ESL-TR-97/01-01

ESTIMATED SAVINGS FROM TURNING OFF UNNECESSARY LIGHTS AT THE LANGFORD ARCHITECTURE CENTER DURING THE 1996 CHRISTMAS HOLIDAYS

REPORT

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ABSTRACT

During the 1996 Christmas holidays the College of Architecture initiated a trial program to turn off unnecessary lights during unoccupied periods. This effort targeted the unnecessary lights in all studios, classrooms, labs and offices. Had those lights been left on, the building would have consumed 100 kW more electricity every hour. The total electricity savings was about 31,200 kWh over 13 days, which is equivalent to a total cost saving of $936.00. If the College continues to turn off unnecessary lights during unoccupied periods, the estimated annual cost savings would be $13,711, which is 40% of the target savings estimated in the test we performed earlier in 1996. Labor costs to accomplish a manual shut-down are approximately $96.00 per week. If this is deducted from the annual cost savings, the lighting turn-off program still saves about $8,632 per year.

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INTRODUCTION

The electricity and thermal energy use of the Langford Architecture buildings are monitored by the Energy Systems Laboratory (ESL) as part of the campus-wide monitoring study initiated in the Spring of 1995 by President Bowen. The monitoring includes the whole-building electricity use (WBE), the motor control center (MCC), the chilled water and hot water consumption. As part of the monitoring study, in May 1996 we conducted an on-off test to determine the lighting load in the studios in Building A. The results of the on-off test were then used to estimate the savings that could be achieved by turning off the studio lights during unoccupied periods (Soebarto et al., 1996).

The results from the on-off test showed that turning off the studio lights during unoccupied periods would reduce the hourly electricity use by about 40 kW (from about 410 kW to 370 kW), or 10% of the total hourly whole-building electricity use (from 2.4 Watt/ sq.ft. to 2.16 Watt/sq.ft.). The annual savings was estimated to be $5,340. However, previous retrofit projects conducted by the Energy Systems Laboratory at the University of Texas at Austin campus showed that the electricity use during unoccupied periods in similar buildings could be reduced to 0.5 to 1.0 Watt/sq.ft. Thus, if the same savings were to be achieved at the Langford Architecture Center, other unnecessary loads should also be turned off during unoccupied periods in addition to turning off the studio lights. We targeted an hourly reduction of 250 kW, which would lower the hourly whole-building electricity use to 170 kW or 1.0 Watt/sq.ft. (Figure 1), and we estimated an annual potential savings of $34,208.

On November 29, 1996, we conducted an additional test to confirm the reduction in the electricity use from turning off the studio lights. The results, as presented in Figure 2, confirmed the previous result that about 40 kW was reduced hourly by turning off the studio lights.

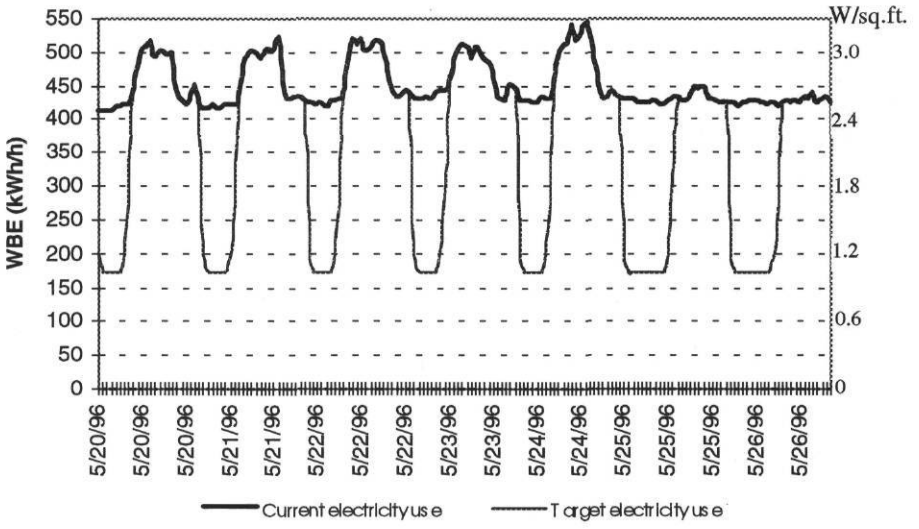


FIGURE 1. TARGET OF WEEKLY ELECTRICITY USE

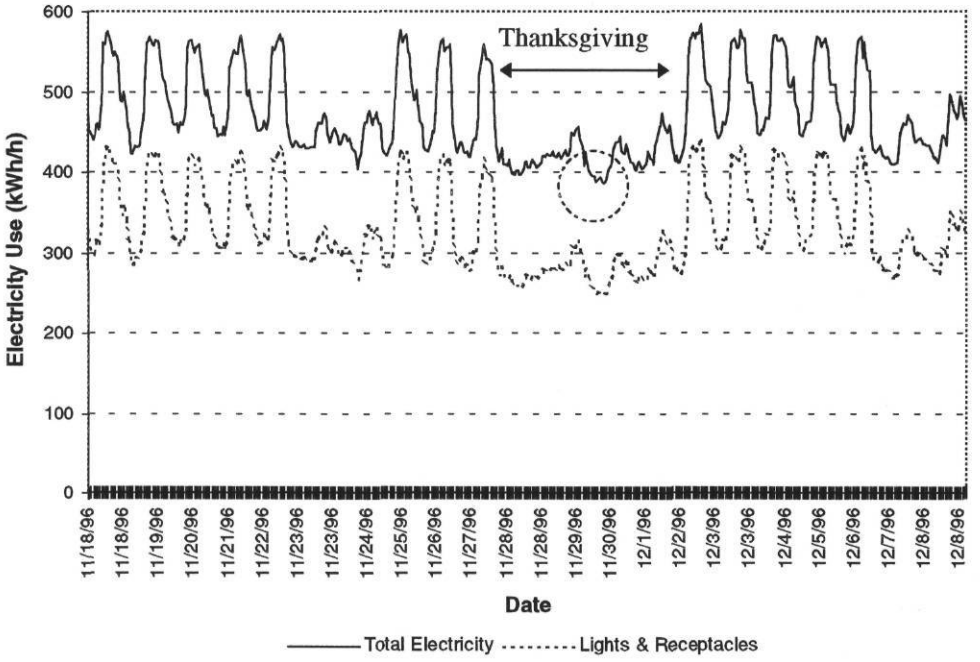


FIGURE 2. TOTAL ELECTRICITY USE BEFORE, DURING, AND AFTER THE THANKSGIVING BREAK

Before the 1996 Christmas break, Dean Wendler had approved the pilot project to shut-down all unnecessary lights during the break. The objective of this shut-down was to find out the actual savings that could be achieved by turning off **all unnecessary lights** in all three buildings. During this shut-down period, the electricity use as well as the chilled water and hot water use for the HVAC systems were monitored by data loggers. The monitored data would be used to assess the next steps required to achieve the target savings.

PROCEDURE

The shut-down started on the evening of December 20, 1996. All unused lights in Building A, B and C (excluding the emergency and night lights) were turned off. Then, every evening one of the ESL students walked through the buildings to make sure that those lights were still off. However, because the master keys could not open all rooms in the buildings, the lights in several rooms, as presented in Table 1, may have stayed on during the shut-down period. Further, some lights could not be turned off from the light switches; thus, they also stayed on during this period. We estimate this additional potential to be 14.5 kW.

TABLE 1. UNCONTROLLED LIGHTS DURING THE SHUT-DOWN PERIOD

Rooms	% of lights that were on	Total estimated load
Building A (*):		
• Offices (105, 310, 328, 330, 336, 428)	100%	3.4 kW
• Computer Labs (216/Viz, EDS, Landscape)	50%	7.5 kW
• Rest rooms (all floors)	100%	3.0 kW
Building C (*):		
• One bank in Rm. 204 (studio)	100%	0.6 kW
• Psycho-physiology Lab (429)	unknown	unknown
• Viz Lab (416)	unknown	unknown
• Mechanical Room (405)	unknown	unknown
TOTAL	-	**14.5 kW**

(*) Also, for a security reason, most of the hallway lights in Building A were left on, but most of the hallway lights in Building C were turned off.

RESULTS

The whole-building electricity use as well as the electricity use for the lights and receptacles is presented in Figure 3. Before the shut-down, the hourly total electricity use during unoccupied periods was about 410 to 440 kW. Turning off all unnecessary lights brought down the electricity use to the 310 to 340 kW range, or an average of hourly reduction of 100 kW or 0.6 Watt/sq.ft. On December 24 there was a campus-wide power outage, as also shown in Figure 3. After this power outage, the hourly electricity use dropped to the 250 kW to 280 kW range, which is about 60 to 70 kW less than before the outage. The difference is believed to be due to equipment and HVAC fans which were either turned off manually or stayed off automatically after the outage. Thus, this additional hourly reduction of about 60 to 70 kW is an unexpected effect of the power outage and will not be counted in estimating the savings.

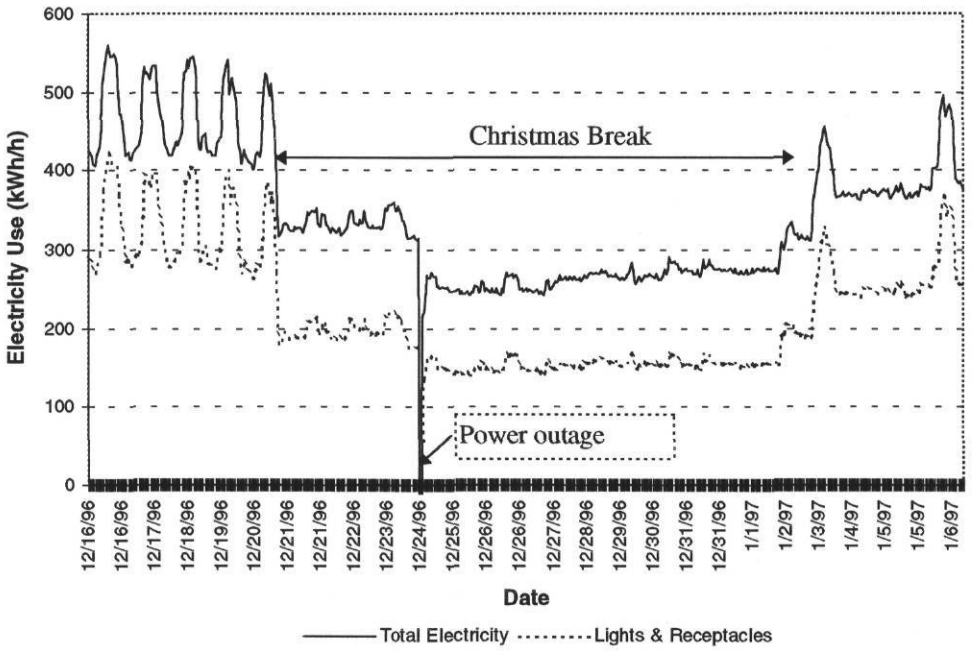


FIGURE 3. TOTAL ELECTRICITY USE BEFORE, DURING, AND AFTER THE CHRISTMAS BREAK

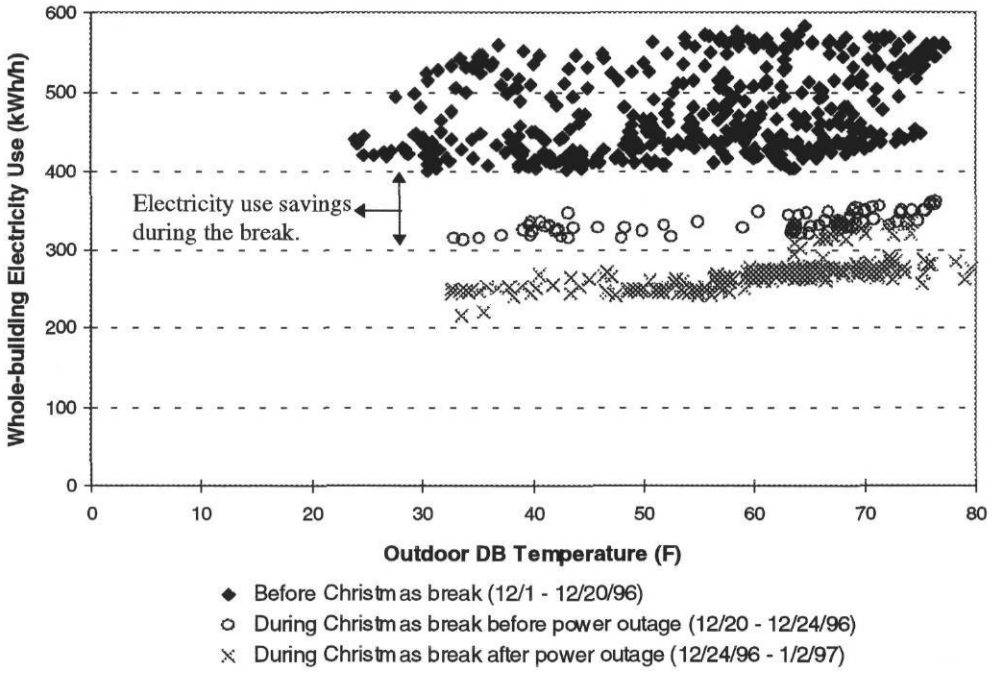


FIGURE 4. TOTAL ELECTRICITY USE vs OUTDOOR DB TEMPERATURES BEFORE AND DURING THE CHRISTMAS BREAK

Figure 4 shows the hourly whole-building electricity use before and during the Christmas break, plotted against the hourly outdoor temperature. This plot shows that the electricity use during the break continuously stayed at the 310 to 340 kW range (excluding the electricity use after the power outage), or about 100 kW less than the electricity use during unoccupied periods before the break.

Figure 5 confirms that the reduction of about 100 kW in the electricity use during the period of December 21 to December 24, 1996, was due to shutting-down the lighting use only and not to the air-conditioning systems. This figure shows that the hourly electricity use for the air handling units or Motor Control Center (MCC) stayed at around 140 kW even after the lights were turned off in the evening of December 20, 1996. Only after the power outage did the hourly electricity use for the MCC decrease to 100 kW which accounts for a large portion of the unknown drop that followed the power outage.

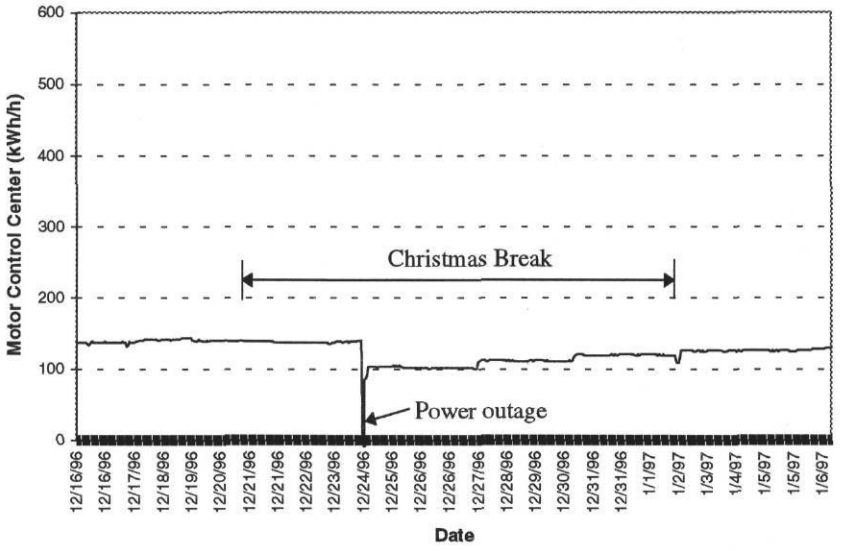


FIGURE 5. MCC ELECTRICITY USE FROM 12/16/96 TO 1/6/97

Figure 6 and Figure 7 show the chilled water and hot water use from December 1, 1996 to January 2, 1997. However, although we see that the chilled water use at the 50 to 80 degrees range decreased during the break, it was not clear whether the changes were caused by the changes in the internal load from the lights. This was because during the shut-down period the HVAC systems in the Langford Architecture buildings was under repair (the Variable Frequency Drive control and the variable speed pumping were being installed). Further, the hot water use also decreased during the Christmas break (instead of increased). Thus, it is inconclusive that the changes in the chilled water and hot water use were affected by the changes in the lighting load, even though Figures 8 and 9 show that the chilled water and hot water use may have been affected by the reduction in the lighting load.

Figure 8 shows the outdoor temperatures before and during the break. Figure 9 shows that the chilled water use in the beginning of the Christmas break increased from the 500 to 2,000 MBtu range to 2,400 MBtu as the outdoor temperature increased. However, it then dropped to about 1,600 to 1,900 MBtu even though the outdoor temperature was still increasing. From December 25 to January 2, 1997, the hourly chilled water use increased, but it was within the same range as the use before the break even though the outdoor temperature

during that period was about 10 to 30 degrees higher than before the break. Thus, it was possible that the reduction in the lighting load actually affected the chilled water use; however, because the HVAC systems in the buildings were still being repaired, we do not feel that we can draw any conclusions about the thermal energy use from this result. To estimate the annual savings, however, we will use the previous chilled water and hot water ratios as reported in the earlier report (Soebarto et al., 1996).

