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AN EVALUATION OF ENERGY-SAVING RETROFITS FROM THE TEXAS LOANSTAR PROGRAM

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ABSTRACT

This report discusses the LoanSTAR retrofit savings through December 1993 with an emphasis on the Constant Volume to Variable Air Volume air-handler retrofits. The report also summarizes several key findings about the LoanSTAR program which has 70 sites monitored as of December 1993.

By December 1993, on average, the retrofits in the LoanSTAR program were performing within the expectations of the energy audits as indicated which speaks well of the value of the effort to monitor the savings and feedback the results to the participating agencies. For certain of the sites the retrofits out-performed the estimates by substantial margins (as much as 3 times the estimates), whereas in some cases almost no savings occurred. On average the estimated paybacks of 3.8 years are in the same range as the measured paybacks of 5.06 years. The average investment for the agencies with completed retrofits as of December 1993 was $2.43 per square foot with the largest majority of sites in the $2 to $3 per square foot range.

Thirteen sites which contained Constant Volume to Variable Air Volume air-handler retrofits were further evaluated to determine why some sites were good performers and why some were not. A detailed analysis of the hourly before/after air-handler electricity consumption indicates that fan over-sizing plays a major role in the cost effectiveness of these retrofits. In the performing sites the fan over-sizing was 3 to 6 times what is needed by the VAV system in the post-retrofit period. In the non-performing sites the fan over-sizing was about 2 times what the VAV system uses in the post-retrofit period.

PREFACE

This report has been prepared for the United States Environmental Protection Agency through the Global Change Division. The purpose of this report is to document the retrofit savings, in particular the Constant Volume to Variable Air Volume air-handler retrofits in the Texas LoanSTAR program so that useful information can be obtained to guide the EPA's Energy Star program.

This report has been prepared by Jeff Haberl, Tia Heneghan, Richard Sieggreen, and Jennifer Sims and includes significant input from Dr. David Claridge. Editing assistance was provided by Jean Mahoney.

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EXECUTIVE SUMMARY

This report discusses the LoanSTAR retrofit savings with an emphasis on the Constant Volume to Variable Air Volume air-handler retrofits. The report summarizes several key facts about the LoanSTAR program which has 70 sites monitored as of December 1993. These 70 sites include 201 buildings with a total floor area of 18,262,000 square feet, and includes $36.8 million in retrofits (310 Energy Cost Reduction Measures) which are estimated to generate $9.6 million in annual energy savings.

Certain patterns begin to emerge as we examine the broad range of retrofits that have been applied to agencies participating in the LoanSTAR program. On average the retrofits in the LoanSTAR program are performing within the expectations of the energy audits. This speaks well of the effort to monitor the savings and to provide feedback about the results to the participating agencies. For some of the sites the retrofits outperformed the estimates by substantial margins (as much as 3 times the estimates), whereas in some cases almost no savings occurred. The estimated 3.8 year payback compared well to the average measured paybacks of 5.06 years. Much of this difference can be attributed to a few large sites where measured payback periods drifted upwards to as much as 80 years because retrofits were not performing!

Some clear patterns begin to emerge as to why some of the retrofits performed and why others did not. For example, the data indicate that the potential for retrofit savings diminishes when the annual energy bill is less than $0.50 to $1.00 per square foot of conditioned area. The average investment for the agencies with completed retrofits as of December 1993 was $2.43 per square foot with the largest majority of sites in the $2 to $3 per square foot range.

Thermal storage systems are the most expensive type of retrofit in the LoanSTAR program at $4.13 per square foot. Six retrofits (i.e., VAV, VFD, HVAC, Other, Co-generation, and EMCS) fall within the $0.50 to $1.50 per square foot range and six

retrofits fall below the $0.50/sqft. range (chillers, boilers, pump replacements, motor retrofits, lighting retrofits and occupancy sensors). Average ratios of retrofit costs to post-retrofit annual utility costs were 1.34.

Thirteen sites were further investigated that contained CV to VAV air-handler retrofits to determine why some sites were good performers and why some were not. Good performers were arbitrarily chosen as those sites where measured performance was within 100 to 200% of the audit estimate. Poor performance was chosen as those sites where measured savings was 50% or less of the audit estimated performance.

A detailed analysis of the hourly before/after air-handler electricity consumption indicates that fan over-sizing plays a major role in the cost effectiveness of the retrofit. In the performing sites the fan over-sizing was 3 to 6 times what is needed by the VAV system in the post-retrofit period. In the non-performing sites the fan over-sizing was about twice what the VAV system uses in the post-retrofit period.

Clearly, one additional feature that comes out of this analysis is the importance of taking into account the presence of on/off performance in the pre-retrofit period. In the LoanSTAR program this was one of the major causes of the inaccuracies in the energy audits.

Several other features have been identified during the analysis that may prove useful for future CV to VAV air-handler retrofits. First, it is important to commission the VAV system once it has been installed and prevent the building operators from raising the static pressure to the point where the system no longer functions as a VAV. Second, it appears that a good average range of post-retrofit VAV energy use is about 0.3 to 0.7 W/sqft. of conditioned area. Perhaps this can be useful for improving future energy audits.

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This report would not have been possible without the data that have been routinely collected to measure savings in the LoanSTAR program. The Texas LoanSTAR program is sponsored by Texas State Energy Conservation Office in Austin, Texas, Tobin Harvey -- Director. Special thanks are also due to the LoanSTAR computer support staff, including: Robert Sparks, Ron Chambers, and Chris Cunningham. Thanks also to Jean Mahoney of the ESL staff for helpful editing.

TABLE OF CONTENTS

ABSTRACT i

PREFACE ii

EXECUTIVE SUMMARY iv

ACKNOWLEDGMENTS vi

1.0 INTRODUCTION 1

2.0 OVERVIEW AND OBJECTIVES OF THE STUDY
- 2.1 LoanSTAR Overview 1
- 2.2 Objectives of the Study 2

3.0 RESULTS
- 3.1 Analysis of the Overall Retrofit Savings 3
- 3.2 Constant Volume to Variable Air Volume Retrofits 58

4.0 REFERENCES 77

APPENDIX 78

LIST OF TABLES

Table 1: ECRM Categorized By The 13 EPA Types..... 5
Table 2a: Audit Estimated Cost By Types Of ECRMs In The LoanSTAR Program..... 6
Table 2b: Audit Estimated Cost Per Square Foot By Types Of ECRMs In The LoanSTAR Program..... 8
Table 2c: Actual Costs By Types Of ECRMs In The LoanSTAR Program..... 10
Table 2d: Actual Costs Per Square Foot By Types Of ECRMs In The LoanSTAR Program..... 12
Table 3: Sites Monitored By LoanSTAR As Of December 1993.... 17
Table 4: Measured Savings Compared To Estimated Savings For 1993..... 20
Table 5: Summary Of Measured Savings To Estimated Savings For 1993..... 32
Table 6: Summary Of Estimated Costs, Measured Savings & Estimated Savings..... 39

LIST OF FIGURES

Figure 1: Sites Monitored Under LoanSTAR As Of December, 1993 4
Figure 2: Audit Estimated Cost For Retrofits As December 1993... 15
Figure 3: Status of the LoanSTAR Retrofits as of December 1993. 16
Figure 4: Measured Savings Compared To Estimated Savings For 1993 30
Figure 4b: Measured Savings Compared To Estimated Savings.... 31
Figure 5: Measured Saving Compared To 1993 Post-Retrofit Annual Utility Costs 34
Figure 6: Measured Savings And Pre-Retrofit Annual Utility Costs ($/Sqft) 35
Figure 7: Estimated Retrofit Costs Compared To Estimated And Measured Savings 36
Figure 8: Estimated Costs Per Square Foot Of Conditioned Area.. 37
Figure 9: Estimated Costs Compared To The 1993 Utility Costs... 38
Figure 10: Site Area 41
Figure 11: Estimated Cost Per Square Foot Of Conditioned Area (VFD To AHU) 43
Figure 12: Estimated Cost Per Square Foot Of Conditioned Area (HVAC VAV) 45
Figure 13: Estimated Cost Per Square Foot Of Conditioned Area (HVAC Other) 46
Figure 14: Estimated Cost Per Square Foot Of Conditioned Area (Pumping Systems) 47
Figure 15: Estimated Cost Per Square Foot Of Conditioned Area (Motor Retrofits) 48
Figure 16: Estimated Cost Per Square Foot Of Conditioned Area (Lighting Modifications) 50
Figure 17: Estimated Cost Per Square Foot Of Conditioned Area (Occupancy Controls) 51
Figure 18: Estimated Cost Per Square Foot Of Conditioned Area (Thermal Storage) 52
Figure 19: Estimated Cost Per Square Foot Of Conditioned Area (Chiller Modifications) 53
Figure 20: Estimated Cost Per Square Foot Of Conditioned Area (Boiler Modifications) 55
Figure 21: Estimated Cost Per Square Foot Of Conditioned Area (EMCS) 56
Figure 22: Estimated Cost Per Square Foot Of Conditioned Area (Other Retrofits) 57
Figure 23: Estimated Average Cost Of Different ECRM Category Per Square Foot Of Conditioned Area 59

LIST OF FIGURES (CONT)

Figure 24: Measured Savings (1993) Compared To Estimated Annual Savings For CV To VAV Retrofits..... 60
Figure 25: Measured Saving Compared To 1993 Post-retrofit Annual Utility Costs For CV To VAV Retrofits..... 61
Figure 26: Measured Savings And Pre-Retrofit Annual Utility Costs ($/Sqft) For CV To VAV Retrofits..... 62
Figure 27: Estimated Retrofit Costs Compared To Estimated And Measured Savings For CV To VAV Retrofits..... 63
Figure 28: Estimated Costs Per Square Foot Conditioned Area For CV To VAV Retrofits..... 64
Figure 29: Estimated Costs Compared To The 1993 Utility Costs For CV To VAV Retrofits..... 65
Figure 30: Hourly Before/After Analysis Of Cv To VAV Retrofits As A Percent Of Manufacturer's Rated Full Load..... 67

1.0 INTRODUCTION

This report analyzes the savings from energy conservation retrofits in the Texas LoanSTAR program in buildings that had retrofits completed and savings reported as of December 1993. In the first section the objectives of the LoanSTAR program are described. Following this is a discussion of the overall savings and a comparison of the measured savings to the audit estimated savings for the retrofits completed by December 1993. The next section discusses thirteen sites where constant volume (CV) to variable air volume (VAV) air-handler retrofits were implemented. This section emphasizes both the pre-retrofit and post-retrofit air-handler electricity use to provide insight into the effective of the retrofits. The final section summarizes the findings of this report. In the additional information is provided for the thirteen sites which received CV to VAV retrofits.

2.0 OVERVIEW AND OBJECTIVES OF THE STUDY

2.1 LoanSTAR Overview

In 1988, the Governor's Energy Management Center (GEMC)[1] of Texas received approval from the U. S. Department of Energy to establish a $98.6 million statewide retrofit demonstration revolving loan program, the LoanSTAR (Loan to Save Taxes and Resources) program. The LoanSTAR program uses a revolving loan financing mechanism to fund energy-conserving retrofits in state, public school, and local government buildings. Retrofit projects are identified by energy audits conducted by engineering teams under contract to the GEMC. Each retrofit competes for funds on the basis of the estimated payback period, ability to repay the loan through energy savings, engineering assessment of the viability of the retrofit, and the feasibility of metering the project effectively. Public

[1] GEMC is an acronym for the Texas Governor's Energy Management Center, the predecessor to the Texas State Energy Conservation Office.

sector institutions participating in the program must repay the loans according to estimated energy savings in four years or less (Verdict et al. 1990).

As part of this program, a statewide energy Monitoring and Analysis Program (MAP) has been established. The major objectives of the LoanSTAR MAP are: 1) to verify energy and dollar savings of the retrofits, 2) to reduce energy costs by identifying operational and maintenance improvements, 3) to improve retrofit selection in future rounds of the LoanSTAR program, and 4) to initiate a data base of energy use in institutional and commercial buildings located in Texas (Turner et al. 1990; Claridge et al. 1991).

The projects funded by LoanSTAR include retrofits to lighting, HVAC systems, the building shell or envelope, electric motors, energy management and control systems, boilers, and thermal energy recovery systems. Retrofits using alternative or renewable energy systems and load management also are considered.

2.2 Objectives of This Study

This study's first objective is to identify and categorize LoanSTAR Energy Cost Reduction Measures (ECRM) using EPA criteria. These ECRM are then evaluated to determine how well the measured energy savings compared to the audit estimated savings.

The second objective of the study is to explore in greater detail the Constant Volume (CV) to Variable Air Volume (VAV) air-handler retrofits. To accomplish this thirteen sites were chosen for further analysis. Each of these sites has undergone a CV to VAV air-handler retrofits and has sufficient data recorded to facilitate a comparison of the electricity savings that are attributed to the CV to VAV air-handler retrofit.

Discussion of the methods used to gather data, analyze and report savings is beyond the scope of this study. Additional information can be found in the report by Haberl et al.

(1995) and in various other papers and reports available from the Energy Systems Laboratory. A list of publications can be obtained by contacting the authors.

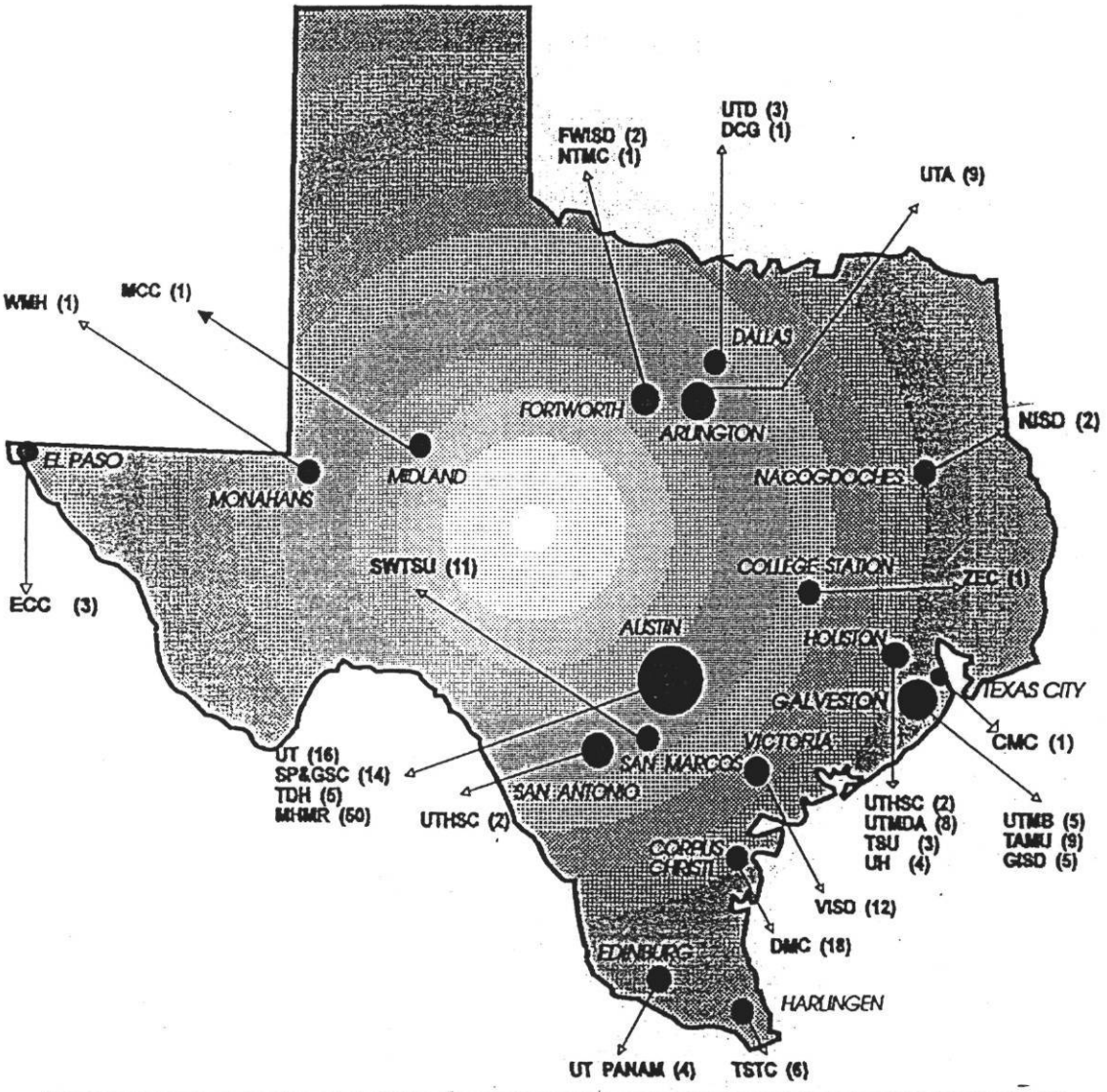
3.0 RESULTS

3.1 Analysis of the Overall Retrofit Savings

To analyze the effectiveness of the many different types of retrofits in the LoanSTAR program thirteen categories were identified as the most representative types of ECRMs in the LoanSTAR program. These categories are shown in Table 1 along with the number of sites that had retrofits belonging to these categories, audit-estimated dollar amounts of the retrofits at the sites, and the percentages of the retrofits by site and by dollar amount expended. Table 1 also contains the audit estimated costs of the retrofits from the 74 sites analyzed for this study. Figure 1 illustrates the geographical distribution of the LoanSTAR sites around the state of Texas.

The 203 ECRMs listed in Table 1 represent roughly 2.7 retrofits for each of the 74 sites listed in Table 2. Table 2a shows the estimated costs for each retrofit broken down by the type of retrofit and Table 2b shows the estimated costs per square foot of conditioned space. Table 2c shows the actual LoanSTAR costs of the retrofits according to accounting records maintained by the Texas State Energy Conservation Office. Table 2d shows the same information as 2c expressed as a cost per square foot.

Figure 1: Sites Monitored under LoanSTAR as of December, 1993



Legends: *Note: Number of buildings monitored at each site are given in parenthesis*

1. CMC - College of Mainland
2. DCG - Dallas County Government Center
3. DMC - Delmar College
4. ECC - El Paso Community College
5. FWISD - Forth Worth ISD
6. GISD - Galveston ISD
7. MCC- Midland County Courthouse
8. MHMR - Mental Health & Mental Retardation
9. NISD - Nacogdoches ISD
10. NTMC - Univ. of North Texas Medical Center
11. SWTSU - Southwest Texas State University
12. SP&GSC - State Purchasing & General Services
13. TAMU - Texas A&M University at Galveston
14. TDH - Texas Department of Health
15. TSU- Texas Southern University
16. TSTC - Texas State Technical College
17. UT PANAM - Univ of Texas, PanAmerica
18. UH - University of Houston
19. UT - University of Texas at Austin
20. UTMB - University of Texas Med. Branch
21. UTA - University of Texas at Arlington
22. UTD - University of Texas at Dallas
23. UTHSC - Univ. of Texas Health Science Center
24. UTMDA - UTMD Anderson Cancer Center
25. VISD - Victoria ISD
26. WMH - Ward Memorial Hospital
27. TSTC - Texas State Technical College

Table 1: ECRMs Categorized by 13 Types.

	NO. SITES	% OF SITES	EST.COST	AVG. $/SITES	% of tot $
VSD ONLY	3	1.0%	$3,011,107	$1,505,554	8.2%
VAV	24	11.9%	$6,892,556	$287,190	18.7%
OTHER HVAC	17	8.5%	$3,592,796	$211,341	9.8%
PUMPING	9	4.5%	$3,006,535	$334,059	8.2%
MOTOR RETRO	26	12.9%	$1,698,792	$65,338	4.6%
LIGHT.MOD.	49	24.4%	$3,863,026	$78,837	10.5%
OCC.CNTRL.	10	5.0%	$131,052	$13,105	0.4%
CO-GEN	2	1.0%	$4,331,500	$2,165,750	11.8%
THERMAL STOR.	8	4.0%	$3,567,963	$445,995	9.7%
CHILL.MOD.	13	6.5%	$1,936,886	$148,991	5.3%
BOIL.MOD.	14	7.0%	$1,063,458	$75,961	2.9%
E.M.C.S.	18	9.0%	$3,369,000	$187,167	9.2%
OTHER	10	5.0%	$328,782	$32,878	0.9%
TOTAL	203	100.0%	$36,793,453	$183,052	100.0%

NOTE: Total for the column labeled "No.of Sites" represents the total number of ECRMs and does not reflect the sum of the sites indicated in Table 2.

VSD ONLY = variable speed drive applied to systems other than the air-handlers.
VAV = variable air volume air-handler retrofits.
OTHER HVAC = retrofits to other portions of the HVAC system, excluding controls.
PUMPING = retrofits to the pumping systems that do not include VSD.
MOTOR RETRO = retrofit to one more electric motors in the building.
LIGHT.MOD. = a retrofit that involved the lighting systems, excluding occupancy sensors.
OCC.CNTRL. = a retrofit to the lighting systems that included occupancy sensors.
CO-GEN = a retrofit that included a co-generation system.
THERMAL STOR. = a retrofit that included the installation of a thermal storage system.
CHILL.MOD. = a retrofit that included a modification to the building's chiller.
BOIL.MOD. = a retrofit that included a modification to the building's boiler.
E.M.C.S. = a retrofit to the building's control system.
OTHER = retrofits that are not defined by the above, for example power factor corrections, etc.

Table 2a: Audit Estimated Cost by Types of ECRMs in the LoanSTAR Program

SITE	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
ZEC		1,331,660										??		1,331,660
EDB		555,066			30,021	50,036	1,854							636,977
UTC		328,820			34,344	3,091								366,255
PCL		706,764			25,129		3,250							735,143
WAG		86,852												86,852
WEL		734,726			30,002	16,715								781,443
BUR		122,966			11,993									134,959
NUR		161,842			10,674									172,516
WIN		178,157			33,655									211,812
STD			19,369											19,369
PAI		173,318	80,993											254,311
WCH		64,700	2,790		9,675									77,165
GAR		59,979			8,313							19,194		87,486
GEA		134,815			10,643									145,458
CBA	20,399				255,467	19,588								275,055
GSB		314,412			30,949									345,361
MNB		148,455	955,250		61,850	30,800								1,196,355
UNV		239,382			12,845	20,785								273,012
BUS		304,225				25,404								329,629
FNA		262,073			27,591	21,074								310,738
ENG						??								0
DVS		197,740	2,933			??								200,673
NUH						??								0
LSB			2526		20,039	14,145								36,710
LIB		346,741			12,845	4,619								364,205
TEP				2,078,478						52,858	36,800		211,960	2,380,096
CPP				242,155						409,448	361,673			1,013,276
SHB					131,516	8,117	5,000				206			144,839
SFA				169,395	287,600	148,597				41,475	7,475			654,542
JHR			6,650			12,948	48,737				206			68,541
JER						6,800				6,435				13,235
INS			3,130			6,804	14,696				206			24,836
INX			64,078			5,128					206			69,412
ARC						6,308	31,907				206			38,421
WBT			52,720			81,180								133,900
LBJ					241,900	141,700								383,600
LHW						13,442						260,170		273,612

Table 2a (cont.): Audit Estimated Cost by Types of ECRMs in the LoanSTAR Program

SITE	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
MSB	2,812,279					412,400								3,224,679
SPH			1,188,811		193,075							207,786		1,589,672
UTP	178,429		5,558		41,292	37,152	20,962			239,514		73,294	7,090	603,291
VISD						9,130	560					380,980		390,670
SHS						3,606				190,000				193,606
VHS										149,100				149,100
FWISD						1,200,000								1,200,000
SIM						??								0
DMS						??								0
TDH												262,885		262,885
MDA			821,397			627,879						637,158		2,086,434
UTD			28,744			285,177		331,500				37,987	13,135	696,543
COM						14,650				30,400	84,317	845	2,546	132,758
TAG		35,460			43,819	14,436						364,343	21,523	479,581
SAD		37,178			53,715								8,227	99,120
SAM		101,688				397							15,599	117,684
DMC						52,405			984,780				15,000	1,052,185
MCC						15,689	3,836			16,373		80,300		116,198
WMH									81,000					81,000
DCG		265,537			49,206	178,279	250			233,414	37,111	50,518		814,315
SWT				374,487		8,559				451,847	108,738	113,569	25,454	1,082,654
TST									612,664					612,664
MHR					30,634	86,204					391,279	36,482		544,599
NHS						??				101,640	24,725	289,800		416,165
CMS						??						??		0
OES									377,904					377,904
WMS									377,904					377,904
PES									377,904					377,904
MES									377,904					377,904
RES									377,904					377,904
JSN			29,384			7,114				14,382				50,880
CSB				21,703		15,191								36,894
BSB			302,688	43,302		28,249								374,239
MLB			25,775	10,929		10,893							8,248	55,845
JSS				31,136		52,220								83,356
	3,011,107	6,892,556	3,592,796	3,006,535	1,698,792	3,863,026	131,052	4,331,500	3,567,963	1,936,886	1,063,458	3,369,000	328,782	36.8

?? - Data Not Avaliable

Table 2b: Audit Estimated Cost by Types of ECRMs in the LoanSTAR Program ($/sqft.)

SITE	AREA sq-ft	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
AVG	318727	$ 1.15	$ 1.50	$ 0.82	$ 8.46	$ 0.26	$ 0.17	$ 0.08	$ 0.69	$ 4.13	$ 0.46	$ 0.18	$ 0.51	$ 0.70	$ 2.68
ZEC	324000		$ 4.11										??		$ 4.11
EDB	251161		$ 2.21			$ 0.12	$ 0.20	$ 0.01							$ 2.54
UTC	152690		$ 2.15			$ 0.22	$ 0.02								$ 2.40
PCL	483895		$ 1.46			$ 0.05		$ 0.01							$ 1.52
WAG	57600		$ 1.51												$ 1.51
WEL	439540		$ 1.67			$ 0.07	$ 0.04								$ 1.78
BUR	103441		$ 1.19			$ 0.12									$ 1.30
NUR	94815		$ 1.71			$ 0.11									$ 1.82
WIN	109000		$ 1.63			$ 0.31									$ 1.94
STD	56800			$ 0.34									$ 0.35		$ 0.34
PAI	128409		$ 1.35	$ 0.63											$ 1.98
WCH	48905		$ 1.32	$ 0.06		$ 0.20									$ 1.58
GAR	54069		$ 1.11			$ 0.15									$ 1.62
GEA	61000		$ 2.21			$ 0.17									$ 2.38
CBA	242857	$ 0.08				$ 1.05	$ 0.08								$ 1.22
GSB	146763		$ 2.14			$ 0.21									$ 2.35
MNB	328752		$ 0.45	$ 2.91		$ 0.19	$ 0.09								$ 3.64
UNV	123450		$ 1.94			$ 0.10	$ 0.17								$ 2.21
BUS	149900		$ 2.03				$ 0.17								$ 2.20
FNA	223000		$ 1.18			$ 0.12	$ 0.09								$ 1.39
ENG	246102						??								$ -
DVS	101580		$ 1.95	$ 0.03			??								$ 1.98
NUH	155004						??								$ -
LSB	213672			$ 0.01		$ 0.09	$ 0.07								$ 0.17
LIB	201040		$ 1.72			$ 0.06	$ 0.02								$ 1.81
TEP	31555				$ 65.87						$ 1.68	$ 1.17		$ 6.72	$ 75.43
CPP	1791943				$ 0.14						$ 0.23	$ 0.20			$ 0.57
SHB	182961					$ 0.72	$ 0.04	$ 0.03				$ 0.00			$ 0.79
SFA	470000				$ 0.36	$ 0.61	$ 0.32				$ 0.09	$ 0.02			$ 1.39
JHR	169756			$ 0.04			$ 0.08	$ 0.29				$ 0.00			$ 0.40
JER	80000						$ 0.09				$ 0.08				$ 0.17
INS	102000			$ 0.03			$ 0.07	$ 0.14				$ 0.00			$ 0.24
INX	62000			$ 1.03			$ 0.08					$ 0.00			$ 1.12
ARC	120000						$ 0.05	$ 0.27				$ 0.00			$ 0.32
WBT	491000			$ 0.11			$ 0.17								$ 0.27
LBJ	308080					$ 0.79	$ 0.46								$ 1.25
LHW	503000						$ 0.03						$ 0.52		$ 0.54

Table 2b (cont.): Audit Estimated Cost by Types of ECRMs in the LoanSTAR Program ($/sqft.)

SITE	AREA sq-ft	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
MSB	887187	$ 3.17					$ 0.46								$ 3.63
SPH	233738			$ 5.09		$ 0.83							$ 0.89		$ 6.80
UTP	909462	$ 0.20		$ 0.01		$ 0.05	$ 0.04	$ 0.02			$ 0.26		$ 0.08	$ 0.01	$ 0.66
VISD	467488						$ 0.02	$ 0.00					$ 0.81		$ 0.84
SHS	210474						$ 0.02				$ 0.90				$ 0.92
VHS	257014						$ 0.02				$ 0.58				$ 0.60
FWISD	2468122						$ 0.49								$ 0.49
SIM	62400						$ 0.48								$ 0.48
DMS	51693						$ 0.77								$ 0.77
TDH	284000												$ 0.93		$ 0.93
MDA	1522193			$ 0.54			$ 0.41						$ 0.42		$ 1.37
UTD	481549			$ 0.06			$ 0.59		$ 0.69				$ 0.08	$ 0.03	$ 1.45
COM	496000						$ 0.03				$ 0.06	$ 0.17	$ 0.00	$ 0.01	$ 0.27
TAG	382232		$ 0.09			$ 0.11	$ 0.04						$ 0.95	$ 0.06	$ 1.25
SAD	484019		$ 0.08			$ 0.11								$ 0.02	$ 0.20
SAM	606097		$ 0.17				$ 0.00							$ 0.03	$ 0.19
DMC	636702						$ 0.08			$ 1.55				$ 0.02	$ 1.65
MCC	90100						$ 0.17	$ 0.04			$ 0.18		$ 0.89		$ 1.29
WMH	37000									$ 2.19					$ 2.19
DCG	473800		$ 0.56			$ 0.10	$ 0.38	$ 0.00			$ 0.49	$ 0.08	$ 0.11		$ 1.72
SWT	637223				$ 0.59		$ 0.01				$ 0.71	$ 0.17	$ 0.18	$ 0.04	$ 1.70
TST	139193									$ 4.40					$ 4.40
MHR	845435					$0.04	$0.10					$0.46	$0.04		$ 0.64
NHS	202615						??				$0.50	$0.12	$1.43		$2.05
CMS	132443						??						??		$ -
OES	80400									$ 4.70					$ 4.70
WMS	80769									$ 4.68					$ 4.68
PES	81742									$ 4.62					$ 4.62
MES	76798									$ 4.92					$ 4.92
RES	63044									$ 5.99					$ 5.99
JSN	54494			$ 0.54			$ 0.13				$ 0.26				$ 0.93
CSB	124870				$ 0.17		$ 0.12								$ 0.30
BSB	137856			$ 2.20	$ 0.31		$ 0.20								$ 2.71
MLB	67380			$ 0.38	$ 0.16		$ 0.16							$ 0.12	$ 0.83
JSS	373085				$ 0.08		$ 0.14								$ 0.22
		$ 3.45	$ 35.94	$ 13.99	$ 67.69	$ 6.72	$ 6.70	$ 0.81	$ 0.69	$ 33.05	$ 6.03	$ 2.39	$ 7.68	$ 7.04	$ 192.70

?? - Data Not Avaliable

Table 2c: Actual Costs By Types Of ECRMs In The LoanSTAR Program

SITE	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
ZEC		1,265,018												1265018
EDB		555,066			20,531	68,200	0							643797
UTC		335,083			18,000	3,019								356102
PCL		647,053			22,217		3,500							672770
WAG		156,983												156983
WEL		243,627			28,423	12,998								285048
BUR		142,002			16,458									158460
NUR		161,932			12,805									174737
WIN		229,358			43,869									273227
STD			112,205											112205
PAI		219,434	93,498											312932
WCH		126,590	6,580		19,739									152909
GAR		134,108			20,804							43,253		198165
GEA		195,523			21,032									216555
CBA	21,147				289,008	28,196								338351
GSB		331,301			35,245									366546
MNB		171,078	1,079,113		65,800	0								1315991
UNV		174,659			39,392	14,271								228322
BUS		218,633			11,297									229930
FNA		150,095			1,113	22,028								173236
ENG						??								0
DVS		148,037	0			??								148037
NUH						??								0
LSB			2,577		1,236	18,330								22143
LIB		??			702	8,190								8892
TEP				??						??	??		??	0
CPP				??						??	??			0
SHB					??	??	??				??			0
SFA				??	??	??				??	??			0
JHR			??			??	??			??	??			0
JER						??				??				0
INS			??			??	??				??			0
INX			??			??	??				??			0
ARC						??	??				??			0
WBT					??	??								0
LBJ			??			??								0
LHW						??						??		0
MSB	??					??								0
SPH			??	??	??							??		0
UTP	0		46,500		108,200	26,712	0			211,000		110,600	0	503012
VISD						??	??							0
SHS						??								0
VHS										??				0
FWISD						1,200,000								1200000

Table 2c (cont.): Actual Costs By Types Of ECRMs In The LoanSTAR Program

SITE	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modified	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modified	EMCS	Other retrofits	TOTAL
SIM						??								0
DMS						??								0
TDH												289,174		289174
MDA			??			??						??		0
UTD			??			419,404		329,583				16,393		765380
COM						11,607				29,647	143,928	8,757	6,131	200070
TAG		??			??	??						??		0
SAD		39,514			57,090								10,736	107340
SAM		108,077				??							13,487	121564
DMC						??			??				??	0
MCC						??	??			??		??		0
WMH									??					0
DCG		0			57,868	0	0			234,456	20,551	0		312875
SWT				374,487		8,559				451,847	108,738	113,569	25,454	1082654
TST									724,564					724564
MHR					??	??					??	??		0
NHS						??				101,640	0	225,843		327483
CMS						??						??		0
OES									??					0
WMS									??					0
PES									??					0
MES									??					0
RES									??					0
JSN			256,272			2,052				34,243				292567
CSB				33,819		$2,078								35897
BSB			286,982	8,811		??								295793
MLB			115,070	18,739		??							??	133809
JSS				85,859		2,077								87936
Totals	21147	5753171	1998797	521715	890829	1847721	3500	329583	724564	1062833	273217	807589	55808	14290474

?? - Data Not Received

Table 2d: Actual Costs Per Square Foot By Types Of ECRMs In The LoanSTAR Program

SITE	AREA sq-ft	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modification	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modification	EMCS	Other retrofits	TOTAL
ZEC	324000		$ 3.90										??		$ 3.90
EDB	251161		$ 2.21			$ 0.08	$ 0.27	$ -							$ 2.56
UTC	152690		$ 2.19			$ 0.12	$ 0.02								$ 2.33
PCL	483895		$ 1.34			$ 0.05		$ 0.01							$ 1.39
WAG	57600		$ 2.73												$ 2.73
WEL	439540		$ 0.55			$ 0.06	$ 0.03								$ 0.65
BUR	103441		$ 1.37			$ 0.16									$ 1.53
NUR	94815		$ 1.71			$ 0.14									$ 1.84
WIN	109000		$ 2.10			$ 0.40									$ 2.51
STD	56800			$ 1.98											$ 1.98
PAI	128409		$ 1.71	$ 0.73											$ 2.44
WCH	48905		$ 2.59	$ 0.13		$ 0.40									$ 3.13
GAR	54069		$ 2.48			$ 0.38							$ 0.80		$ 3.67
GEA	61000		$ 3.21			$ 0.34									$ 3.55
CBA	242857	$ 0.09				$ 1.19	$ 0.12								$ 1.39
GSB	146763		$ 2.26			$ 0.24									$ 2.50
MNB	328752		$ 0.52	$ 3.28		$ 0.20	$ -								$ 4.00
UNV	123450		$ 1.41			$ 0.32	$ 0.12								$ 1.85
BUS	149900		$ 1.46				$ 0.08								$ 1.53
FNA	223000		$ 0.67			$ 0.00	$ 0.10								$ 0.78
ENG	246102						??								$ -
DVS	101580		$ 1.46	$ -			??								$ 1.46
NUH	155004						??								$ -
LSB	213672			$ 0.01		$ 0.01	$ 0.09								$ 0.10
LIB	201040		$ 1.72			$ 0.00	$ 0.04								$ 1.77
TEP	31555				$ -						$ -	$ -		$ -	$ -
CPP	1791943				$ -						$ -	$ -			$ -
SHB	182961					$ -	$ -	$ -				$ -			$ -
SFA	470000				$ -	$ -	$ -				$ -	$ -			$ -
JHR	169756			$ -			$ -	$ -				$ -			$ -
JER	80000						$ -				$ -				$ -
INS	102000			$ -			$ -	$ -				$ -			$ -
INX	62000			$ -			$ -					$ -			$ -
ARC	120000						$ -	$ -				$ -			$ -
WBT	491000			$ -			$ -								$ -
LBJ	308080					$ -	$ -								$ -
LHW	503000						$ -						$ -		$ -
MSB	887187	$ -					$ -								$ -
SPH	233738			$ -		$ -							$ -		$ -
UTP	909462	$0.00		$ 0.05		$ 0.12	$ 0.03	$0.00			$ 0.23		$ 0.12	$ 0.00	$ 0.55
VISD	467488						$ -	$ -					$ -		$ -
SHS	210474						$ -				$ -				$ -
VHS	257014						$ -				$ -				$ -
FWISD	2468122						$ 0.49								$ 0.49
SIM	62400						$ 0.48								$ 0.48
DMS	51693						$ 0.77								$ 0.77
TDH	284000												$ 1.02		$ 1.02

Table 2d (cont.): Actual Costs Per Square Foot By Types Of ECRMs In The LoanSTAR Program

SITE	AREA sq-ft	VFD to AHU	HVAC VAV	HVAC Other	Pumping systems	Motor retrofits	Lighting modification	Occup controls	Co-generation	Thermal storage	Chiller modified	Boiler modification	EMCS	Other retrofits	TOTAL
MDA	1522193			$ -			$ -						$ -		$ -
UTD	481549			?			$ 0.87		$ 0.68				$ 0.03	$ 0.03	$ 1.62
COM	496000						$ 0.02				$ 0.06	$ 0.29	$ 0.02	$ 0.01	$ 0.40
TAG	382232		$ -			$ -	$ -						?	$ -	$ -
SAD	484019		$ 0.08			$ 0.12								$ 0.02	$ 0.22
SAM	606097		$ 0.18				??							$ 0.02	$ 0.20
DMC	636702						$ -			$ -				$ -	$ -
MCC	90100						$ -	$ -			$ -		$ -		$ -
WMH	37000									$ -					$ -
DCG	473800		$ -			$ 0.12	$ -	$ -			$ 0.49	$ 0.04	$ -		$ 0.66
SWT	637223				$ 0.59		$ 0.01				$ 0.71	$ 0.17	$ 0.18	$ 0.04	$ 1.70
TST	139193									$ 5.21					$ 5.21
MHR	845435					$ -	$ -					$ -	$ -		$ -
NHS	202615						??				$ 0.50	$ 0.00	$ 1.11		$ 1.62
CMS	132443						??						??		$ -
OES	80400									$ -					$ -
WMS	80769									$ -					$ -
PES	81742									$ -					$ -
MES	76798									$ -					$ -
RES	63044									$ -					$ -
JSN	54494			$ 4.70			$ 0.04				$ 0.63				$ 5.37
CSB	124870				$ 0.03		$ 0.02								$ 0.05
BSB	137856			$ 2.08	$ 0.06		$ -								$ 2.15
MLB	67380			$ 1.71	$ 0.28		$ -							$ -	$ 1.99
JSS	373085				$ 0.23		$ 0.01								$ 0.24
		$ 0.09	$ 37.86	$ 14.68	$ 1.19	$ 4.46	$ 3.08	$ 0.01	$ 0.68	$ 5.21	$ 2.63	$ 0.50	$ 3.28	$ 0.12	$ 74.31

$ - : No Data Received

Several points about Table 1 are worth mentioning. The first point is that no single retrofit dominates the LoanSTAR program. This is evidenced by the fact that the most frequent Modification of the HVAC systems, which includes variable speed drives to AHUs, complete VAV retrofits, other HVAC retrofits, and EMCS retrofits (total = 62 sites, 30.5%) represents about one third of all sites. However, due to the diverse nature of these retrofits, individual categories were used to describe the ECRMs.

When one considers the average costs of the ECRM categories a slightly different picture is painted. First, the two largest categories (by number) are no longer the largest categories by percent-cost. Clearly, and not unexpectedly, the most costly retrofits are the co-generation retrofits which averaged over $2 million for each site, or nearly 12 times the average retrofit cost of $183,052 (Table 1). The next most costly retrofits are the variable speed drive retrofits[2] to the AHUs which cost on average $287,190. The three sites in this category are dominated by the Medical Sciences Building at the University of Texas Health Science Center in Houston.

At the lower end of the cost per site scale, four categories of retrofits averaged less than $100,000 per site, including motor retrofits, lighting modifications, occupancy controls and boiler modifications. On a site-wise basis only 17 of the 74 sites had less than $100,000 per site. However, the top 11 sites represent $20.9 million or 57% of the total $36.8 million. Figure 2 is a pie chart representing the categorical cost breakdown shown in Table 1. Figure 3 shows the status of the LoanSTAR retrofits as of December 1993.

In Table 3 the sites monitored under the LoanSTAR program are shown as of December 1993. Many of the sites shown are buildings that are part of universities or medical centers and are grouped by their respective campuses. At some of the sites the loggers record

[2] For many of the retrofits in the LoanSTAR program this did not involve a complete CV to VAV air-handler retrofit. For example, in many situations CV terminal boxes were converted and not replaced, in othher cases the entire air distribution system was replaced, including the terminal boxes.

Figure 2: Audit Estimated Cost for Retrofits as December 1993. This figure shows the estimated costs for retrofits contained in Tables 1 and 2.

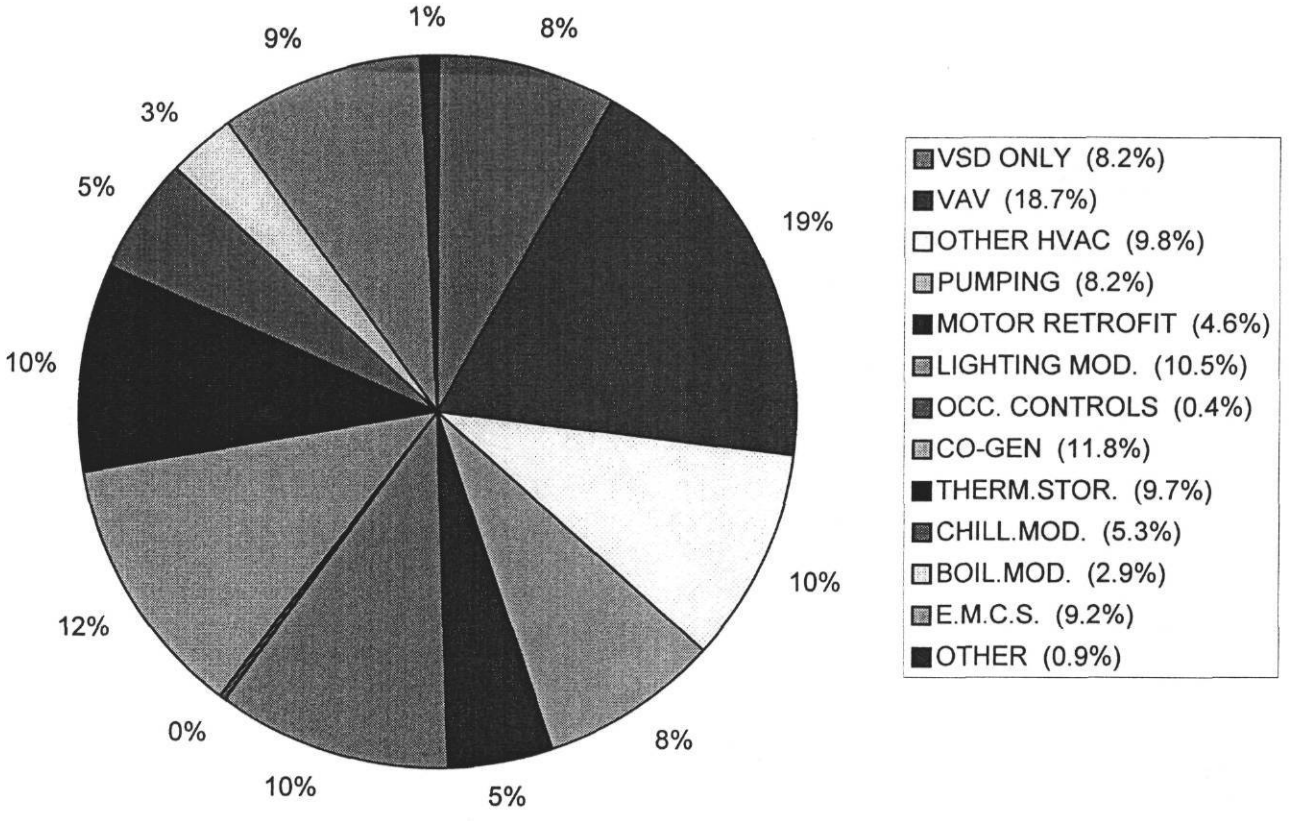


Figure 3: Status of the LoanSTAR Retrofits as of December 1993. The status of LoanSTAR retrofits is shown in this figure and in Table 3.

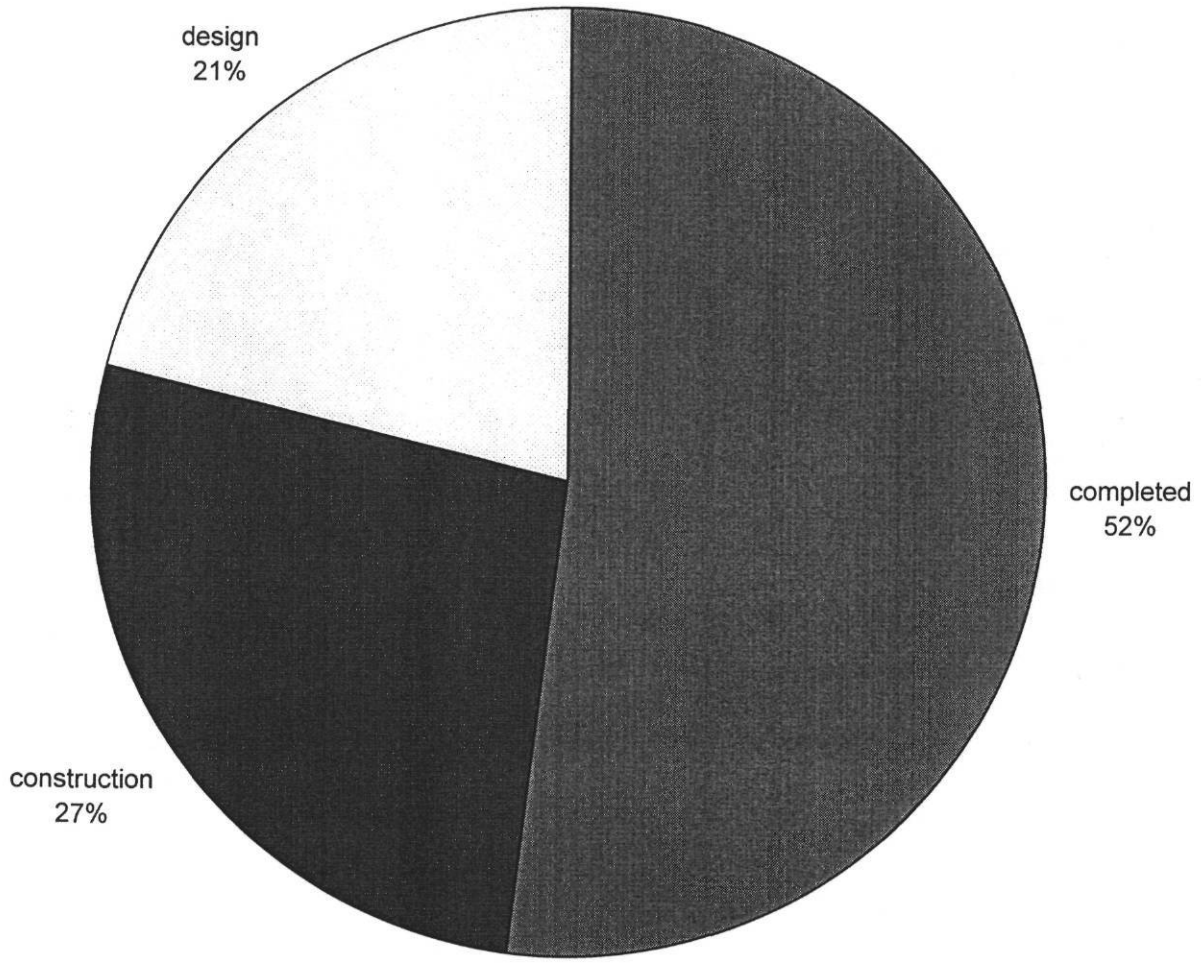


Table 3: Sites Monitored by LoanSTAR as of December 1993

SITE	Site Name	# of Bldgs	Area Sq.-ft	Recommended Retrofits	Retrofit Completion Date
ZEC	Zachry Engineering Center	1	324,000	VAV (480hp), EMCS	March 1991
	U.T. Austin				
EDB	Education Building	1	251,161	Lights, OS, VAV (400hp), VSP (75hp)	May 1991
UTC	University Teaching Center	1	152,690	Lights, VAV (262hp), VSP (50hp)	Nov. 1990
PCL	Perry Castaneda Library	1	483,895	OS, VAV (1,500hp), VSP (60hp)	Nov. 1990
WAG	Waggener Hall	1	57,600	VAV (80hp)	May 1991
WEL	Welch Hall	1	439,540	Lights (Incd), VAV, VSP	Feb. 1992
BUR	Burdine Hall	1	103,441	VAV (175hp), VSP (40hp)	May 1991
NUR	Nursing Building	1	94,815	VAV (200hp), VSP (30hp)	Apr. 1991
WIN	Winship Hall	1	109,000	VAV (185hp), VSP (50hp)	May 1991
STD	Steindham Hall	1	56,800	H/C DR & VAV	Jul. 1991
PAI	Painter Hall	1	128,409	HVAC Mod. VAV	Feb. 1992
WCH	WIC. Hogg Hall	1	48,905	VAV (80hp), VSP (25hp), Replace Econ	May 1991
GAR	Garrison Hall	1	54,069	VAV (60hp), VSP (15hp), EMCS	May 1991
GEA	Gearing Hall	1	61,000	VAV (110hp), VSP (15hp)	May 1991
CBA	College of Bus Admin.	2	242,857	Lights, Lights (incd),	Construction
GSB	Graduate School of Business	1	146,763	Lights, VAV, VFD, & Vent Cycle Cont	Construction
MNB	Main Building	1	328,752	M-zone AHU Conv, Lights, VAV & VSP	Construction
	U.T. Arlington				
UNV	University Hall	1	123,450	Lights, VAV, VSP	Aug. 1991 (VAV)
BUS	Business Building	1	149,900	Lights, VAV	Aug. 1991 (VAV)
FNA	Fine Arts Building	1	223,000	Lights, VAV, VSP	Aug. 1991 (VAV)
ENG	Engineering II	1	246,102	Lights, OS, Lights (Incd), TC & ST	In Design/Const.
DVS	Davis Hall	1	101,580	Lights, OS, Lights, AB, TC & ST	In Design/Const.
NUH	Nursing Hall	1	155,004	Lights, OS, Lights (Incd), TC & ST	In Design/Const.
LSB	Life Science Building	1	213,672	Lights, Lights (Incd), TC & ST	In Design/Const.
LIB	Library	1	201,040	Lights, VAV, Lights (Incd), TC & ST	In Design/Const.
TEP	Thermal Energy Plant	1	31,555	CHW Lp Mod., INS, Lights & Evap Sys	In Design/Const.
	State Capitol Complex				
SHB	Sam Houston Bldg. & C. Pl.	1	182,961	Replace Boiler & Chiller, Pump Mod.	Dec. 1991 (Boiler)
SFA	S. F. Austin Central Plant	1	470,000	VFD, Lights, Pump Mod.	In Design/Const.
JHR	John H. Reagan	1	169,756	NSB, RES, Lights, MD	In Design/Const
JER	James E. Rudder	1	80,000	RES, Chiller Modifications	In Design/Const
INS	Insurance Building	1	102,000	MD, NSB, RES, Lights, Reduce Air Flow	In Design/Const
INX	Insurance Annex	1	62,000	MD, Pump shut-off, RES, H/C DR	In Design/Const
ARC	Archive Building	1	120,000	Pump Shut-off, RES, MD, NSB	In Design/Const
WBT	William B. Travis	1	491,000	HVAC Mod., Lights	In Design/Const
LBJ	Lyndon B. Johnson	1	308,080	VFD, Lights, Lights (incd)	In Design/Const
JHW	J. H. Winter's Complex	3	503,000	EMCS, Lights (incd)	In Design/Const
	U.T.H.S.C. Houston				
MSB	Medical School Building	1	887,187	Lights, VFD to AHUs, VSP	7/91(L), 8/93 (VSP)
SPH	School of Public Health	1	233,738	HVAC Mod., EMCS, VAV, VSP	3/92 (L), 8/93 (VSP)
UTP	University of Texas Panam	14	909,462	VSP, Lights, VFD, MD, Outside Air Cont.,	Bidding/Const.

Table 3(cont.): Sites Monitored by LoanSTAR as of December 1993

SITE	Site Name	# of Bldgs	Area Sq.-ft	Recommended Retrofits	Retrofit Completion Date
	Victoria ISD				
SHS	Stroman High School	9	210,474	EMCS, Replace Chiller	Aug. 1991
VHS	Victoria High School	3	257,014	EMCS, Replace Chiller, Lights	Aug. 1991
	Fort Worth ISD				
SIM	Sims ES	1	62,400	Lights	Nov. 1991
DMS	DunbarMS	1	92,884	Lights	Nov. 1991
TDH	Texas Dept. of Health	5	284,000	EMCS	Aug. 1992
MDA	M.D.A Cancer Center	8	1,522,193	Lights, EMCS, Fumehood Mod.	Design/Const.
UTD	University of Texas, Dallas	3	481,549	Lights, MD, Skylights	Design/Bidding
COM	Tex. Coll. of Ostp. Medicine	3	496,000	MD, TC, VAV, CWR/HWR, Rep. Boiler	Jun. 1992
TAG	Texas A&M Univ-Galveston	9	382,232	EMCS, VSCT, VSP, Lights, PF	Mar. 1992
	U.T.H.S.C. San Antonio				
SAD	Dental School	1	484,019	VSP, VAV, Solar screens & Zone isolation	Nov. 1990 (Zone)
SAM	Medical School	1	606,097	VAV, VSP, Photocell & Solar Screens	Nov. 1990 (VSP)
DMC	Del Mar College	18	636,702	Thermal Storage, Lights, PF	June 1993
MCC	Midland County Courthouse	1	90,100	EMCS, OS, Lights, Chiller control	Aug. 1992
WMH	Ward Memorial Hospital	1	37,000	Thermal Storage	Apr. 1992
DCG	Dallas County Gvmt. Center	1	473,800	Chiller Rep., VSP, EMCS, VAV, TC, Lights	Design
SWT	South West Tex. State Univ.	11	637,223	Chiller Rep., EMCS, Lights (Incd.), HSM	Construction
TST	TSTC Harlingen	6	139,193	Chiller Rep., Thermal Storage	Oct. 1992
MHR	MHMR Austin	50	845,435	Lights, EMCS, VFD, HSM	Design
NHS	NISD/Nacogdoches HS	1	202,615	EMCS, Lights, Gas Heating, Install Chiller	Oct. 1992
CMS	NISD/Chamberlain MS	1	132,443	EMCS, Lights	Oct. 1992
OES	GISD/Oppe	1	80,400	Thermal Storage System	May 1993
WMS	GISD/Weis MS	1	80,769	Thermal Storage System	May 1993
PES	GISD/Parker ES	1	81,742	Thermal Storage System	May 1993
MES	GISD/Morgan	1	76,798	Thermal Storage System	Jun. 1993
RES	GISD/Rosengerg ES	1	63,044	Thermal Storage System	Jun. 1993
	UTMB Galveston				
JSN	John Sealy North	1	54,494	New Chillers for suite 5 & 6, VSP & EMCS	Aug. 1992
CSB	Clinical Sciences	1	124,870	VSP & EMCS	Aug. 1992
BSB	Basic Sciences	1	137,856	HVAC Mod., VSP & EMCS	Apr. 1992
MLB	Moody Memorial	1	67,380	VSP, separate AC for rare books & EMCS	Aug. 1992
JSS	John Sealy South	1	373,085	VSP & EMCS	Aug. 1992
TOTAL		**201**	**18,261,995**		

energy for more than one building; hence there are multiple buildings shown for a given site.

In general, logger placement was driven by the location of the major energy consuming systems in the buildings. Hence, there is a wide discrepancy in the square footage covered by the different sites. The average building size of the 201 buildings participating in the LoanSTAR program as of December 1993 is 96,855 sqft. The smallest building monitored is the 31,555 sqft. thermal energy plant (TEP) at the University of Texas at Arlington. The largest building is the 1,522,193 sqft. M.D. Anderson cancer center in Houston.

Table 3 contains summary information and the date of the retrofit completion, and status as of December 1993. The proportion of the retrofits that were completed by December 1993 were 52%, while those in the design mode represented 21%, with 27% in the construction mode. The individual retrofits for each site are listed in Table 4. Table 4 also presents information concerning the comparison of estimated savings to measured savings for the individual retrofits in the 201 sites that were reporting as of December 1993. In Table 4 information is presented as much as possible by individual retrofit for each site. For each retrofit the audit estimated savings and cost is shown. When data were available, the estimated savings were broken out into electricity use, electric demand and thermal energy savings. The total dollar values of the savings were calculated using utility cost data that was available for each site at the time of the energy audit. These same utility costs were used to calculate the measured savings (in dollars) and are included in the appendix for each site.

The measured savings are also shown for those sites where the retrofit had been completed prior to December 1993. These savings are shown for each site as an aggregate number since the calculation methodologies (Haberl et al. 1996) utilized whole-building (or main meter) before-after analysis. In many of the buildings the measured electricity and thermal energy savings are shown. Those sites which were still in design or under construction are indicated as "No Measured Savings".

