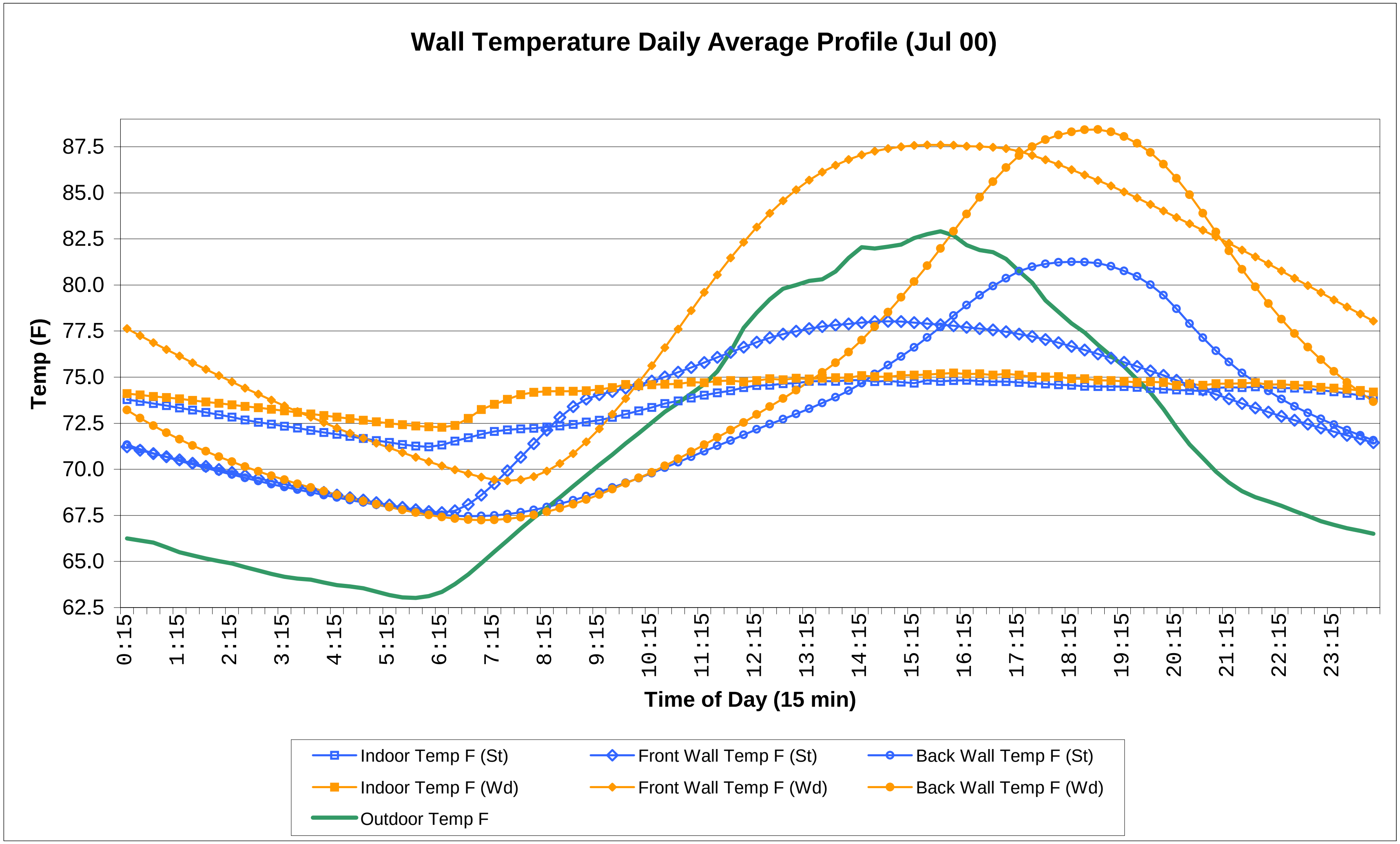


Ceiling/Attic Daily Average Profile (Sep 00)
Temperature (F)
120
110
100
90
80
70
60
50
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Ceiling Joist Temp F (St)
Attic Temp F (St)
Ceiling Joist Temp F (Wd)
Attic Temp F (Wd)
Outdoor Temp F

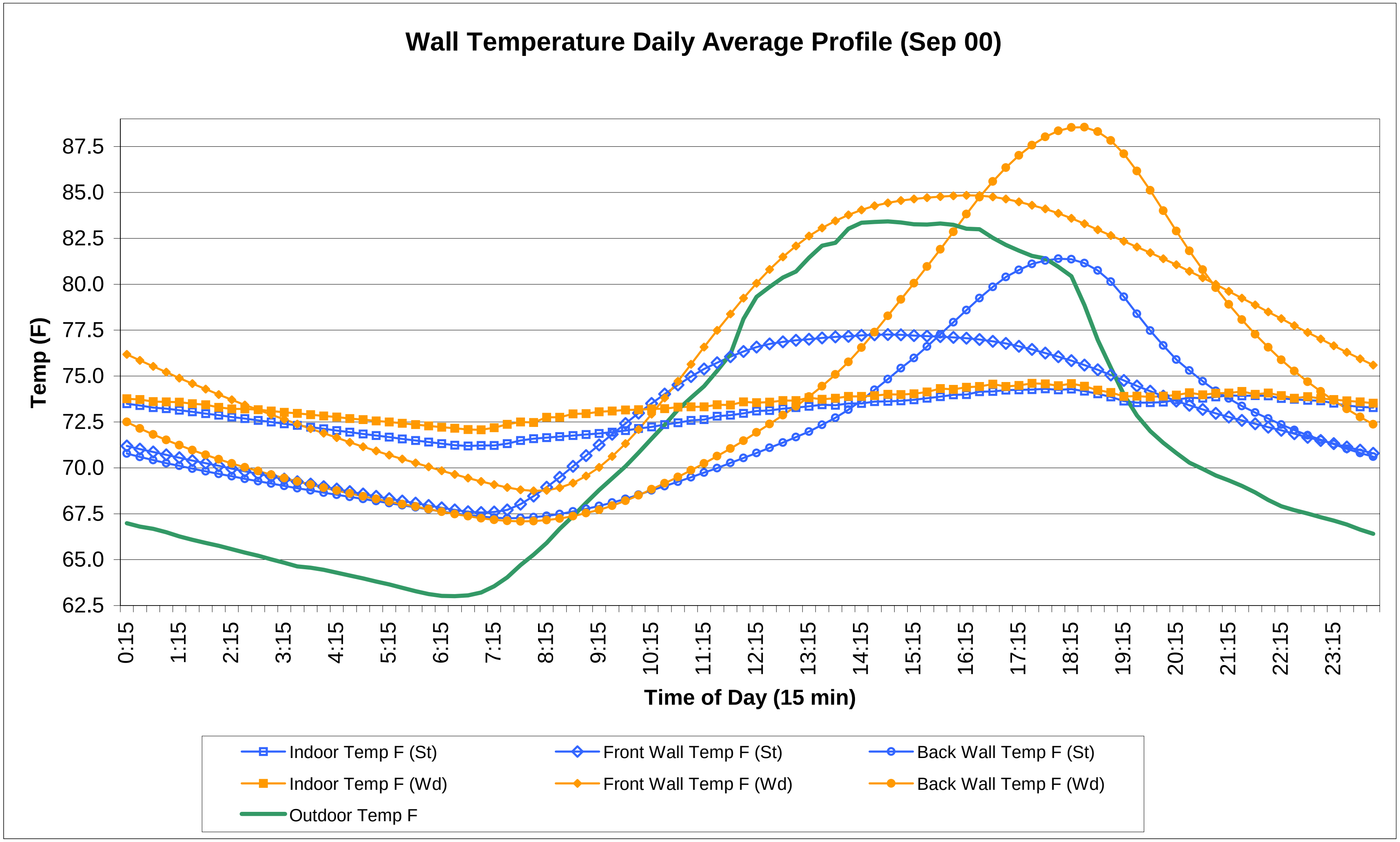

Ceiling/Attic Daily Average Profile (Jan 01)
Temperature (F)
70
65
60
55
50
45
40
35
30
25
20
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Ceiling Joist Temp F (St)
Attic Temp F (St)
Ceiling Joist Temp F (Wd)
Attic Temp F (Wd)
Outdoor Temp F



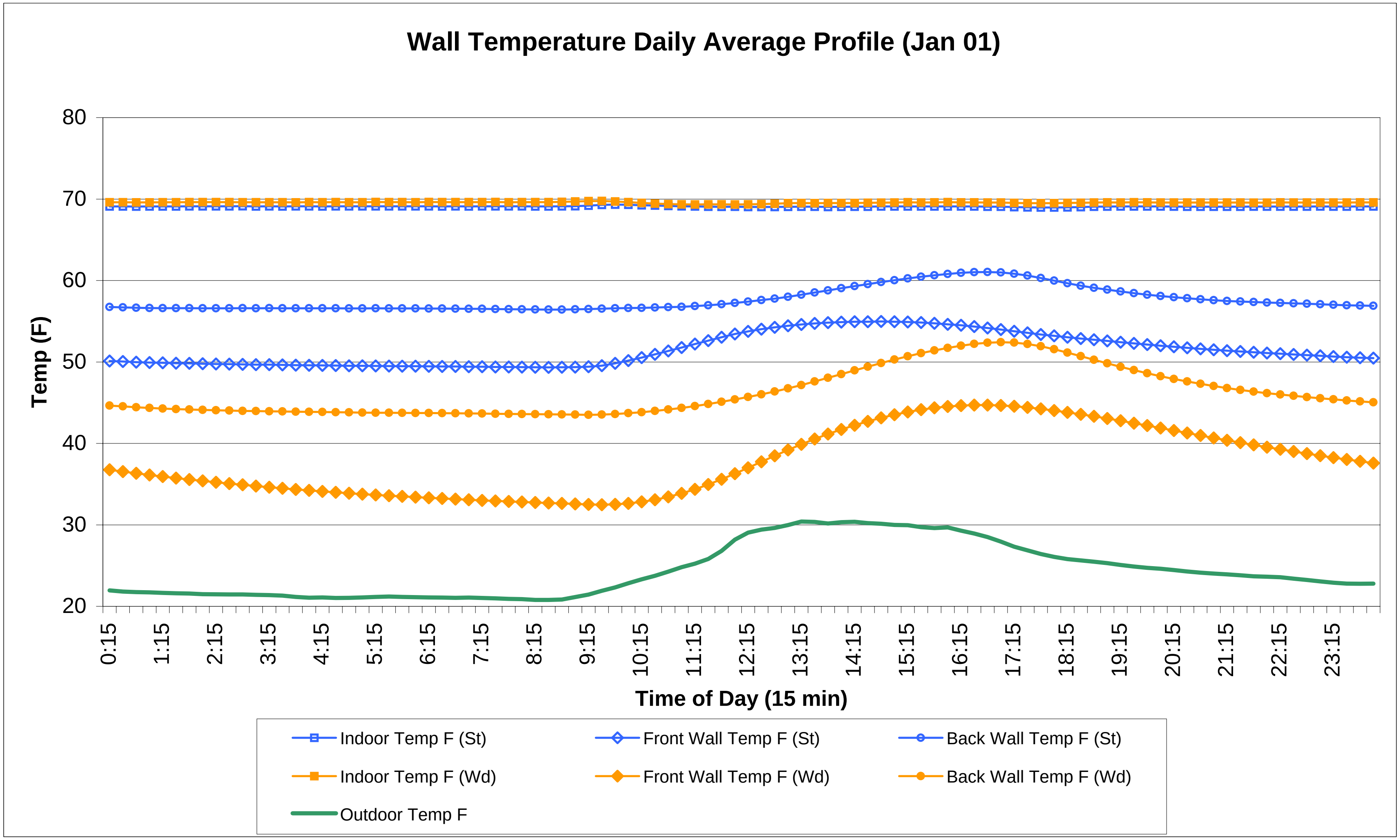
Ceiling/Attic Daily Average Profile (Apr 01)
Temperature (F)
80
75
70
65
60
55
50
45
40
35
30
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Ceiling Joist Temp F (St)
Attic Temp F (St)
Ceiling Joist Temp F (Wd)
Attic Temp F (Wd)
Outdoor Temp F



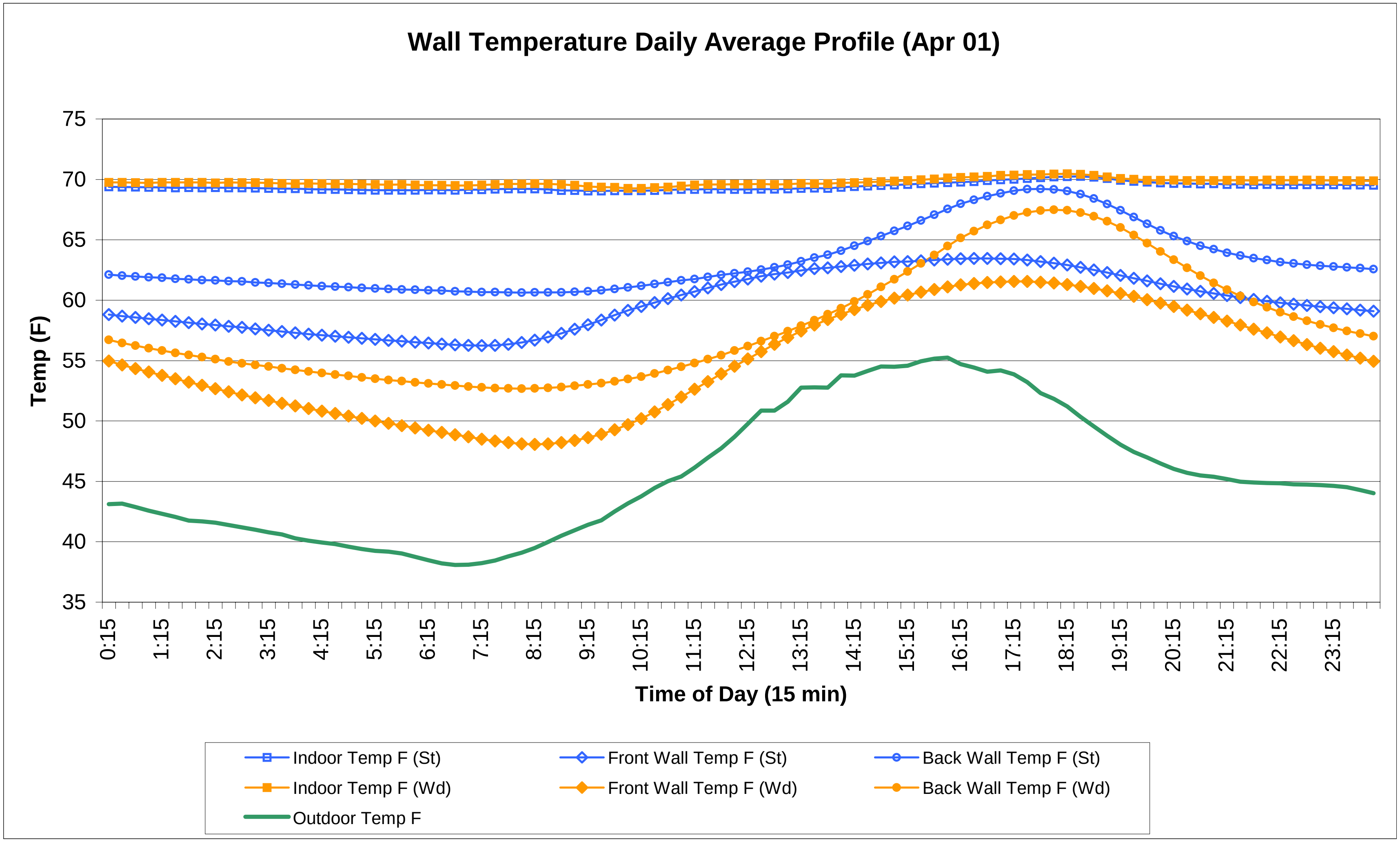
Wall Temperature Daily Average Profile (Jul 00)
Temp (F)
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
67.5
65.0
62.5
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Front Wall Temp F (St)
Back Wall Temp F (St)
Indoor Temp F (Wd)
Front Wall Temp F (Wd)
Back Wall Temp F (Wd)
Outdoor Temp F



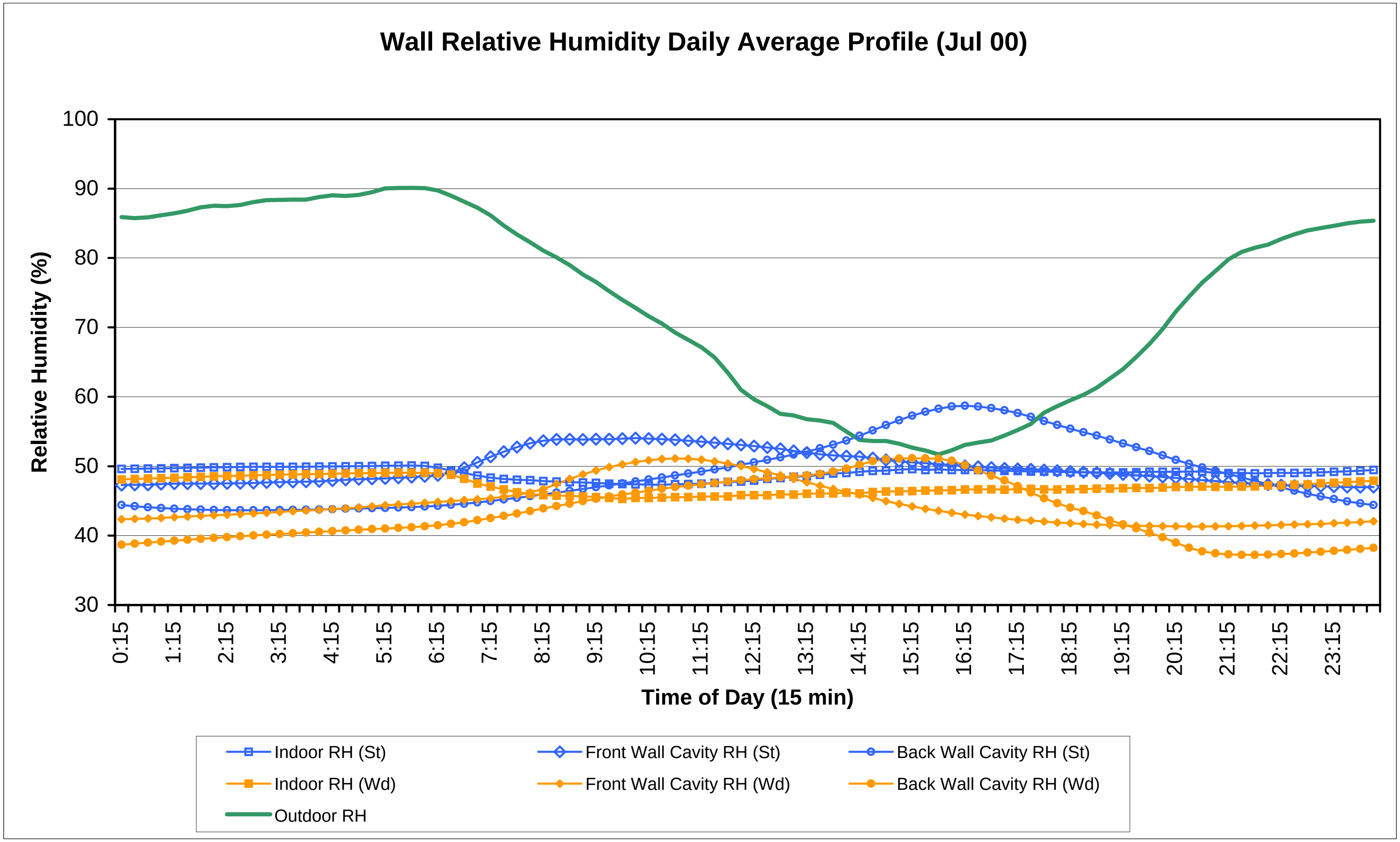
Wall Temperature Daily Average Profile (Sep 00)
Temp (F)
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
67.5
65.0
62.5
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Front Wall Temp F (St)
Back Wall Temp F (St)
Indoor Temp F (Wd)
Front Wall Temp F (Wd)
Back Wall Temp F (Wd)
Outdoor Temp F