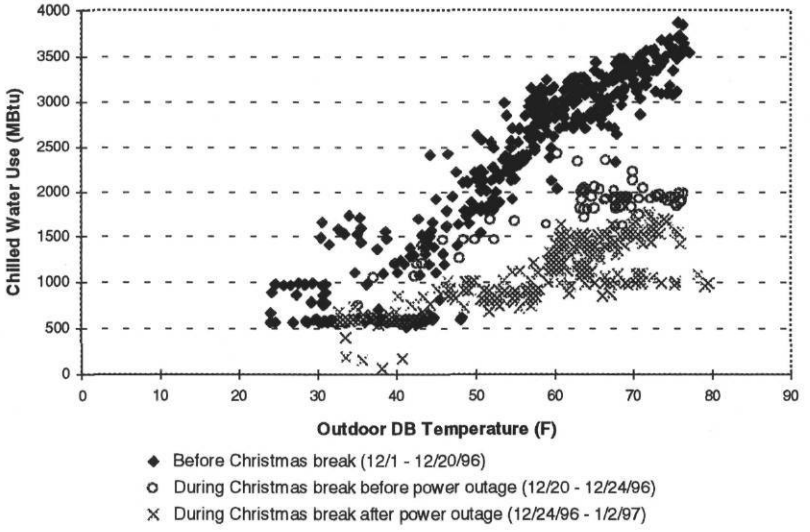


FIGURE 6. HOURLY CHILLED WATER USE vs OUTDOOR DB TEMPERATURES BEFORE AND DURING THE CHRISTMAS BREAK

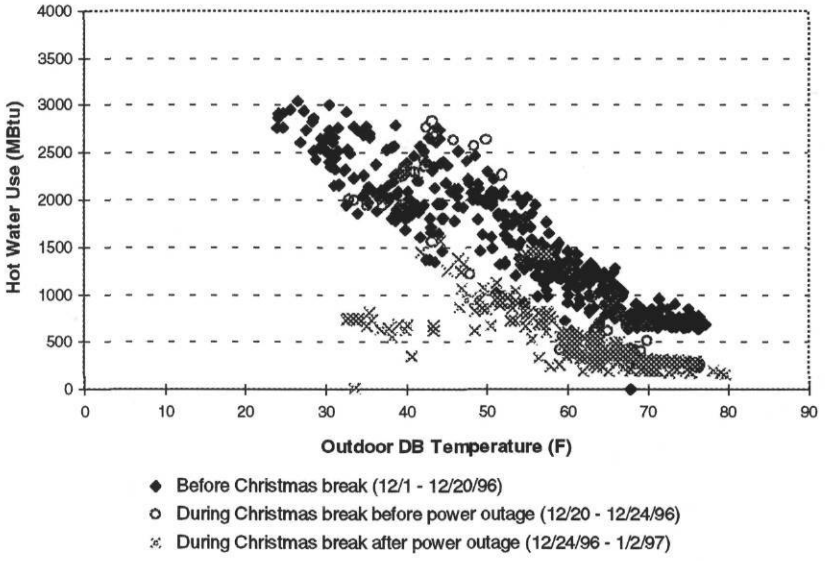


FIGURE 7. HOURLY HOT WATER USE vs OUTDOOR DB TEMPERATURES BEFORE AND DURING THE CHRISTMAS BREAK

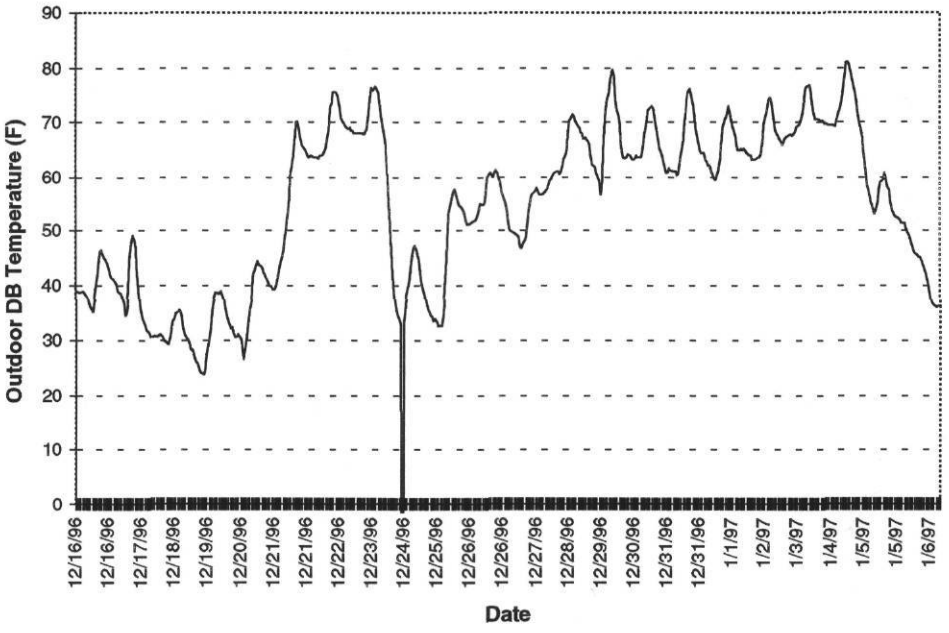


FIGURE 8. OUTDOOR DRY-BULB TEMPERATURES FROM 12/16/96 TO 1/6/97.

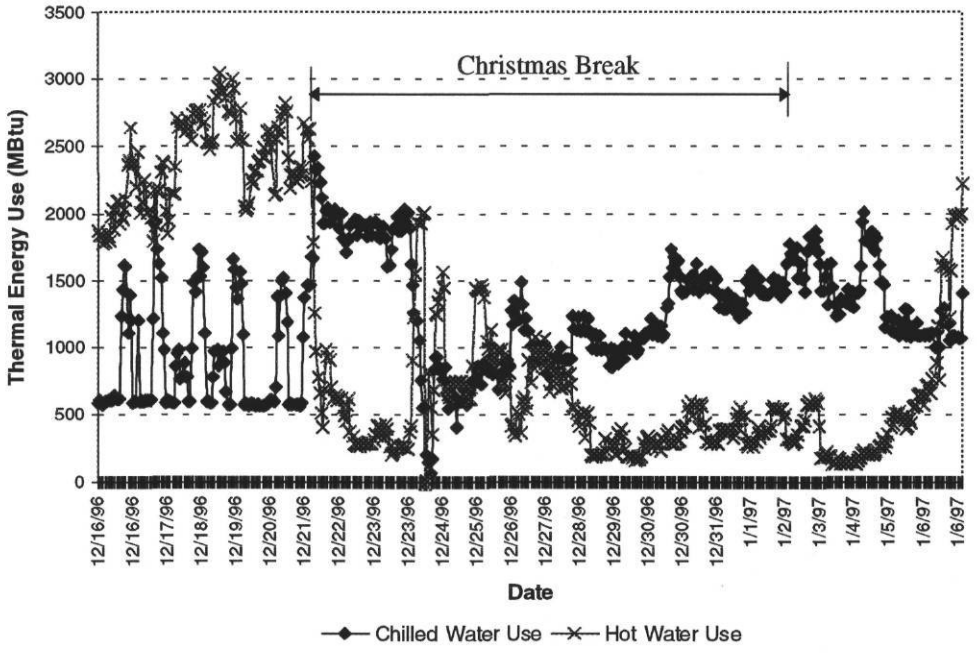


FIGURE 9. CHILLED WATER AND HOT WATER USE FROM 12/16/96 TO 1/6/97.

SAVINGS ANALYSIS

From these results, we predicted that if the lights had not been turned off, the hourly total electricity use would have stayed at about 410 to 430 kW (Figure 10). Thus, turning off almost all unnecessary lights from December 21, 1996 to January 2, 1997 saved about 100 kW per hour, or a total cost savings as estimated below:

Estimated total electricity saving:

= 100 kW x 13 days x 24 hours

= **31,200 kWh.**

Estimated electricity cost savings:

= 31,200 kWh x $0.03/kWh

= **$936.00.**

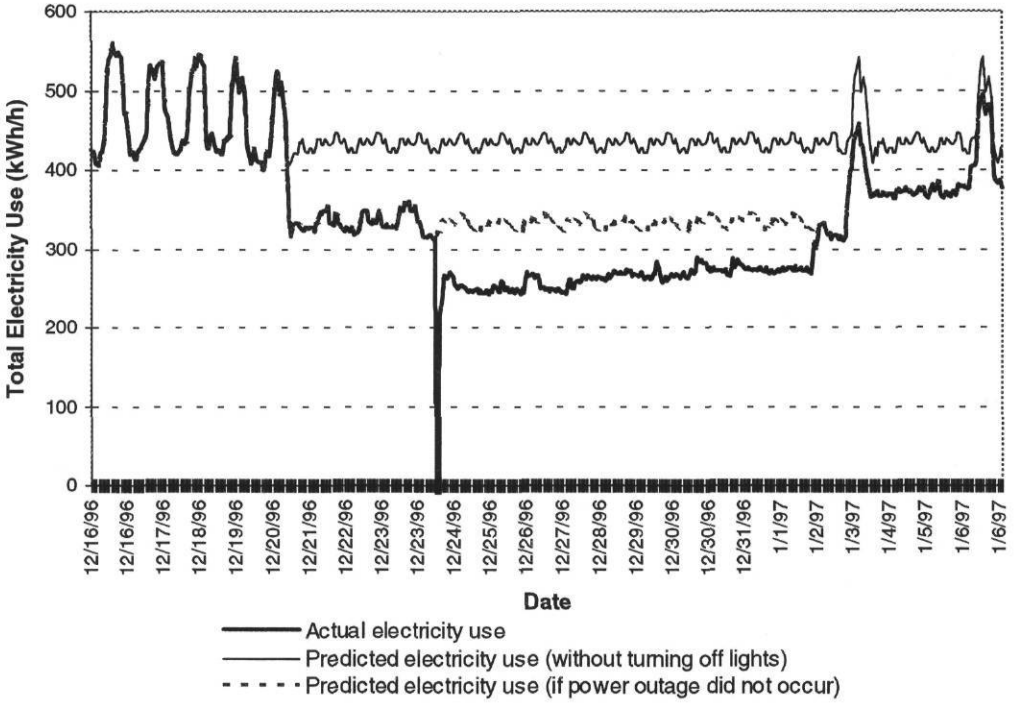


FIGURE 10. PREDICTED AND ACTUAL ELECTRICITY USE DURING THE CHRISTMAS BREAK

Based on these results, the estimated annual savings that could be achieved by turning off unnecessary lights alone during unoccupied periods are as follow:

Estimated annual electricity saving:

= 100 kW x 10 hrs/day x 261 workdays/year +
100 kW x 14 hrs/day x 104 weekends/year
= **406,600 kWh**

Estimated annual electricity cost savings from turning off unnecessary lights alone:

= $0.03 x 406,600 kWh
= **$12,198.**

The reduction of the total electrical load is estimated to result in a 1 Btu to 0.7 Btu reduction of the chilled water use (for space cooling during the cooling season) and a 1 Btu to 0.7 Btu addition of hot water use (for space heating during the heating season). The estimated chilled water and hot water savings would then be:

Estimated annual chilled water savings (8 months per year):

= 8/12 x 0.7 x 406,600 kWh x 3,413 Btu/kWh
= 648 MMBtu

Estimated annual chilled water cost saving:

= 648 MMBtu x $4.67/MMBtu
= **$3,026.**

Estimated increase in hot water use (4 months per year):

= 4/12 x 0.7 x 406,600 kWh x 3,413 Btu/kWh
= 324 MMBtu

Estimated annual chilled water cost saving:

= 324 MMBtu x $4.67/MMBtu

= **$1,513.**

Total annual cost savings from turning off unnecessary lights alone (electric cost savings + cooling cost savings - heating cost):

= $12,198 + $3,026 - $1,513

= **$13,711.**

SUMMARY AND RECOMMENDATION

Our original goal was to reduce the hourly total electricity use during unoccupied periods by 250 kW (1.4 Watt/sq.ft.) or by 60% of the total (from 420 kW or 2.4 Watt/sq.ft. to 170 kW or 1 Watt/sq.ft.). This shut-down of the lights resulted in a reduction of 100 kW (0.6 Watt/sq.ft.) or 40% of the total, bringing down the hourly total electricity use during unoccupied periods to about 320 kW or 1.8 Watt/sq.ft.. Therefore, there is still about 150 kW of "unknown" loads that need to be investigated further (Figure 11).

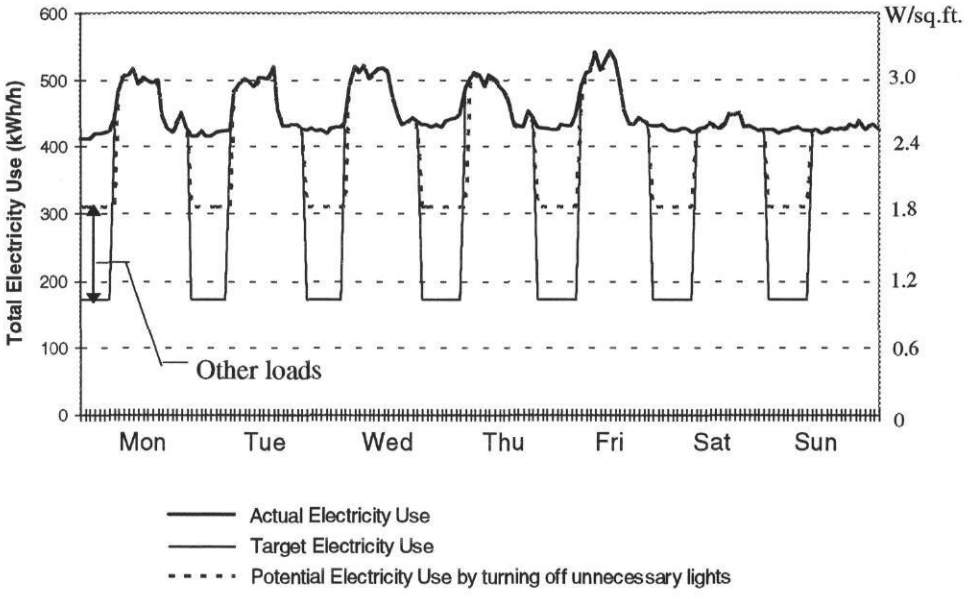


FIGURE 11. ACTUAL, TARGET, AND POTENTIAL WEEKLY ELECTRICITY USE BY TURNING OFF UNNECESSARY LIGHTS DURING UNOCCUPIED PERIODS

To determine this unknown load, and to investigate whether some unnecessary equipment can be turned off during unoccupied periods, we suggest that additional on-off (blink) tests be conducted in the near future. By conducting this test, we would be able to determine the other loads and determine whether those loads can be shut-off during unoccupied periods so that further savings can be achieved.

We would also like to recommend that the College of Architecture continue the lighting turn-off program for the remainder of the semester. It is estimated that this program saves about $34.00 per day on workdays and $46.00 per day on weekends, or a total of $262.00 per week. A student worker would require 1.5 hours per day to the turn off the lights at midnight for a total of 10.5 hours per week, and another 1.5 hours per week to process the measured data and create the weekly feedback plots. The hourly wage of a student worker is about $5.50, thus the total cost would be $66.00 per week. Another 1.5 hours per week would be needed for faculty or staff to supervise this program, which would cost about $30.00. The total labor cost would be $96.00 per week; thus, the total savings by continuing the lighting turn-off program would be about $166.00 per week or about $8,632 per year.

For best results, we would recommend setting up an appropriate feedback mechanism for the College. This could consist of either posting weekly graphs on a placard in the lobby of the building A, or perhaps transferring an electronic image of the graphs to either the video display of the Architecture homepage or some combinations of both options.

ACKNOWLEDGMENTS

We would like to thank the College of Architecture Dean's office for their cooperation and support. We would also like to thank Peter Klima and Kie Whan-Oh for conducting this shut-down during the 1996 Christmas break.

REFERENCES

Soebarto, V.I., J.S. Haberl, and L.O. Degelman. 1996. Estimated savings from turning off unnecessary electrical loads during unoccupied periods at the Langford Architecture Center. *Report ESL-TR-96/10-02*, Energy Systems Laboratory, Texas Engineering Experiment Station, Texas A&M University System, October.