Table 4: Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft. Area	Building/ Facility	ECRMs	Estimated Savings					Estimated Cost Savings ($)	Measured Savings					Measured Cost Savings ($)[4]
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
7110		TEXAS A&M UNIVERSITY														
1	324,000	Zachry Engineering Center	Modifications to existing double duct system	1,952,784			2,215,587		11,479	$411,066	1,529,698			1,134,539		12,486	$165,520
7210		U.T. AUSTIN															
100	251,161	Education	Replace Incandescent Lights	1,256,880			236,070	-1,416		$38,220							
			Occupancy (Motion) Sensors[1]	25,920			4,910	4,910		$1,199							
			Variable Air Volume System	1,195,530			290,930	5,123		$118,071							
			Variable Speed Pumping	108,200			30,770	0		$7,665							
			TOTAL[2]	2,560,410			557,770	3,707		$161,958	2,694,440			1,073,886	3,525		$249,209
101	152,690	UTC	3 position light switch	170,726			36,418	-146		$9,996							
			Variable Air Volume System	767,270			301,084	5,145		$97,646							
			Variable Speed Pumping	231,585			0	0		$10,537							
			TOTAL	1,169,581			337,502	4,998		$118,179	1,219,983			809,051	2,645		$143,980
102	483,895	PCL	Occupancy (Motion) Sensors	17,230			3,270	19		$1,210							
			Variable Air Volume System	1,319,180			1,247,440	27		$362,896							
			Variable Speed Pumping	209,130			0	0		$9,515							
			TOTAL	1,545,540			1,250,710	46		$373,621	3,846,265			4,107,712	27,152		$709,271
103	54,069	Garrison	Variable Air Volume System	184,883			57,729	461		$9,066							
			Variable Speed Pumping	50,873			0	0		$1,419							
			Connect to FMCS[1]	163,452			55,395	723		$9,401							
			TOTAL[2]	235,556			57,729	461		$10,485	287,339			238,974	117		$35,090
104	61,000	Gearing	Variable Air Volume System	582,904			123,425	1		$24,280							
			Variable Speed Pumping	74,530			0	0		$2,087							
			TOTAL	657,434			123,425	1		$26,367	421,505			229,520	1,105		$46,476
105	57,600	Waggener	Variable Air Volume System	442,126			116,064	979		$20,400							
			TOTAL	442,126			116,064	979		$20,400	222,460			159,128	1,000		$30,496
106	439,540	Welch	Replace Incandescent Lights	106,310			16,110	-97		$3,184							
			Variable Air Volume System	2,094,090			795,390	15,810		$278,494							
			Variable Speed Pumping	335,350			95,380	0		$23,757							
			TOTAL	2,535,750			906,880	15,713		$303,435	1,535,492			842,054	-7,961		$95,522
107	103,441	Burdine	Variable Air Volume System	791,739			212,765	2,302		$36,138							
			Variable Speed Pumping	211,116			0	0		$5,911							
			TOTAL	1,002,855			212,765	2,302		$42,049	698,768			585,141	986		$90,034
108	94,815	Nursing	Variable Air Volume System	747,888			253,737	3,066		$38,440							
			Variable Speed Pumping	99,814			0	0		$2,795							
			TOTAL	847,502			253,737	3,066		$41,235	655,783			360,584	-385		$59,573
109	109,000	Winship	Variable Air Volume System	893,178			191,678	2,432		$38,567							
			Variable Speed Pumping	225,495			0	0		$6,314							
			TOTAL	1,118,673			191,678	2,432		$44,881	945,319			1,222,494	4,118		$177,447
109	56,800	Steindam	Hot and Cold Deck Reset	0			99,735	545		$5,768							
			Installed Variable frequency drive on Dual Duct AHUs[1]														
			TOTAL[2]	0			99,735	545		$5,768	0[3]			45,171	61		$4,404
110	128,409	Painter	Cold deck control AC-1	33,492			121,376	1,853		$10,374							
			VAV AC-1,5,6	616,215			425,328	4,763		$45,618							
			Occupancy control AC-2,3,4	114,891			0	0		$4,805							
			Replace AC-3,4	8,736			53,192	1,098		$5,158							
			TOTAL	773,334			599,894	7,714		$65,955	854,671			165,677	4,788		$83,333
110	48,905	W.C. Hogg	Variable Air Volume System	234,315			73,928	529		$11,301							
			Variable Speed Pumping	131,102			0	0		$3,671							
			Replace economizer AC-1	0			21	0		$710							
			TOTAL	365,417			73,949	529		$15,682	289,465			406,008	3,201		$69,189
185	242,857	College of Business Admin.	Re-Lens/Delamp Troffers (B1)[1]	167,755			31,490	286		$7,761							
			Replace Lamps (B3)[1]	4,032			757	7		$186							
			New VFD @ AHU-7 (CBA) (B8)[1]	94,297			0	0		$3,451							
			New Fan Volume Controls (CBA) (B6)[1]	1,175,864			311,675	4,233		$77,283							
			Vent Cycle Controls @ AHU-1,3,9 (CBA) (B7)[1]	76,290			165,724	0		$15,205							
			TOTAL	1,518,238			509,646	4,526		$103,886	No Measured Savings						
186	146,783	Graduate School of Business	Variable Speed Pumping (GSB) (B10)[1]	220,009			240	0		$8,070							
			VAV Conversion and Vent Cycle (GSB) (B5)[1]	1,418,305			724,402	5,965		$121,529							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings						Estimated Cost Savings ($)	Measured Savings						Measured Cost Savings ($)
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr		Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
			TOTAL	1,638,314			724,642	5,965		$129,599	No Measured Savings						
167	328,752	Main Building	Replace Light Fixtures[1]	164,356			17,409	158		$6,911							
			Multizone Air Handler Conversion[1]	110,673			2,401,404	41,382		$290,488							
			VAV Conversion of Induction Reheat System[1]	155,731			315,883	6,875		$47,064							
			Variable Speed Pumping[1]	325,131			356	0		$11,926							
			TOTAL	755,891			2,735,052	48,415		$356,389	No Measured Savings						
7140			U.T.ARLINGTON														
111	123,450	University Hall	Lighting Control	192,624	0		0		0	$5,646							
			Variable Air Volume System	1,299,636	0		447,500		1,758	$75,431							
			Variable Speed Pumping[1]	79,141	0		0		0	$2,320							
			TOTAL[3]	1,492,260	0		447,500		1,758	$81,077	341,766			312,590	-181		$25,998
112	149,900	Business	Variable Air Volume System	1,060,442	0		407,417		4,836	$76,206							
			Lighting Control	264,564	0					$7,754							
			TOTAL	1,325,006	0		407,417		4,836	$83,960	172,606			433,448	1,837		$33,991
113	223,000	Fine Arts	Lighting Control	149,796	0					$4,391							
			Variable Air Volume System	1,737,138	0		474,583		6,059	$104,943							
			Variable Speed Pumping[1]	164,309	0					$4,816							
			TOTAL	1,886,932	0		474,583		6,059	$109,334	512,521			439,339	2,912		$48,903
168	246,102	Engineering II	Lighting Upgrade[1]	702,900	4,186		188,244										
			Provide timed control for domestic hot water pump[1]														
			Provide timed control of laboratory chilled water pump[1]														
			Insulation wrap for steam PRVs and CHW pumps[1]														
			TOTAL								No Measured Savings						
169	101,580	Davis Hall	Variable Air Volume System (1st Loan)[1]	878,216			332,750		1,672	$54,760							
			Lighting Upgrade (2nd Loan)[1]	759,930	2,082		203,481										
			Air Balance on M-Z #3, turn HW pump off[1]	31,866	41					$1,200							
			Provide timed control for domestic hot water pump[1]														
			Insulation wrap for steam PRVs and CHW pumps[1]														
			TOTAL	1,669,812	2,123		536,231		1,672	$55,960	No Measured Savings						
170	155,004	Nursing Hall	Lighting Upgrade (2nd Loan)[1]	430,711	1,930		115,339										
			Provide timed control for domestic hot water pump[1]														
			Insulation wrap for steam PRVs and CHW pumps[1]														
											No Measured Savings						
171	213,672	Life Science Building	Lighting Upgrade (2nd Loan)[1]														
			Provide timed control for domestic hot water pump[1]														
			Insulation wrap for steam PRVs and CHW pumps[1]														
			TOTAL								No Measured Savings						
172	201,040	Library	Lighting Upgrade[1]														
			Provide timed control for domestic hot water pump[1]														
			Insulation wrap for steam PRVs and CHW pumps[1]														
			Variable Air Volume System Conversion[1]	791,518			954,478		5,973								
			TOTAL	791,518			954,478		5,973		No Measured Savings						
173-175	31,555	Thermal Energy Plant	Primary/Secondary decoupling system[1]	5,316,898	7,335					$206,236							
			Insulate Condensate Return Lines[1]			16,662				$52,151							
			Evaporative Cooling System[1]	1,048,090						$25,154							
			Lighting Upgrade (2nd Loan)[1]	7,866	66		2,099										
		Steam Distribution System	Insulation Wrap for Steam PRV's and CHW pumps[1]			5,347				$16,736							
		20 Buildings (All not monitored)	Lighting Upgrade (Est. Savings Listed by Building)[1]							$626,404							
			TOTAL	1,055,956	66	22,009	2,099			$926,681	No Measured Savings						
3030			STATE CAPITOL COMPLEX														
204	10,000	Sam Houston Central Power	Chilled Water System Modification[1]	654,827	1,159	0				$28,096							
		Plant	Primary/Secondary pump modification[1]	861,277	1,070	0				$32,715							
			Replace Existing Boile[4]	0	0	22,346				$79,439							
			Boiler Feed Water Pump Replacement[1]	287,390	388	0				$11,223							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings					Estimated Cost Savings ($)	Measured Savings					Measured Cost Savings ($)[3]
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
			Condenser Water Reset[1]	542,557	0	0				$13,871						
			Replace Existing Carrier Chiller[1]	638,153	1,133	0				$27,609						
			Rebuild Steam Condensate Components[1]	0	0	2,224				$7,895						
			TOTAL	2,984,004	3,750	24,570				$200,848	No Measured Savings					
201	182,961	SHB	Occupancy (Motion) Sensors[1]	24,890	4	0				$1,097						
			Domestic HW Pump Shutdown[1]	2,029	0	70				$300						
			Install Variable Speed Drives[1]	2,103,904	0	3,253				$84,985						
			Replace Exit Signs[1]	12,159	1	0				$473						
			Reduce Lighting Levels[1]	50,776	9	0				$2,333						
			Replace Incandescent Lighting[1]	26,070	3	0				$1,014						
			TOTAL	2,219,828	17	3,323				$70,202	No Measured Savings					
202	470,000	SFA	Var speed motor dr & new controllers[1]	2,970,770	111	2,370				$88,251						
			TOTAL	2,970,770	111	2,370				$88,251	No measured savings					
203	169,756	JHR	Night Set Back[1]	782,605	0	1,188				$27,069						
			Reduce Corridor Lighting Levels[1]	127,345	24	91				$6,613						
			Replace Exit Signs[1]	3,276	0	0				$680						
			Install Motion Detectors (Lighting)[1]	9,726	2	0				$519						
			TOTAL	140,347	26	91				$34,881	No measured savings					
205	80,000	JER	New chiller controls[1]													
			Exit sign[1]													
			Domestic HW pump shut down[1]													
			Install two speed fan on cooling towers[1]													
			Economizer cycle for AHU's[1]													
			Night set back for AHUs[1]													
			Motion detectors for restrooms[1]													
			TOTAL								No measured savings					
206	102,000	INS	Install Motion Detectors (Lighting)[1]	12,345	2	0				$656						
			Night Set Back[1]	683,870	0	1,864				$30,417						
			Domestic HW Pump Shut Down[1]	2,088	0	29				$175						
			Reduce OA Flow[1]	30,845	95	375				$2,423						
			TOTAL	729,148	97	2,268				$33,671	No measured savings					
207	62,000	INX	Install Motion Detectors (Lighting)	5,238	0	0				$284						
			Domestic HW Pump Shut Down[1]	1,566	0	31				$172						
			Replace Exit Signs	13,377	2	0				$641						
			Hot/cold Deck Reset[1]	384,287	0	27,502				$28,609						
			TOTAL[2]	18,815	2	0				$925	No measured savings					
208	120,000	ARC	Domestic HW Pump Shut Down[1]	2,029	0	95				$391						
			Replace Exit Signs[1]	7,551	1	0				$292						
			Install Motion Detectors (Lighting)[1]	10,849	2	0				$475						
			Night Set Back for AHUs[1]	635,078	0	736				$18,834						
			Install variable frequency drives[1]													
			VAV retrofit[1]													
			Reduce lighting levels[1]													
			TOTAL	655,507	3	831				$19,992	No measured savings					
209	491,000	WBT	Interior Lighting Control[1]	695,600	1,123	-160				$33,317						
			Photocell Lighting Control[1]	16,700	0	0				$558						
			TOTAL	712,300	1,123	-160				$33,875	No measured savings					
210	308,080	LBJ	Interior Lighting Control[1]	883,000	1,426	-200				$42,292						
			Replace Incandescent Lights[1]	270,800	330	0				$12,226						
			New DDC controls[1]	49,900	69	0				$2,331						
			TOTAL	1,203,700	1,825	-200				$56,849	No measured savings					
211	503,000	J.H.Winters	Upgrade Energy Management System[1]	2,269,946	0	0				$78,994						
			Incandescent Lighting Conversion	58,254	242	0				$4,318						
			TOTAL[2]	2,269,946	0	0				$78,994	No measured savings					
7440																
			UTHSC - HOUSTON													
300	233,738	School of Public Health	Air-side Modification Floors 8-10[1]	183,960			302,492	3,521		$39,533						
			Variable Speed Pumping/Piping Modification[1]	1,619,987				0		$43,075						

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings						Estimated Cost Savings ($)	Measured Savings						Measured Cost Savings ($)[3]
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr		Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
			EMCS for AHU Control[1]	950,000			915,782	4,695		$98,098							
			Convert AHUs on Floors B to 7[1]	1,655,808			1,184,865	8,310		$150,278							
			Lighting conversion														
			TOTAL[2]	0			0	0		$0	385,660			0	0		$18,283
120-123	887,187	Medical School	Modify Lighting	1,278,720			242,460	-2,748		$96,469							
			Modify air & water distribution system[1]	13,887,973	1,283		8,765,000	82,190		$588,120							
			TOTAL[2]	1,278,720	0		242,460	-2,748		$96,469	1,648,321			0	0		$52,418
5010			TEXAS DEPT. OF HEALTH														
130	284,000	Records Tower	Install Energy Management System	1,527,400		203				$80,583							
			Hot & cold deck modifications (Record and bld G)[1]														
			AHU speed controls, temp reset (A - lab)[1]														
			Variable frequency drives and AHU controls[1]														
				1,527,400		203				$80,583	787,944		915,574			4,901	$110,932
7450			UTHSC San Antonio														
140	484,019	Dental School	Variable Speed CHW Pumping[1]	716,458			137,546	-550		$26,101							
			Solar Screens[1]				31,100			$3,275							
			Variable Air Volume Conversion[1]	100,214			80,031	501		$13,272							
			Zone Isolation/Hot Deck Dampers														
			TOTAL[2]	0			0	0		$0	No measured savings						
140	606,097	Medical School	Variable Air Volume Conversion[1]	938,740			269,200	1,349		$82,636							
			Solar Screens[1]				51,930			$5,468							
			Photocell Control[1]	4,910			1,050	-4		$186							
			Duct Modification[1]														
			Variable Volume Pumping														
			TOTAL[2]	0			0	0		$0	No measured savings						
77902			VICTORIA ISD														
126	210,474	Stroman High School	Replace Absorption Chiller	-262,760	-1,931	13,060				$31,914							
			Rewire Lighting in Hallways	20,410	43	113				$1,180							
			Energy Management System	126,392	3	2,710											
			TOTAL	-115,958	-1,885	15,883				$33,094	14,674	-483	12,522				$43,339
127	257,014	Victoria High School	Replace Absorption Chiller	-133,410	-1,003	6,800				$12,754							
			Energy Management System (from Above)	209,605	0	1,140											
			TOTAL	76,195	-1,003	7,940				$12,754	386,849	287	5,767				$38,261
7230			UT Medical Branch-Galveston														
		Campus	Hot Water Turnoff During Cooling Season	310,800				42,794		$224,588							
			Lighting Replacement Program	1,535,903	264		385,820	-170		$77,482							
			TOTAL	1,846,703	264		385,820	42,624		$302,070	No measured savings						
			Energy Mangement Control System	1,395,420			1,212,345	1,904		$83,199							
403	87,380	Moody Memorial	Lighting Program	406,870	54		76,450	-23		$17,900							
			Rare Books	75,800	-7		143,200	195		$15,493							
			Chilled Water Pump Speed Control	42,700	6		170,900	1,276		$22,699							
			TOTAL	42,700	8		1,602,895	1,276		$139,291	54,569	0		0	0		$1,451
402	137,856	Basic Sciences	Lighting Program	274,805	72		66,705	-23		$13,570							
			HVAC Modifications (BDM)	119,700			297,500	520		$287,557							
			Chilled Water Pump Speed Control	419,700	61					$12,595							
			Install energy management system														
			TOTAL	814,005	61		364,205	497		$313,722	1,479,391	0		0	0		$39,337
401	124,870	Clinical Sciences	Lighting Program	152,815	33		38,900	-14		$7,648							
			Hot water pump speed control														
			Chilled/Water Water Pump Speed Controls	149,400	21		223,200	2,808		$38,217							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings						Estimated	Measured Savings						Measured
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Cost Savings ($)	Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Cost Savings ($)[1]
			Install energy management control system														
			TOTAL	302,215	54		223,200	2,808		$45,865	164,573	0		0	0		$4,376
400	54,494	John Sealy North	Lighting Program	87,260	15		21,716	-11		$4,391							
			New AHU for Operating Suites 5 & 6	-11,500	-3		578,700	323		$51,998							
			Temperature Controlled Speed for CHW Pump	127,269	17		320,000	2,178		$42,850							
			Install energy management control system														
			TOTAL	203,029	29		920,416	2,490		$99,239	171,267	0		0	0		$4,554
404	373,085	John Sealy South	Lighting Program	1,750,050	353		435,500	-215		$86,252							
			CHW Pump Speed Control	471,300	123		720,430	24,755		$139,555							
			Install energy management control system														
			TOTAL	2,221,350	476		1,155,930	24,540		$225,807	648,326	0		0	0		$17,239
7360	909,462		U.T Pan American														
125		Academic Supp Fac	OA Control Modifications[1]	3,460		15				$135							
			Install Adjustable Frequency Drive on CHW Pump[1]	16,688						$471							
			Install Adjustable Frequency Drive on AHUs[1]	80,015		-21				$2,204							
			TOTAL	100,163		-21				$2,810	No measured savings						
125		Business Administ.	Install Motion Sensors (Lighting)[1]	24,923						$703							
			Incandescent to Fluorescent Conversion[1]	8,424	19					$412							
			OA Control Modifications[1]	8,340		27				$247							
			Install Adjustable Frequency Drive on CHW Pump[1]	23,398						$660							
			Install Adjustable Frequency Drive on AHUs[1]	195,990		-46				$5,405							
			TOTAL	259,075	19	-19				$7,427	No measured savings						
125		Communication/Arts	Install Motion Sensors (Lighting)[1]	19,014						$452							
		& Science Bldg	Incandescent to Fluorescent Conversion[1]	12,636	29					$821							
			Install Adjustable Frequency Drive on CHW Pump[1]	33,929						$957							
			Install Adjustable Frequency Drive on AHUs[1]	123,406		-31				$3,403							
			TOTAL	188,985	29	-31				$5,433	No measured savings						
125		Education Complex	Incandescent to Fluorescent Conversion[1]	7,789	11					$321							
			OA Control Modifications[1]	1,043		17				$157							
			Install Adjustable Frequency Drive on CHW Pump[1]	22,327						$630							
			Install Adjustable Frequency Drive on AHUs[1]	112,868		-27				$3,115							
			TOTAL	144,027		-27				$4,223	No measured savings						
125		Fine Arts Complex	Install Motion Sensors (Lighting)[1]	10,853						$306							
			Incandescent to Fluorescent Conversion[1]	12,712	11					$459							
			OA Control Modifications[1]	14,366		61				$559							
			Install Adjustable Frequency Drive on CHW Pump[1]	16,121						$455							
			TOTAL	54,052	11	61				$1,779	No measured savings						
125		Health & Physical	Incandescent to Fluorescent Conversion[1]	7,211	10					$295							
		Education Complex	Install Adjustable Frequency Drive on CHW Pump[1]	230,930						$851							
			Install Adjustable Frequency Drive on AHUs[1]	150,143		-36				$4,144							
			TOTAL	388,284	10	-36				$5,090	No measured savings						
125		Learning Resource	Install Motion Sensors (Lighting)[1]	27,222						$768							
		Center	Incandescent to Fluorescent Conversion[1]	62,577	140					$3,045							
			Delamp above Bookshelf Area[1]	52,005	118					$2,547							
			OA Control Modifications[1]	17,153		73				$668							
			Install Adjustable Frequency Drive on CHW Pump[1]	78,835						$2,167							
			Install Adjustable Frequency Drive on AHUs[1]	571,694		-139				$15,773							
			TOTAL	807,486		-139				$24,968	No measured savings						
125		Liberal Arts	Install Motion Sensors (Lighting)[1]	16,397						$462							
			Incandescent to Fluorescent Conversion[1]	19,729	45					$968							
			OA Control Modifications[1]	9,584		41				$373							
			Install Adjustable Frequency Drive on CHW Pump[1]	32,816						$920							
			Install Adjustable Frequency Drive on AHUs[1]	163,705		-39				$4,519							
			TOTAL	242,011		2				$7,242	No measured savings						
125		Mens' Dormitory	Install Motion sensors to Control Room A/C[1]	79,752		-22				$2,194							
			Incandescent to Fluorescent Conversion[1]	54,519	77					$2,241							
			Replace Existing Thermostat[1]	15,053		192				$907							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings						Estimated Cost Savings ($)	Measured Savings					Measured Cost Savings ($)[2]
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr		Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
			Install Variable Speed Drive on CHW Pump[1]	27,687						$781							
			TOTAL	177,011	77	177,088				$6,123	No measured savings						
125		Womens' Dormitory	Install Motion sensors to Control Room A/C[1]	79,752		-22				$2,194							
			Incandescent to Fluorescent Conversion[1]	54,519	77					$2,241							
			Replace Existing Thermostat[1]	15,053		192				$907							
			Install Variable Speed Drive on CHW Pump[1]	27,687						$781							
			TOTAL	177,011	77	192				$8,123	No measured savings						
125		Science Bldg Comp	Install Motion sensors to Control Lighting[1]	18,240						$514							
			Incandescent to Fluorescent Conversion[1]	15,065	29					$690							
			Install Adjustable Frequency Drive on AHUs[1]	60,022		-17				$1,649							
			TOTAL	93,327	29	-17				$2,853	No measured savings						
125		Student Service	Install Motion sensors to Control Lighting[1]	15,480						$437							
			Incandescent to Fluorescent Conversion[1]	3,066	1					$95							
			OA Control Modifications[1]	2,552		11				$99							
			Install Adjustable Frequency Drive on CHW Pump[1]	16,841						$469							
			Install Adjustable Frequency Drive on AHUs[1]	169,458		-43				$4,671							
			TOTAL	207,197	1	-43				$5,771	No measured savings						
125		Univ Center Complex	Incandescent to Fluorescent Conversion[1]	4,212	10					$211							
			OA Control Modifications[1]	2,635		11				$103							
			Install Adjustable Frequency Drive on CHW Pump[1]	9,236						$280							
			Install Adjustable Frequency Drive on AHUs[1]	84,839		-21				$2,339							
			TOTAL	100,922	10	-21				$2,913	No measured savings						
125		Central Cooling plant	Install 600 Ton Chiller[1]	1,089,428	1,925					$48,336							
			Convert to a DDC Energy Management System[1]	852,032						$24,027							
			TOTAL	1,941,460	1,925					$72,363	No measured savings						
7540	637,223		**Southwest Texas St Univ,**														
149			**San Marcos**														
		Aqua Sports Center	Install Drop Ceiling			1,680				$4,737							
			Incandescent Lighting Conversion	55,500	144	-61				$2,495							
		Music	Replace Electric Resistance Heat with Steam Heat	43,963		-194				$594							
		Butler/Falls/Sterry/Lantana	Install 2-300 ton Screw Chillers & Interconnect with CHW Piping	-795,182	-3,093	37,600				$59,084							
		Chiller Plant East	Install DDC Energy Management System	594,354						$15,440							
		Sc/Psych/Flowers	Interconnect Buildings CHW Piping	-280,582	-2,142	37,373				$79,892							
		Chiller Plant West	Reduce Pumping Requirements in Chiller Plant West	1,193,762	580					$35,942							
		Steam/Cond Sys	Steam Trap Survey and Replacement			97,799				$275,793							
			TOTAL	811,815	-4,511	174,197				$473,977	No measured savings						
79702			**Midland County**														
144	90,100	Courthouse	Energy Management System	412,128	484	1,220				$21,772							
			Occupancy Sensors	37,387		-34				$1,005							
			Modify Chiller Piping and Control	18,702	219					$2,909							
			Electronic Ballast	34,663	38	-17				$1,383							
			TOTAL	502,880	740	1,169				$27,069	186,200	1,316					$19,660
7180	382,232		**Texas A&M University, Galveston**														
139					In kVA												
		E. O Kirkham Hall	Energy Management System	1,071,149	641	866		13,305		$40,829							
		Engineering lab	i) Start /Stop Scheduling														
		Oceanography/Offl/Res/Main	ii) OA Ventilation Reduction														
		M.M.Northern Student Center	iii) Chiller Optimization														
		Dormitories A & B	iv) Demand Limiting														
		Central Services	Variable Speed CT Conversion	198,478	201	0		2,302		$8,232							
		Classroom/ Lab	A & B Dorm VAV Conversion	418,021	268	0		4,849		$15,364							
		J.K William Lab	Variable Speed CHW Pumping	200,465	301	0		2,325		$9,552							
			Power Factor Correction Note: ECRMs are not	0	634	0		0		$8,061							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft. Area	Building/ Facility	ECRMs	Estimated Savings						Estimated Cost Savings ($)	Measured Savings						Measured Cost Savings ($)
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr		Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	
			Fan Slowdown individually listed.	167,190	347	0		1,939		$9,194							
			Lighting Projects	239,402	389	0		2,777		$11,876							
			Install time clocks														
			TOTAL	2,294,705	2,781	866		27,497		$103,108	No measured savings						
7830	496,000	Texas College of Osteopathic Med,FW															
138		Medical Building I	Install Timeclocks & Motion Detectors for Lights	113,162						$3,508							
			Shutdown Exhaust Fans	265,408						$8,228							
				378,570						$11,736							
138		Medical Building II	Utilize Existing Heat Reclaim System	28,109	214	2,450				$15,731							
138		Medical Building III	Shutdown the Domestic Hot Water Circulation Syste	5,105		179				$1,132							
135		All	Chilled Water Reset	423,417						$13,126							
			Heating Water Reset			509				$2,769							
			Provide High Efficiency Boilers			1,810				$9,846							
			TOTAL	423,417		2,319				$25,741	No measured savings						
7360																	
137		UT at Dallas															
	82,606	Berkner/Founders/McDermott	High-Eff Floures Lamps & Ballasts[1]	1,432,200	281		252,552	-1,124		$74,148							
	48,736	FoundersN/Green/Jonsson	High-Eff Floures Lamps & Ballasts[1]	864,628	192		133,465	-594		$46,189							
	121,113	Founders	Air Handling Unit Conversion[1]							$14,862							
		Energy Plant	Cogeneration Plant Modifications[1]							$109,897							
	211,798	McDermott	Skylight Solar Screen[1]				47,725			$1,904							
	135,796	Green	EMS Lighting Control[1]	271,692						$4,949							
	134,055	Jonsson	EMS Lighting Control[1]	289,347						$4,493							
			TOTAL	2,857,867	473		433,742	-1,718		$256,242	No measured savings						
5060																	
		M.D.Anderson, Houston, TX															
136	1,522,193	Cancer Center	Lighting Modifications[1]	2,544,000	668		542,867	-2,171		$89,578							
			Upgrade EMCS[1]	641,136			1,307,550	6,340		$118,067							
			Air-Side Modifications to Fume Hood Areas[1]	438,000			1,352,091	5,080		$108,421							
			TOTAL	3,623,136	668		3,202,308	9,249		$316,066	No measured savings						
7192																	
		TSTC Harlingen, TX															
150	20,750	Learning Resouce Center'B'	Install Central Chillers with Partial Thermal Storage	1,451,299	6,329				16,835	$129,916							
150	20,750	Technical Office Training 'C'															
150	20,750	Medical Science Building 'D'															
150	27,743	Electronics/Computer Tech 'G'															
150	18,000	Chemical Instr. Tech 'J'															
150	31,200	Engineering Des. ad Graphics															
											$129,916	No measured savings					
75202																	
		Dallas County, Government Center															
		Facility Based	Install Reflectors and Delamp Fixtures[1]	813,855	3,320	-623				$55,807							
			Install Motion Sensors to Control Lighting[1]	118,791						$3,333							
146	473,800	Government Center	Chiller Replacement[1]	696,050	1,139					$32,075							
			EMCS upgrade[1]	297,425		477				$10,497							
			Install VFD's on CHW pumps[1]	834,682						$23,822							
			Replace/Rebuild Faulty Steam Traps and Valves			6,438				$27,102							
			Steam Generation Modifications			3,306				$13,918							
			Timeclock Control of Drinking CHW System[1]	31,194						$890							
			Replace Flourescent Fixtures at the Plaza Level[1]	88,457	242	-88				$4,830							

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft Area	Building/ Facility	ECRMs	Estimated Savings						Estimated	Measured Savings					Measured
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Cost Savings ($)	Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr	Cost Savings ($)
			VAV Conversion[1]	638,233		2,778				$29,910							
			TOTAL	3,516,687	4,701	12,307				$202,184	No measured savings						
78404	836,702	Delmar College, Corpus Christi															
143		Campus	Thermal Energy Storage/Industrial	-1,717,800	13,662					$252,952							
			water source heat pump[1]														
			Capacitors for Power Factor Improvement							$19,896							
			Interior Lighting Control[1]							$12,226							
			Exterior Lighting Control[1]							$751							
			Fixture Relamping[1]							$2,113							
			TOTAL	-1,717,800	13,662					$267,938	No measured savings						
78107		FW ISD, Fort Worth, TX															
128	62,400	Sims Elementary School	Delamp 4-bulb Fluorescent Fixtures, replace with							$17,240							
129	92,884	Dunbar Middle School	Polished Reflectors (Note: This is a combined							$17,240	114,110						$7,691
			ECRM)														
											81,409						$5,487
75963		Nacogdoches ISD															
151	202,815	Nacogdoches H.S	Install District wide EMS (applies to all schools)	725,317		2,236				$59,729							
			Convert to Gas Heating	61,940		-259				$3,152							
			Increase Cooling Capacity at Chiller Station	297,611						$20,535							
			Exterior lighting conversion and relamping														
			TOTAL	1,084,868		1,977				$83,416	459,260						$31,849
152	132,443	Chamberlain Middle School	Install District wide EMS (see above)														
			Exterior lighting conversion and relamping														
			High efficiency motor installation														
			Cooling unit replacement														
											125,304						$8,648
6780		TDHHMR, Austin															
855			Energy Management System	194,520		1,026				$11,586							
			Variable Speed Motors	281,410	17					$11,017							
			TOTAL	475,930	17	475,947				$22,603	No measured savings						
		Galveston ISD															
160	80,400	Oppe Elementary	Thermal Storage System[1]							$16,715							
										$16,715	No measured savings						
161	80,769	Weis Middle	Thermal Storage System[1]							$16,274							
										$16,274	No measured savings						
162	81,742	Parker Elementary	Thermal Storage System[1]							$30,640							
										$30,640	No measured savings						
163	76,798	Morgan Elementary	Thermal Storage System[1]							$18,008							
										$18,008	No measured savings						
164	63,044	Rosengerg Elementary	Thermal Storage System[1]							$13,607							
										$13,607	No measured savings						
		Ward Memorial Hospital															
145	37,000		Thermal Storage System[1]		1,230					$16,154							
										$16,154	No measured savings						

Table 4 (cont.): Measured Savings Compared to Estimated Savings for 1993

Agency /Site #	Sq. Ft. Area	Building/ Facility	ECRMs	Estimated Savings							Estimated Cost Savings ($)	Measured Savings							Measured Cost Savings ($)*
				Energy kWh/yr	Demand kW-mo/yr	Gas MCF/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr			Energy kWh/yr	Demand kW-mo/yr	Gas MMBtu/yr	CHW Ton-hr/yr	Steam MMBtu/yr	Others MMBtu/yr		
TOTALS	17,679,115	200 Buildings		#########	78,910	#######	########	523,537	68,910		$7,236,297	23,096,138	1,120	933,883	########	44,740	17,387		$2,501,777

/ Implemented too recently for inclusion
d audit estimates for [1]
and Analysis Program: Annual Energy Consumption Report 1993

Table 5 summarizes the comparisons of the detailed information presented in Table 4 and includes the 1993 annual utility cost information as presented in the 1993 LoanSTAR Annual Energy Consumption Report (AECR). The first six columns of Table 5 represent the site number, three letter name of the site, square footage of conditioned area, 1993 post-retrofit annual utility bill (from the 1993 AECR), estimated dollar savings, and measured dollar savings. The seventh column represents the percentage ratio of the measured savings versus the estimated savings. The next column (eighth column) shows the measured savings per square foot of conditioned area. The ninth column shows the estimated savings per square foot of conditioned area. The tenth column shows the annual utility bill (i.e., the 1993 AECR) per square foot of conditioned area. Finally, the eleventh column shows the measured savings as a percentage of the 1993 annual utility costs.

Figure 4a illustrates the measured dollar savings for each site compared to the estimated savings for those sites in Table 4 reporting substantial savings as of December 1993. Figure 4b presents the same information in an x-y format where a perfect agreement between the measured and estimated savings would align along the 45 degree line in the middle of the graph. Clearly, there are substantial differences in the estimated versus measured savings across the sites that were reporting savings as of 1993. For four of the sites (WCH, WIN, GAR, and VHS) the measured savings were more than 3 times the audit estimated savings. While at 9 of the sites the savings were less than 50% of the audit estimated savings. On average (i.e., the last bar in Figure 4a) the measured savings were about 75% of the estimated savings for the sites listed in Table 5.

In Figure 5 the measured savings are compared to the post-retrofit annual energy costs where the post-retrofit energy costs represent those listed in the 1993 AECR. In this figure ratios of 100% mean that the retrofit is saving roughly one-half (i.e., 50%) of the pre-retrofit energy use. In nine of the sites that were reporting savings as of December 1993 the measured energy savings represent 80% or more of the post-retrofit annual energy use. On average the measured savings for the sites listed in Table 5 were 26% of the 1993 post-retrofit costs.

Figure 4a: Measured Savings (1993) Compared to Estimated Annual Savings. The estimated savings are compared to the measured savings in this figure and in Table 5.

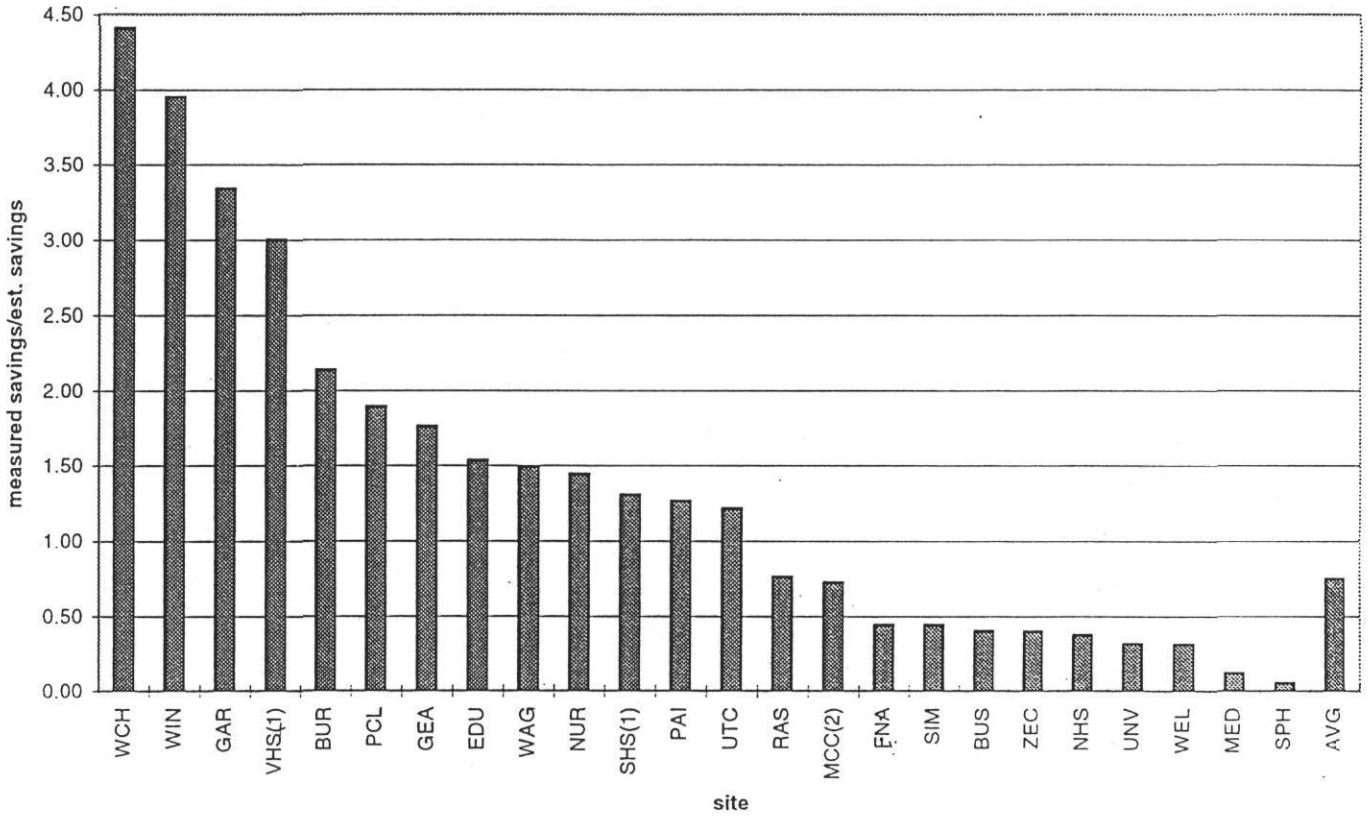


Figure 4b: Measures Savings Compared to Estimated Savings

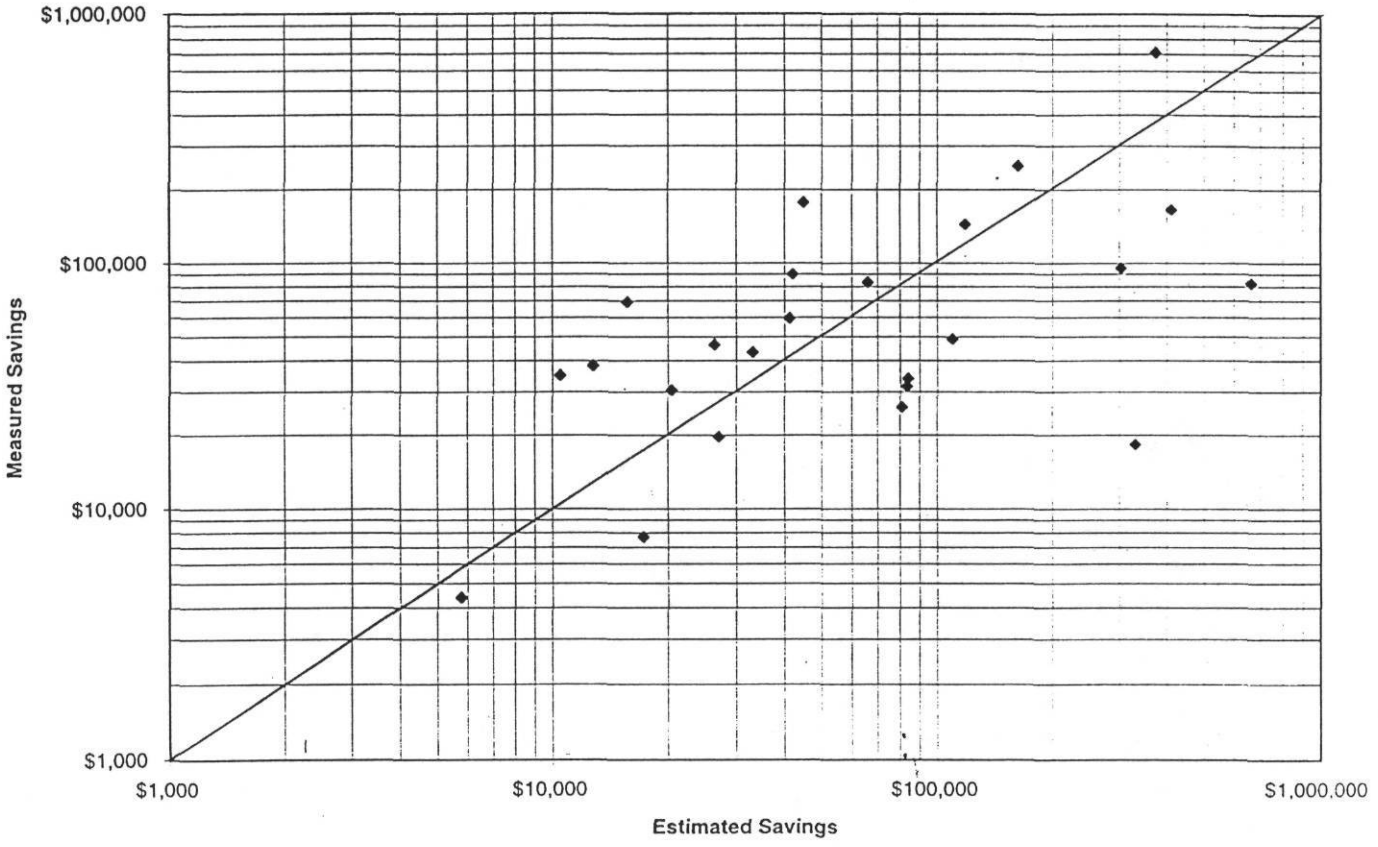


Table 5: Summary of Measured Savings to Estimated Savings for 1993

SITE #	NAME	SQFT	1993 ANN. UTIL. $	EST $ SAVE	MEAS $ SAVE	MEAS/ EST $	MEAS $/SQFT	EST $/SQFT	ANN UTL$ /SQFT	MEAS $/ANN UTL $
1	ZEC	324,000	$584,972	$411,066	$165,520	40.3%	$0.51	$1.27	$1.81	28.3%
100	EDU	251,161	$261,276	$161,956	$249,209	153.9%	$0.99	$0.64	$1.04	95.4%
101	UTC	152,690	$139,782	$118,179	$143,980	121.8%	$0.94	$0.77	$0.92	103.0%
102	PCL	483,895	$649,474	$373,621	$709,271	189.8%	$1.47	$0.77	$1.34	109.2%
103	GAR	54,069	$41,738	$10,485	$35,090	334.7%	$0.65	$0.19	$0.77	84.1%
104	GEA	61,000	$57,784	$26,367	$46,476	176.3%	$0.76	$0.43	$0.95	80.4%
105	WAG	57,600	$84,482	$20,400	$30,496	149.5%	$0.53	$0.35	$1.47	36.1%
106	WEL	439,540	$1,111,240	$303,435	$95,522	31.5%	$0.22	$0.69	$2.53	8.6%
107	BUR	103,441	$105,296	$42,049	$90,034	214.1%	$0.87	$0.41	$1.02	85.5%
108	NUR	94,815	$114,741	$41,235	$59,573	144.5%	$0.63	$0.43	$1.21	51.9%
109	RAS	56,849	$54,048	$5,768	$4,404	76.4%	$0.08	$0.10	$0.95	8.1%
109	WIN	109,000	$188,269	$44,881	$177,447	395.4%	$1.63	$0.41	$1.73	94.3%
110	PAI	128,409	$278,985	$65,955	$83,333	126.3%	$0.65	$0.51	$2.17	29.9%
110	WCH	48,905	$64,197	$15,682	$69,189	441.2%	$1.41	$0.32	$1.31	107.8%
112	BUS	149,900	$147,743	$83,960	$33,991	40.5%	$0.23	$0.56	$0.99	23.0%
113	FNA	223,000	$239,569	$109,334	$48,903	44.7%	$0.22	$0.49	$1.07	20.4%
120	MED	887,187	$3,677,292	$664,589	$82,416	12.4%	$0.09	$0.75	$4.14	2.2%
126	SHS(1)	210,500	$52,342	$33,094	$43,339	131.0%	$0.21	$0.16	$0.25	82.8%
127	VHS(1)	257,000	$76,440	$12,754	$38,281	300.1%	$0.15	$0.05	$0.30	50.1%
128	SIM	62,400	$55,064	$17,240	$7,691	44.6%	$0.12	$0.28	$0.88	14.0%
149	MCC(2)	90,100	$47,229	$27,069	$19,660	72.6%	$0.22	$0.30	$0.52	41.6%
151	NHS	202,615	$171,504	$83,416	$31,649	37.9%	$0.16	$0.41	$0.85	18.5%
165	UNV	123,450	$77,532	$81,077	$25,998	32.1%	$0.21	$0.66	$0.63	33.5%
300	SPH	233,738	$473,094	$330,984	$18,283	5.5%	$0.08	$1.42	$2.02	3.9%
	AVG	200,219	$364,754	$128,525	$96,240	74.9%	$0.48	$0.64	$1.82	26.4%

NOTE:

(1) The savings at these sites include electric demand savings which are not reflected in the 1993 annual energy costs.

(2) The savings at this site includes electric demand savings. This site also consumes natural gas which is not reflected in the 1993 annual energy costs.

Figure 6 shows the measured energy savings (upper portion of the stacked bar chart) combined with the 1993 annual energy use ($/sqft). This graph is intended to provide a visual indicator of the $/sqft reductions attributable to the retrofit savings. In this figure a clear pattern seems to emerge that helps to explain why some sites experienced more savings ($/sqft) than other sites. This can be seen as the general leveling-off of the post-retrofit energy use around 0.5 to 1.5 $/sqft. In general, those sites that had a combined pre-retrofit energy use (i.e., measured savings + post-retrofit use) of more than 1.5 $/sqft saw the greatest retrofit savings, while those sites that had a pre-retrofit energy use of less than 1.0 $/sqft. showed generally less energy savings. The exceptions to this include the Medical Center at Houston which showed very little savings (i.e., the first bar that remains at over $4/sqft) and the Welch chemistry building on the University of Texas Campus. The average combined measured savings plus 1993 post-retrofit energy use is $2.46 which represents $0.64 retrofit savings and $1.82 in 1993 post-retrofit energy costs.

Table 6 presents an additional summary of the information presented in Table 4 combined with the audit estimated cost information from Table 2. The first four columns are the site number, the name of the site, the conditioned area, and the 1993 post-retrofit utility bill. The fifth column is the column is the audit estimated total retrofit cost (from Table 2) and the sixth column is the audit estimated savings. The seventh column is the measured energy savings from the 1993 LoanSTAR AECR. The eighth column is a ratio of audit estimated cost to the estimated savings (i.e., simple payback). The ninth column is audit estimated cost compared to the measured savings. The tenth column is the audit estimated cost per square foot of conditioned area. Finally, the eleventh column is the estimated cost compared to the 1993 annual utility costs.

Figures 7, 8 and 9 show information extracted from Table 6. Figure 7 shows the ratios of the audit estimated costs to both the estimated savings and measured savings for each site. For two of the sites the ratios of the estimated costs to the measured savings had to be trimmed to allow for a reasonable graph (i.e., MED=39.1, SPH=86.9). At each of these sites investigations are underway to determine why the retrofits are not working as

Figure 5: Measured Saving Compared to 1993 Post-retrofit Annual Utility Costs.
Tabular values for this figure are contained in Table 5.

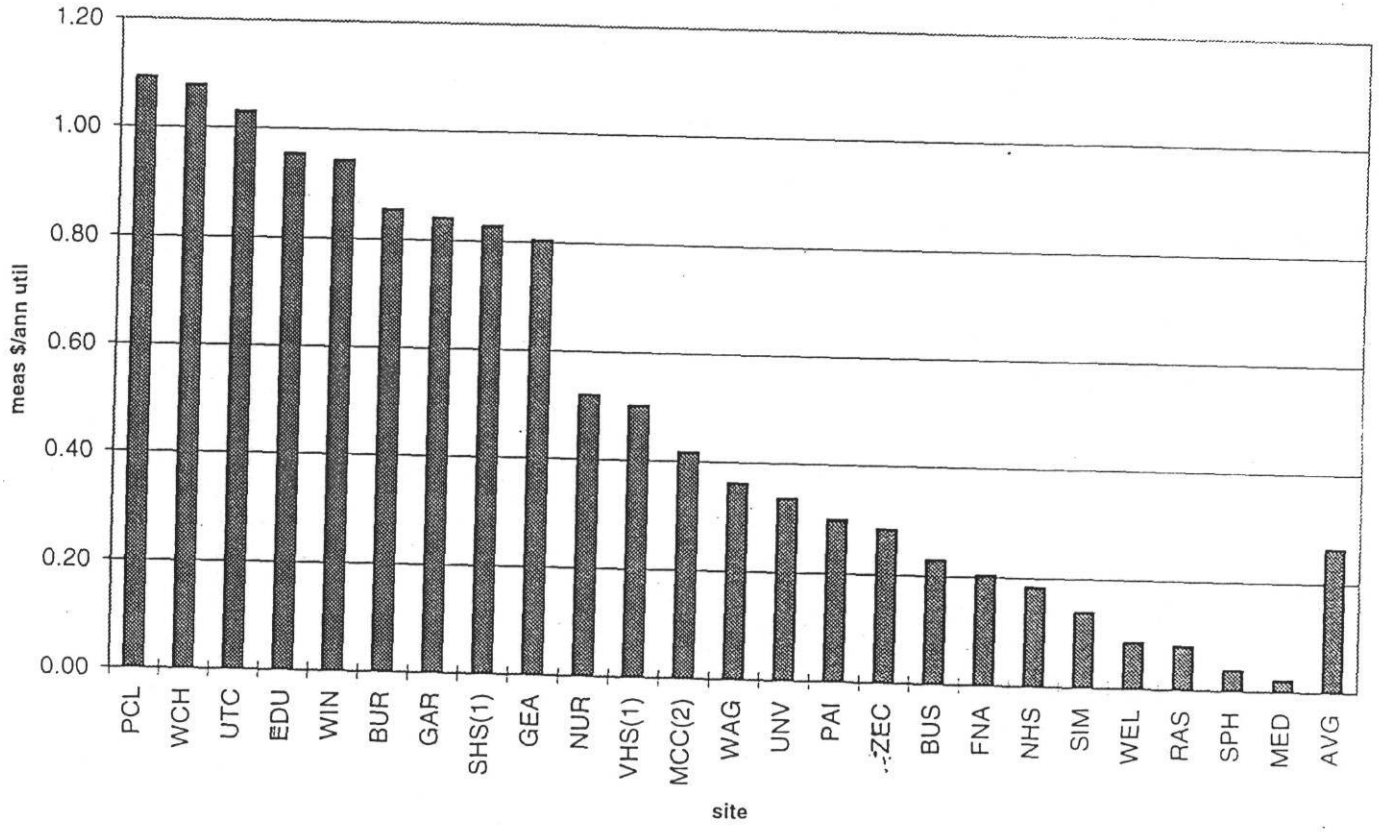


Figure 6: Measured Savings and Pre-Retrofit Annual Utility Costs ($/sqft). Tabular values for this figure are contained in Table 5.

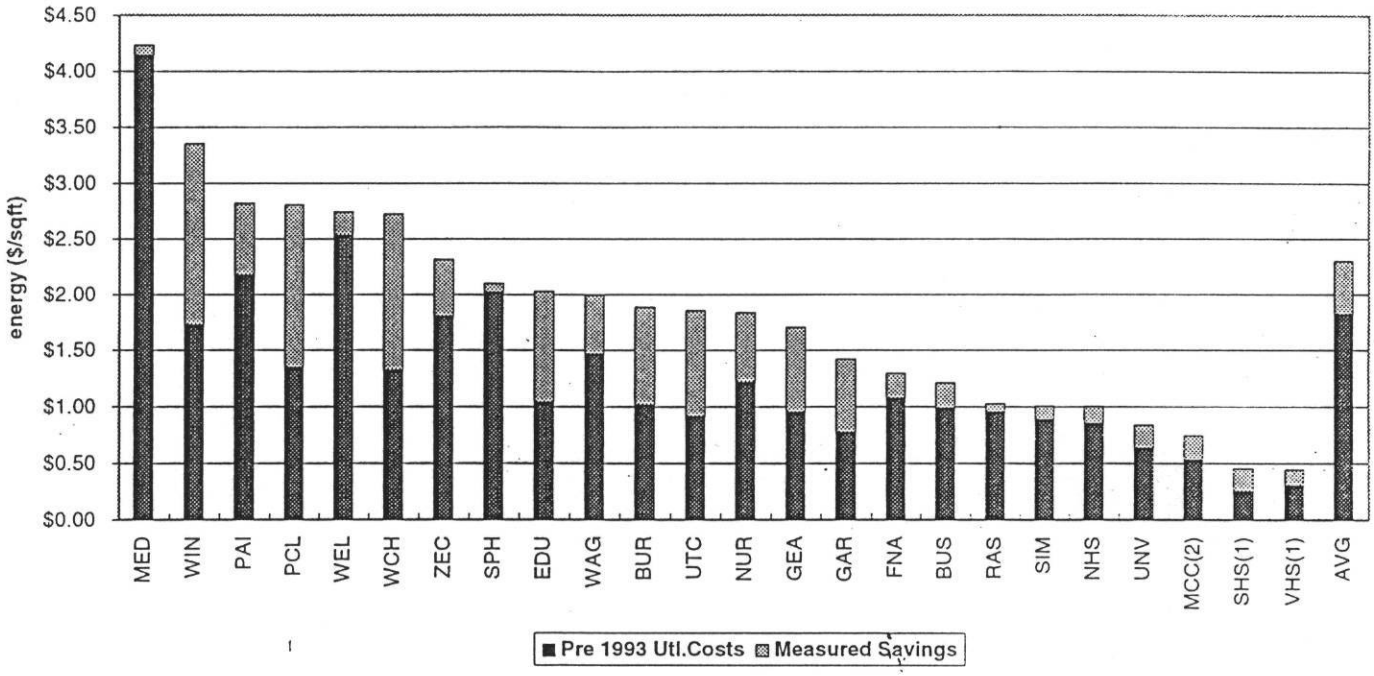


Figure 7: Estimated Retrofit Costs Compared to Estimated and Measured Savings.
Tabular values for this figure (and Figures 8 & 9) are contained in Table 6.

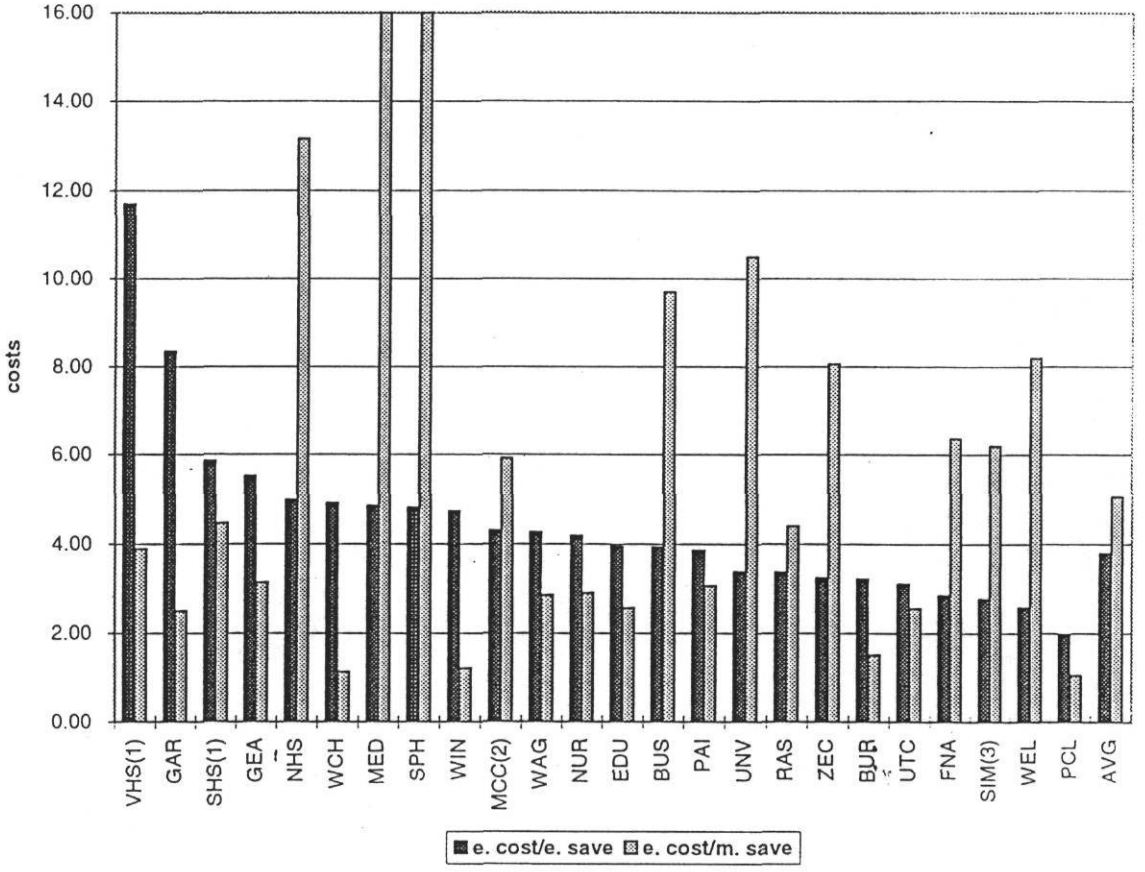


Figure 8: Estimated Costs per Square Foot of Conditioned Area

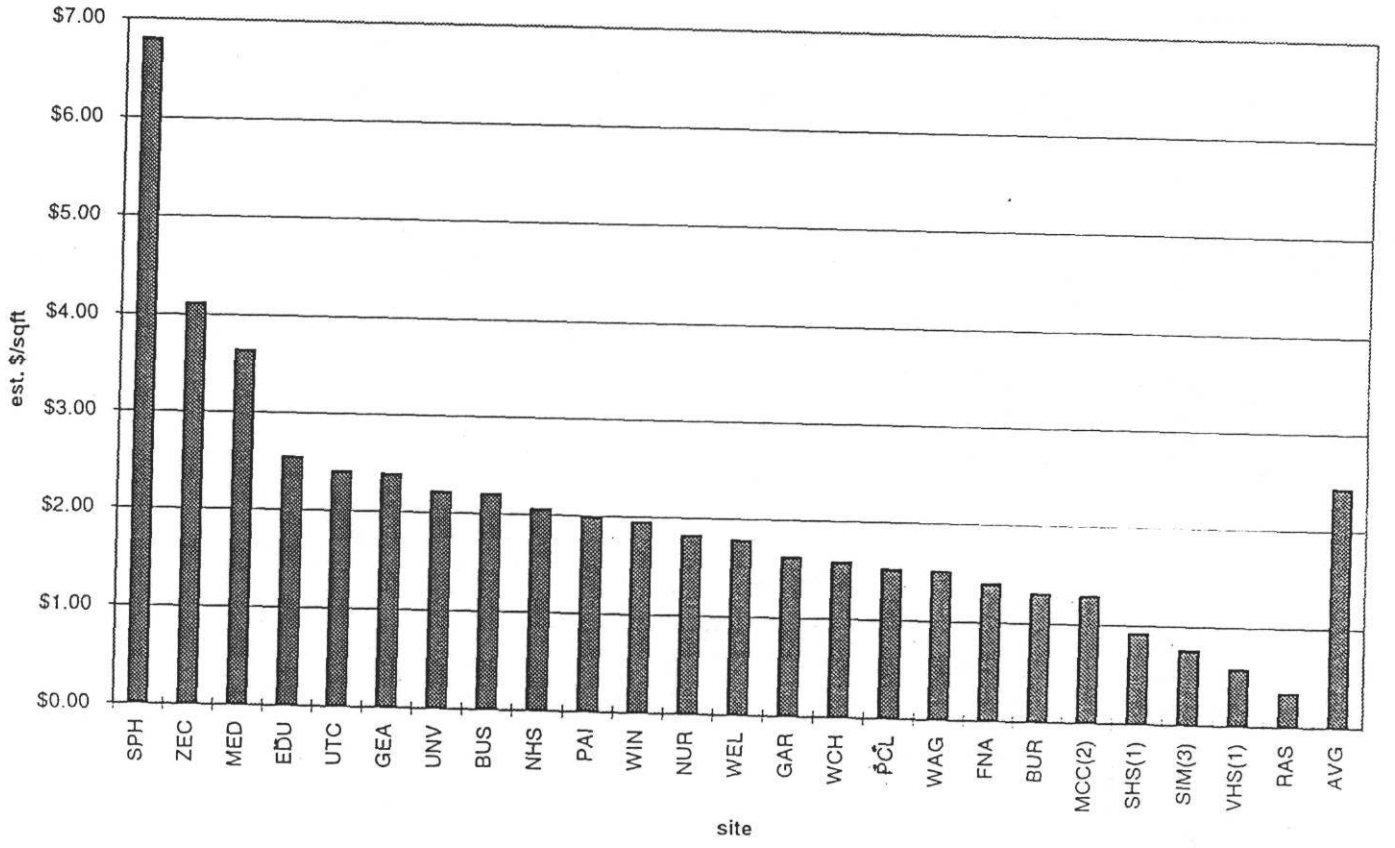


Figure 9: Estimated Costs Compared to the 1993 Utility Costs

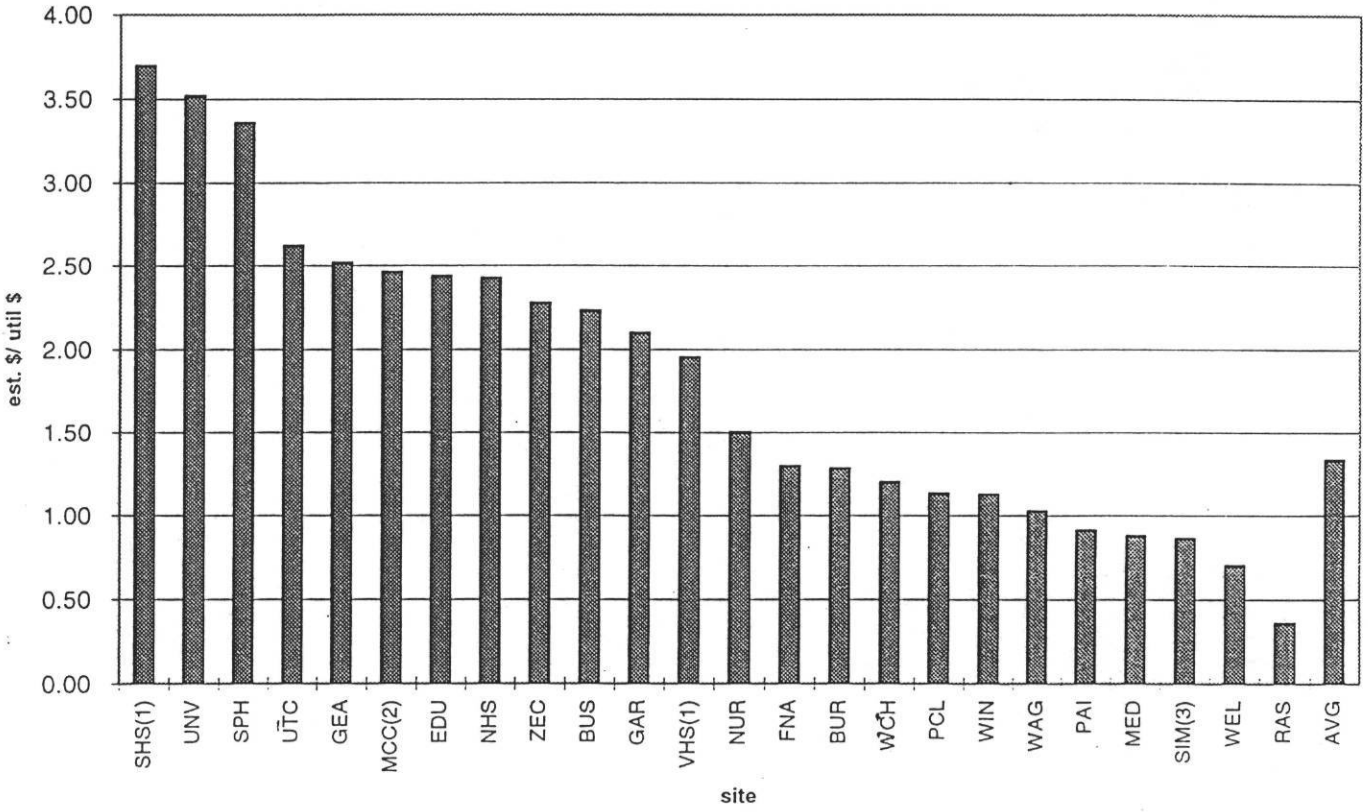


Table 6: Summary of Estimated Costs, Measured Savings & Estimated Savings

SITE #	NAME	SQFT	1993 ANN.UTIL. $	EST.COST $	EST $ SAVE	MEAS $ SAVE	COST/ EST SAVE	COST/ MEAS. SAVE	E.COST /SQFT	E.COST /1993 $
1	ZEC	324,000	$584,972	$1,331,660	$411,066	$165,520	3.24	8.05	$4.11	2.28
100	EDU	251,161	$261,276	$636,977	$161,956	$249,209	3.93	2.56	$2.54	2.44
101	UTC	152,690	$139,782	$366,255	$118,179	$143,980	3.10	2.54		2.62
102	PCL	483,895	$649,474	$735,143	$373,621	$709,271	1.97	1.04	$1.52	1.13
103	GAR	54,069	$41,738	$87,486	$10,485	$35,090	8.34	2.49	$1.62	2.10
104	GEA	61,000	$57,784	$145,458	$26,367	$46,476	5.52	3.13	$2.38	2.52
105	WAG	57,600	$84,482	$86,852	$20,400	$30,496	4.26	2.85	$1.51	1.03
106	WEL	439,540	$1,111,240	$781,443	$303,435	$95,522	2.58	8.18	$1.78	0.70
107	BUR	103,441	$105,296	$134,959	$42,049	$90,034	3.21	1.50	$1.30	1.28
108	NUR	94,815	$114,741	$172,516	$41,235	$59,573	4.18	2.90	$1.82	1.50
109	WIN	109,000	$188,269	$211,812	$44,881	$177,447	4.72	1.19	$1.94	1.13
109	RAS	56,849	$54,048	$19,369	$5,768	$4,404	3.36	4.40	$0.34	0.36
110	WCH	48,905	$64,197	$77,165	$15,682	$69,189	4.92	1.12	$1.58	1.20
110	PAI	128,409	$278,985	$254,311	$65,955	$83,333	3.86	3.05	$1.98	0.91
112	BUS	149,900	$147,743	$329,629	$83,960	$33,991	3.93	9.70	$2.20	2.23
113	FNA	223,000	$239,569	$310,738	$109,334	$48,903	2.84	6.35	$1.39	1.30
120	MED	887,187	$3,677,292	$3,224,769	$664,589	$82,416	4.85	39.13	$3.63	0.88
126	SHS(1)	210,500	$52,342	$193,606	$33,094	$43,339	5.85	4.47	$0.92	3.70
127	VHS(1)	257,000	$76,440	$149,100	$12,754	$38,281	11.69	3.89	$0.58	1.95
128	SIM(3)	62,400	$55,064	$47,600	$17,240	$7,691	2.76	6.19	$0.76	0.86
149	MCC(2)	90,100	$47,229	$116,198	$27,069	$19,660	4.29	5.91	$1.29	2.46
151	NHS	202,615	$171,504	$416,165	$83,416	$31,649	4.99	13.15	$2.05	2.43
165	UNV	123,450	$77,532	$273,012	$81,077	$25,998	3.37	10.50	$2.21	3.52
300	SPH	233,738	$473,094	$1,589,672	$330,984	$18,283	4.80	86.95	$6.80	3.36
	AVG	200,219	$364,754	$487,162	$128,525	$96,240	3.79	5.06	$2.43	1.34

NOTE:

(1) The savings at these sites include electric demand savings which are not reflected in the 1993 annual energy costs.

(2) The savings at these sites include electric demand savings. This site also consumes natural gas which is not reflected in the 1993 annual report.

(3) The audit estimated costs at this site were estimated at 4 x savings.

planned. On average, the ratio of estimated costs to savings is 3.8 and the ratio of the estimated costs to measured savings is 5.06.

Figure 8 shows estimated costs per square foot of conditioned area. For three of the sites (SPH, ZEC, MED) the cost of the retrofit exceeded three dollars per square foot. However for the majority of the sites the costs stayed in the $2 - 3 per square foot range. The average cost for the sites in Table 6 (which are the same sites as Table 5) the was $2.43.

Finally, Figure 9 shows the estimated costs as a ratio of the 1993 annual energy costs (from the LoanSTAR AECR). For three of the sites the costs of the retrofits was more than three times the 1993 annual utility costs (SHS, SPH, UNV) whereas the average ratio of costs to 1993 annual utility costs was 1.34. It is interesting to note that almost one-half of the sites had cost ratios in excess of 2 times the 1993 annual utility costs. This clearly indicates why most of these agencies could not afford to finance energy retrofits without assistance from a revolving loan.