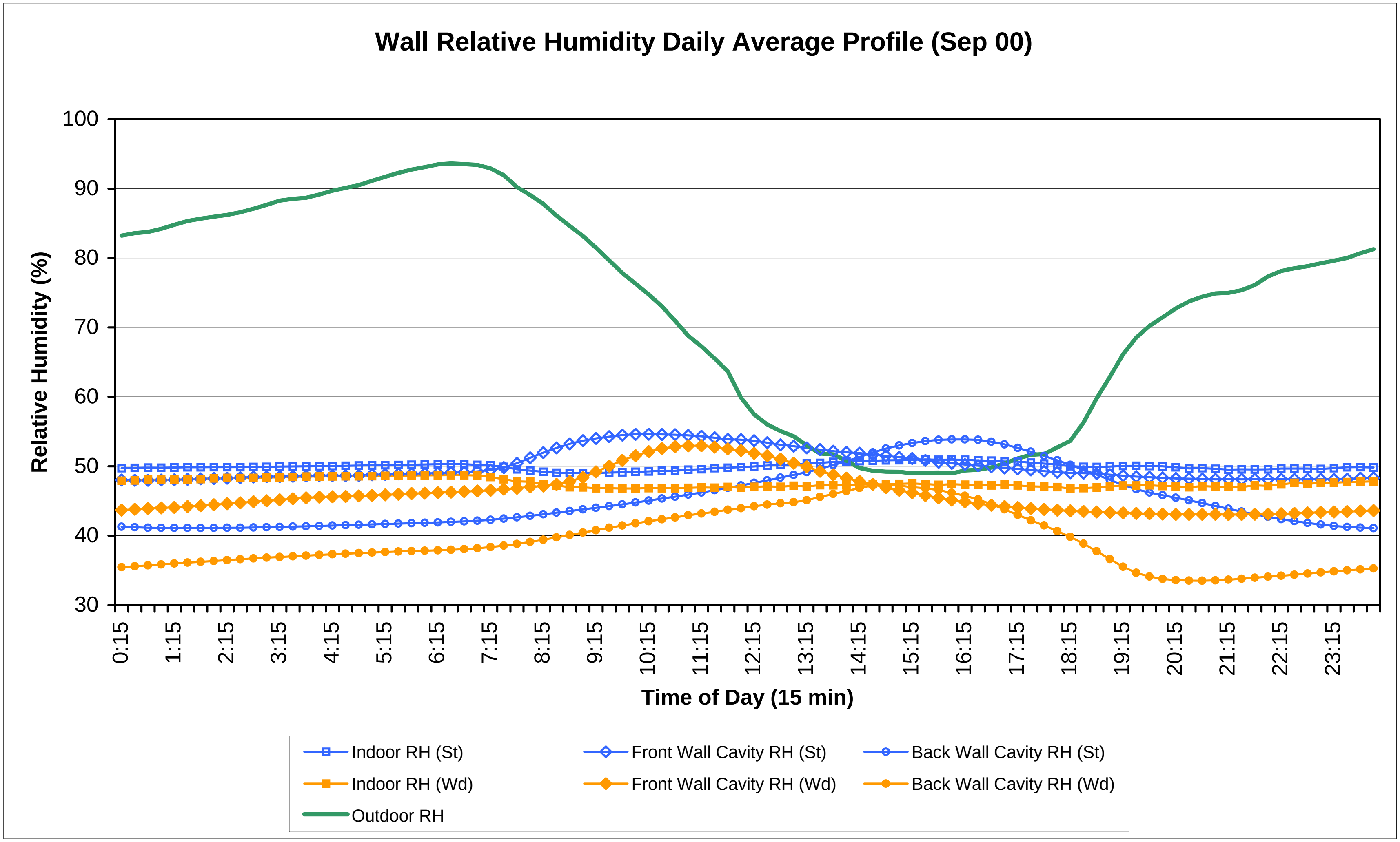
Wall Temperature Daily Average Profile (Jan 01)
80
70
60
50
40
30
20
Temp (F)
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Front Wall Temp F (St)
Back Wall Temp F (St)
Indoor Temp F (Wd)
Front Wall Temp F (Wd)
Back Wall Temp F (Wd)
Outdoor Temp F



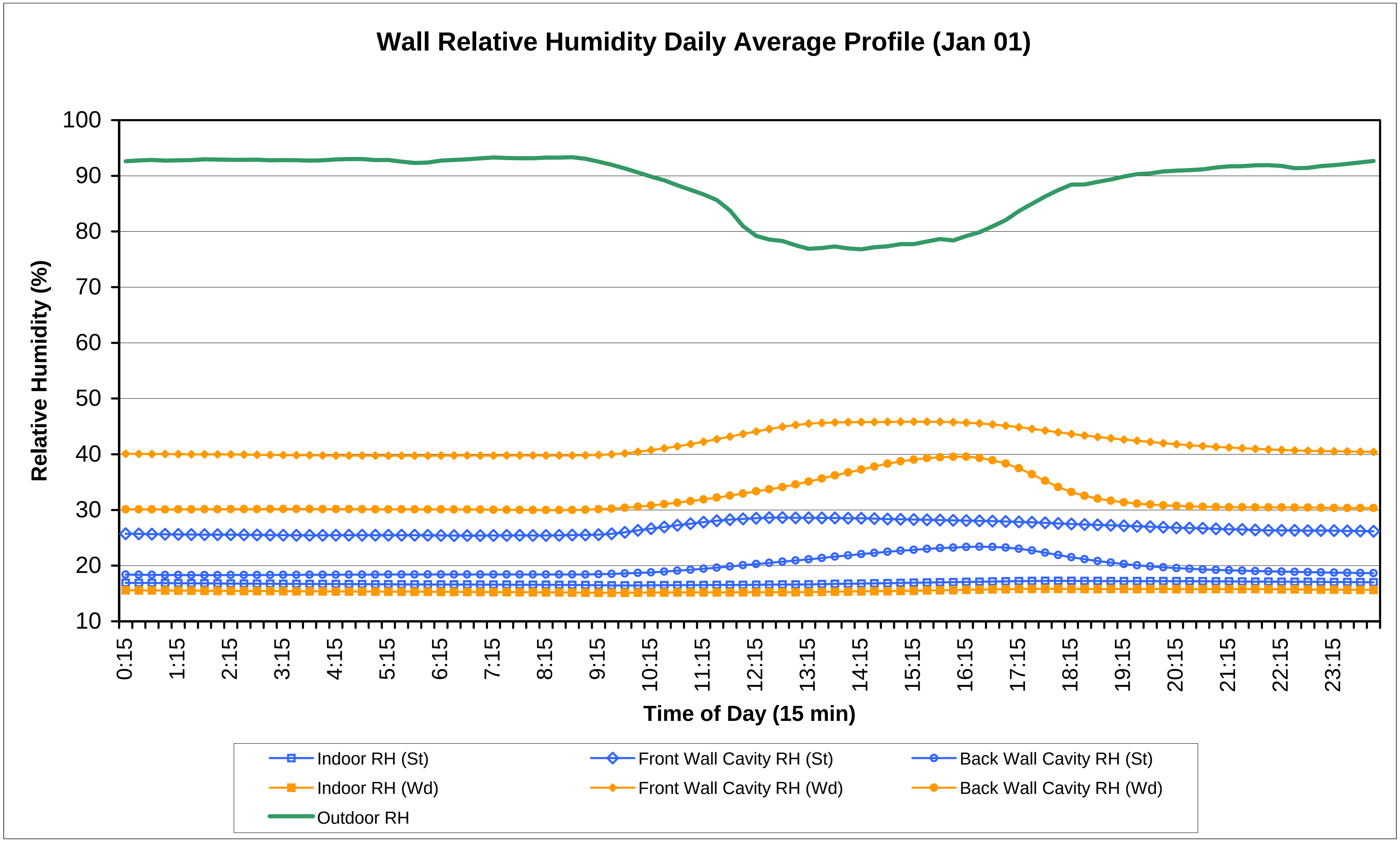
Wall Temperature Daily Average Profile (Apr 01)
Temp (F)
75
70
65
60
55
50
45
40
35
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor Temp F (St)
Front Wall Temp F (St)
Back Wall Temp F (St)
Indoor Temp F (Wd)
Front Wall Temp F (Wd)
Back Wall Temp F (Wd)
Outdoor Temp F

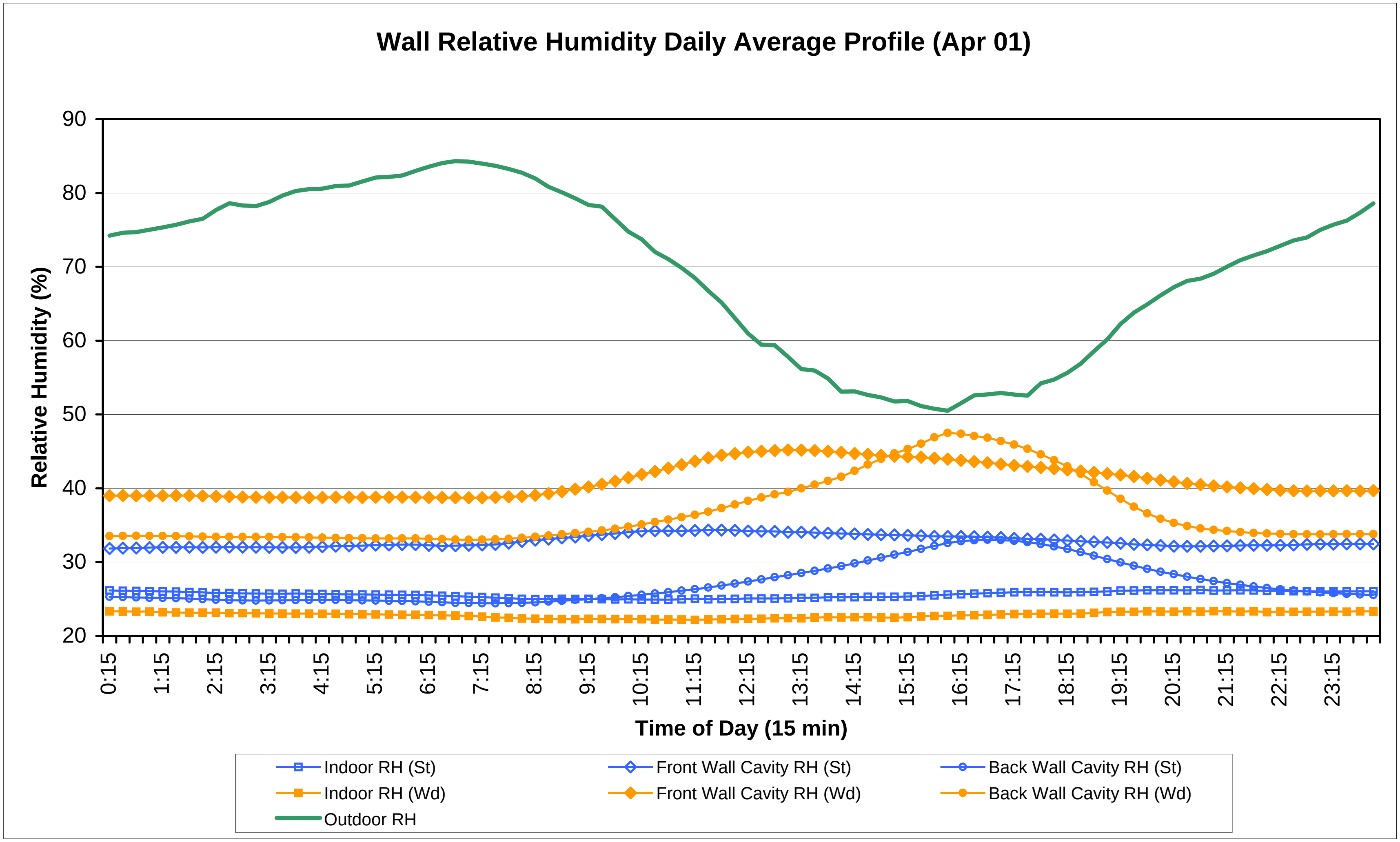


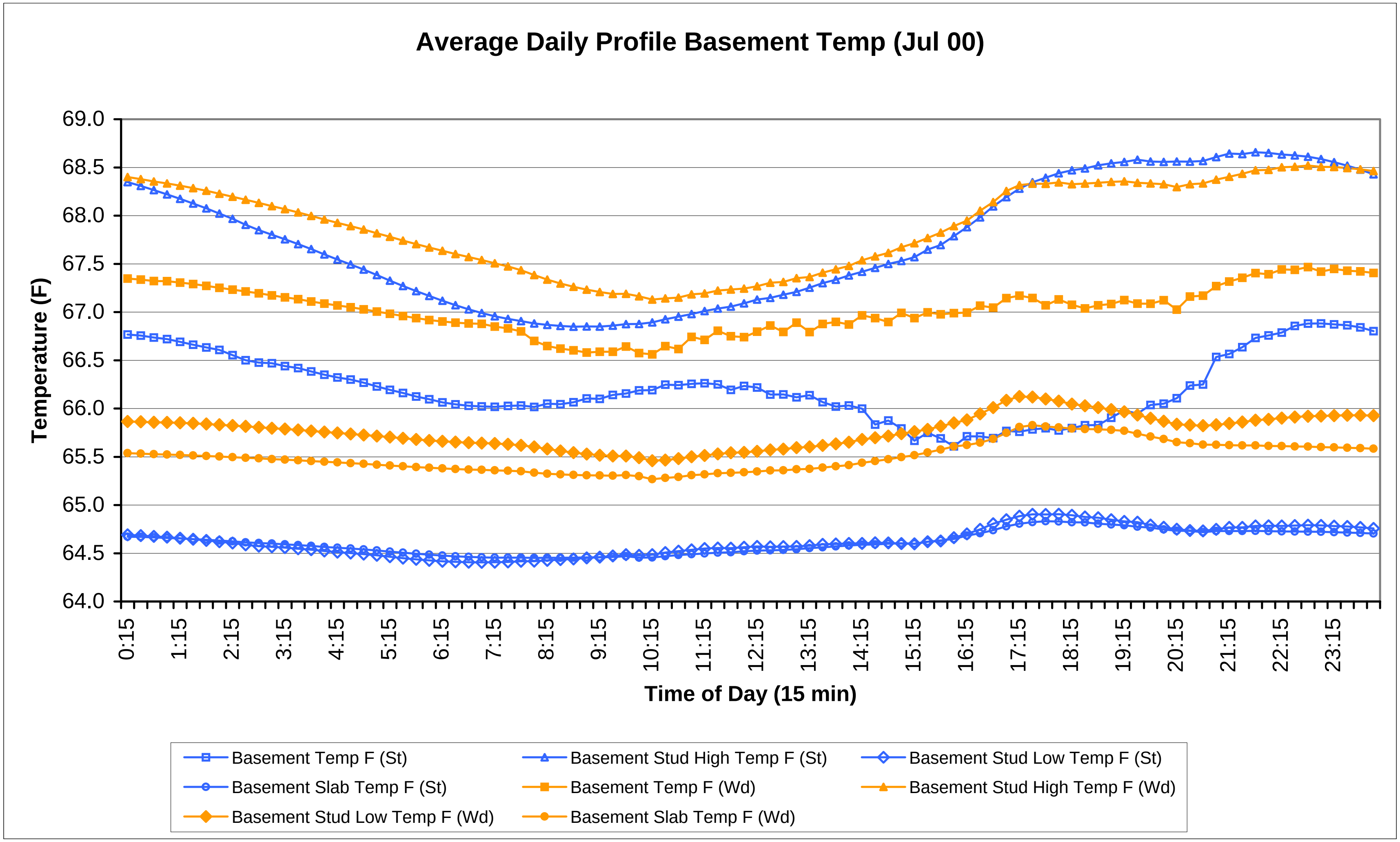
Wall Relative Humidity Daily Average Profile (Jul 00)
Relative Humidity (%)
100
90
80
70
60
50
40
30
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor RH (St)
Front Wall Cavity RH (St)
Back Wall Cavity RH (St)
Indoor RH (Wd)
Front Wall Cavity RH (Wd)
Back Wall Cavity RH (Wd)
Outdoor RH