APPENDIX

Weekly plots and ESL monthly energy consumption report for Langford Architecture Buildings A and B / C

Langford Arch Bldg A

Texas A&M University
102,105 square feet

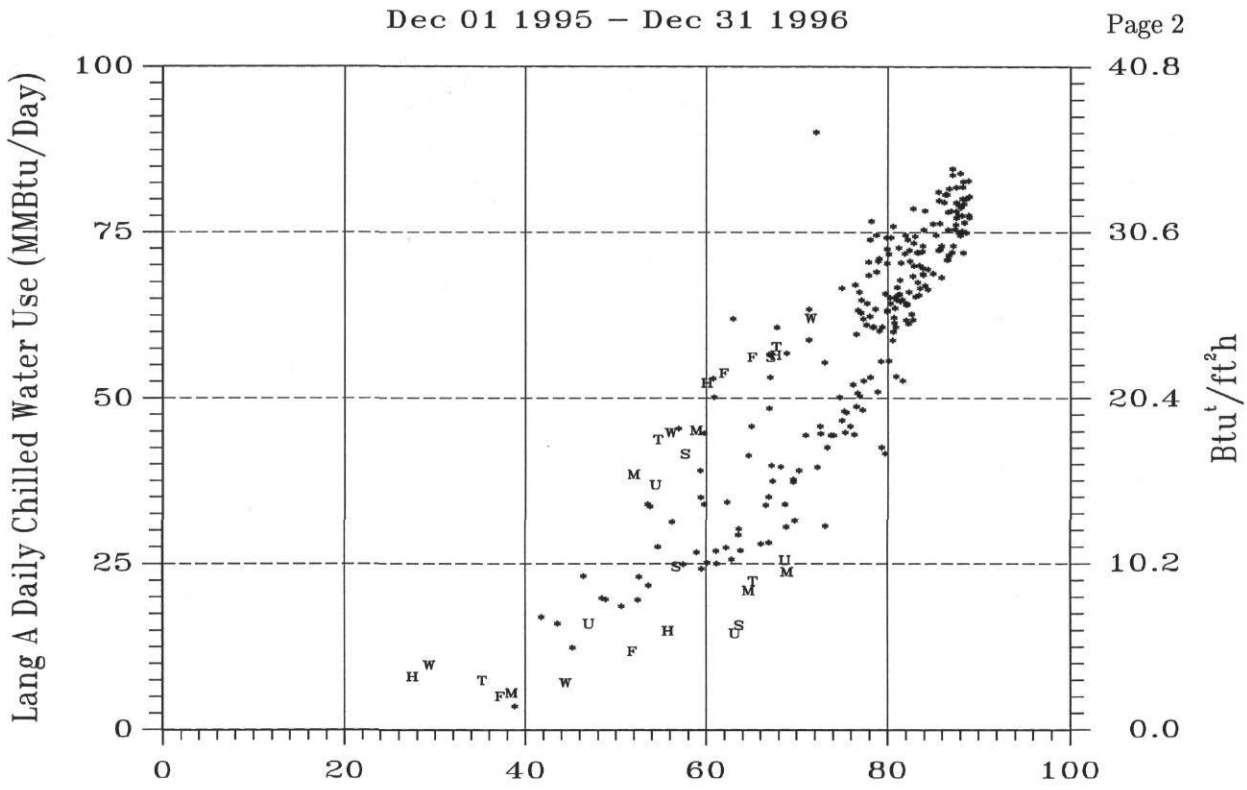
Site Contact	ESL Metering Contact
Mr. Charles Darnell, Jr.	Namir Saman
Physical Plant Administration	053A WERC
Texas A&M University	Texas A&M University
(409) 845–5318	College Station, TX 77843-3123
Gene Stewart	(409) 845–9213
(409) 845–5511	

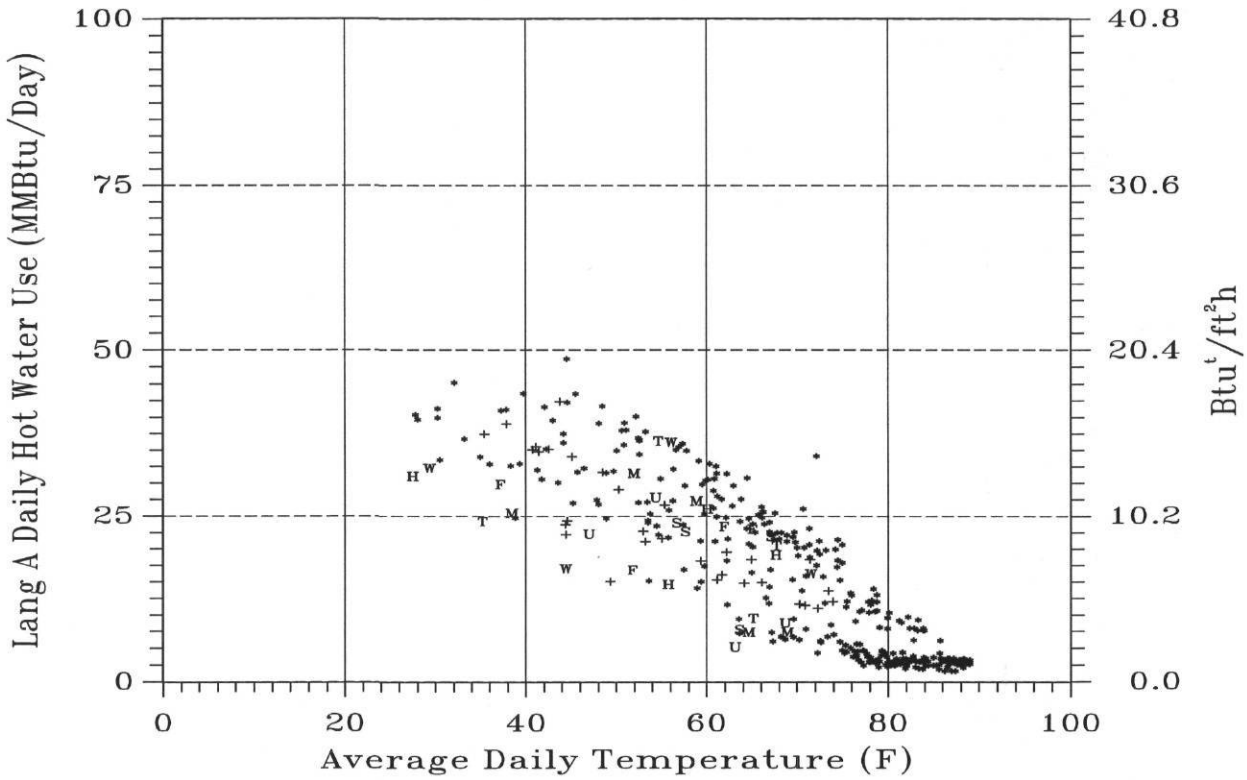
Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	215915 kWh	100	$0.02788	$6020
Peak 60 Minute Demand	423 kW	100	-	-
Chilled Water	918.4 MMBtu	100	$4.670	$4289
Hot Water	673.3 MMBtu	100	$4.750	$3198

Peak 60 minute demand was recorded at 1600 Monday 12/02/96.
There were 744 hours in this month.

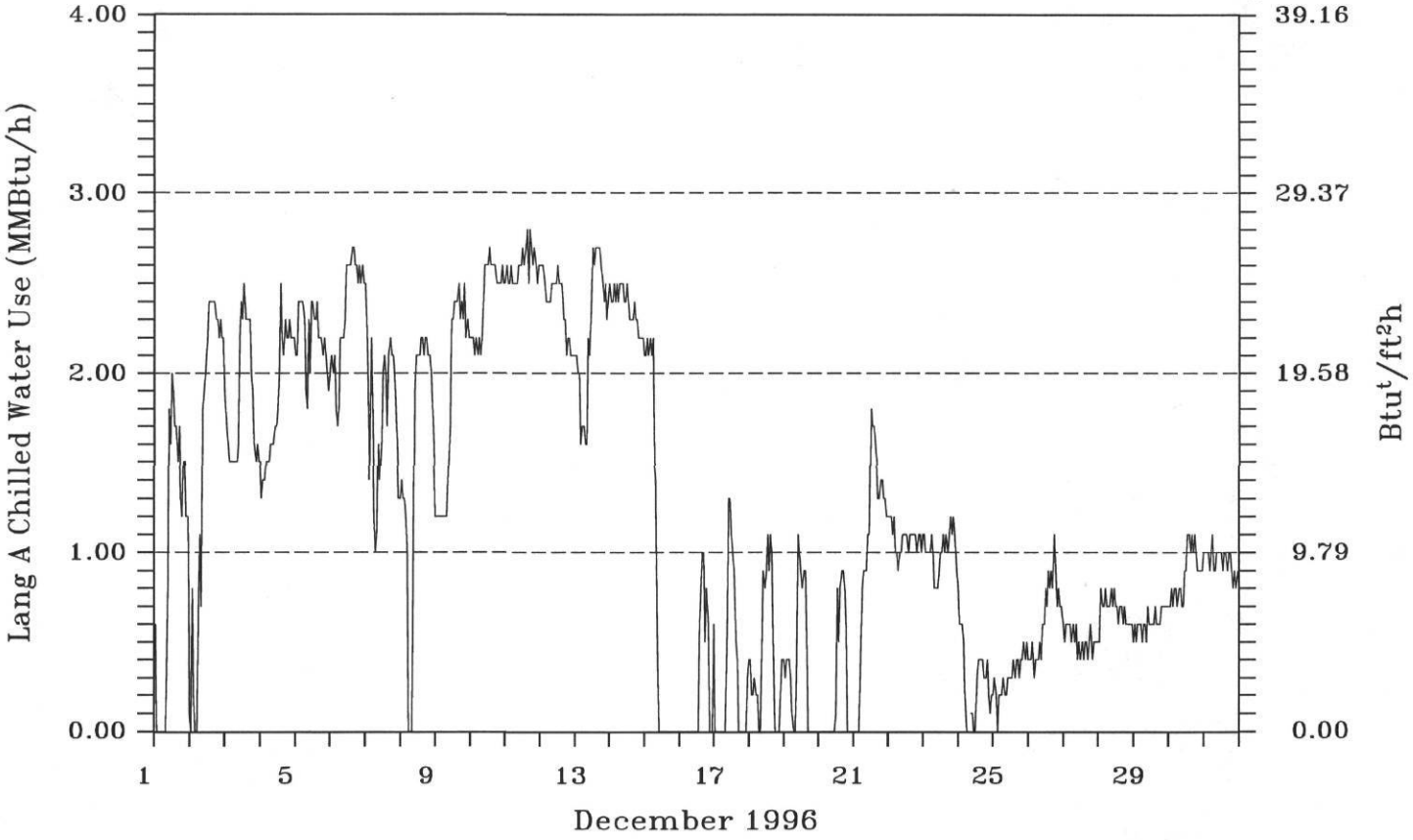
Comments

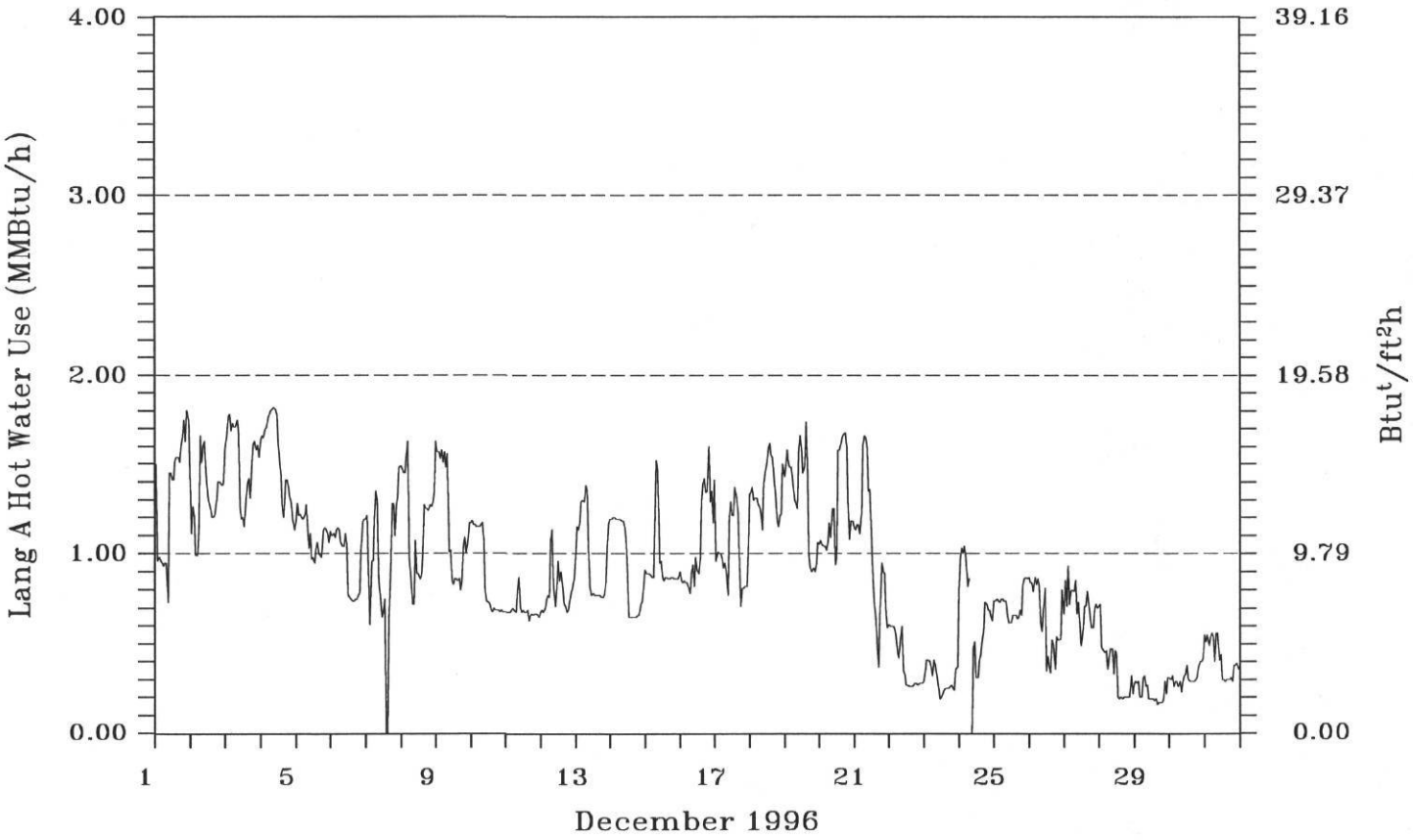




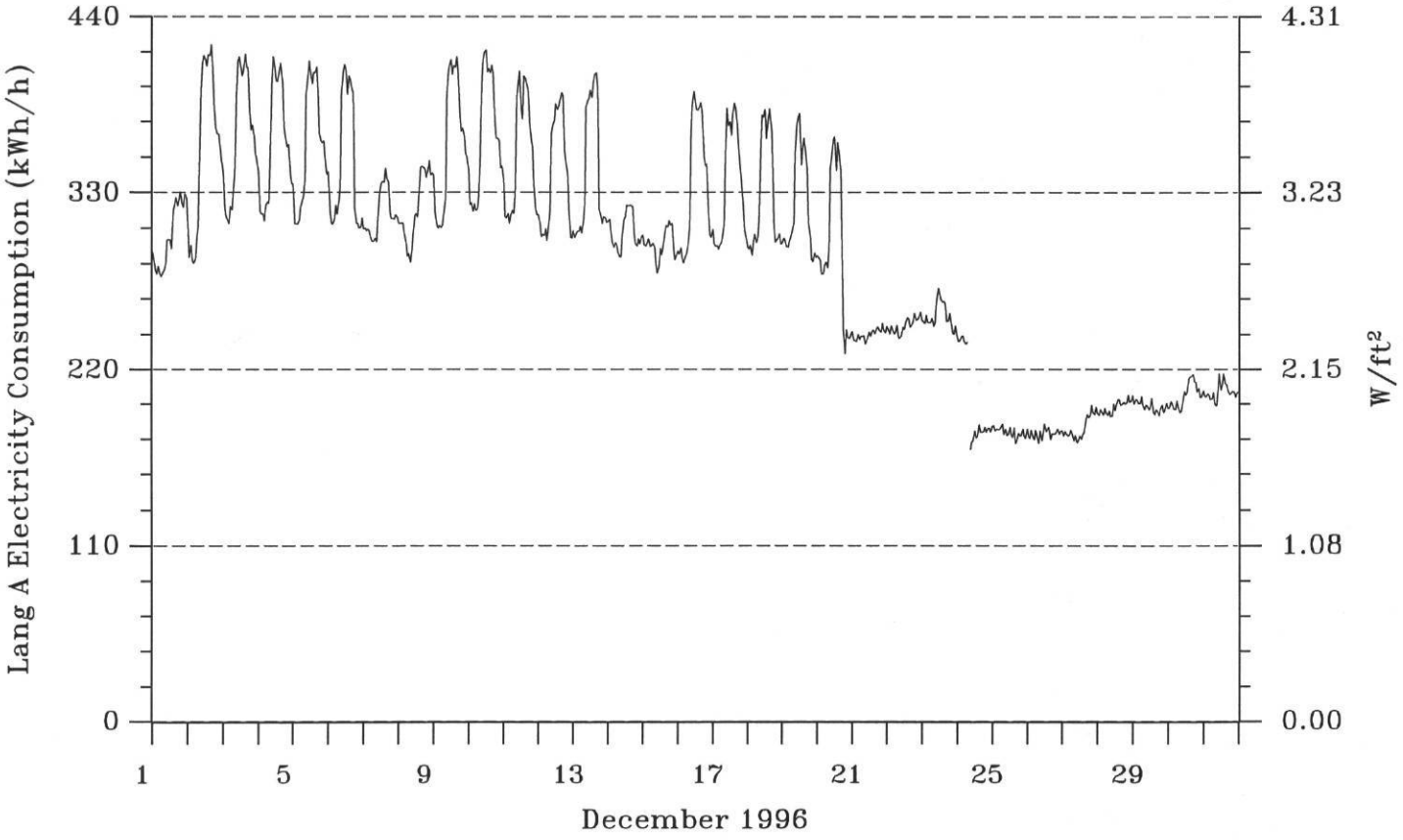
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