Figure 10 has been provided to give the reader a sense of the diversity of the different types of buildings that are included in this report. Several features are worth noting in this figure. First, the reader should note the scale change in Figure 10. The first portion of Figure 10 uses a y-axis of 500,000 sqft. while the second portion of Figure 10 uses a y-axis of 2,500,000 sqft. to accommodate several of the very large sites. The 300,000 sqft. average size of the buildings does not representative the majority of the buildings since this average is influenced by three very large sites. In fact, most of the buildings are below 250,000 sqft. in size. Figures 11 through 22 break down the average costs of the various different types of retrofits. These average costs are indicated in Table 2b in the top row marked "AVG" and are organized according to the 13 types of retrofits listed in Table 1.

Figure 11 shows an average estimated cost per square foot for variable frequency drive retrofits (VFD) to air-handling units (AHU) of $1.15 which occurred at three sites. This

Figure 10: Site Area

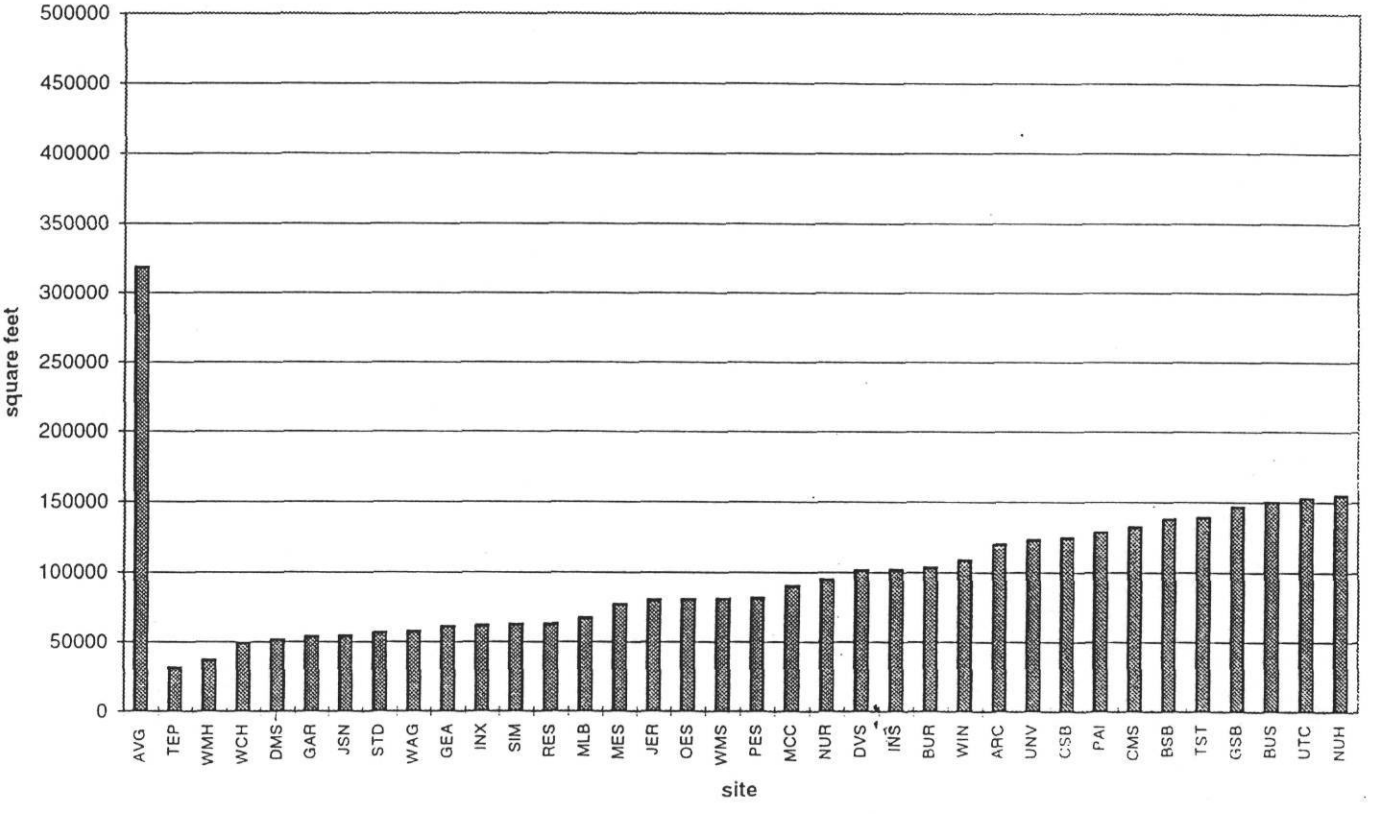


Figure 10 (Cont.): Site Area

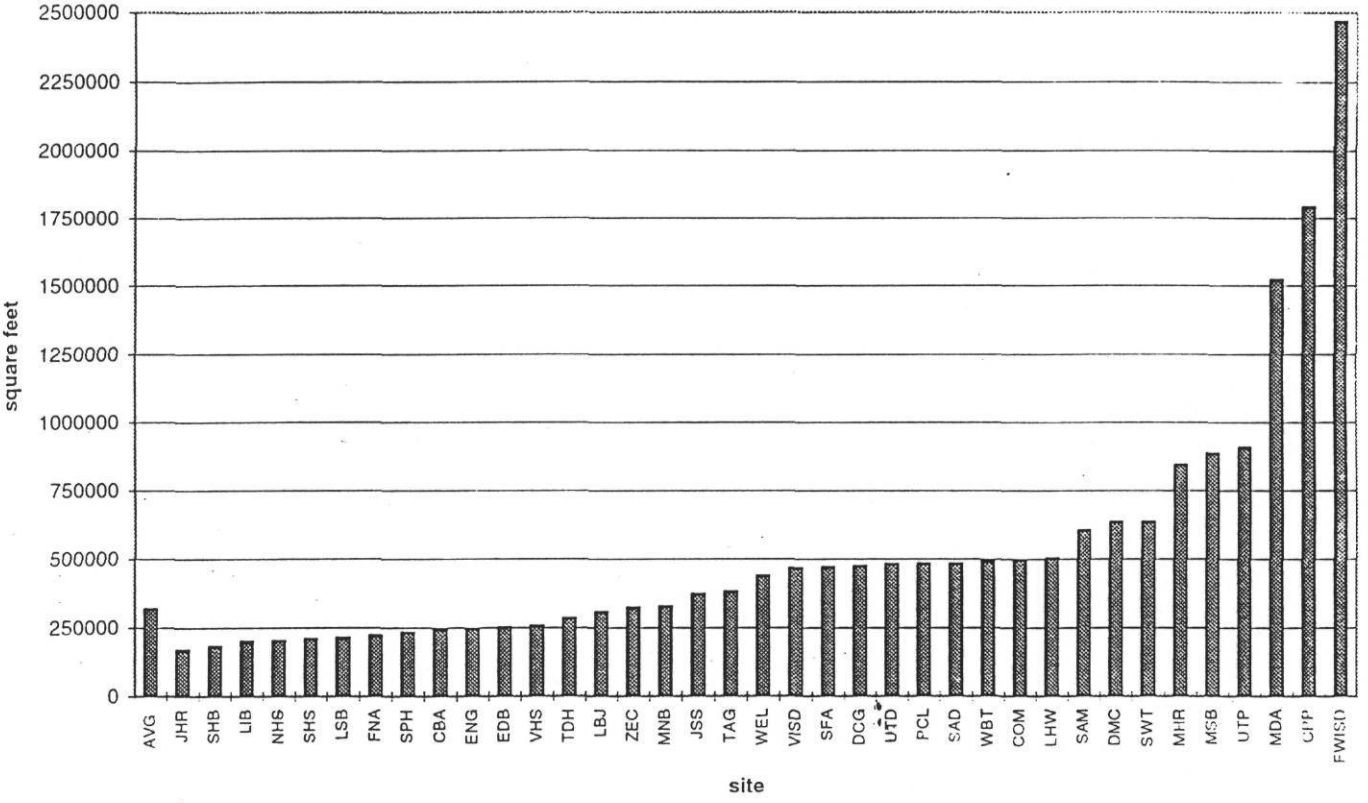
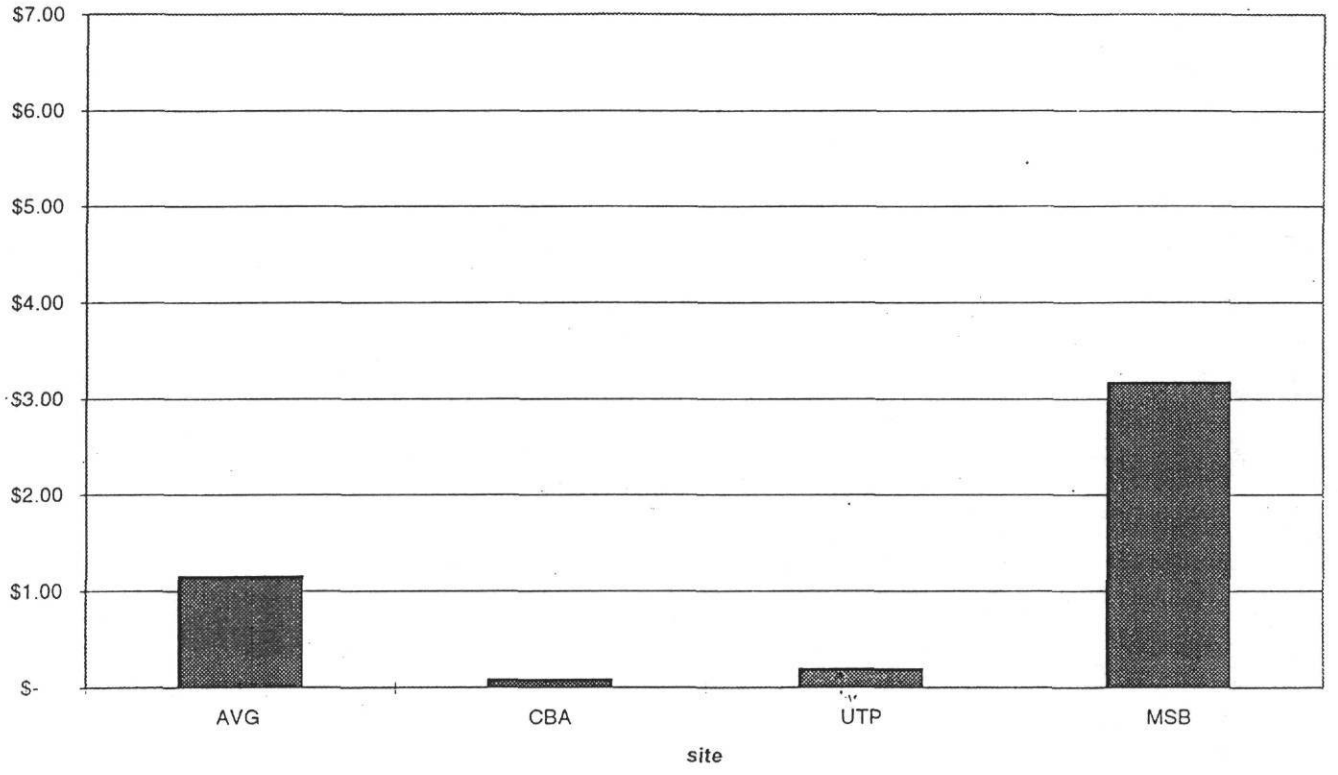


Figure 11: Estimated Cost per Square Foot of Conditioned Area (VFD to AHU)



average value is somewhat high due to the $3.17 cost at the Medical School Building at the University of Texas Health Science Center at Houston. However, the $1.15 is very close to the same cost as the HVAC VAV retrofits that are shown in Figure 12.

In Figure 12 an average cost of $1.50 is shown for variable air volume (i.e., variable speed drive) retrofits to air-handling systems at 24 sites. At one of these sites the VAV retrofit cost 2.7 times the average price. This is because at this site the VAV retrofit also included a complete replacement of 96 terminal boxes as well as extensive modifications to the duct work and large air handling units. In general, those sites that were more costly included replacements and/or upgrades to the terminal boxes; whereas those sites that were less expensive did not.

Figure 13 shows an average retrofit cost of $0.82 for "other HVAC" retrofits. At three of these sites the retrofits includes modifications to existing HVAC systems that cost over $2 per square foot. For example, these included the modification of a multizone system at the Main Building at the University of Texas at Austin campus, and a modifications to the HVAC systems at the School of Public Health at the University of Texas Health Science Center in Houston.

Figure 14 shows an average pumping system retrofit cost of $8.46 per square foot of conditioned area. This average is probably unrealistic high due to the $65.87 cost per square foot at one site (i.e., the thermal energy plant at the University of Texas at Arlington). Removal of this site from the average yields a $0.26 per square foot estimated cost which is more representative of the remaining seven sites.

Figure 15 shows an average estimated cost per square foot for motor retrofits of $0.26 across 26 sites. It is interesting to note that this average estimated cost is about the same as the $0.26 per square foot for pumping system retrofits shown in Figure 14.

Figure 12: Estimated Cost per Square Foot of Conditioned Area (HVAC VAV)

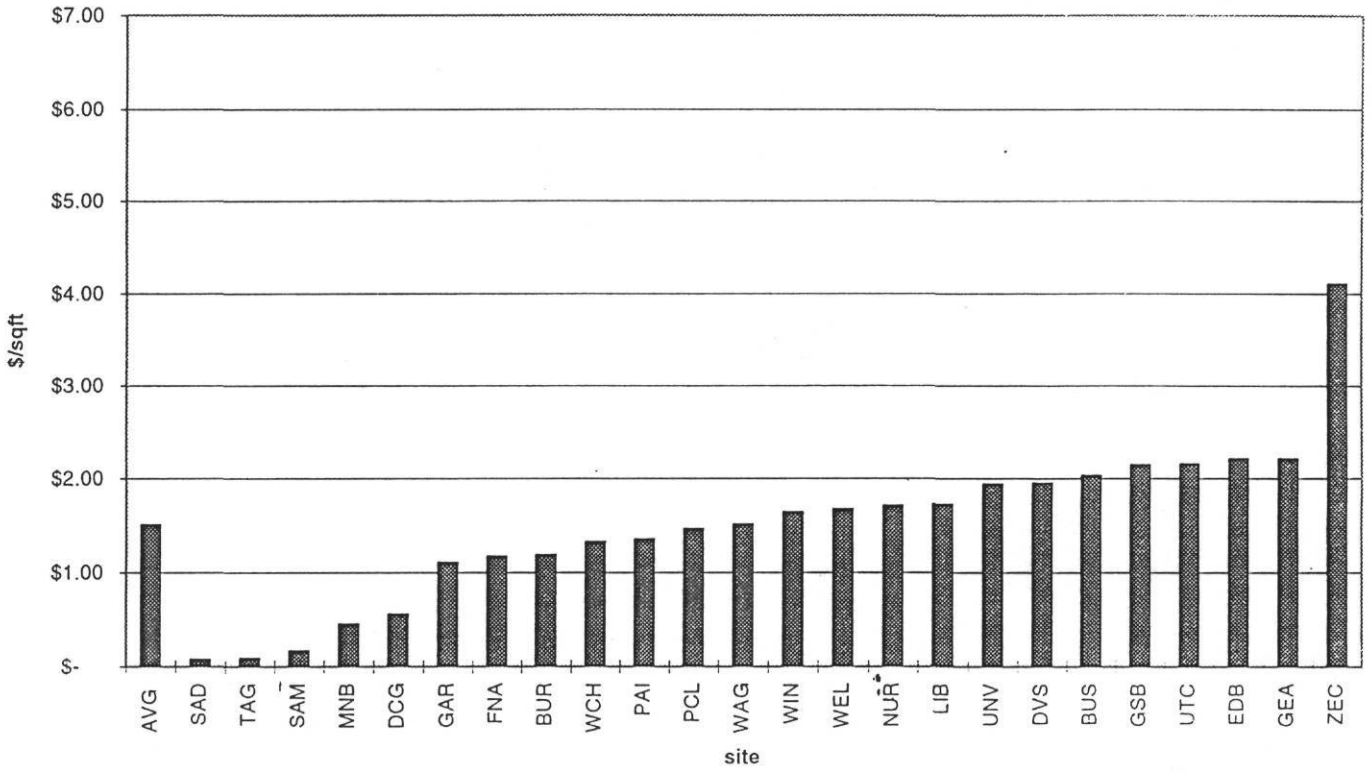


Figure 13: Estimated Cost per Square Foot of Conditioned Area (HVAC other)

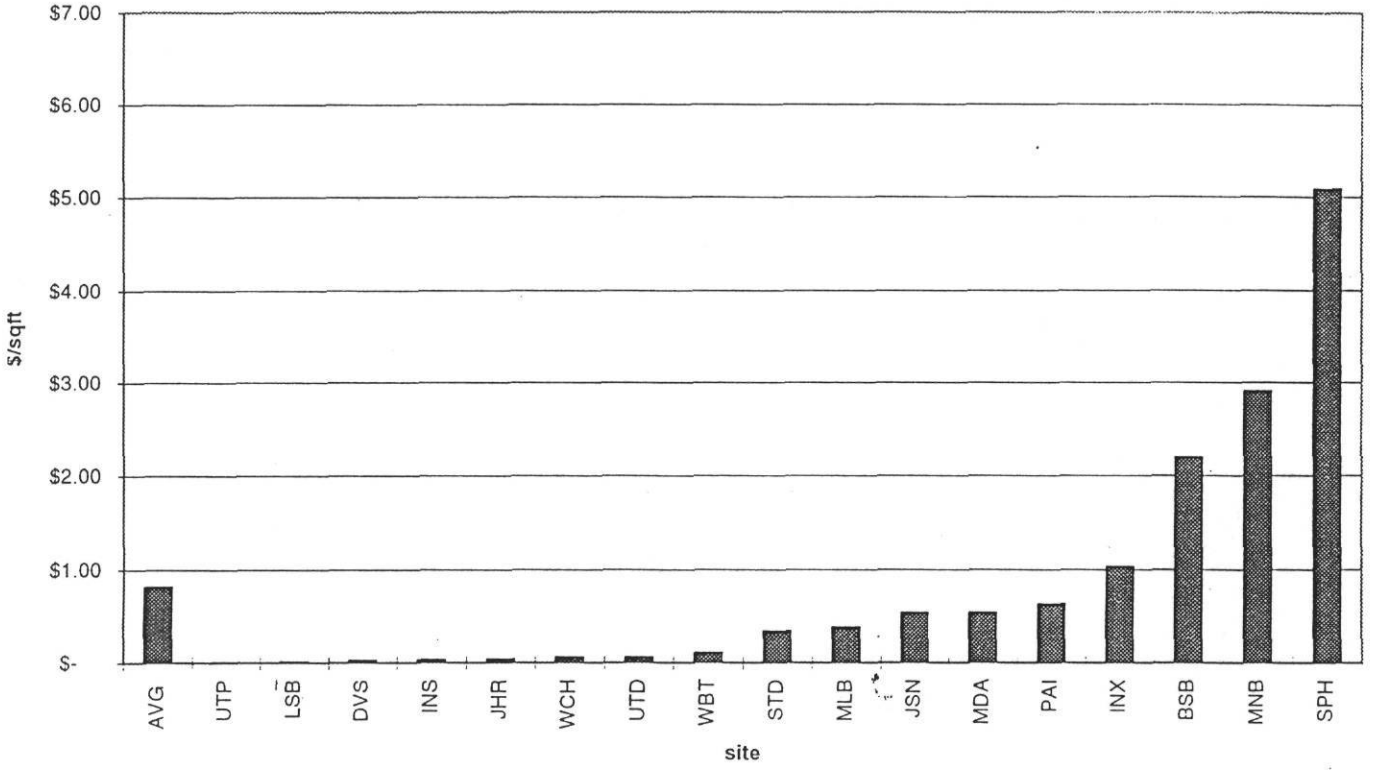


Figure 14: Estimated Cost per Square Foot of Conditioned Area (Pumping Systems)

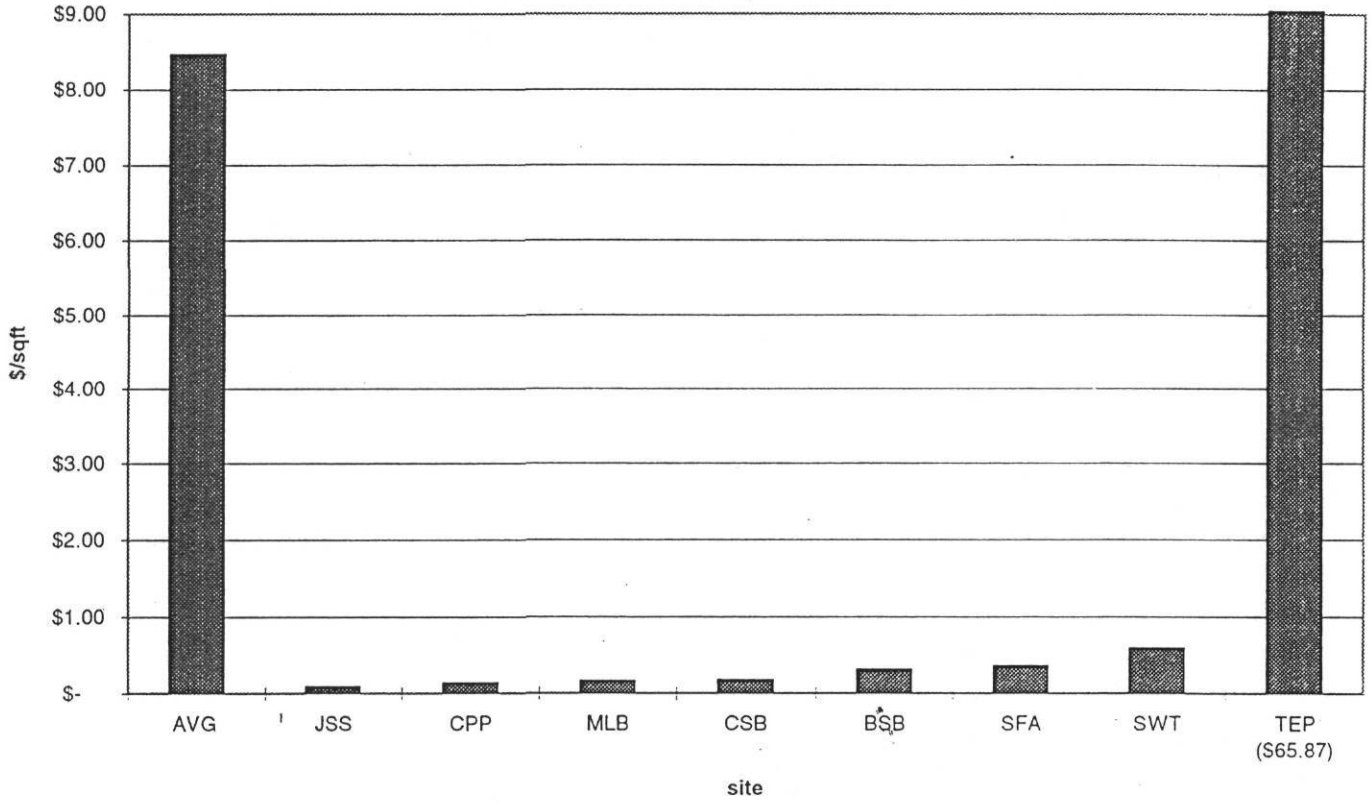


Figure 15: Estimated Cost per Square Foot of Conditioned Area (Motor Retrofits)

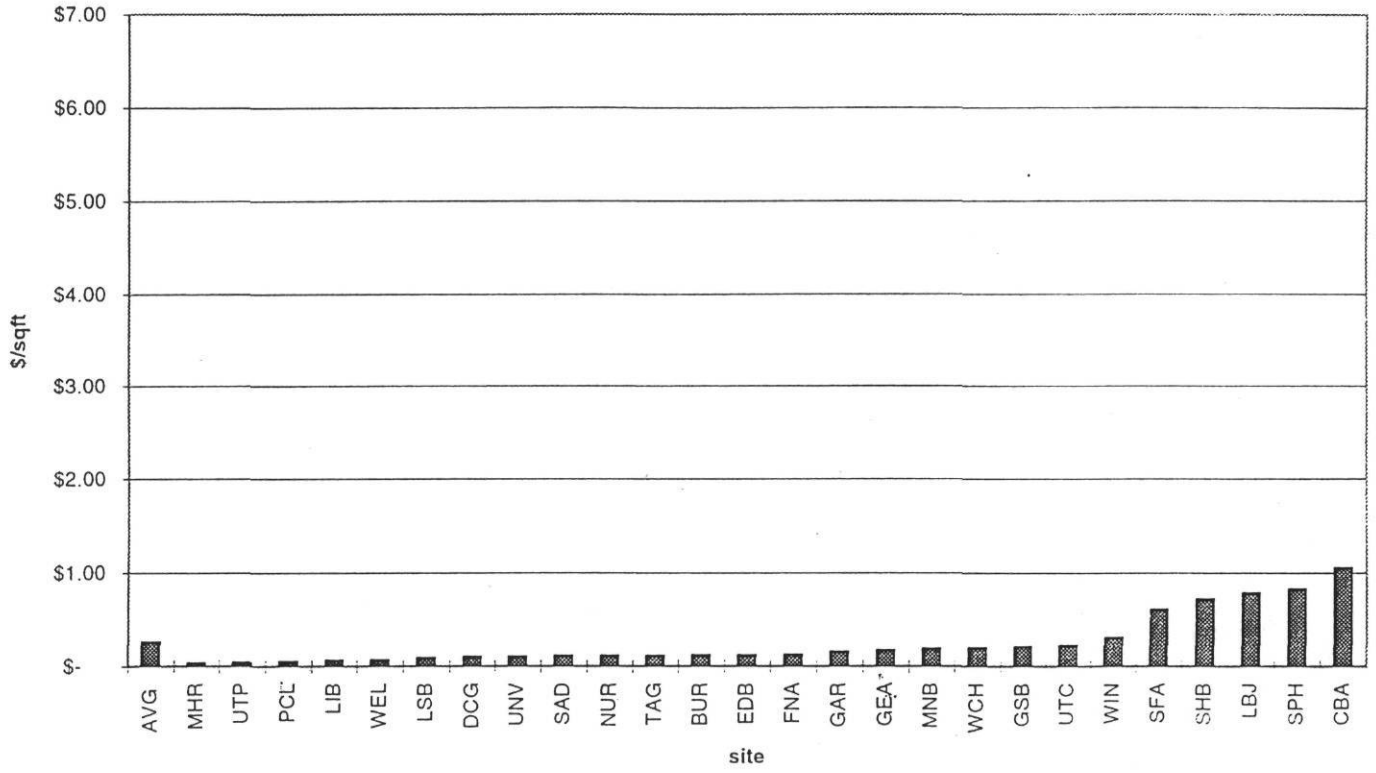


Figure 16 shows average estimated costs for lighting retrofits across 43 sites. The $0.17 average cost represents mainly conversions of existing fixtures from 40 Watt T12 fluorescent fixtures with magnetic ballasts to 30 Watt T8 fixtures with electronic ballasts. In the more expensive sites this includes reflectors; in other sites this did not. At several of the sites (i.e., the Education building at the University of Texas at Austin) the retrofit included replacement of incandescent lamps with compact fluorescent lamps.

Figure 17 shows an average estimated cost of $0.08 for occupancy controls across ten sites. Clearly, occupancy controls are a low cost energy conservation retrofit for the sites contained in this report. The average cost per square foot for co-generation retrofits was $0.69 which represents one site at the University of Texas at Dallas.

Figure 18 shows an average cost of $4.13 for thermal storage retrofits. Five of these sites were schools in the Galveston Independent School District. The remaining three sites represent two college campuses and a hospital in west Texas. It is interesting to note that six of the sites had estimated costs exceeding $4.00 per square foot, whereas only two sites had costs at or below $2.00 per square foot. One of these sites, the Ward Memorial Hospital, has experienced operation difficulties with the thermal storage system. A preliminary analysis of this site determined that the storage system and replacement chiller were both too small (Abbas et al. 1995). A recent analysis of this site has developed an improved operating strategy that now allows the system to function properly (Liu et al. 1996).

Figure 19 shows that chiller modifications averaged $0.46 per square foot across 13 sites. This value may be slightly high since it includes a $1.68 per square foot cost for chiller modifications to the thermal energy plant at the University of Texas at Arlington campus. When this is removed from the sites and the average recalculated the average cost drops to $0.36.

Figure 16: Estimated Cost per Square Foot of Conditioned Area (Lighting Modifications)

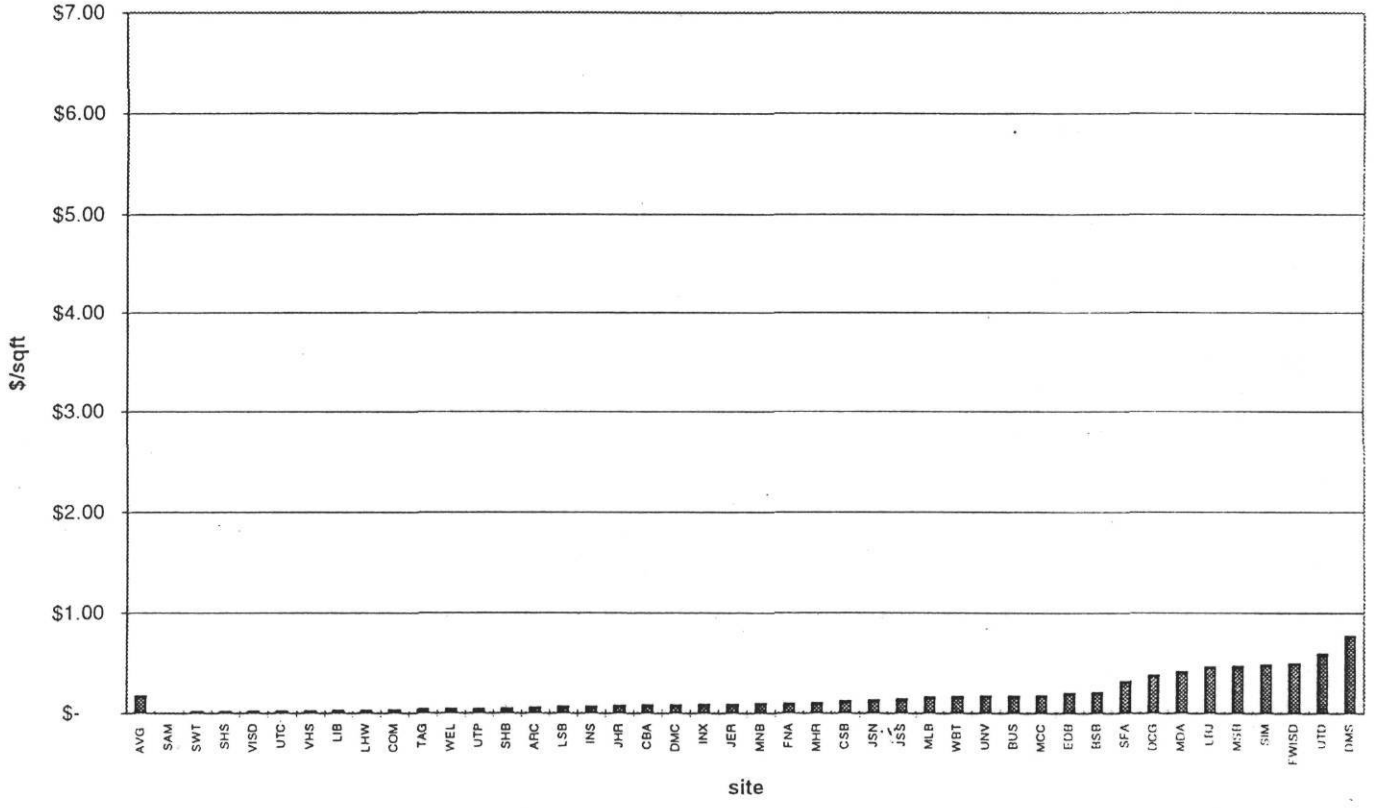


Figure 17: Estimated Cost per Square Foot of Conditioned Area (Occupancy Controls)

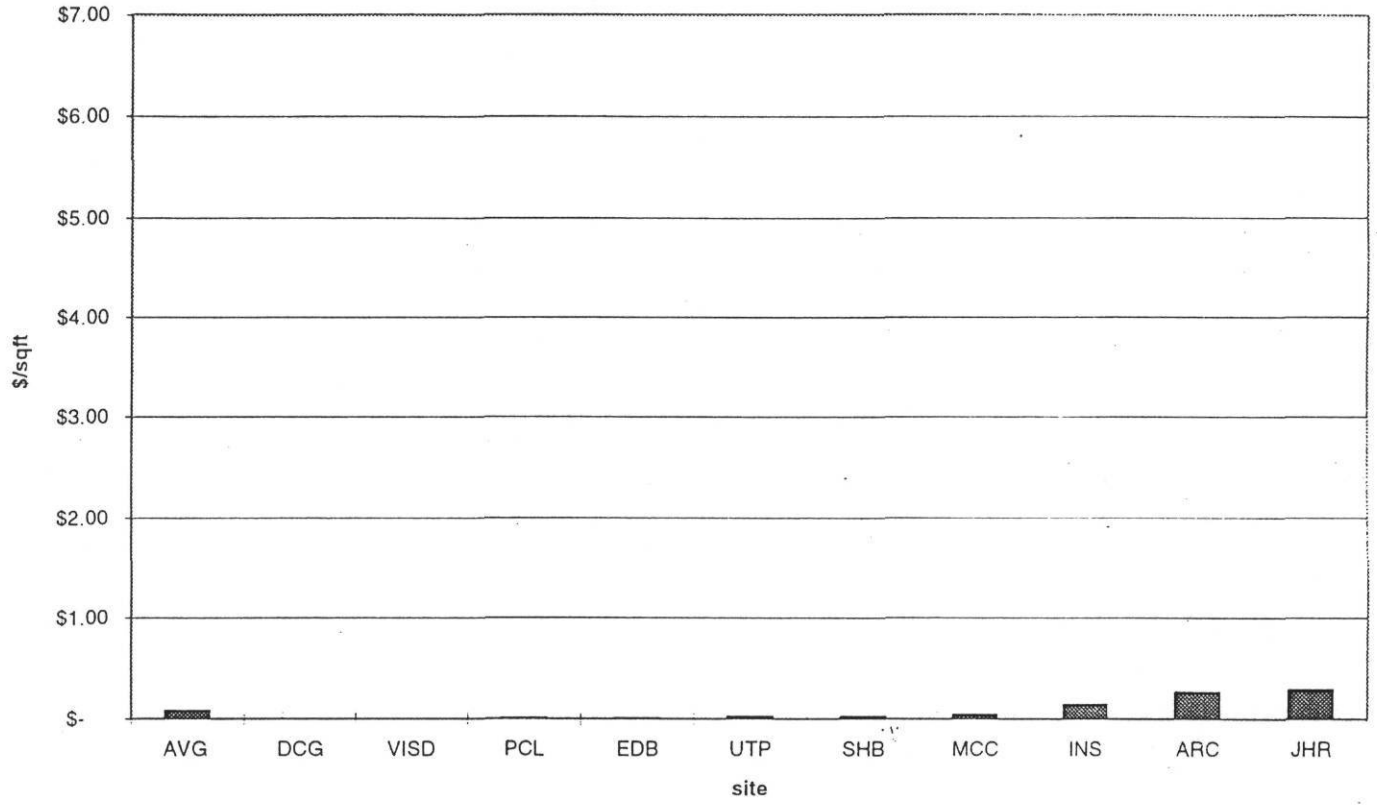


Figure 18: Estimated Cost per Square Foot of Conditioned Area (Thermal Storage)

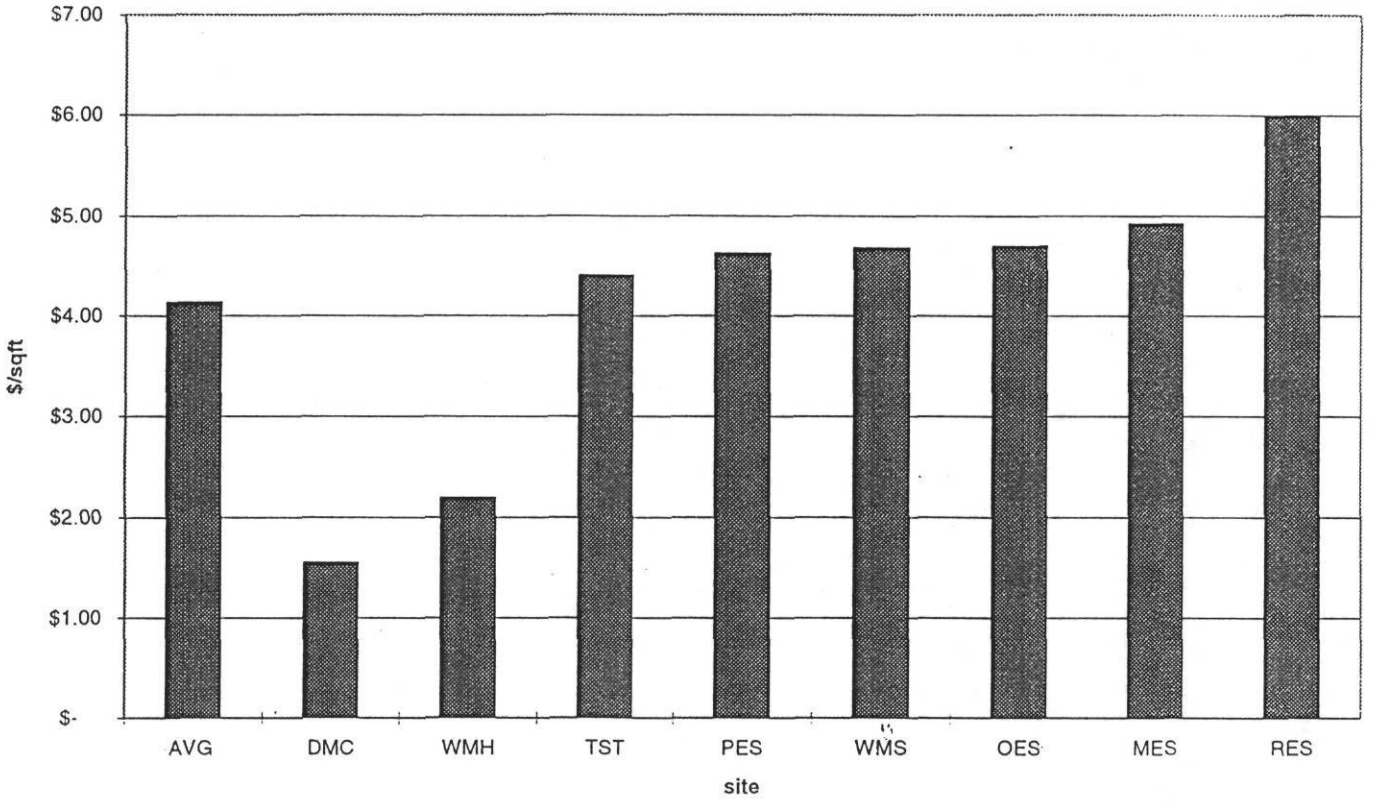


Figure 19: Estimated Cost per Square Foot of Conditioned Area (Chiller Modifications)

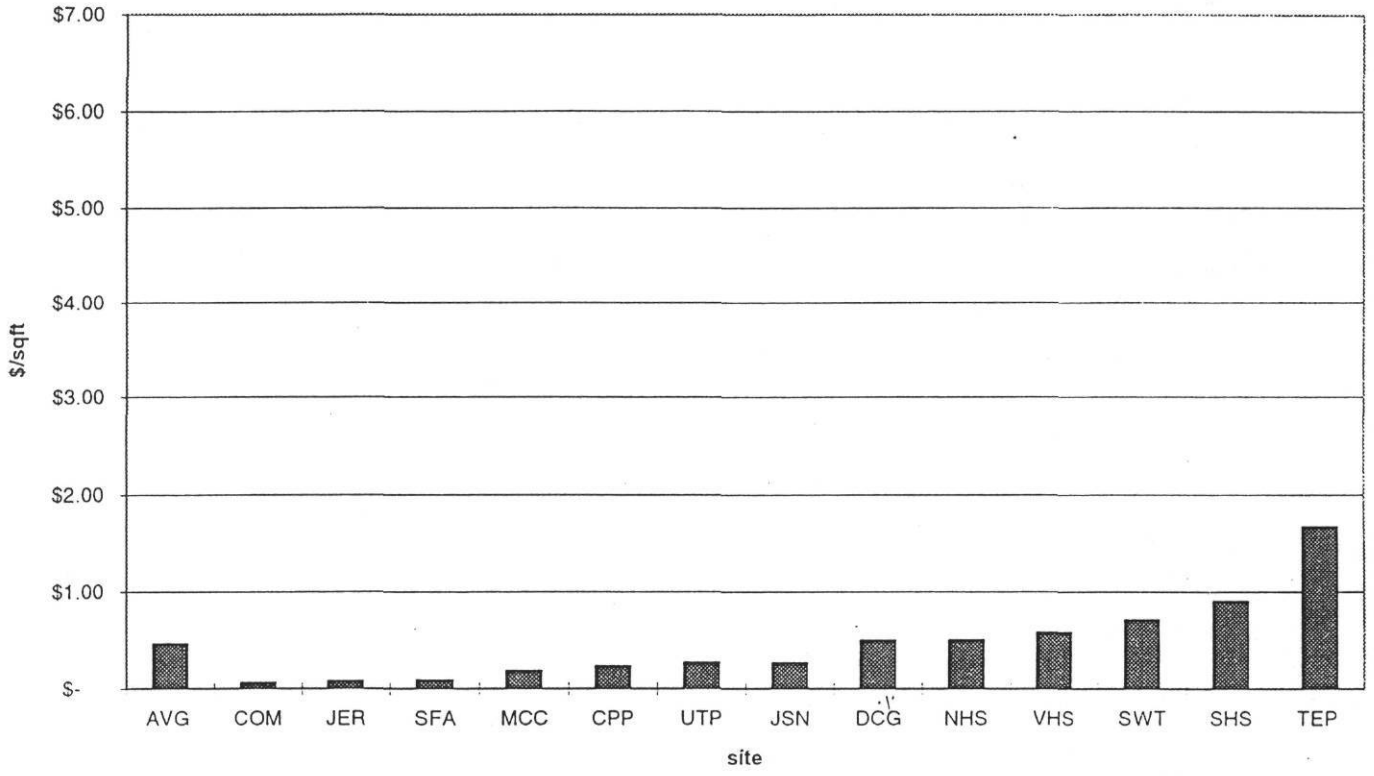


Figure 20 indicates that a boiler modification usually costs $0.18 as indicated across 13 sites. Unfortunately, this value is probably low due to the way that the retrofit costs are allocated in the Texas State Capitol Complex, which includes the SHB, JHR, ARC, INS, INX, SFA, and CPP sites. At these sites the boilers for SHB, JHR, ARC, INS, INX are contained in the one centralized CPP central plant. Therefore, if we drop the apx. $0.00 value sites from the average calculation and recalculate we obtain an average cost of $0.34 which is probably more representative of the cost of a boiler retrofit.

Figure 21 indicates that an EMCS retrofit costs about $0.51 per square foot, as indicated by 15 sites that received EMCS retrofits. It is interesting to note that about 1/2 of these sites have retrofit costs approaching (or exceeding in one case) $1.00 per square foot. Whereas, six sites had EMCS retrofit costs of less than $0.20 per square foot.

Figure 22 indicates that the "other" retrofit costs averaged $0.70 per square foot. This value is significantly influenced by one site that had $6.72 per square foot costs for retrofits to the thermal energy plant at the University of Texas at Arlington. If one removes this and recalculates the average "other" retrofit drop to $0.04 per square foot. These retrofits include such items as power factor corrections, installation of special HVAC systems for rare medical books (which reduces the need to operate the main HVAC that serves the entire building), etc.

Summary

In summary we see that certain patterns begin to emerge as we look across the broad range of retrofits that have been applied to agencies participating in the LoanSTAR program. On average the retrofits in the LoanSTAR program are performing within the expectations of the energy audits as indicated which speaks well of the value of the monitoring of the savings and feedback of results to the participating agencies. For certain of the sites the retrofits out-performed the estimates by substantial margins (as much as 3 times the estimates), whereas in some cases almost no savings occurred. On average the

Figure 20: Estimated Cost per Square Foot of Conditioned Area (Boiler Modifications)

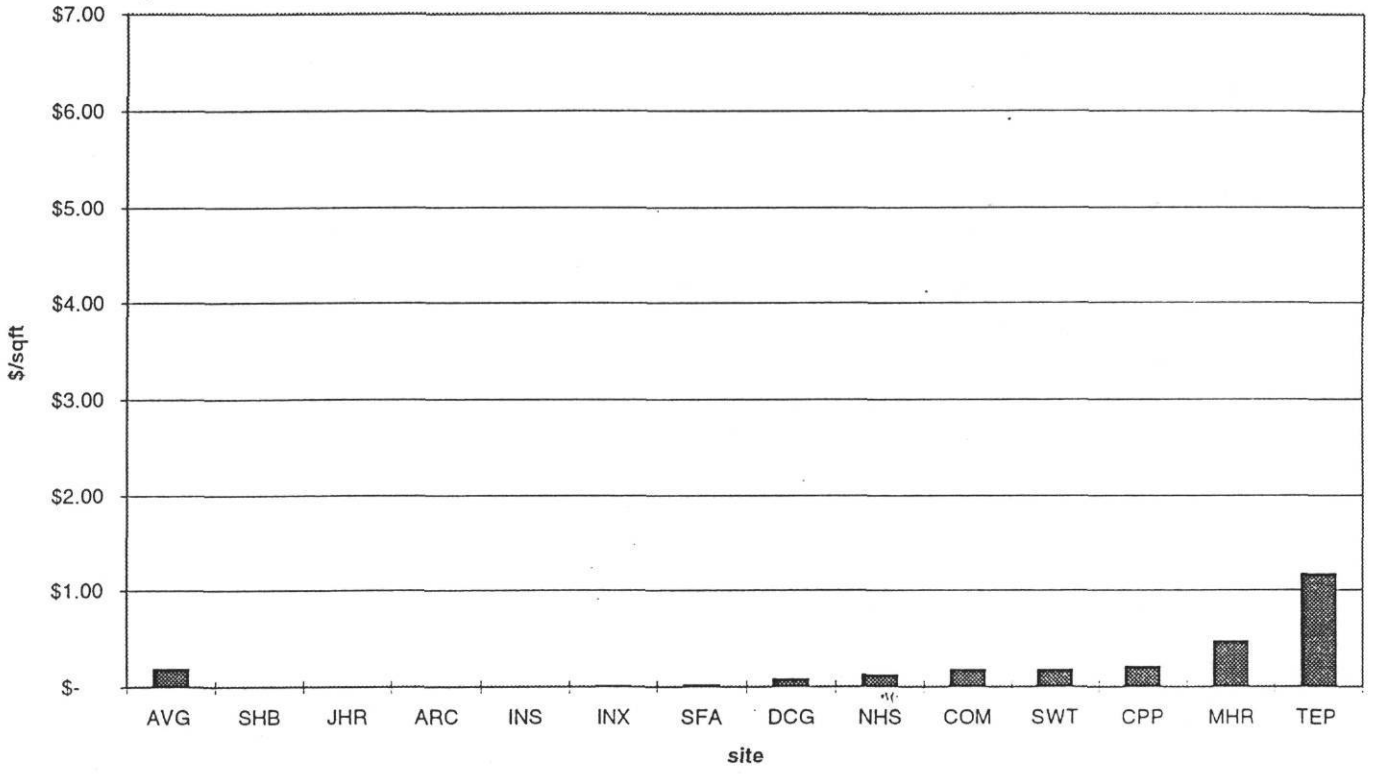


Figure 21: Estimated Cost per Square Foot of Conditioned Area (EMCS)

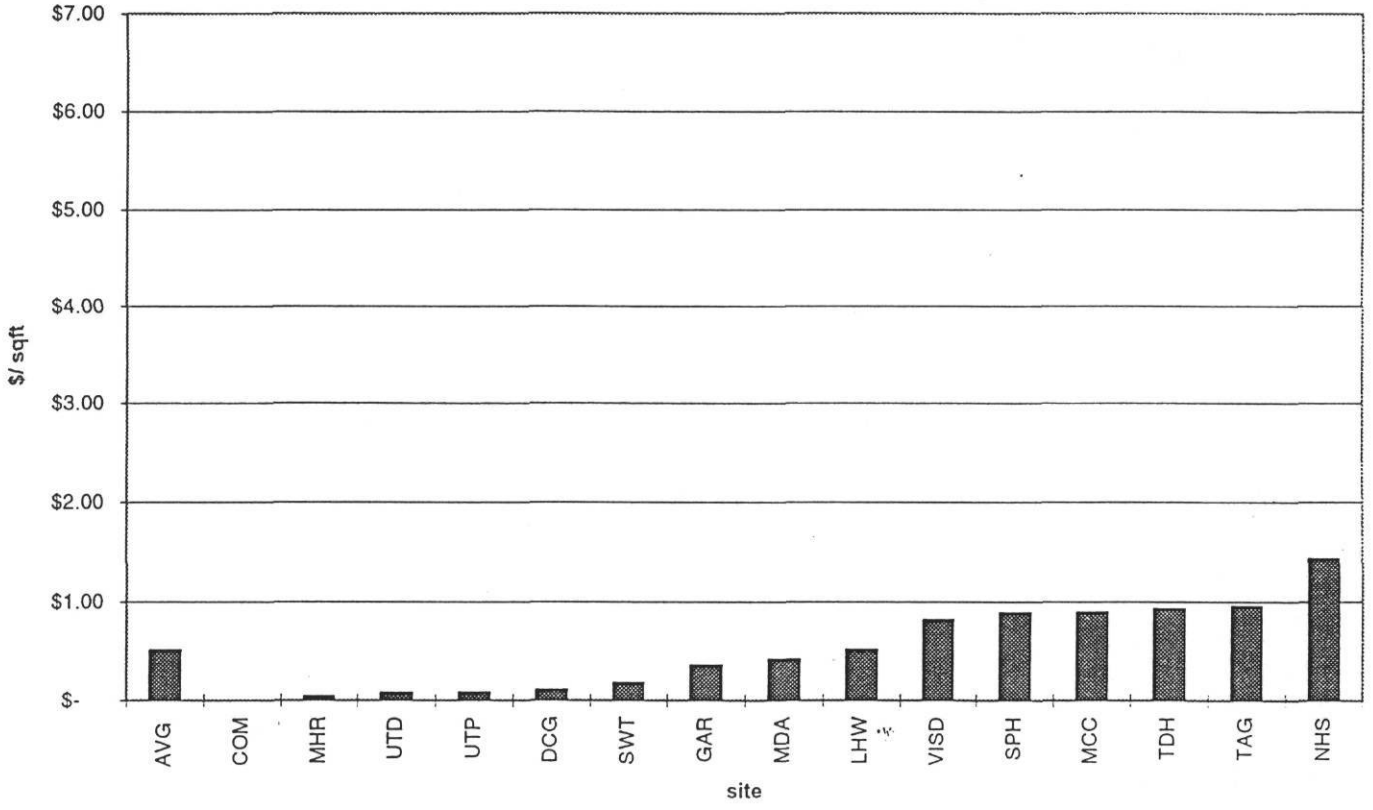
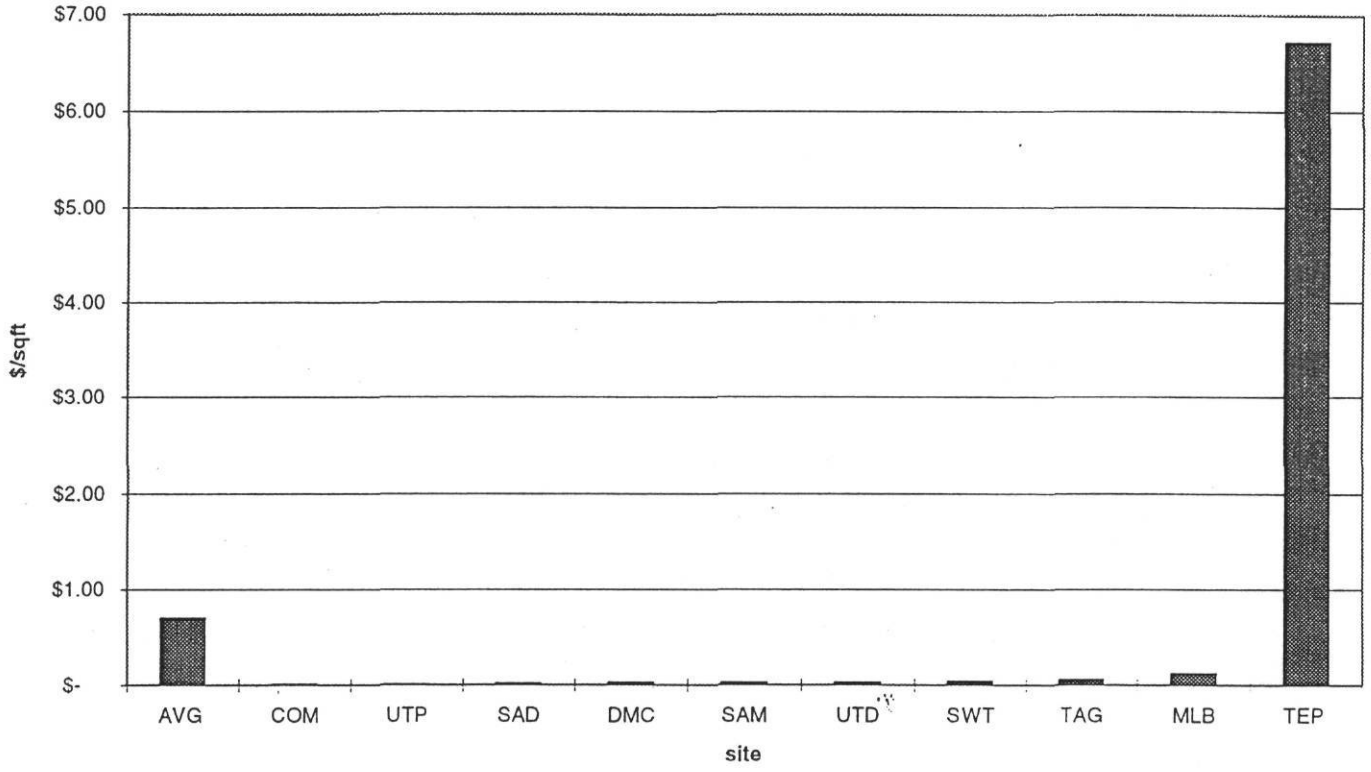


Figure 22: Estimated Cost per Square Foot of Conditioned Area (Other Retrofits)



estimated paybacks of 3.8 years compared well to the measured paybacks of 5.06 years. Much of this difference can be attributed to a few large sites where measured payback drifted upward to as much as 80 years because retrofits were not performing!

Some clear patterns begin to emerge as to why some of the retrofits performed and why others did not. For example, the data indicate that the potential for retrofit savings diminishes as the annual energy bill approaches $0.50 to $1.00 per square foot of conditioned area. The average investment for the agencies with completed retrofits as of December 1993 was $2.43 with the largest majority of sites in the $2 to $3 range[3]. Average ratios of retrofit costs to post-retrofit annual utility costs were 1.34.

Figure 23 shows a summary of the average retrofit costs after the costs have been adjusted for known sites that have unusually high or low costs[4] as indicated in the discussion for pumps, chillers and boilers. Clearly, thermal storage systems are the most expensive type of retrofit in the LoanSTAR program at $4.13 per square foot. Six retrofits fall within the $0.50 to $1.50 per square foot range and six retrofits fall below the $0.50/sqft. range.

3.2 Constant Volume to Variable Air Volume Retrofits

The next phase of this report focuses on Constant Volume (CV) to Variable Air Volume (VAV) air-handler retrofits. For this analysis 13 of the sites that were reporting savings as of December 1993 were analyzed in detail using the hourly data that had been collected as part of the LoanSTAR program. This section summarizes the important features of what has been identified in the analysis.

First, as shown in Figures 24 through 29, these sites showed substantial differences in retrofit performance. In Figure 24 the measured savings are compared to the estimated

[3] This $2 to $3 per square foot is calculated as an average of the sites contained in Table 2b. It does not include the removal of certain sites that are known to have unusually high (or low) costs as pointed out in Figures 11 through 22.
[4] This includes modification to the average costs shown for pump ($8.46 average cost in Table 2b becomes $0.26), chiller (Table 2b average cost of $0.46 becomes $0.36), and boiler retrofits ($0.18 becomes $0.34).

Figure 23: Estimated Average Cost of Different ECRM Category per Square Foot of Conditioned Area.