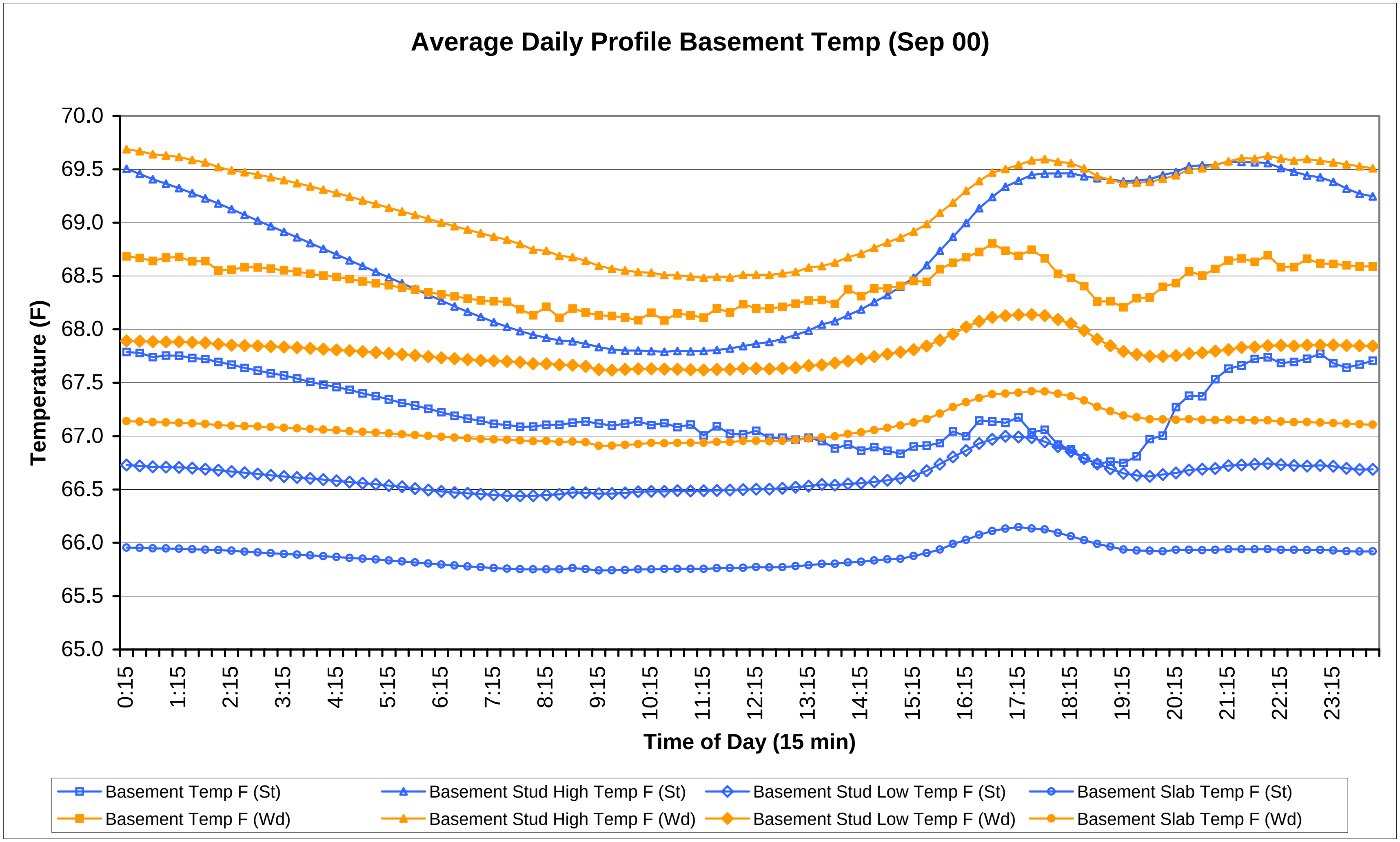


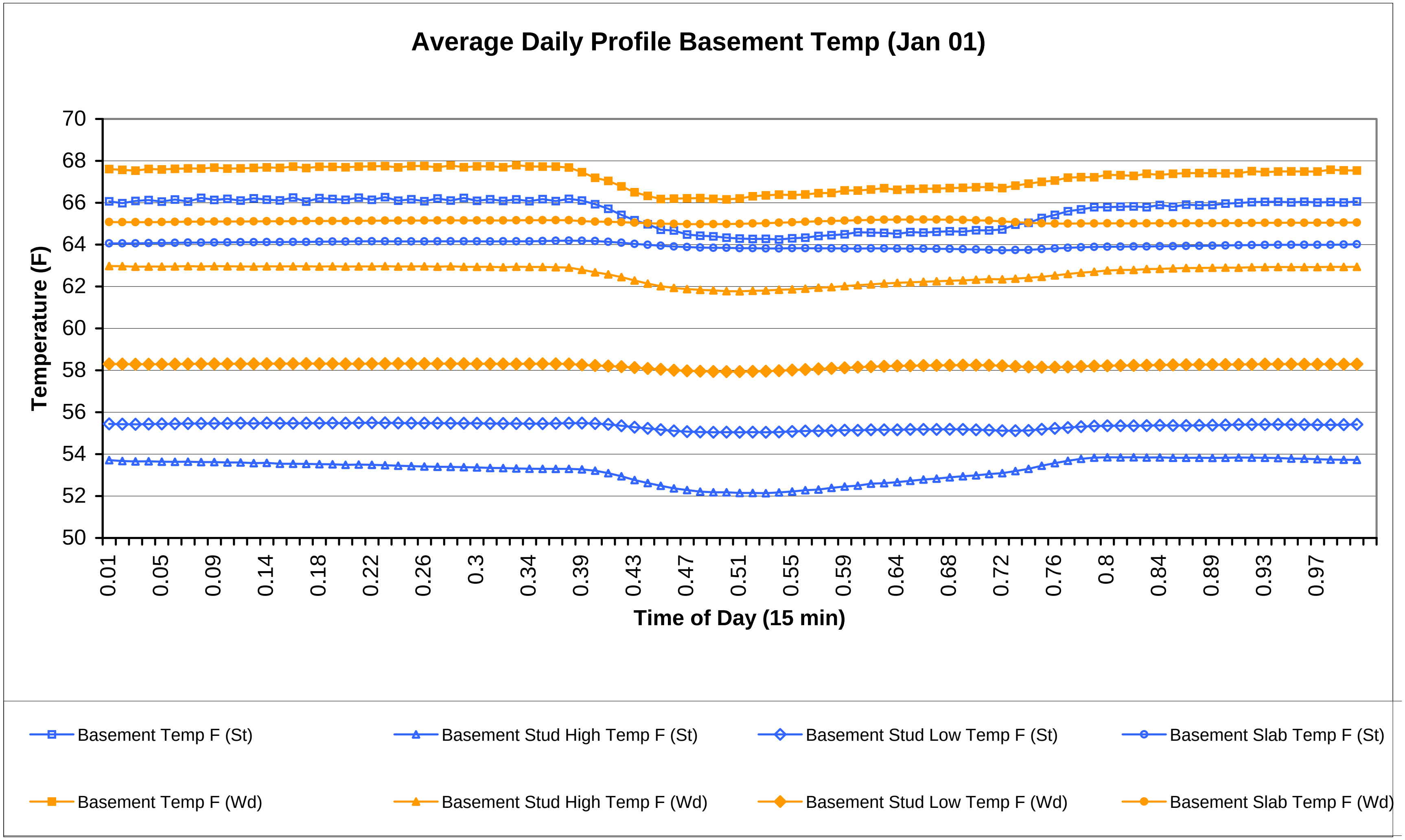
Wall Relative Humidity Daily Average Profile (Sep 00)
Relative Humidity (%)
100
90
80
70
60
50
40
30
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor RH (St)
Front Wall Cavity RH (St)
Back Wall Cavity RH (St)
Indoor RH (Wd)
Front Wall Cavity RH (Wd)
Back Wall Cavity RH (Wd)
Outdoor RH


Wall Relative Humidity Daily Average Profile (Jan 01)
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor RH (St)
Front Wall Cavity RH (St)
Back Wall Cavity RH (St)
Indoor RH (Wd)
Front Wall Cavity RH (Wd)
Back Wall Cavity RH (Wd)
Outdoor RH

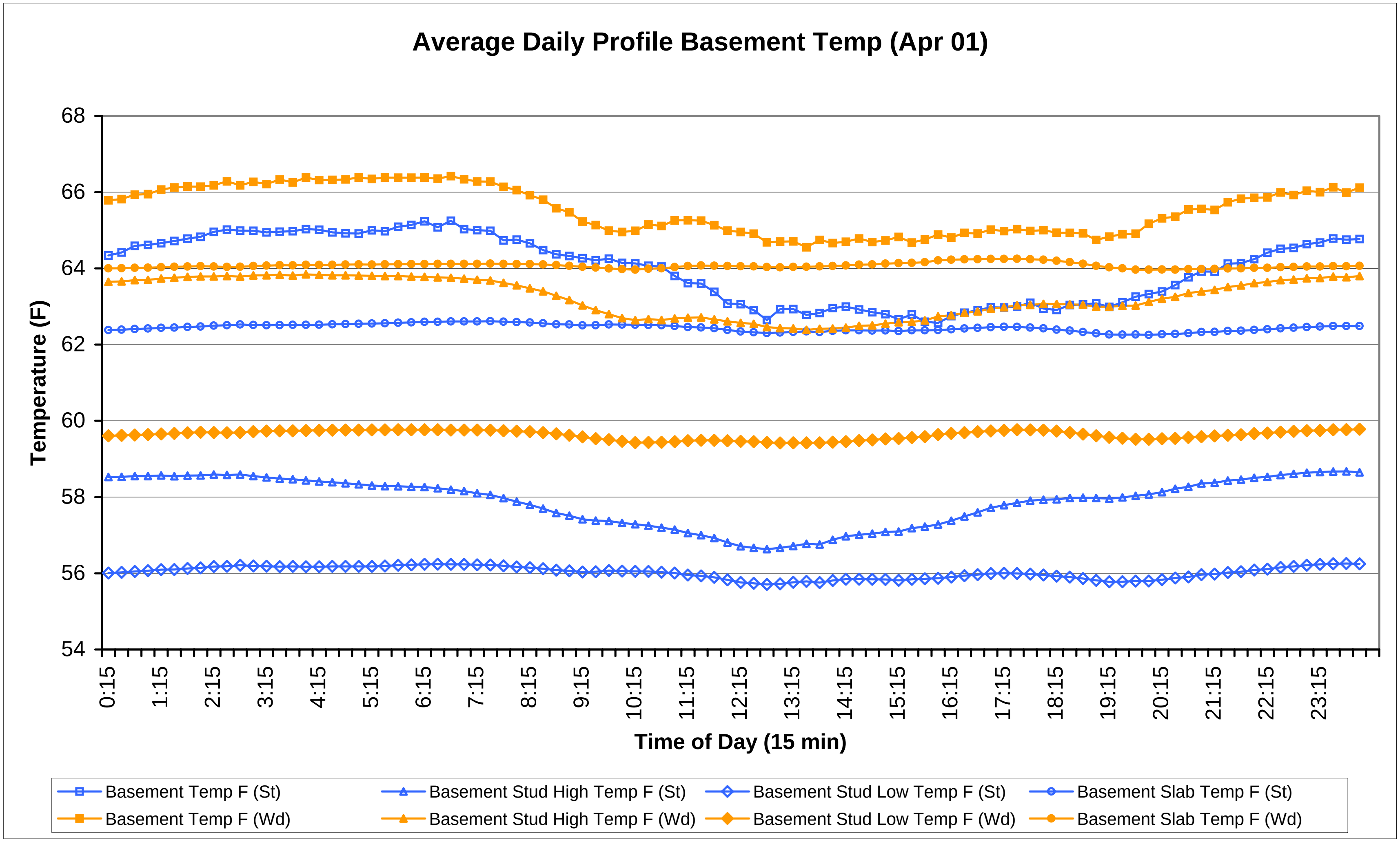

Wall Relative Humidity Daily Average Profile (Apr 01)
Relative Humidity (%)
90
80
70
60
50
40
30
20
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Indoor RH (St)
Front Wall Cavity RH (St)
Back Wall Cavity RH (St)
Indoor RH (Wd)
Front Wall Cavity RH (Wd)
Back Wall Cavity RH (Wd)
Outdoor RH

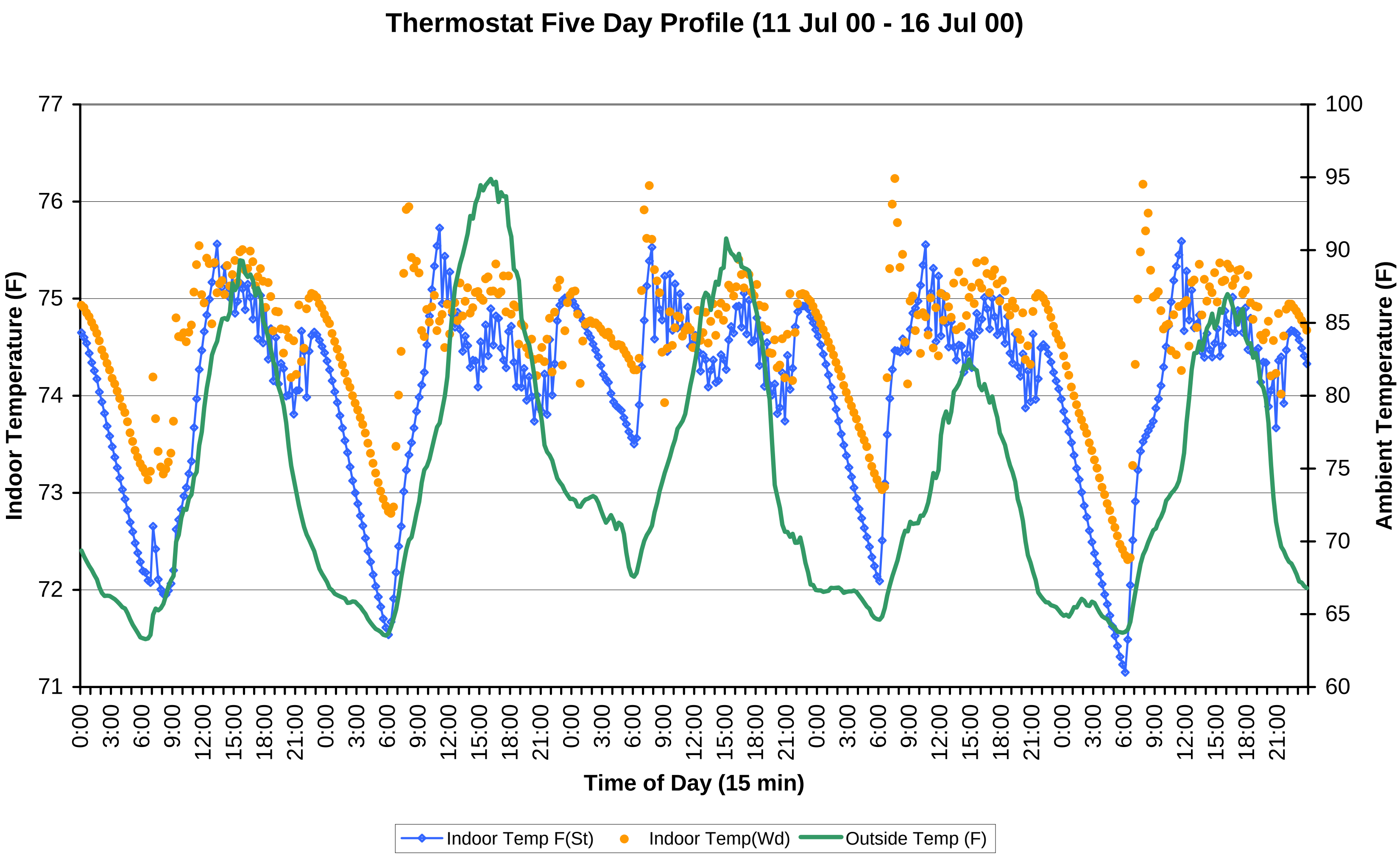

Average Daily Profile Basement Temp (Jul 00)
Temperature (F)
69.0
68.5
68.0
67.5
67.0
66.5
66.0
65.5
65.0
64.5
64.0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Basement Temp F (St)
Basement Stud High Temp F (St)
Basement Stud Low Temp F (St)
Basement Slab Temp F (St)
Basement Temp F (Wd)
Basement Stud High Temp F (Wd)
Basement Stud Low Temp F (Wd)
Basement Slab Temp F (Wd)

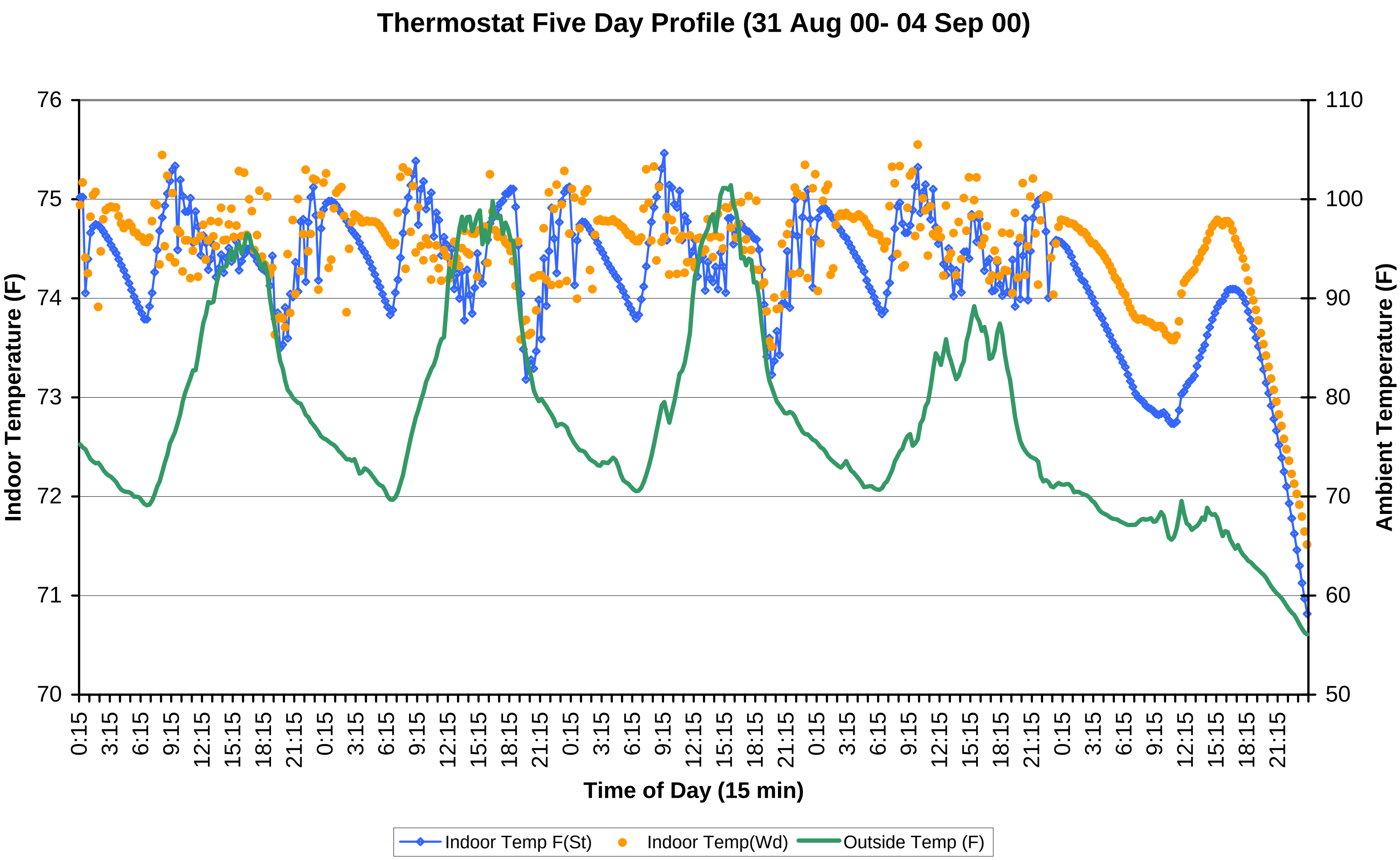

Average Daily Profile Basement Temp (Sep 00)
Temperature (F)
70.0
69.5
69.0
68.5
68.0
67.5
67.0
66.5
66.0
65.5
65.0
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Basement Temp F (St)
Basement Stud High Temp F (St)
Basement Stud Low Temp F (St)
Basement Slab Temp F (St)
Basement Temp F (Wd)
Basement Stud High Temp F (Wd)
Basement Stud Low Temp F (Wd)
Basement Slab Temp F (Wd)