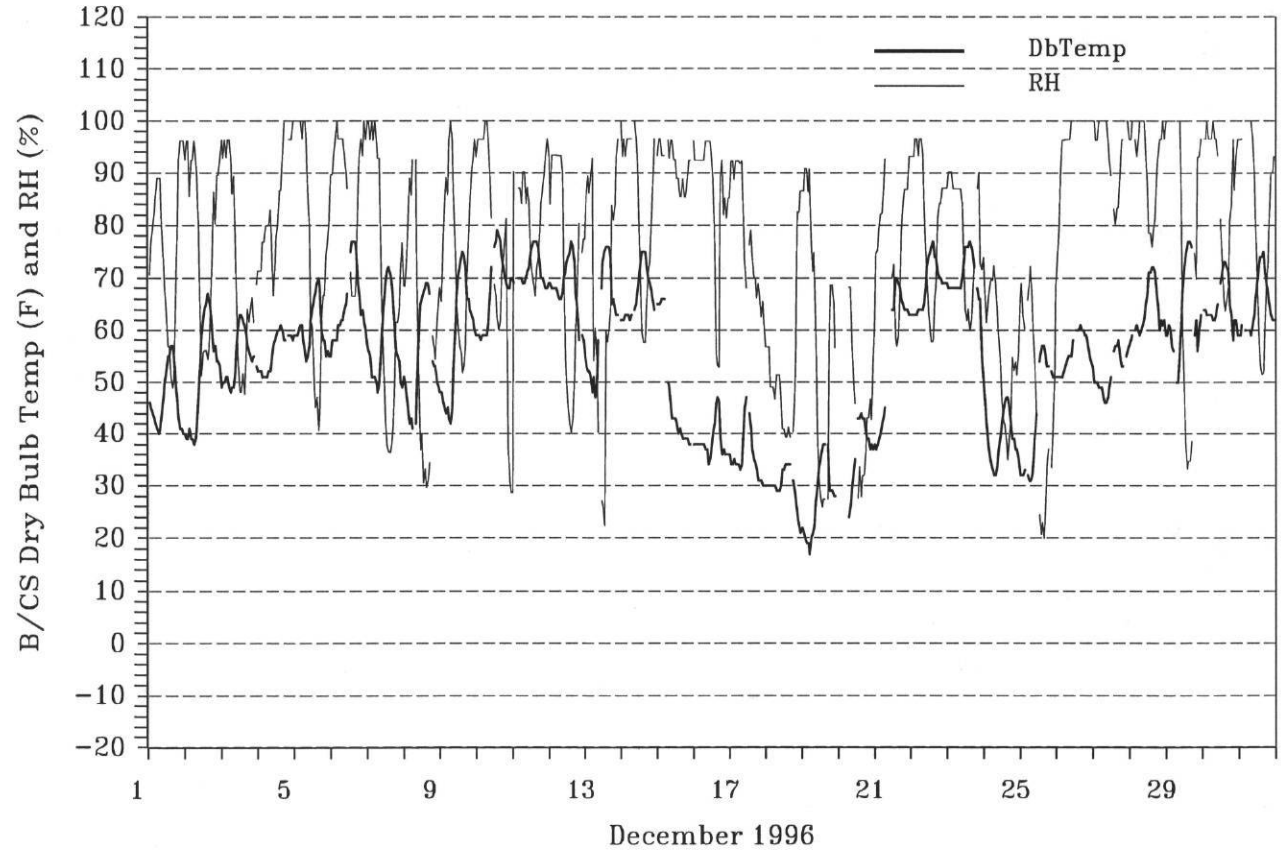
Points from this month last year are shown as +.
All other points are shown as *.





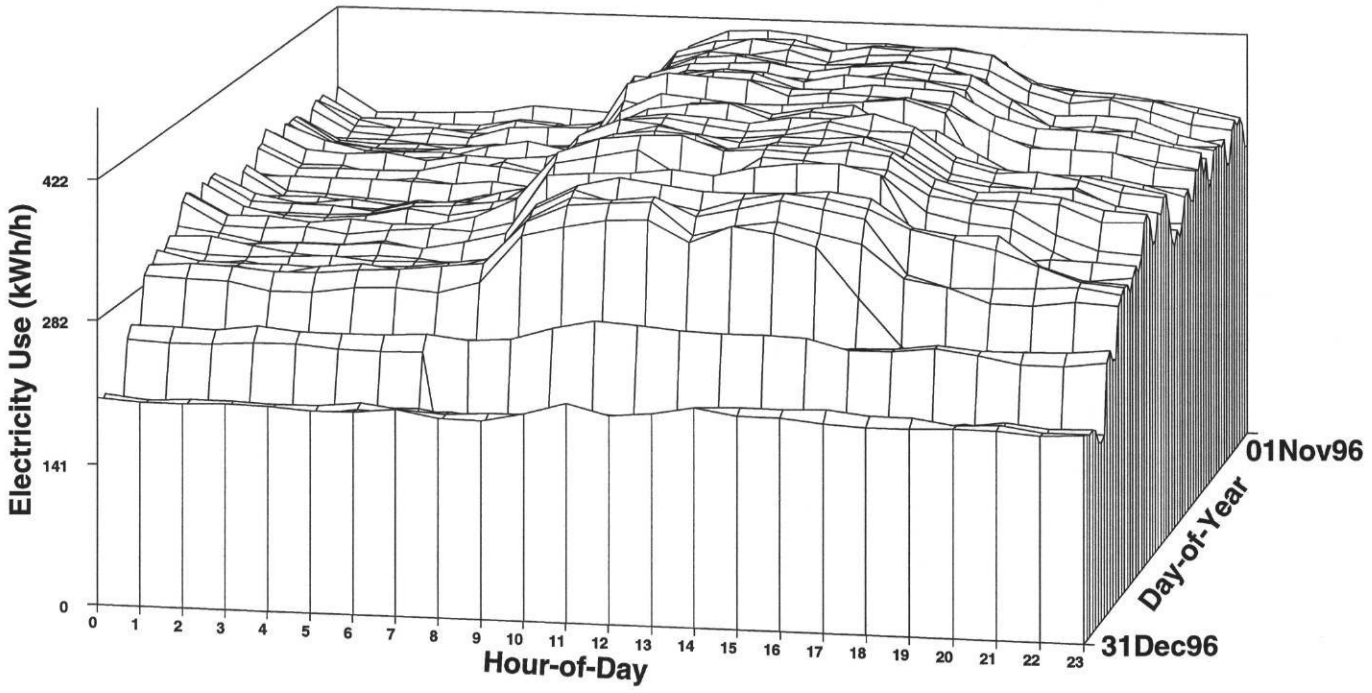
Langford Arch Bldg A - Texas A&M University - December 1996



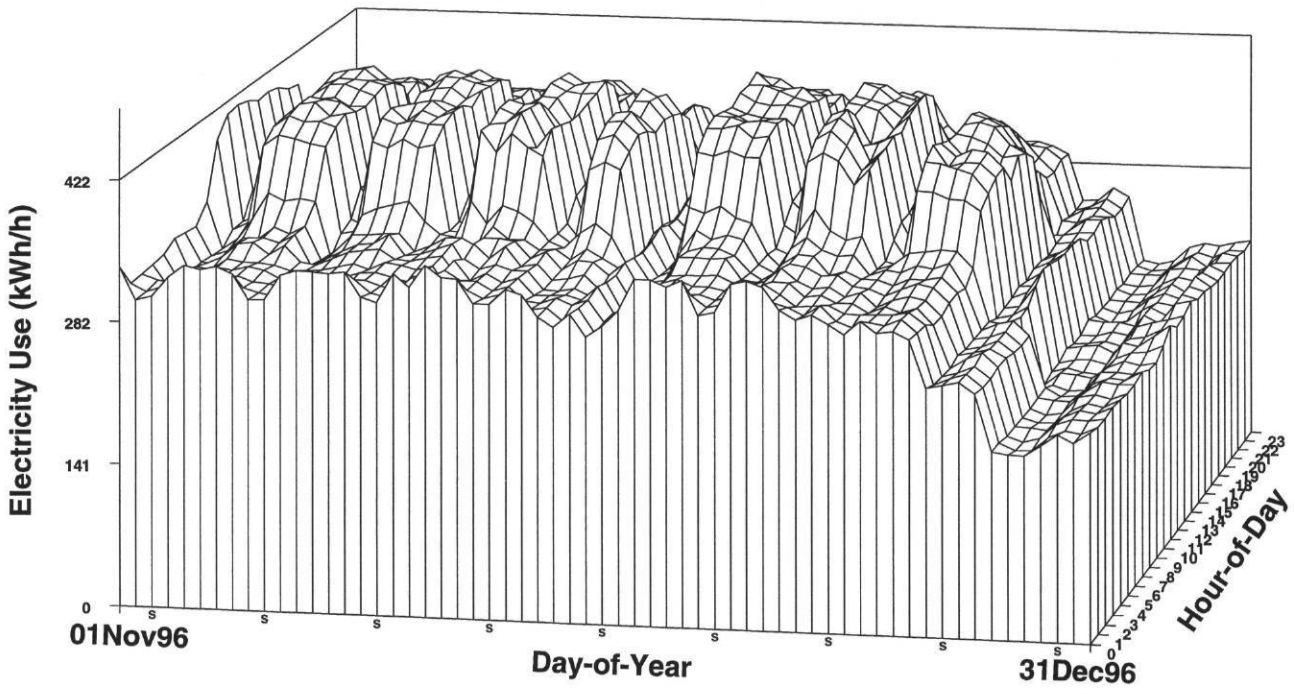


Langford Arch Bldg A - Texas A&M University - December 1996

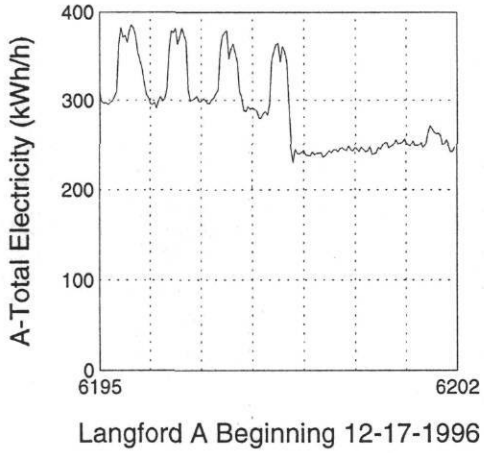
Whole–Building Electric

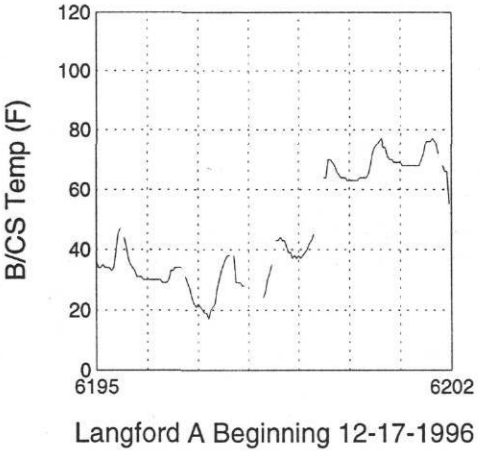


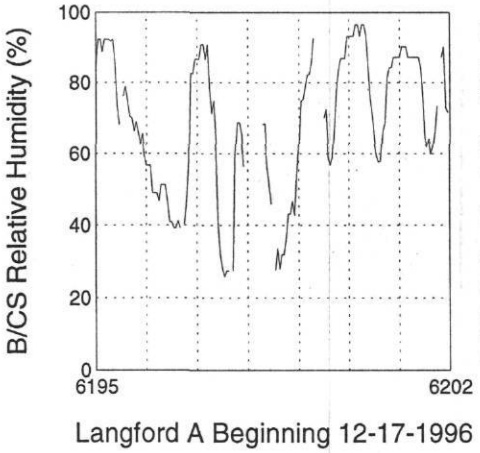
Whole–Building Electric

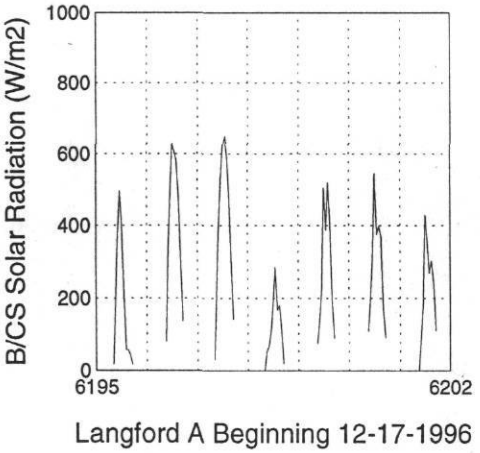


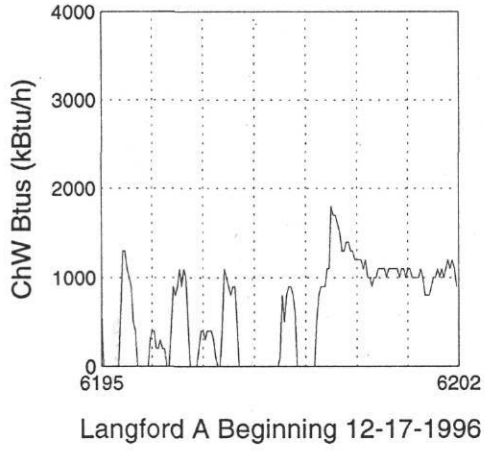
Sundays are marked with an "S"

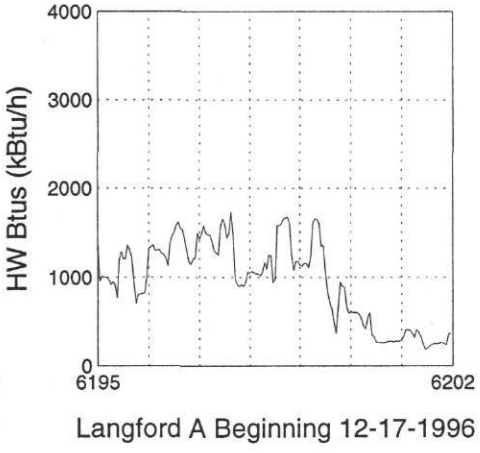

A-Total Electricity (kWh/h)
0
100
200
300
400
6195
6202
Langford A Beginning 12-17-1996

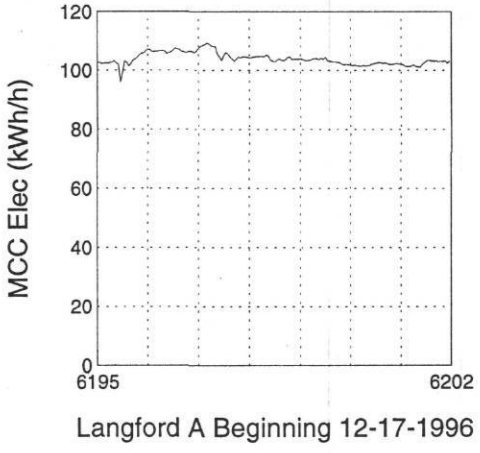

B/CS Temp (F)
0
20
40
60
80
100
120
6195
6202
Langford A Beginning 12-17-1996

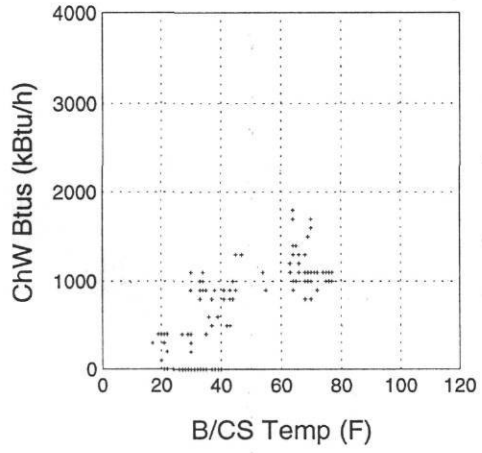

B/CS Relative Humidity (%)
0
20
40
60
80
100
6195
6202
Langford A Beginning 12-17-1996

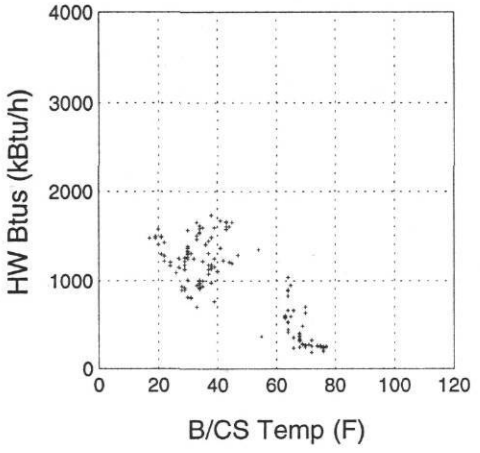

B/CS Solar Radiation (W/m2)
0
200
400
600
800
1000
6195
6202
Langford A Beginning 12-17-1996

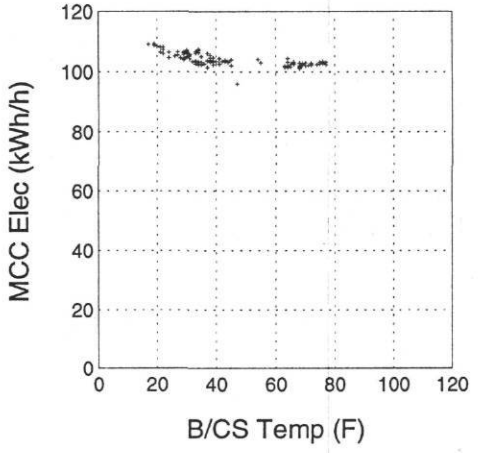

ChW Btus (kBtu/h)
0
1000
2000
3000
4000
6195
6202
Langford A Beginning 12-17-1996