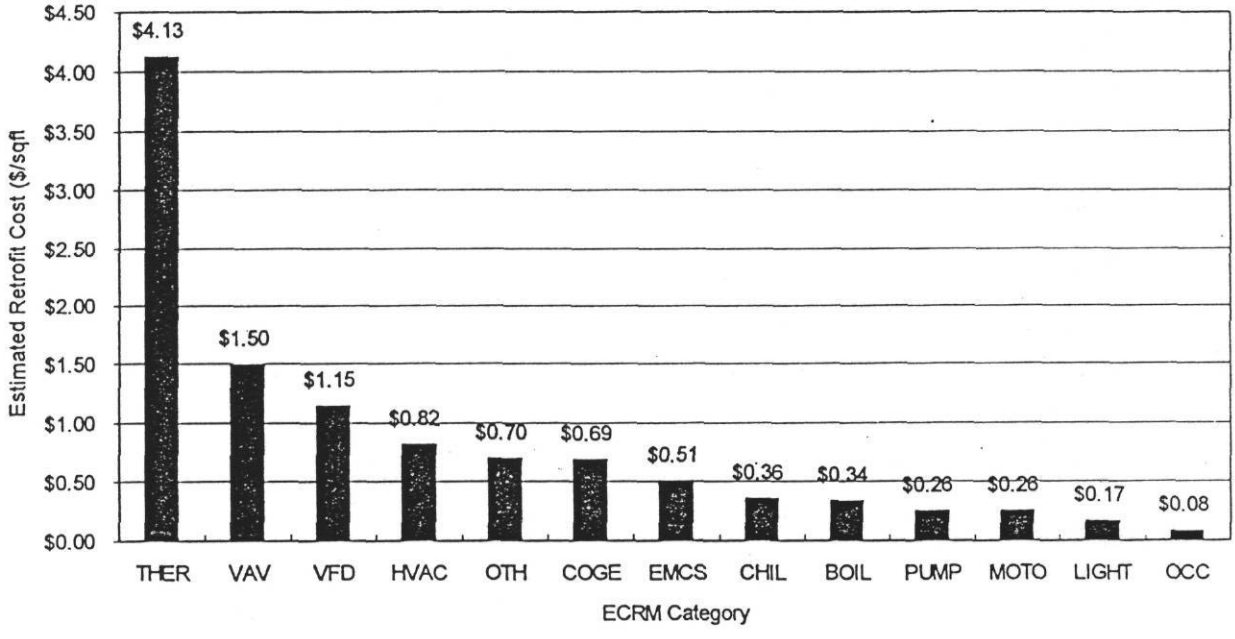


Figure 24: Measured Savings (1993) Compared to Estimated Annual Savings for CV to VAV Retrofits

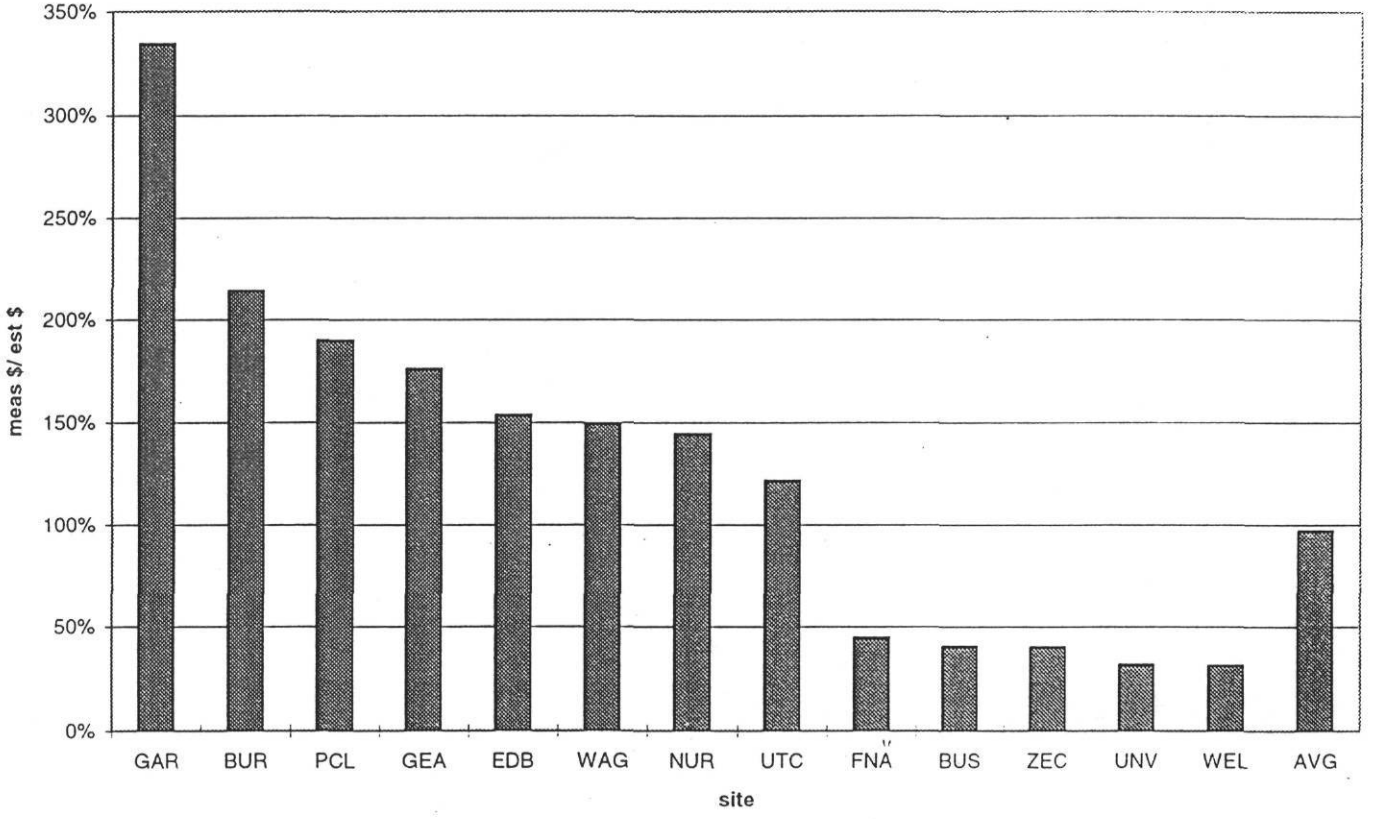


Figure 25: Measured Saving Compared to 1993 Post-retrofit Annual Utility Costs for CV to VAV Retrofits

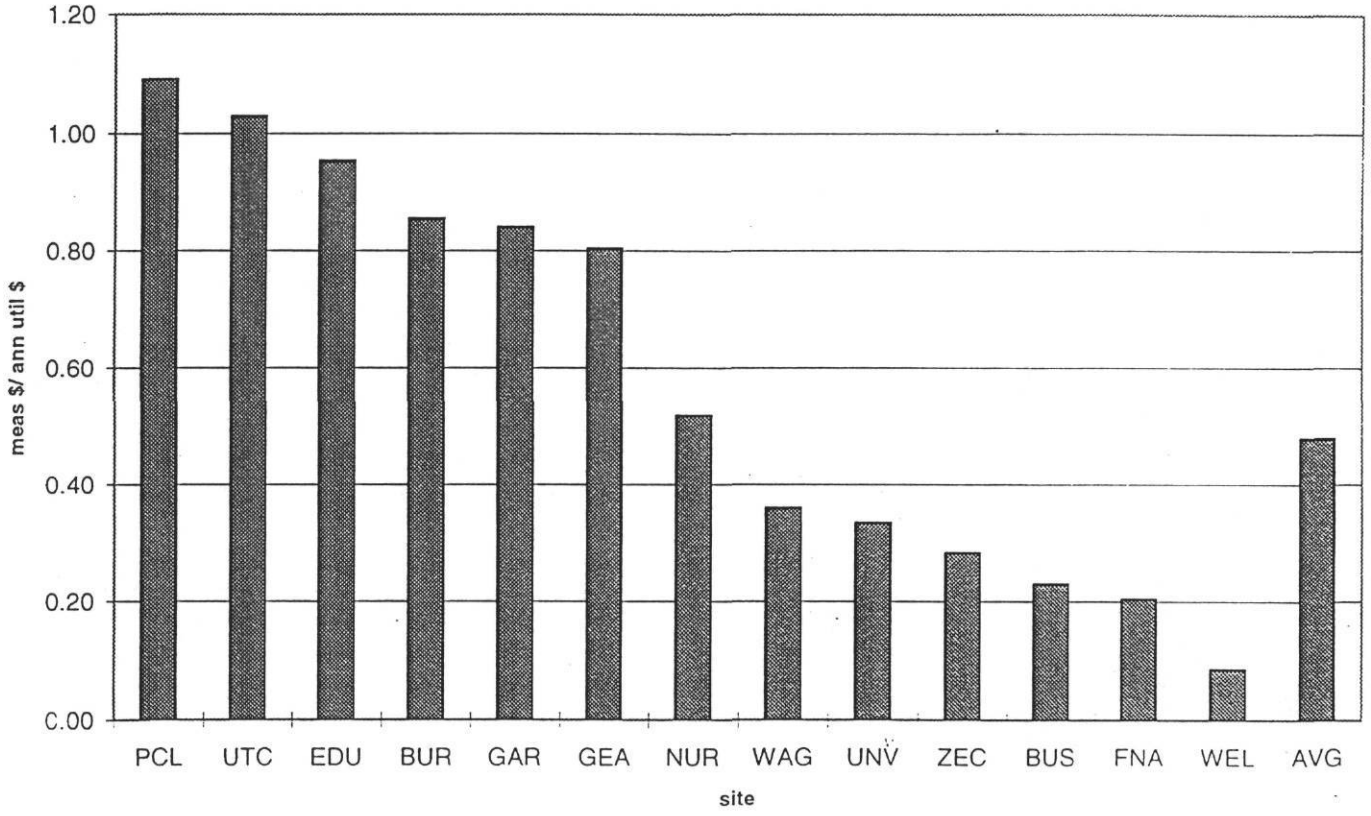


Figure 26: Measured Savings and Pre-Retrofit Annual Utility Costs ($/sqft) for CV to VAV Retrofits

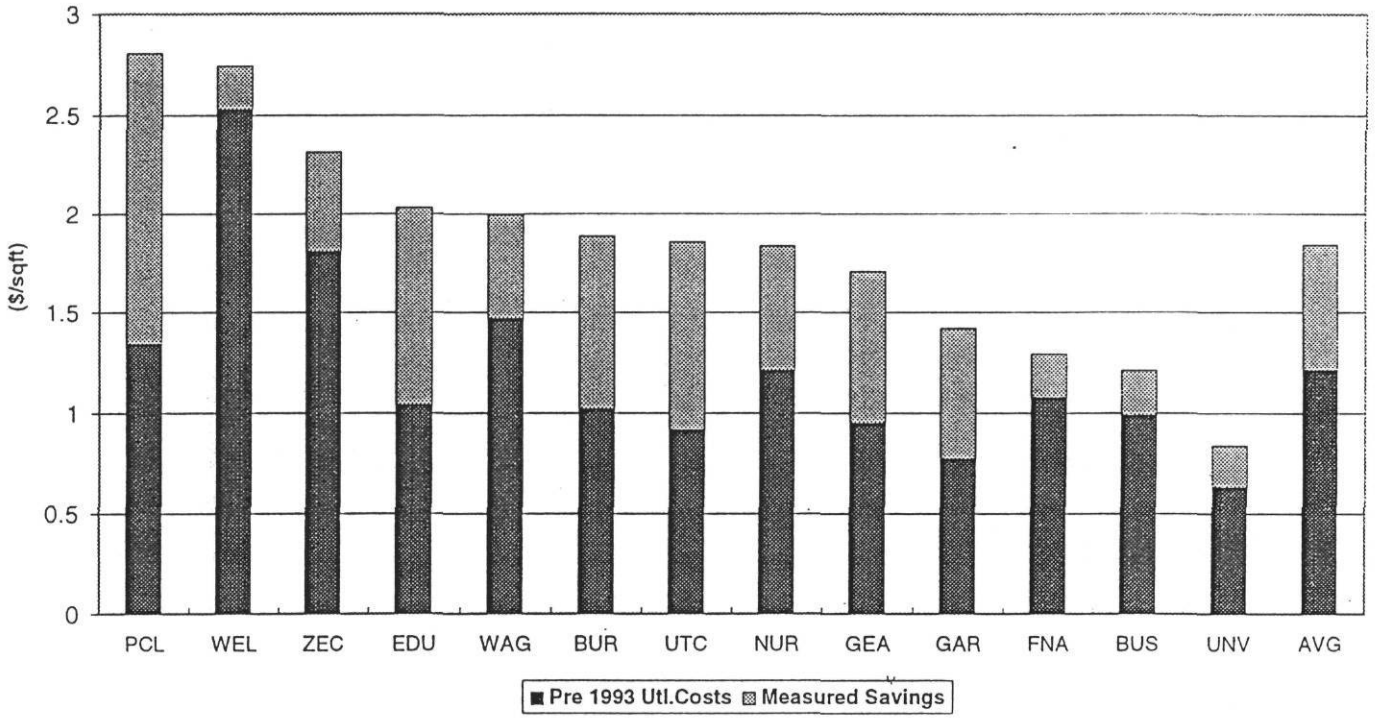


Figure 27: Estimated Retrofit Costs Compared to Estimated and Measured Savings for CV to VAV Retrofits

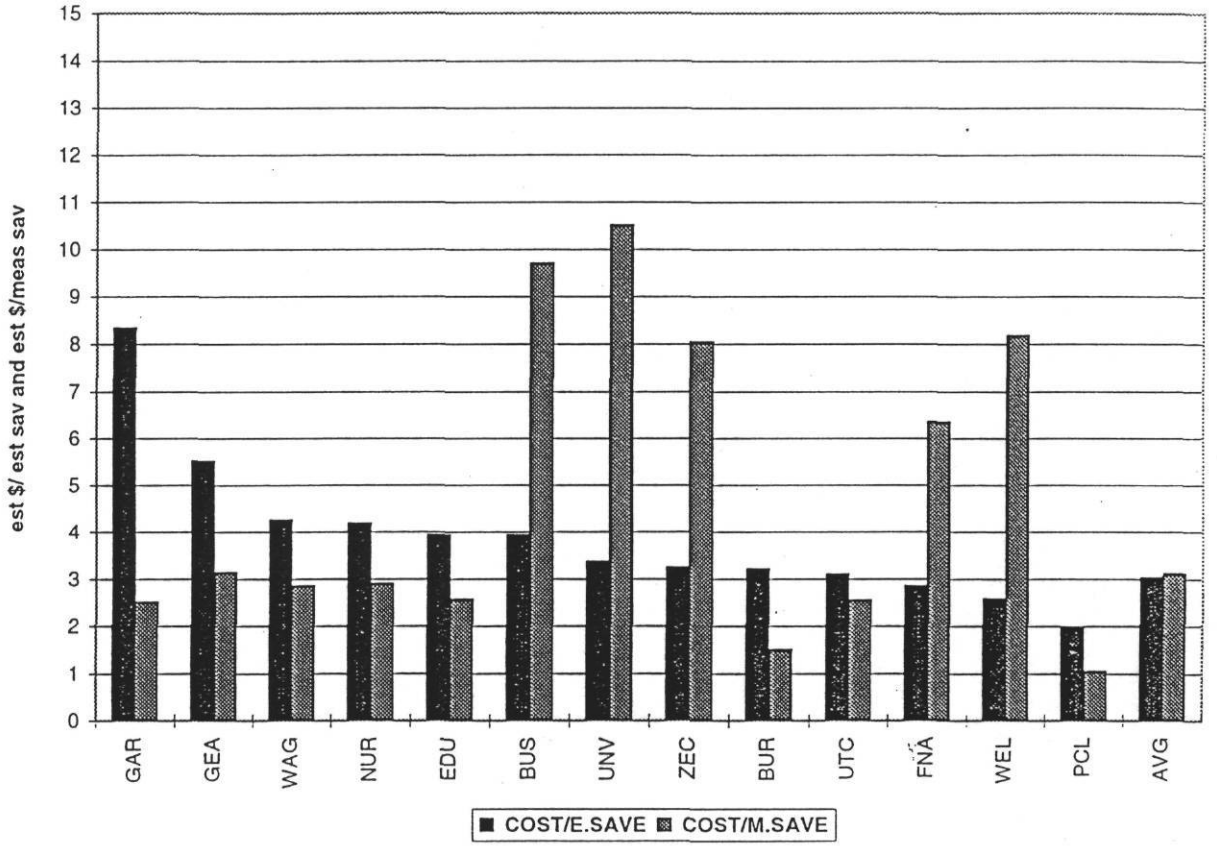


Figure 28: Estimated Costs per Square Foot Conditioned Area for CV to VAV Retrofits

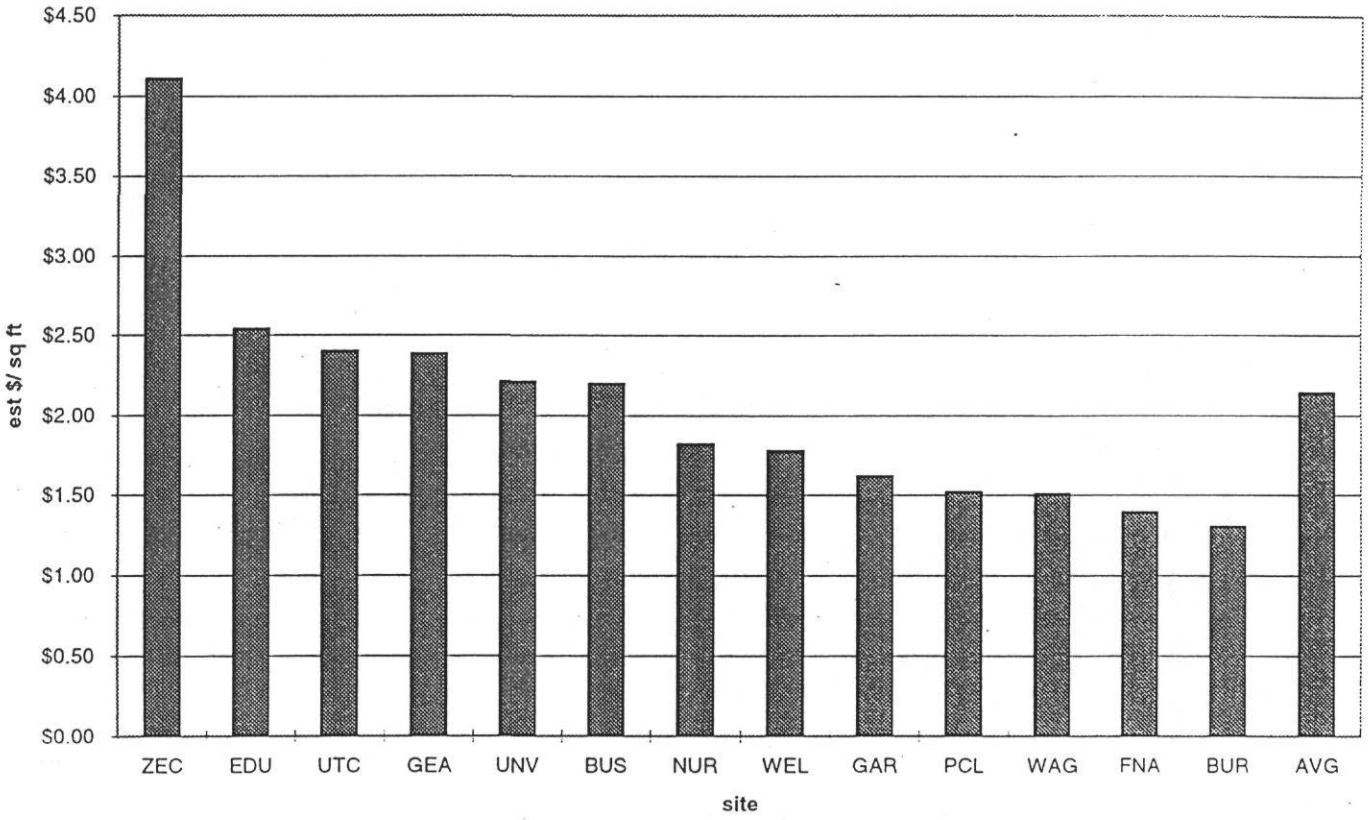
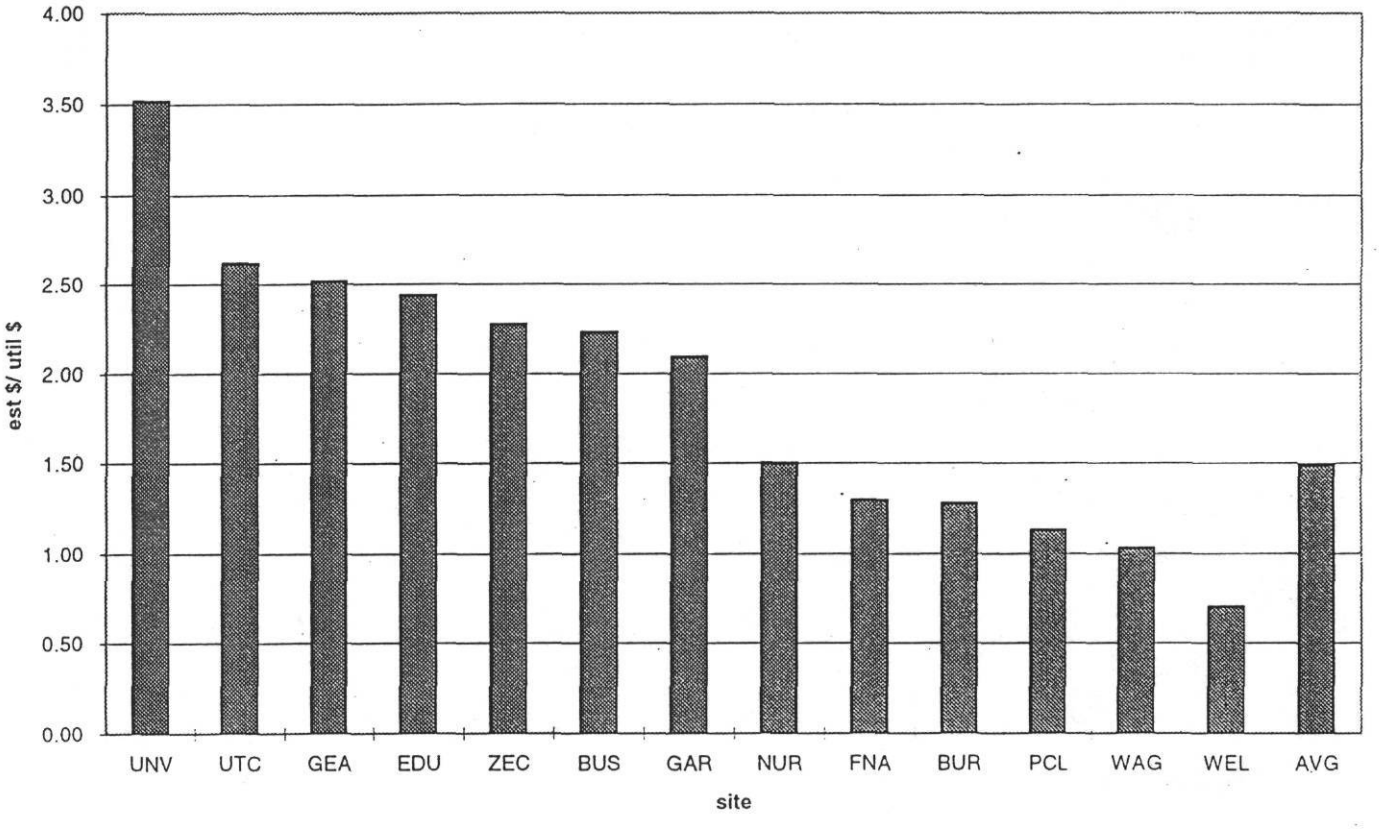


Figure 29: Estimated Costs Compared to the 1993 Utility Costs for CV to VAV Retrofits



savings for the calendar year 1993. At one of the sites (GAR) the measured savings were more than three times the estimated savings, while at five sites (FNA, BUS, ZEC, UNV and WEL) the measured savings were less than 50% of the audit estimated savings.

At the seven remaining sites the measured savings fell within 100 to 200% of the audit estimated savings. This is an indication that there is much room for improvement in the techniques used by energy auditors to estimate savings from CV to VAV retrofits. Fortunately, there is hourly before-after electricity and thermal energy consumption data to turn to for a closer look at why these retrofits are not performing as expected. This information is summarized in Figure 30 for each of the thirteen sites that contained LoanSTAR retrofits.

In Figure 25 the measured savings are compared to the post-retrofit annual utility costs as reported in the 1993 LoanSTAR Annual Energy Consumption Report (AECR). The average for the thirteen sites is about 50 % (i.e., the retrofits are saving 25% of the pre-retrofit utility bill). It is interesting to note that six of the sites had savings that approached the cost of their post-retrofit utility bill (i.e., the retrofits are saving 50% of the pre-retrofit utility bill) and six of the sites have savings that were less than 50% of the post-retrofit utility bill. Nine of the thirteen sites were located on the same university campus in Austin, Texas.

Figure 26 shows the measured savings plus pre-retrofit (i.e., pre-1993) utility bill for the thirteen sites that received CV to VAV air-handler retrofits ($/sqft)[5]. This is intended to be an indicator of the $/sqft reductions attributable to the retrofit savings. In a similar fashion to Figure 6, this figure also shows a clear pattern. First, there is a general leveling-off of post-retrofit energy costs[6] between $0.50 and $1.50/sqft. The exceptions to this are the Welch chemistry building and the Zachry engineering center. The Welch chemistry building's VAV retrofit is not expected not save as much as other buildings since this

[5] This figure is similar to Figure 6.

[6] This is indicated by the top of dark shaded portion of each bar.

Figure 30: Hourly Before/After Analysis of CV to VAV Retrofits as a Percent of Manufacturer's Rated Full Load

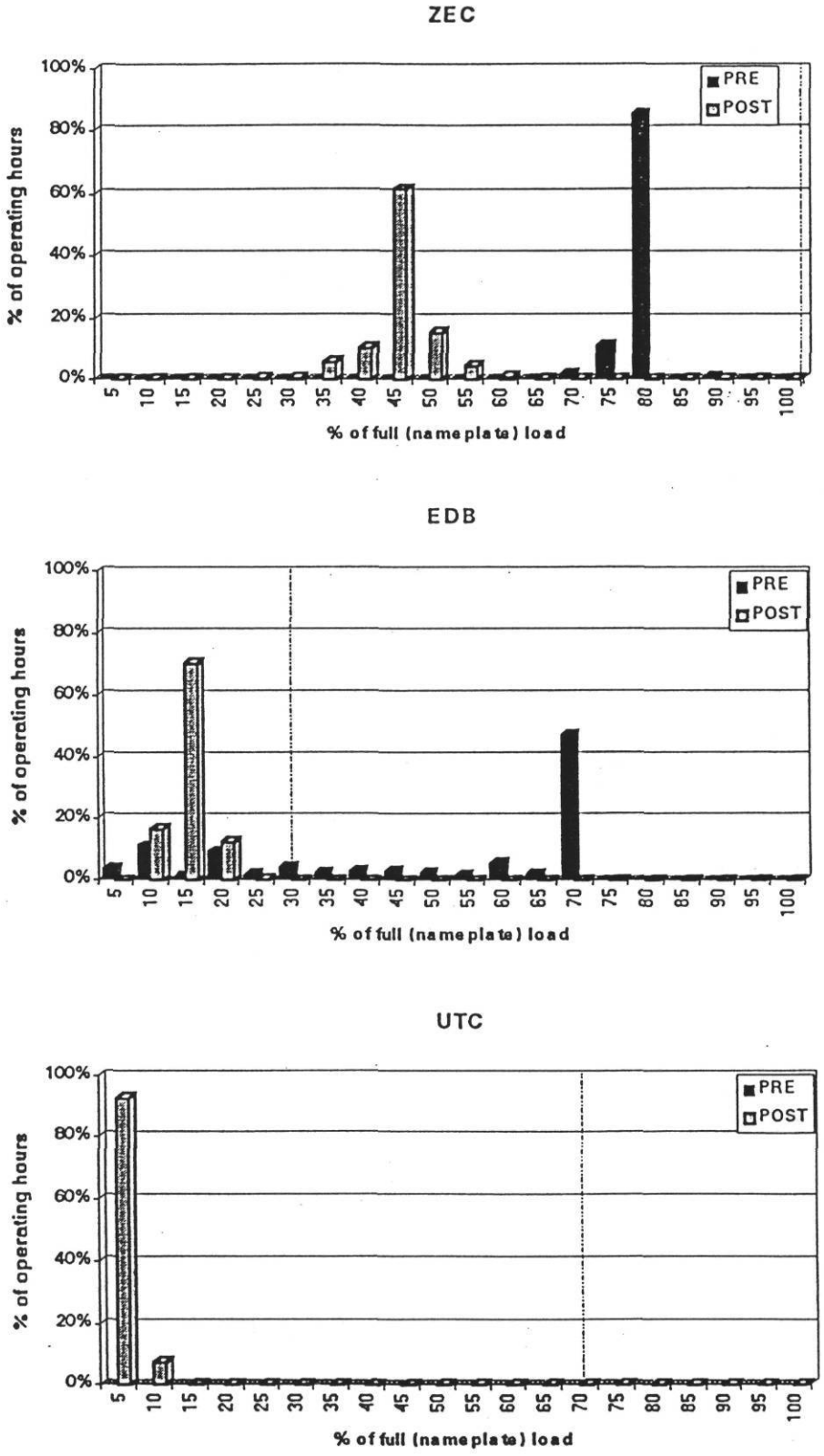


Figure 30 (cont.): Hourly Before/After Analysis of CV to VAV Retrofits as a Percent of Manufacturer's Rated Full Load

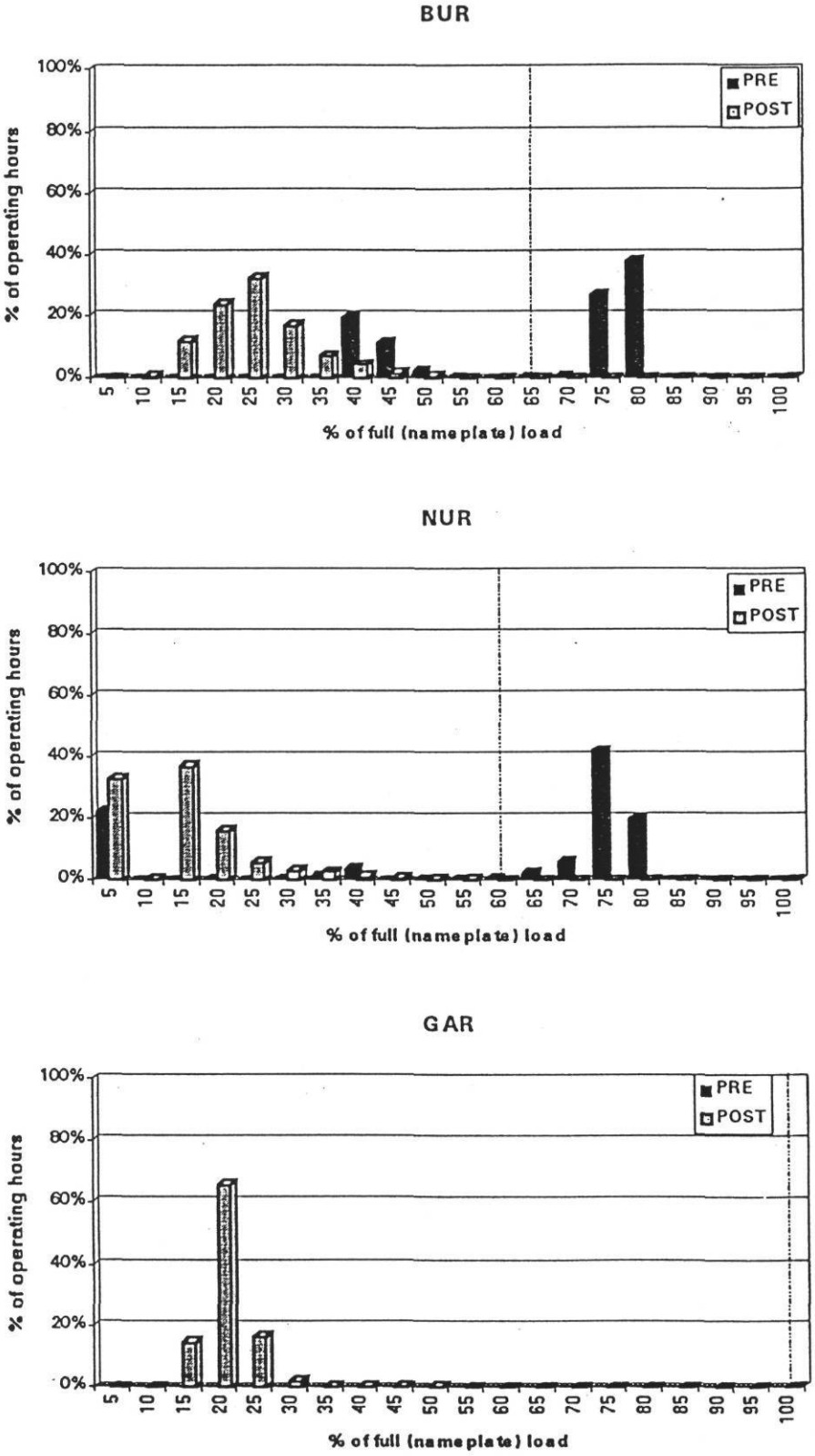


Figure 30 (cont.): Hourly Before/After Analysis of CV to VAV Retrofits as a Percent of Manufacturer's Rated Full Load

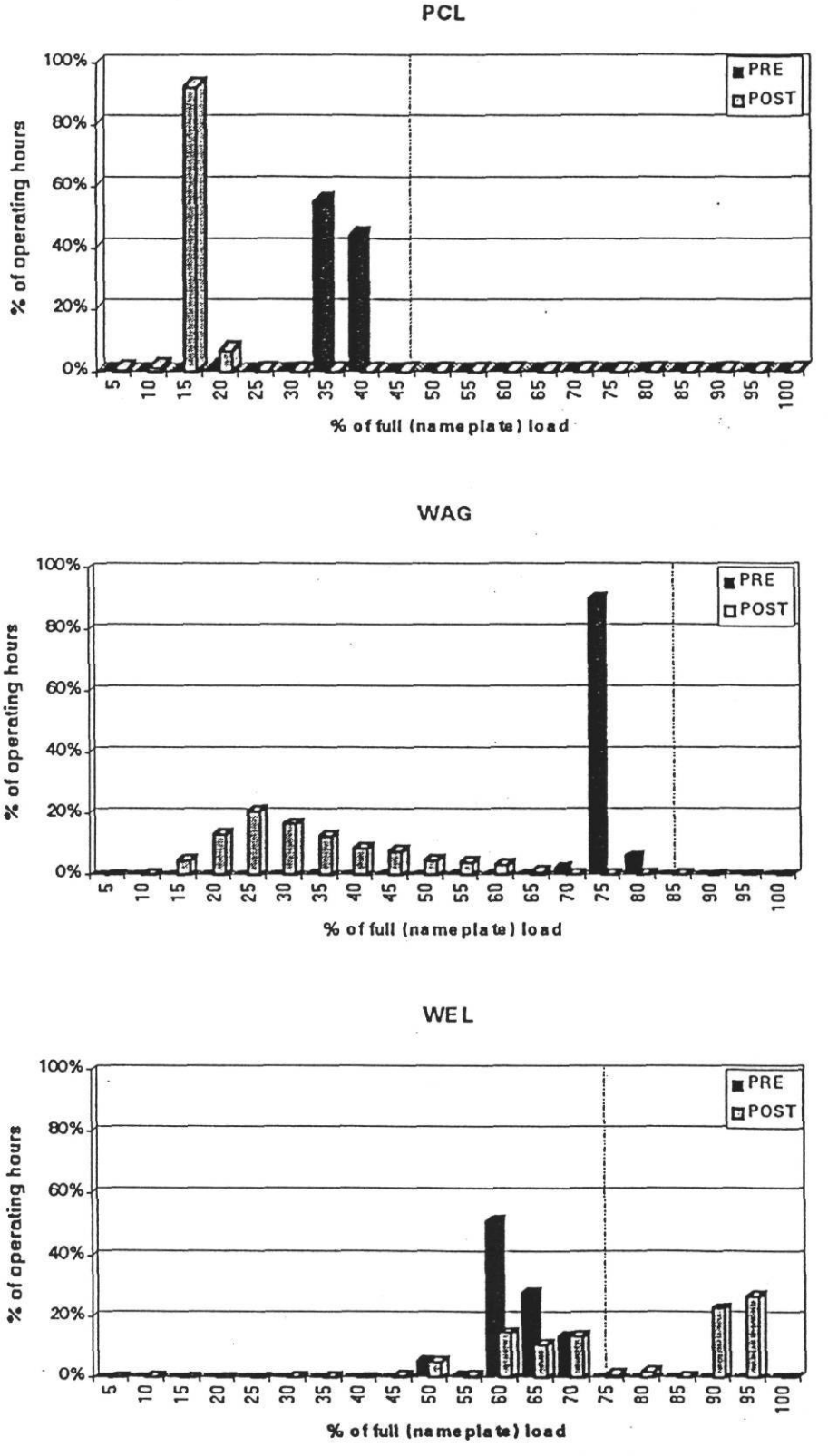


Figure 30 (cont.): Hourly Before/After Analysis of CV to VAV Retrofits as a Percent of Manufacturer's Rated Full Load

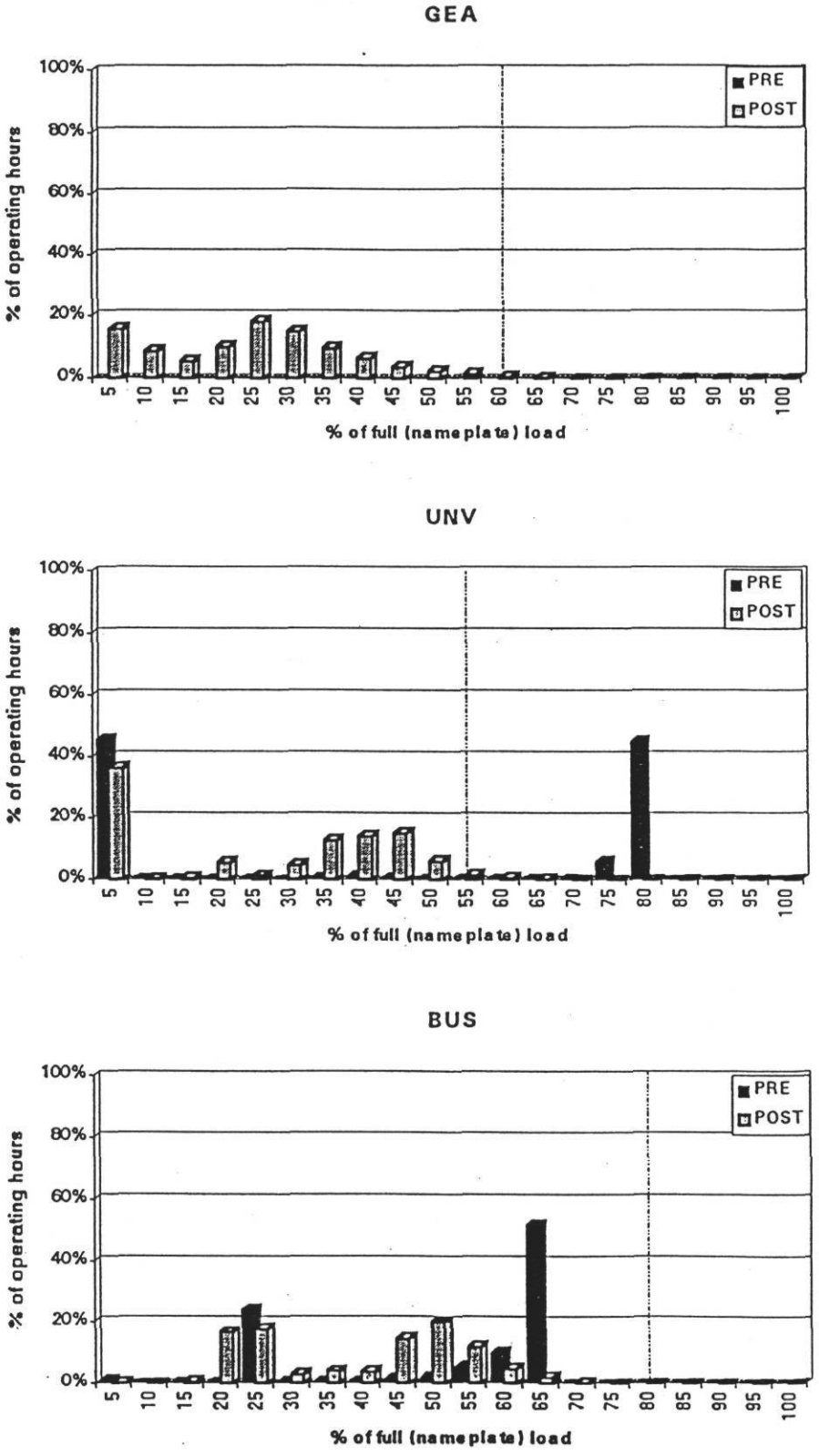
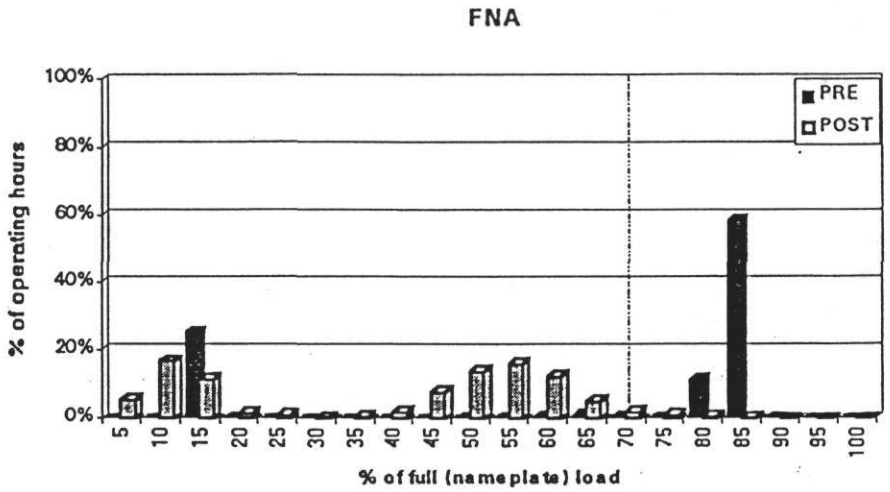


Figure 30 (cont.): Hourly Before/After Analysis of CV to VAV Retrofits as a Percent of Manufacturer's Rated Full Load



building has a large number of fume hoods that are not served by the VAV air-handler. In the ZEC, a large portion of the electricity use is consumed by a central computing facility and computer labs scattered around the building.

Figure 27 shows the ratios of the estimated costs to both estimated savings and measured savings[7]. On average, the thirteen buildings that received CV to VAV air-handler retrofits showed remarkably similar ratios of estimated costs to both estimated savings and measured savings of about $3.00/sqft. In five of the buildings the measured savings were significantly less that estimated which causes the ratio of estimated cost to measured savings to be significantly higher than the ratio of the estimated cost to the estimated savings. In the BUS, UNV, and FNA buildings it is speculated that this is due to an incorrect assumption about operating hours in the energy audit. In the ZEC the energy audit also overestimated the energy savings from the retrofit. In the WEL building the CV to VAV air-handler retrofit under-performed because of the large number of fume hoods in the building.

Figure 28 shows the estimated costs per square foot of conditioned area for the CV to VAV air-handler retrofits. Unlike some of the previous graphs the grouping of the estimated costs if fairly tight around $0.75 to $2.50 per square foot with an average cost of about $2.10. One of the buildings is significantly above the average, the ZEC at over $4.00/sqft. One of the contributing factors to the high cost at this site may be the fact that the CV to VAV air-handler retrofit also included the replacement of 96 terminal boxes and the associated controls (partially paid for by other, non-LoanSTAR money).

Figure 29 shows that the estimated retrofit costs compared to the 1993 post-retrofit utility costs averaged 150 % for the thirteen sites receiving CV to VAV retrofits. Two of these sites were either significantly above or below the average. At the UNV building the estimated cost of the retrofit was slightly above 350 %. This is probably explained by the fact that the UNV building was a low energy building before the retrofit at $0.63/sqft.

---

[7] This figure is similar to Figure 7.

However, the cost of the retrofit was also high at $2.21/sqft. which yields the high ratio of 3.51.

To better understand why some CV to VAV air-handler retrofits were performing and why others were not an examination of the detailed before-after hourly electricity use was undertaken. Figure 30 shows the results of the analysis of the before-after CV to VAV air-handler electricity consumption profiles. There are two important features that were driving the effectiveness of the CV to VAV air-handler retrofits.

First, it was important to know the total installed power rating of the electrical motors that were driving the air-handling units. This was determined by obtaining manufacturer's nameplate information and applying standard conversions to obtain the Wattage consumption for a given motor given the size and efficiency of motor. This is the right axis of each of the graphs in Figure 30 which represents the sum of the name plate electricity use of the motors in each building. This calculation was performed for each site.

Second, using LoanSTAR hourly data, before/after measured hourly electricity use of the air-handling units was super-imposed upon this scale in bins that represented 5% increments of the total nameplate electricity use. Finally, a simple proxy indicator was added to these plots that represents an somewhat arbitrary average pre-retrofit electricity use of 1 W/sqft. for motor control centers which was determined by inspecting those sites which had substantial pre-retrofit measured electricity use for the air-handler units. This is indicated on Figure 30 as a single vertical line.

Here are some of the features that can be gleaned from the hourly data presented in Figure 30. First, it is instructive to divide the groups of CV to VAV air-handler retrofits into "performers" and "non-performers" according to their grouping as shown in Figure 24. For the sake of comparison "performers" are indicated as those sites where measured savings were within 100 to 200% of the audit estimated savings. "non-performers" are those sites where measured savings were less than 50% of the audit estimated savings.

A review of the analysis in Figure 30 reveals two common features about the performers. First, almost without exception, at all of the performing sites the installed air-handling units were substantially oversized. This is indicated as the distance between the right side of the plot and the post-retrofit grouping of hourly points. For those sites that had good performance of the CV to VAV air-handler retrofits this indicated significant fan oversizing by as much as 3 to 6 times what is being used by the majority of hours of the post-retrofit VAV system. The second feature worth mentioning in several of the sites that were good performers is that the data show that the CV air-handler systems were mostly operated 24 hours per day[8] in the pre-retrofit period. This can be seen at the PCL, WAG and EDB sites. At the NUR and BUR sites the air-handling units were cycled on/off. At the remaining sites no pre-retrofit data are available.

For the non-performing sites the most striking feature is that the fan oversizing was only about twice what is being used by the VAV system in the post-retrofit mode. The second noticeable feature for three of the sites is that there was significant on/off operation of air-handling units during the pre-retrofit period. At the WEL site the post-retrofit electricity use actually exceeds the pre-retrofit energy use.

One other feature worth noting involves the distribution of the post-retrofit data points, or rather the lack of distribution. Site inspections of the LoanSTAR sites have revealed that many of these sites have high static pressures in the AHU's supply ducts. This can be caused by several things including bad HVAC system design and/or a lack of understanding of the by the operators concerning the importance of keeping the duct static pressure low. This second cause is common in buildings where complaints are received about zone temperatures. In many cases the building operators respond to the complaints (usually during extreme winter or summer conditions) by raising the static pressure which increases fan electricity use. The duct static pressure is then not reset when milder

[8] In the graphs that are shown in Figure 30 this has the appearance of a single bin containing all of the measured data for the pre-retrofit period.

conditions occur. The indicator for this is a tight packing of post-retrofit points into only a few bins. This can be seen in the plots for the ZEC, EDB, PCL, UTC, and GAR sites in Figure 30. Clearly, there may be a potential for additional savings at these sites since the current operation of the air-handlers behaves more like a reduced-size CV air-handler system than a VAV air-handler system.

For three of the sites (i.e., WAG, BUR, and GEA) the good distribution of load across many bins indicates that the systems are operating as VAVs. Interestingly, at the BUR site the air-handling units were operated in an on/off mode in the pre-retrofit period that was roughly equivalent to the post-retrofit VAV mode when the air-handling units were off.

At four of the sites (NUR, UNV, BUS, and FNA) there was substantial on/off operation of the air-handling units in the pre-retrofit period. This clearly contributed to three of these sites being poor performers. At the NUR site this had less of an effect due to the substantial reduction in electricity use in the post-retrofit period.

Certainly, in many of the sites it will be worth investigating if both VAV and on/off operation can be achieved in the post-retrofit period[9]. What certainly needs to be avoided is a site where on/off operation of the air-handling units in the pre-retrofit period is replaced with constant VAV operation that is actually higher than the pre-retrofit energy use.

Finally, it appears that most of the VAV air-handler retrofits seem to be performing in the 0.3 to 0.7 W/sqft. range in the post-retrofit period, although this varies quite a bit due to the varying nature of the VAV systems and, in some cases post-retrofit on/off VAV operation. However, this may point the way toward the development of a general rule of thumb about efficient air-handler energy use.

[9] This can be achieved using a "slow roll" technique, which was first coined by Mr. Jim Von Wolske at the University of Texas. This technique lowers the duct static pressure during unoccupied periods. This can be seen in the MECR plots in the appendix to this report as a drop in evening-time MCC use.

Summary

Thirteen sites were further evaluated for their CV to VAV air-handler retrofits to determine why some sites were good performers and why some were not. Good performers were arbitrarily chosen as those sites where measured performance was within 100 to 200% of the audit estimate. Poor performance was chosen as those sites where measured savings was 50% or less of the audit estimated performance.

A detailed analysis of the hourly before/after air-handler electricity consumption indicates that fan over-sizing plays a major role in the cost effectiveness of the retrofit. In the performing sites the fan over-sizing was 3 to 6 times what is needed by the VAV system in the post-retrofit period. In the non-performing sites the fan over-sizing was about 2 times what the VAV system uses in the post-retrofit period.

Another feature uncovered by this analysis is the importance of taking factoring the presence of on/off performance of the air handling units in the pre-retrofit period into the audit calculations. In the LoanSTAR program this was one of the major causes of the inaccuracies in the energy audits which contributed to the under-performance of the CV to VAV air-handler retrofits.

Several other features have been identified during the analysis that may prove useful for future CV to VAV air-handler retrofits. First, it is important to commission the VAV system once it has been installed to prevent the building operators from raising the static pressure to the point where the system no longer functions as a VAV. Second, it appears that there is an average post-retrofit energy use of about 0.3 to 0.7 W/sqft of conditioned area. Perhaps this can be useful for improving future energy audits.

4.0 REFERENCES

Abbas, M., Haberl, J., Claridge, D. 1996. "Thermal Storage System Analysis for A Multipurpose Municipal Facility", *Proceedings of the 1995 ASME/JSME/JSES International Solar Energy Conference,* (March).

Claridge, D., Haberl, J., O'Neal, D., Heffington, W., Turner, D., Tombari, C., Roberts, M., Jaeger, S. 1991. "Improving Energy Conservation Retrofits with Measured Results." *ASHRAE Journal*, Vol.33, No. 10, pp. 14-22, (October).

Haberl, J., Reddy, A., Claridge, D., Turner, D., O'Neal, D., Heffington, W. 1996. Measuring Energy-Saving Retrofits: Experiencs From the Texas LoanSTAR Program, ORNL Report, Oak Ridge National Laboratory.

Liu, M., Veteto, B., Claridge, D. 1996. Analysis of the Thermal Storage Unit at the Ward Memorial Hospital, Energy System Laboratory, internal report (July).

Verdict, M., Haberl, J., Claridge, D., O'Neal, D., Heffington, W., Turner, D. 1990. "The Texas LoanSTAR Monitoring and Analysis Program: Overview," *Proceedings of the 1990 ACEEE Summer Study,* pp. 7.261-7.271, (August).

Verdict, M., Haberl, J., Claridge, D., O'Neal, D., Heffington, W., Turner, D. 1990. "The Texas LoanSTAR Monitoring and Analysis Program: Overview," *Proceedings of the 1990 ACEEE Summer Study,* pp. 7.261-7.271, (August).

APPENDIX

- Zachry Engineering Center (ZEC)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Education Building (EDB)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- University Teaching Center (UTC)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Perry Castaneda Library (PCL)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Waggener Hall (WAG)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Welch Building (WEL)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Burdine Building (BUR)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Nursing Building (NUR)
  - 1993 LoanSTAR AECR
  - MECR & Building Description
  - Monitoring Diagrams & HVAC Diagrams

- Garrison Hall (GAR)
  - 1993 LoanSTAR AECR

MECR & Building Description
Monitoring Diagrams & HVAC Diagrams

- Gearing Hall (GEA)
  1993 LoanSTAR AECR
  MECR & Building Description
  Monitoring Diagrams & HVAC Diagrams

- University Hall (UNV)
  1993 LoanSTAR AECR
  MECR & Building Description
  Monitoring Diagrams & HVAC Diagrams

- Business Building (BUS)
  1993 LoanSTAR AECR
  MECR & Building Description
  Monitoring Diagrams & HVAC Diagrams

- Fine Arts Building (FNA)
  1993 LoanSTAR AECR
  MECR & Building Description
  Monitoring Diagrams & HVAC Diagrams

UT AUSTIN

Nursing Building

Building Envelope:
- 94,815 sq.ft
- classrooms, lecture halls, lounges
- walls: pre-cast concrete
- windows: single pane clear
- roof: flat concrete

Building Schedule:
- 6:30 am to 9:30 pm, 7 days a week, all year long

Building HVAC:
- 2 variable volume AHUs (2-100hp)
- 8 relief air fans (8-5hp)
- 1 variable volume chilled water pump (30 hp)
- 1 domestic hot water pump (1/12hp)
- 10 exhaust fans (1/20hp - 1hp)
- economizer cycle has been added as a part of the retrofit

HVAC Schedule:
- 24 hrs/day

Lighting:
- flourescent and some incandescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- Both the retrofits were completed at the end of April 1991.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

Zachry Engineering Center

Texas A&M University
324,400 square feet

Site Contact

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

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	687820	$19176	100	$3630	1822	$8509	71	$6662	783	$3719	100	$8662	$18954	$18954
Feb	668560	$18639	100	$3273	1929	$9008	54	$5507	504	$2394	100	$7240	$16020	$34974
Mar	716741	$19983	100	$3642	2134	$9966	0	$7181	489	$2323	100	$7116	$17939	$52913
Apr	721039	$20103	99	$3686	2701	$12614	96	$5377	310	$1472	99	$5500	$14563	$67476
May	704213	$19633	100	$3788	2989	$13959	0	$6244	125	$594	100	$4705	$14737	$82213
Jun	704897	$19653	31	$3515	3893	$18180	0	$3454	10	$48	100	$2190	$9159	$91372
Jul	746361	$20809	52	$3436	4479	$20917	71	$2100	132	$627	99	$531	$6067	$97439
Aug	706167	$19688	100	$3294	4346	$20296	100	$3185	107	$508	52	$542	$7021	$104460
Sep	723258	$20164	99	$3738	3704	$17298	99	$4145	3	$14	99	$2245	$10128	$114588
Oct	739555	$20619	100	$3568	3012	$14066	100	$5445	206	$978	0	$4989	$14002	$128590
Nov	714056	$19908	100	$3456	1966	$9181	100	$6591	523	$2484	100	$7602	$17649	$146239
Dec	669624	$18669	99	$3622	1802	$8415	99	$7676	707	$3358	99	$7983	$19281	$165520
Total	8502291	$237044		$42648	34777	$162409		$63567	3899	$18519		$59305		$165520
EUI	26.2	$\frac{kWh}{ft^2yr}$			107204	$\frac{Btu}{ft^2yr}$			12019	$\frac{Btu}{ft^2yr}$				

Comments

★ **The unit costs used for estimating the audit and the measured savings are: $0.02788/kWh, $4.67/MMBtu (CW), and $4.74/MMBtu (HW).**

★ **The HVAC retrofit was completed in March 1991.**

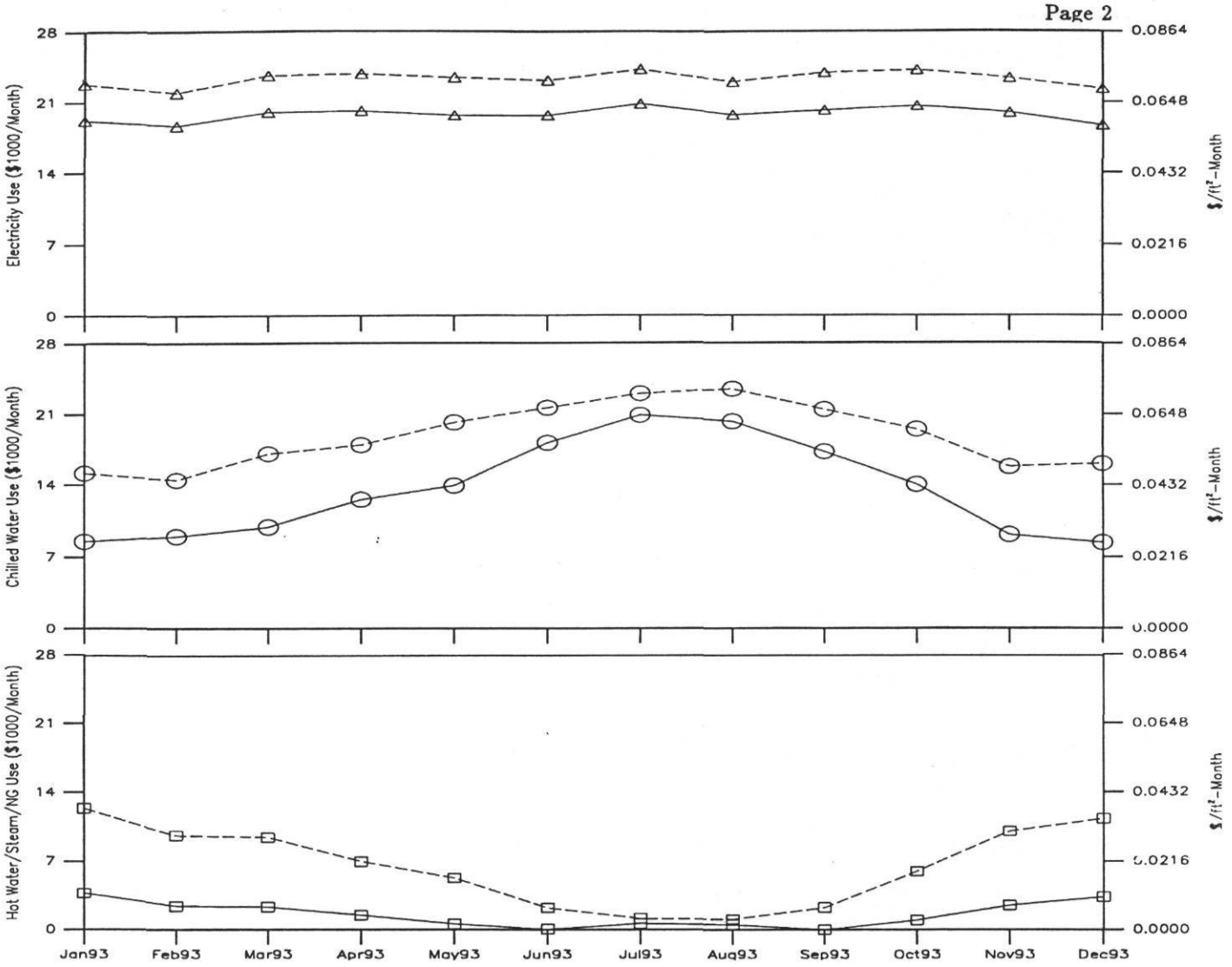
★ **The LoanSTAR monitoring began in June 1989.**

★ **The percent columns indicate the number of hours reported in that month.**

★ **The audit estimated savings for the HVAC retrofits are: $54,300 (ELE), $124,100 (CW), $54,500 (HW), and $232,900 (Total).**

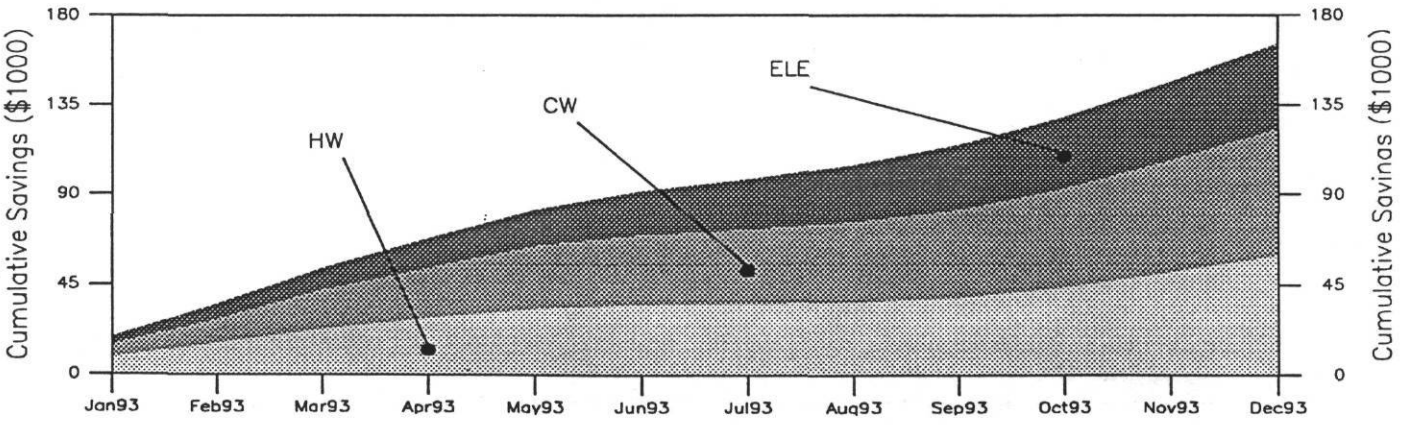
★ **The chilled water consumption for March, May, June and part of August 1993 were estimated using a post-retrofit regression model because of missing data due to hardware problems.**

★ **Hot water consumption for part of August and October 1993 were estimated using a post-retrofit regression model because of missing data due to hardware problems.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



TEXAS A&M UNIVERSITY

Zachry Engineering Center

Building Envelope:
- 324,400 sq.ft
- 3-1/2 floors and a ground floor level, erected 1973, classes, offices, labs, computer facility, and clean rooms for Solid State Electronics
- walls: cement block
- windows: 22% of total wall area
  single pane with built-in-place vertical blinds
- roof: flat

Building Schedule:
- classrooms and labs: 7:30 am to 6:30 pm weekdays
- offices: 7:30 am to 5:30 pm weekdays
- computer facility: 24 hrs/day

Building HVAC:
- 12 variable volume dual duct AHUs (12-40hp)
- 3 constant volume multizone AHU (1-1 hp, 1-7hp, 1-10hp)
- 4 constant volume single zone AHU (4-3hp)
- 10 fan coils (10-0.5 hp)
- 2 constant volume chilled water pump (2-30hp)
- 2 constant hot water pump (2-20hp)
- 7 misc. pumps (total of 5.8hp)
- 50 exhaust fans (50-0.5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- control modifications to the dual duct system
- variable volume dual duct system

Other Information:
- EMCS system to control HVAC was also installed along with the retrofits.

Date of Retrofits:
- date of completion for VAV and control modifications to the dual duct system: 3/30/91.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

Zachry Engineering Center

Texas A&M University
324,400 square feet

Site Contact	LoanSTAR Metering Contact
Mr. Charles Darnell, Jr.	Aamer Athar
Physical Plant Administration	053D 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	631903 kWh	100	$0.02788	$17617
Peak 60 Minute Demand	1162 kW	100	-	-
Chilled Water	2556.6 MMBtu	100	$4.670	$11939
Hot Water	88.7 MMBtu	39	$4.750	$421

Peak 60 minute demand was recorded at 1600 Wednesday 03/06/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	124889	$3482	162730	$4524
Chilled Water (MMBtu)	1002	$4679	2215	$10344
Cond./H.W./N.G. (MMBtu)	1777	$8441	956	$4541
Monthly Total		$16602		$19409
Total to Date*	(65 months)	$853462	(61 months)	$1183946

*Measured savings include construction period. Audit estimated savings do not.

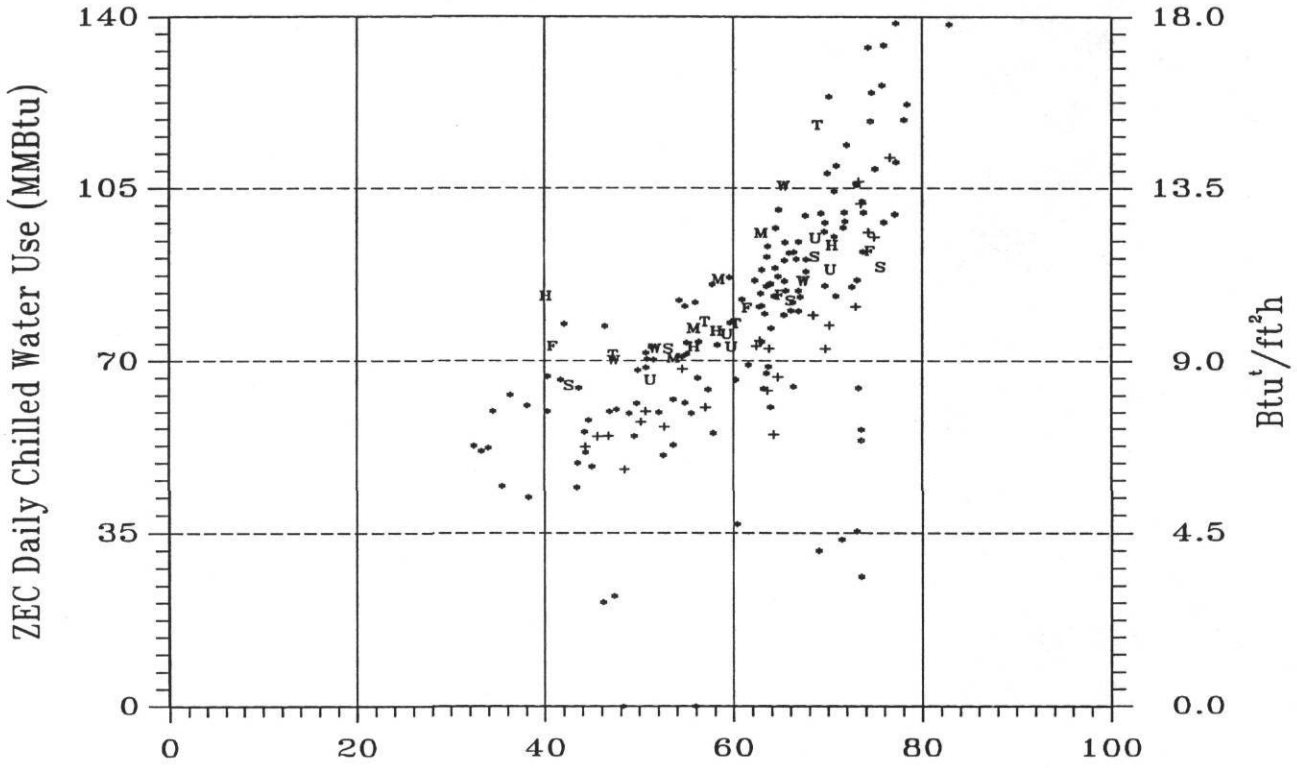
Comments

★ Hot water data are missing from 3/01/96 to 3/08/96 and 3/11/96 to 3/31/96 due to a hardware problem.

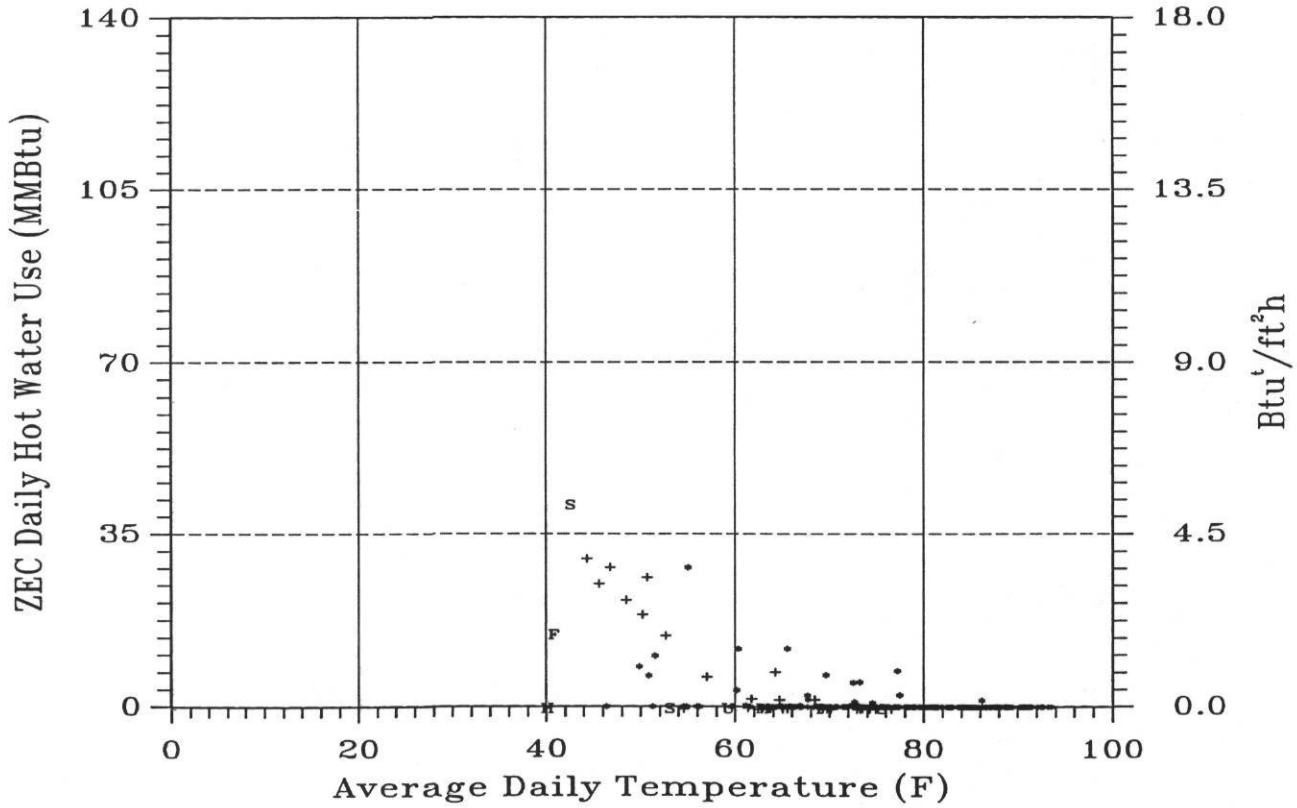
★ Electricity consumption has decreased compared to similar periods during March 1995.

★ Spring Break is evident as reduced electricity consumption from 3/11/96 to 3/17/96.