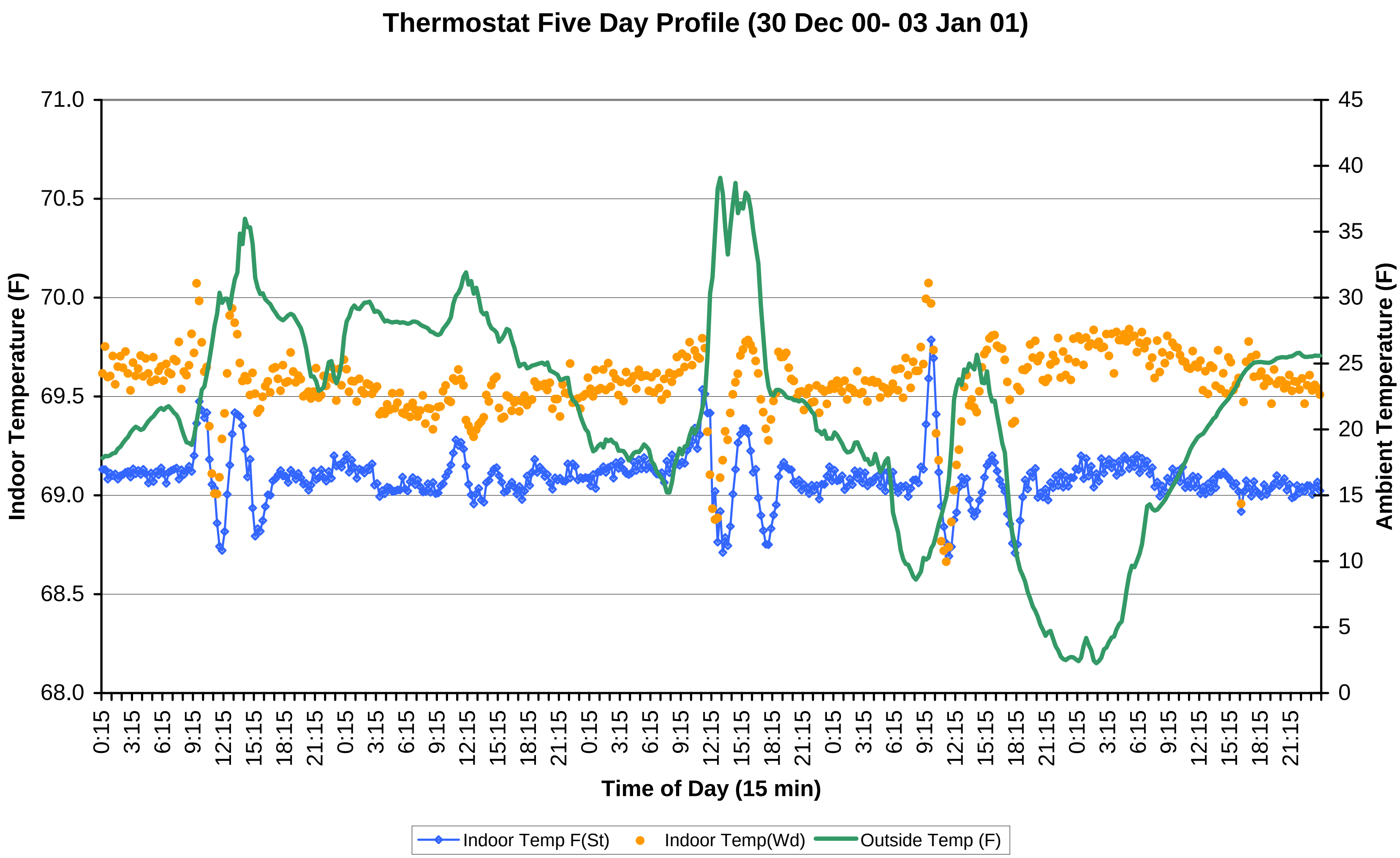
Average Daily Profile Basement Temp (Jan 01)
Temperature (F)
70
68
66
64
62
60
58
56
54
52
50
0.01
0.05
0.09
0.14
0.18
0.22
0.26
0.3
0.34
0.39
0.43
0.47
0.51
0.55
0.59
0.64
0.68
0.72
0.76
0.8
0.84
0.89
0.93
0.97
Time of Day (15 min)
Basement Temp F (St)
Basement Stud High Temp F (St)
Basement Stud Low Temp F (St)
Basement Slab Temp F (St)
Basement Temp F (Wd)
Basement Stud High Temp F (Wd)
Basement Stud Low Temp F (Wd)
Basement Slab Temp F (Wd)


Average Daily Profile Basement Temp (Apr 01)
Temperature (F)
68
66
64
62
60
58
56
54
0:15
1:15
2:15
3:15
4:15
5:15
6:15
7:15
8:15
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
17:15
18:15
19:15
20:15
21:15
22:15
23:15
Time of Day (15 min)
Basement Temp F (St)
Basement Stud High Temp F (St)
Basement Stud Low Temp F (St)
Basement Slab Temp F (St)
Basement Temp F (Wd)
Basement Stud High Temp F (Wd)
Basement Stud Low Temp F (Wd)
Basement Slab Temp F (Wd)

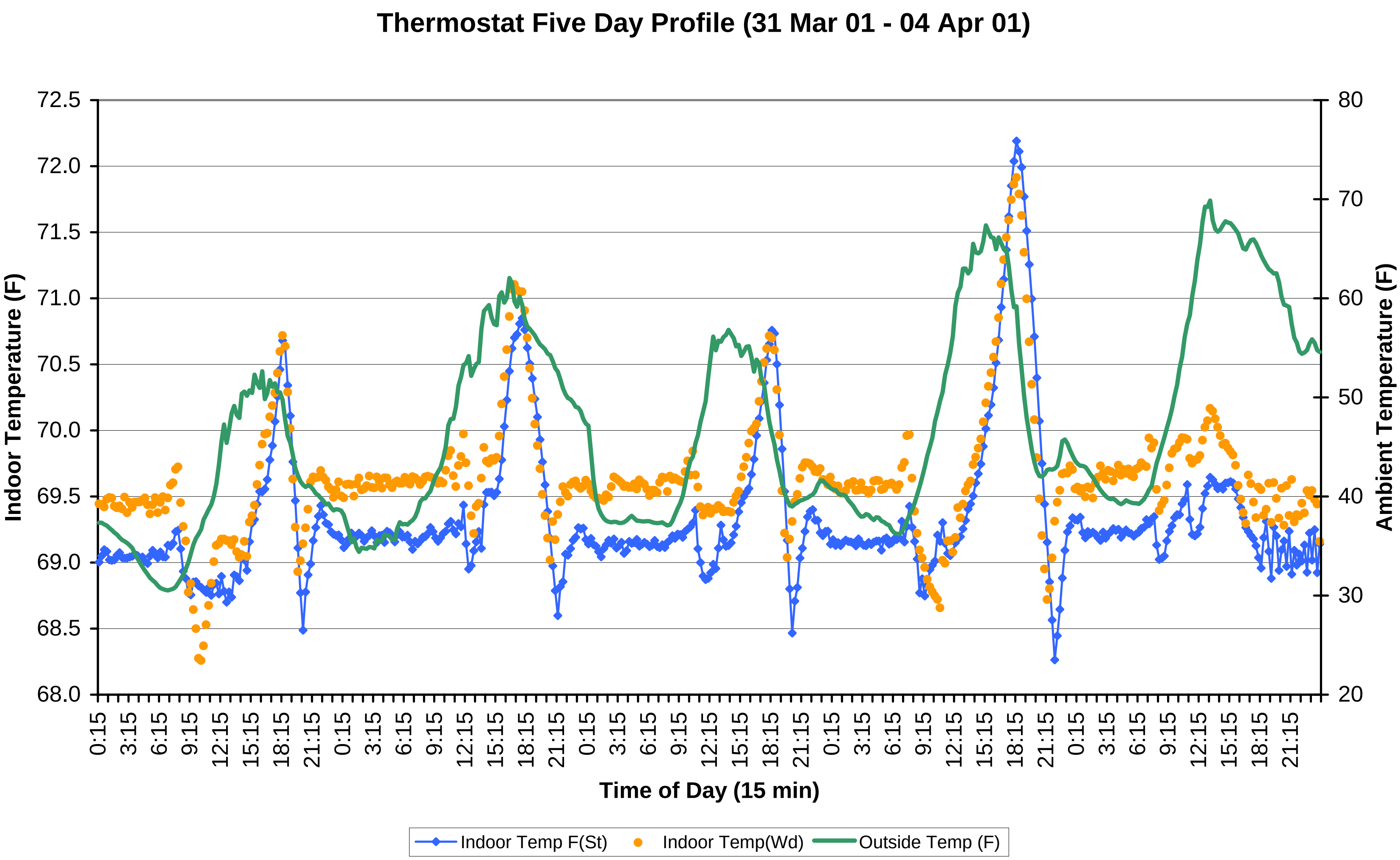

Thermostat Five Day Profile (11 Jul 00 - 16 Jul 00)
Indoor Temperature (F)
Ambient Temperature (F)
Time of Day (15 min)
77
76
75
74
73
72
71
100
95
90
85
80
75
70
65
60
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp F(St)
Indoor Temp(Wd)
Outside Temp (F)



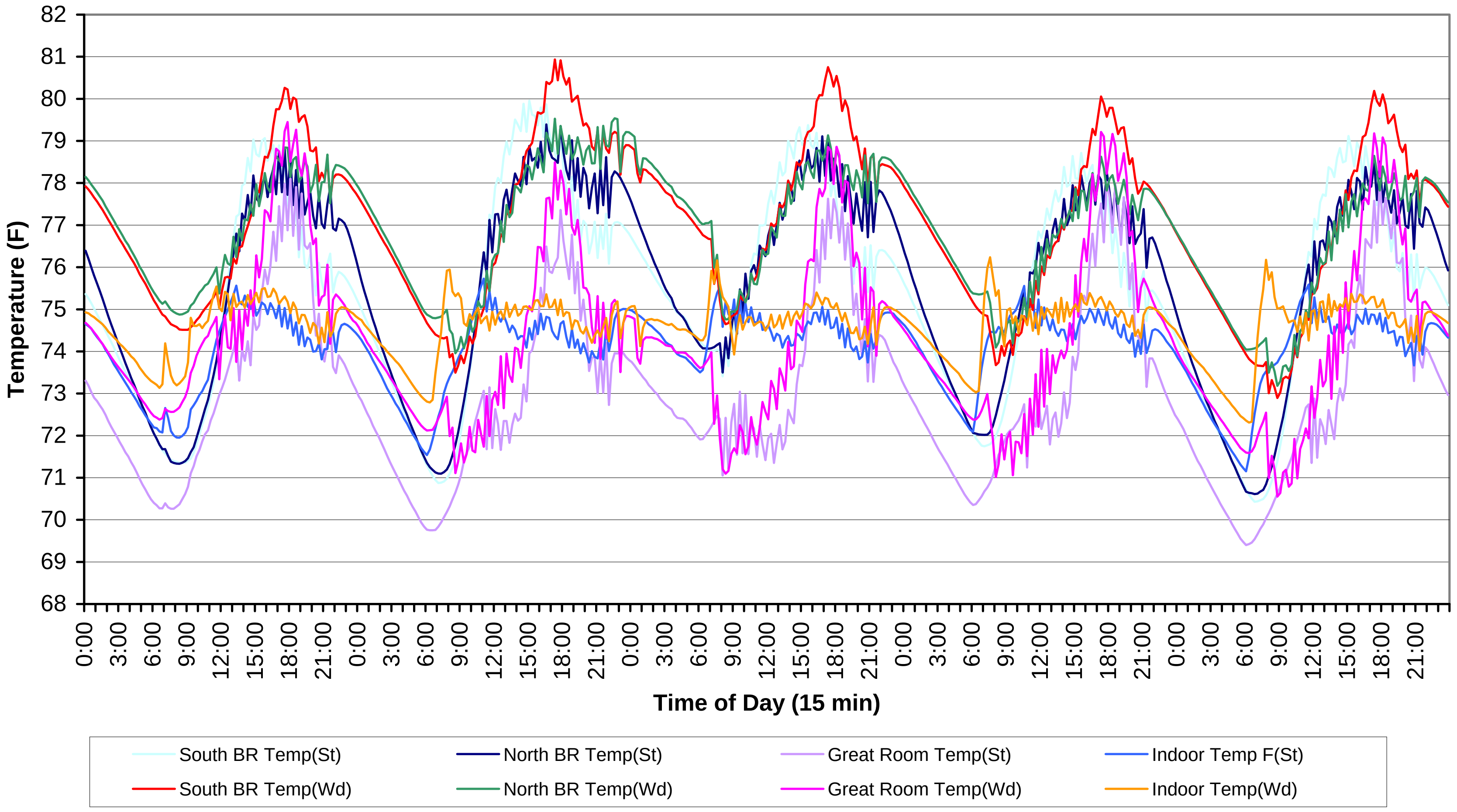
Thermostat Five Day Profile (31 Aug 00- 04 Sep 00)
Indoor Temperature (F)
Ambient Temperature (F)
Time of Day (15 min)
76
75
74
73
72
71
70
110
100
90
80
70
60
50
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Indoor Temp F(St)
Indoor Temp(Wd)
Outside Temp (F)

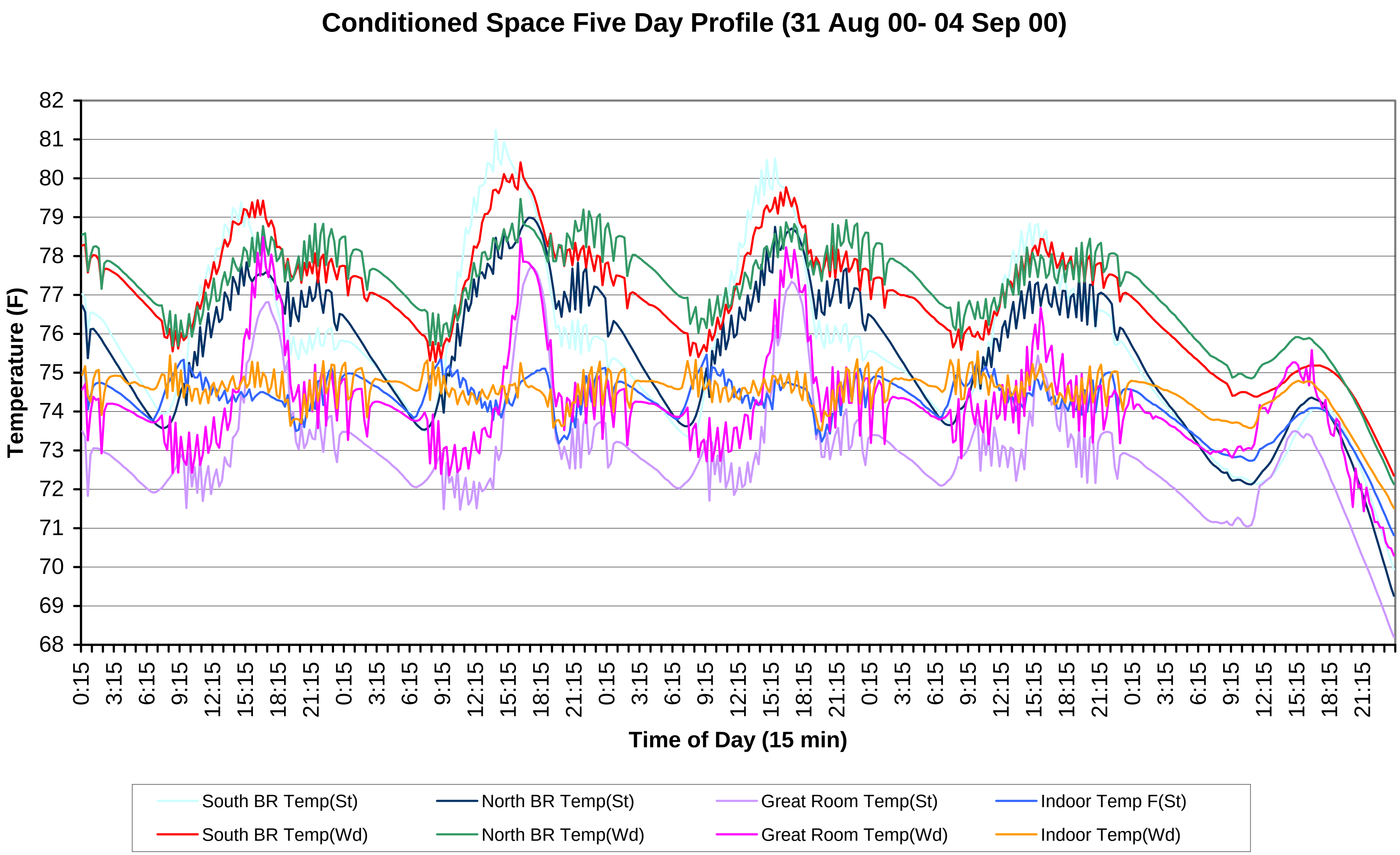


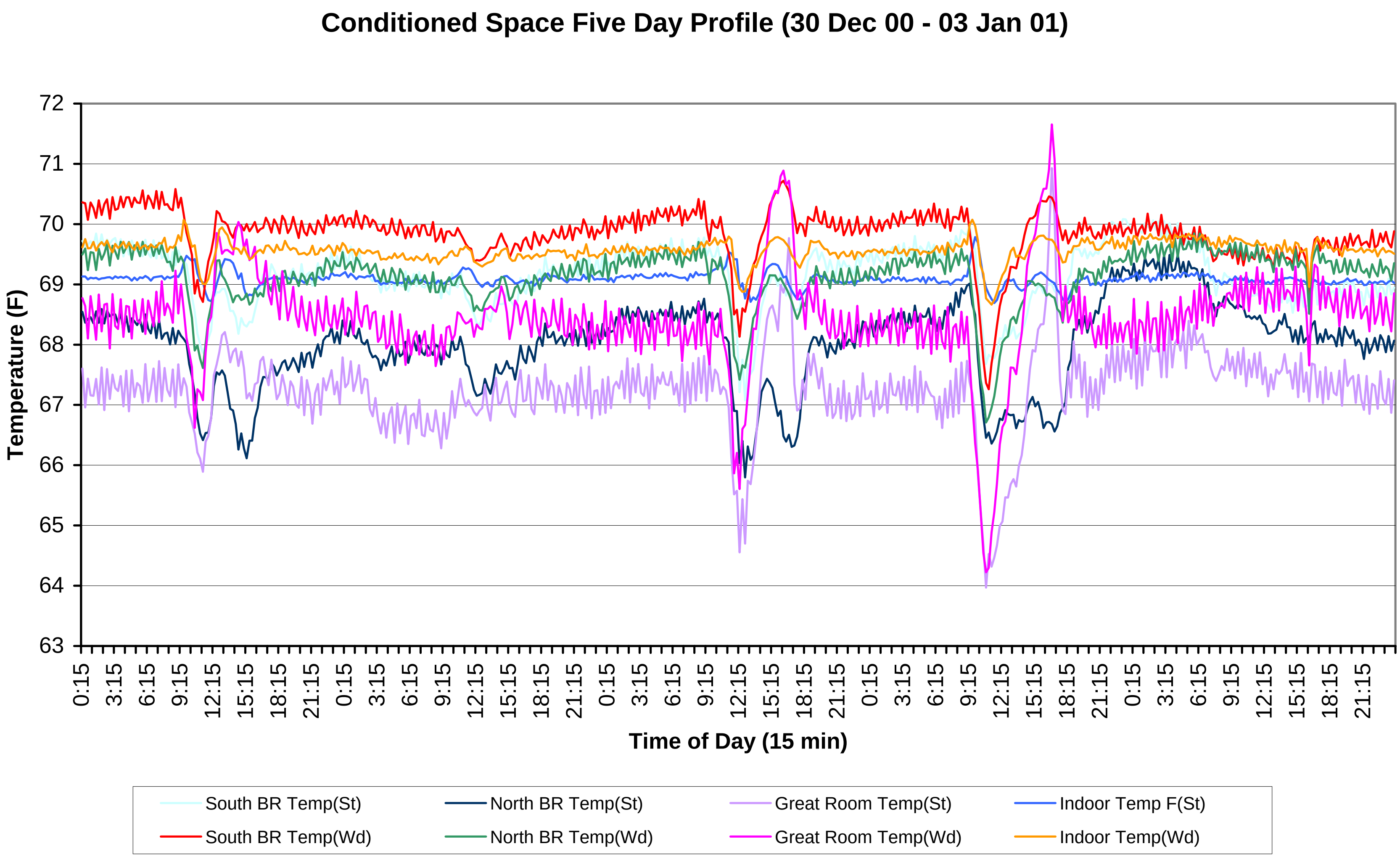
Thermostat Five Day Profile (30 Dec 00- 03 Jan 01)
Indoor Temperature (F)
Ambient Temperature (F)
Time of Day (15 min)
71.0
70.5
70.0
69.5
69.0
68.5
68.0
45
40
35
30
25
20
15
10
5
0
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Indoor Temp F(St)
Indoor Temp(Wd)
Outside Temp (F)