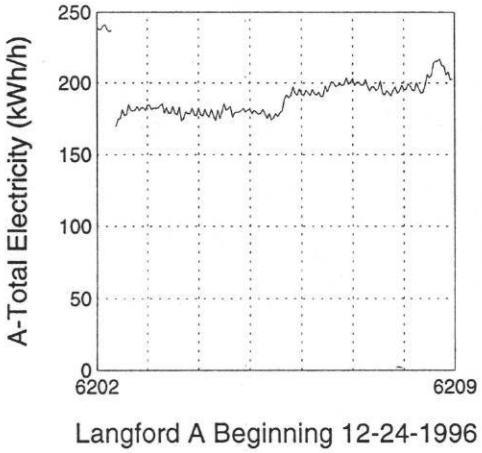

HW Btus (kBtu/h)
0
1000
2000
3000
4000
6195
6202
Langford A Beginning 12-17-1996

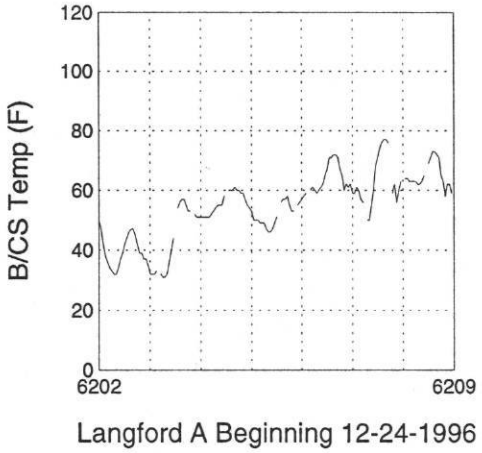

MCC Elec (kWh/h)
0
20
40
60
80
100
120
6195
6202
Langford A Beginning 12-17-1996

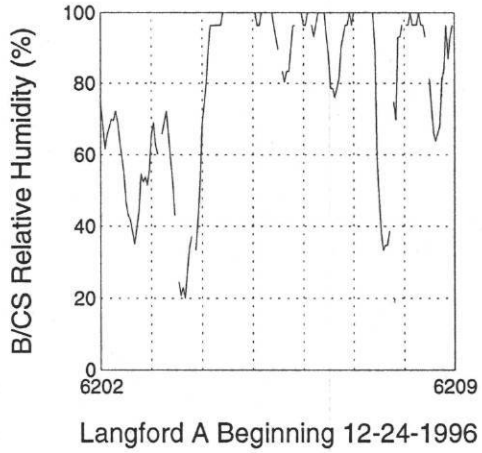

ChW Btus (kBtu/h)
0
1000
2000
3000
4000
0
20
40
60
80
100
120
B/CS Temp (F)

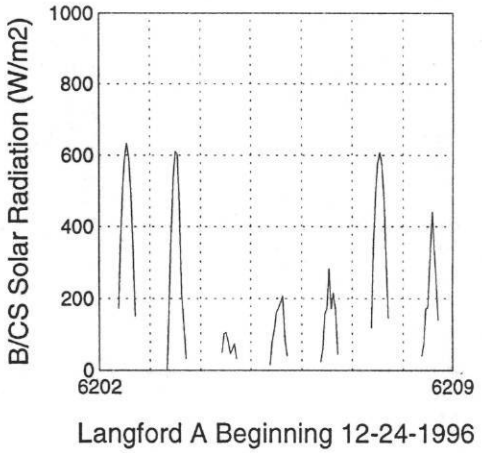

HW Btus (kBtu/h)
0
1000
2000
3000
4000
0
20
40
60
80
100
120
B/CS Temp (F)

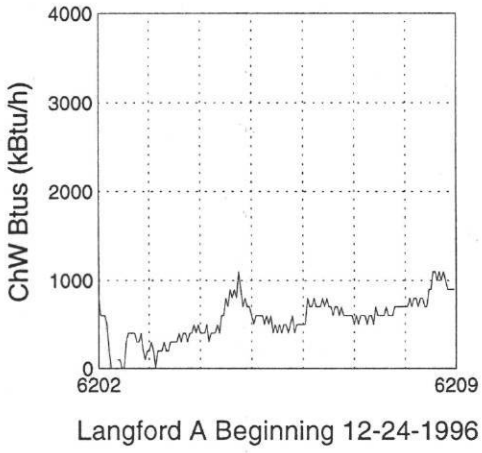

MCC Elec (kWh/h)
0
20
40
60
80
100
120
0
20
40
60
80
100
120
B/CS Temp (F)

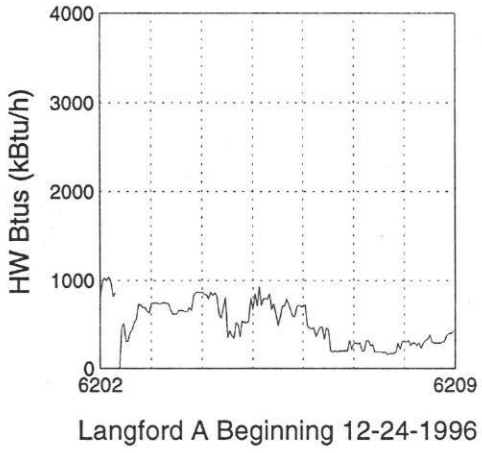

A-Total Electricity (kWh/h)
250
200
150
100
50
0
6202
6209
Langford A Beginning 12-24-1996

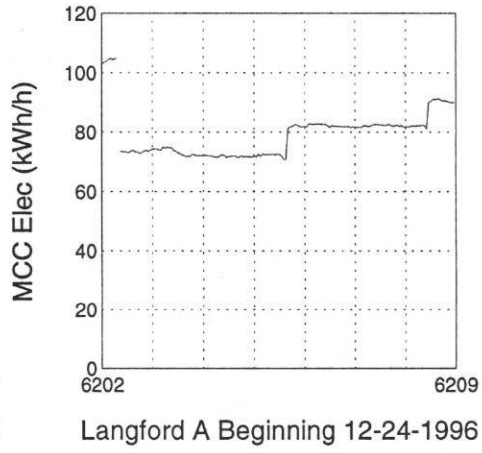

B/CS Temp (F)
120
100
80
60
40
20
0
6202
6209
Langford A Beginning 12-24-1996

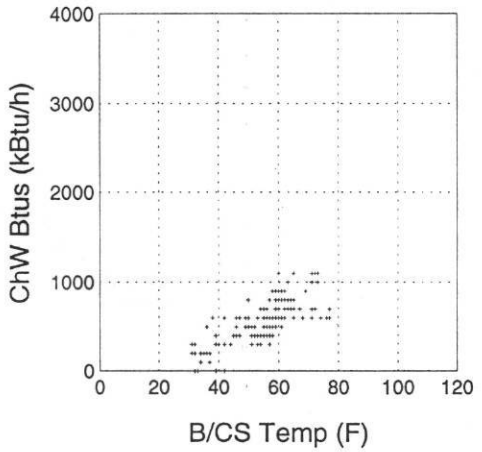

B/CS Relative Humidity (%)
100
80
60
40
20
0
6202
6209
Langford A Beginning 12-24-1996

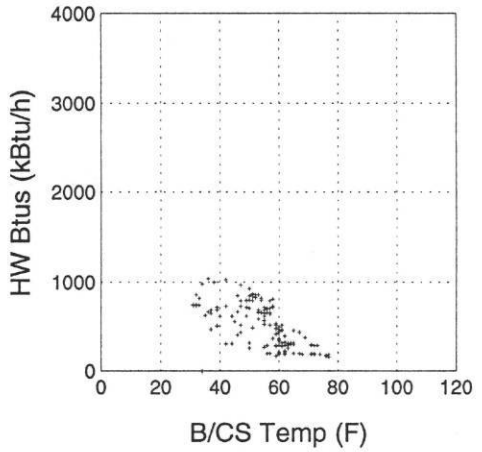

B/CS Solar Radiation (W/m2)
1000
800
600
400
200
0
6202
6209
Langford A Beginning 12-24-1996

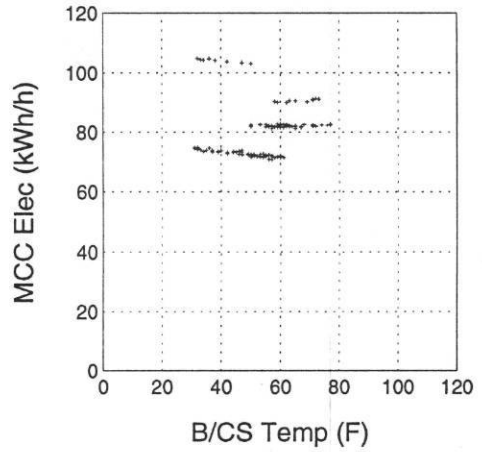

ChW Btus (kBtu/h)
4000
3000
2000
1000
0
6202
6209
Langford A Beginning 12-24-1996


HW Btus (kBtu/h)
4000
3000
2000
1000
0
6202
6209
Langford A Beginning 12-24-1996

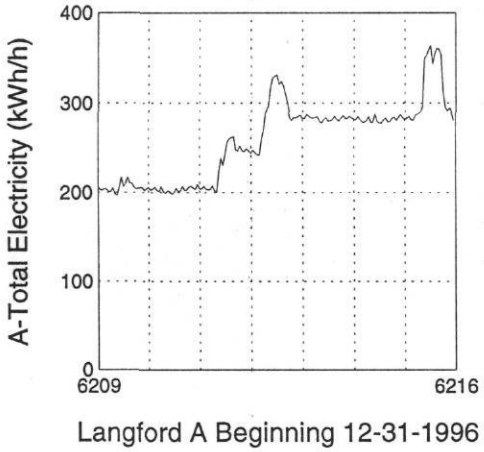

MCC Elec (kWh/h)
120
100
80
60
40
20
0
6202
6209
Langford A Beginning 12-24-1996

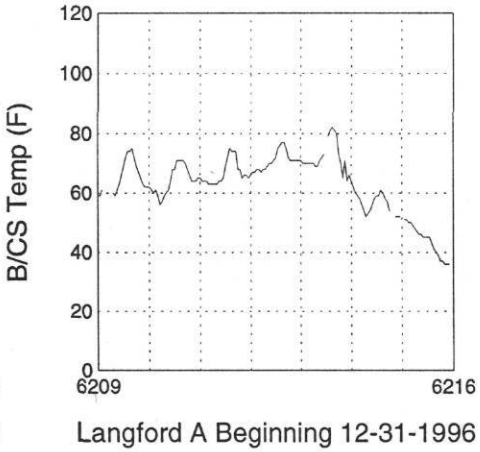

ChW Btus (kBtu/h)
4000
3000
2000
1000
0
0
20
40
60
80
100
120
B/CS Temp (F)

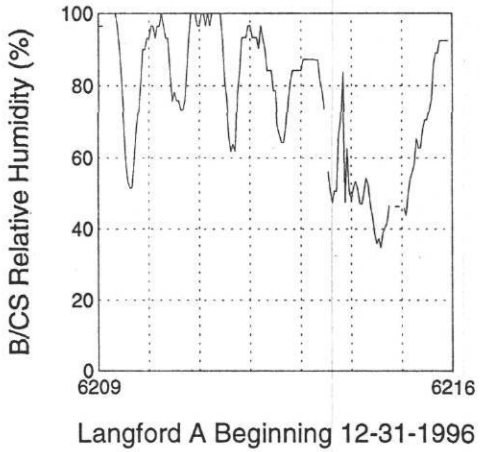

HW Btus (kBtu/h)
4000
3000
2000
1000
0
0
20
40
60
80
100
120
B/CS Temp (F)

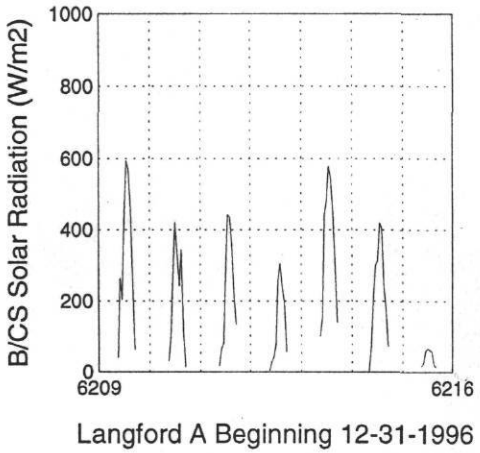

MCC Elec (kWh/h)
120
100
80
60
40
20
0
0
20
40
60
80
100
120
B/CS Temp (F)

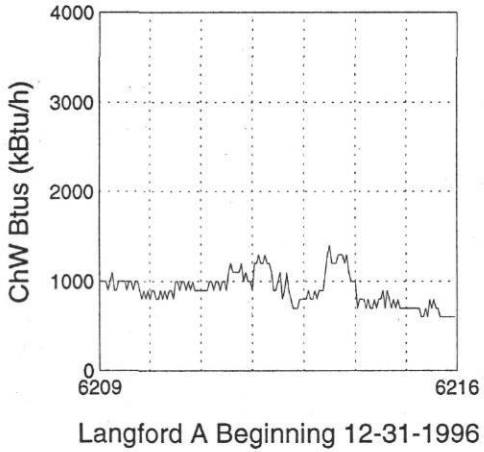
Site 494 Page 1

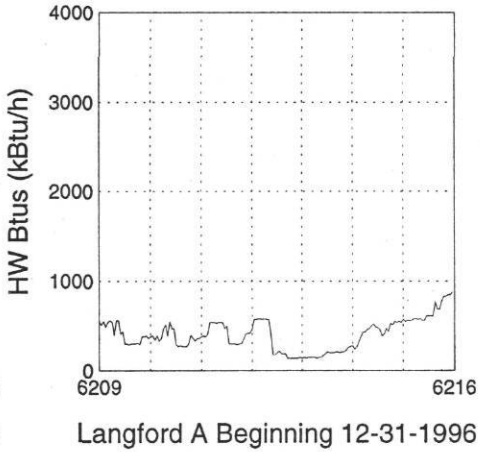


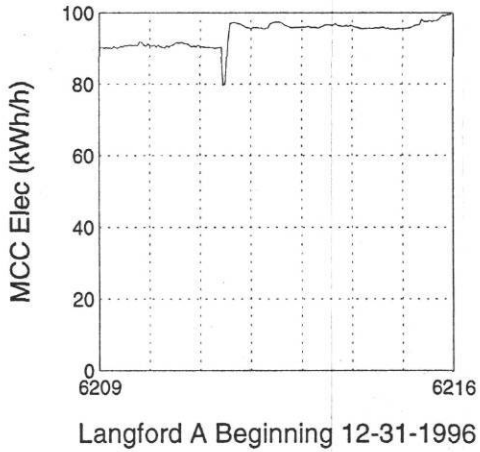


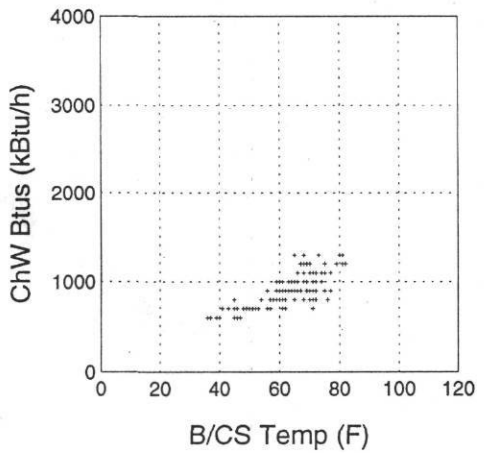


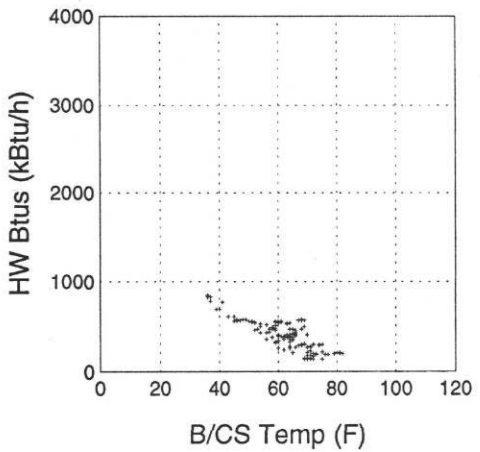


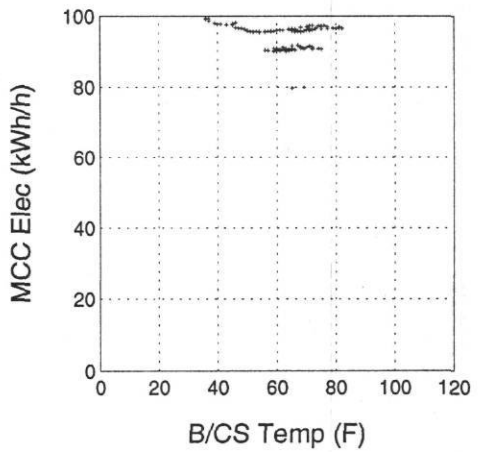












Langford Arch Bldg B

Texas A&M University
69,950 square feet

Site Contact

Mr. Charles Darnell, Jr.
Physical Plant Administration
Texas A&M University
(409) 845–5318
Gene Stewart
(409) 845–5511