Mar 01 1995 – Mar 31 1996

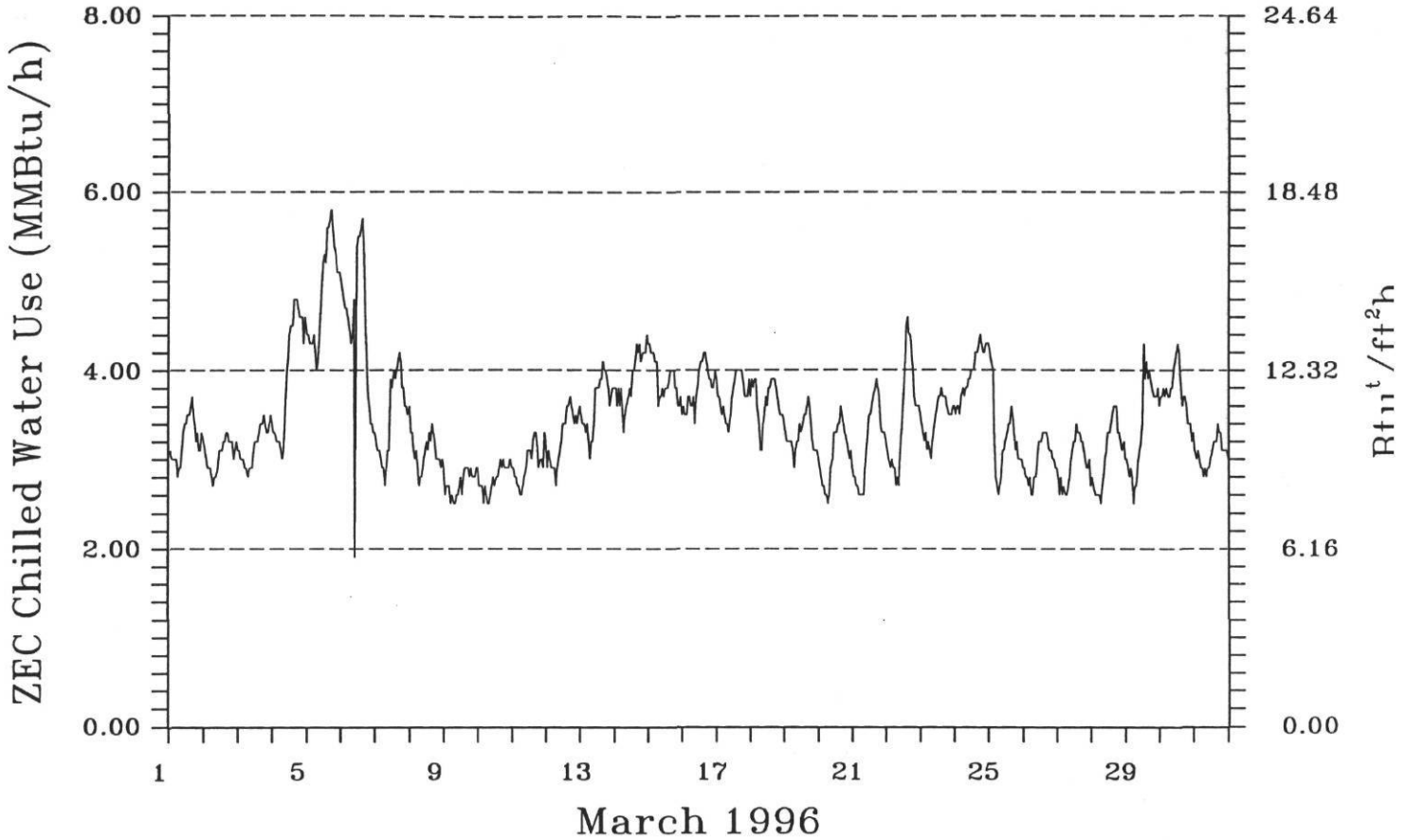


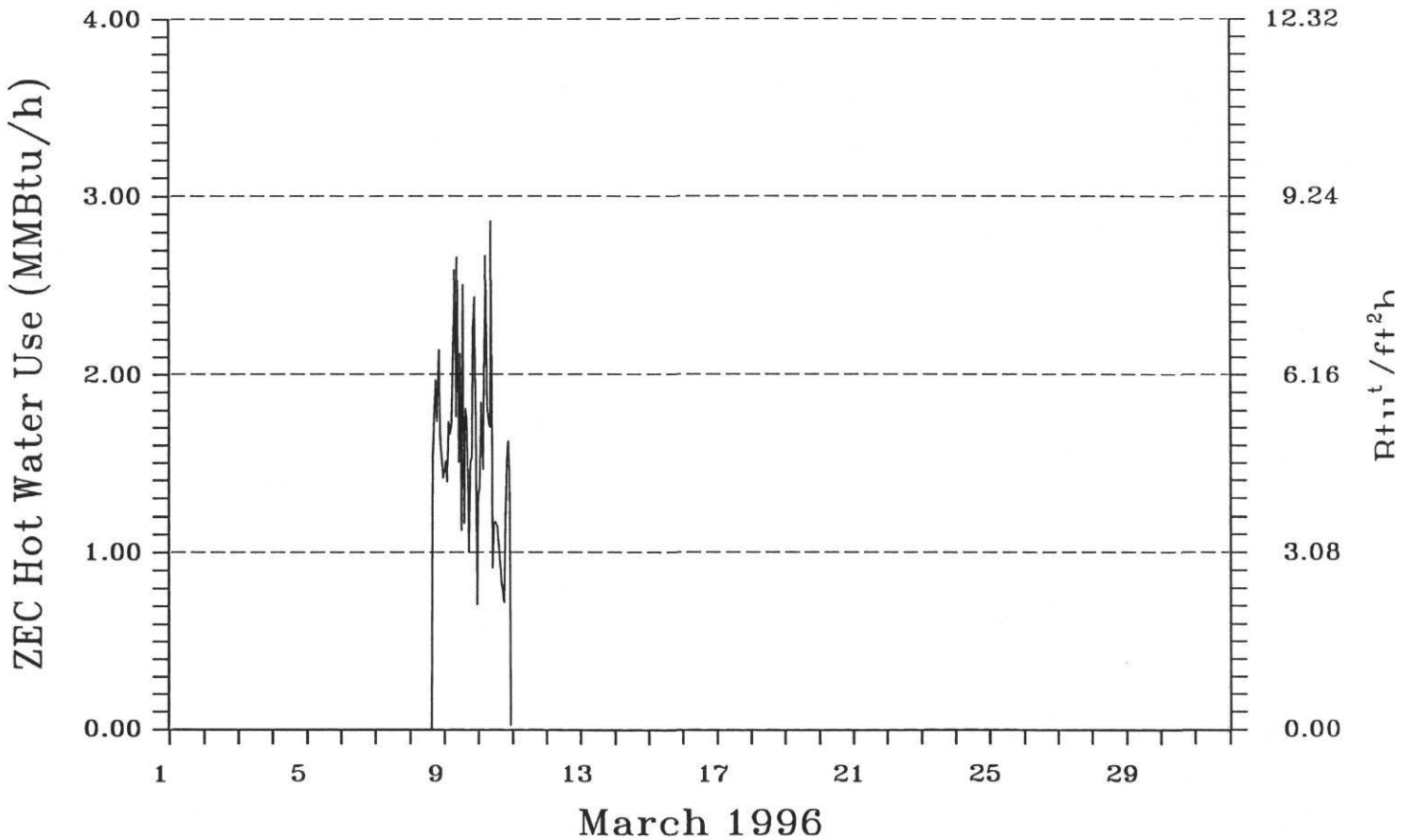
Mar 01 1995 – Mar 31 1996

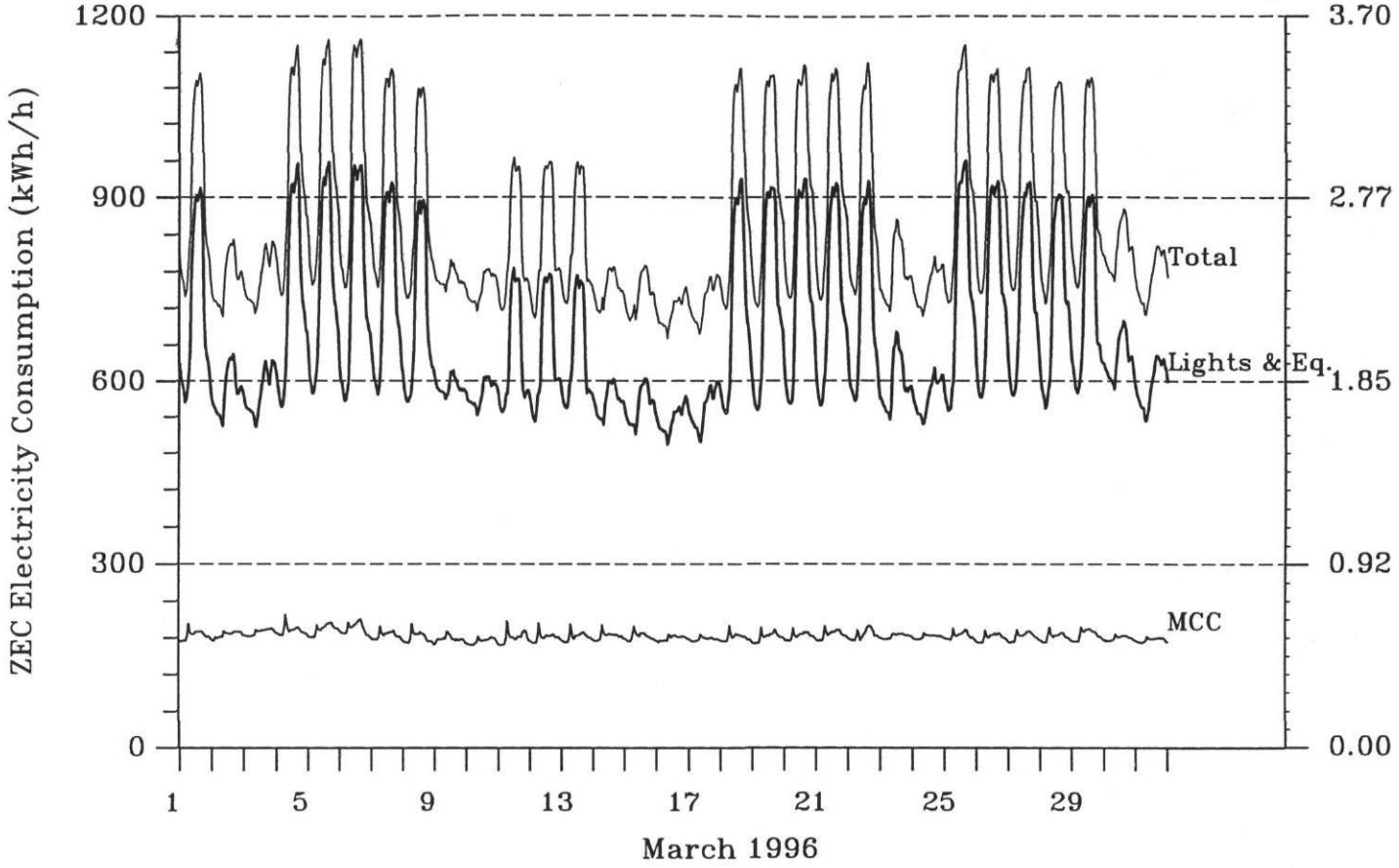


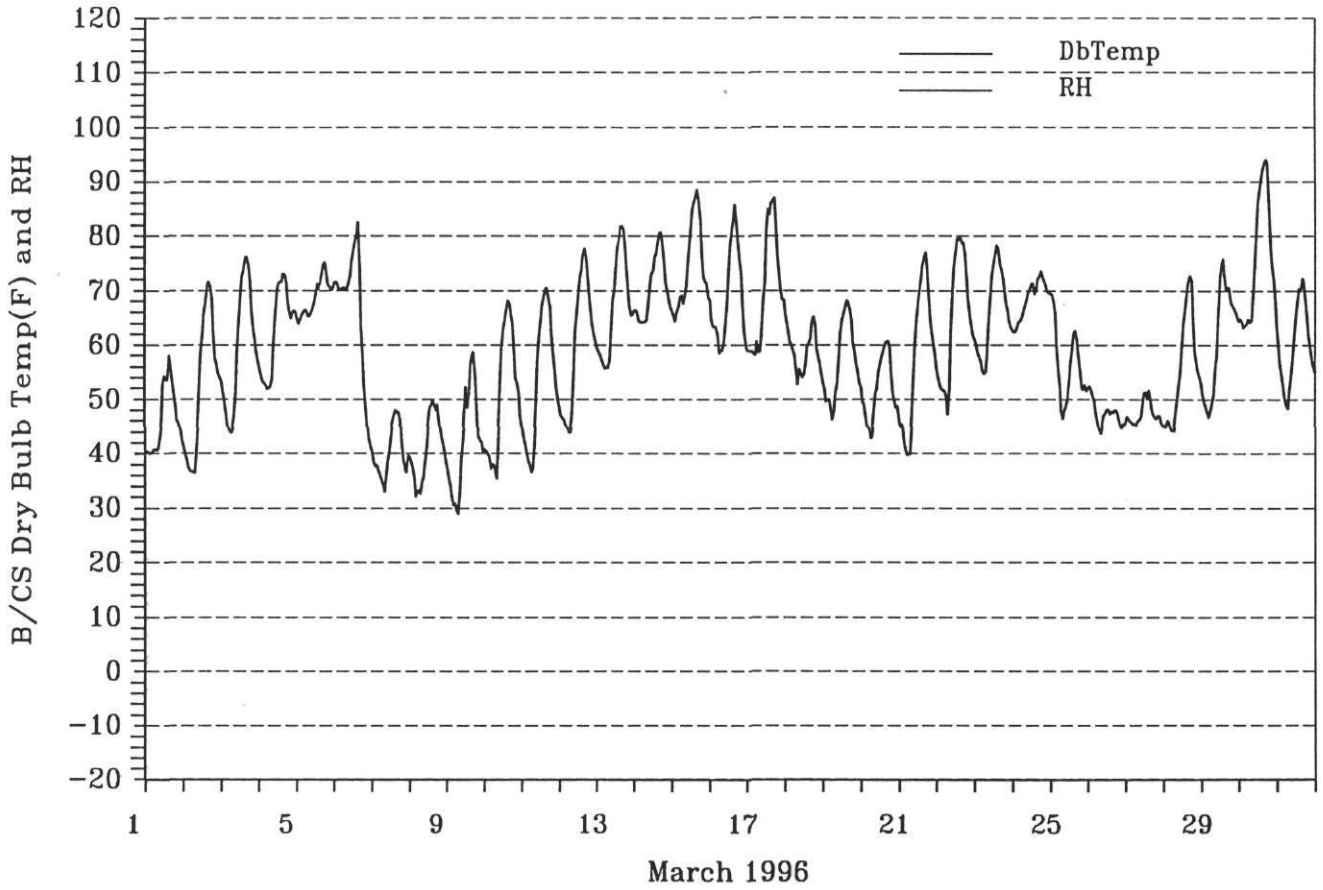
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

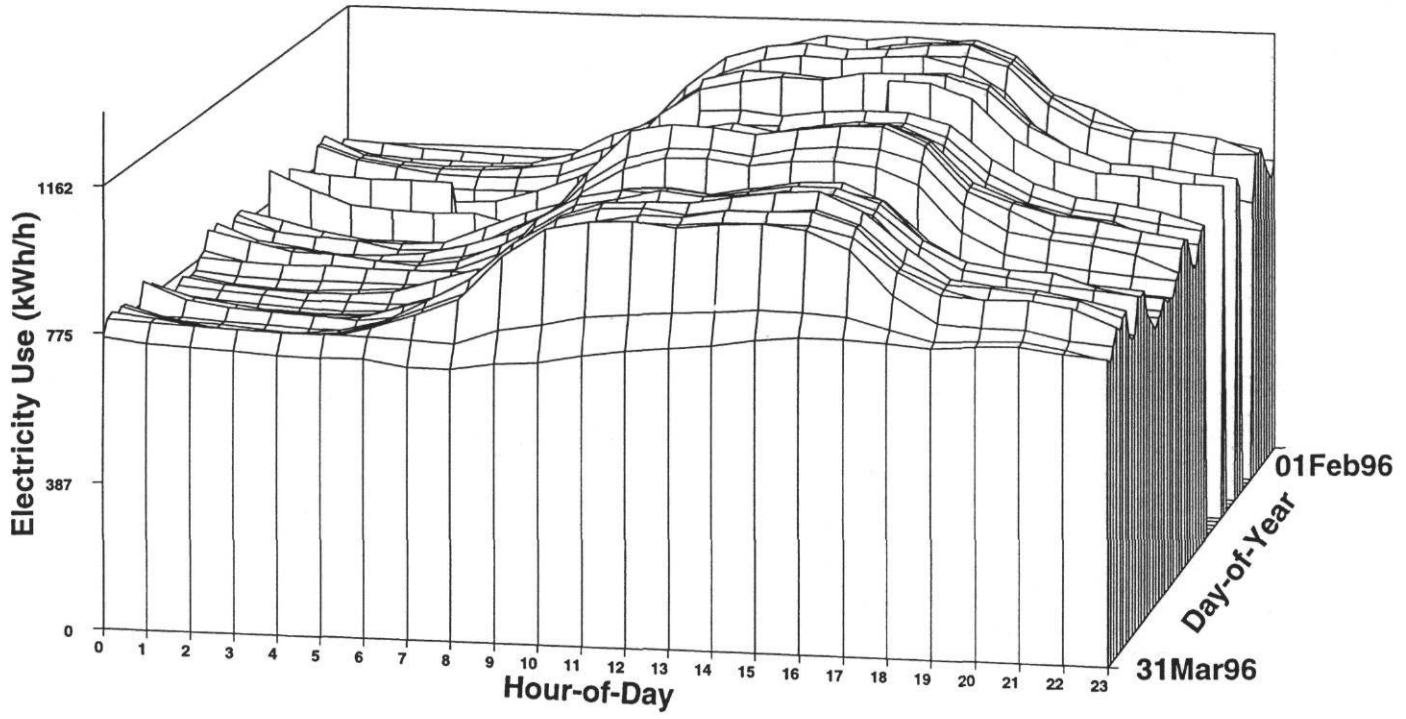

ZEC Chilled Water Use (MMBtu/h)
8.00
6.00
4.00
2.00
0.00
24.64
18.48
12.32
6.16
0.00
Rtn^t/ft^2h
1
5
9
13
17
21
25
29
March 1996


ZEC Hot Water Use (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
12.32
9.24
6.16
3.08
0.00
Rtn^t/ft^2h
1
5
9
13
17
21
25
29
March 1996

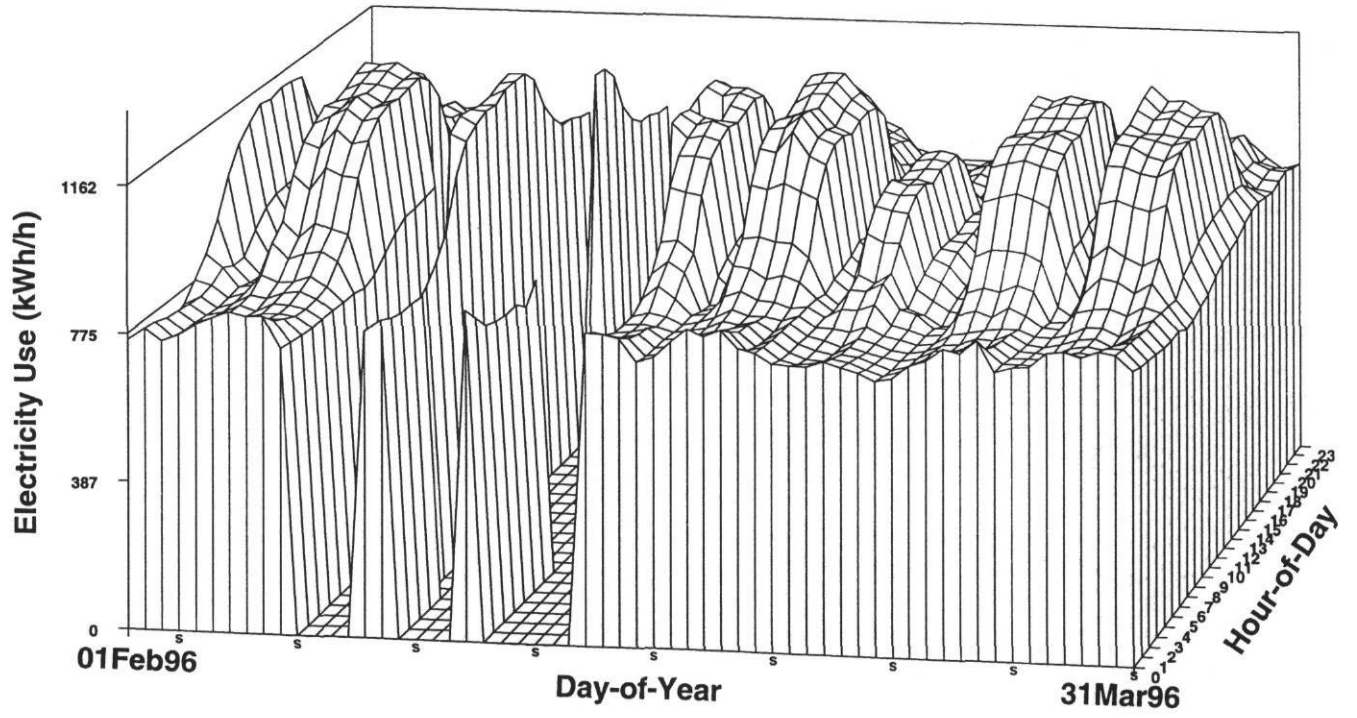

ZEC Electricity Consumption (kWh/h)
1200
900
600
300
0
3.70
2.77
1.85
0.92
0.00
Total
Lights & Eq.
MCC
1
5
9
13
17
21
25
29
March 1996


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

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

TEXAS A&M UNIVERSITY

Zachry Engineering Center

Building Envelope:
- 324,400 sq.ft
- 3-1/2 floors and a ground floor level, erected 1973, classes, offices, labs, computer facility, and clean rooms for Solid State Electronics
- walls: cement block
- windows: 12% of total wall area
  single pane with built-in-place vertical blinds
- roof: flat

Building Schedule:
- classrooms and labs: 7:30 am to 6:30 pm weekdays
- offices: 7:30 am to 5:30 pm weekdays
- computer facility: 24 hrs/day

Building HVAC:
- 12 variable volume dual duct AHUs (12-40hp)
- 3 constant volume multizone AHU (1-1 hp, 1-7hp, 1-10hp)
- 4 constant volume single zone AHU (4-3hp)
- 10 fan coils (10-0.5 hp)
- 2 constant volume chilled water pump (2-30hp)
- 2 constant hot water pump (2-20hp)
- 7 misc. pumps (total of 5.8hp)
- 50 exhaust fans (50-0.5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- control modifications to the dual duct system
- variable volume dual duct system

Other Information:
- EMCS system to control HVAC was also installed along with the retrofits.

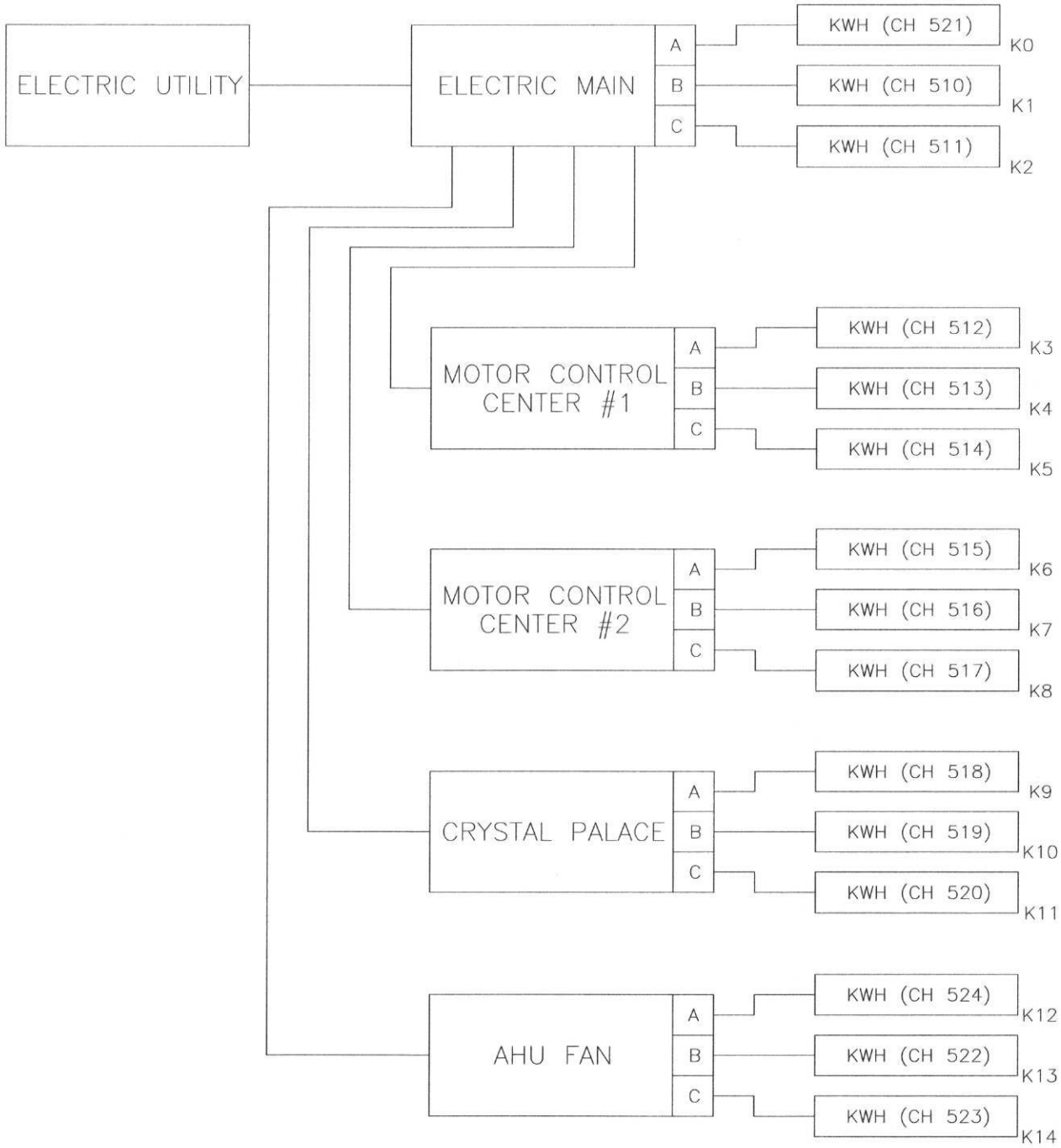
Date of Retrofits:
- date of completion for VAV and control modifications to the dual duct system: 03/05/91.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

TEXAS A&M UNIVERSITY
ZACHRY ENGINEERING CENTER
ELECTRICAL MONITORING DIAGRAM

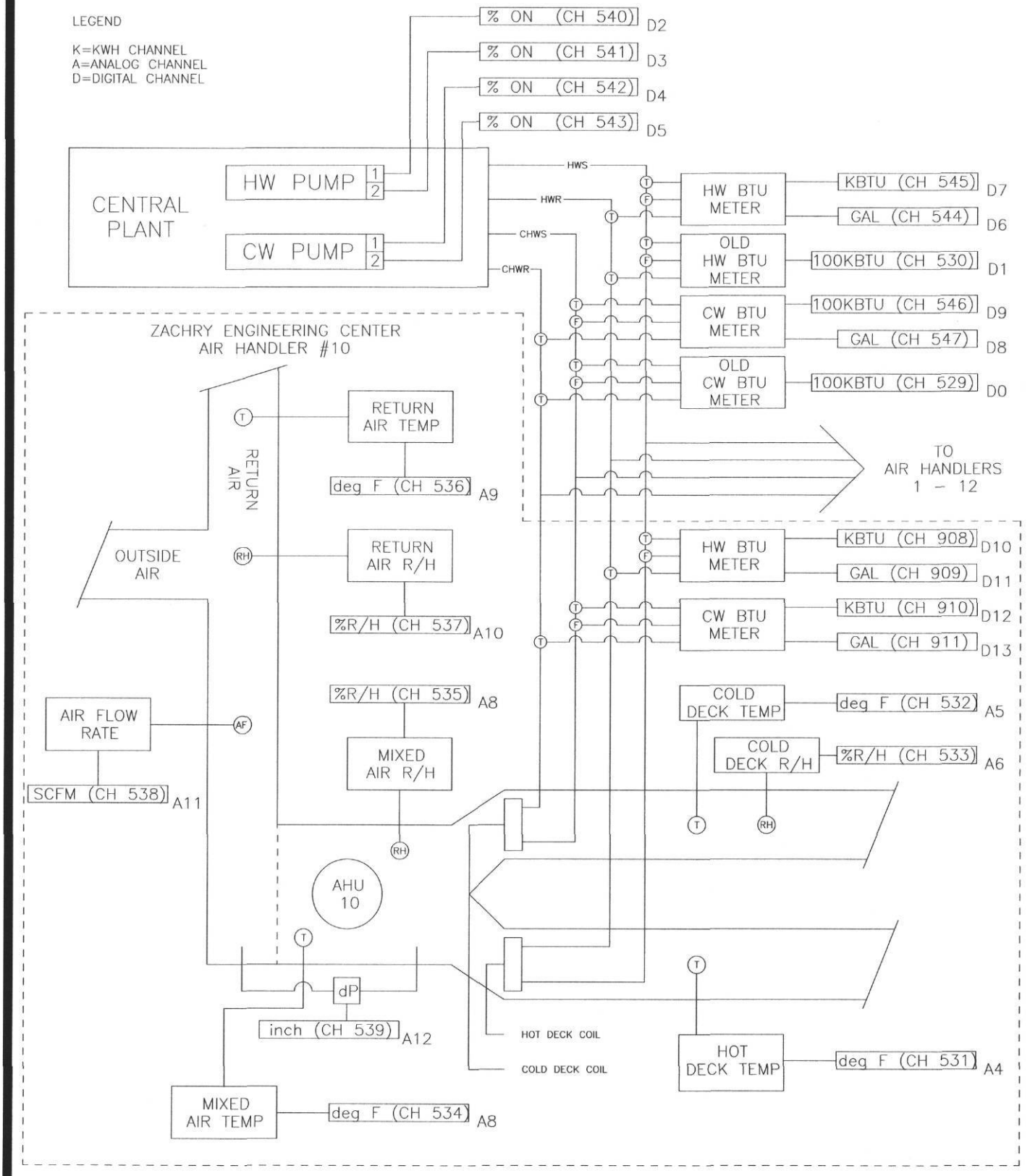
LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



ZACHRY ENGINEERING CENTER – SITE 001

THERMAL MONITORING DIAGRAM
ZACHRY ENGINEERING CENTER

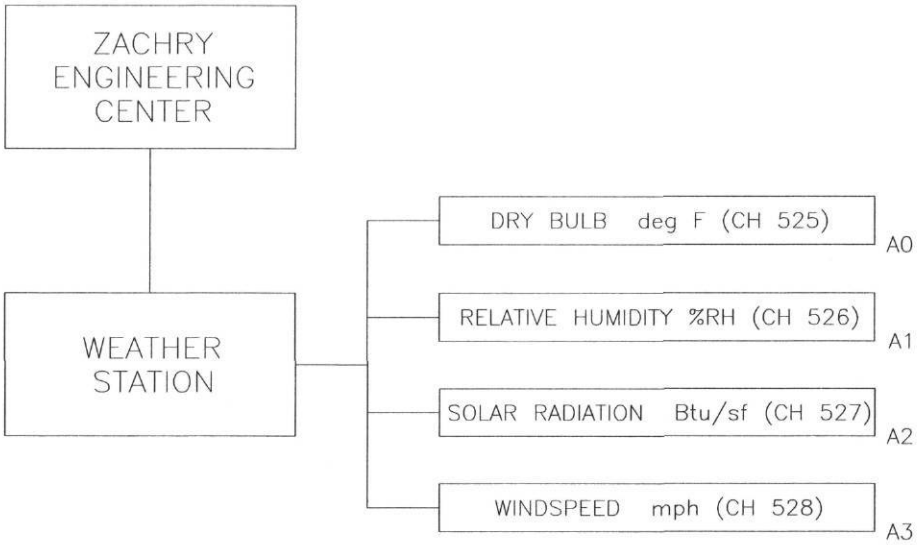


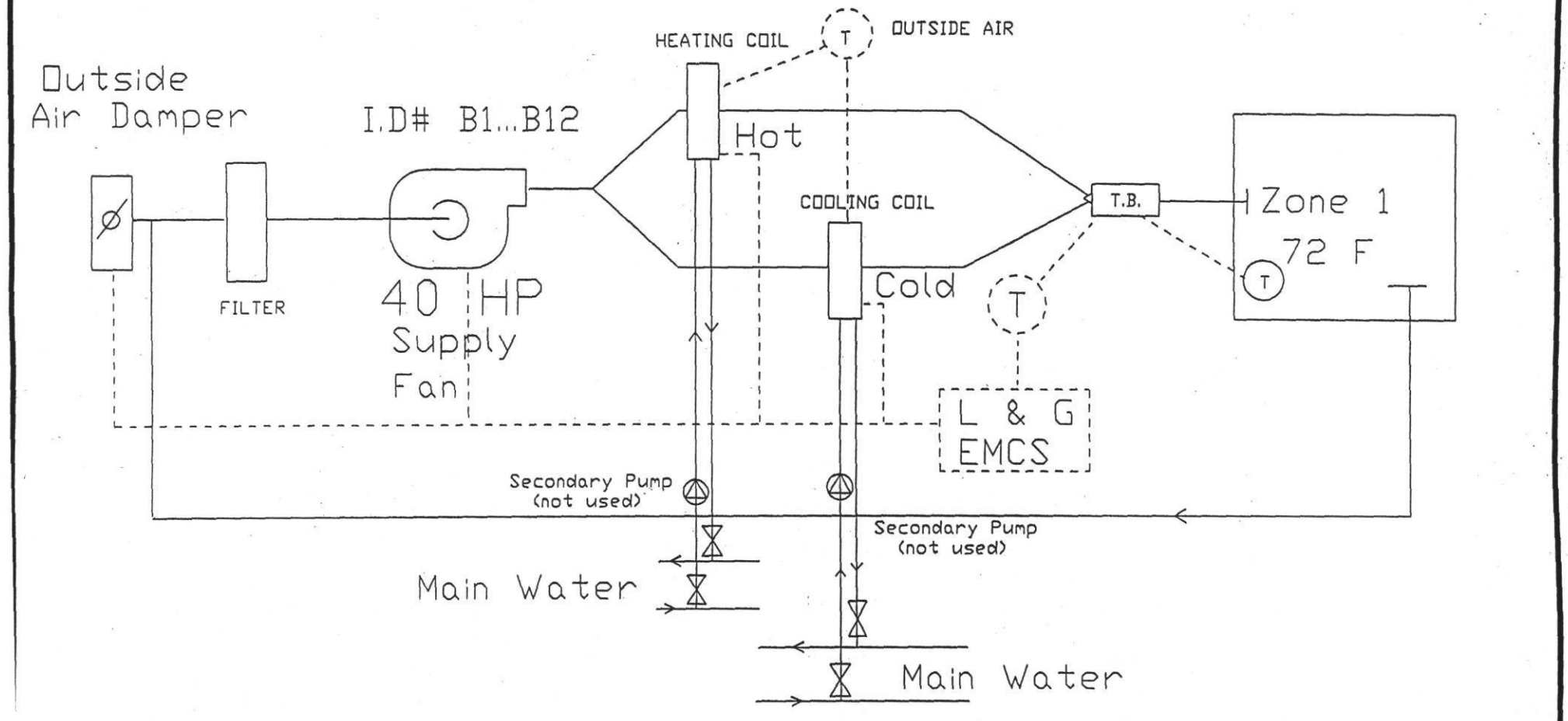
ZACHRY ENGINEERING CENTER – SITE 001

WEATHER MONITORING DIAGRAM
ZACHRY ENGINEERING CENTER

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL

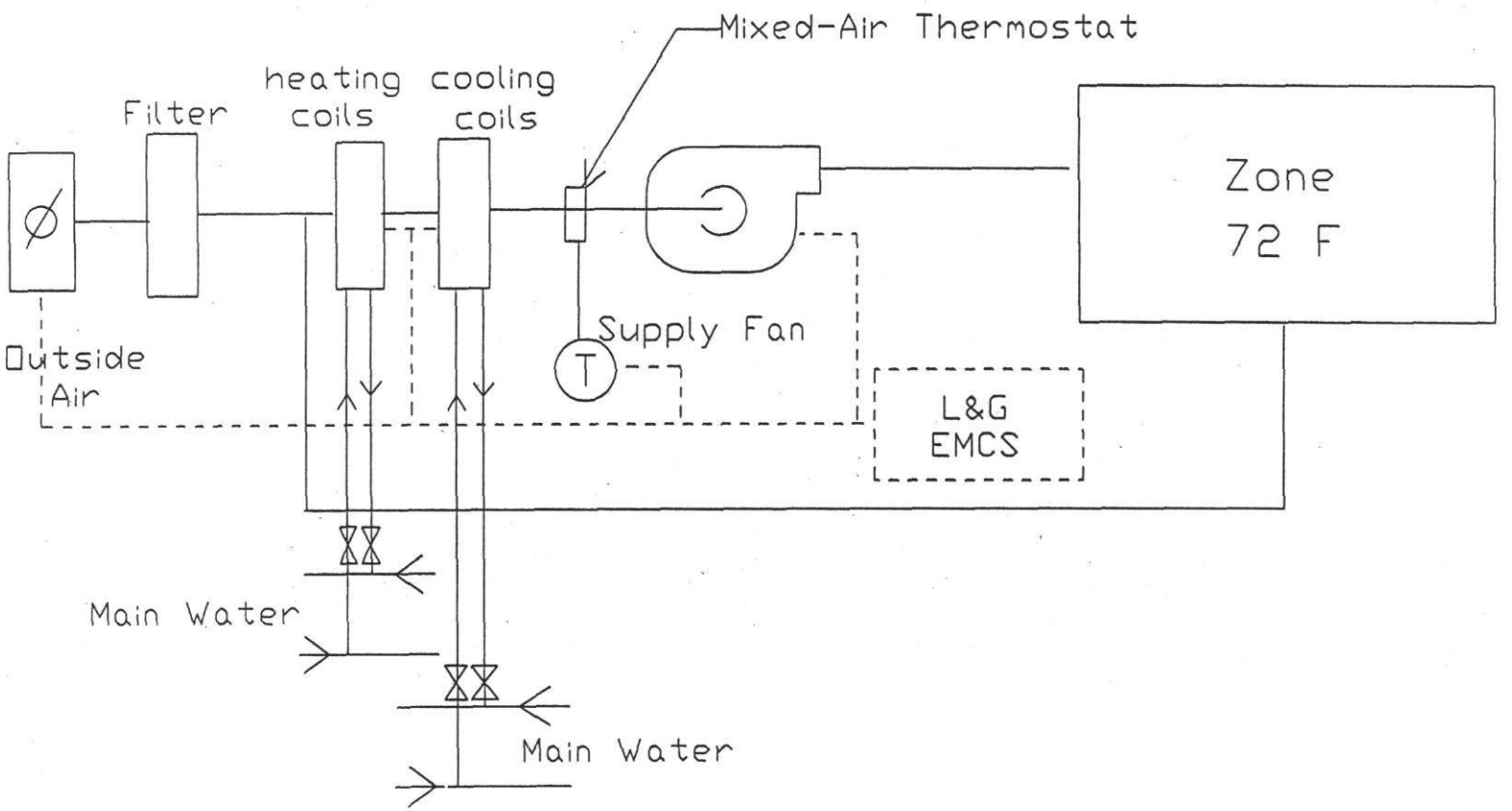




Variable-volume

35,000 CFM
Central Operated Thermostates

Texas LoanSTAR Program	
TEXAS A&M UNIV.- ZACHRY ENGINEERING CEN.	
Typical Dual-Duct System	Date: May 1, 1991
ZAC-001D	Drawn by: Mark Rivera



Centrally Operated Thermostats

Constant-Volume

Texas LoanSTAR Program	
TEXAS A&M UNIV.- ZACHRY ENGINEERING CEN.	
Typical Single-Duct System	Date: May 1, 1991
ZAC-001S	Drawn by: Mark Rivera

EDB0025

Education Building

University of Texas

251,161 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	150054	$6827	100	$10663	248	$1841	100	$13497	1548	$9598	0	$980	$25140	$25140
Feb	157252	$7155	100	$10336	406	$3015	100	$11117	1214	$7527	0	$390	$21843	$46983
Mar	168640	$7673	100	$11277	1040	$7722	100	$8515	1074	$6659	0	$703	$20495	$67478
Apr	168339	$7659	99	$11147	1468	$10900	99	$5692	792	$4910	0	$790	$17629	$85107
May	156312	$7112	100	$10737	1648	$12236	100	$5655	568	$3522	0	$1362	$17754	$102861
Jun	166578	$7579	100	$11058	1842	$13677	100	$6533	327	$2027	0	$1910	$19501	$122362
Jul	165682	$7539	100	$10949	2020	$14999	100	$6872	226	$1401	0	$2216	$20037	$142399
Aug	163370	$7433	100	$11054	2034	$15102	100	$7468	161	$998	0	$2367	$20889	$163288
Sep	170182	$7743	100	$11363	1653	$12274	100	$8161	204	$1265	30	$2575	$22099	$185387
Oct	173678	$7902	100	$11464	1370	$10172	100	$7823	341	$2114	100	$3198	$22485	$207872
Nov	173840	$7910	99	$11015	1082	$8034	99	$7628	880	$5456	99	$3196	$21839	$229711
Dec	158360	$7205	100	$10631	1251	$9289	100	$6702	1097	$6801	99	$2165	$19498	$249209
Total	1972287	$89737		$131694	16062	$119261		$95663	8432	$52278		$21852		$249209
EUI	7.9	$\frac{kWh}{ft^2yr}$			63951	$\frac{Btu}{ft^2yr}$			33572	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in October 1990.**

★ **The HVAC and the lighting retrofits were completed in May 1991.**

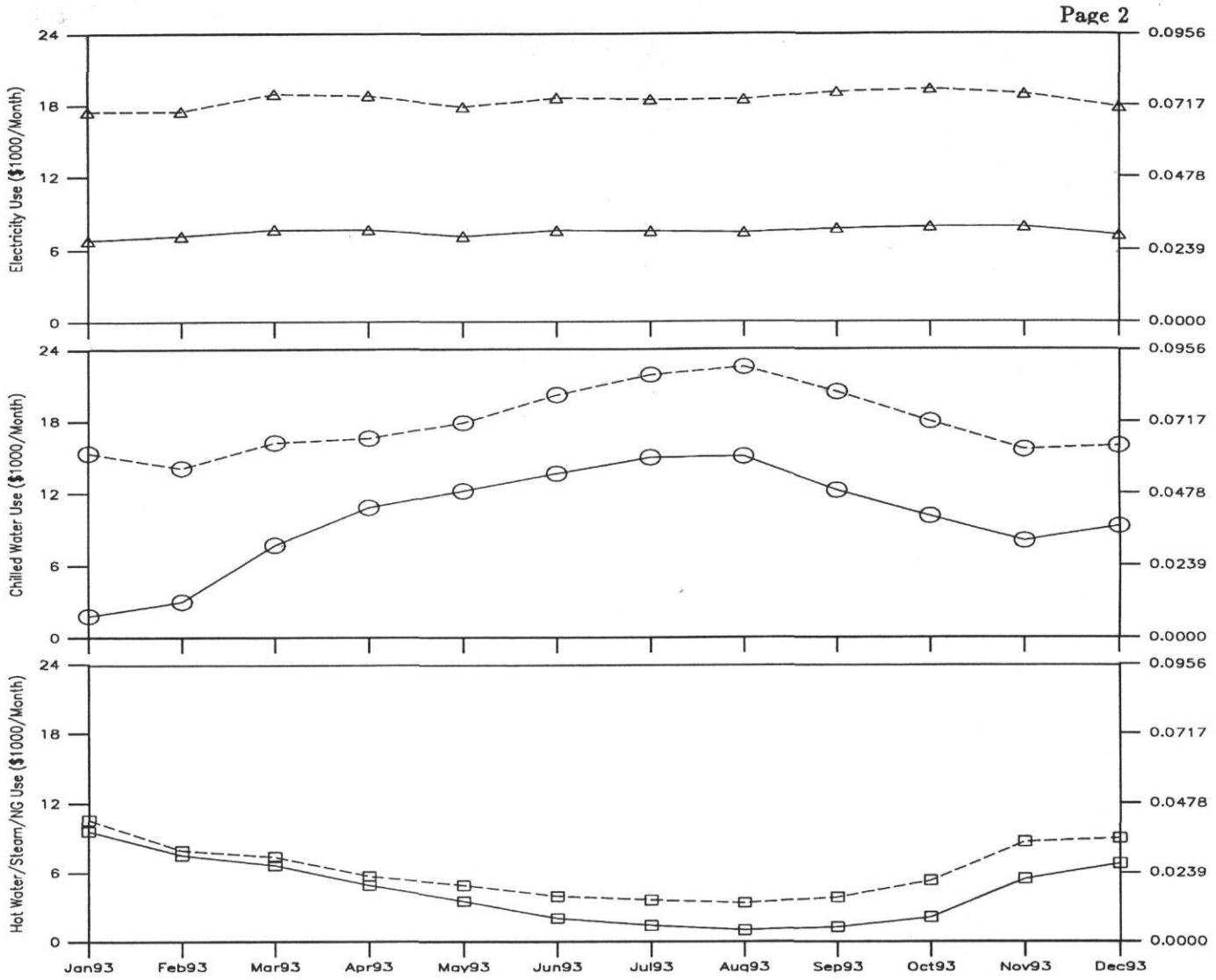
★ **The unit costs used for estimating audit and measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (steam).**

★ **The audit estimated savings for HVAC and lighting retrofits are: $116,500 (ELE), $25,900 (CW), $31,800 (Steam), and $174,200 (Total).**

★ **The measured electricity savings also include savings from the lighting retrofit.**

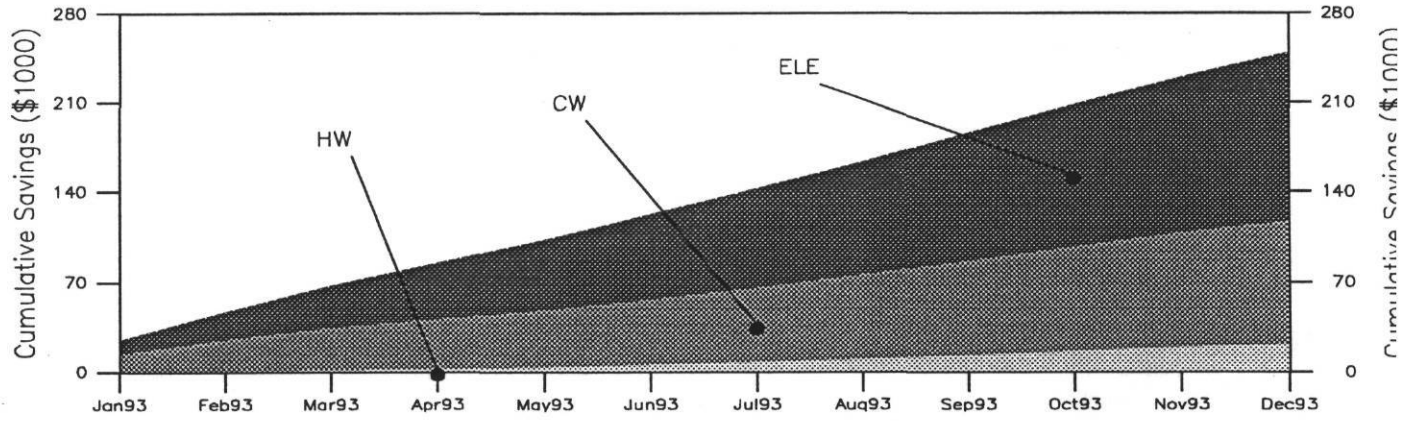
★ **Steam consumption from January through September was estimated using a post-retrofit regression model, because of missing data due to hardware problems.**

★ **Chilled water consumption increased from October through December 1993 when compared with 1992. Conversations with UT personnel have revealed that the economiser was disabled in October 1993 and was not used through December.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



UT AUSTIN

Education Building

Building Envelope:

- 251,161 sq.ft
- 5-story, erected 1976, classrooms, administration offices
- walls: face brick on block
- windows: 30% of total wall area, single pane tinted glass
- roof: flat

Building Schedule:

- 8 am to 5 pm (M-F), various groups occupying on various schedule

Building HVAC:

- 3 constant volume dual duct AHUs (2-7.5hp,1-5hp)
- 8 variable volume dual duct AHUs (50 hp)
- 8 variable frequency return air fans (6-15hp, 2-20hp)
- 2 return air fans (1-2hp, 1-1hp)
- 1 variable volume chilled water pump (75 hp)
- 2 constant volume chilled water pumps (1-75hp, 1-1hp)
- 1 hot water pump (1-3/4 hp)
- Economizer cycle has been added as a part of the retrofit

HVAC Schedule:

- 24 hrs/day

Lighting:

- Lighting is primarily fluorescent with 34-watt and 18-W screw-in fluorescent lamps.

Retrofits Implemented:

- variable air volume
- variable speed pumping
- replace incandescent lights

Date of Retrofits:

- VAV conversion, variable speed pumping and lighting retrofits were completed at the end of May 1991.

Savings Calculations:

- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

EDB0025

Education Building

University of Texas
251,161 square feet

Site Contact
Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact
Aamer Athar
053D 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	187704 kWh	100	$0.04550	$8541
Peak 60 Minute Demand	452 kW	100	-	-
Chilled Water	1177.9 MMBtu	100	$7.425	$8746
Condensate	1211.7 MMBtu	100	$6.200	$7513

Peak 60 minute demand was recorded at 1400 Wednesday 03/27/96.
There were 744 hours in this month.

Monthly Retrofit Savings

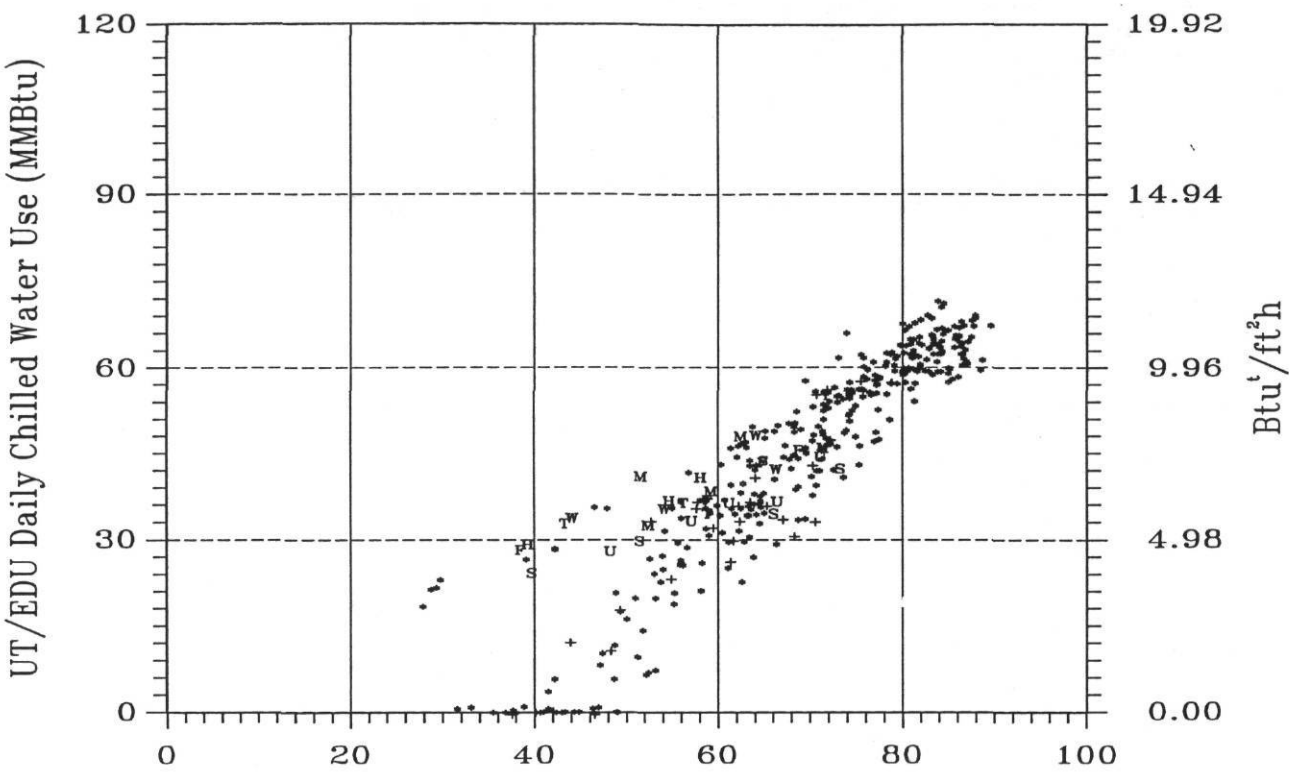
	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	250460	$11396	213367	$9708
Chilled Water (MMBtu)	940	$6980	291	$2161
Cond./H.W./N.G. (MMBtu)	199	$1234	427	$2647
Monthly Total		$19609		$14516
Total to Date*	(60 months)	$1220445	(58 months)	$841944

*Measured savings include construction period. Audit estimated savings do not.

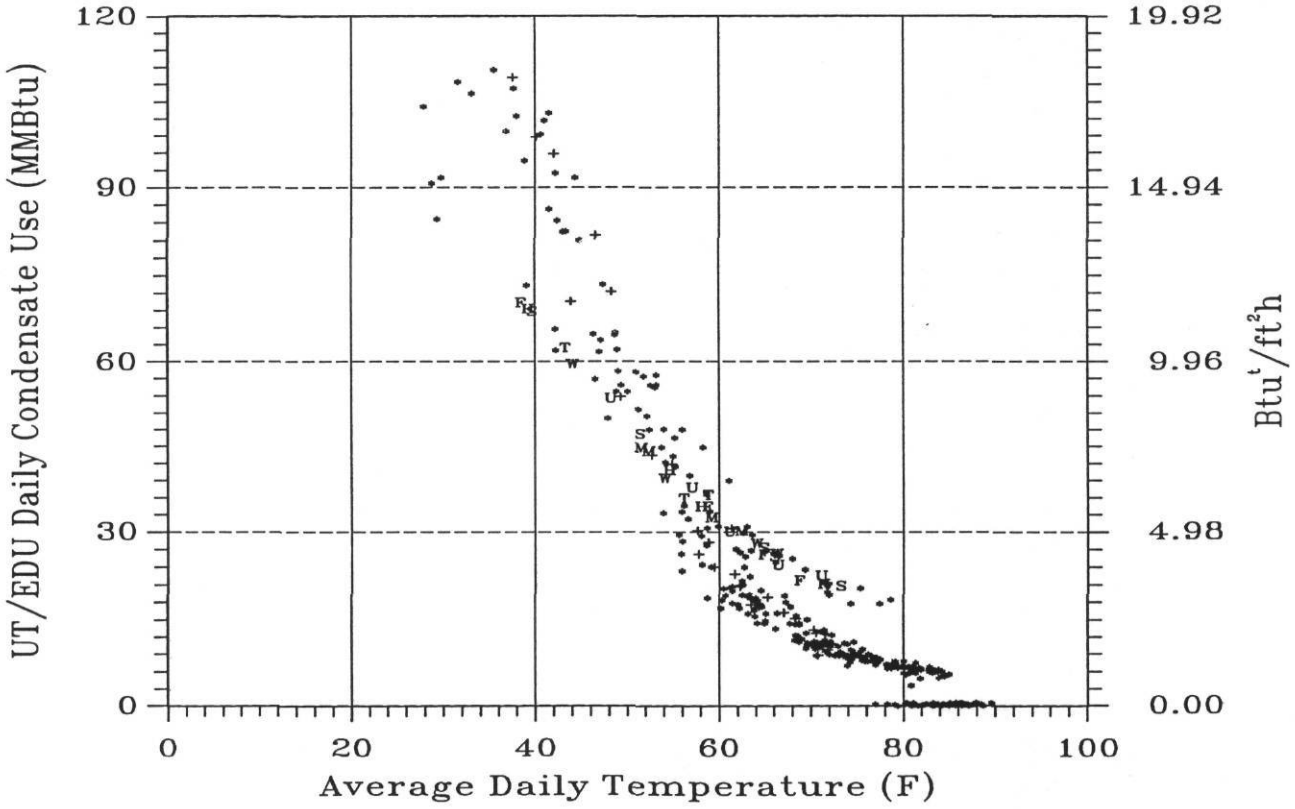
Comments

★ The economizer (vent) cycle does not seem to be working this month.
★ Spring Break is evident as reduced electricity consumption from 3/11/96 to 3/17/96.
★ Steam energy consumption is significantly lower at 40°F daily temperature than March 1995.