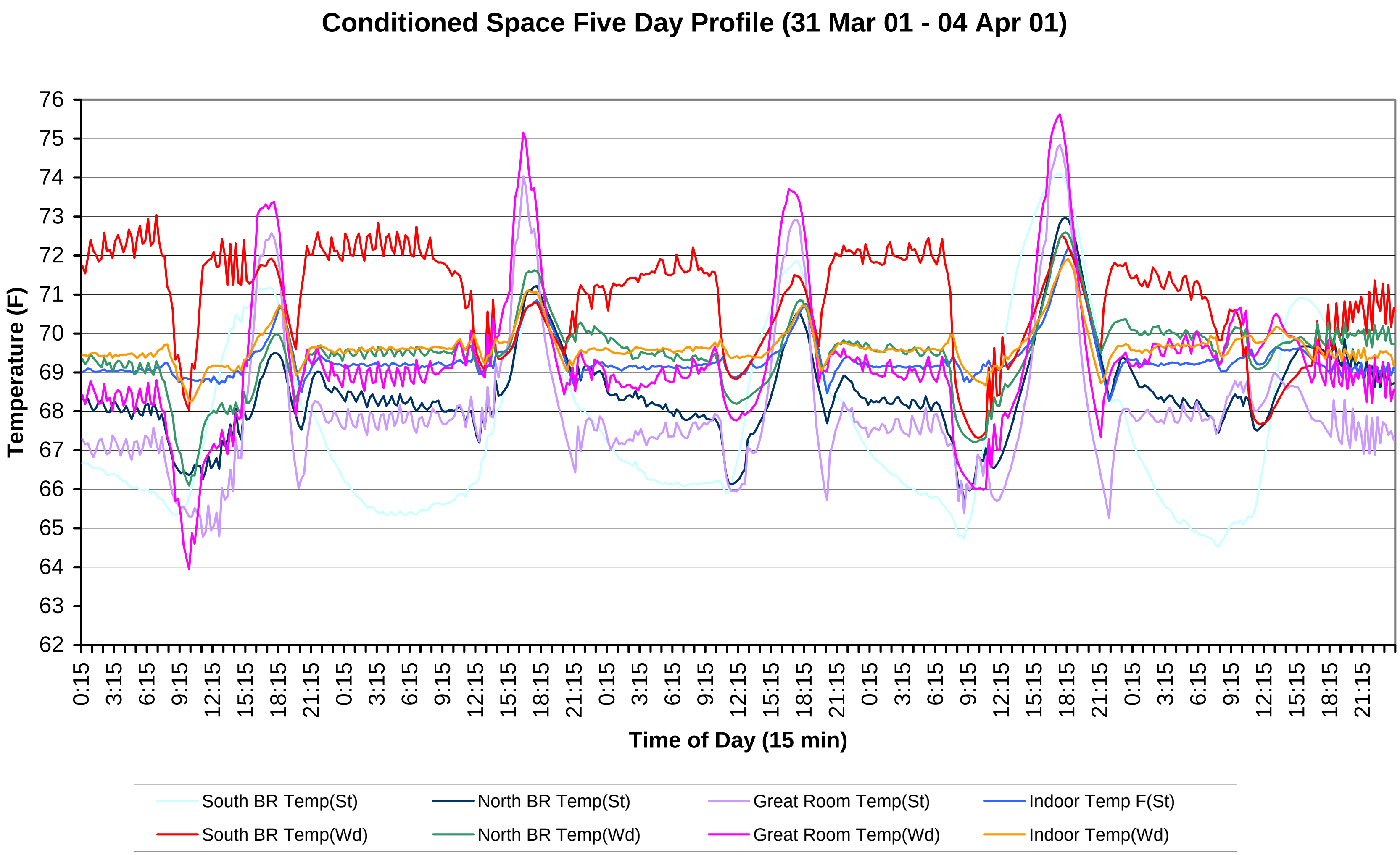

Thermostat Five Day Profile (31 Mar 01 - 04 Apr 01)
Indoor Temperature (F)
Ambient Temperature (F)
Time of Day (15 min)
72.5
72.0
71.5
71.0
70.5
70.0
69.5
69.0
68.5
68.0
80
70
60
50
40
30
20
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Indoor Temp F(St)
Indoor Temp(Wd)
Outside Temp (F)

Conditioned Space Five Day Profile (12 Jul 00 - 16 Jul 00)

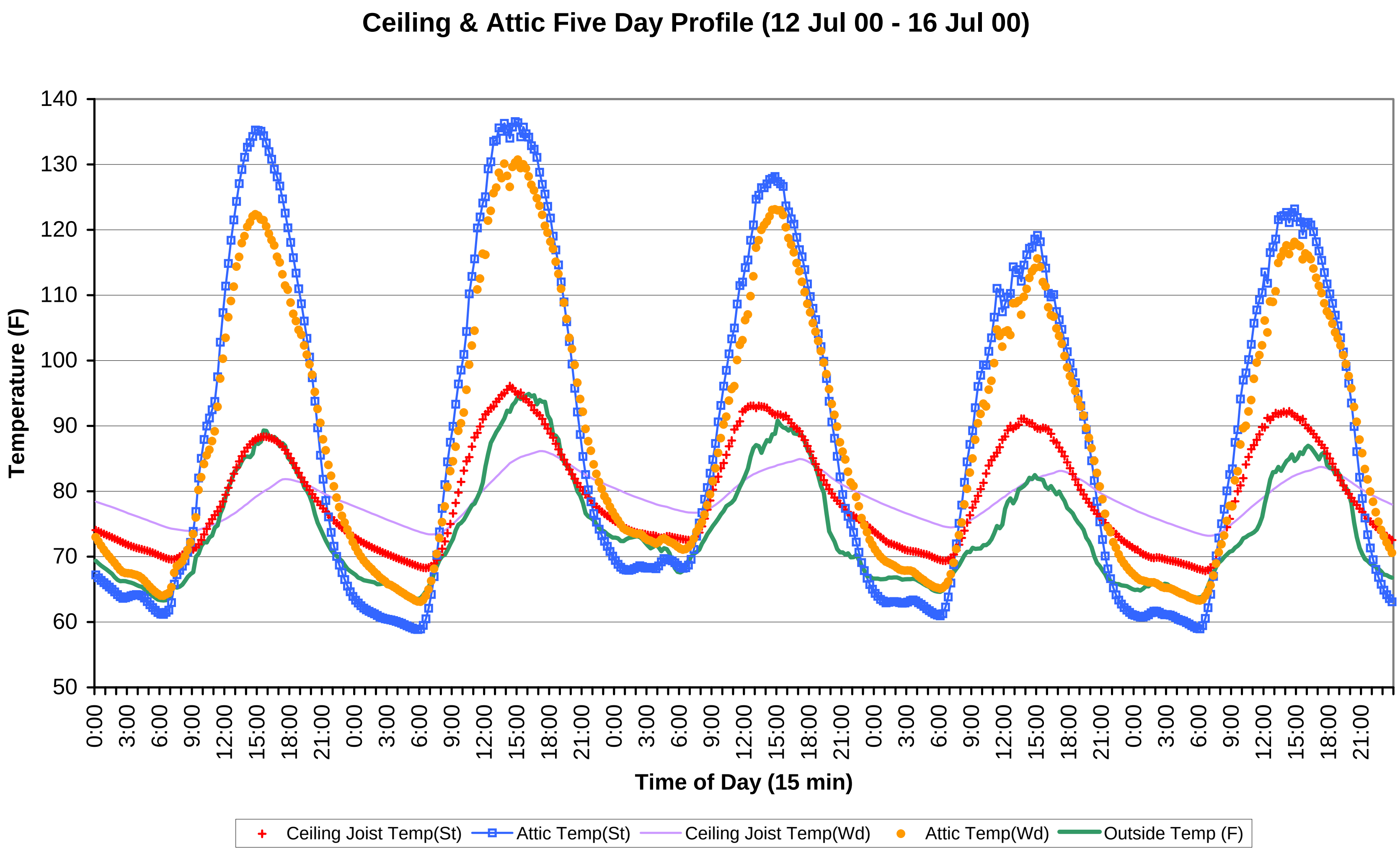


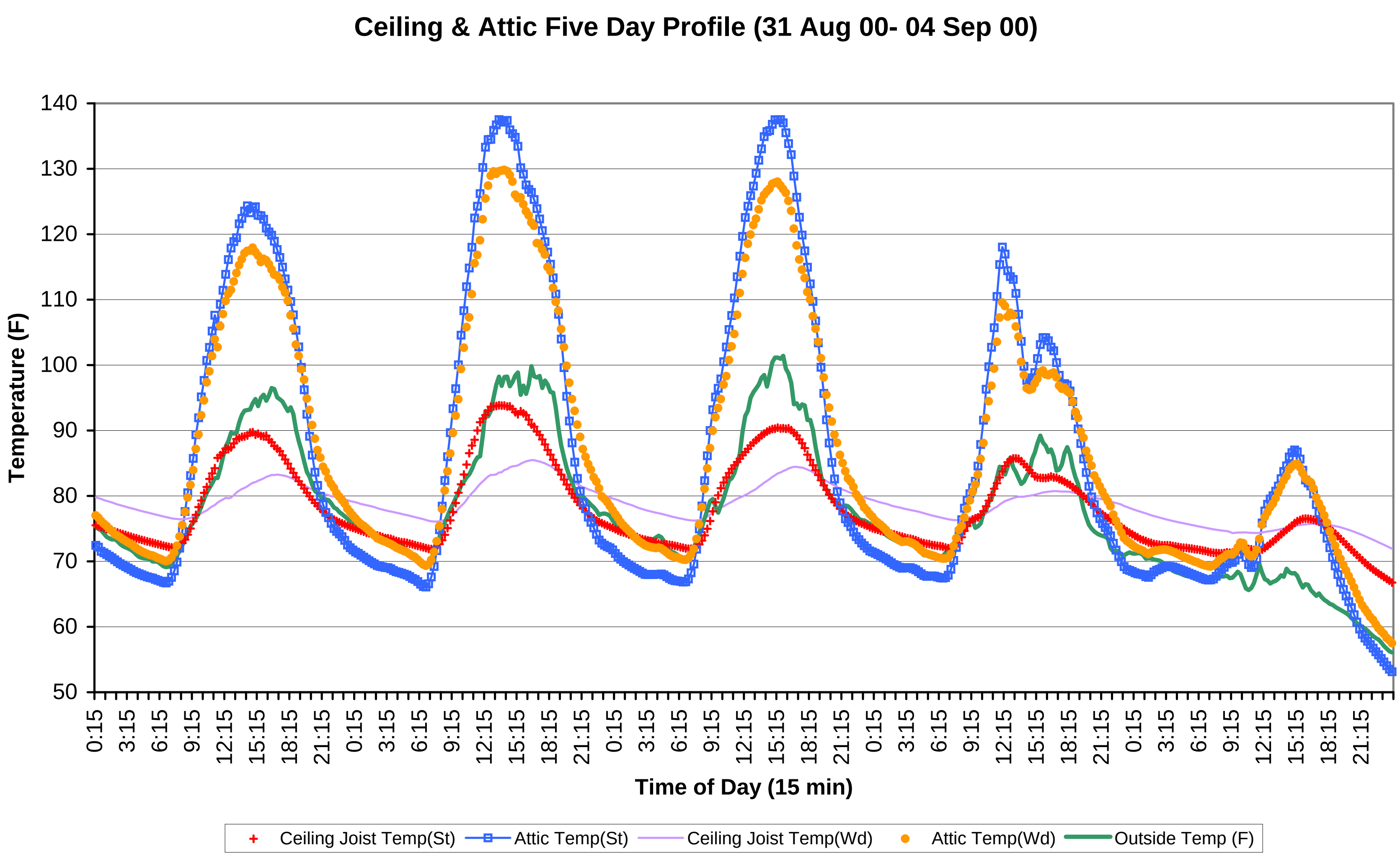

Conditioned Space Five Day Profile (31 Aug 00- 04 Sep 00)
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
Temperature (F)
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
South BR Temp(St)
North BR Temp(St)
Great Room Temp(St)
Indoor Temp F(St)
South BR Temp(Wd)
North BR Temp(Wd)
Great Room Temp(Wd)
Indoor Temp(Wd)


Conditioned Space Five Day Profile (30 Dec 00 - 03 Jan 01)
Temperature (F)
72
71
70
69
68
67
66
65
64
63
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
South BR Temp(St)
North BR Temp(St)
Great Room Temp(St)
Indoor Temp F(St)
South BR Temp(Wd)
North BR Temp(Wd)
Great Room Temp(Wd)
Indoor Temp(Wd)

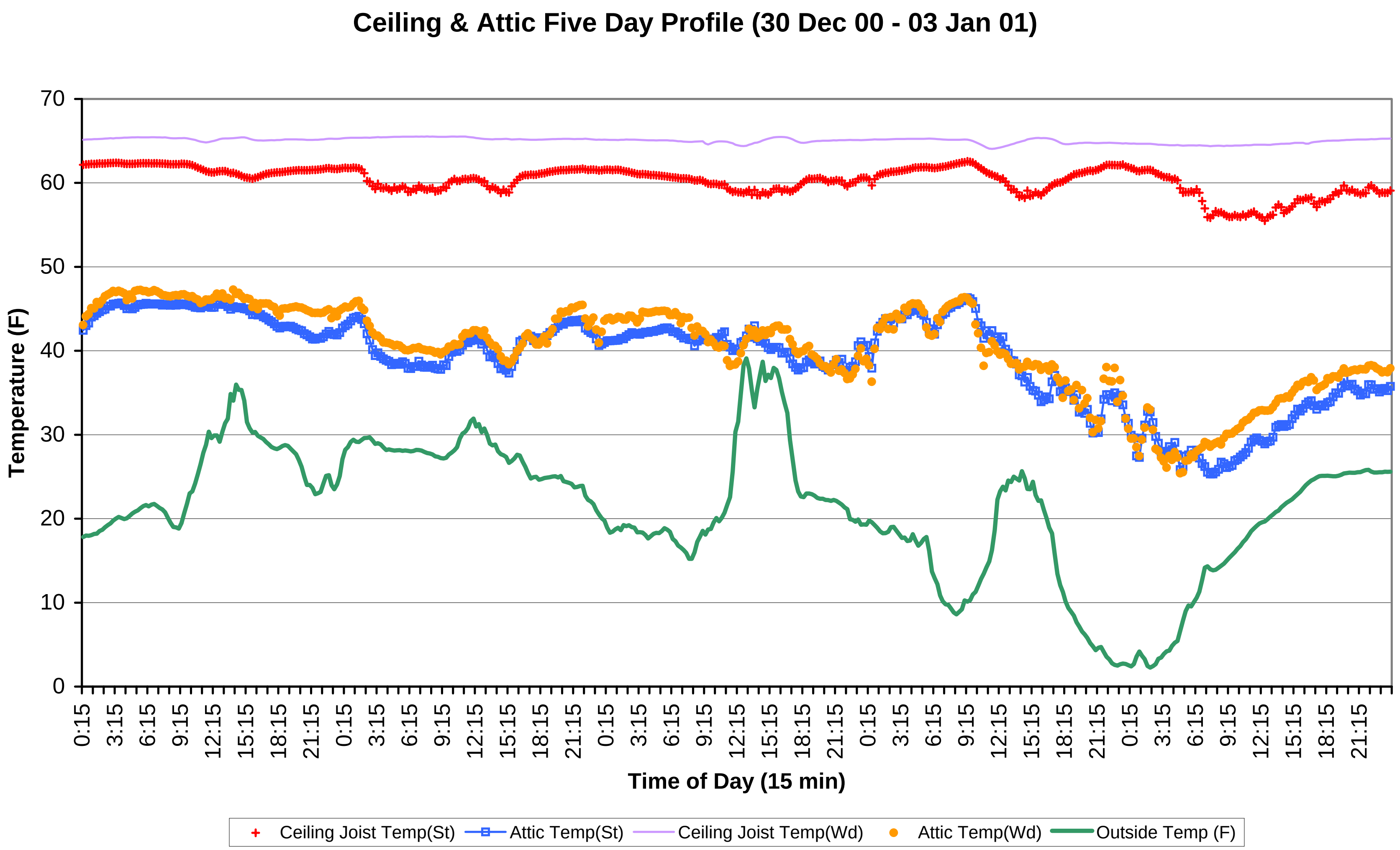


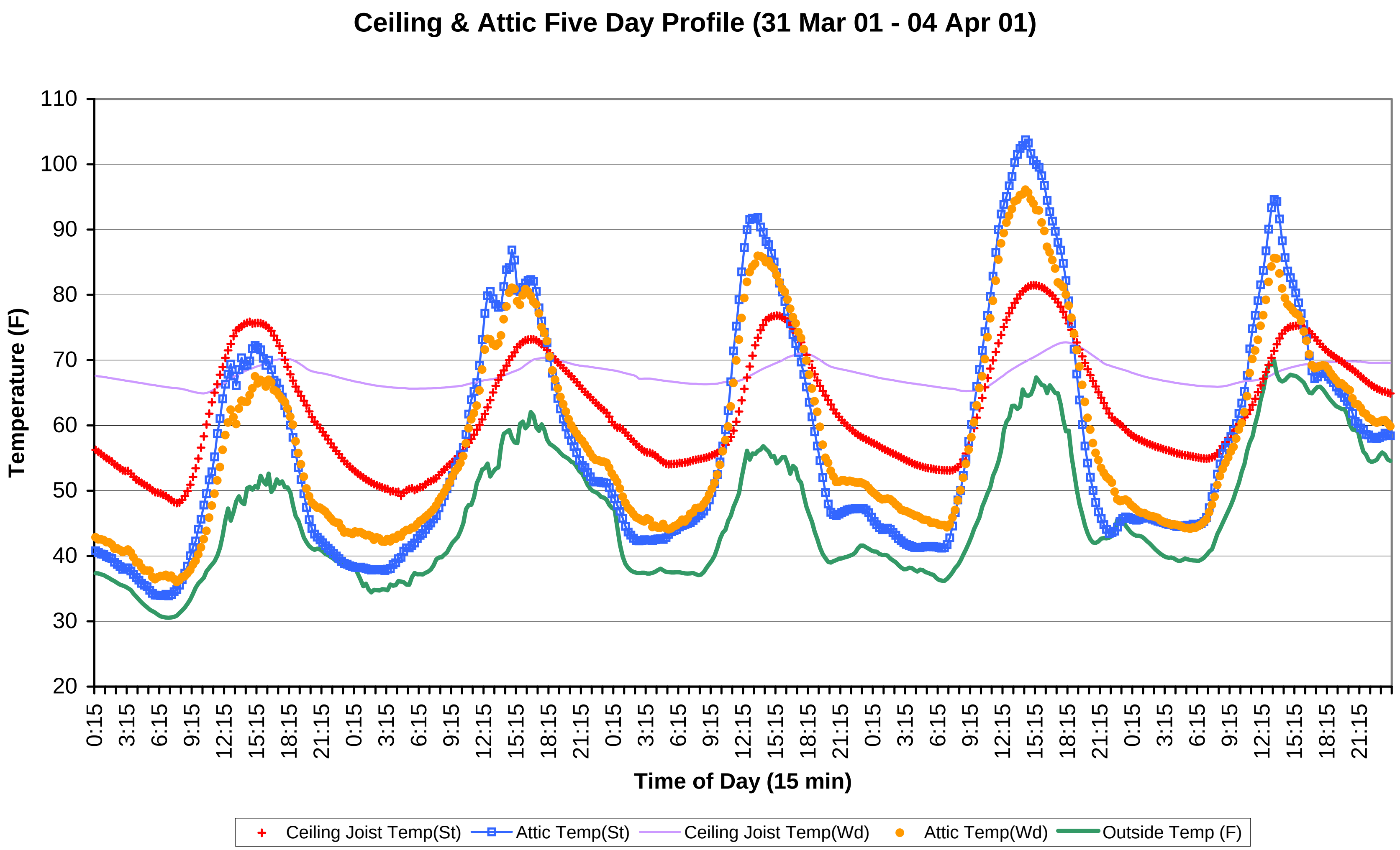
Conditioned Space Five Day Profile (31 Mar 01 - 04 Apr 01)
Temperature (F)
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
South BR Temp(St)
North BR Temp(St)
Great Room Temp(St)
Indoor Temp F(St)
South BR Temp(Wd)
North BR Temp(Wd)
Great Room Temp(Wd)
Indoor Temp(Wd)