ESL Metering Contact

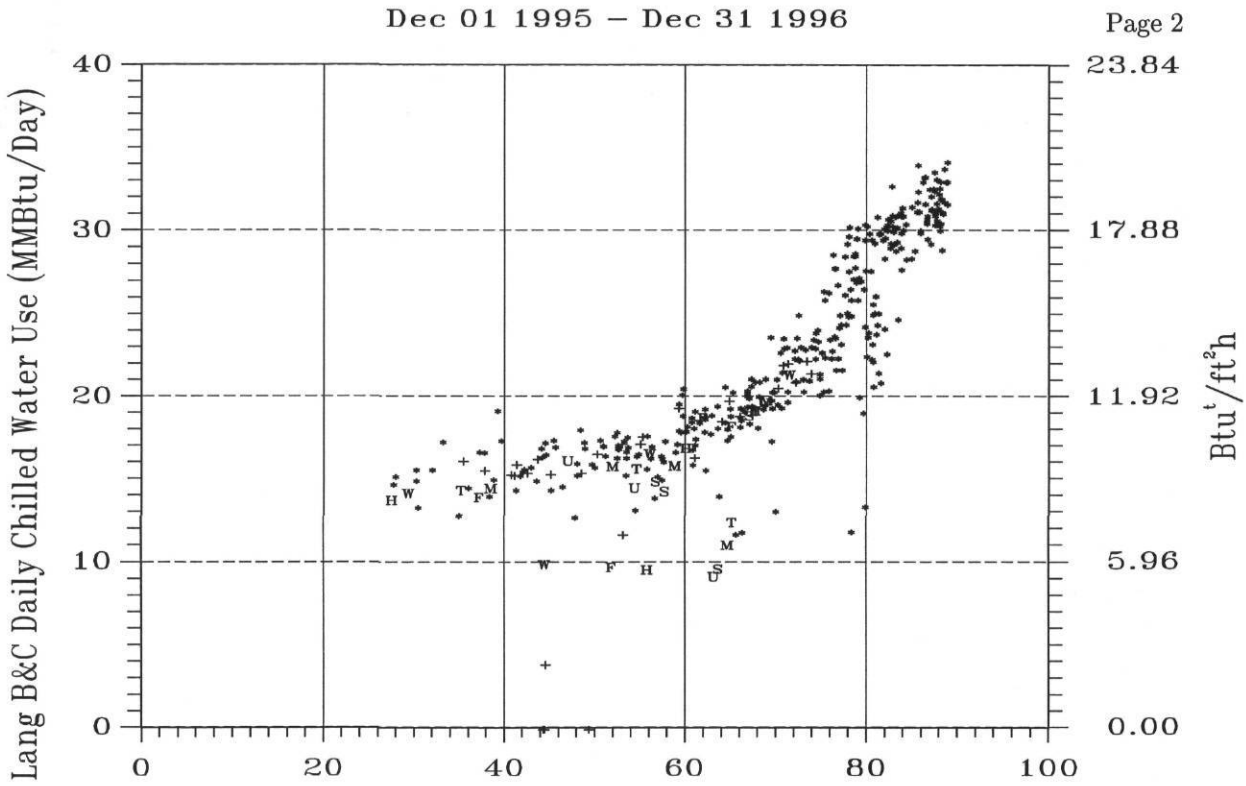
Namir Saman
053A WERC
Texas A&M University
College Station, TX 77843-3123
(409) 845–9213

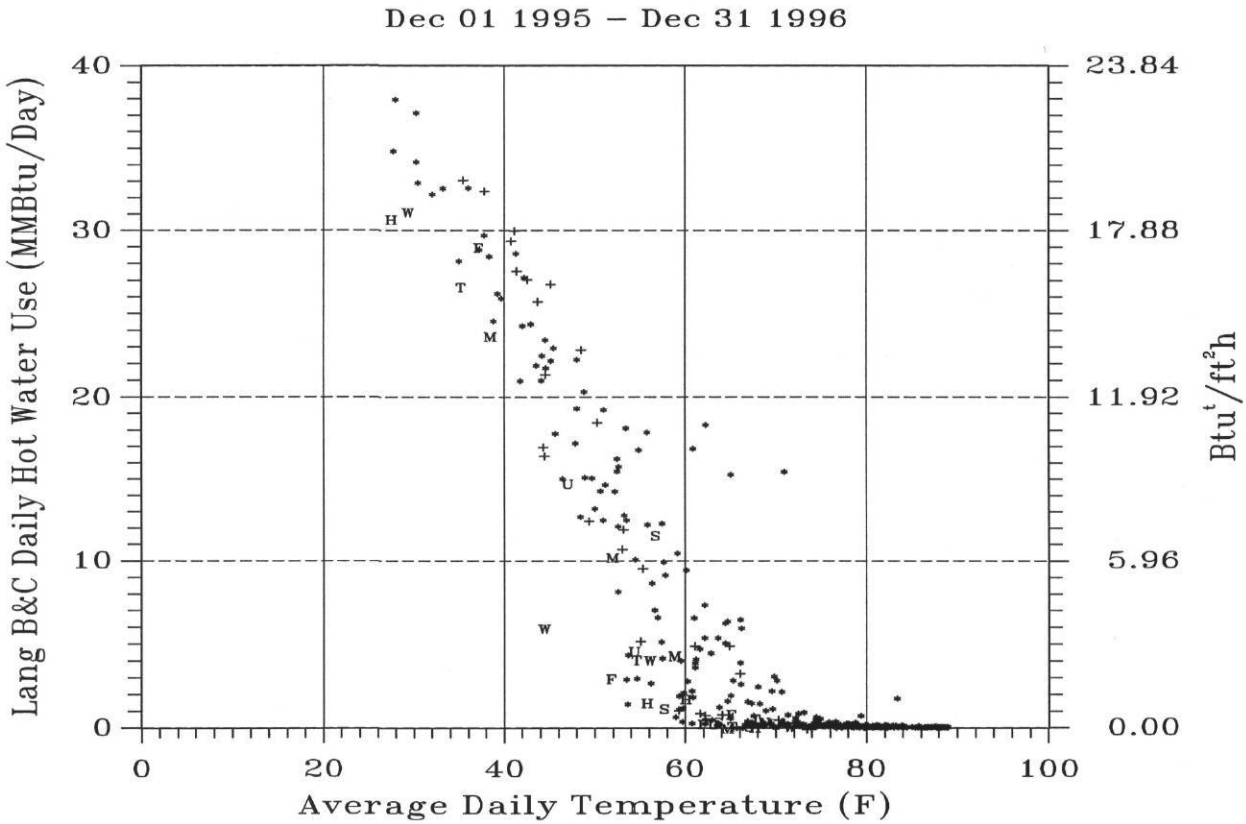
Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	84421 kWh	100	$0.02788	$2354
Peak 60 Minute Demand	172 kW	100	-	-
Chilled Water	463.9 MMBtu	100	$4.670	$2167
Hot Water	240.4 MMBtu	100	$4.750	$1142

Peak 60 minute demand was recorded at 1200 Monday 12/16/96.
There were 744 hours in this month.

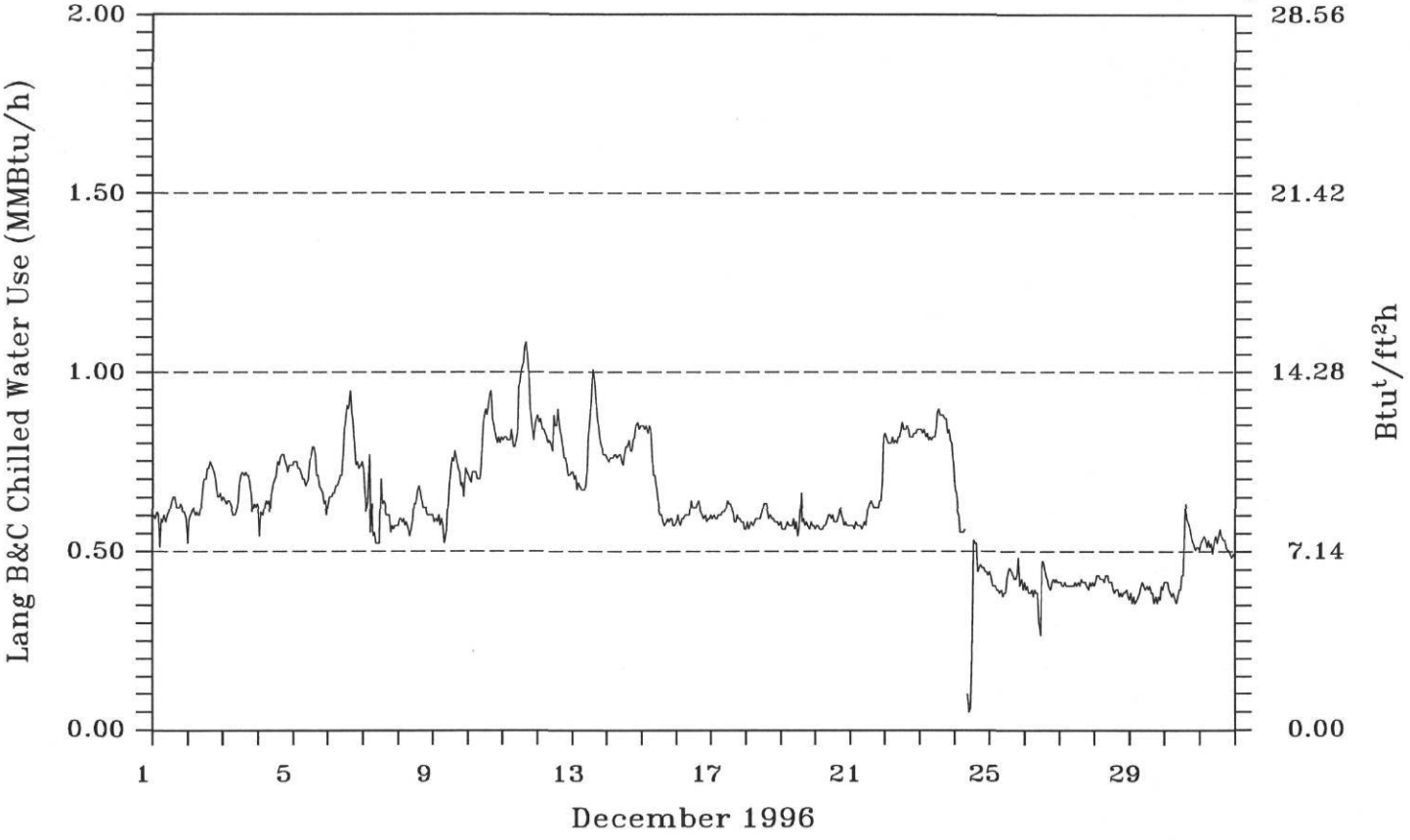
Comments

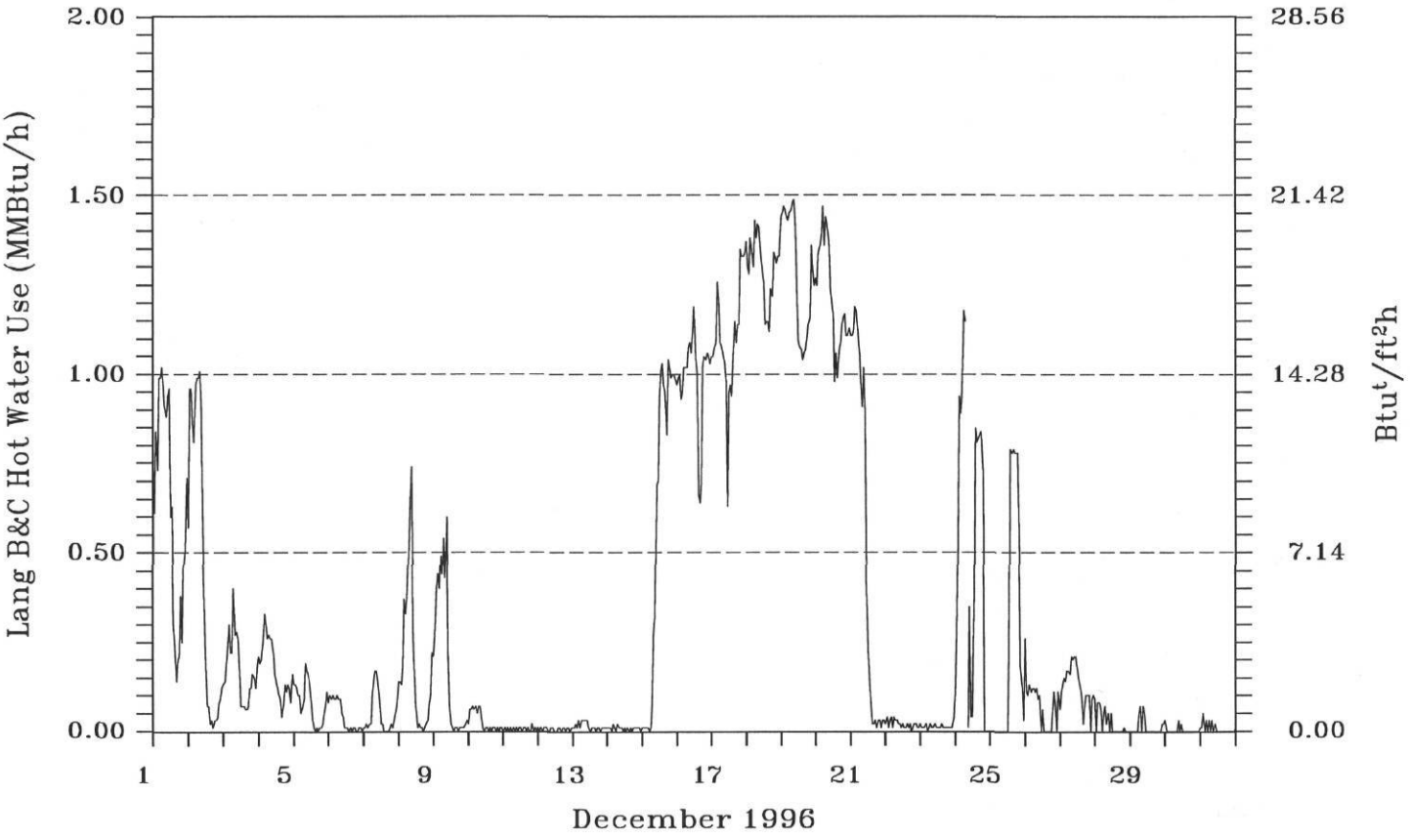




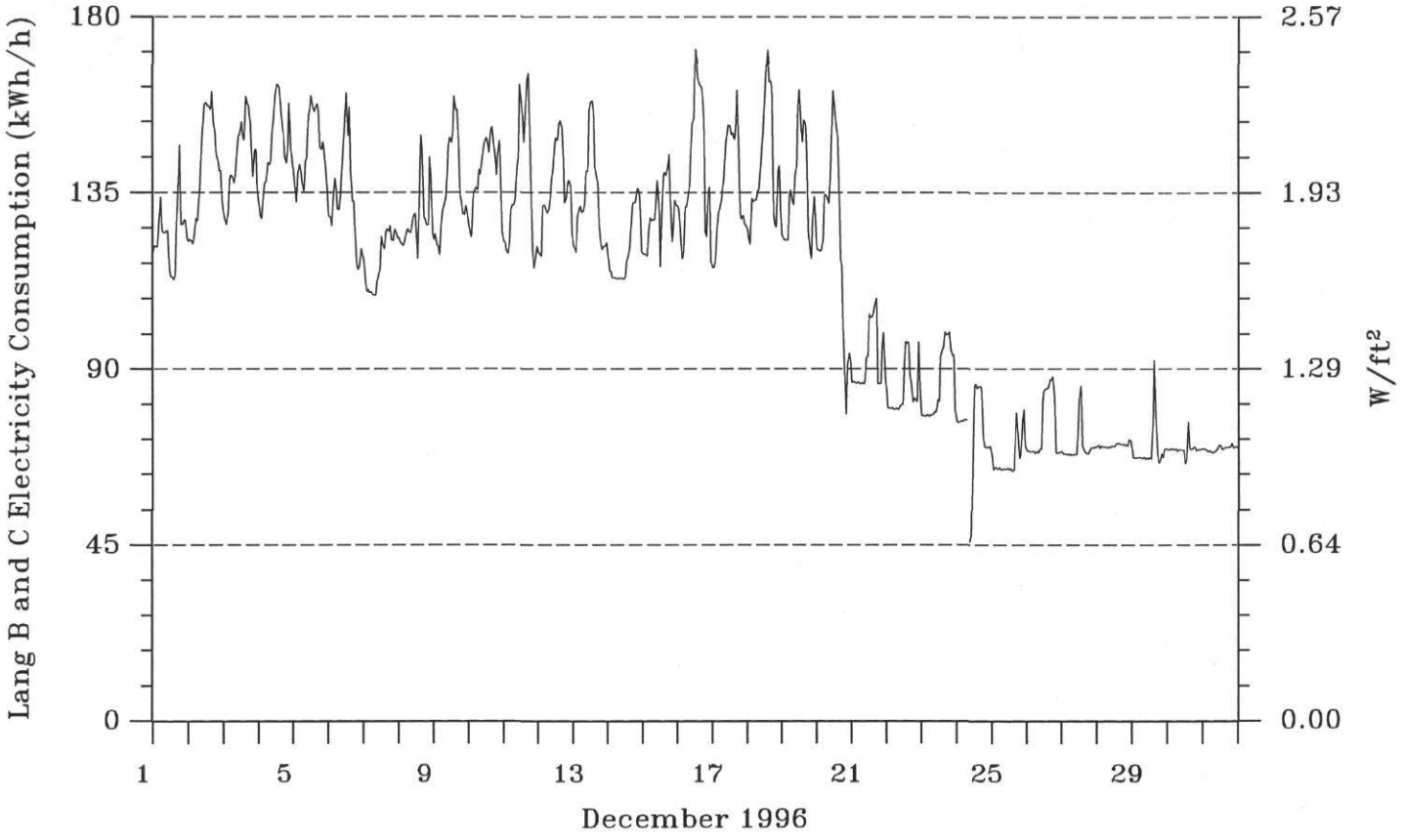
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