Mar 01 1995 – Mar 31 1996

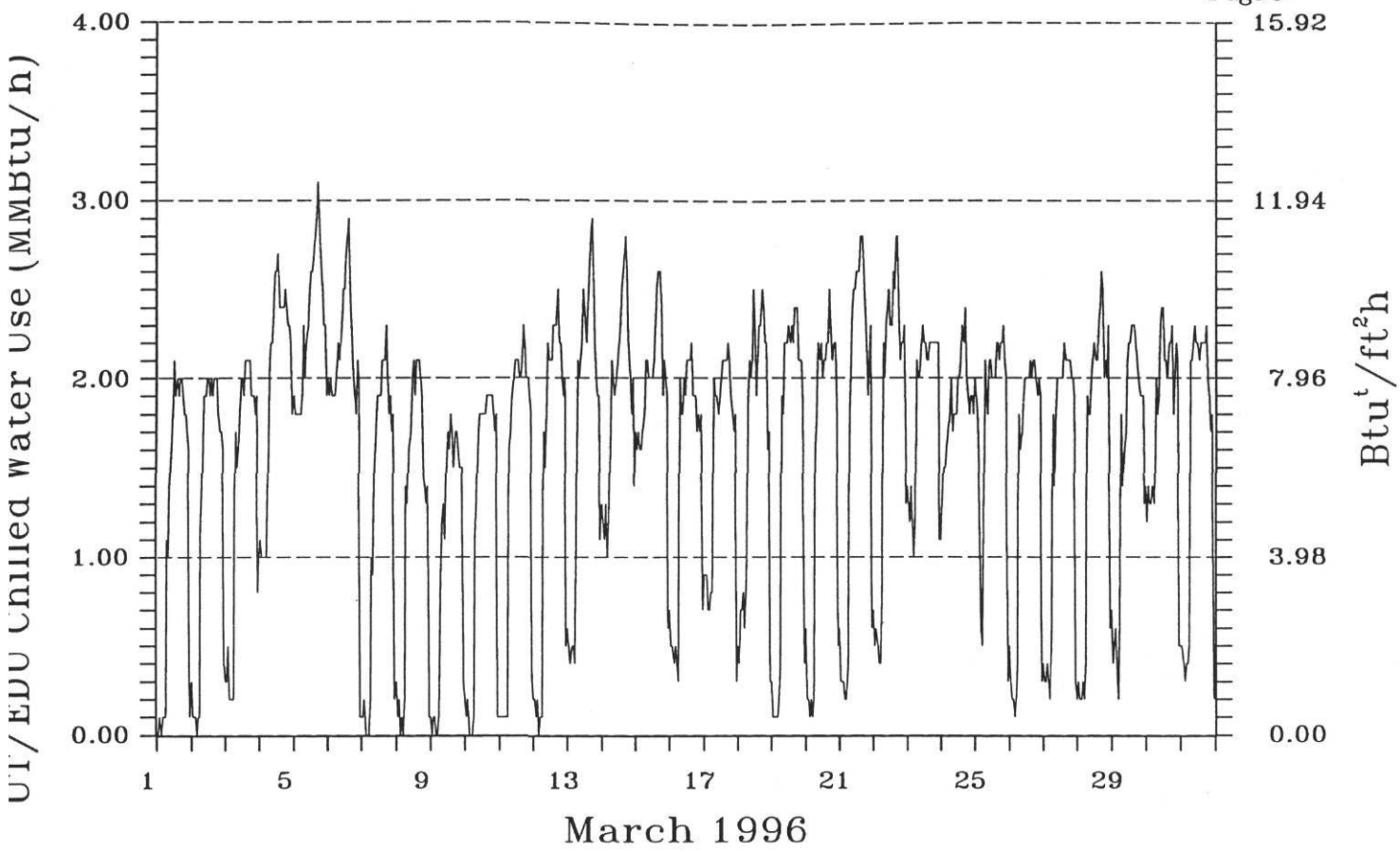


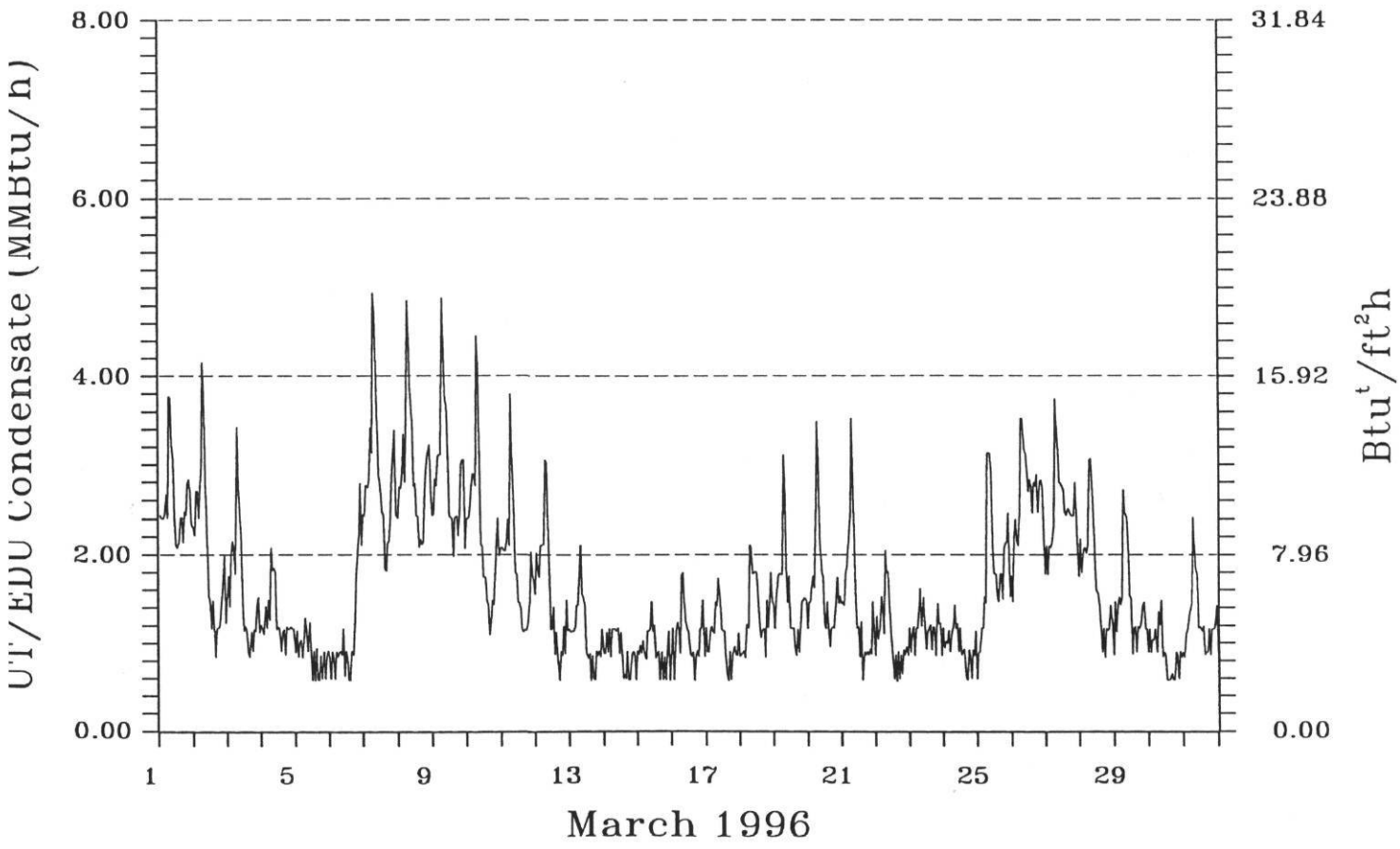
Mar 01 1995 – Mar 31 1996

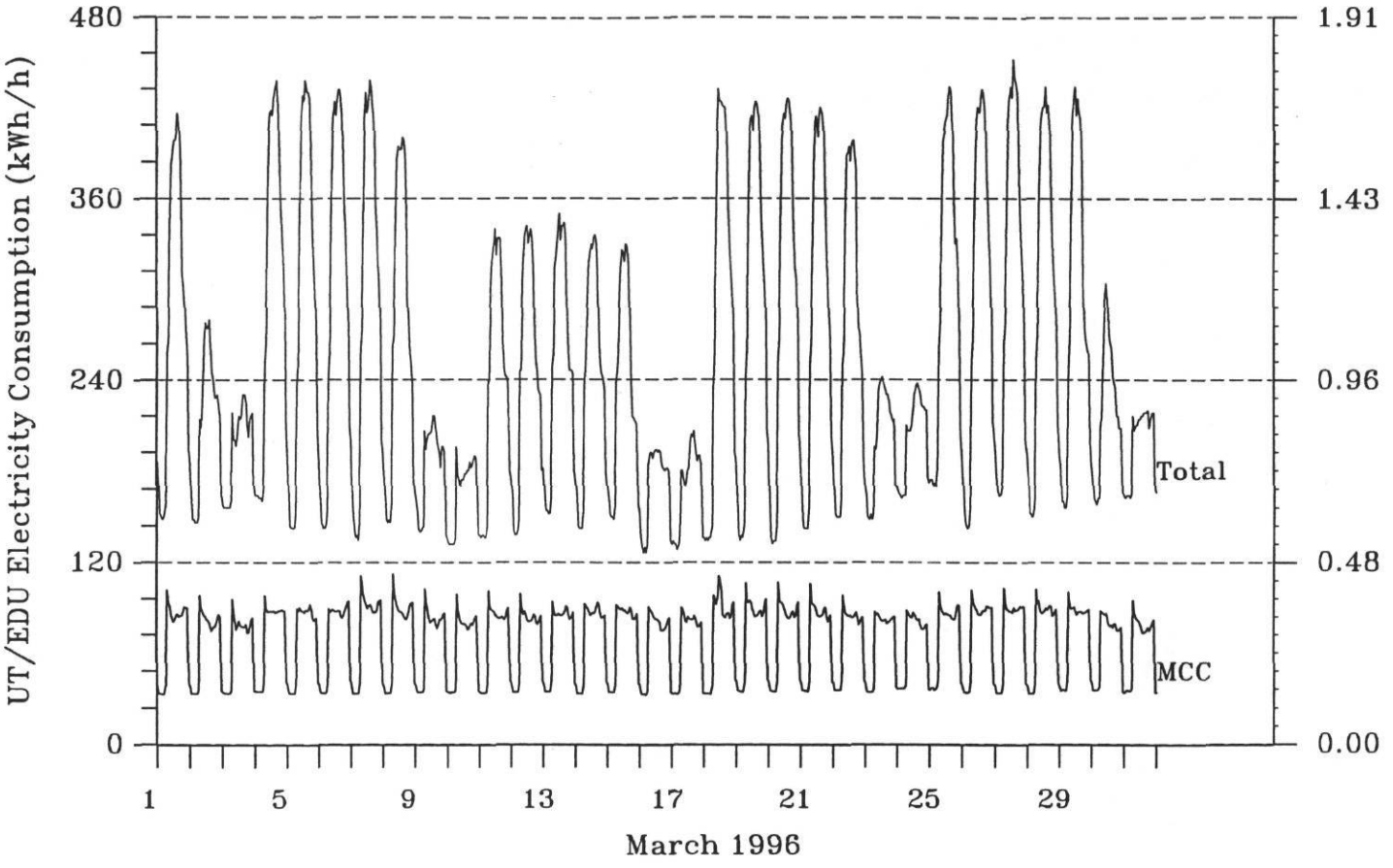


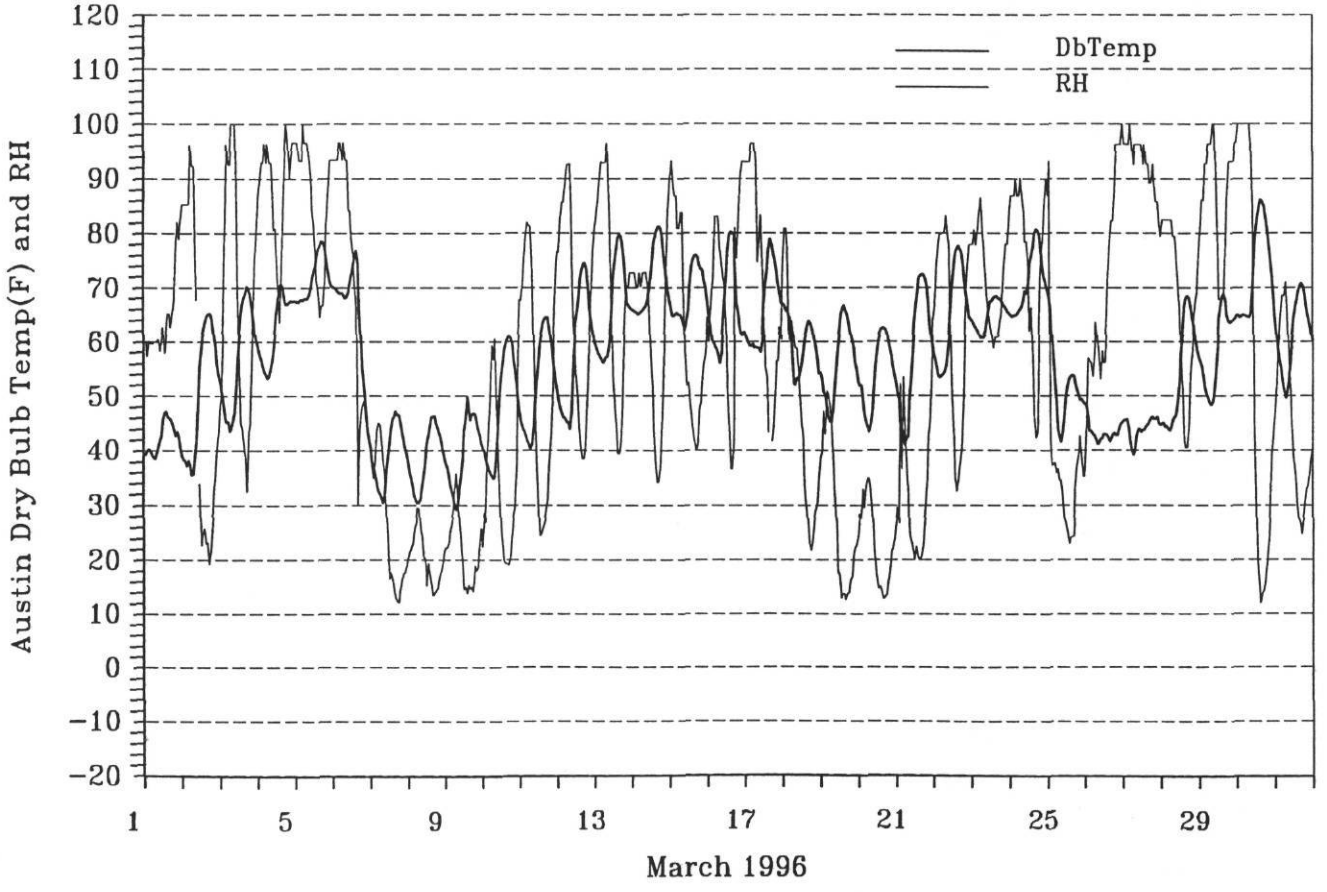
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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


Chilled Water Use (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
15.92
11.94
7.96
3.98
0.00
Btu/ft²h
1
5
9
13
17
21
25
29
March 1996

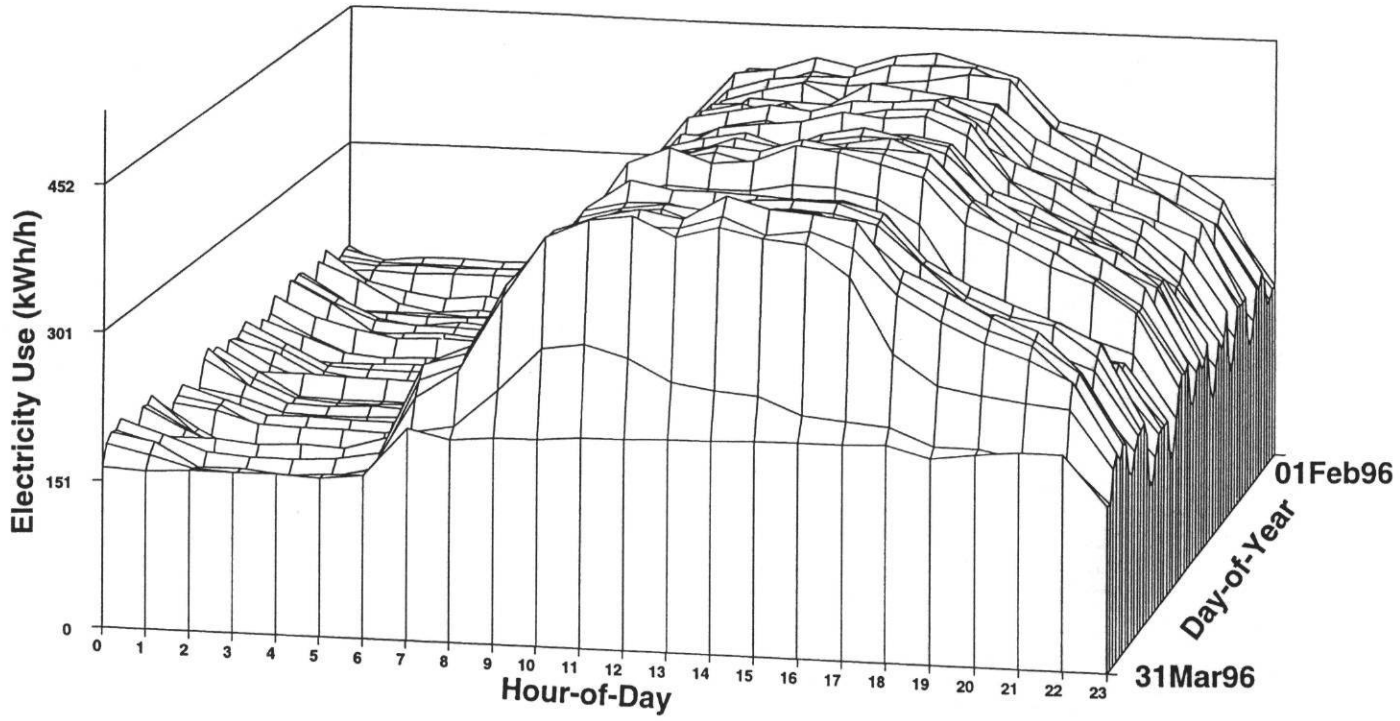

Condensate (MMBtu/h)
8.00
6.00
4.00
2.00
0.00
31.84
23.88
15.92
7.96
0.00
Btu/ft²h
1
5
9
13
17
21
25
29
March 1996



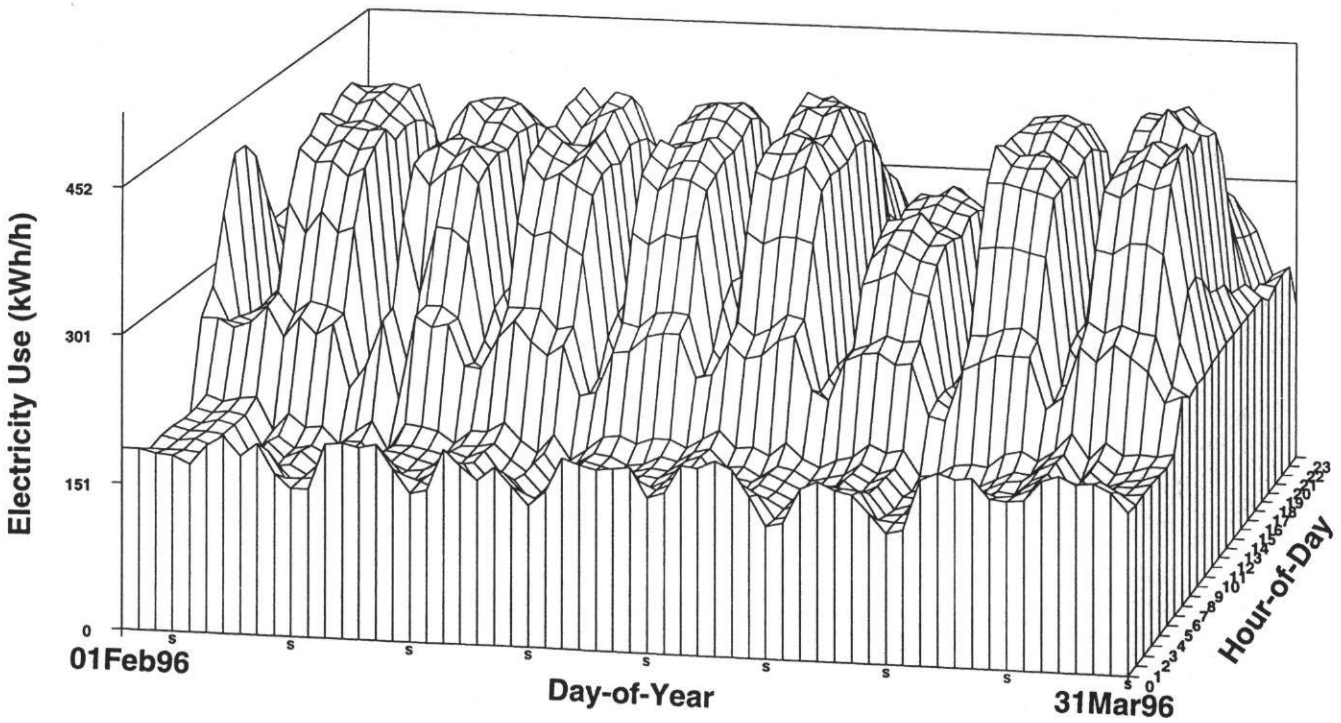


EDB0025 - Education Building - University of Texas - March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

Education Building

Building Envelope:
- 251,161 sq.ft
- 5-story, erected 1976, classrooms, administration offices
- walls: face brick on block
- windows: 30% of total wall area, single pane tinted glass
- roof: flat

Building Schedule:
- 8 am to 5 pm (M-F), various groups occupying on various schedule

Building HVAC:
- 3 constant volume dual duct AHUs (2-7.5hp,1-5hp)
- 8 variable volume dual duct AHUs (50 hp)
- 8 variable frequency return air fans (6-15hp, 2-20hp)
- 2 return air fans (1-2hp, 1-1hp)
- 1 variable volume chilled water pump (75 hp)
- 2 constant volume chilled water pumps (1-75hp, 1-1hp)
- 1 hot water pump (1-3/4 hp)
- Economizer cycle has been added as a part of the retrofit

HVAC Schedule:
- 24 hrs/day

Lighting:
- Lighting is primarily fluorescent with 34-watt and 18-W screw-in fluorescent lamps.

Retrofits Implemented:
- variable air volume
- variable speed pumping
- replace incandescent lights

Date of Retrofits:
- VAV conversion, variable speed pumping and lighting retrofits were completed at the end of May 1991.

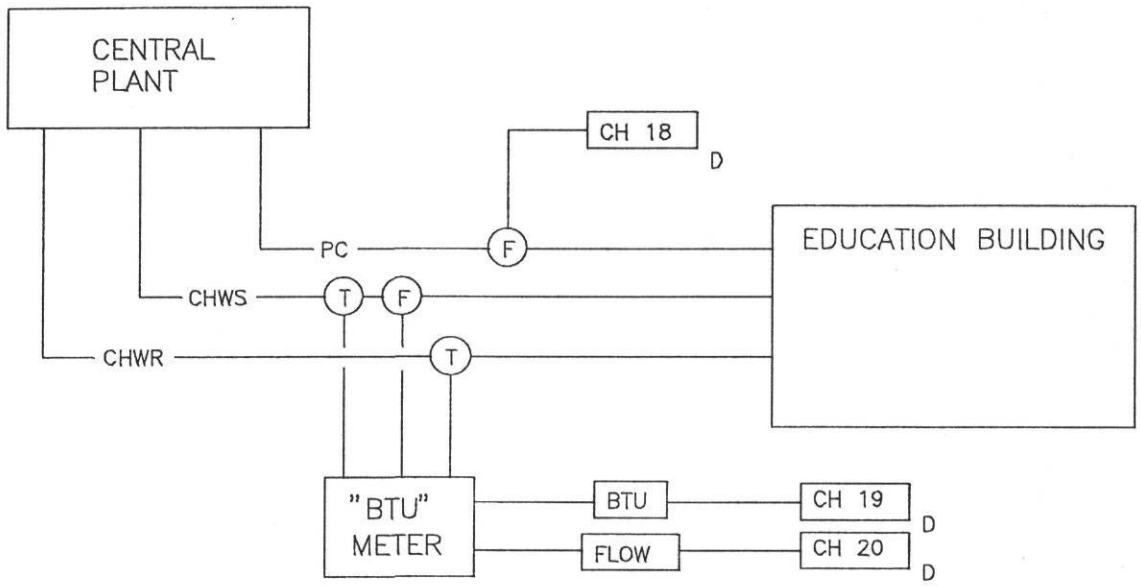
Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – EDUCATION BLDG

LEGEND

K=KWH CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



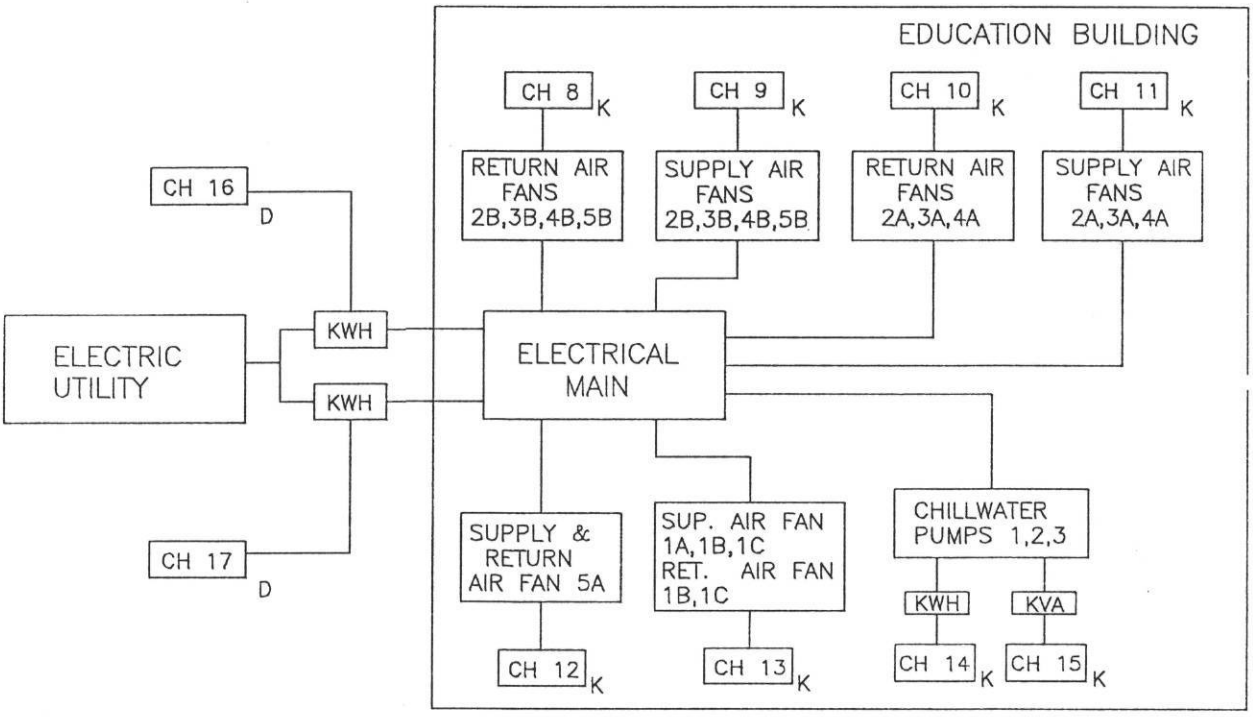
UT AUSTIN/EDUCATION – SITE 100

ELECTRICAL MONITORING DIAGRAM

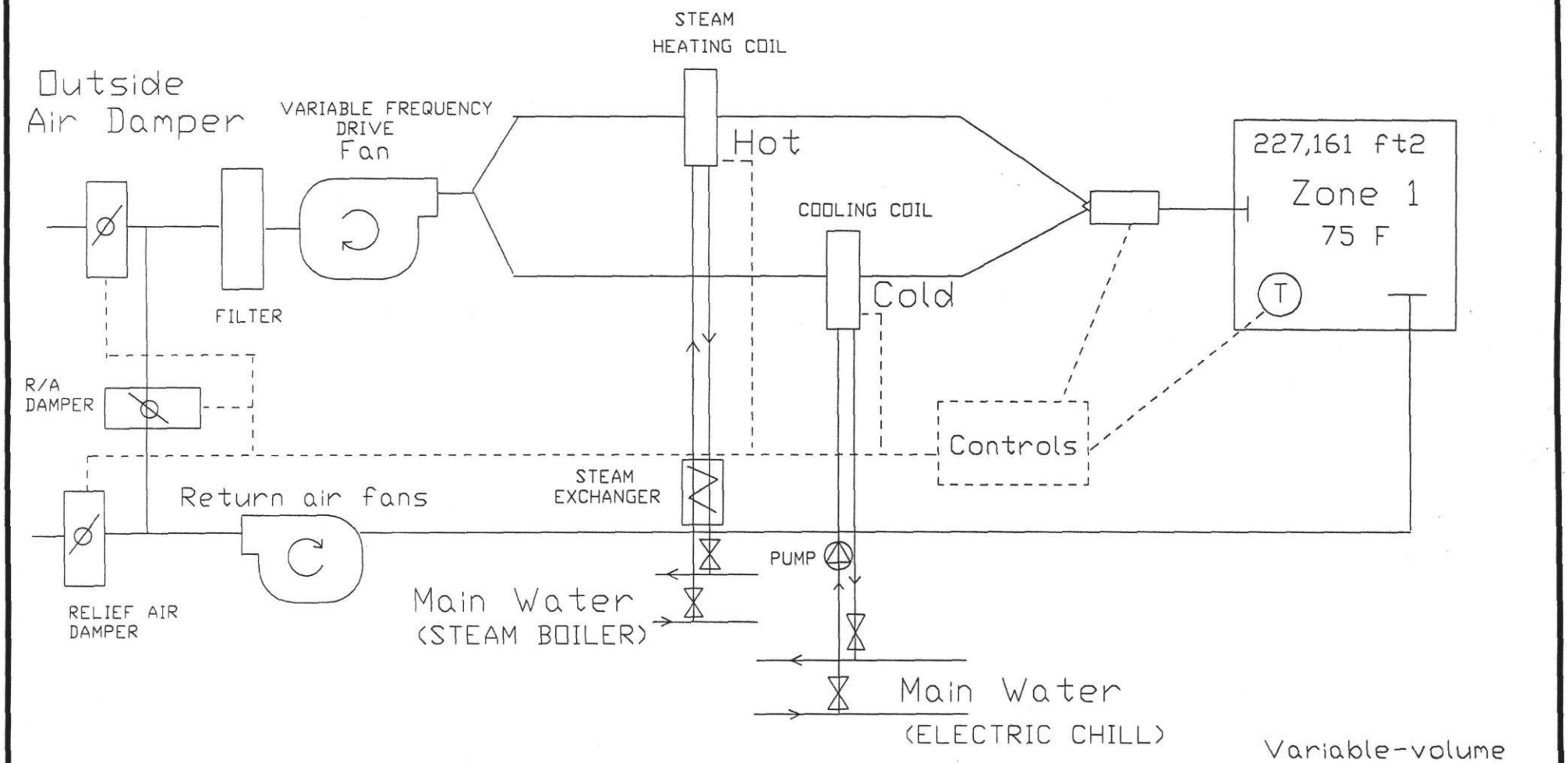
UT AUSTIN – EDUCATION BLDG

LEGEND

K=KWH CHANNEL
D=DIGITAL CHANNEL



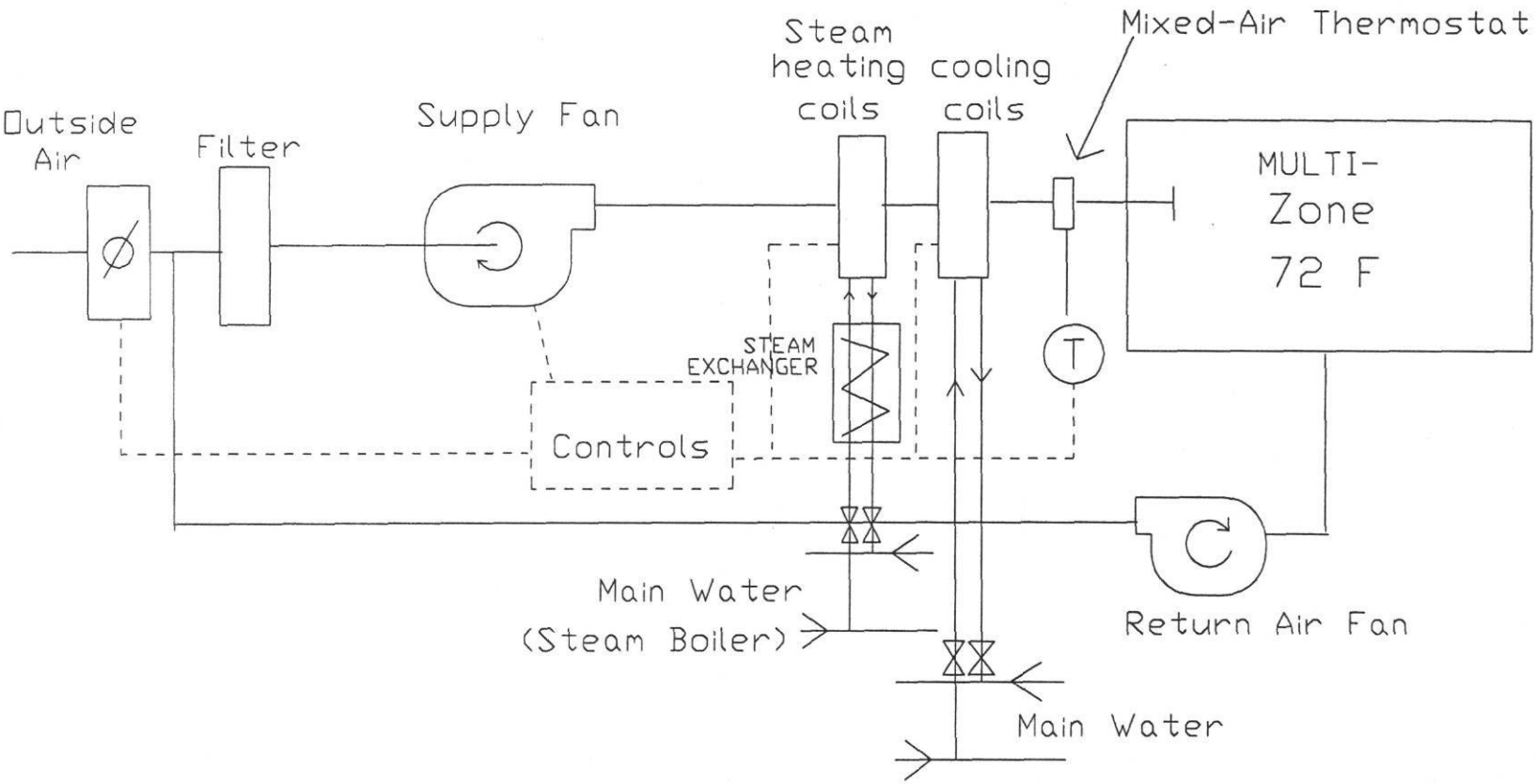
UT AUSTIN/EDUCATION – SITE 100



Variable-volume

Pneumatically controlled thermo.
2 AHU/floor (N & S)

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- EDUCATION BUILDING	
Typical Dual-Duct System	Date: May 1, 1991
EDB-100	Drawn by: Mark Rivera



(single fan system)

Centrally Operated Thermostats

Constant-Volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- EDUCATION BUILDING	
Typical Single-Duct System	Date: May 1, 1991
EDB-100S	Drawn by: Mark Rivera

UTC0500

University Teaching Center

University of Texas

152,690 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	110448	$5025	100	$4831	284	$2109	100	$5479	531	$3292	100	$2977	$13287	$13287
Feb	123748	$5631	100	$4269	377	$2799	100	$4525	396	$2455	100	$2898	$11692	$24979
Mar	131690	$5992	100	$4729	463	$3438	100	$5556	391	$2424	100	$3090	$13375	$38354
Apr	131303	$5974	99	$4534	538	$3995	99	$5440	317	$1965	99	$2998	$12972	$51326
May	115494	$5255	100	$4708	628	$4663	100	$6513	296	$1835	100	$2950	$14171	$65497
Jun	117560	$5349	100	$4618	781	$5799	100	$7126	189	$1172	100	$1175	$12919	$78416
Jul	119526	$5438	100	$4764	798	$5925	100	$7833	124	$769	100	$-614	$11983	$90399
Aug	117360	$5340	100	$4718	815	$6051	100	$7546	149	$924	100	$-769	$11495	$101894
Sep	133934	$6094	100	$4439	801	$5947	100	$5965	162	$1004	100	$-855	$9549	$111443
Oct	137098	$6238	100	$4548	658	$4886	100	$5590	309	$1916	100	$-1765	$8373	$119816
Nov	127358	$5795	99	$4465	401	$2977	99	$5266	517	$3205	99	$2440	$12171	$131987
Dec	107256	$4880	100	$4886	235	$1745	100	$5233	238	$1476	100	$1874	$11993	$143980
Total	1472775	$67011		$55509	6779	$50334		$72072	3619	$22437		$16399		$143980
EUI	9.6	$\frac{kWh}{ft^2yr}$			44397	$\frac{Btu}{ft^2yr}$			23701	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in November 1990.**

★ **The HVAC retrofit was completed in October 1990.**

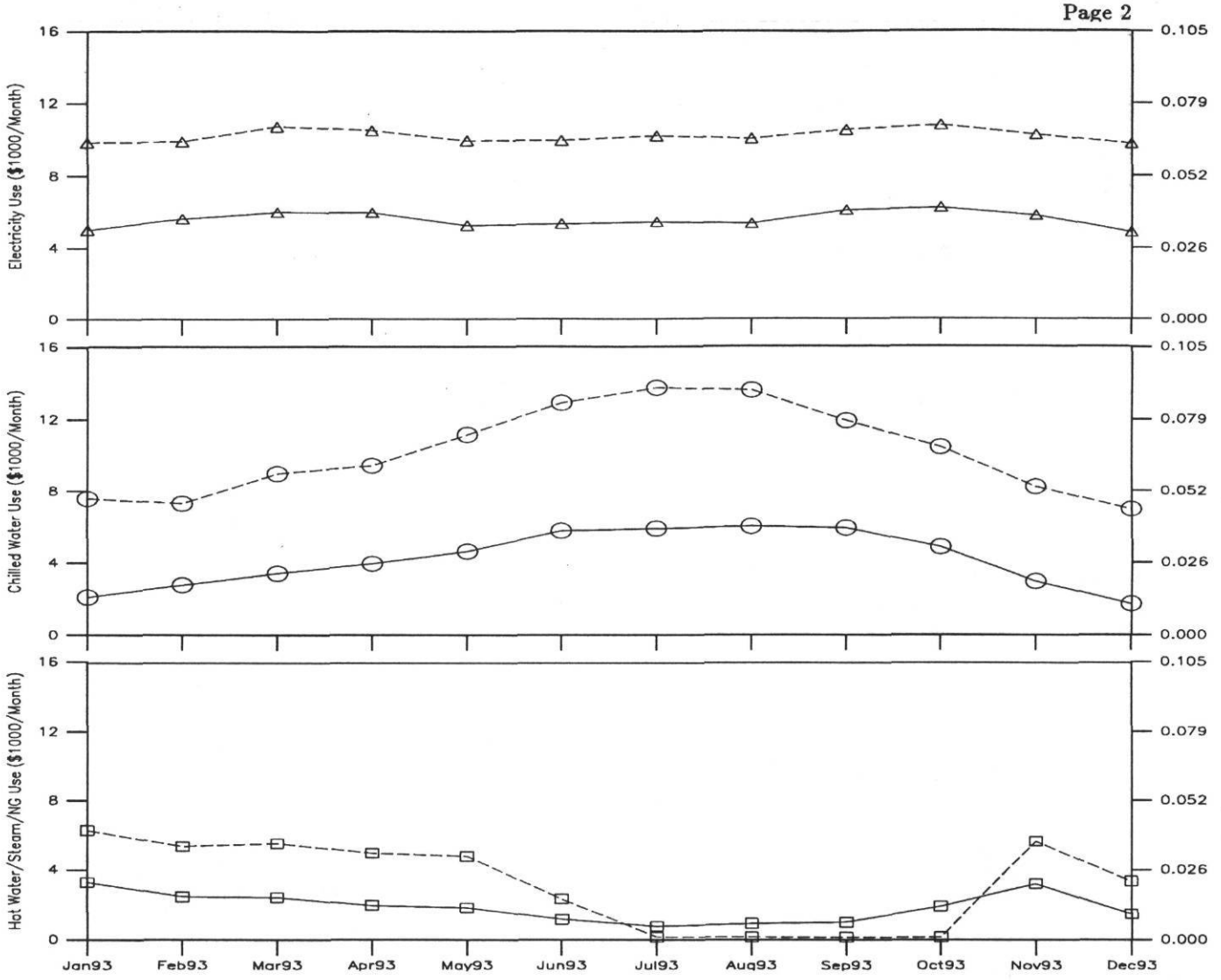
★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

★ **The audit estimated savings for HVAC retrofits are: $53,200 (ELE), $30,000 (CW), $31,000 (Steam), and $114,200 (Total).**

★ **Since the monitoring began after the retrofits were completed, no pre-retrofit monitored data are available. The chilled water and steam savings are based on a simplified calibrated baseline model.**

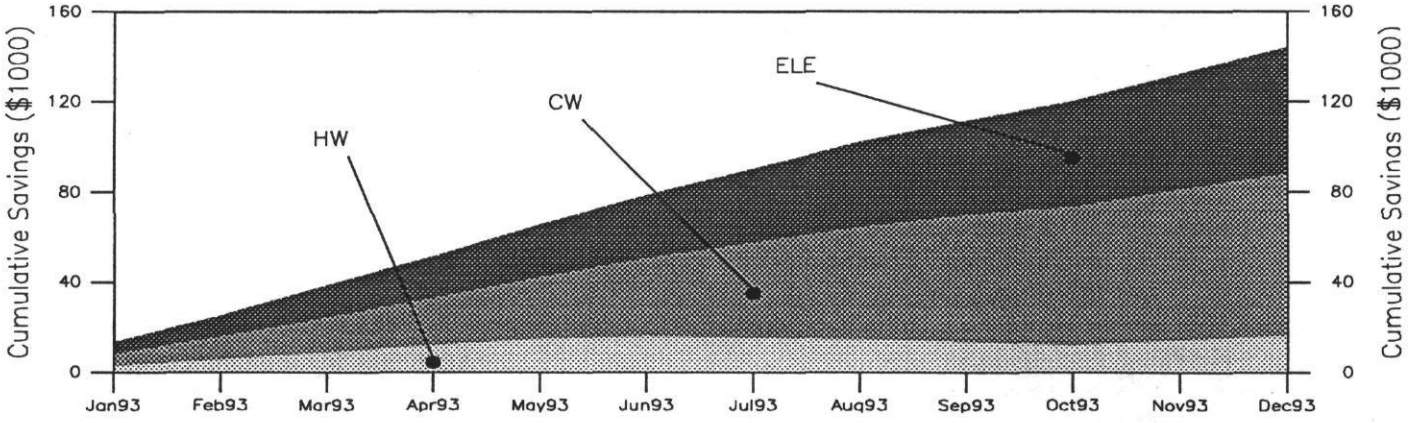
★ **Negative steam savings were measured from July to October 1993. Conversations with UT personnel have revealed that steam valves for two AHUs supplying air to the auditorium were opened in July 1993.**

UTC0500 - University Teaching Center - University of Texas



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



UT AUSTIN

University Teaching Center

Building Envelope:
- 152,690 sq.ft
- 6-story, erected 1984, classrooms
- walls: hollow clay tile with a cut stone exterior
- windows: 9% of total wall area, single pane clear operable
- roof: build-up roof on light weight insulation fill

Building Schedule:
- classrooms: 7 am to 11 pm but the building is open 24 hrs/day.

Building HVAC:
- 8 variable volume dual duct AHUs (2-30hp, 2-20hp, 3-25hp, 1-15hp)
- 8 variable frequency return air fans (5-7.5hp, 2-10hp, 1-5hp)
- 8 variable frquency hot deck fans (2-15hp, 1-10hp, 3-7.5hp, 2-5hp)
- 1 variable volume chilled water pump (50hp)
- 1 constant volume chilled water pump (50 hp)
- Economizer cycle has been added as a part of the retrofit (not operable at this moment)

HVAC Schedule:
- 24 hrs/day, 7 days/wk

Lighting:
- high pressure sodium, fluorescent, and incandescent

Proposed Retrofits:
- 3 position light switch
- variable air volume
- variable speed pumping

Date of Retrofits:
- all retrofits completed by December 1990.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

UTC0500

University Teaching Center

University of Texas
152,690 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

Aamer Athar
053D 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	114628 kWh	100	$0.04550	$5216
Peak 60 Minute Demand	238 kW	100	-	-
Chilled Water	298.3 MMBtu	100	$7.425	$2215
Condensate	904.6 MMBtu	100	$6.200	$5608

Peak 60 minute demand was recorded at 1400 Thursday 03/28/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	103927	$4729	83238	$3787
Chilled Water (MMBtu)	843	$6259	337	$2502
Cond./H.W./N.G. (MMBtu)	27	$167	416	$2579
Monthly Total		$11155		$8869
Total to Date*	(66 months)	$727716	(66 months)	$585338

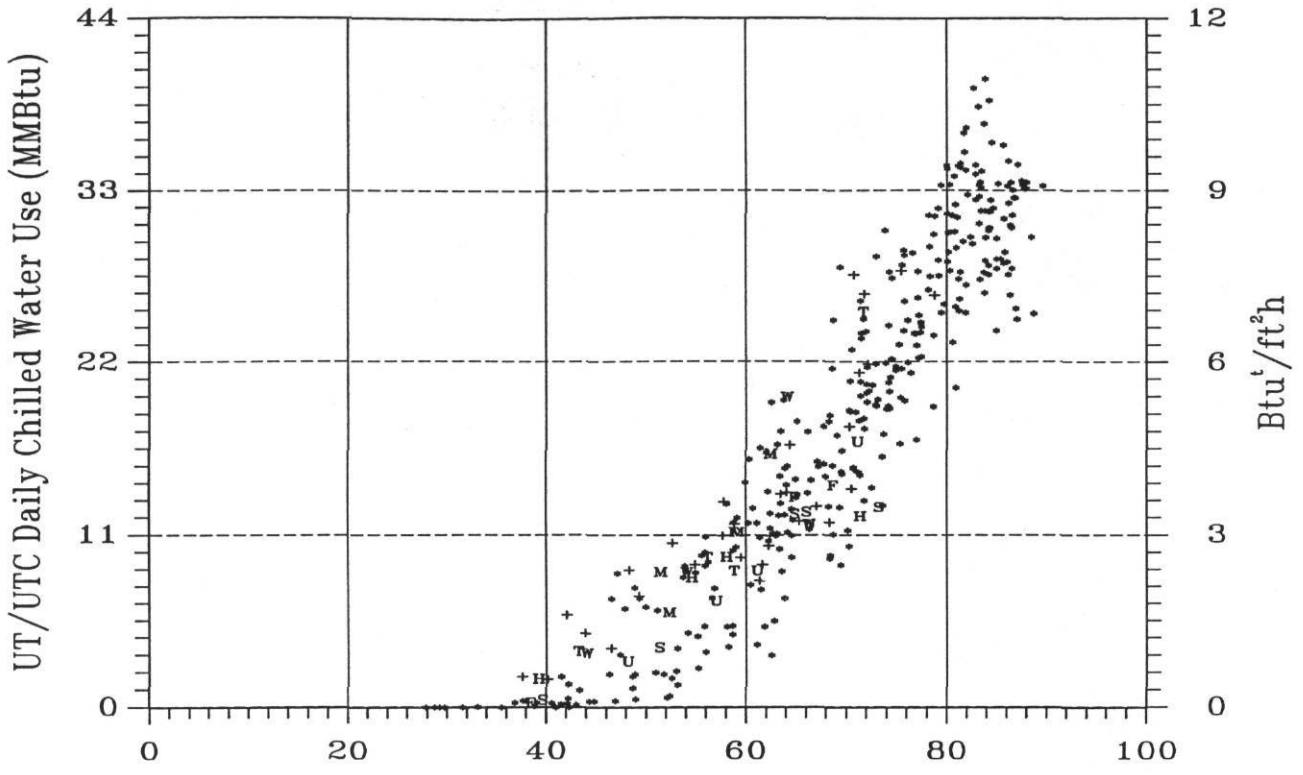
*Measured savings include construction period. Audit estimated savings do not.

Comments

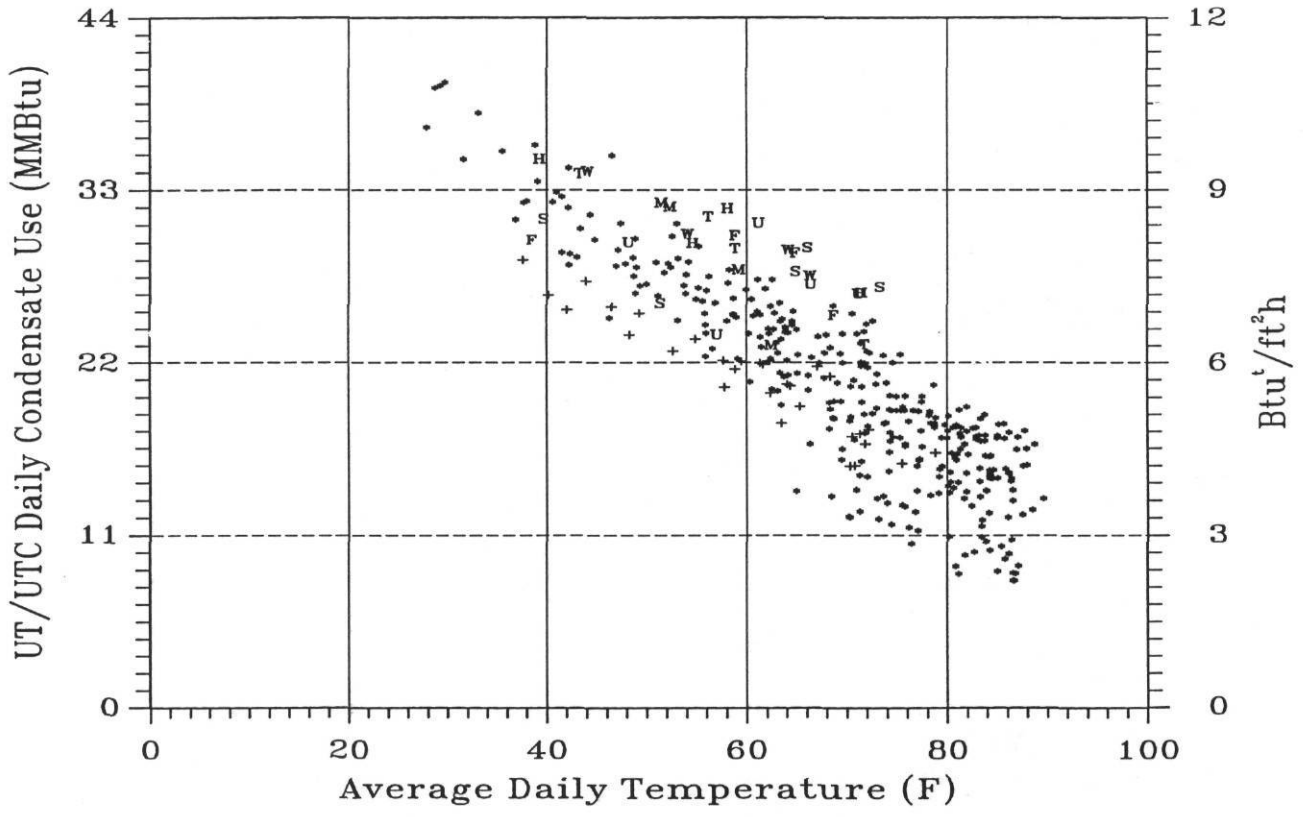
★ Steam energy consumption increased significantly when compared to March 1995.

★ Nighttime electricity use by the MCC has decreased significantly when compared to March 1995.

Mar 01 1995 – Mar 31 1996



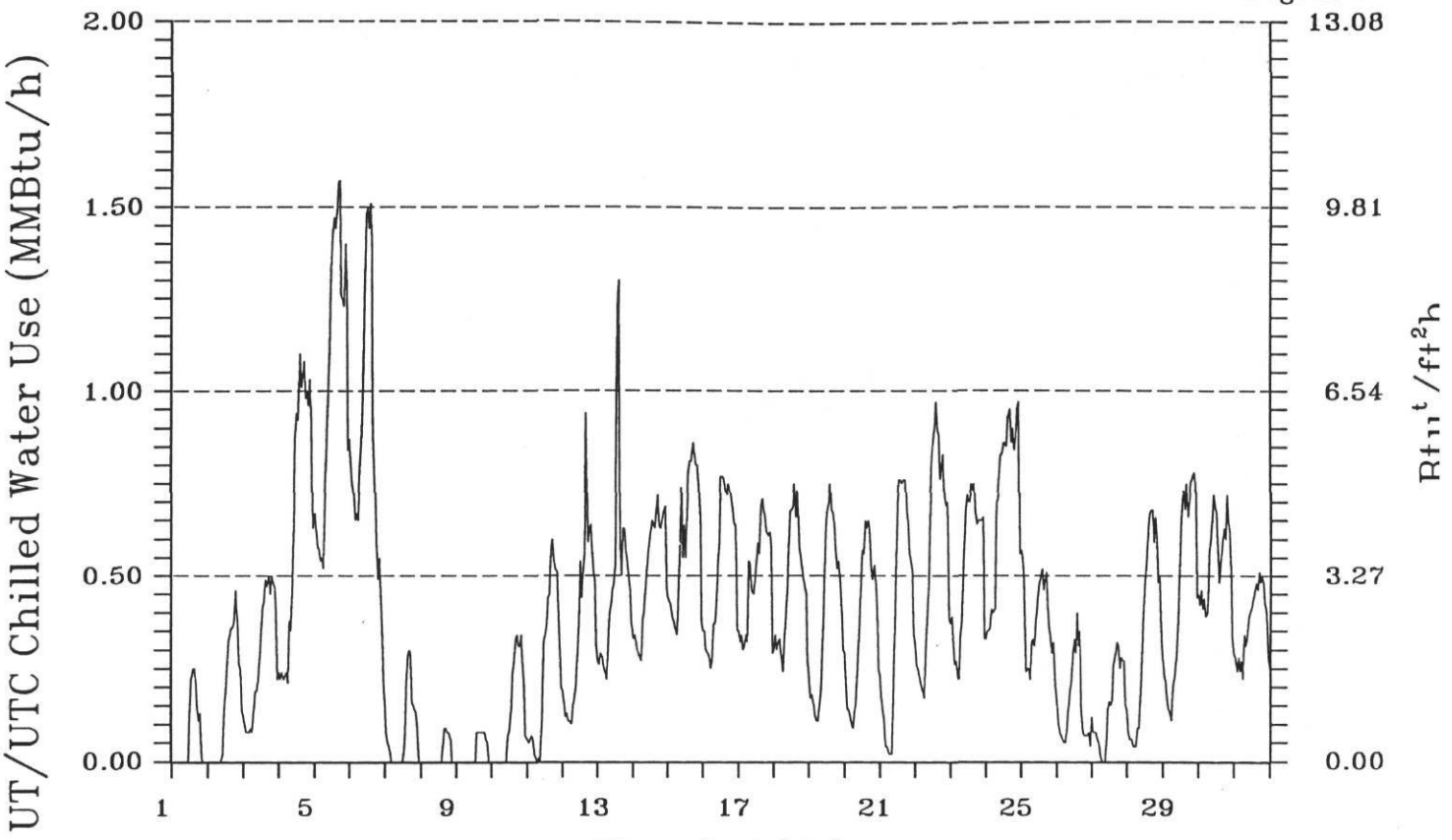
Mar 01 1995 – Mar 31 1996

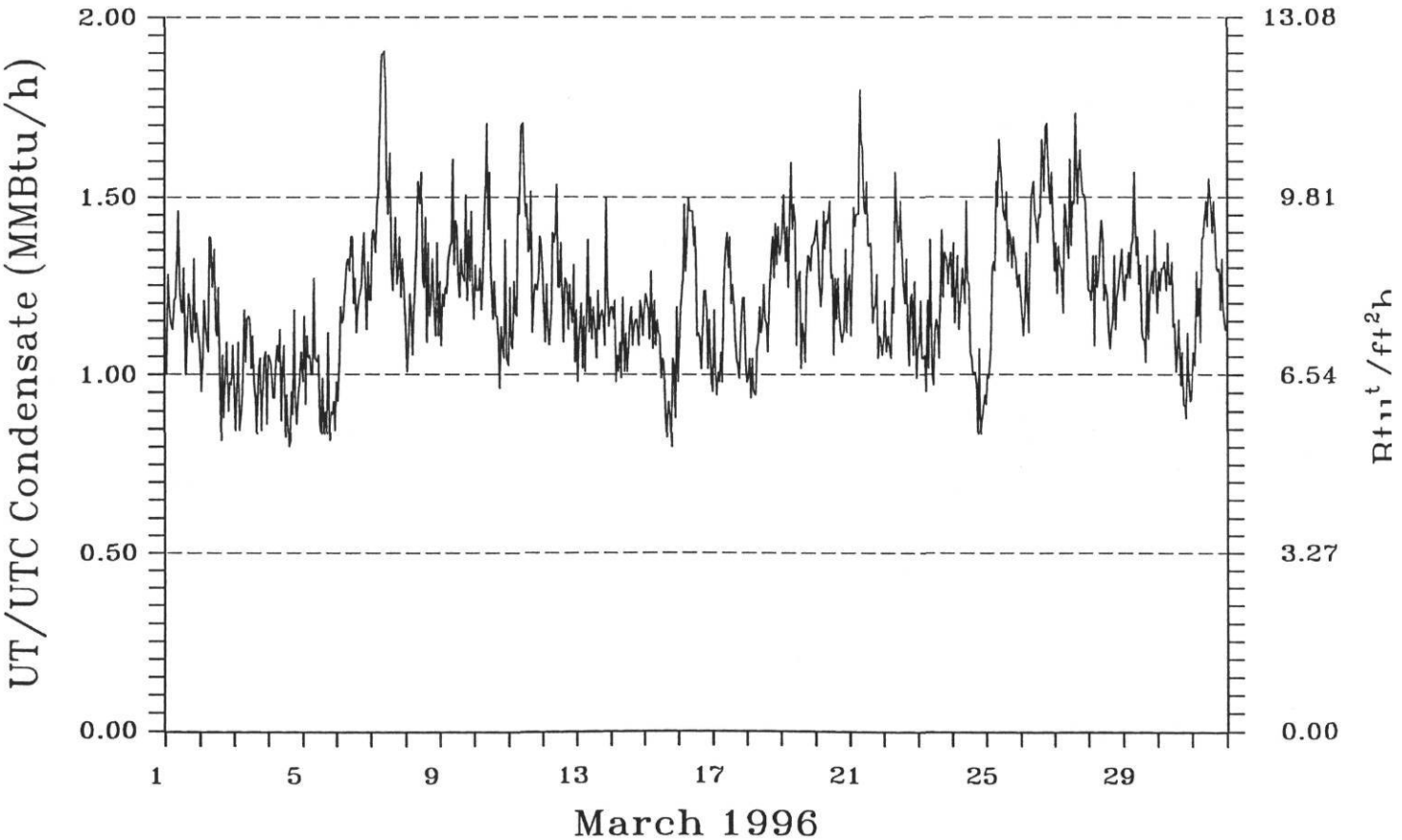


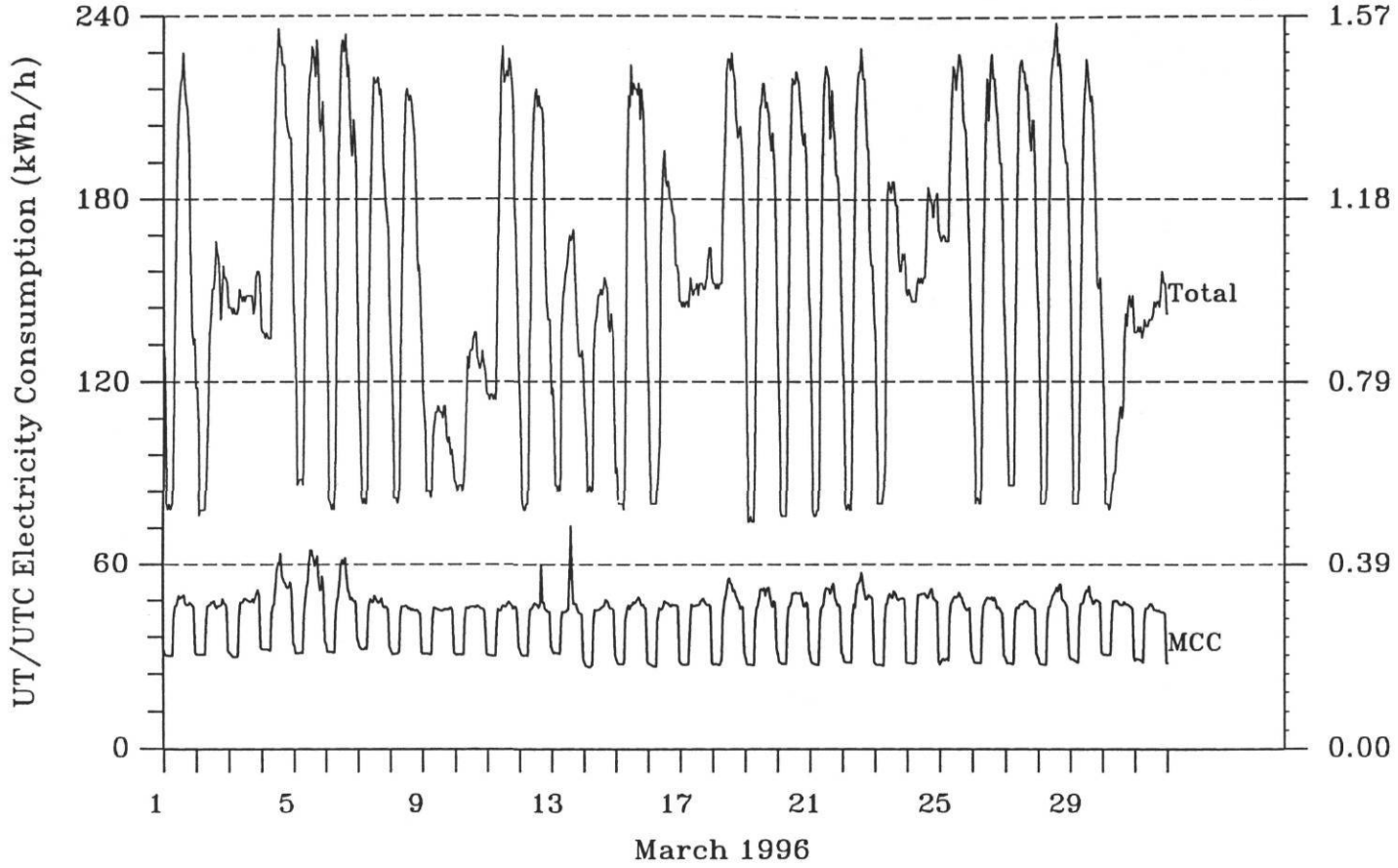
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

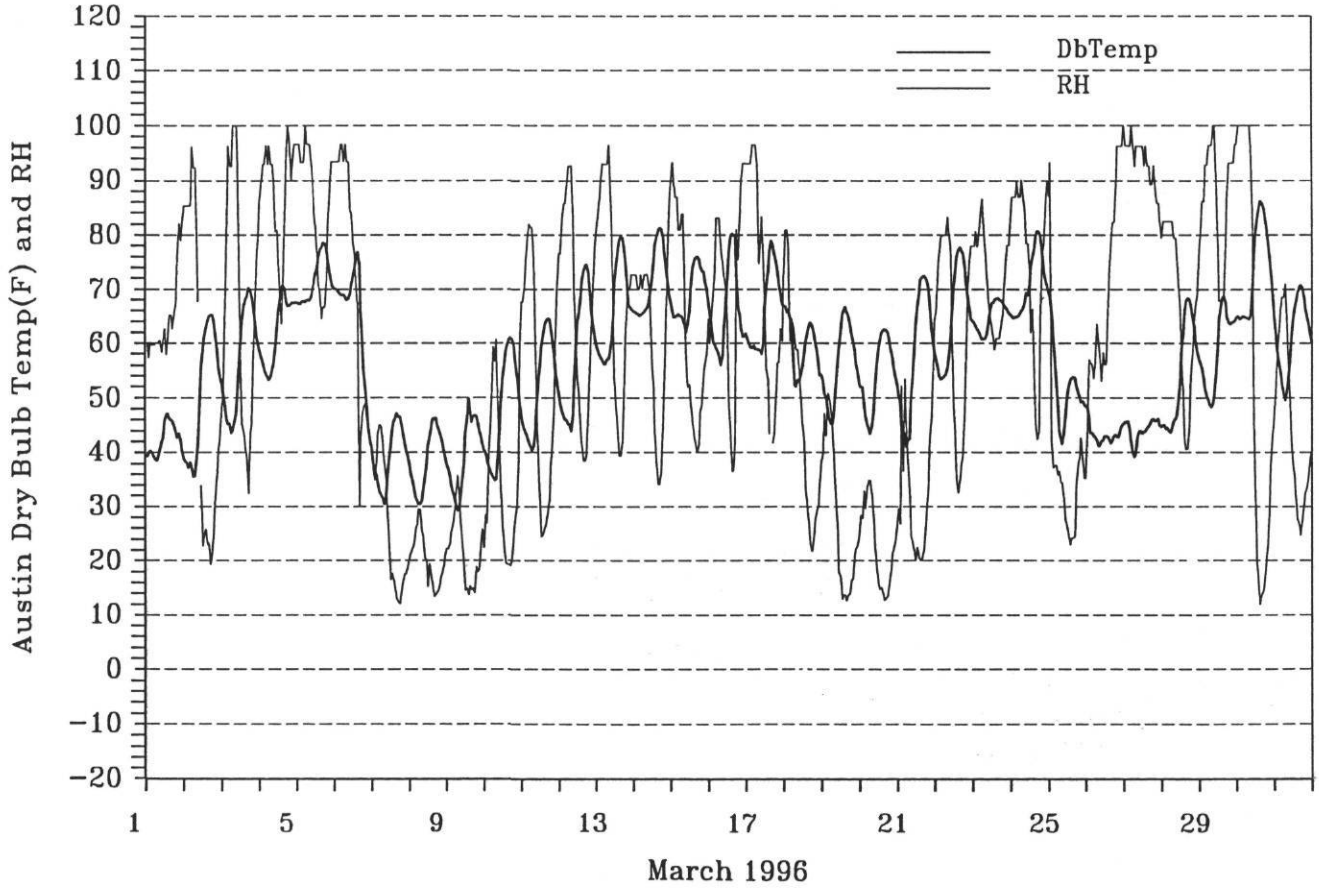
Points from this month last year are shown as +.
All other points are shown as *.

UTC0500 - University Teaching Center - University of Texas - March 1996


UT/UTC Chilled Water Use (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
13.08
9.81
6.54
3.27
0.00
Rtn t/ft2h
1
5
9
13
17
21
25
29
March 1996

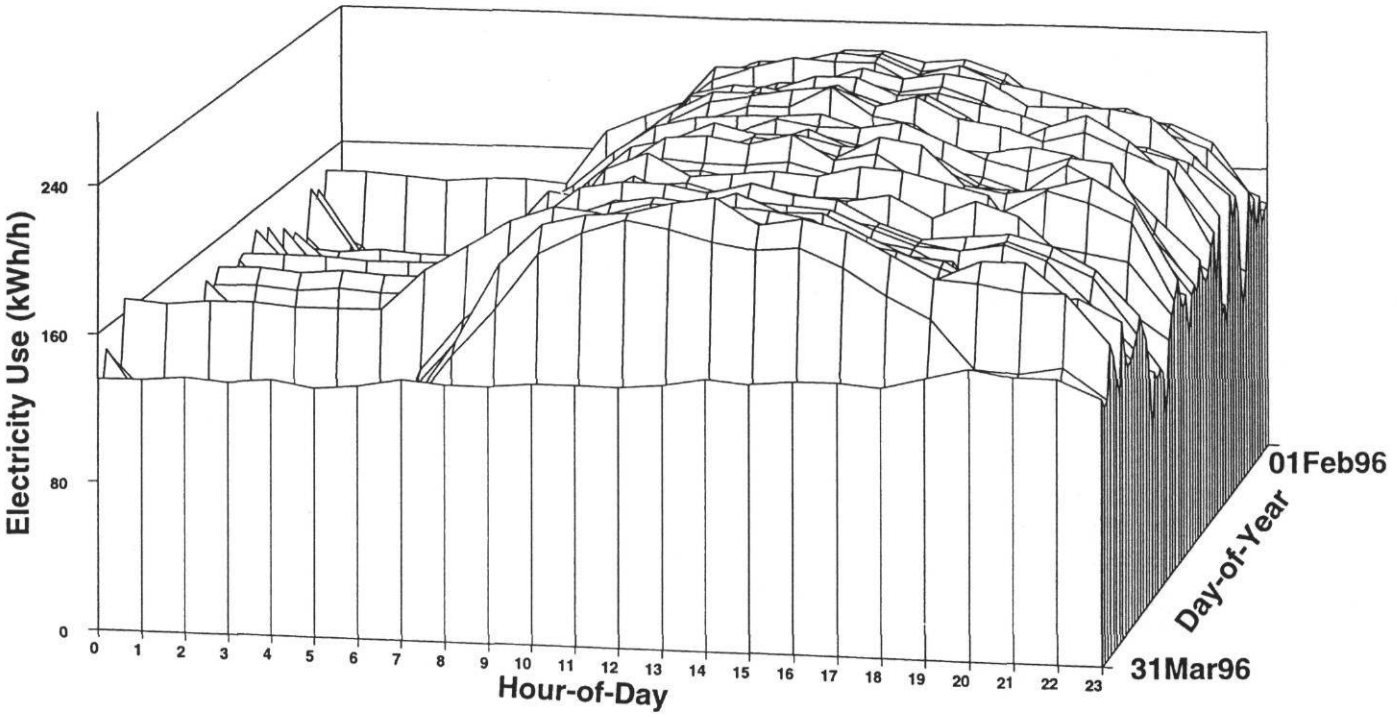

UT/UTC Condensate (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
13.08
9.81
6.54
3.27
0.00
Rtn t/ft2h
1
5
9
13
17
21
25
29
March 1996



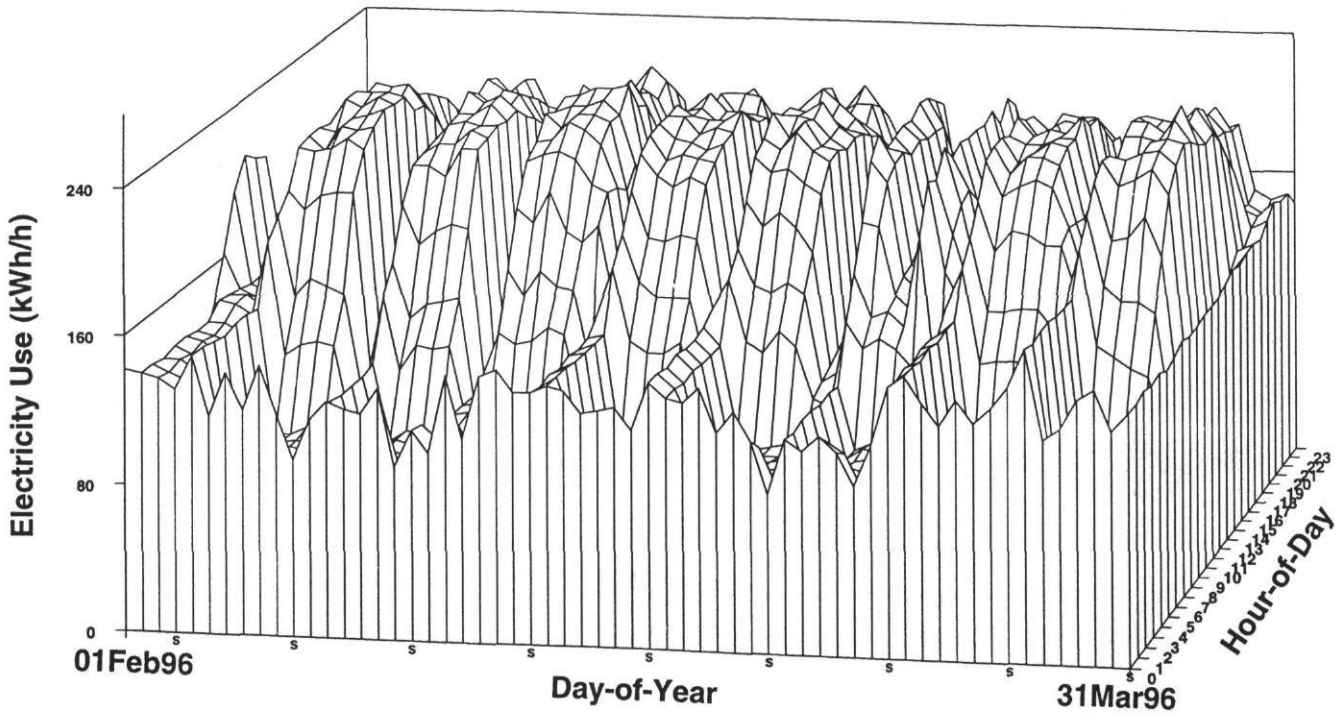


UTC0500 - University Teaching Center - University of Texas - March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

University Teaching Center

Building Envelope:
- 152,690 sq.ft
- 6-story, erected 1984, classrooms
- walls: hollow clay tile with a cut stone exterior
- windows: 9% of total wall area, single pane clear operable
- roof: build-up roof on light weight insulation fill

Building Schedule:
- classrooms: 7 am to 11 pm but the building is open 24 hrs/day.