Ceiling & Attic Five Day Profile (12 Jul 00 - 16 Jul 00)
Temperature (F)
140
130
120
110
100
90
80
70
60
50
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of Day (15 min)
Ceiling Joist Temp(St)
Attic Temp(St)
Ceiling Joist Temp(Wd)
Attic Temp(Wd)
Outside Temp (F)

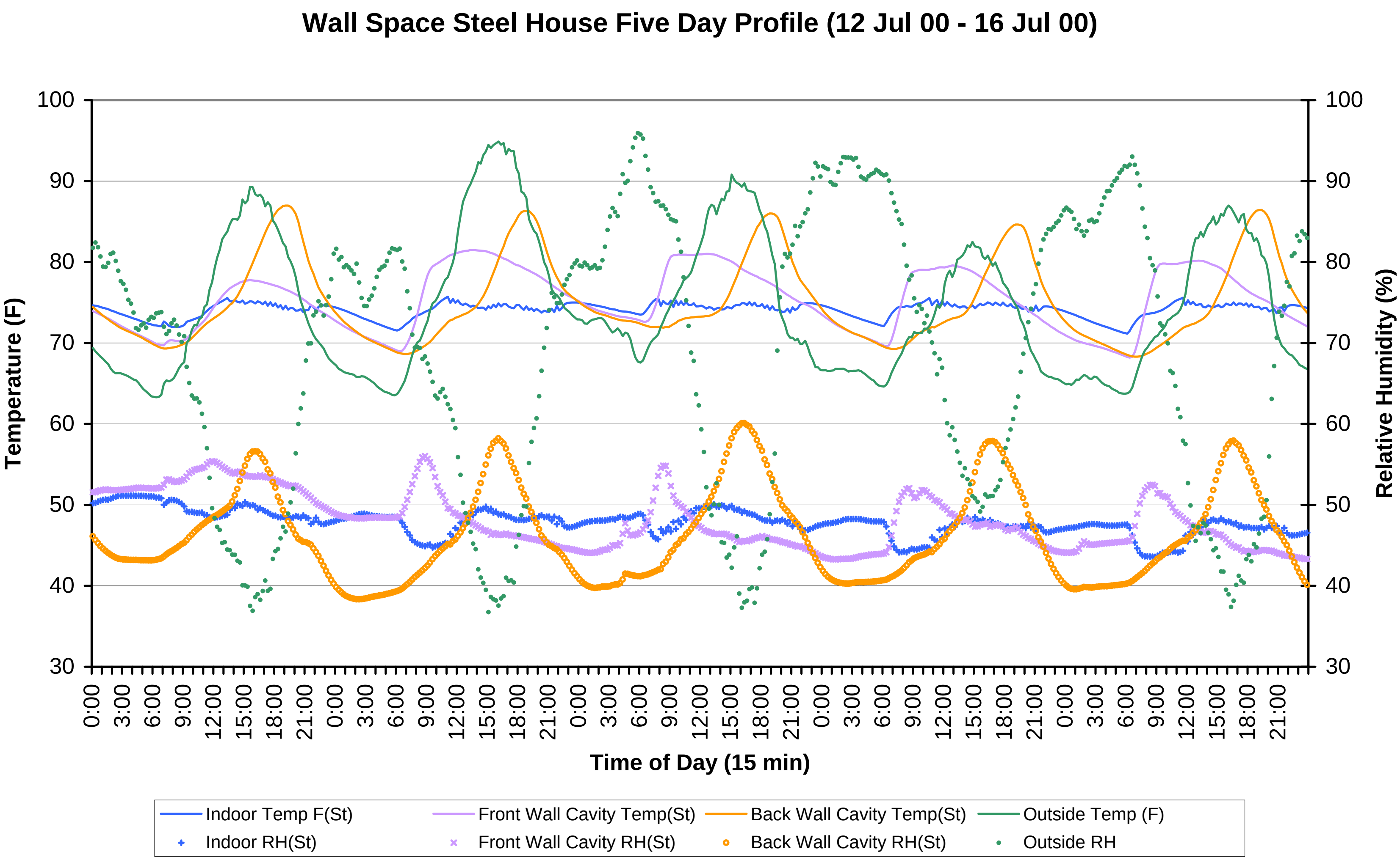


Ceiling & Attic Five Day Profile (31 Aug 00- 04 Sep 00)
Temperature (F)
140
130
120
110
100
90
80
70
60
50
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
Ceiling Joist Temp(St)
Attic Temp(St)
Ceiling Joist Temp(Wd)
Attic Temp(Wd)
Outside Temp (F)

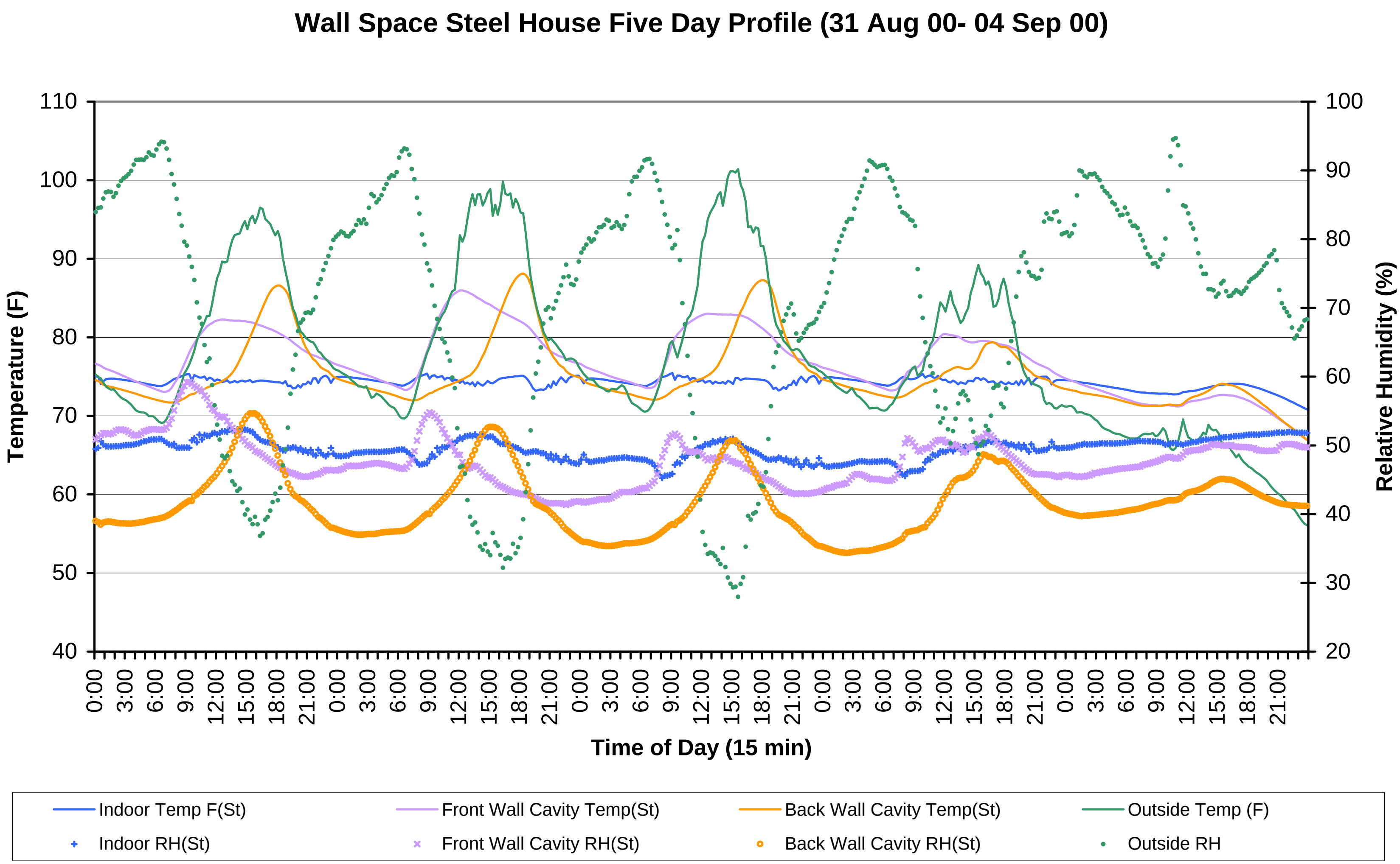

Ceiling & Attic Five Day Profile (30 Dec 00 - 03 Jan 01)
Temperature (F)
70
60
50
40
30
20
10
0
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
Ceiling Joist Temp(St)
Attic Temp(St)
Ceiling Joist Temp(Wd)
Attic Temp(Wd)
Outside Temp (F)



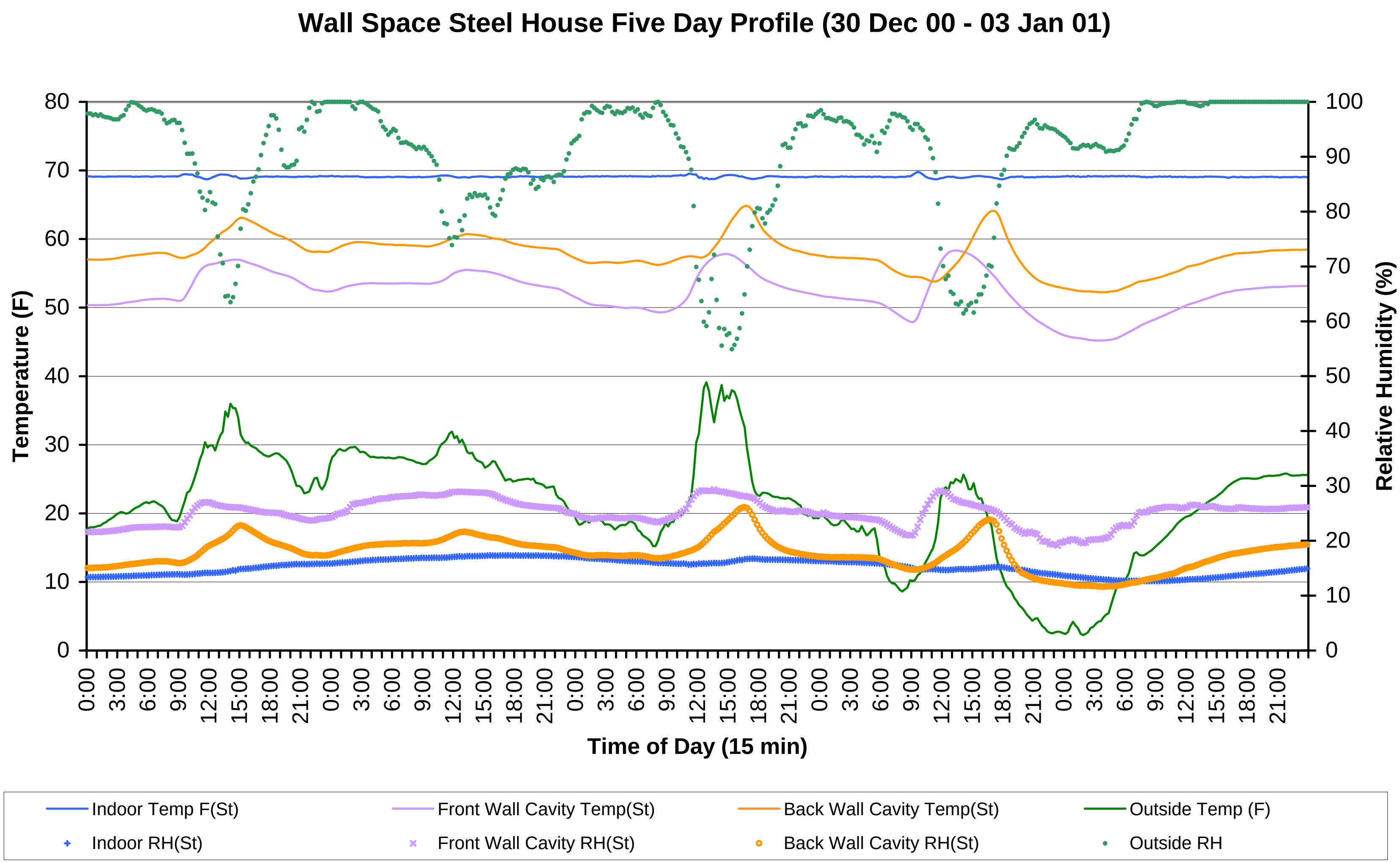
Ceiling & Attic Five Day Profile (31 Mar 01 - 04 Apr 01)
Temperature (F)
110
100
90
80
70
60
50
40
30
20
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Time of Day (15 min)
Ceiling Joist Temp(St)
Attic Temp(St)
Ceiling Joist Temp(Wd)
Attic Temp(Wd)
Outside Temp (F)



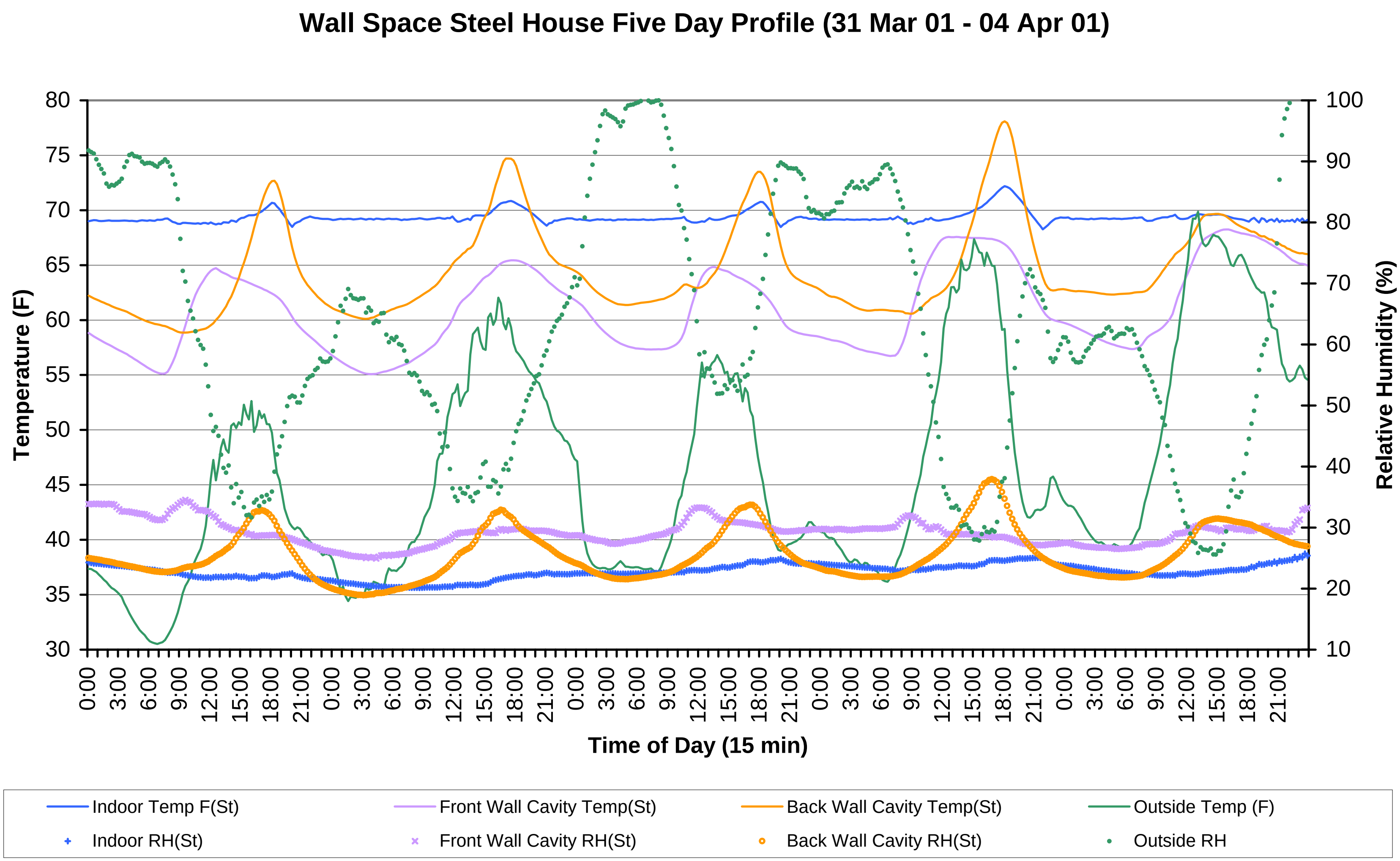
Wall Space Steel House Five Day Profile (12 Jul 00 - 16 Jul 00)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
100
90
80
70
60
50
40
30
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp F(St)
Front Wall Cavity Temp(St)
Back Wall Cavity Temp(St)
Outside Temp (F)
Indoor RH(St)
Front Wall Cavity RH(St)
Back Wall Cavity RH(St)
Outside RH