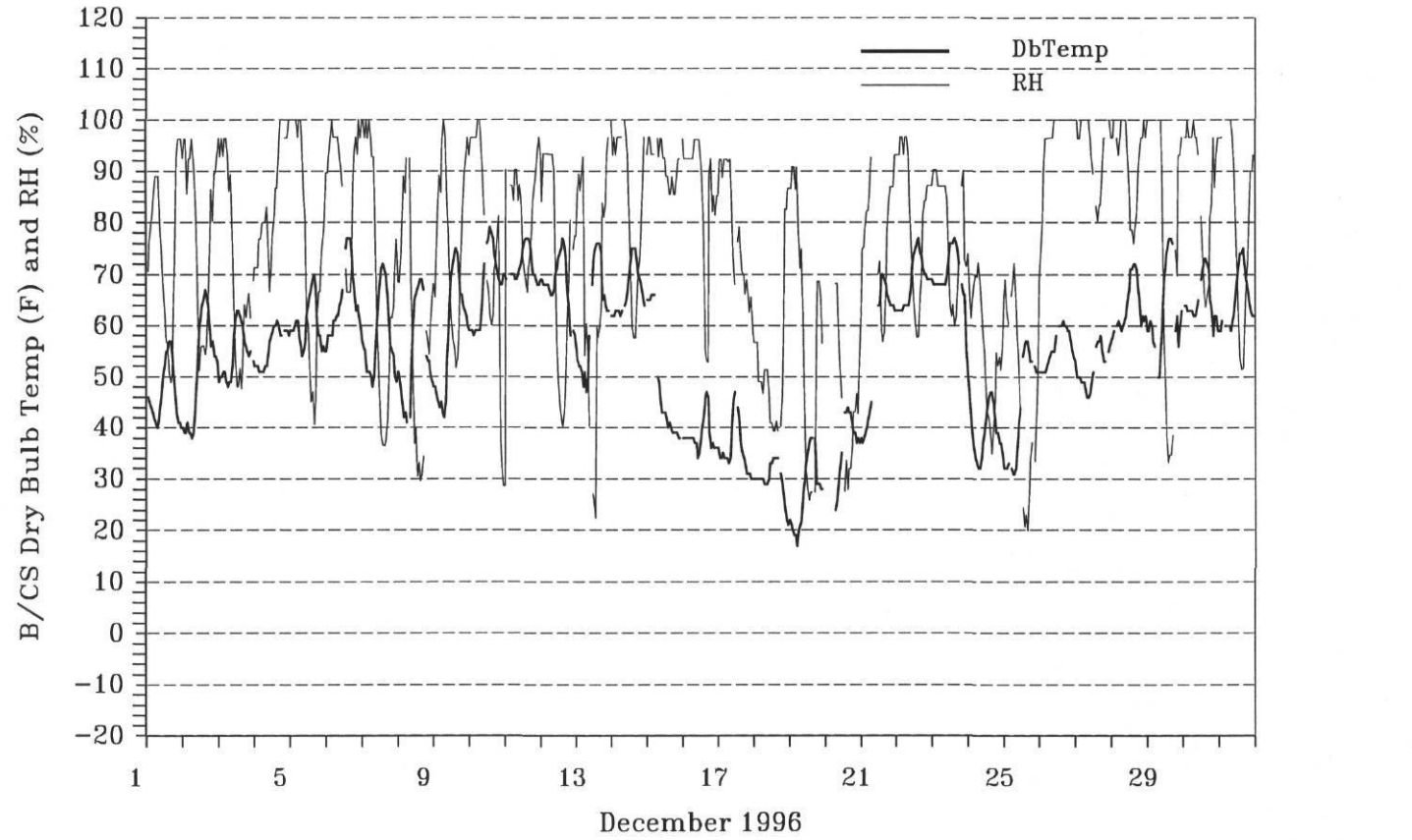
Points from this month last year are shown as +.
All other points are shown as *.



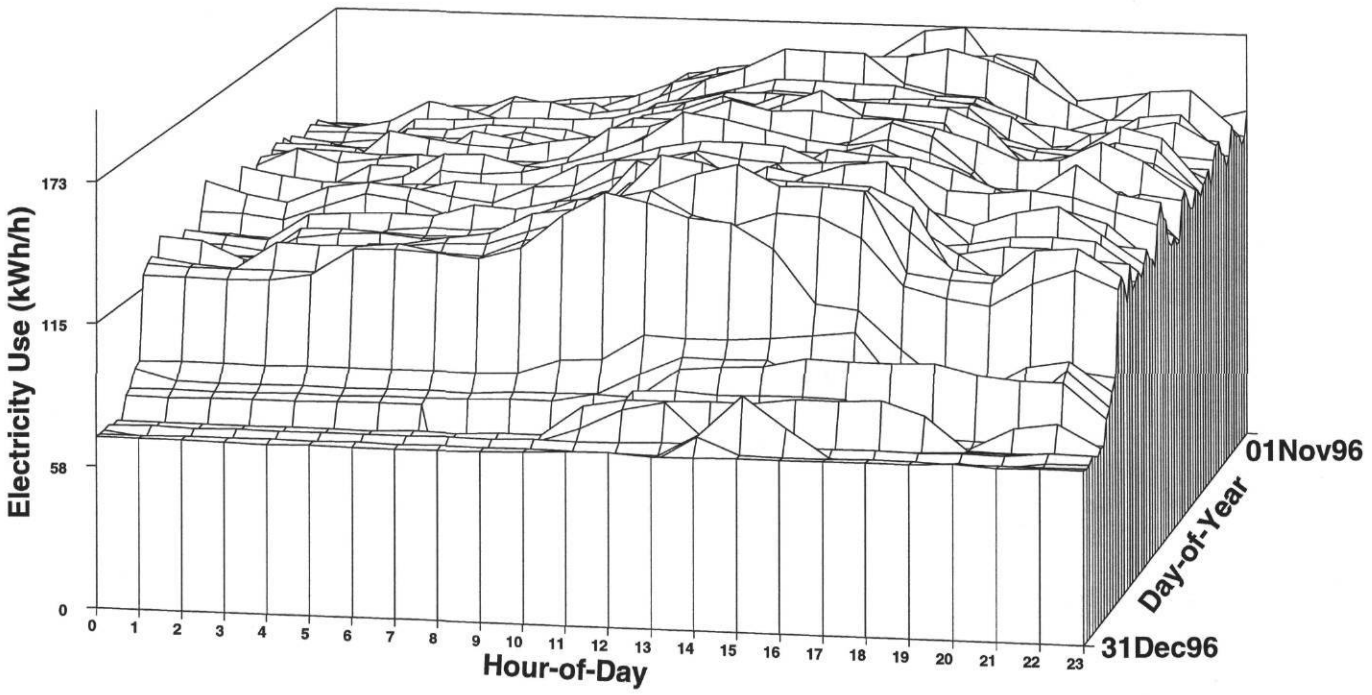


Langford Arch Bldg B - Texas A&M University - December 1996

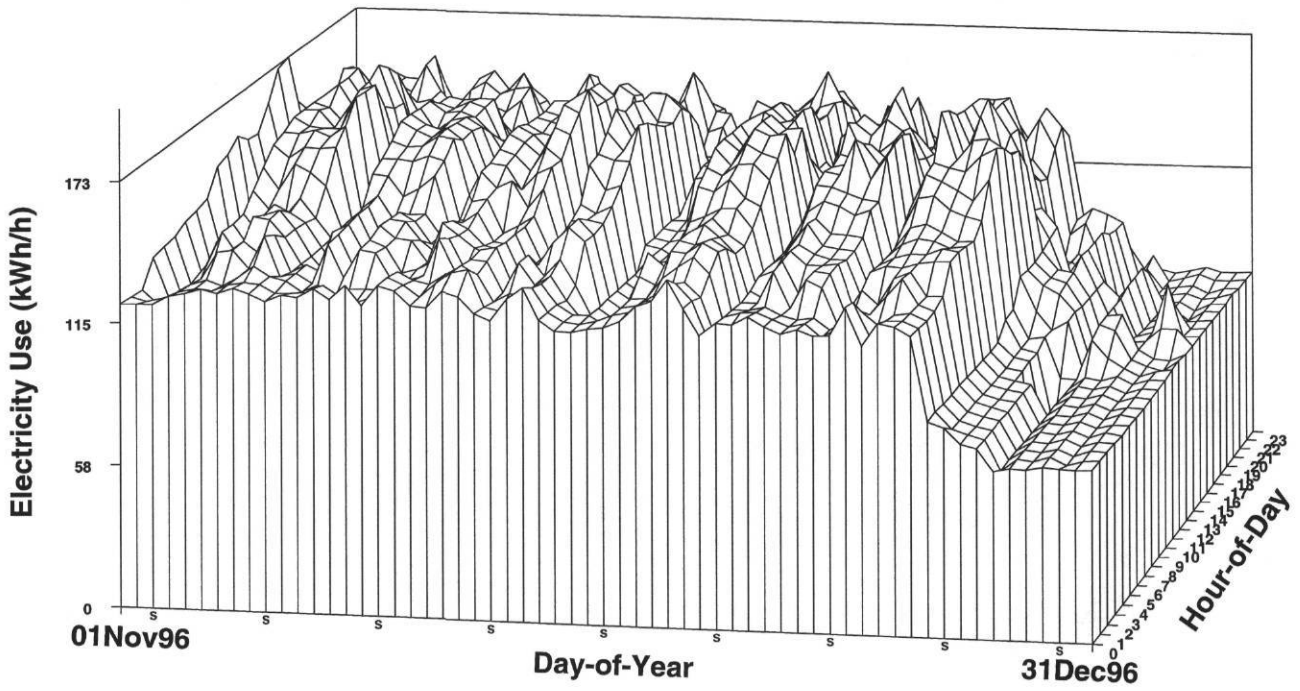

Lang B and C Electricity Consumption (kWh/h)
180
135
90
45
0
2.57
1.93
1.29
0.64
0.00
W/ft²
1
5
9
13
17
21
25
29
December 1996


B/CS Dry Bulb Temp (F) and RH (%)
DbTemp
RH
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
1
5
9
13
17
21
25
29
December 1996

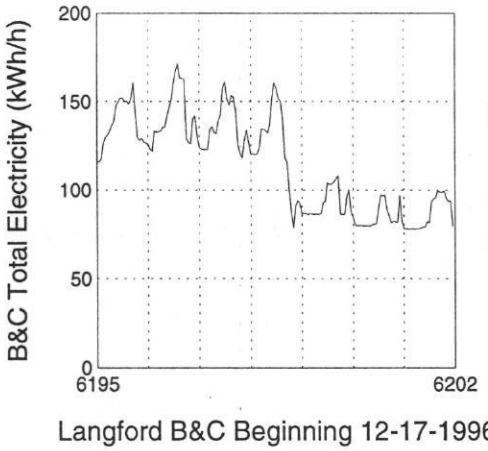
Whole–Building Electric

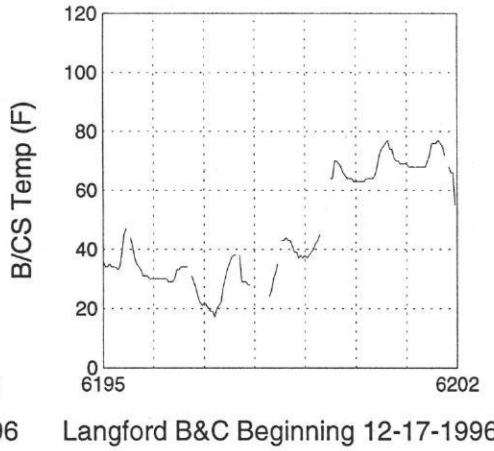


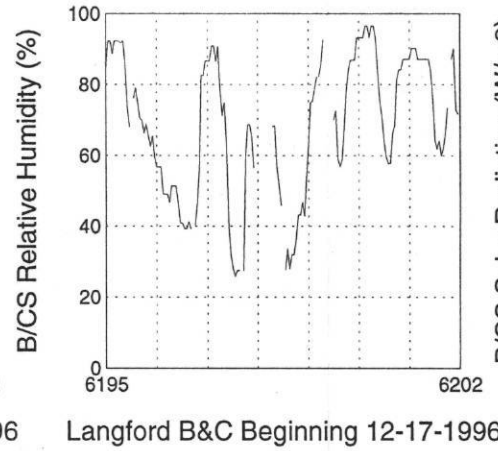
Whole–Building Electric

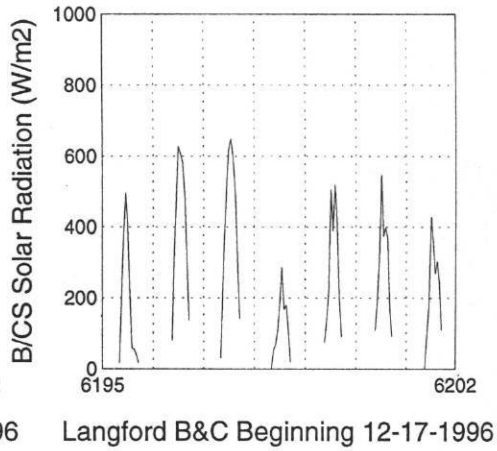


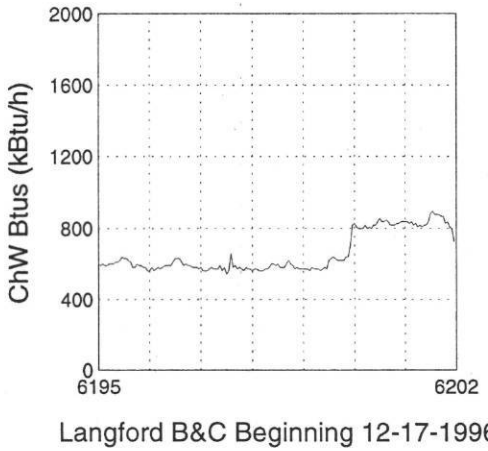
Sundays are marked with an "S"

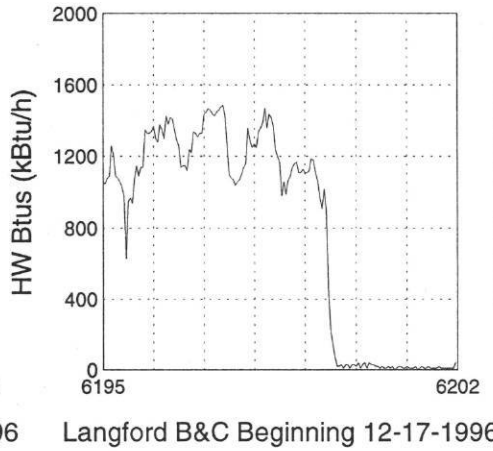

B&C Total Electricity (kWh/h)
200
150
100
50
0
6195
6202
Langford B&C Beginning 12-17-1996

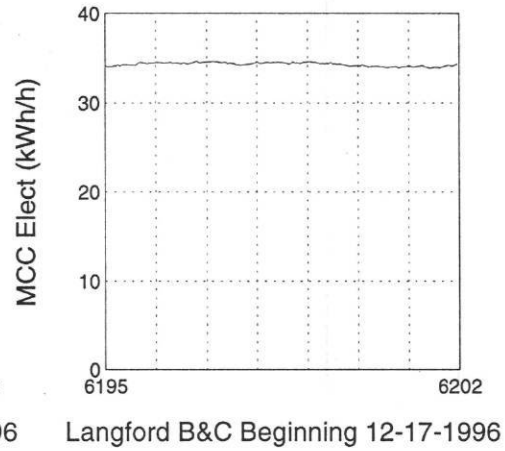

B/CS Temp (F)
120
100
80
60
40
20
0
6195
6202
Langford B&C Beginning 12-17-1996

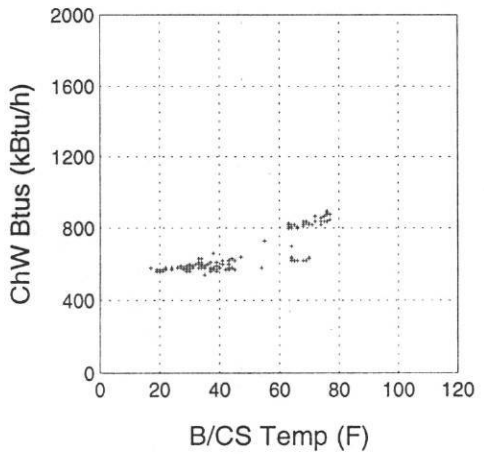

B/CS Relative Humidity (%)
100
80
60
40
20
0
6195
6202
Langford B&C Beginning 12-17-1996

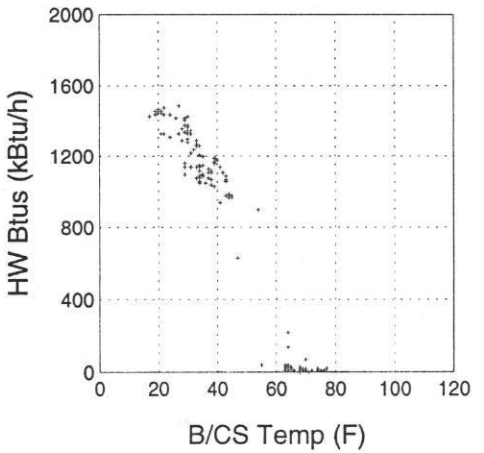

B/CS Solar Radiation (W/m2)
1000
800
600
400
200
0
6195
6202
Langford B&C Beginning 12-17-1996

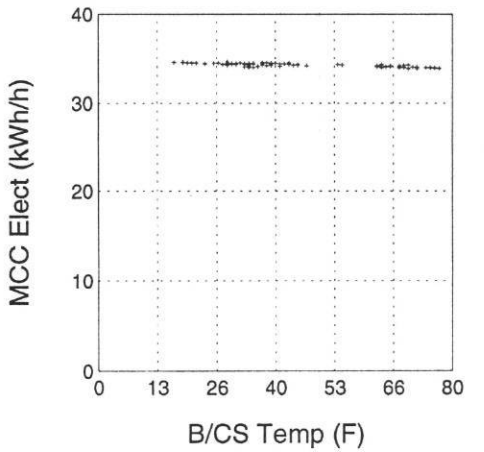

ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
6195
6202
Langford B&C Beginning 12-17-1996