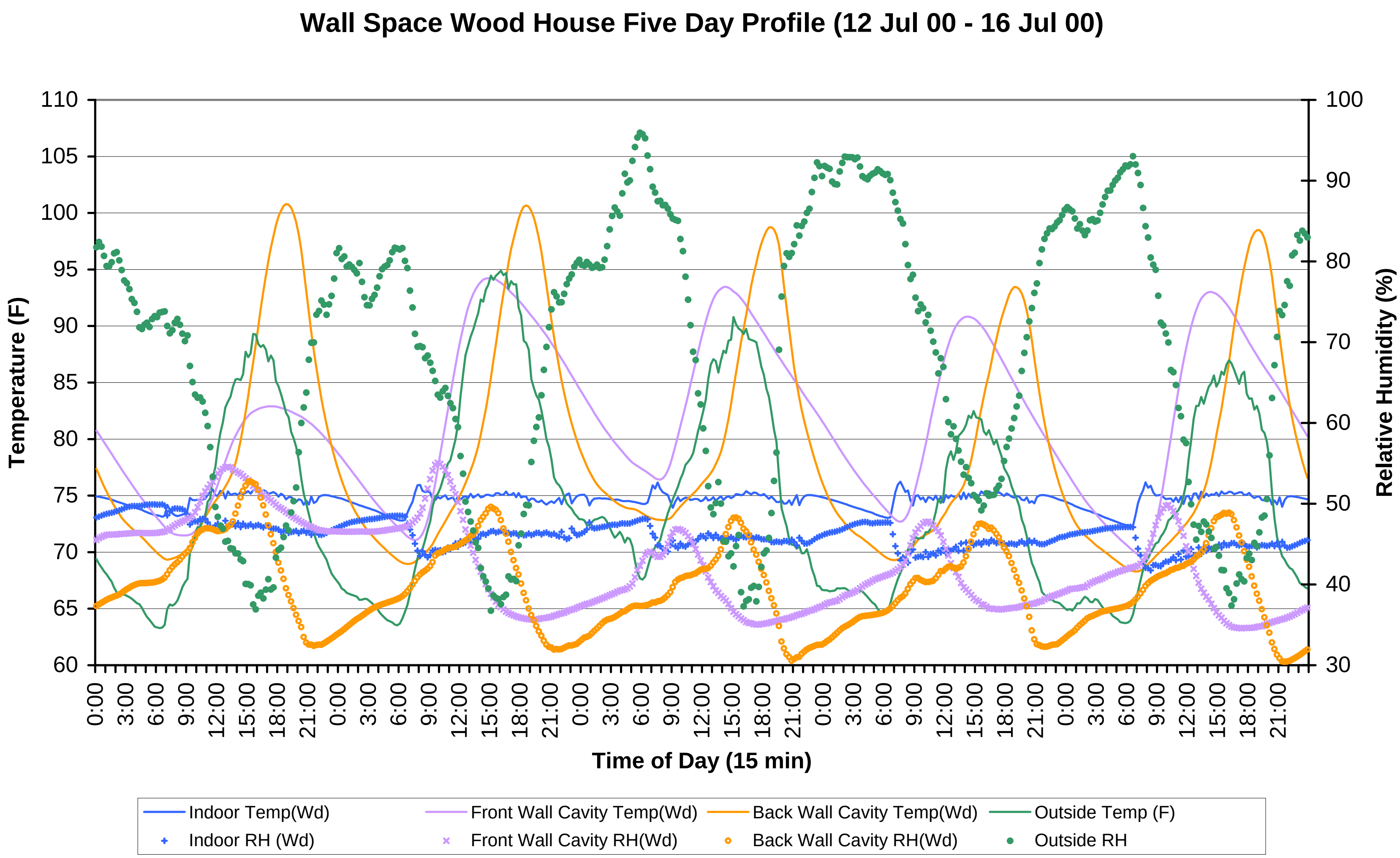
Wall Space Steel House Five Day Profile (31 Aug 00- 04 Sep 00)
Temperature (F)
Relative Humidity (%)
110
100
90
80
70
60
50
40
100
90
80
70
60
50
40
30
20
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of Day (15 min)
Indoor Temp F(St)
Front Wall Cavity Temp(St)
Back Wall Cavity Temp(St)
Outside Temp (F)
Indoor RH(St)
Front Wall Cavity RH(St)
Back Wall Cavity RH(St)
Outside RH



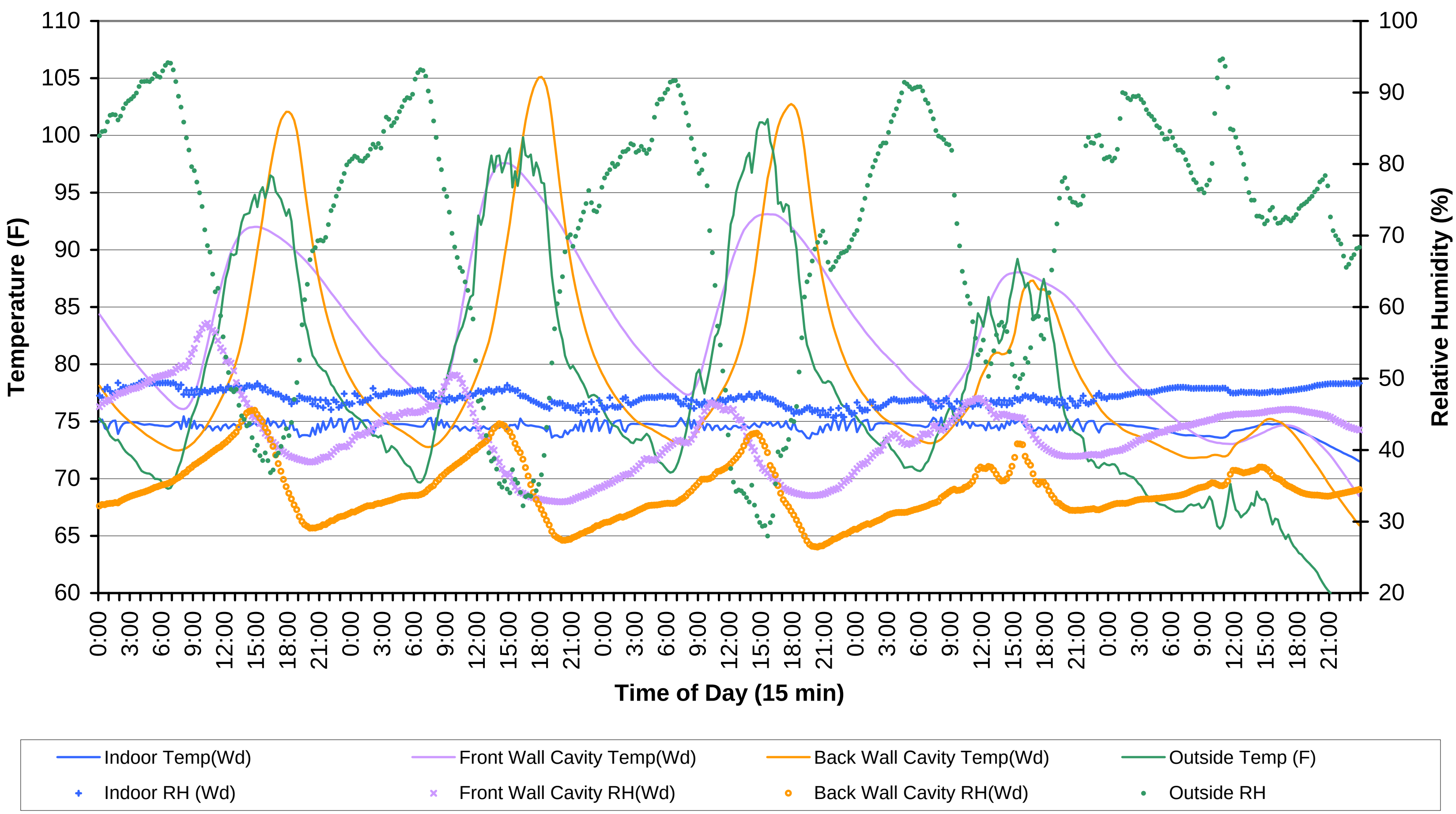
Wall Space Steel House Five Day Profile (30 Dec 00 - 03 Jan 01)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
0
10
20
30
40
50
60
70
80
100
90
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp F(St)
Front Wall Cavity Temp(St)
Back Wall Cavity Temp(St)
Outside Temp (F)
Indoor RH(St)
Front Wall Cavity RH(St)
Back Wall Cavity RH(St)
Outside RH

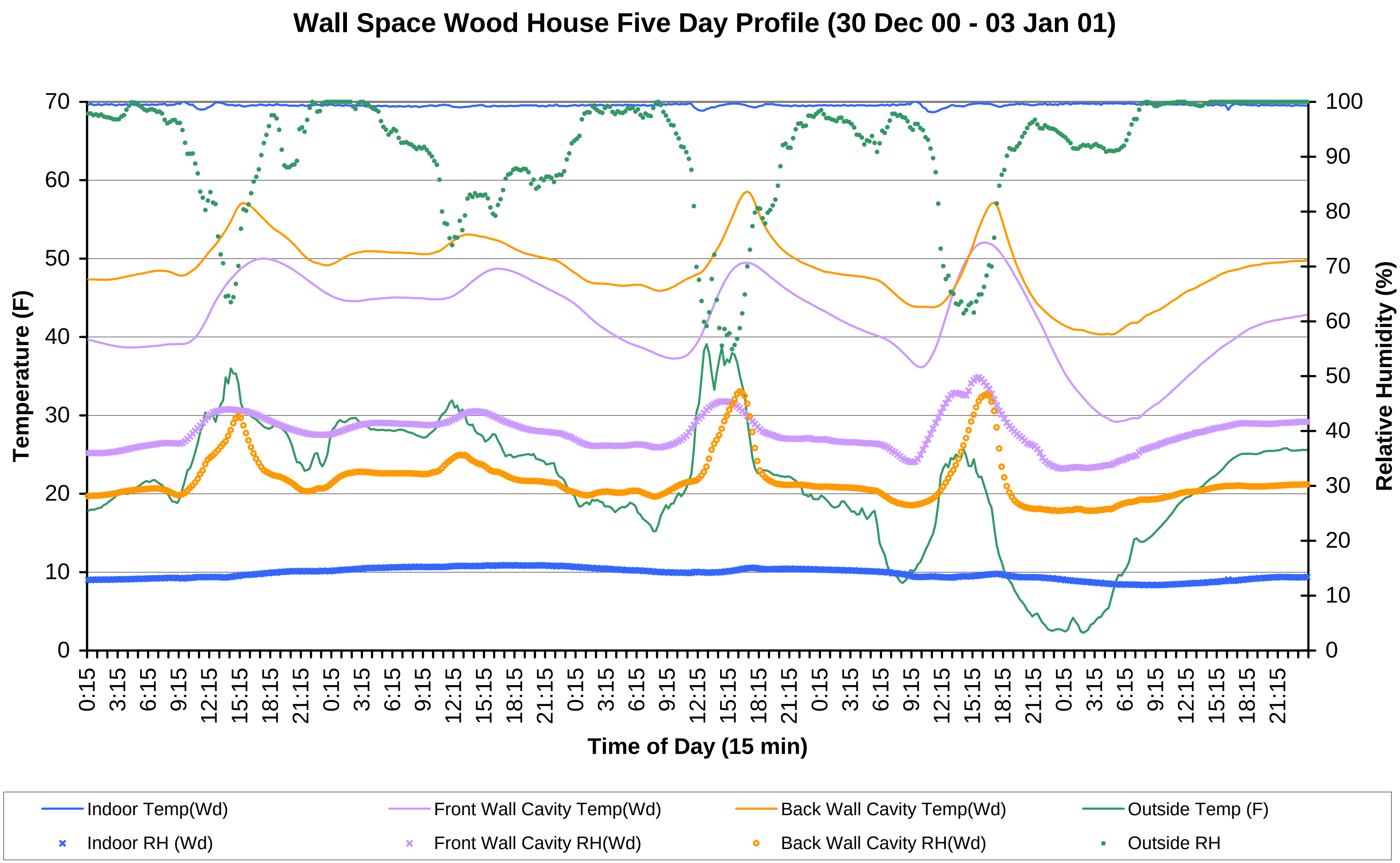


Wall Space Steel House Five Day Profile (31 Mar 01 - 04 Apr 01)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
80
75
70
65
60
55
50
45
40
35
30
100
90
80
70
60
50
40
30
20
10
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp F(St)
Front Wall Cavity Temp(St)
Back Wall Cavity Temp(St)
Outside Temp (F)
Indoor RH(St)
Front Wall Cavity RH(St)
Back Wall Cavity RH(St)
Outside RH

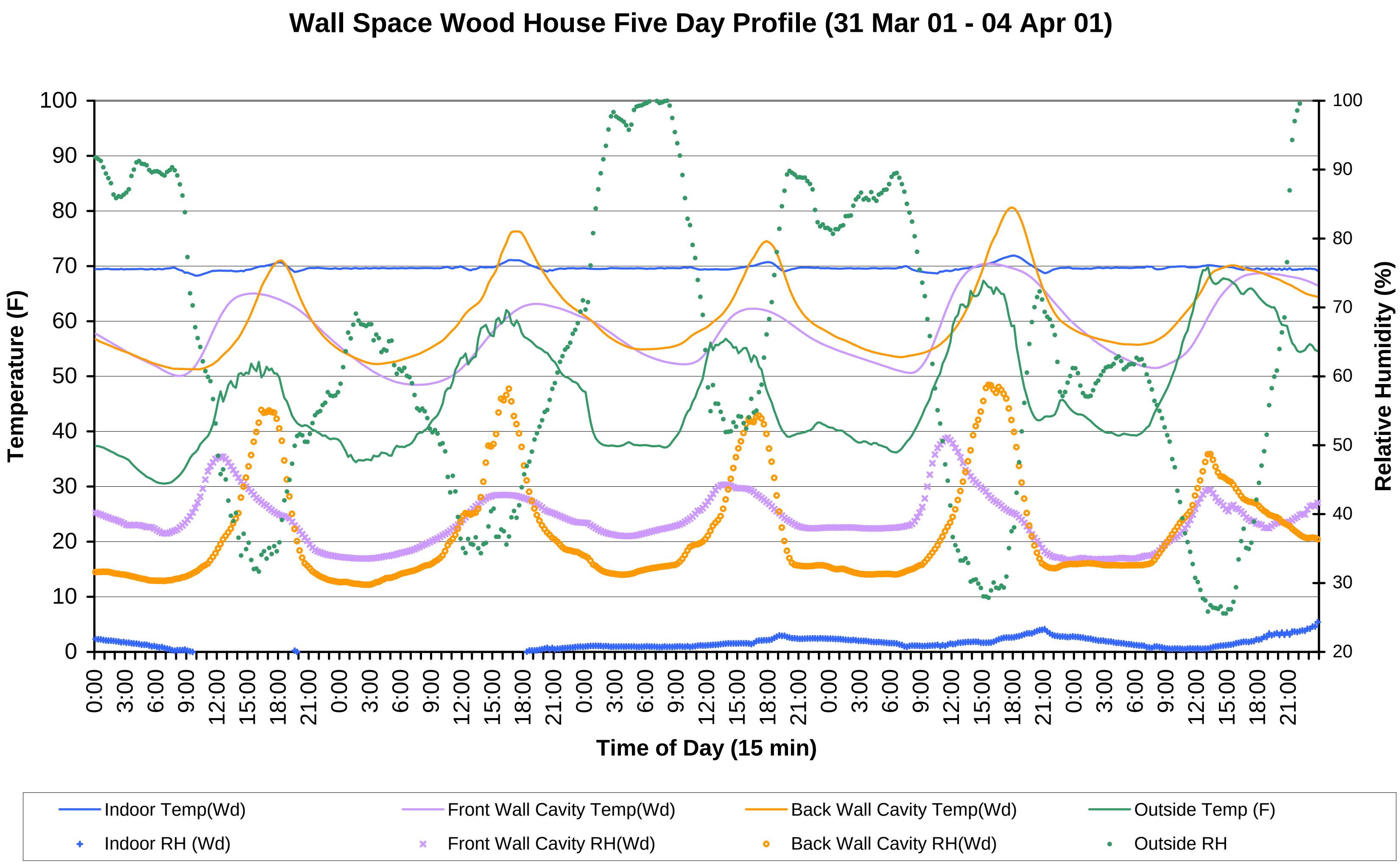

Wall Space Wood House Five Day Profile (12 Jul 00 - 16 Jul 00)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
110
105
100
95
90
85
80
75
70
65
60
100
90
80
70
60
50
40
30
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp(Wd)
Front Wall Cavity Temp(Wd)
Back Wall Cavity Temp(Wd)
Outside Temp (F)
Indoor RH (Wd)
Front Wall Cavity RH(Wd)
Back Wall Cavity RH(Wd)
Outside RH

Wall Space Wood House Five Day Profile (31 Aug 00- 04 Sep 00)





Wall Space Wood House Five Day Profile (30 Dec 00 - 03 Jan 01)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
0
10
20
30
40
50
60
70
80
90
100
0:15
3:15
6:15
9:15
12:15
15:15
18:15
21:15
Indoor Temp(Wd)
Front Wall Cavity Temp(Wd)
Back Wall Cavity Temp(Wd)
Outside Temp (F)
Indoor RH (Wd)
Front Wall Cavity RH(Wd)
Back Wall Cavity RH(Wd)
Outside RH


Wall Space Wood House Five Day Profile (31 Mar 01 - 04 Apr 01)
Temperature (F)
Relative Humidity (%)
Time of Day (15 min)
0
10
20
30
40
50
60
70
80
90
100
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Indoor Temp(Wd)
Front Wall Cavity Temp(Wd)
Back Wall Cavity Temp(Wd)
Outside Temp (F)
Indoor RH (Wd)
Front Wall Cavity RH(Wd)
Back Wall Cavity RH(Wd)
Outside RH

APPENDIX D

HOUSE PHOTOGRAPHS

Steel House Sheathed with Rigid Foam Insulation

Finished Steel House

Framed Wood House

Finished Steel House

APPENDIX E

AIR INFILTRATION TEST

AIR INFILTRATION TEST (BLOWER DOOR TEST)

Air infiltration into and out of a house comprises a large portion of the overall heating and cooling load in a home. Air infiltration testing is used to quantify how much fresh air enters a building with all exterior openings closed. The results of a blower door test indicate how leaky a house is, where the major sources of air leakage are located, and how the house compares to other homes of similar size and type.

TEST METHOD

The air infiltration test is performed in accordance with ASTM E779[1].

Results of air infiltration testing are presented in several ways, including Air Changes per Hour (ACH) value. An Air Change occurs when a building has its entire volume of air replaced with new air. The fraction of air replaced in an hour is the infiltration rate of a building.

An ACH_{50} value is often used to quantify a home's infiltration rate because the value is directly obtainable from the test and does not require any assumptions about the building's performance under natural (i.e. not under artificially elevated pressures) conditions. Results may also be presented in terms of airflow at a pressure differential of 50 Pascals, or CFM_{50}.

RESULTS

The air infiltration test was performed on the wood and steel houses in Valparaiso, Indiana on March 9, 2000. The results are summarized in Table 12.1 below:

TABLE E.1
SUMMARY OF BLOWER DOOR TEST

MEASUREMENT	WOOD HOUSE	STEEL HOUSE
Blower door – building tightness	4.6 ACH_{50} (2431 CFM@ 50 Pa)	4.7 ACH_{50} (2488 CFM @ 50 Pa)

For SI: 1 CFM = 0.0283 m^3/minute.