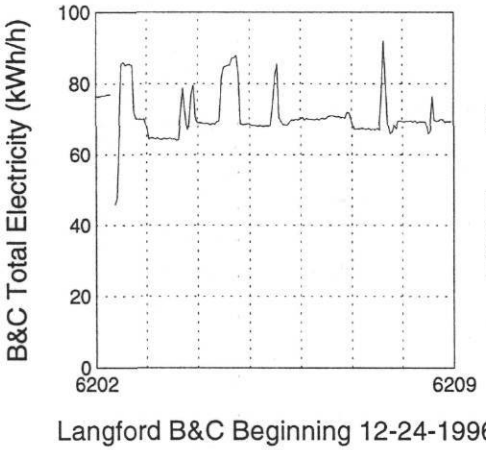

HW Btus (kBtu/h)
2000
1600
1200
800
400
0
6195
6202
Langford B&C Beginning 12-17-1996

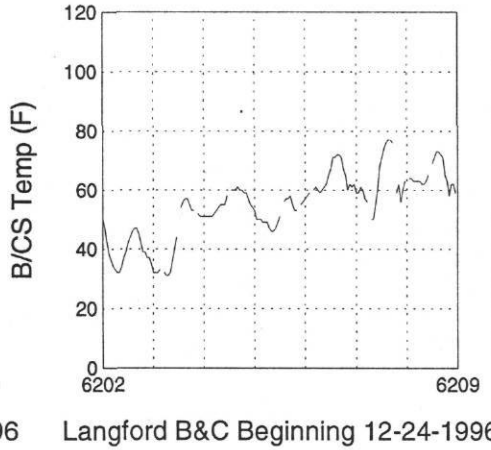

MCC Elect (kWh/h)
40
30
20
10
0
6195
6202
Langford B&C Beginning 12-17-1996

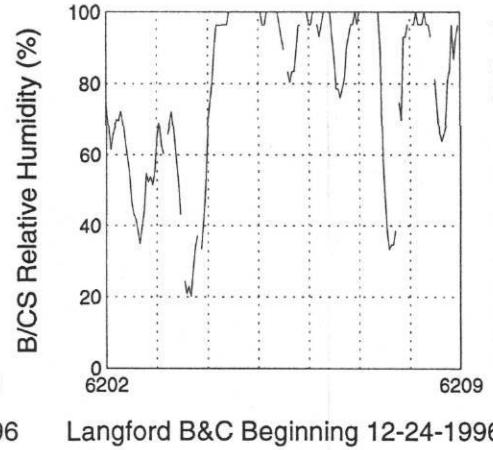

ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
B/CS Temp (F)

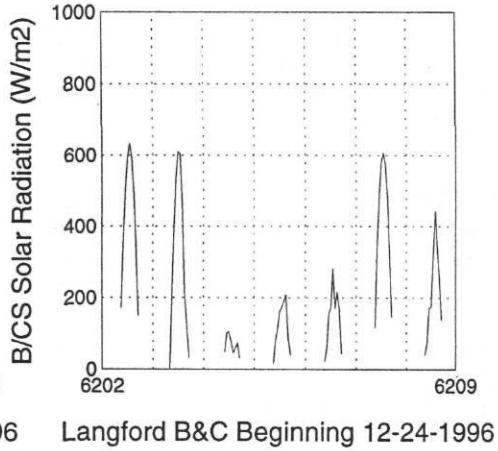

HW Btus (kBtu/h)
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
B/CS Temp (F)

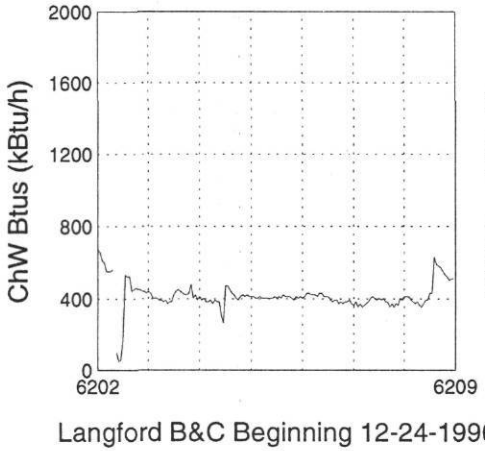

MCC Elect (kWh/h)
40
30
20
10
0
0
13
26
40
53
66
80
B/CS Temp (F)

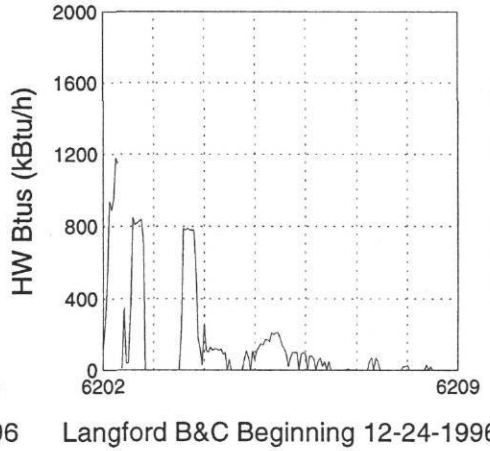

B&C Total Electricity (kWh/h)
100
80
60
40
20
0
6202
6209
Langford B&C Beginning 12-24-1996

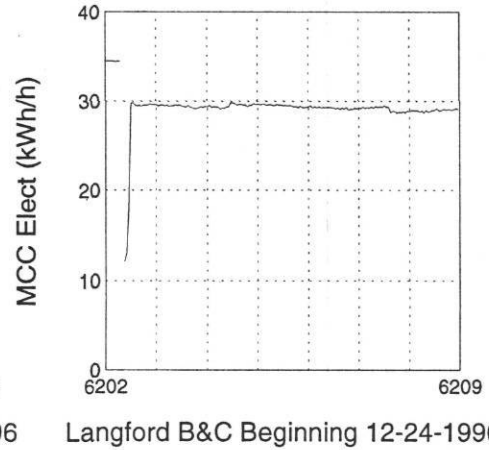

B/CS Temp (F)
120
100
80
60
40
20
0
6202
6209
Langford B&C Beginning 12-24-1996

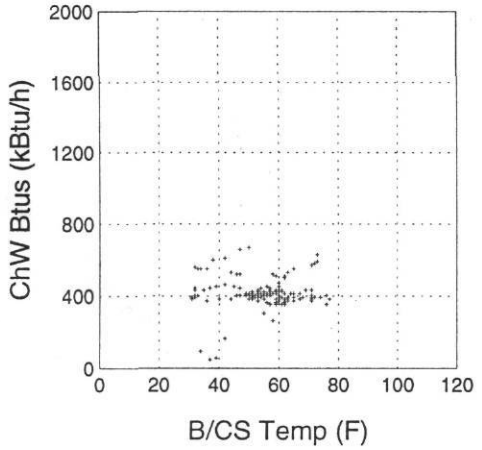

B/CS Relative Humidity (%)
100
80
60
40
20
0
6202
6209
Langford B&C Beginning 12-24-1996

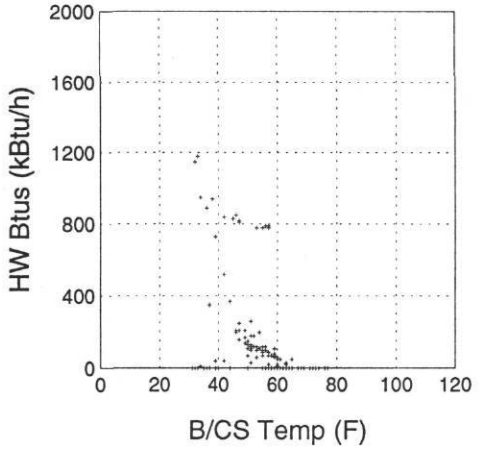

B/CS Solar Radiation (W/m2)
1000
800
600
400
200
0
6202
6209
Langford B&C Beginning 12-24-1996

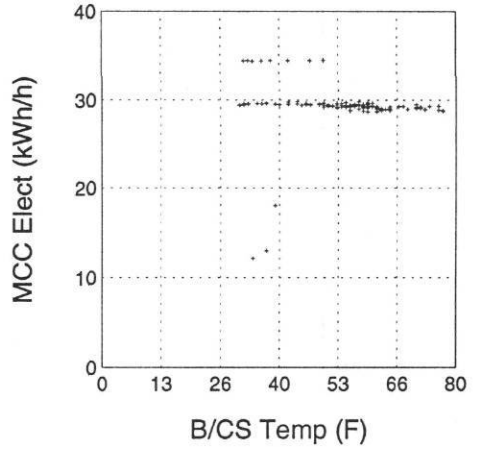

ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
6202
6209
Langford B&C Beginning 12-24-1996

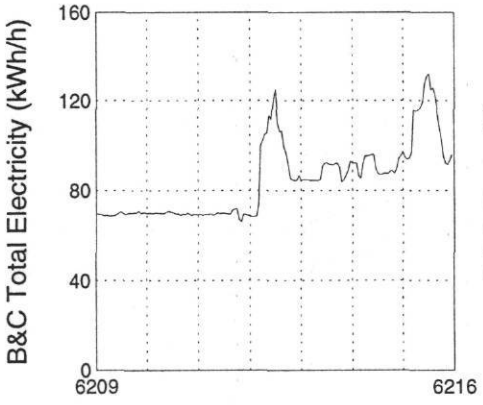

HW Btus (kBtu/h)
2000
1600
1200
800
400
0
6202
6209
Langford B&C Beginning 12-24-1996

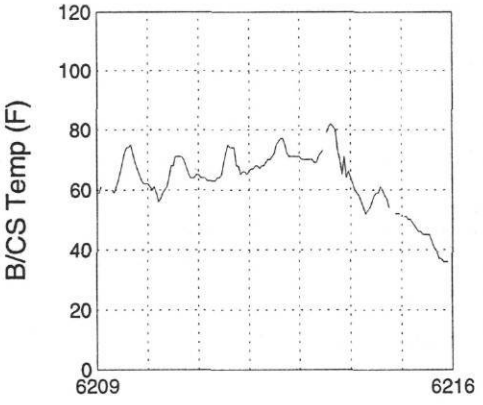

MCC Elect (kWh/h)
40
30
20
10
0
6202
6209
Langford B&C Beginning 12-24-1996

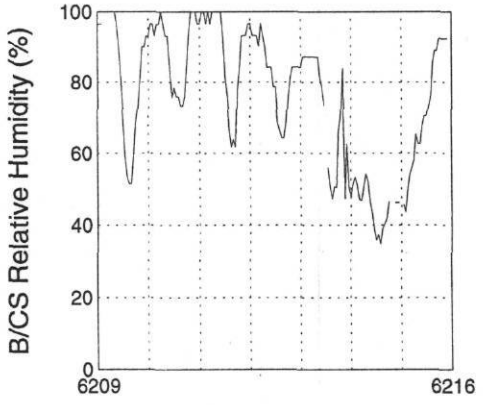

ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
B/CS Temp (F)

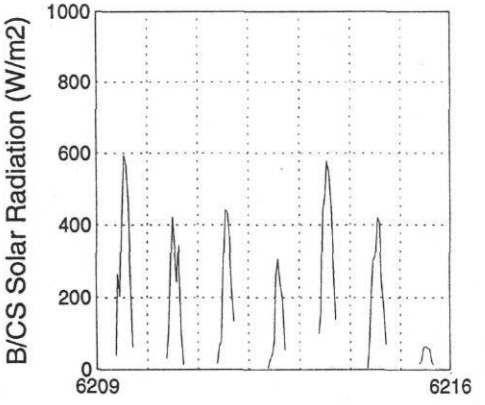

HW Btus (kBtu/h)
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
B/CS Temp (F)

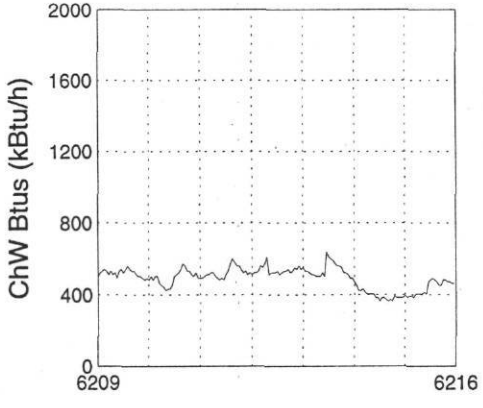

MCC Elect (kWh/h)
40
30
20
10
0
0
13
26
40
53
66
80
B/CS Temp (F)

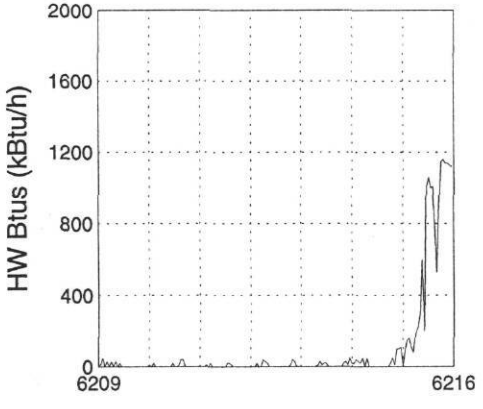

B&C Total Electricity (kWh/h)
160
120
80
40
0
6209
6216
Langford B&C Beginning 12-31-1996

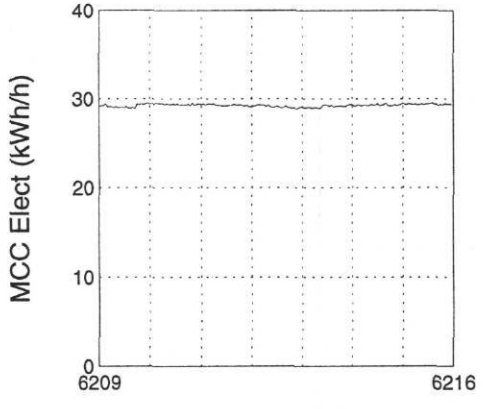

B/CS Temp (F)
120
100
80
60
40
20
0
6209
6216
Langford B&C Beginning 12-31-1996

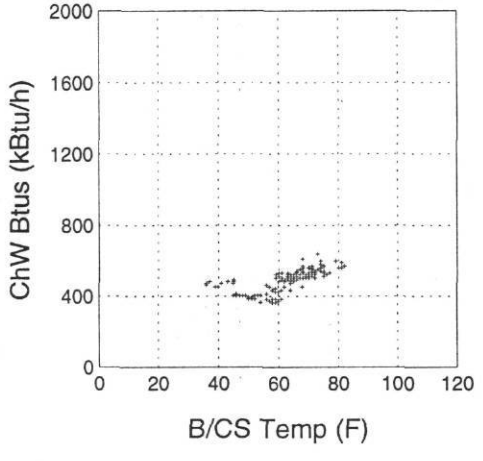

B/CS Relative Humidity (%)
100
80
60
40
20
0
6209
6216
Langford B&C Beginning 12-31-1996

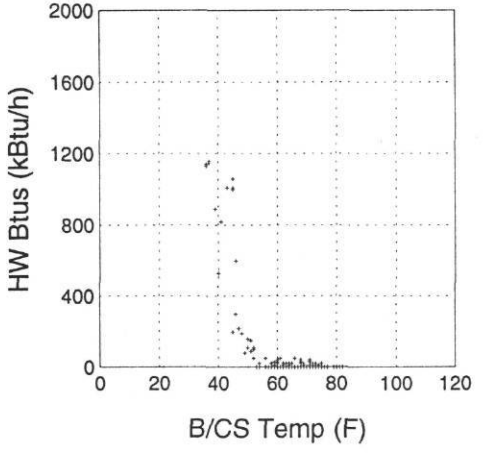

B/CS Solar Radiation (W/m2)
1000
800
600
400
200
0
6209
6216
Langford B&C Beginning 12-31-1996

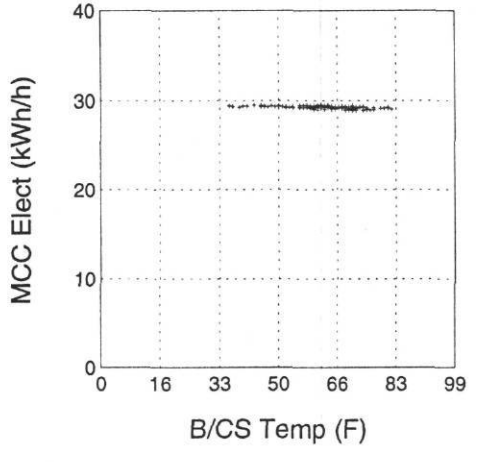

ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
6209
6216
Langford B&C Beginning 12-31-1996


HW Btus (kBtu/h)
2000
1600
1200
800
400
0
6209
6216
Langford B&C Beginning 12-31-1996


MCC Elect (kWh/h)
40
30
20
10
0
6209
6216
Langford B&C Beginning 12-31-1996


ChW Btus (kBtu/h)
2000
1600
1200
800
400
0
0 20 40 60 80 100 120
B/CS Temp (F)


HW Btus (kBtu/h)
2000
1600
1200
800
400
0
0 20 40 60 80 100 120
B/CS Temp (F)


MCC Elect (kWh/h)
40
30
20
10
0
0 16 33 50 66 83 99
B/CS Temp (F)