The blower door results are virtually identical for the two houses, as the difference between the two is only 2.3 percent. The wood house achieved its tightness value despite the fact that the steel house has a layer of exterior foam that the wood house does not. The similarity of the results may indicate that the leakage is originating from common details like the rim joists, windows, plumbing/electrical penetrations, recessed lights, and attic hatches. The volume of the basement is included in the calculations, which brings the ACH_{50} value down considerably.

[1]ASTM E779-99 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. American Society for Testing and Materials, West Conshohocken PA.

APPENDIX F

DUCT TIGHTNESS TEST

The duct tightness test is a similar measurement to the air infiltration test. Like a blower door test, the duct tightness test quantifies the air leakage from a duct system by pressurizing the system with a fan. Duct leakage wastes heating and cooling energy, especially when the ducts are located outside of the conditioned space of the building.

TEST METHOD

A duct tightness test is performed in accordance with ASTM E1554-94[1]. The duct system is pressurized using an auxiliary fan, and flow and pressure data points are recorded. Duct tightness results are usually referenced to a duct pressure of 25 Pascals relative to the house. Typical results are airflow at 25 Pa (cfm @ 25 Pa) and air leakage at 25 Pa normalized by house square footage (cfm/ft^2 @ 25 Pa).

RESULTS

The total duct leakage results are very high, but not surprising considering that a substantial portion of each system is formed with sheet metal, the large size of the systems, and the use of panned return ducts. No tape was applied to sheet metal joints.

TABLE F.1
SUMMARY OF DUCT BLASTER TESTS

MEASUREMENT	WOOD HOUSE	STEEL HOUSE
Duct blaster – total duct leakage	1038 CFM_{25}	944 CFM_{25}
Duct blaster – duct leakage to outdoors	206 CFM_{25}	133 CFM_{25}

For SI: 1 CFM = 0.0283 m^3/minute.

The duct leakage to outdoors is a much smaller part of the total leakage, and is due primarily to the flex duct runs in the attic. It is also possible that some leakage is occurring between the attic and panned wall cavities used as returns on the second floor. The source of the sizeable difference between the wood (206-cfm) and steel (133-cfm) leakage rates is not evident.

[1] ASTM E1554-94 *Standard Test Methods for Determining External Air Leakage of Air Distribution Systems by Fan Pressurization*. American Society for Testing and Materials, West Conshohocken PA.

APPENDIX G

SHORT-TERM THERMAL PERFORMANCE TEST

The thermal performance of a building can be measured in one night through the use of a Co-Heat Test. A co-heat test is conducted to help determine the building load coefficient (UA) of a building. The building load coefficient represents the thermal conductivity of the conditioned building envelope. Air infiltration that occurs during the test must be backed out to accurately calculate the building load coefficient. The UA can be divided by the surface area of the entire envelope to determine the average U value (1/R) for the house.

TEST METHOD

Short-term monitoring is typically done by measuring heat energy used to keep a constant indoor temperature. During the test, thermostatically controlled portable electric heaters placed throughout the living area of the building maintain a constant indoor temperature. This is done to provide a steady state indoor temperature that will be compared to the outdoor conditions and building energy consumption to determine the thermal performance of the building. Energy and temperature data are gathered by a data logger that monitors the parameters and controls the indoor temperatures.

To avoid the effects of solar gains, the test must be conducted during the nighttime hours. The test duration should be a minimum of one hour; this must follow achievement of thermal steady-state conditions. Temperature drifting within the living area should be minimized, ideally equipment will be designed to keep all areas within ±2°F.

It must be assumed that all electricity consumed during the test is converted into useable heat. The UA is determined as follows:

$$UA = Q/(\Delta T)t$$

Q = Energy consumed by the building for the test period (BTU)
ΔT = Average difference in indoor and outdoor temperatures for the test period (°F)
UA = Thermal resistance for the test building (BTU/hr-°F)
t = Test interval (hours)

It should also be noted that air infiltration can also account for a significant amount of heat loss. Blower door or tracer gas testing must be conducted to estimate the magnitude of the infiltration heat loss.

Test Apparatus and Procedure for the Valparaiso Demonstration Homes

Co-heat testing requires equipping the subject house with extensive monitoring and control equipment. Ambient air temperatures were taken at sixty-four different points throughout the house. Forty-eight of the temperatures were assigned to twelve zones with the average of four sensors associated with a heater determining whether the heater is on or off. The remaining sixteen sensors were placed in unconditioned areas such as the attic, garage and crawl space. Outside, a mini-weather station was located between 50-75 feet (15,240 to 22,860 mm) from the house. The station monitors temperature, humidity, wind speed and direction.

At the center of all the equipment is a programmable data logger and electric relay box. The data logger records all the readings from the instruments and is able to calculate area temperatures and control the zone heaters as necessary. The relay box takes the low voltage signals from the data logger and controls the 240V heaters (up to 16). The power to the relay box is run directly from the main panel on a 100-amp circuit breaker.

The intention for testing the homes in Valparaiso was to determine a UA value for the entire house (including the basement) and the finished living space (excluding the basement). The energy used in the basement would be backed out of the total based upon run time and a calibrated power consumption rate. Tests were conducted on three different nights, the first in the steel house and the second and third night in the wood house. The tests were run overnight with the data being used to calculate UA values gathered one hour prior to dawn when the previous day's solar gains are at their minimum.

It is generally accepted that a single co-heat test is accurate within a measurement error +/-5% at the 95% Confidence level (5,6) (Footnote:Buildings in a Test Tube: Validation of the Short-Term Energy Monitoring (STEM) Method, Judkoff, R., Balcomb, J.D., Subbarao, K., National Renewable Energy Laboratory, Golden Colorado. 2001, Uncertainty Analysis of the Measured Performance Rating Method, NAHB Research Center, 1994.) with multiple tests, this error can be reduced.

SHORT-TERM ENERGY TEST COMPARISON

Short term automated thermal measurement tests were performed on the two nearly identical homes in Valparaiso, Indiana in late April 2000 and repeated in mid-December 2000 and in March 2001 with additional insulation added to the vaulted ceiling in the steel house. The co-heat test, as it is commonly known, is an overnight evaluation of the building envelopes' thermal performance. Testing was intended to evaluate the thermal performance of a steel-framed house relative to a traditional wood framed house.

April 2000 Short-Term Energy Test

During the April tests, two unexpected problems occurred that made it difficult to arrive at a definitive answer regarding the UA values for the steel and wood houses. The first had to do with an imbalance in basement temperature in the two homes. Temperature measurements were taken prior to the setup of the test in both basements. There was an average difference of 4°F (2.22°C) (both ambient and slab temperatures) between the houses with the steel house basement being warmer. The "build-up" of heat in the steel basement could significantly skew the results of the test without backing out the energy required to heat the basement. Second, calculating the UA co-heat value for the living space was complicated by a secondary condition of room heaters internally overheating and shutting down. This made it impossible to isolate the basement heater run-time and back out the actual energy (heat) supplied solely to the basement.

DECEMBER 2000 SHORT-TERM ENERGY TEST

The co-heat tests were repeated in mid-December (2000) with modified testing equipment and run over three consecutive nights, one night in the wood house and two nights in the steel house.

Prior to setup, preliminary ambient temperatures were taken in both houses. Temperatures in the wood house were determined to be in the 68-70°F (20-21°C) range in the living areas and 66-68°F (18.9-20°C) in the basement. The steel house temperatures were also 68-70°F (20-21°C) in the living areas and 65-69°F (18.3-20.6°C) in the basement. These measurements were done to ensure that the test settings would be as close as possible to the established equilibrium temperatures of the homes.

The first night of testing was performed in the wood house. A total of 16 heaters were used (each heater was paired with two temperature sensors) and placed in all rooms with exterior exposure. Where necessary, fans were used to assist in the distribution of heat. Heaters in the living areas were set to turn on when the temperature went below 68°F (20°C) in the room and turn off when the temperature exceeded 70 °F. The respective on-off temperatures in the basement were 67°F (19.4°C) and 69°F (20.6°C). Outdoor, garage, attic and crawl space temperatures as well as wind speed and power consumption were monitored.

For the second night of testing, all equipment was moved from the wood to the steel house. Careful attention was paid to move the heaters and sensors to the same corresponding positions in the steel house. In addition, the same indoor temperature set points were used. This test was repeated for the third night in the steel house.

MEASURED RESULTS (DECEMBER 2000 TEST)

The resulting data were all taken from 2:00AM-5:00AM on each respective testing night. The 2-5 AM time frame was used for a number of reasons: 1) The outdoor temperatures were very steady (within 2°F range on each night); 2) This time of the day is the farthest from any solar radiation effects that can skew the data; 3) Two of the three nights had minimum wind speed over this time period. Wind speed can have a dramatic effect on the results of the test therefore, the results of the third night testing of the steel house where the wind speed was over seven times that of the wood house was not used in the determination of the final $UA_{co\text{-}heat}$ calculations. Results are summarized in Table 13.1 below.

TABLE G.1
CO-HEAT TEST RESULTS FOR VALPARAISO DEMONSTRATION HOMES (DECEMBER 2000)

HOUSE TYPE	$UA_{co\text{-}heat}$[3] (BTU/hr °F)	WIND SPEED (mph)	AVERAGE OUTSIDE TEMPERATURE (°F)	STANDARD DEVIATION OF UA[1] (BTU/hr °F)	$U_{Overall}$ VALUE[2,3] (BTU/hr °F ft^2)	OVERALL R VALUE (hr ft^2 °F/BTU)
Wood House–1st Night	308	0.59	-2.6	13.9	0.084	11.90
Steel House–2nd Night	326	0.52	19.2	12.9	0.089	11.24
Steel House–3rd Night	341	3.74	9.9	18.1	0.093	10.75

For SI: 1 BTU/hr °F = 0.53 W/ºC, 1 mph = 1.6 km/hr, °F = (1.8°C + 32), 1 BTU/hr ft^2 °F = 5.71 W/ºCm^2,
1 hr ft^2°F/BTU = 0.175 m^{2}K/W
[1] Standard deviation of UA for 15 minute averages of 5-second data.
[2] $U_{Overall}$ values were determined by dividing the UA values by the external surface area of each house.
[3] $UA_{co\text{-}heat}$ and $U_{Overall}$ include the effects of infiltration, $UA_{thermal}$ and $U_{thermal\ overall}$ could have a lower value.

Using the resulting data, the $UA_{co\text{-}heat}$ of the wood house, 308 BTU/hr°F (163 W/°C), was 5.8 percent lower than that of the steel house based upon the second night testing in the steel house (Table 13.1), 326 BTU/hr°F (173 W/°C).

ANALYSIS OF RESULTS (DECEMBER 2000 TEST)

To establish if the tested UA and $U_{overall}$ (U_o) from the thermal testing are reasonable numbers, a comparison can be made between the tested results and modeled values. There are several commercially available software packages to do this type of modeling. For this study MECcheck[1] and REM/Design[2] were used. Because of limited capabilities of these programs (and most of the off-the-shelf programs) in determining the UA and $U_{overall}$ values for steel-framed houses, only the wood home was modeled and the results were compared to the tested ones. MECcheck resulted in a thermal UA ($UA_{thermal}$) of 284 Btu/hrºF (151W/°C) that is 8.5% less than the tested results. REM/Design, a more sophisticated simulation program, produced a thermal U_o of 0.067 Btu/hrºFft^2 ($UA_{thermal}$ of 245 Btu/hrºF) (U_o of 0.382W/°Cm^2; $UA_{thermal}$ of 130 W/°C) that is 25.4% less than the tested result. The simulated results represent $UA_{thermal}$ and do not include infiltration losses.

The UA values shown in Table G.1 (field tested) also include infiltration effects. Because both the Blower Door test results and the wind speed over the test period were nearly the same (first night and second night of testing), it is reasonable to assume that air infiltration effects are similar for both houses.

All of the results have excluded the effects of the basement. There is a large amount of thermal mass in the basement that requires a sizable amount of energy to overcome any temperature differences in the basements, thereby biasing the results in favor of the basement with the higher temperature. Heaters were placed in the basement solely to counteract the heat transfer between the basement and the first floor. The energy used by the basement heaters was subtracted from the power consumed during the tests thus eliminating the basement effects from the tests.

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[1] MECcheck version 3.0. Developed by Pacific Northwest National Laboratory for the Department of Housing and Urban Development.
[2] REM/Design version 9.12, copyright Architectural Energy Corporation.

Thermal resistance (R-value) of materials is known to change with changes in temperature. There was a 21.8ºF and 13ºF difference in the average outdoor temperature and attic temperature, respectively between the wood house test and the first night test of the steel house. There are two dynamics occurring with the ways the houses in Valparaiso were constructed that can affect the tested R-value. First, the effective R-value of blown-in fiberglass insulation gradually increases until an approximate 30-40ºF-temperature difference is reached. At that point, there is an inversion in the R-value which begins to decrease as the temperature difference increases[3]. Secondly, the batting in the wall increases slightly in R-value with an increase in temperature difference[4]. Taking these thermophysical properties into account, it has been concluded that thermal conductivity, within the range of temperatures observed during the various co-heat tests, was determined to be minimal (<1%). Therefore, the impact of the outdoor temperature difference on the tested UA values was found insignificant and not adjusted for in the calculations.

MARCH 2001 SHORT-TERM ENERGY TEST

Follow-up short-term automated thermal measurement tests were again performed on the two nearly identical homes in Valparaiso, Indiana, in March 2001. This series of tests was done after 3/4-inch (19 mm) R-4 rigid foam insulation was installed on the vaulted part of the ceilings in the great room, living room and bonus room of the steel house. The rigid foam insulation was installed on the interior face of the vaulted ceiling on top of the drywall. Another layer of drywall was applied on top of the rigid foam. As in the previous runs, the tests were run over three consecutive nights, one night in the wood house and two separate nights of testing in the steel house.

The test procedure and heater locations were similar to the tests conducted in December 2000.

MEASURED RESULTS (MARCH 2001)

The resulting data from the March 2001 tests used to determine the UA were taken from 12:00AM- 6:00AM on each respective testing night. The 12:00 AM to 6:00 AM time frame was used for a number of reasons:

1. The outdoor temperatures were steady (within a 3ºF range on each night).
2. This time of the day is the farthest from any solar radiation effects that can bias the results.
3. The three-hour increase in the duration of the test was due to fluctuations that occurred during the middle of the testing period. The additional three hours of test data increased the confidence levels and accuracy of the data.

Table G.2 summarizes the results of the December 2000 and March 2001 tests and gives the average of these tests for the wood house and the steel house (before insulation retrofit and after insulation retrofit). Table G.2 also lists the $UA_{thermal}$ for each of the houses without any influence due to infiltration.

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[3]Graves, Wilkes, Mc Elroy, 1994, Thermal Resistance of Attic Loose-Fill Insulations Decreases Under Simulated Winter Conditions, ORNL/M-3253, ORNL.

[4]Wilkes, Thermophysical Properties Data Base Activities at Owens-Corning Fiberglass.

TABLE G.2
CO-HEAT TEST RESULTS FOR VALPARAISO DEMONSTRATION HOMES

HOUSE TYPE	$UA_{co\text{-}heat}$[1] (BTU/hr °F)	$UA_{thermal}$[2] (BTU/hr °F)	SAMPLING ERROR[3]	$U_{Overall}$[4] (BTU/hr ft² °F)	OVERALL R VALUE (hr ft² °F/BTU)
Wood House Dec. 2000 Test	308	283	-	.0772	12.96
Wood House March 2001 Test	327	281	-	.0766	13.05
Wood House Average	**317**	**282**	**1.8%**	**0.0769**	**13.00**
Steel House Dec. 2000 2nd Night	326	302	-	.0824	12.14
Steel House Dec. 2000 3rd Night	341	284	-	.0774	12.91
Steel House Dec. 2000 Average	**326**	**293**	**2.1%**	**0.0799**	**12.52**
Steel House March 2001 2nd Night	340	295	-	.0804	12.43
Steel House March 2001 3rd Night	335	276	-	.0753	13.29
Steel House March 2001 Average	**337**	**286**	**2.8%**	**0.0780**	**12.82**

For SI: 1 BTU/hr °F = 0.53 W/ºC, °F = (1.8°C + 32), 1 BTU/hr ft² °F = 5.71 W/ºCm², 1 hr ft²°F/BTU = 0.175 m²K/W

Notes:
[1] $UA_{co\text{-}heat}$ is calculated based upon the total heat loss for the test (conduction and infiltration)
[2] UA_{hermal} values exclude the effects of infiltration as described in the LBL single zone equation with a calculated stack coefficient of 0.008 and a calculated wind coefficient of 0.0121.
[3] Sampling error is at the 95% confidence level.
[4] $U_{Overall}$ values were determined by dividing the $UA_{thernal}$ values by the external surface area of each house.

BASEMENT

Basements in the test homes would fall under the category of semi-conditioned non-living space. Small variations in basement ambient or slab temperatures can cause a large change in heating needs (in the basement) due to the thermal mass of the concrete slab and its coupling with the ground. Because of these conditions the energy used to condition the basements has been eliminated from the tests (for both wood and steel homes).

Temperature measurements were taken in both homes to ensure test settings were as close as possible to the existing equilibrium temperatures of the homes. Temperatures in both homes were determined to be in the 68-70ºF (20 - 21ºC) range in the living area and 66-68ºF (18.9 - 20ºC) in the basement. Co-heat test protocol recommends that each house be at a constant temperature for at least 48 hours prior to testing[5]. Sufficient time was allowed for both homes to reach equilibrium. Heaters were placed in the basement to, in effect, zero out the heat transfer between the basement and the first floor. The energy used by the basement heaters was subtracted from the power consumed during the tests thus eliminating the basements from the tests.

[5] NYSERDA, New York State Energy Research and Development Authority, Short-Term Test Methods for Predicting the Thermal Performance of Buildings, Albany, NY (August 1991).

INFILTRATION

In March 2001 a blower door test was performed on both houses establishing ELA values for both houses. The wood house leakage area was 105.5 in^2 (68,064 mm^2) and the steel house was 104.8 in^2 (67,613 mm^2). With nearly identical ELA's, it can be assumed that the infiltration for both houses is similar under similar conditions.

The baseline wood house was calibrated to itself using the two nights of testing in determining the stack coefficient in the LBL model. The same calibration factor was used for the steel house based on similar blower door results and house shape.

ANALYSIS OF RESULTS

The tested mean $UA_{thermal}$ of the wood house (282 Btu/hrºF from Table 13.2) was 3.9% more thermally resistant than that of the steel house (293 Btu/hrºF from Table 13.2) before ceiling insulation retrofit. After the retrofit, the tested difference was reduced to 1.4% (286 Btu/hrºF from Table 13.2). A two-tail t-test at a 90% confidence level indicated that the difference between the means of the wood and retrofitted steel house is statistically insignificant. The addition of the rigid foam insulation on the vaulted portions of the ceiling in the steel house showed an overall thermal improvement of 2.5%. A one-tailed t-test indicated that this thermal improvement was statistically significant at the 90% confidence level.

In summary, the tested 3.9% difference between the wood and steel house (as originally constructed) was small yet large enough to see statistically. After the retrofit, the thermal difference between the two houses was no longer statistically significant. The final test results indicated that there was no discernable thermal performance difference between the two homes.