Building HVAC:
- 8 variable volume dual duct AHUs (2-30hp, 2-20hp, 3-25hp, 1-15hp)
- 8 variable frequency return air fans (5-7.5hp, 2-10hp, 1-5hp)
- 8 variable frquency hot deck fans (2-15hp, 1-10hp, 3-7.5hp, 2-5hp)
- 1 variable volume chilled water pump (50hp)
- 1 constant volume chilled water pump (50 hp)
- Economizer cycle has been added as a part of the retrofit (not operable at this moment)

HVAC Schedule:
- 24 hrs/day, 7 days/wk

Lighting:
- high pressure sodium, fluorescent, and incandescent

Proposed Retrofits:
- 3 position light switch
- variable air volume
- variable speed pumping

Date of Retrofits:
- all retrofits completed by October 1990.

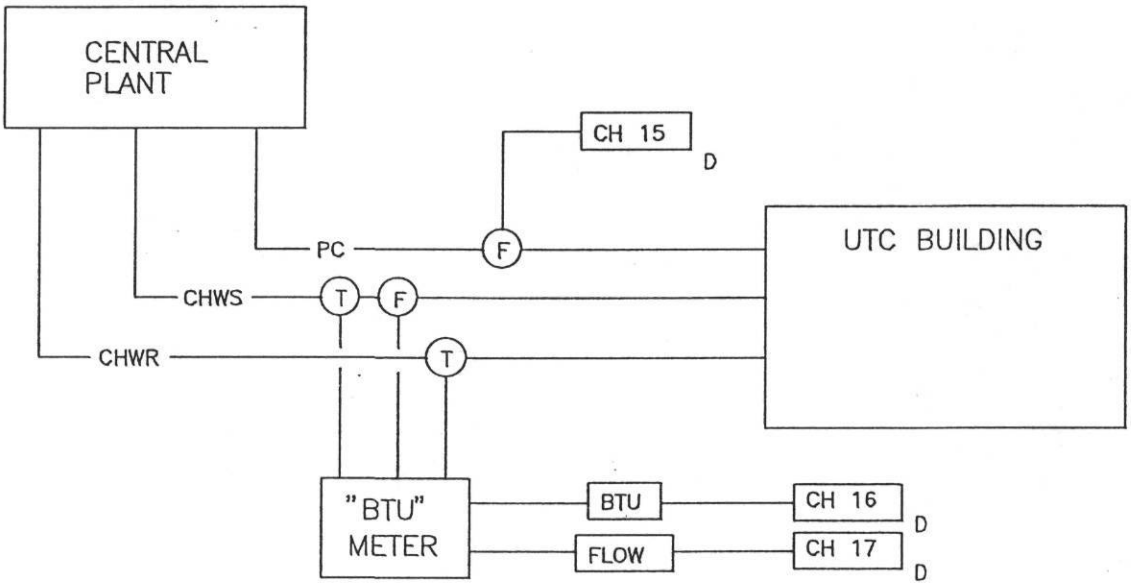
Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – UTC

LEGEND

K=KWH CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

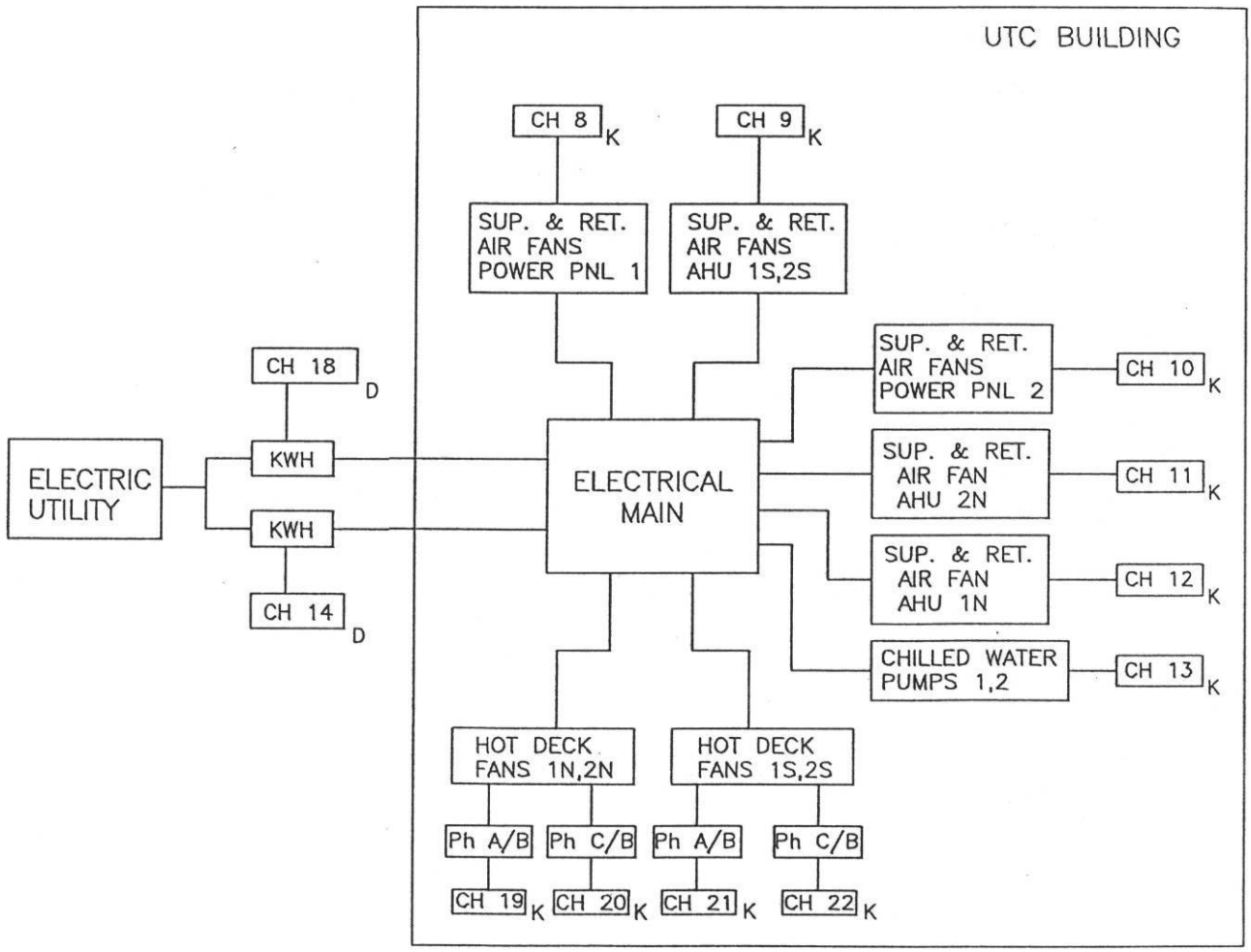


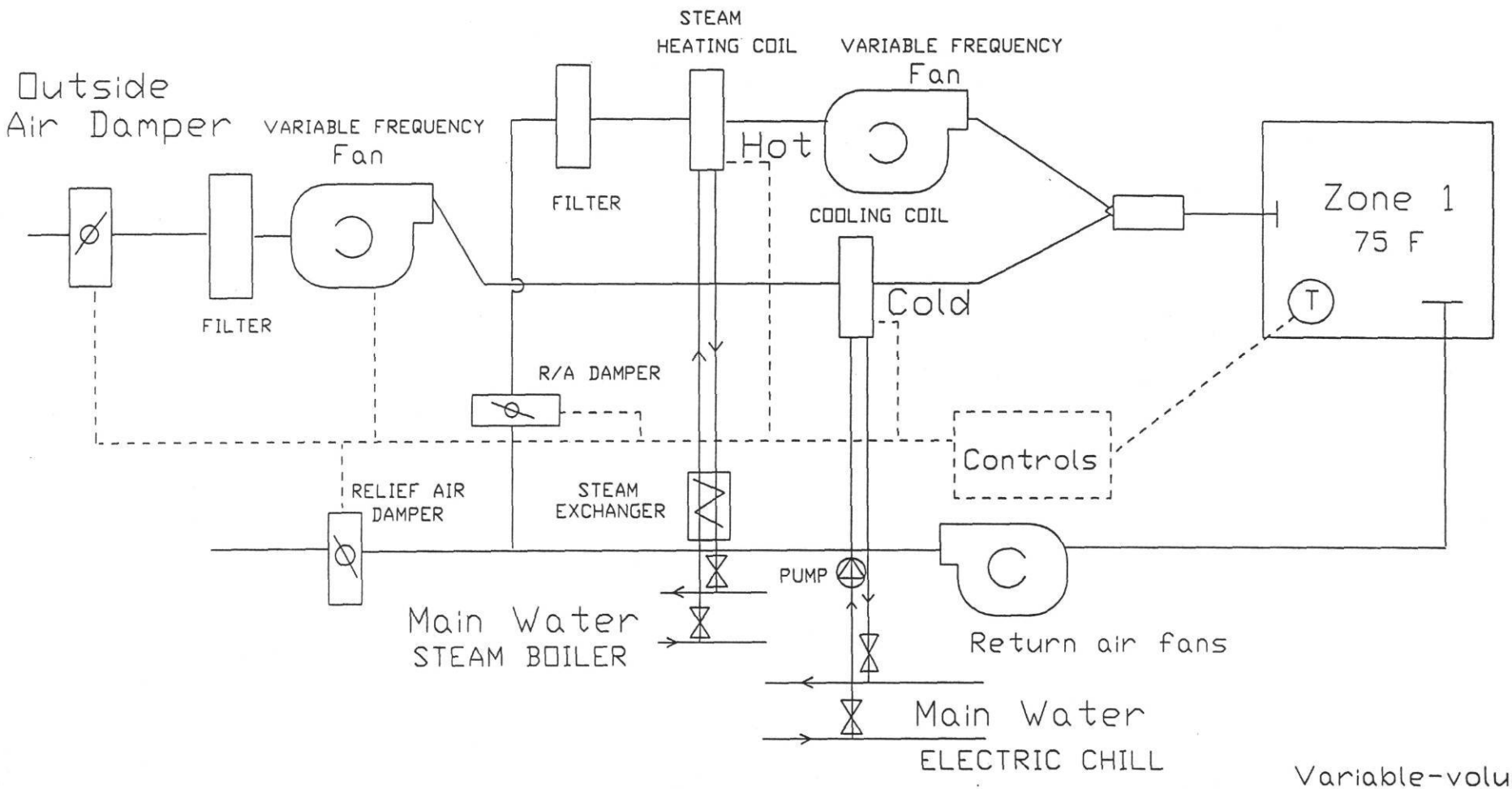
ELECTRICAL MONITORING DIAGRAM

UT AUSTIN – UTC

LEGEND

K=KWH CHANNEL
D=DIGITAL CHANNEL





Variable-volume

Pneumatically controlled thermo.
2 AHU/floor (N & S)

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN-UNIV. TEACHING CEN.	
(DUAL FAN SYSTEM) Typical Dual-Duct System	Date: May 1, 1991
UTC-101	Drawn by: Mark Rivera

PCL0559

Perry Castaneda Library

University of Texas
483,895 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	542222	$24671	100	$15178	1342	$9964	100	$40443	1793	$11117	43	$8585	$64206	$64206
Feb	623828	$28384	100	$13385	1809	$13432	100	$31984	1458	$9040	0	$10272	$55641	$119847
Mar	673222	$30632	100	$14809	2075	$15407	100	$35305	1307	$8103	88	$13853	$63967	$183814
Apr	694810	$31614	99	$14334	2372	$17612	100	$31196	930	$5766	99	$15027	$60557	$244371
May	624426	$28411	99	$15023	2856	$21206	99	$30239	902	$5592	99	$14842	$60104	$304475
Jun	622140	$28307	100	$13961	3613	$26827	100	$24620	882	$5468	100	$11878	$50459	$354934
Jul	623468	$28368	100	$14829	3749	$27836	100	$24169	675	$4185	100	$16142	$55140	$410074
Aug	633726	$28835	100	$14914	3703	$27495	100	$23618	676	$4191	100	$18105	$56637	$466711
Sep	642628	$29240	100	$14369	3184	$23641	100	$25601	658	$4080	100	$18320	$58290	$525001
Oct	684336	$31137	100	$14717	2740	$20345	100	$30431	977	$6057	100	$15694	$60842	$585843
Nov	665614	$30285	99	$14591	1881	$13966	99	$34929	1507	$9343	99	$11123	$60643	$646486
Dec	616968	$28072	100	$14895	1018	$7559	100	$33390	530	$3286	100	$14500	$62785	$709271
Total	7647388	$347956		$175005	30342	$225290		$365925	12295	$76228		$168341		$709271
EUI	15.8	$\frac{kWh}{ft^2yr}$			62703	$\frac{Btu}{ft^2yr}$			25408	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in November 1990.**

★ **The HVAC retrofit was completed in December 1990.**

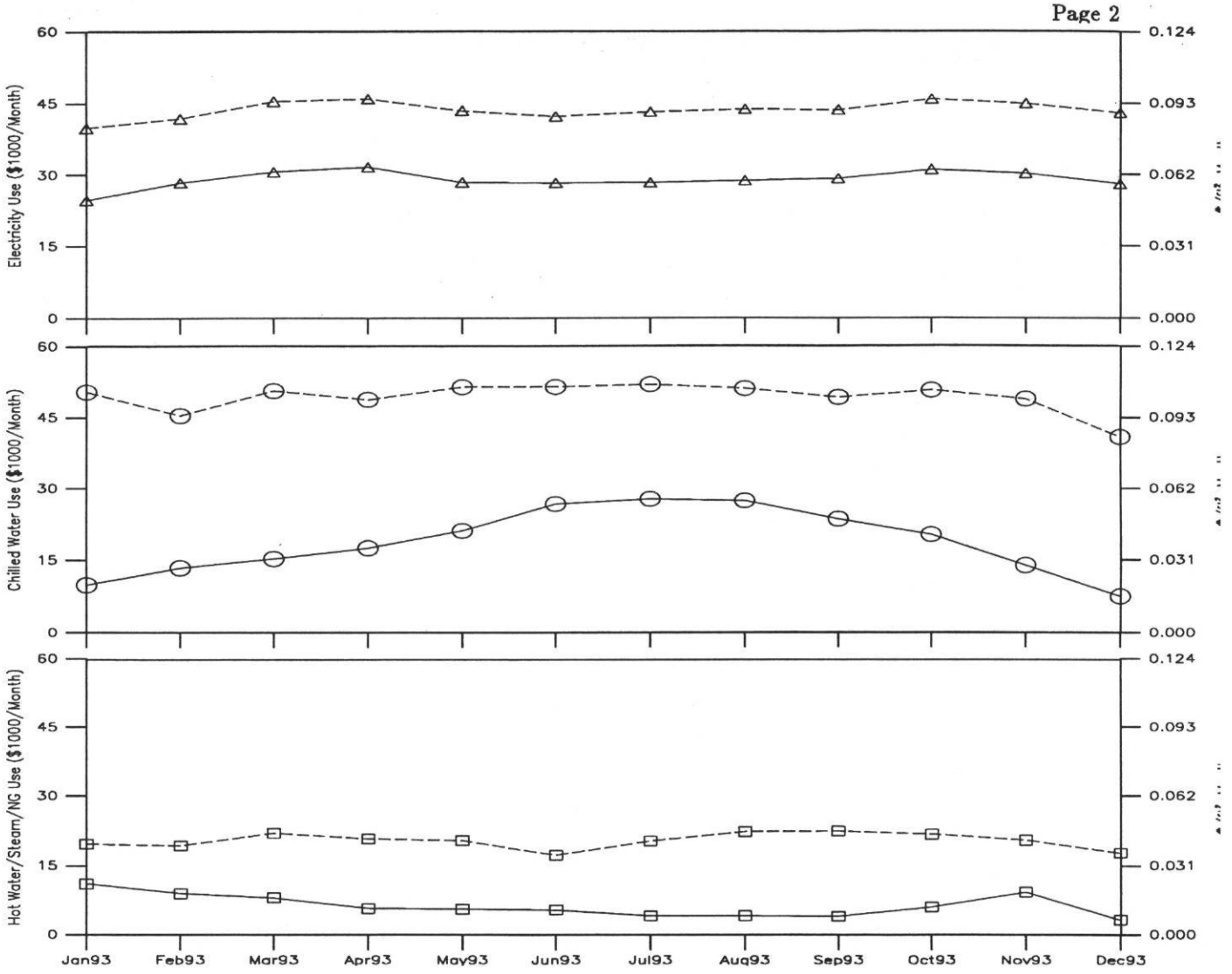
★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

★ **The audit estimated savings for HVAC retrofits are: $69,500 (ELE), $111,100 (CW), $170,300 (Steam), and $350,900 (Total).**

★ **Since the monitoring began after the retrofits were completed, no pre-retrofit monitored data are available. The chilled water and steam savings are based on a simplified calibrated baseline model.**

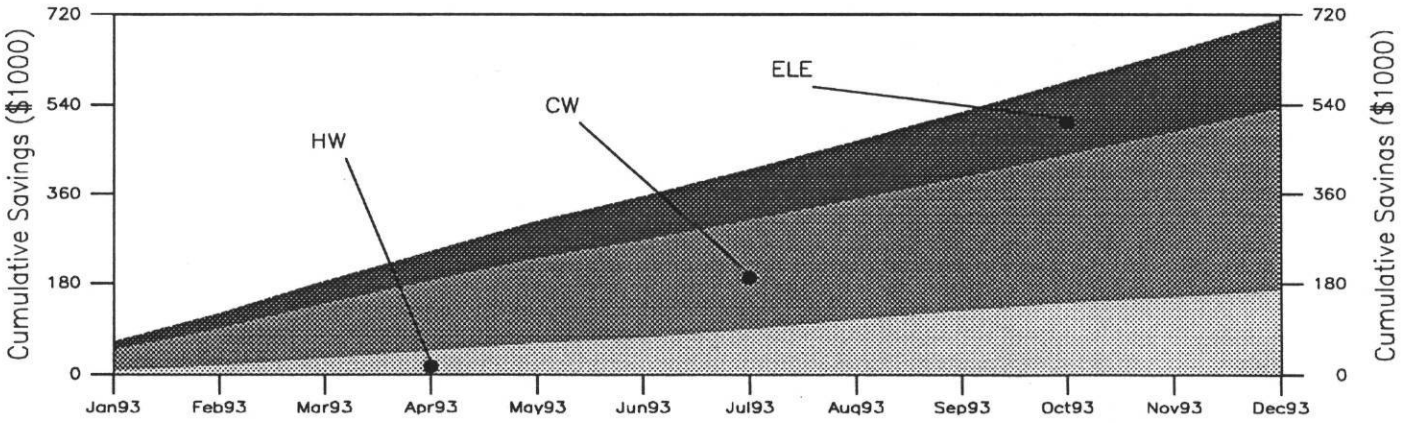
★ **Savings attributable to O&M improvements include: improved lighting schedule (May 1992) $52,900 (not included in the comulative savings), and steam valve shut–off (July 1991) $33,200 (included).**

PCL0559 - Perry Castaneda Library - University of Texas



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



UT AUSTIN

Perry Castaneda Library

Building Envelope:
- 483,895 sq.ft
- 6-story, erected 1977, book shelves, offices, open-stack lib., computer facilities
- walls: limestone panels on concrete block
- windows: 12% of total wall area, single pane tinted glass (setback 3 ft)
- roof: flat built-up roof on light weight insulation fill

Building Schedule:
- 8 am to 12 am (M-F)
- 8 am to 5 pm Saturday
- 12 noon to 10 pm Sunday

Building HVAC:
- 8 variable volume single duct AHUs (8-75hp)
- 4 variable volume dual duct AHUs (4-100hp)
- 12 variable frequency drive return air fans (12-25hp)
- 4 variable frequency drive hot deck fans (4-50hp)
- 2 constant volume chilled water pumps (1-60hp,1-3hp)
- 1 variable volume chilled water pump (60 hp)
- 1 hot water pump (1-3hp)
- economizer cycle has been added as a part of the retrofit

HVAC Schedule:
- 24 hrs/day.

Lighting:
- fluorescent 34-watt.

Retrofits Implemented:
- occupancy sensors
- variable air volume
- variable speed pumping

Date of Retrofits:
- variable air volume : completed December 1990.
- variable speed pumping : completed August 1990.
- occupancy sensors : completed November 1990.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

PCL0559

Perry Castaneda Library

University of Texas
483,895 square feet

Site Contact	LoanSTAR Metering Contact
Mr. Jim Von Wolske	Aamer Athar
University of Texas at Austin	053D WERC
Utilities Department	Texas A&M University
PO Box 7580	College Station, TX 77843-3123
Austin, TX 78713	(409)–845–9213
(512)–471–1010	

Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	629186 kWh	100	$0.04550	$28628
Peak 60 Minute Demand	1162 kW	100	-	-
Chilled Water	956.3 MMBtu	52	$7.425	$7101
Condensate	2117.3 MMBtu	100	$6.200	$13127

Peak 60 minute demand was recorded at 1500 Monday 03/04/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	303246	$13798	127358	$5795
Chilled Water (MMBtu)	4166	$30933	1247	$9259
Cond./H.W./N.G. (MMBtu)	1761	$10918	2289	$14192
Monthly Total		$55648		$29246
Total to Date*	(65 months)	$3740418	(65 months)	$1900962

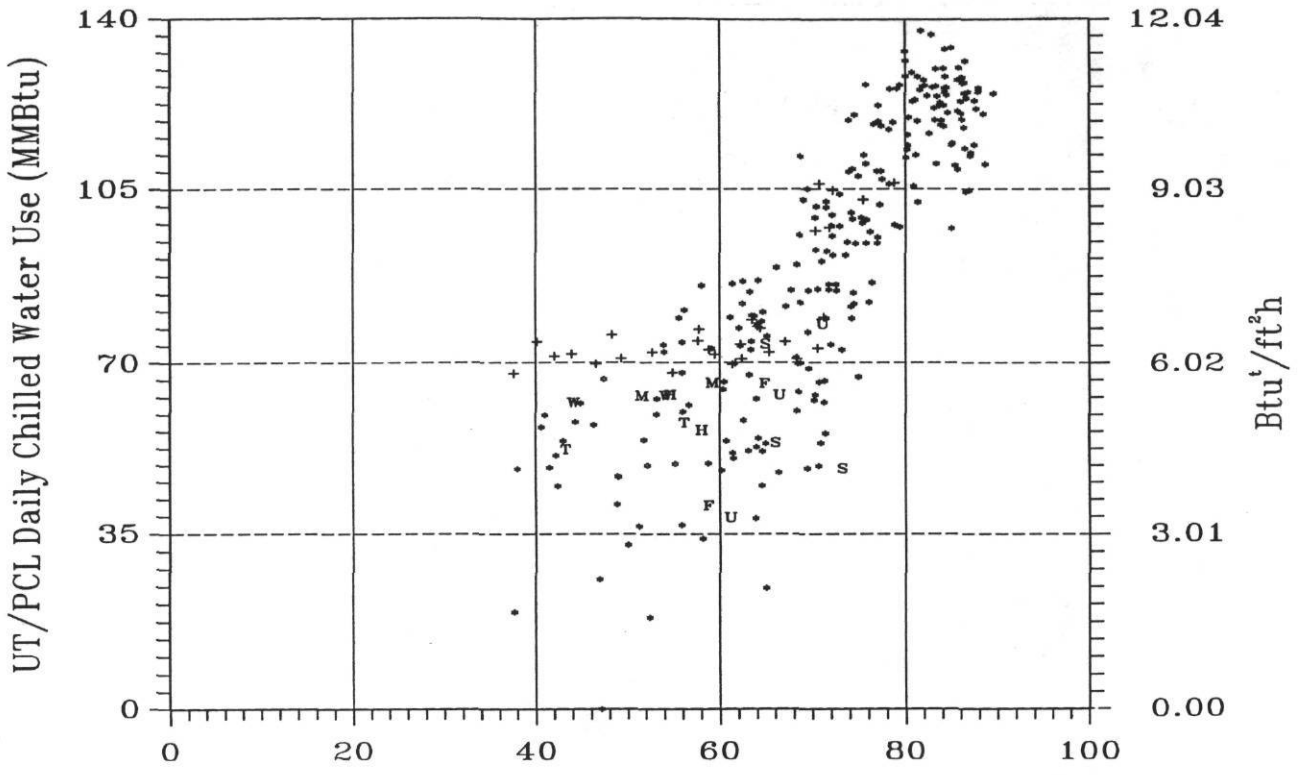
*Measured savings include construction period. Audit estimated savings do not.

Comments

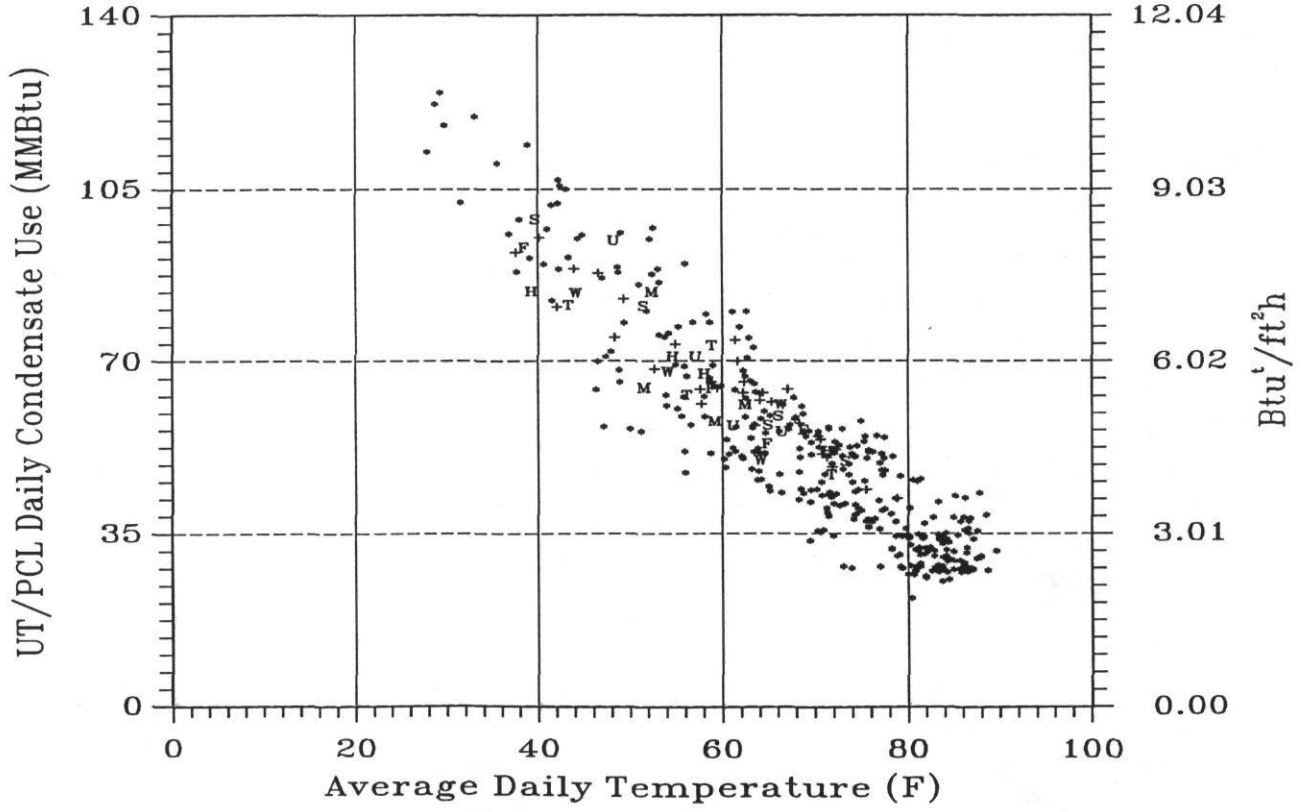
★ Chilled water energy consumption has decreased when compared to March 1995.

★ Chilled water energy use data are missing from 3/1/96 to 3/16/96 due to a monitoring hardware problem.

Mar 01 1995 – Mar 31 1996

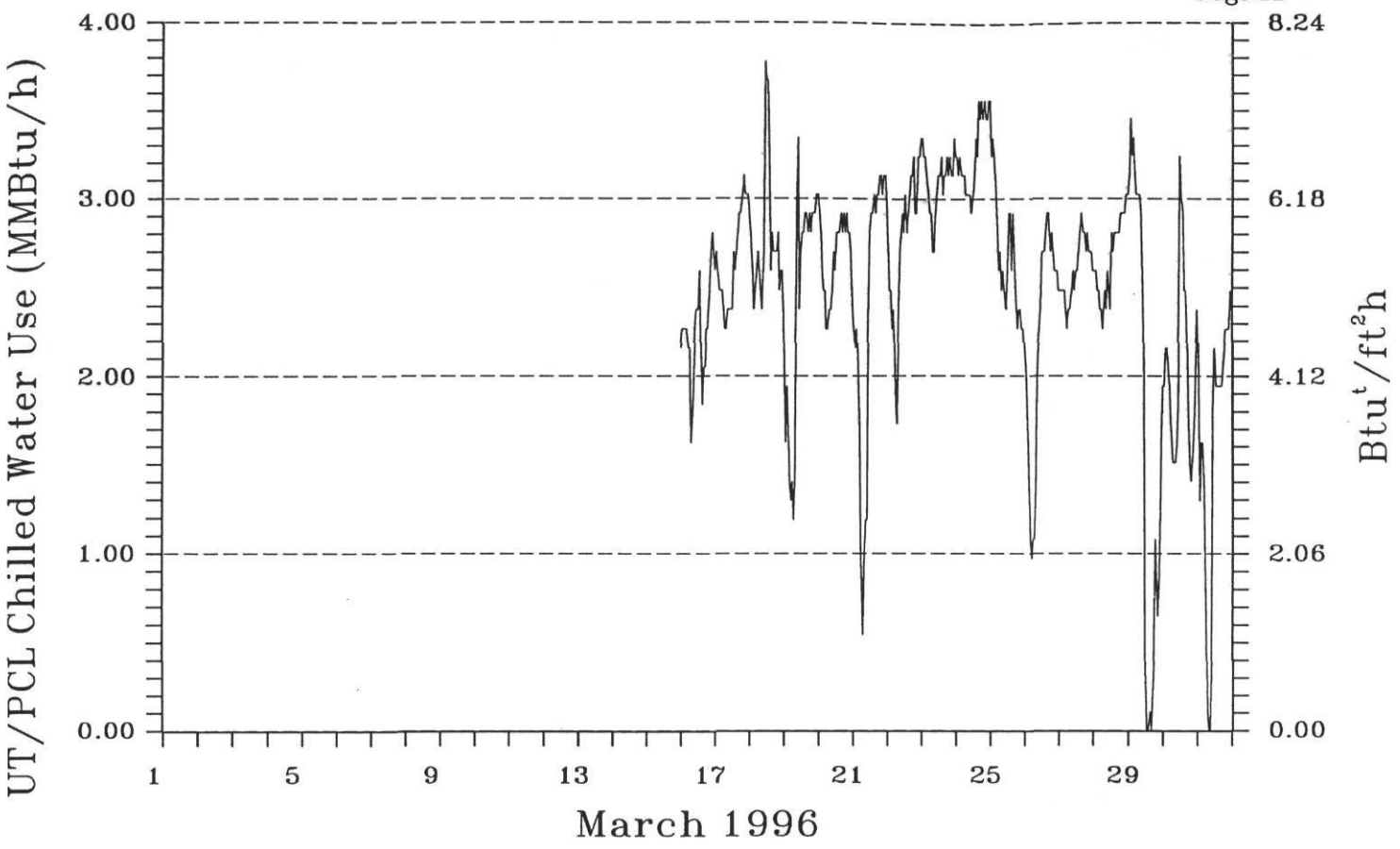


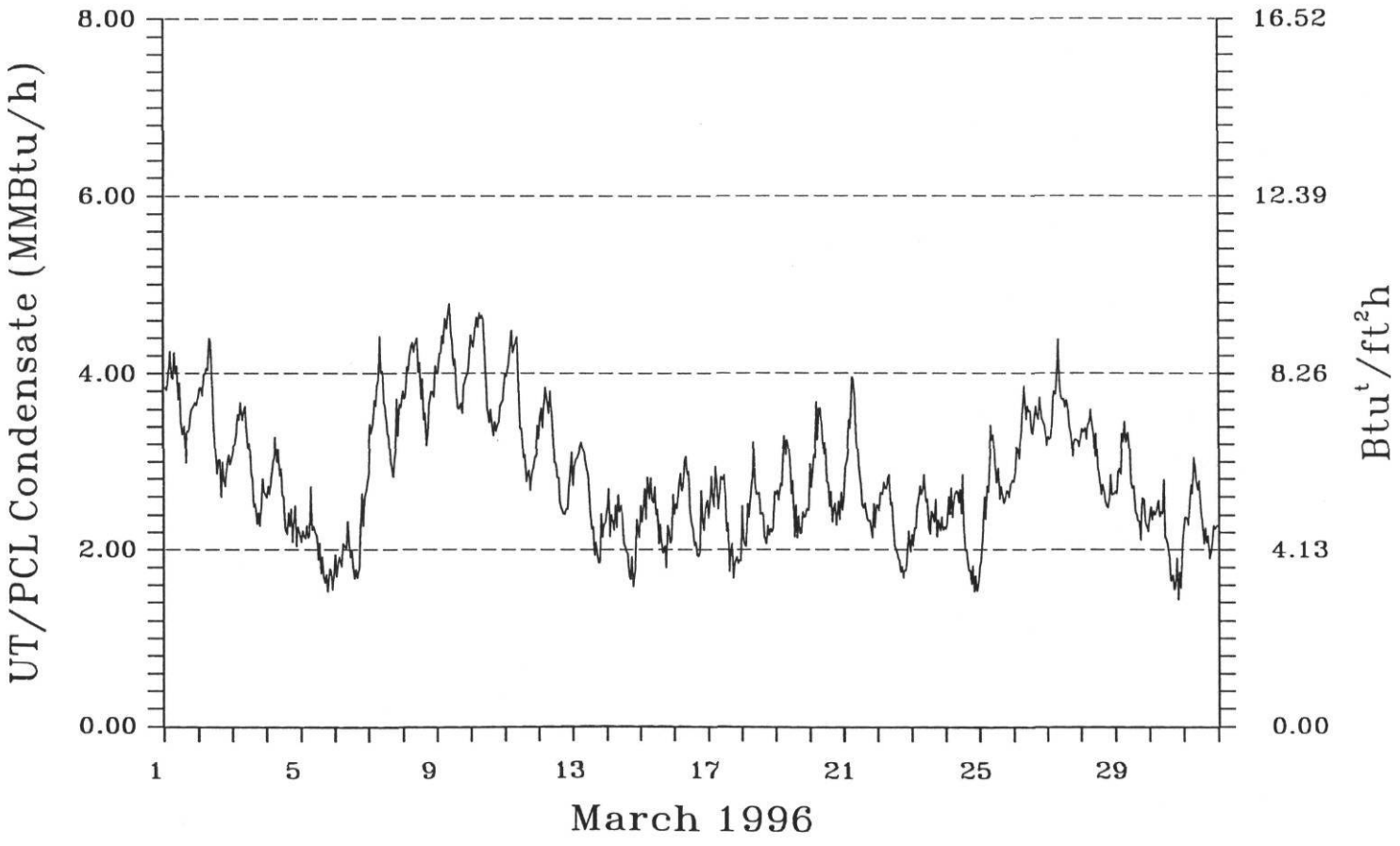
Mar 01 1995 – Mar 31 1996

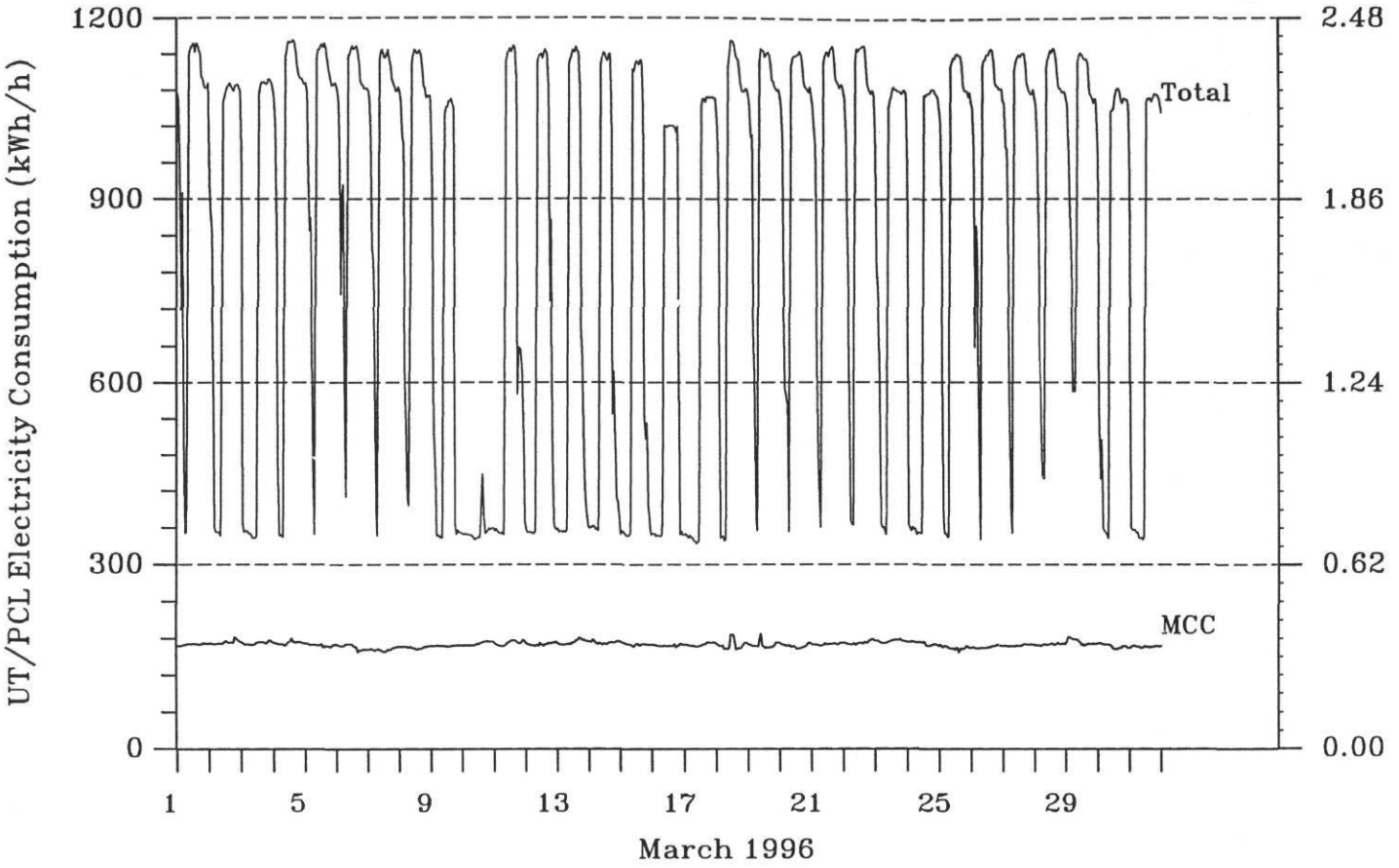


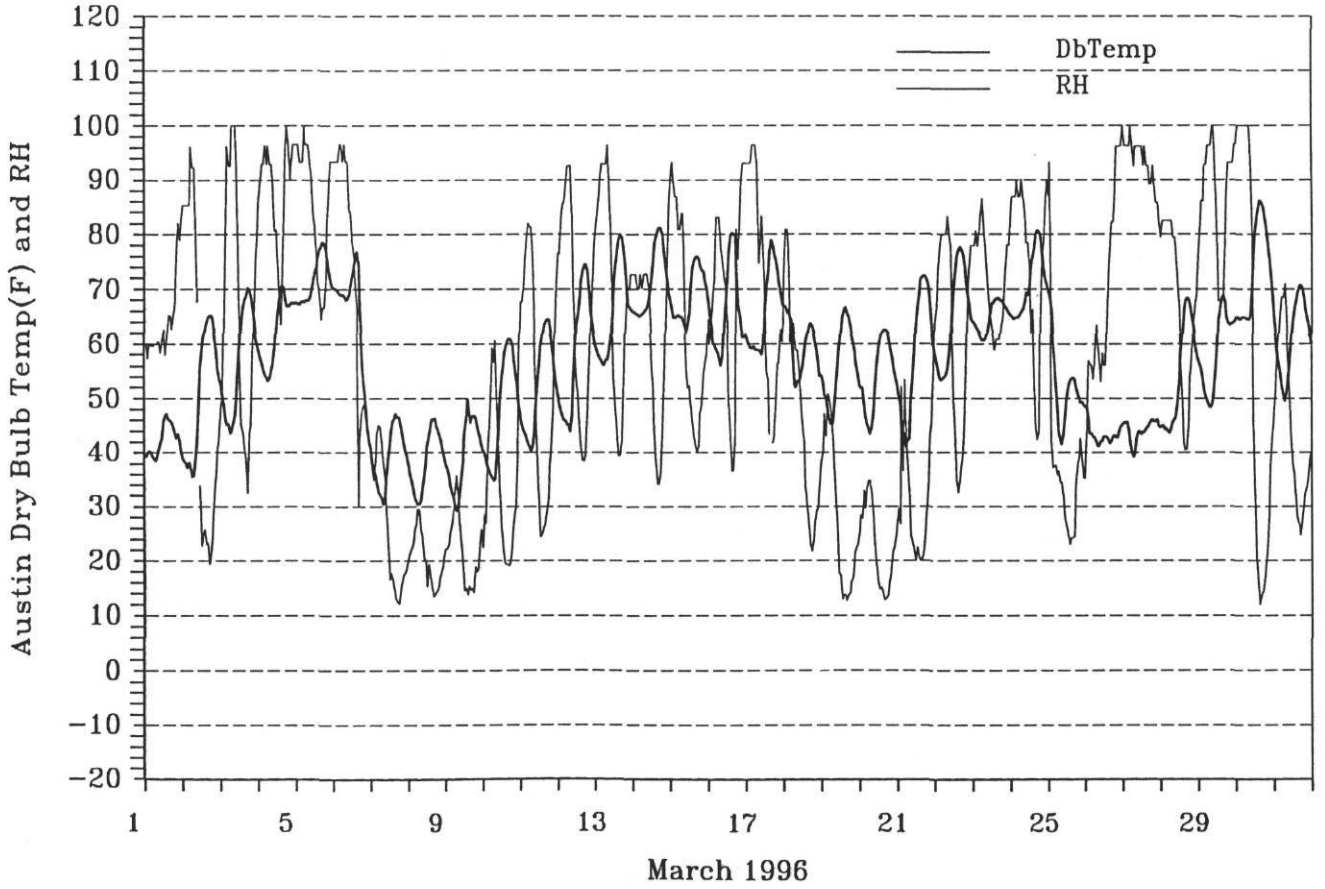
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

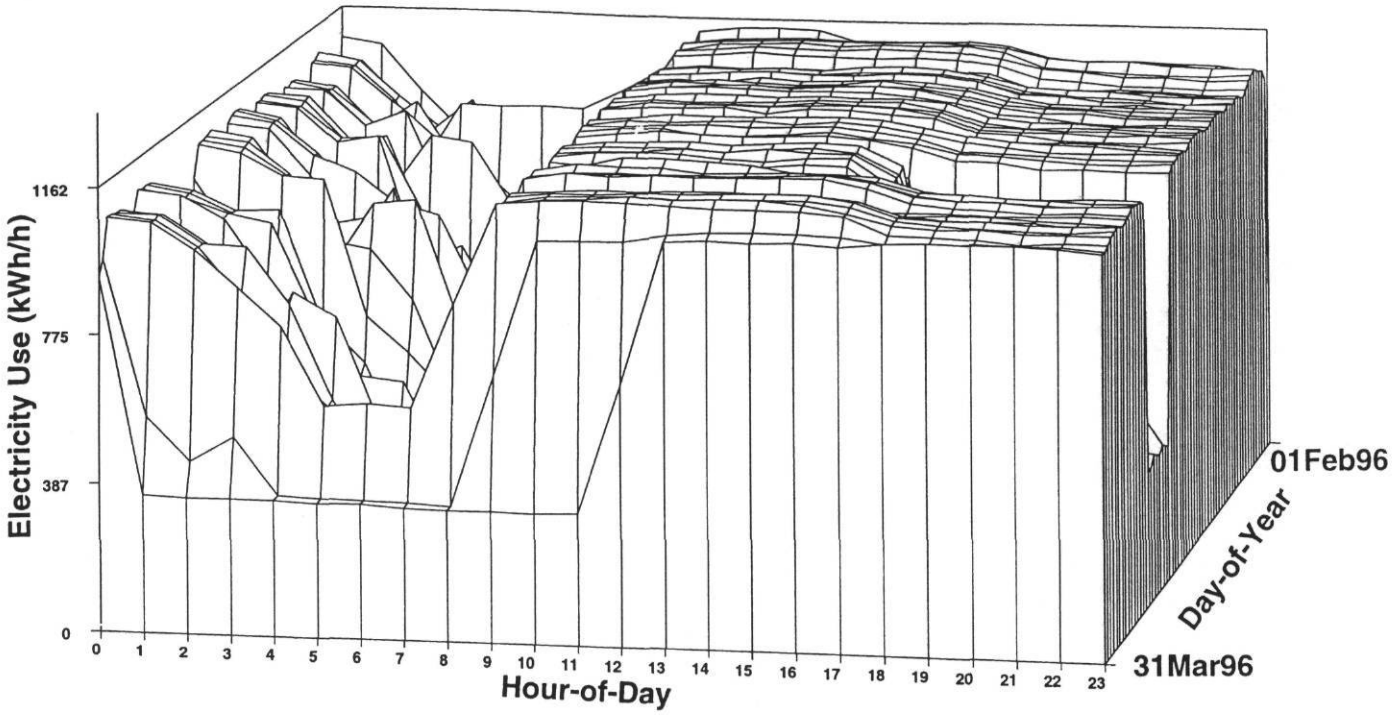

UT/PCL Chilled Water Use (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
8.24
6.18
4.12
2.06
0.00
Btu^t/ft^2h
1
5
9
13
17
21
25
29
March 1996


UT/PCL Condensate (MMBtu/h)
8.00
6.00
4.00
2.00
0.00
16.52
12.39
8.26
4.13
0.00
Btu^t/ft^2h
1
5
9
13
17
21
25
29
March 1996

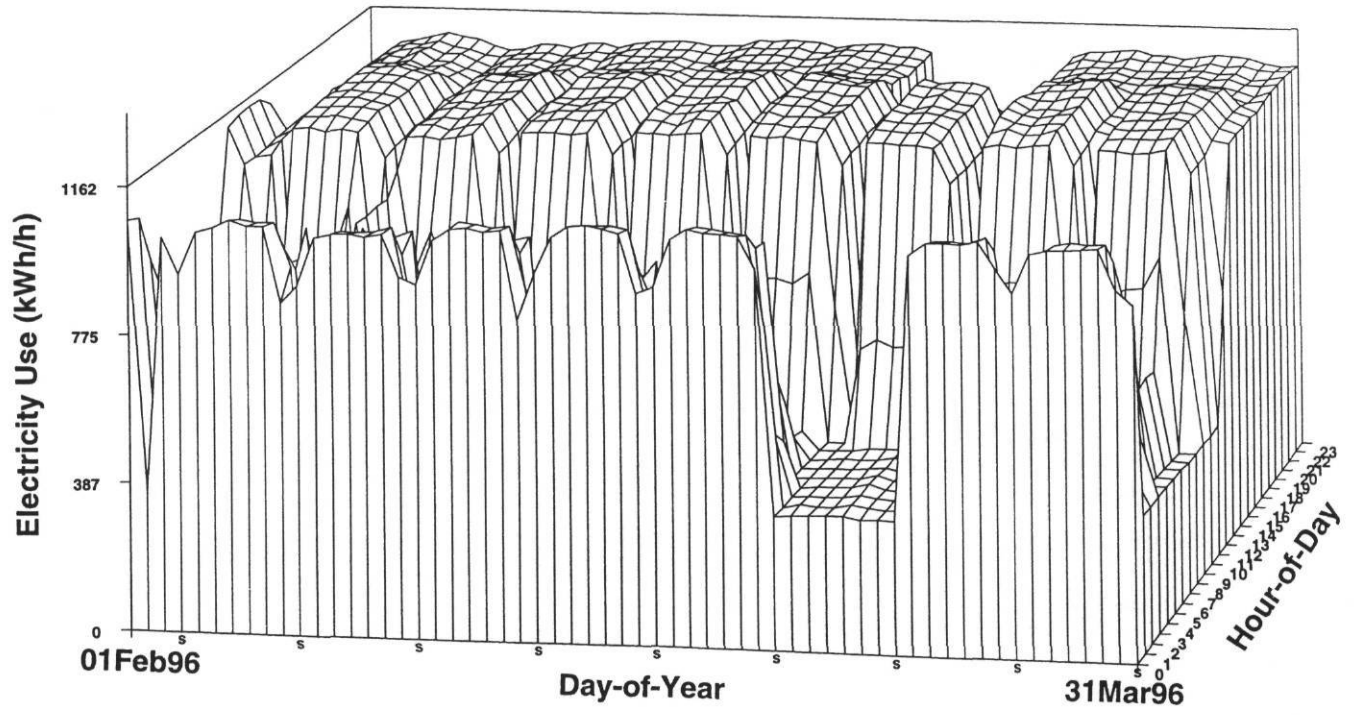

UT/PCL Electricity Consumption (kWh/h)
1200
900
600
300
0
2.48
1.86
1.24
0.62
0.00
Total
MCC
1
5
9
13
17
21
25
29
March 1996


Austin Dry Bulb Temp(F) and RH
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
DbTemp
RH
1
5
9
13
17
21
25
29
March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

Perry Castaneda Library

Building Envelope:
- 483,895 sq.ft
- 6-story, erected 1977, book shelves, offices, open-stack lib., computer facilities
- walls: limestone panels on concrete block
- windows: 12% of total wall area, single pane tinted glass (setback 3 ft)
- roof: flat built-up roof on light weight insulation fill

Building Schedule:
- 8 am to 12 am (M-F)
- 8 am to 5 pm Saturday
- 12 noon to 10 pm Sunday

Building HVAC:
- 8 variable volume single duct AHUs (8-75hp)
- 4 variable volume dual duct AHUs (4-100hp)
- 12 variable frequency drive return air fans (12-25hp)
- 4 variable frequency drive hot deck fans (4-50hp)
- 2 constant volume chilled water pumps (1-60hp,1-3hp)
- 1 variable volume chilled water pump (60 hp)
- 1 hot water pump (1-3hp)
- economizer cycle has been added as a part of the retrofit

HVAC Schedule:
- 24 hrs/day.

Lighting:
- fluorescent 34-watt.

Retrofits Implemented:
- occupancy sensors
- variable air volume
- variable speed pumping

Date of Retrofits:
- variable air volume : completed November 1990.
- variable speed pumping : completed August 1990.
- occupancy sensors : completed November 1990.

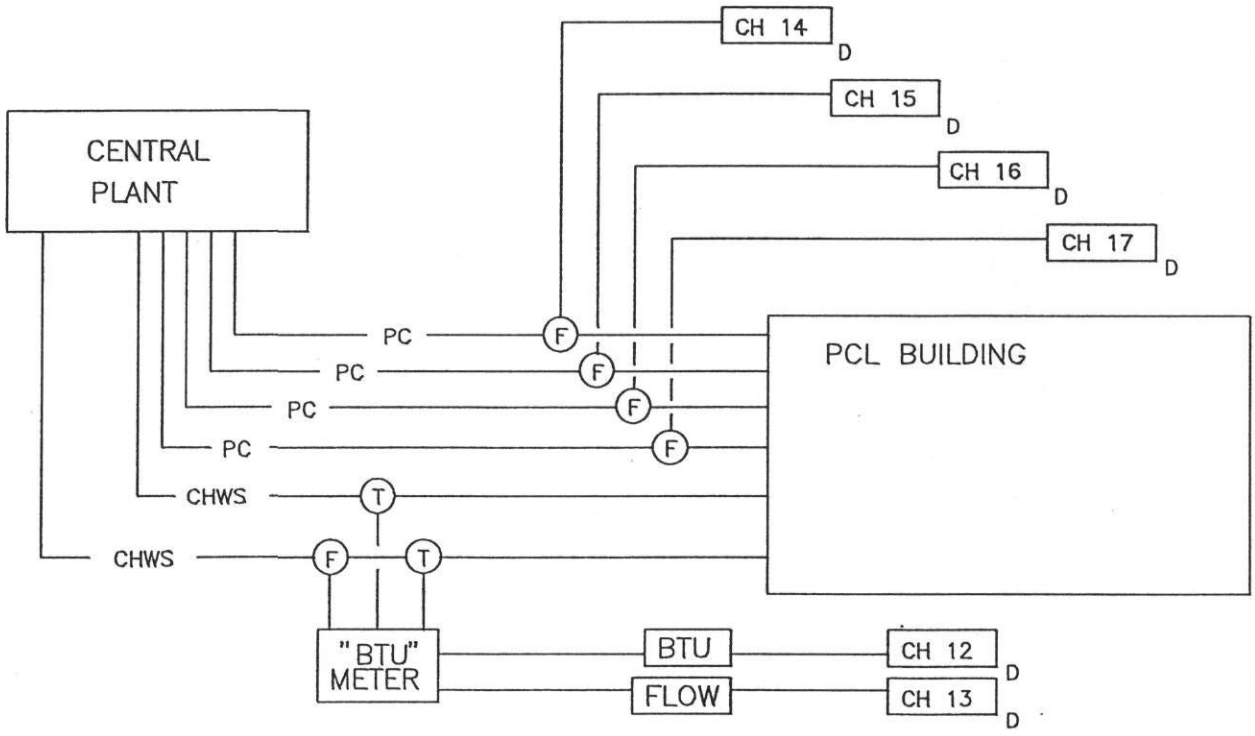
Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – PCL

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



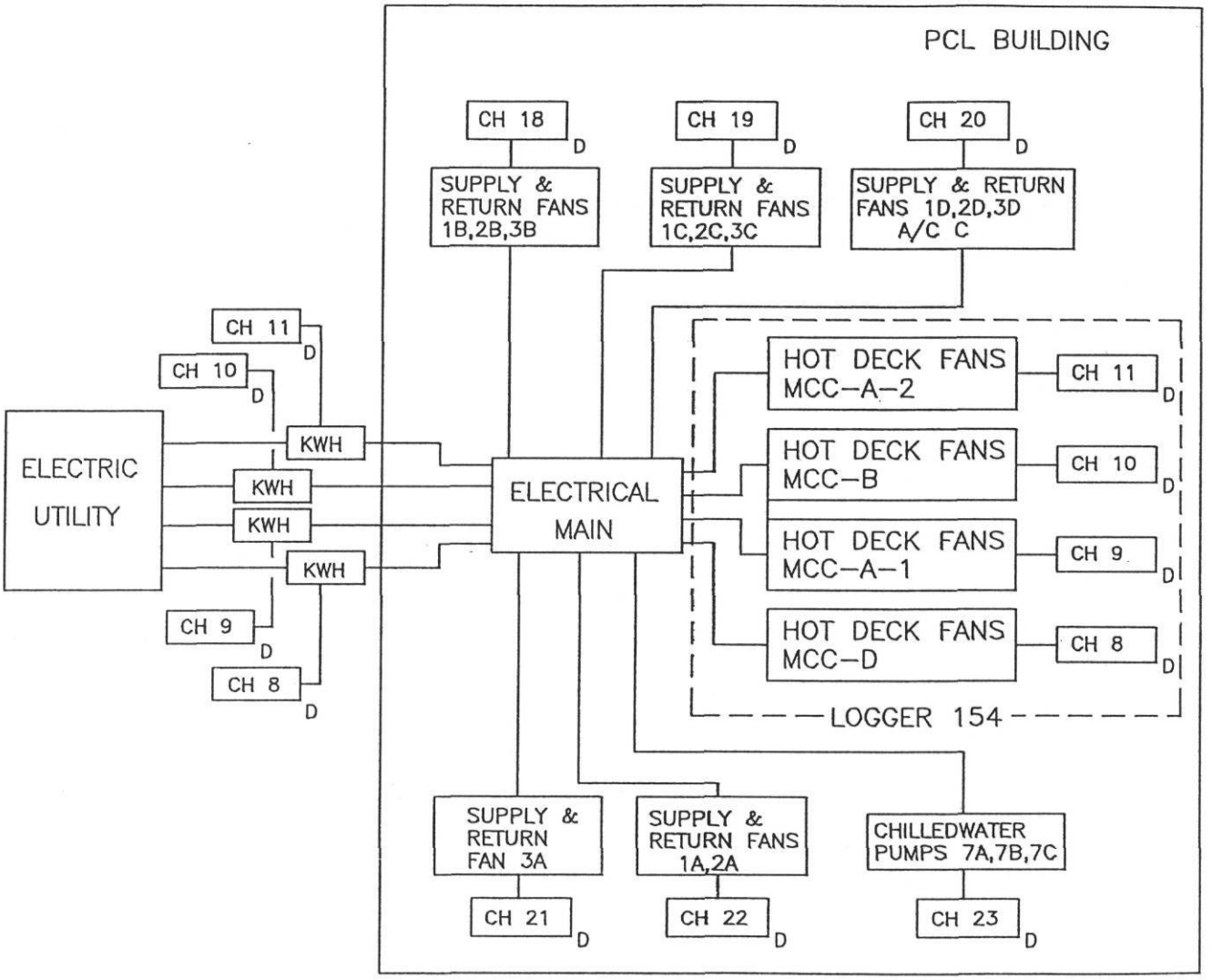
UT AUSTIN/PCL – SITE 102

ELECTRICAL MONITORING DIAGRAM

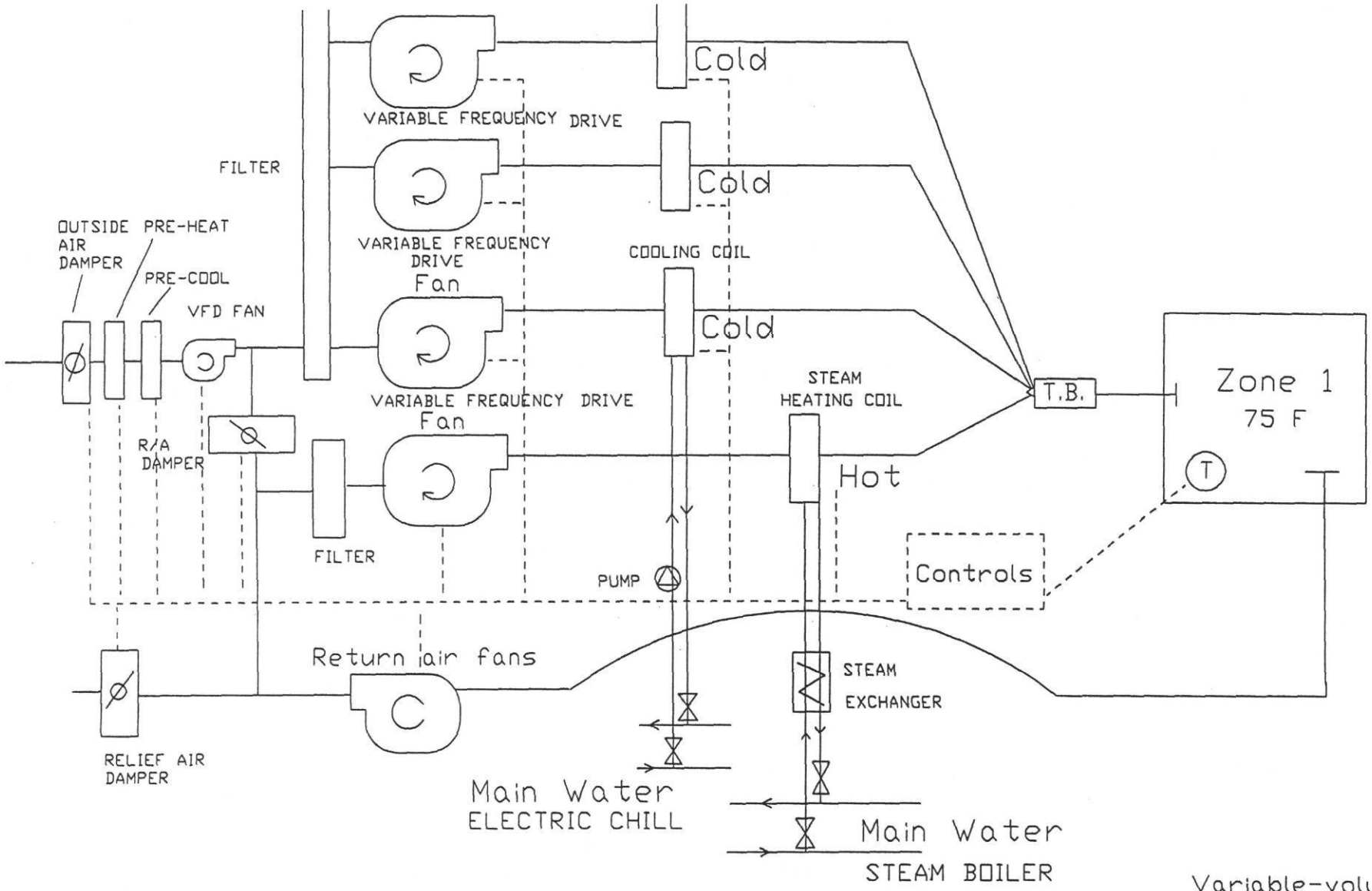
UT AUSTIN – PCL

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



UT AUSTIN/PCL – SITE 102



* Four of these configurations
W, NW, NE, S suppling the building
all 75 HP except for 3A(W) & 3B(NW) 100 HP
All R/A fans 25 HP
All Hot Deck fans 40 HP except
for South 50 HP

Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- PERRY CASTENDEDA	
Typical Dual-Duct System	Date: May 1, 1991
PCL-102	Drawn by: Mark Rivera

WAG0649

Waggener Hall

University of Texas
57,598 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	76556	$3483	100	$914	157	$1166	100	$807	336	$2083	100	$238	$1959	$1959
Feb	77593	$3530	100	$829	179	$1329	100	$751	198	$1228	100	$600	$2180	$4139
Mar	79248	$3606	100	$1145	225	$1671	100	$1124	90	$558	100	$1053	$3322	$7461
Apr	83216	$3786	99	$1009	314	$2331	99	$901	16	$99	99	$1054	$2964	$10425
May	83978	$3821	100	$919	401	$2977	100	$966	3	$19	100	$746	$2631	$13056
Jun	81177	$3694	100	$865	474	$3519	100	$1300	0	$0	100	$214	$2379	$15435
Jul	90397	$4113	100	$770	583	$4329	100	$1348	0	$0	100	$59	$2177	$17612
Aug	92837	$4224	100	$699	608	$4514	100	$1530	0	$0	100	$23	$2252	$19864
Sep	90743	$4129	100	$781	475	$3527	99	$1548	0	$0	100	$234	$2563	$22427
Oct	96826	$4406	100	$767	294	$2183	100	$1771	21	$130	100	$749	$3287	$25714
Nov	99338	$4520	100	$708	168	$1247	100	$1073	160	$992	100	$899	$2680	$28394
Dec	94346	$4293	100	$716	181	$1344	100	$1056	263	$1631	100	$330	$2102	$30496
Total	1046255	$47605		$10122	4059	$30137		$14175	1087	$6740		$6199		$30496
EUI	18.2	$\frac{kWh}{ft^2yr}$			70471	$\frac{Btu}{ft^2yr}$			18872	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

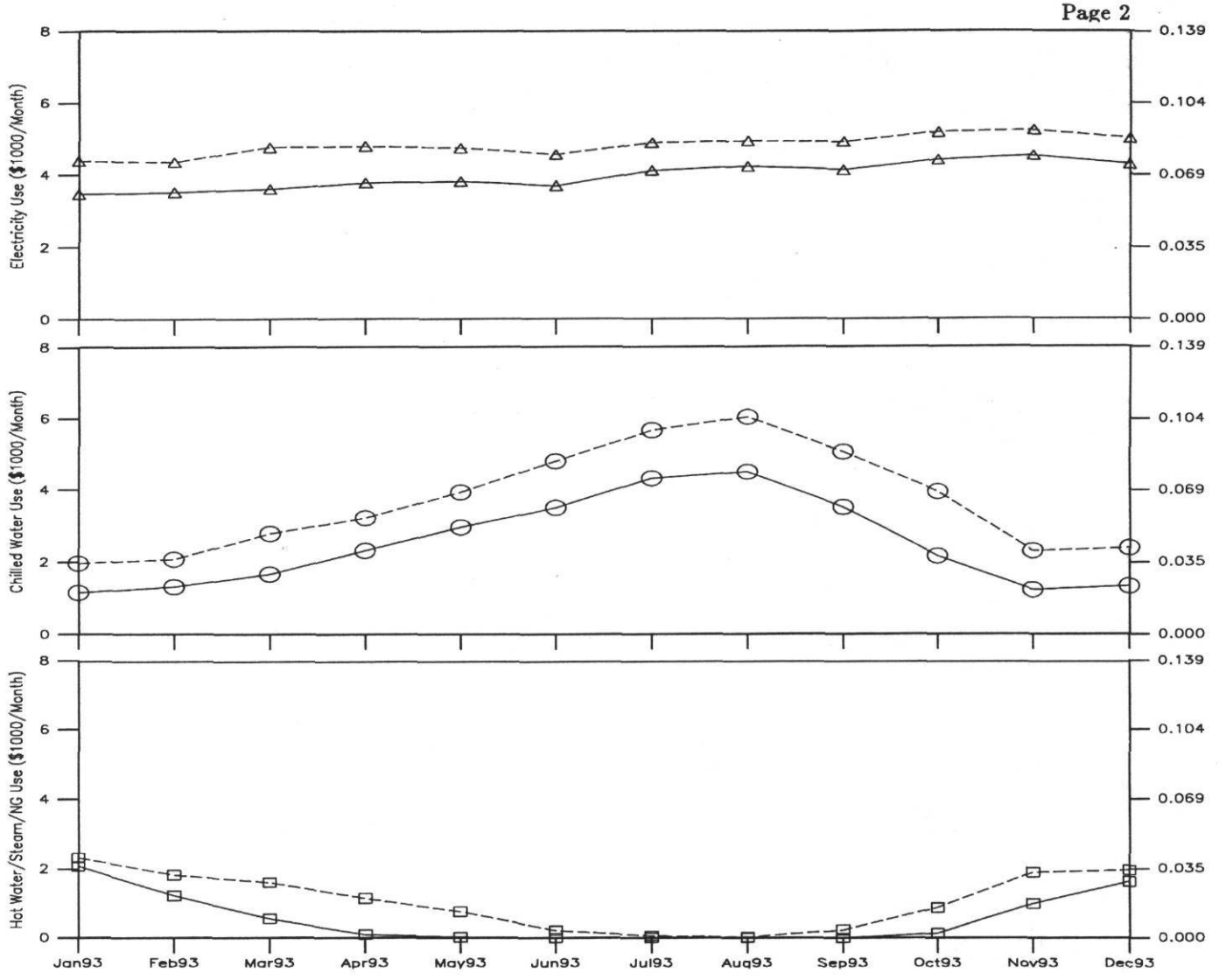
★ **The LoanSTAR monitoring began in November 1990.**

★ **The HVAC retrofit was completed in May 1991.**

★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

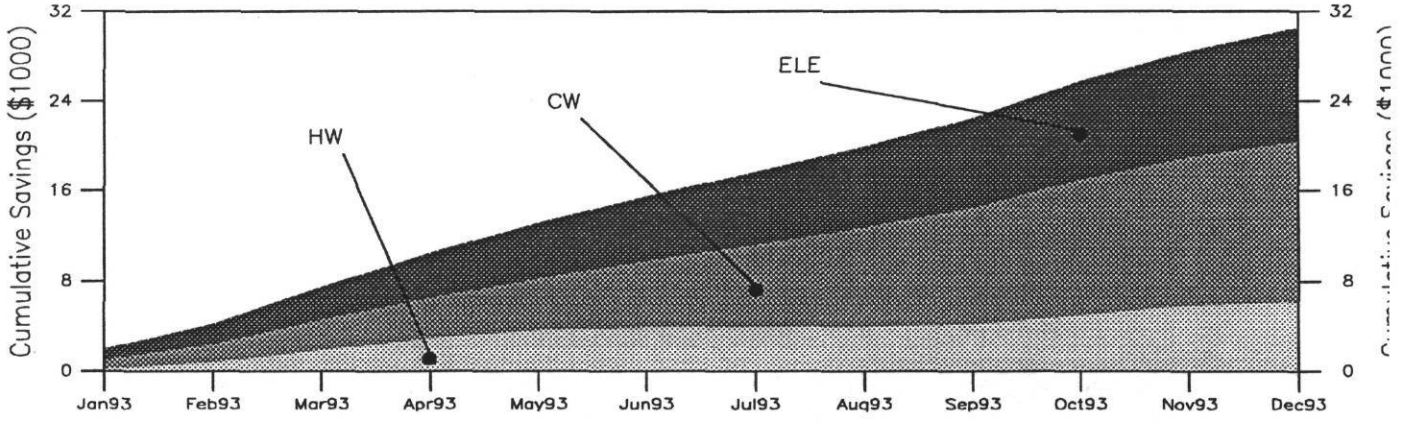
★ **The audit estimated savings for HVAC retrofits are: $20,100 (ELE), $10,300 (CW), $5,900 (Steam) and $36,300 (Total).**

★ **Steam valves were shut between June and September; therefore, there were very small steam savings during these months.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



WAG0649 - Waggener Hall - University of Texas

UT AUSTIN

Waggener Hall

Building Envelope:
- 57,598 sq.ft
- 5-story, erected 1931, classes, offices, and lab
- walls: hollow clay tile with a cut stone exterior
- windows: 22% of total wall area, single pane clear operable
- roof: pitched and constructed of clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- labs: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 2 variable volume dual duct AHUs (2-40hp)
- 1 constant volume hot water pump (1-2hp)
- 1 constant volume chilled water pump (1-5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- variable air volume

Date of Retrofits:
- retrofit completion date: May 1991.

Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

WAG0649

Waggener Hall

University of Texas
57,598 square feet

Site Contact	LoanSTAR Metering Contact
Mr. Jim Von Wolske	Aamer Athar
University of Texas at Austin	053D WERC
Utilities Department	Texas A&M University
PO Box 7580	College Station, TX 77843-3123
Austin, TX 78713	(409)–845–9213
(512)–471–1010	

Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	96854 kWh	100	$0.04550	$4407
Peak 60 Minute Demand	218 kW	100	-	-
Chilled Water	193.6 MMBtu	100	$7.425	$1437
Condensate	107.8 MMBtu	100	$6.200	$668

Peak 60 minute demand was recorded at 1500 Thursday 03/28/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	21954	$999	36843	$1676
Chilled Water (MMBtu)	137	$1017	116	$861
Cond./H.W./N.G. (MMBtu)	199	$1234	80	$496
Monthly Total		$3250		$3034
Total to Date*	(59 months)	$129055	(58 months)	$175952

*Measured savings include construction period. Audit estimated savings do not.

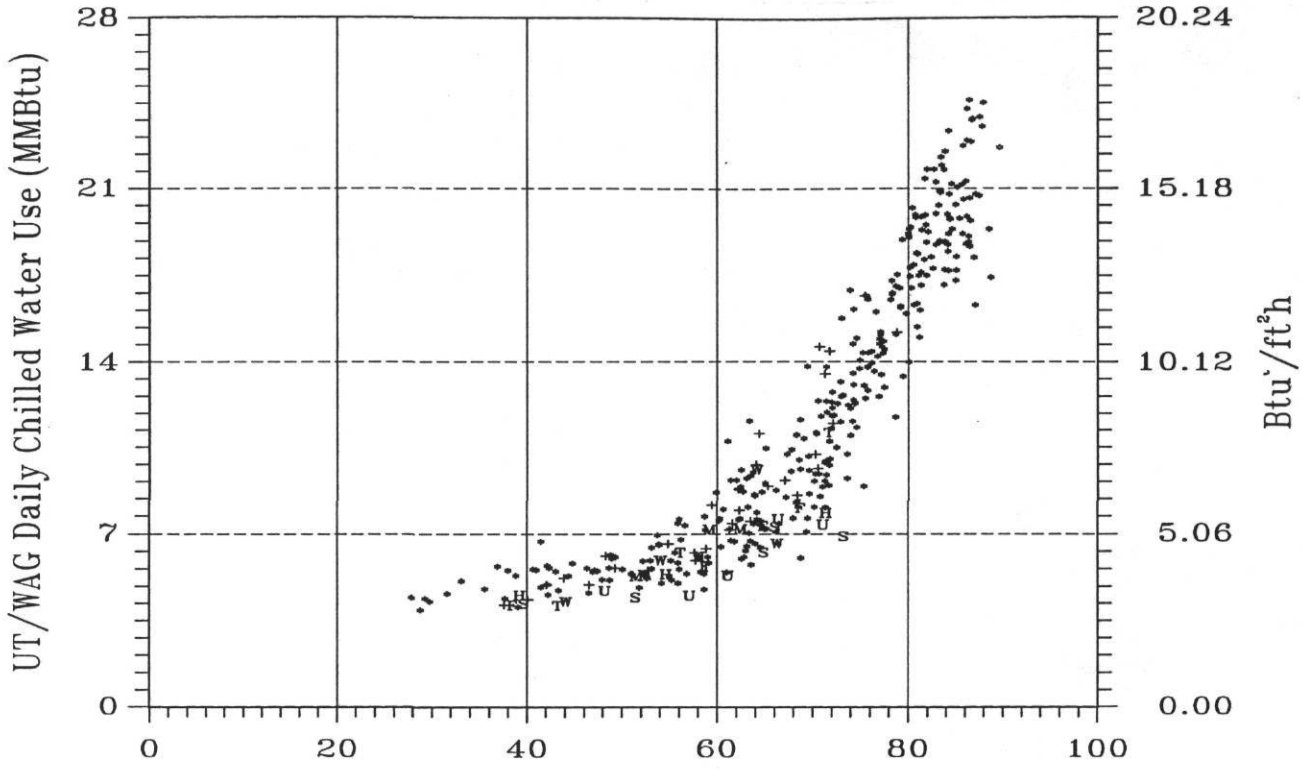
Comments

★ Steam energy consumption decreased significantly when compared to March 1995.

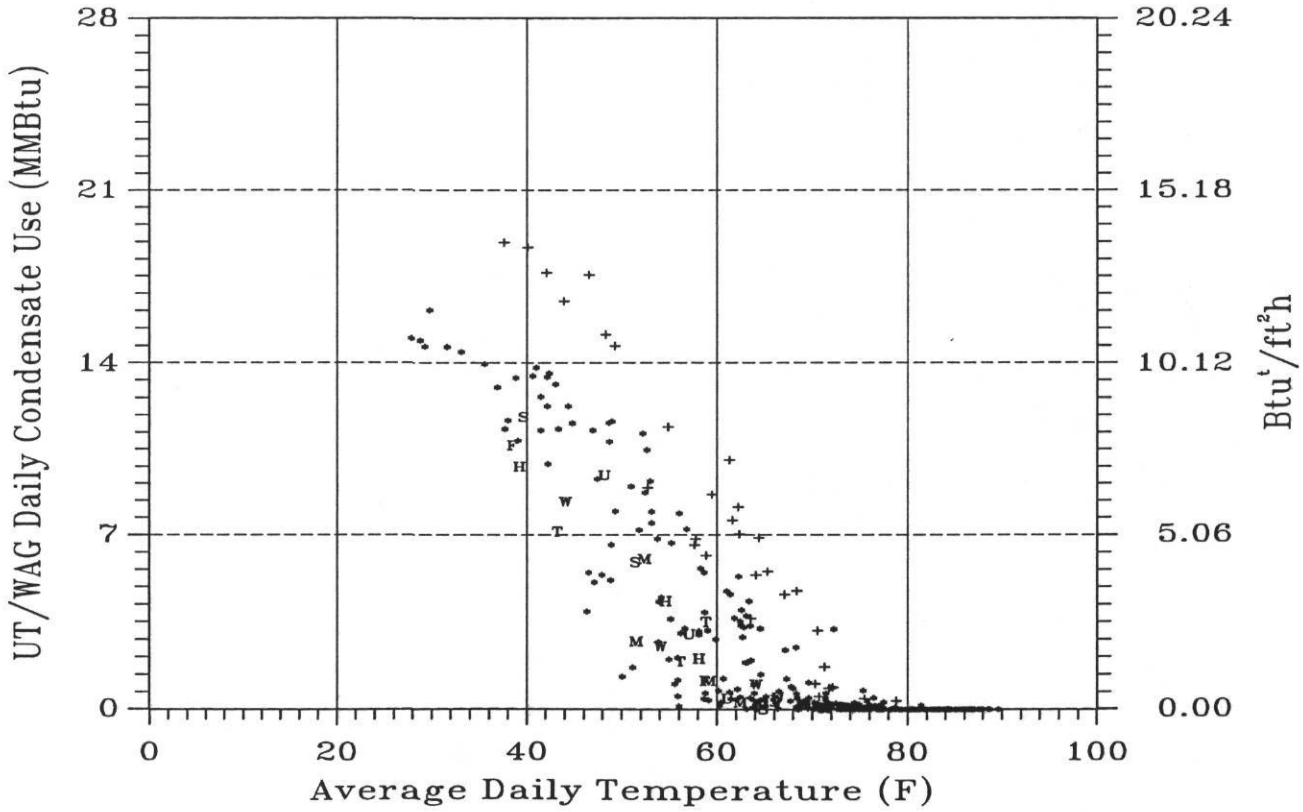
★ Spring Break is evident as reduced electricity consumption from 3/13/96 to 3/17/96.

★ Chilled water energy consumption has decreased slightly when compared to March 1995.

Mar 01 1995 – Mar 31 1996



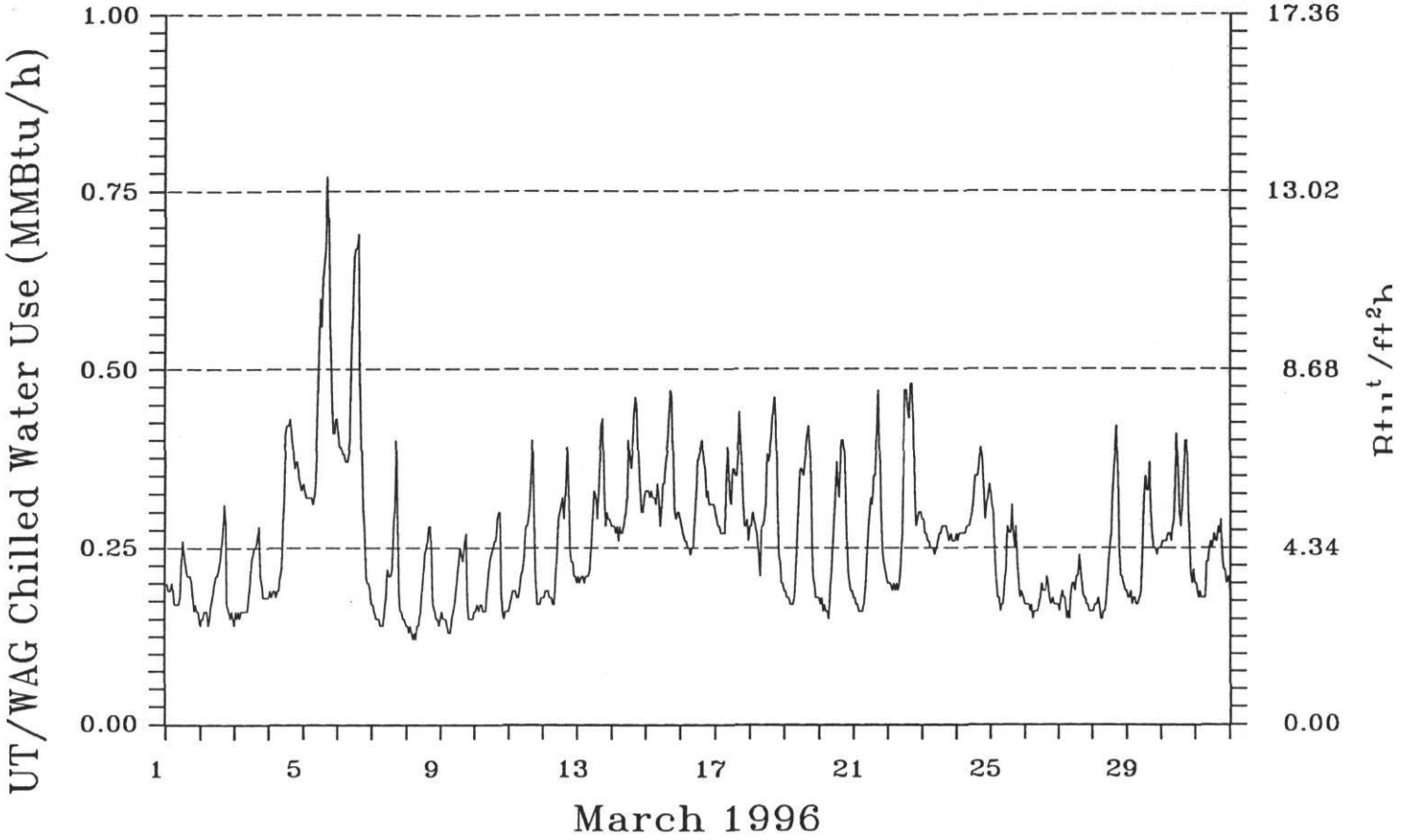
Mar 01 1995 – Mar 31 1996

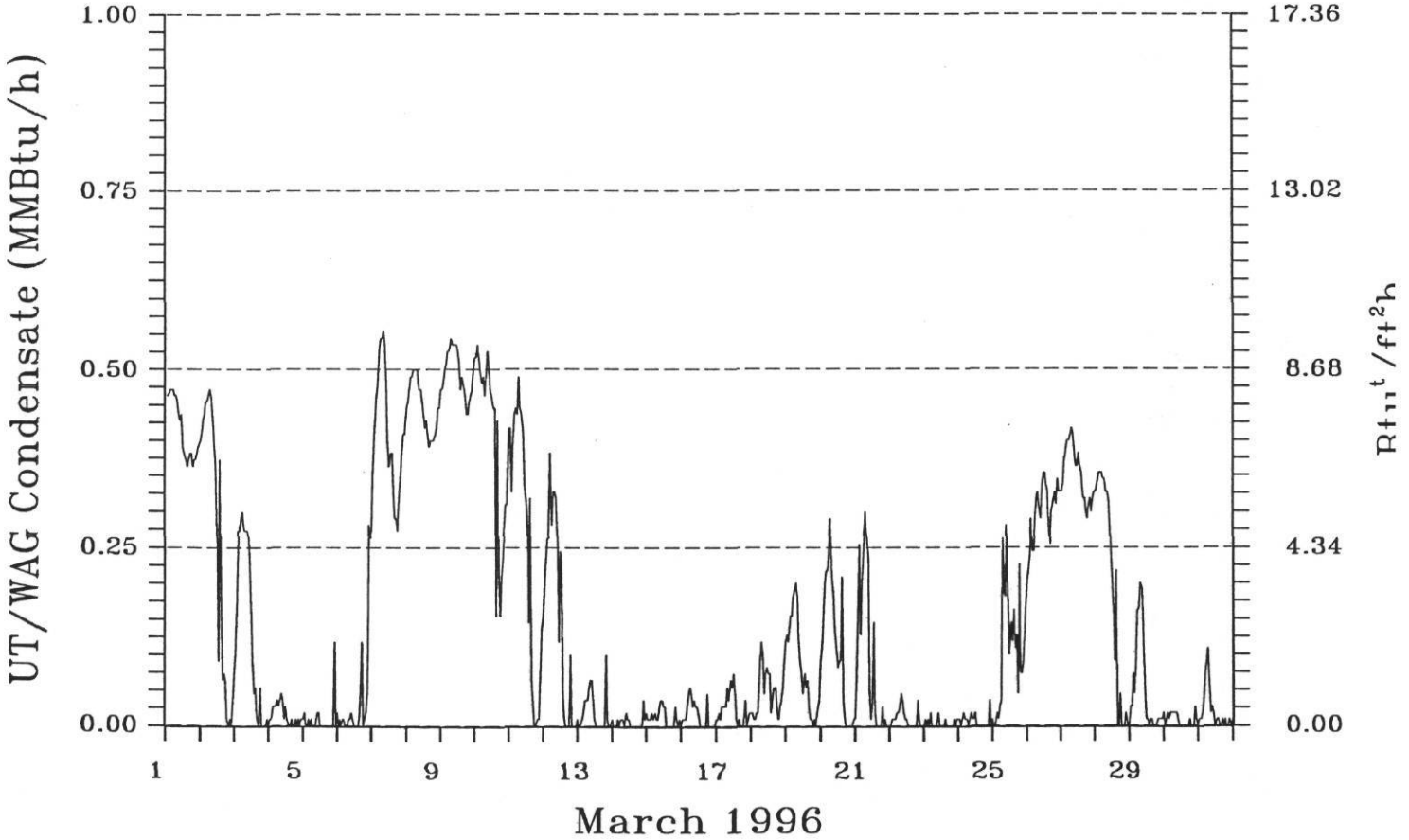


Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

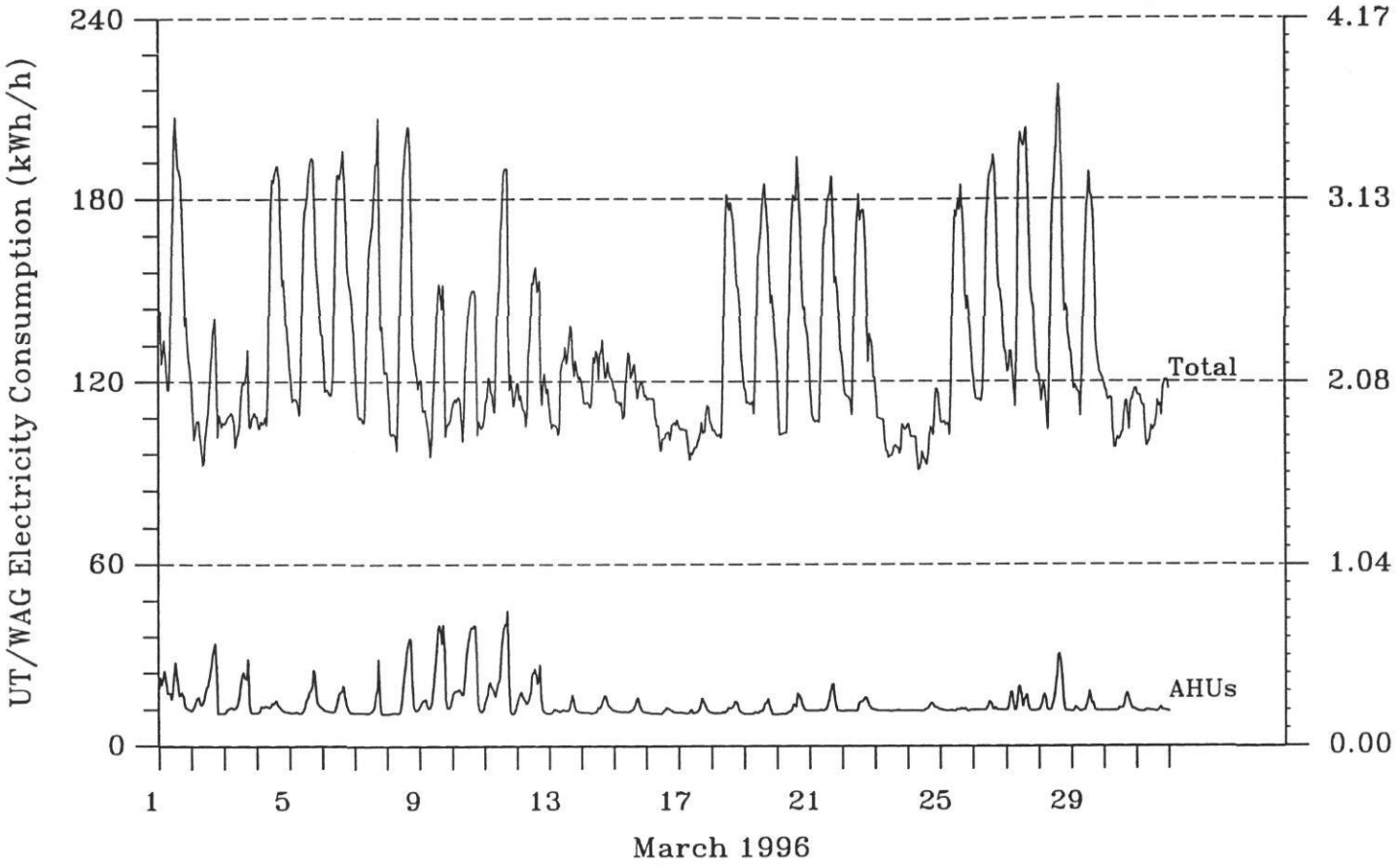
Points from this month last year are shown as +.
All other points are shown as *.

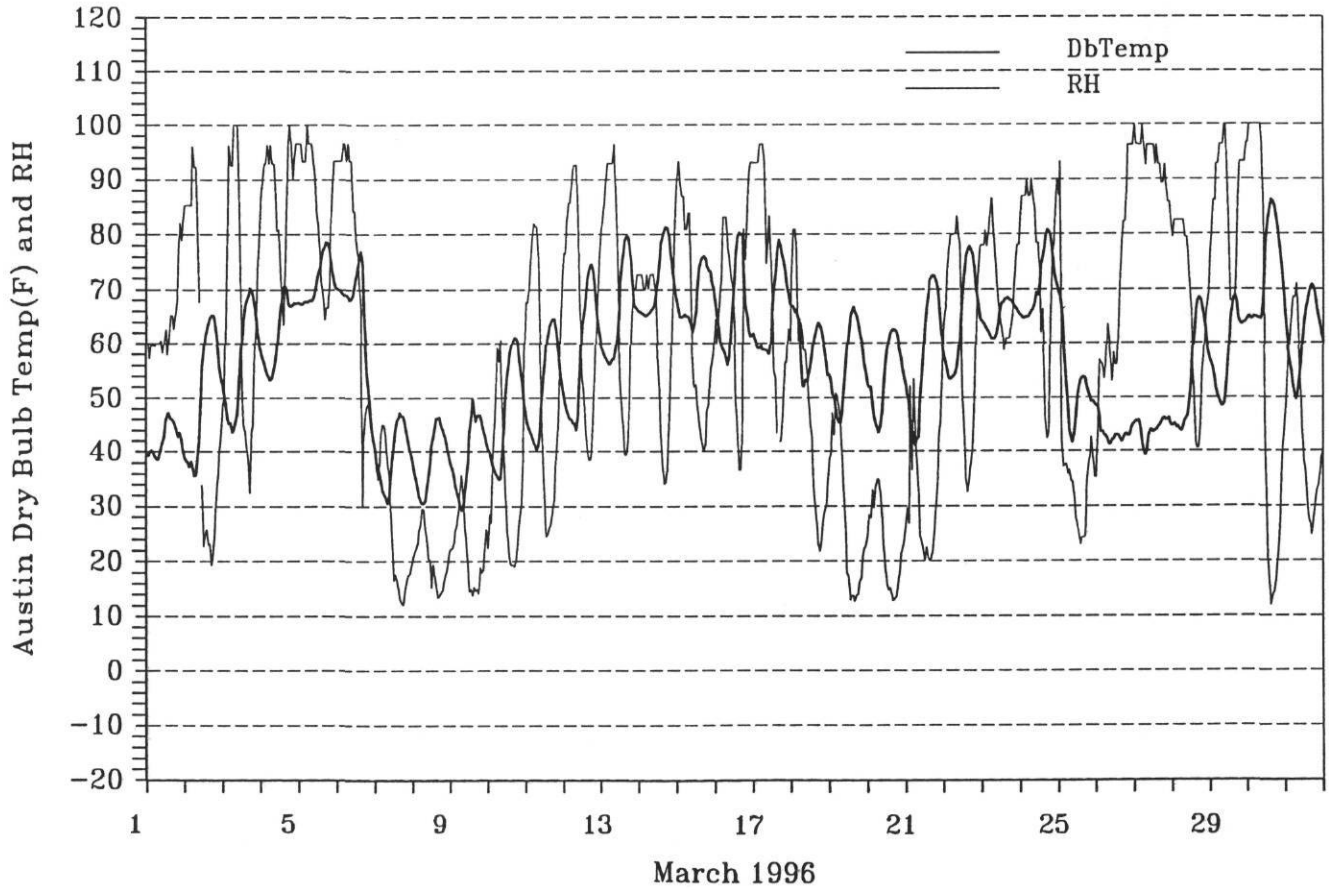
WAG0649 - Waggener Hall - University of Texas - March 1996



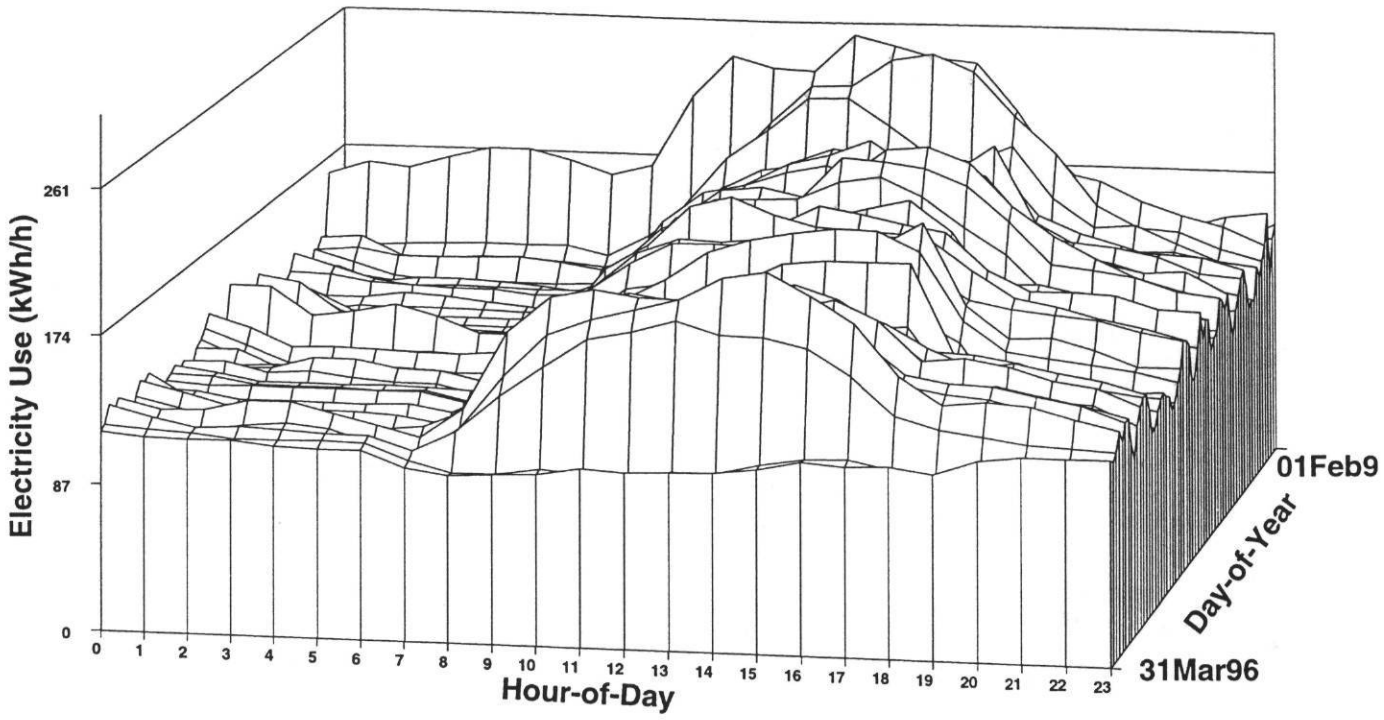


WAG0649 - Waggener Hall - University of Texas - March 1996

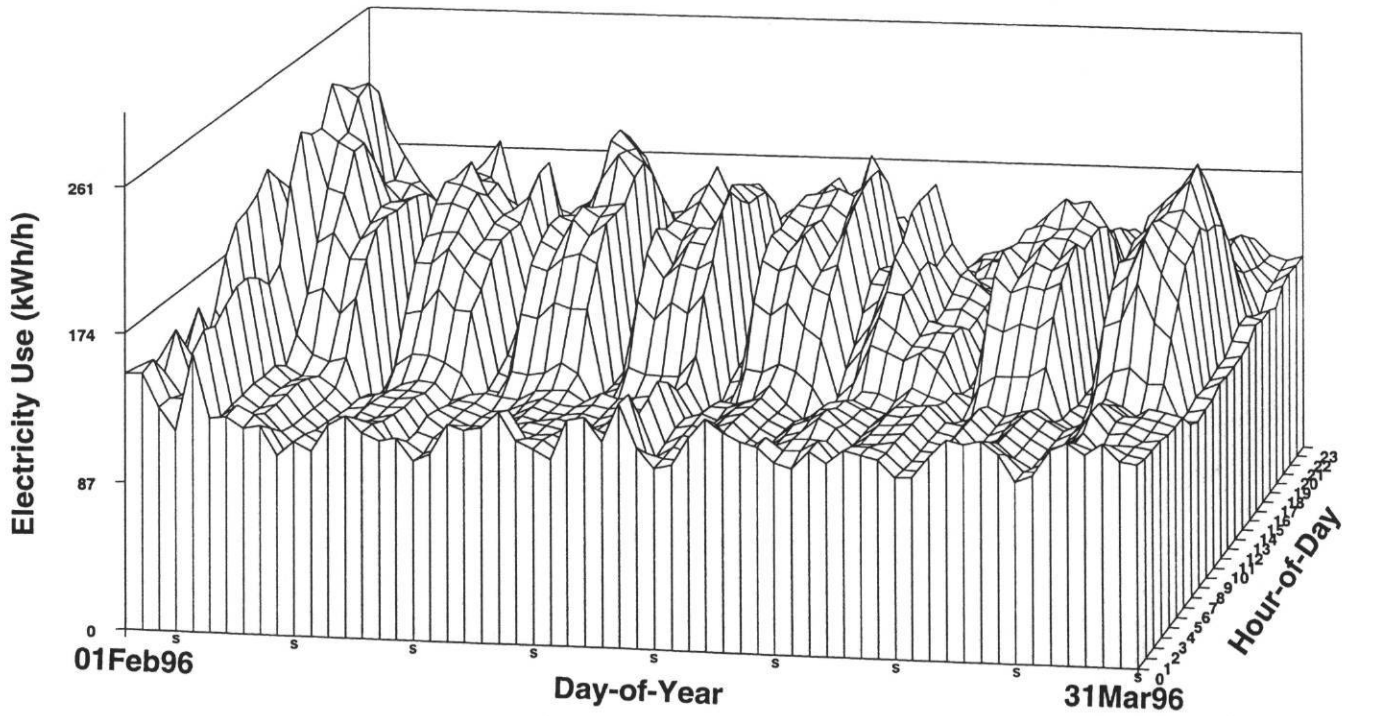

UT/WAG Electricity Consumption (kWh/h)
240
180
120
60
0
4.17
3.13
2.08
1.04
0.00
Total
AHUs
1
5
9
13
17
21
25
29
March 1996


Austin 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
March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

Waggener Hall

Building Envelope:
- 57,598 sq.ft
- 5-story, erected 1931, classes, offices, and lab
- walls: hollow clay tile with a cut stone exterior
- windows: 22% of total wall area, single pane clear operable
- roof: pitched and constructed of clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- labs: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 2 variable volume dual duct AHUs (2-40hp)
- 1 constant volume hot water pump (1-2hp)
- 1 constant volume chilled water pump (1-5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- variable air volume

Date of Retrofits:
- retrofit completion date: May 1991.

Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

UT AUSTIN

Waggener Hall

Building Envelope:
- 57,598 sq.ft
- 5-story, erected 1931, classes, offices, and lab
- walls: hollow clay tile with a cut stone exterior
- windows: 22% of total wall area, single pane clear operable
- roof: pitched and constructed of clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- labs: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 2 variable volume dual duct AHUs (2-40hp)
- 1 constant volume hot water pump (1-2hp)
- 1 constant volume chilled water pump (1-5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- variable air volume

Date of Retrofits:
- retrofit completion date: May 1991.

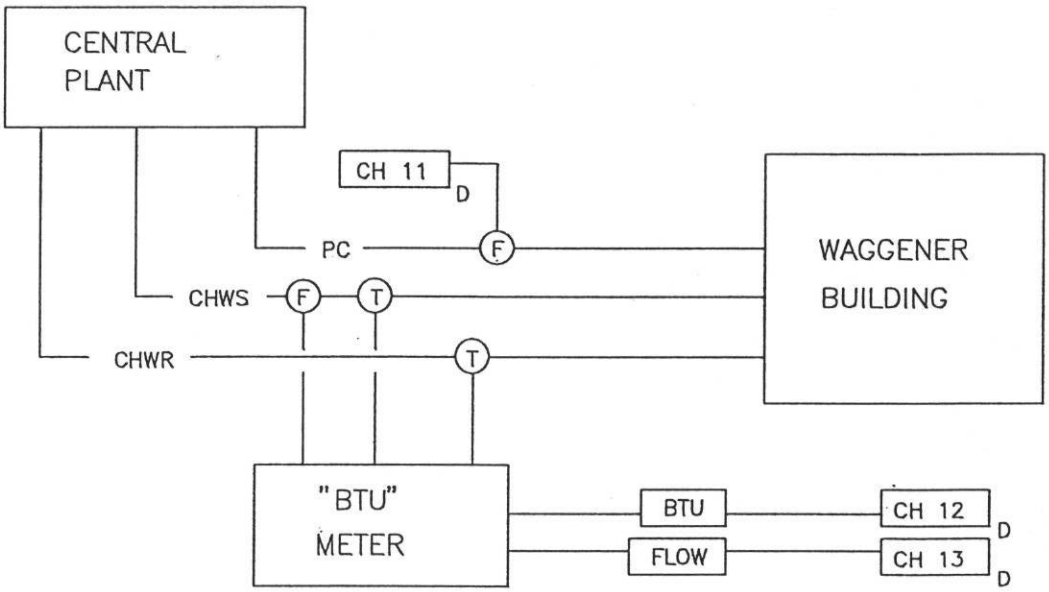
Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – WAGGENER

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

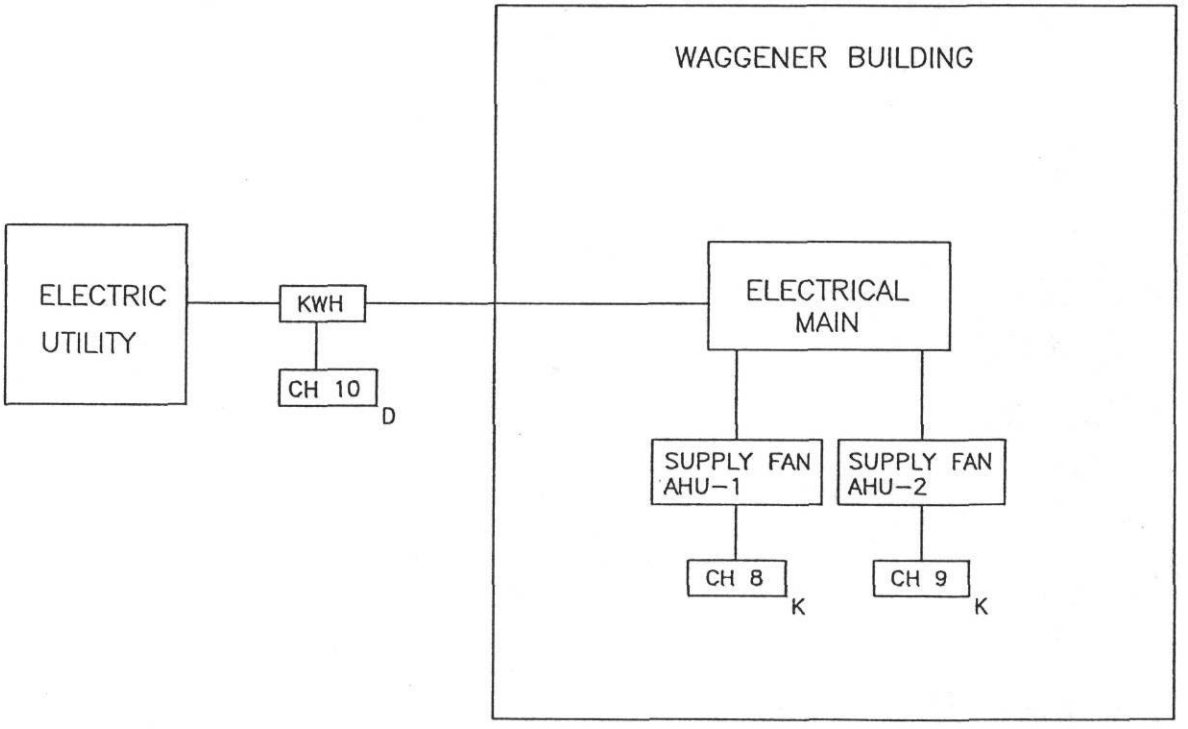


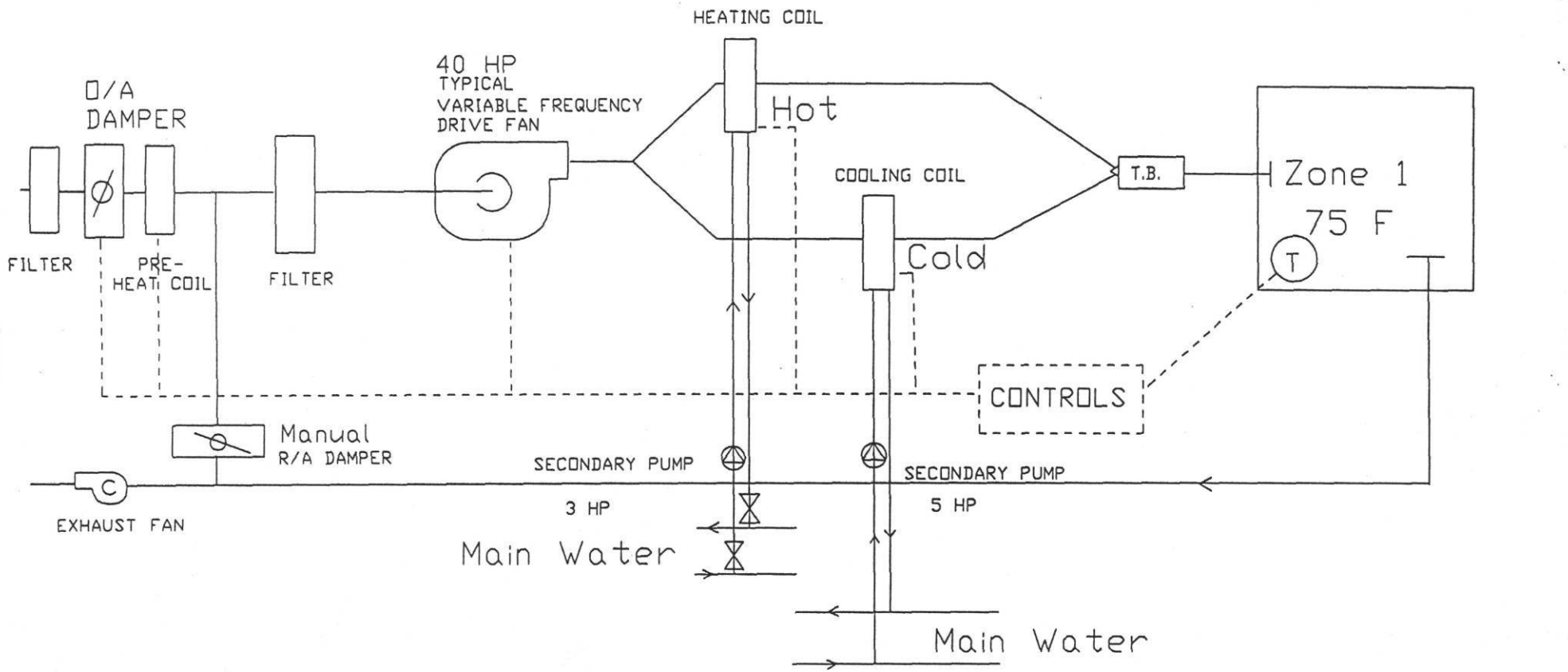
ELECTRICAL MONITORING DIAGRAM

UT AUSTIN – WAGGENER

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL





Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- WAGGENER HALL	
Typical Dual-Duct System	Date: May 1, 1991
WAG-105	Drawn by: Mark Rivera

WEL0161

Welch Hall

University of Texas
439,540 square feet

Site Contact

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University of Texas at Austin
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1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	753715	$34294	100	$5793	3602	$26745	100	$-13642	5492	$34050	100	$-13789	$-21638	$-21638
Feb	706288	$32136	100	$4984	3838	$28497	100	$-12315	4294	$26623	100	$-11244	$-18575	$-40213
Mar	782924	$35623	100	$5760	4296	$31898	100	$-5462	3498	$21688	100	$-6932	$-6634	$-46847
Apr	758185	$34497	99	$5731	3685	$27361	100	$9480	1594	$9883	99	$1886	$17097	$-29750
May	745773	$33933	98	$6115	5928	$44015	98	$12468	1317	$8165	98	$2374	$20957	$-8793
Jun	713603	$32469	100	$5761	9853	$73159	100	$7889	1256	$7787	100	$606	$14256	$5463
Jul	732308	$33320	100	$5970	11417	$84771	100	$13486	1691	$10484	100	$-2732	$16724	$22187
Aug	732629	$33335	100	$5960	10798	$80175	100	$26417	1734	$10751	100	$-3527	$28850	$51037
Sep	726158	$33040	66	$5853	7525	$55873	66	$28216	1642	$10180	66	$-1994	$32075	$83112
Oct	743097	$33811	19	$6089	2082	$15459	19	$12128	2207	$13683	19	$-2231	$15986	$99098
Nov	700478	$31872	100	$5879	2585	$19194	100	$1348	3261	$20218	100	$-3533	$3694	$102792
Dec	708279	$32227	100	$5970	3302	$24517	100	$-5001	4114	$25507	100	$-8239	$-7270	$95522
Total	8803437	$400557		$69865	68911	$511664		$75012	32100	$199019		$-49355		$95522
EUI	20.0	$\frac{kWh}{ft^2yr}$			156779	$\frac{Btu}{ft^2yr}$			73030	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

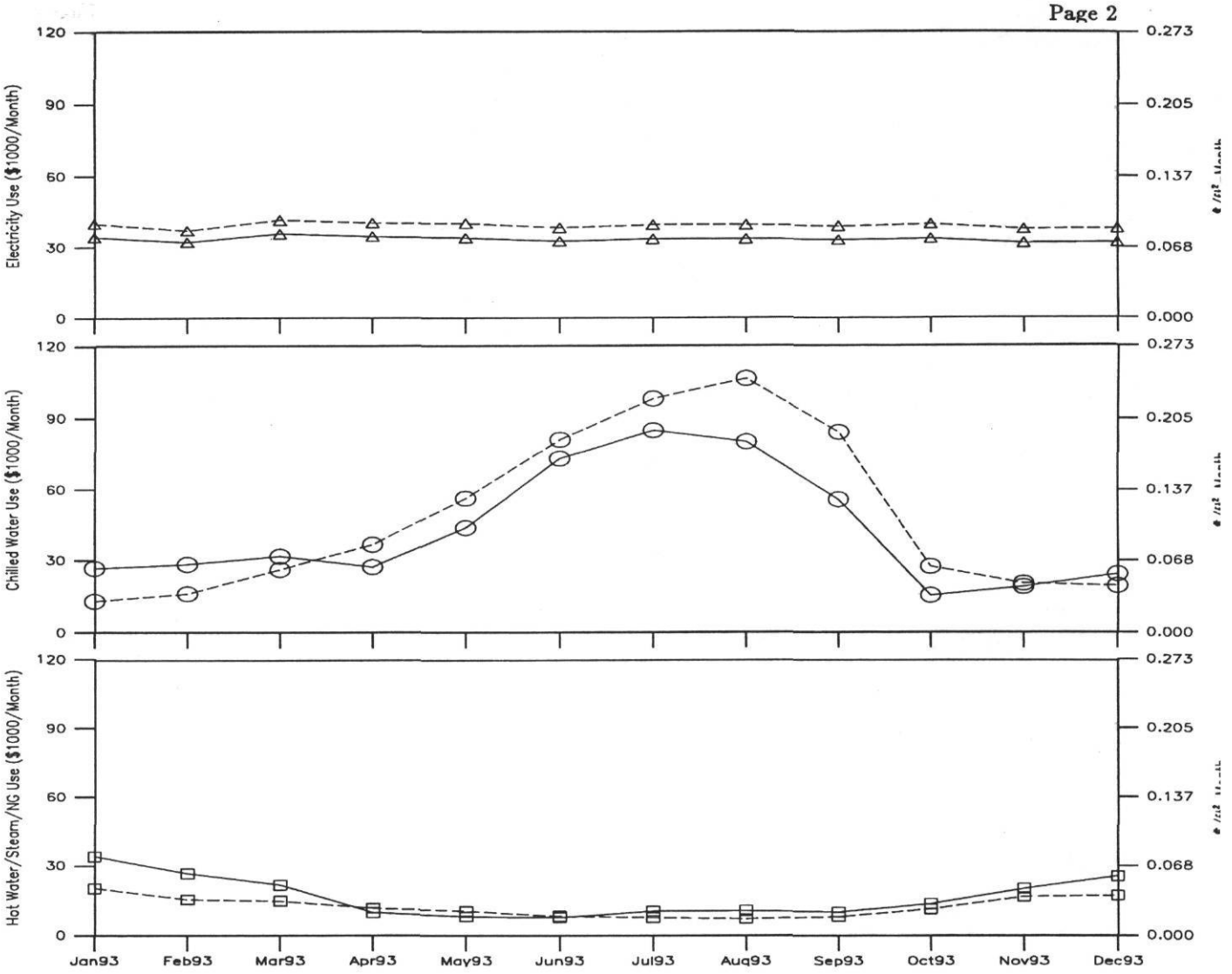
★ **The LoanSTAR monitoring began in November 1990.**

★ **Partial retrofit of HVAC system was completed in February 1992.**

★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

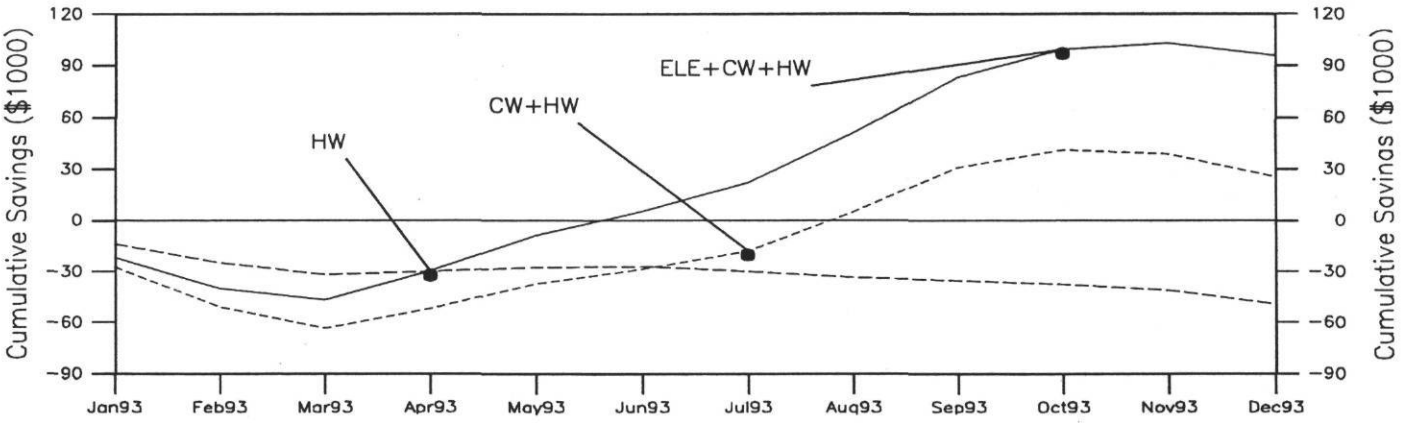
★ **The audit estimated savings for HVAC retrofits beginning in February are: $49,700 (ELE), $35,200 (CW), $39,000 (Steam) and $123,900 (Total).**

★ **Steam and chilled water consumption for September and October 1993 were estimated using a post-retrofit regression model, because of missing data due to hardware problems.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



WEL0161 - Welch Hall - University of Texas

UT AUSTIN

Welch Building

Building Envelope:

- 439,540 sq.ft
- 6-story, erected 1974, classrooms, offices, and labs.
- walls: red face brick on block
- windows: 20% of the total wall area, single pane tinted glass
- roof: build-up roof with 4.5" insulation

Building Schedule:

- 18 hrs/day (7:30 am to 10:30 pm) all week long

Building HVAC:

- 4 constant volume dual duct AHUs (4-100hp SFs of AC1, AC2)
- 2 variable volume dual duct SFs of AC3 (2-100hp)
- 1 variable speed return air fan for AC3 (50hp, originally 30hp)
- 1 variable speed hot deck fan for AC3 (60 hp, originally 30hp return air fan for AC3)
- 3 return air fans (2-30hp, 1-60hp)
- 24 exhaust fan units (6-7.5 hp, 6-15hp, 6-0.75hp)
- 2 variable speed chilled water pump (2-75hp, 1-7.5hp)
- 1 constant speed chilled water pump (7.5hp for AC4)
- economizer cycle has been added on AC-3A and AC-3B as a part of the retrofit (not operable at this moment).

HVAC Schedule:

- 24 hrs/day

Lighting:

- fluorescent (34 - W), incandescent, and mercury vapor

Retrofits Implemented:

- replace incand. lights
- variable air volume (AC3 only, 30hp return air fan converted to 60hp hot deck fan. AC3 constitute of two cold deck fans (100hp each), one hot deck fan (60 hp) and one return air fan (50 hp)).
- variable speed pumping

Date of Retrofits:

- retrofit completion date: February 1992 (VAV & VSP)

Savings Calculations:

- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

WEL0161

Welch Hall

University of Texas
439,540 square feet

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College Station, TX 77843-3123
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Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	746641 kWh	100	$0.04550	$33972
Peak 60 Minute Demand	1246 kW	100	-	-
Chilled Water	3090.9 MMBtu	100	$7.425	$22950
Condensate	4096.7 MMBtu	100	$6.200	$25400

Peak 60 minute demand was recorded at 1400 Monday 03/18/96.
There were 744 hours in this month.

Monthly Retrofit Savings

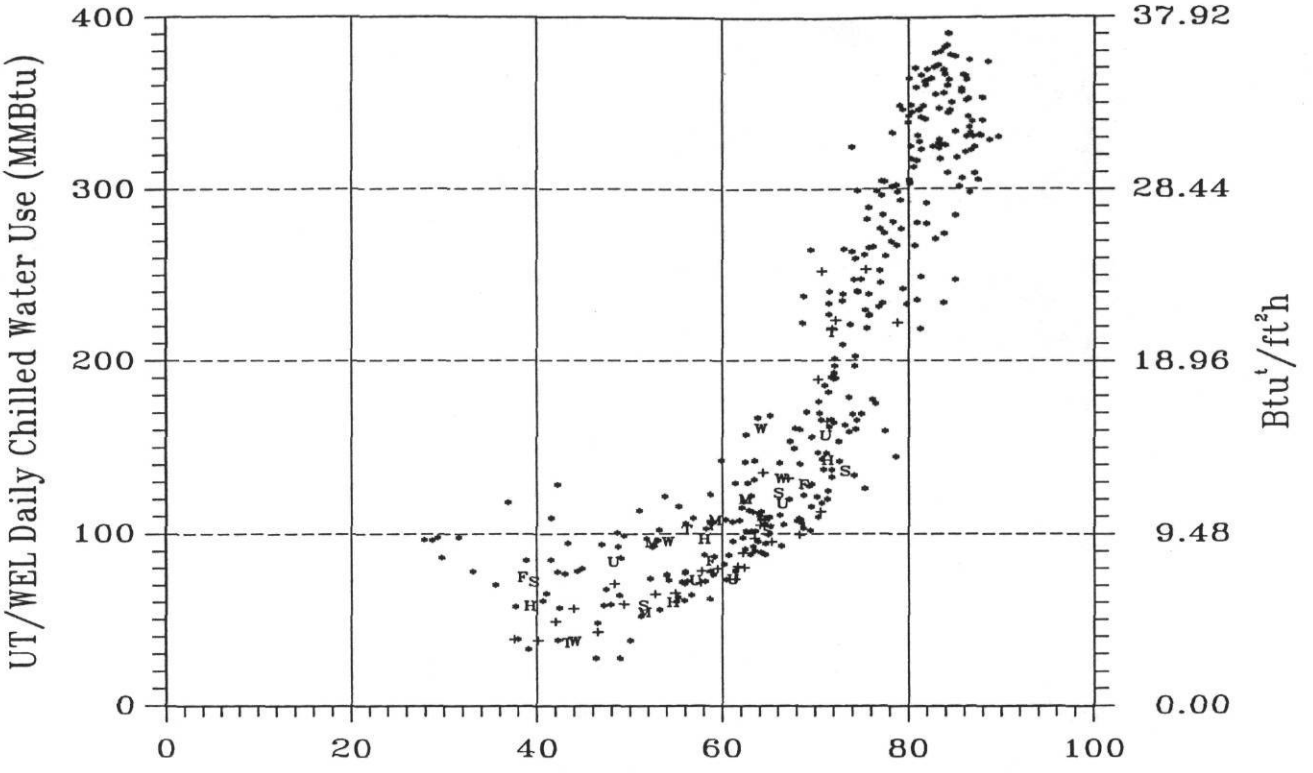
	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	122223	$5561	91030	$4142
Chilled Water (MMBtu)	-148	$-1099	395	$2933
Cond./H.W./N.G. (MMBtu)	-1278	$-7924	525	$3255
Monthly Total		$-3461		$10330
Total to Date*	(63 months)	$516174	(49 months)	$506157

*Measured savings include construction period. Audit estimated savings do not.

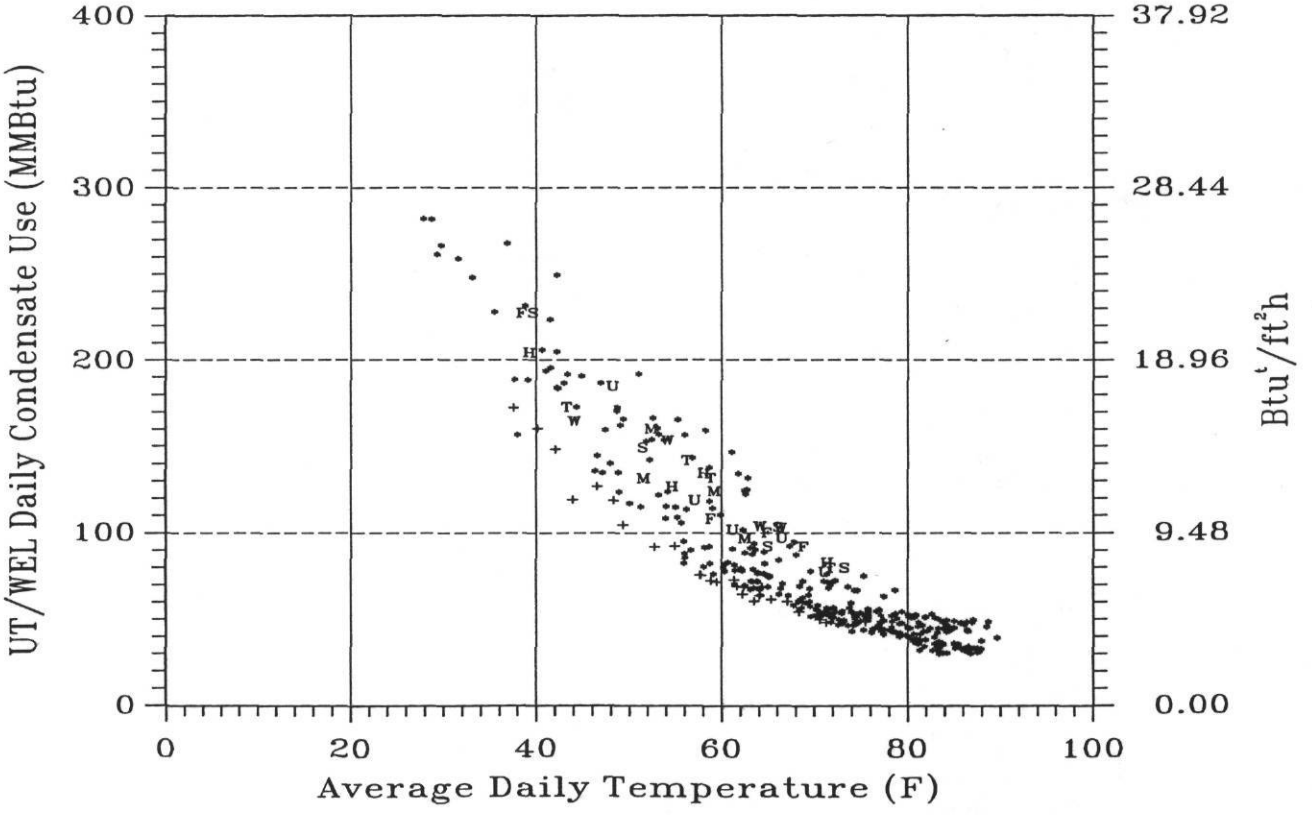
Comments

★ Steam energy consumption increased slightly when compared to March 1995.
★ Spring Break is evident as reduced electricity consumption from 3/10/96 to 3/17/96.
★ MCC electricity use has dropped about 10% when compared to March 1995.

Mar 01 1995 – Mar 31 1996

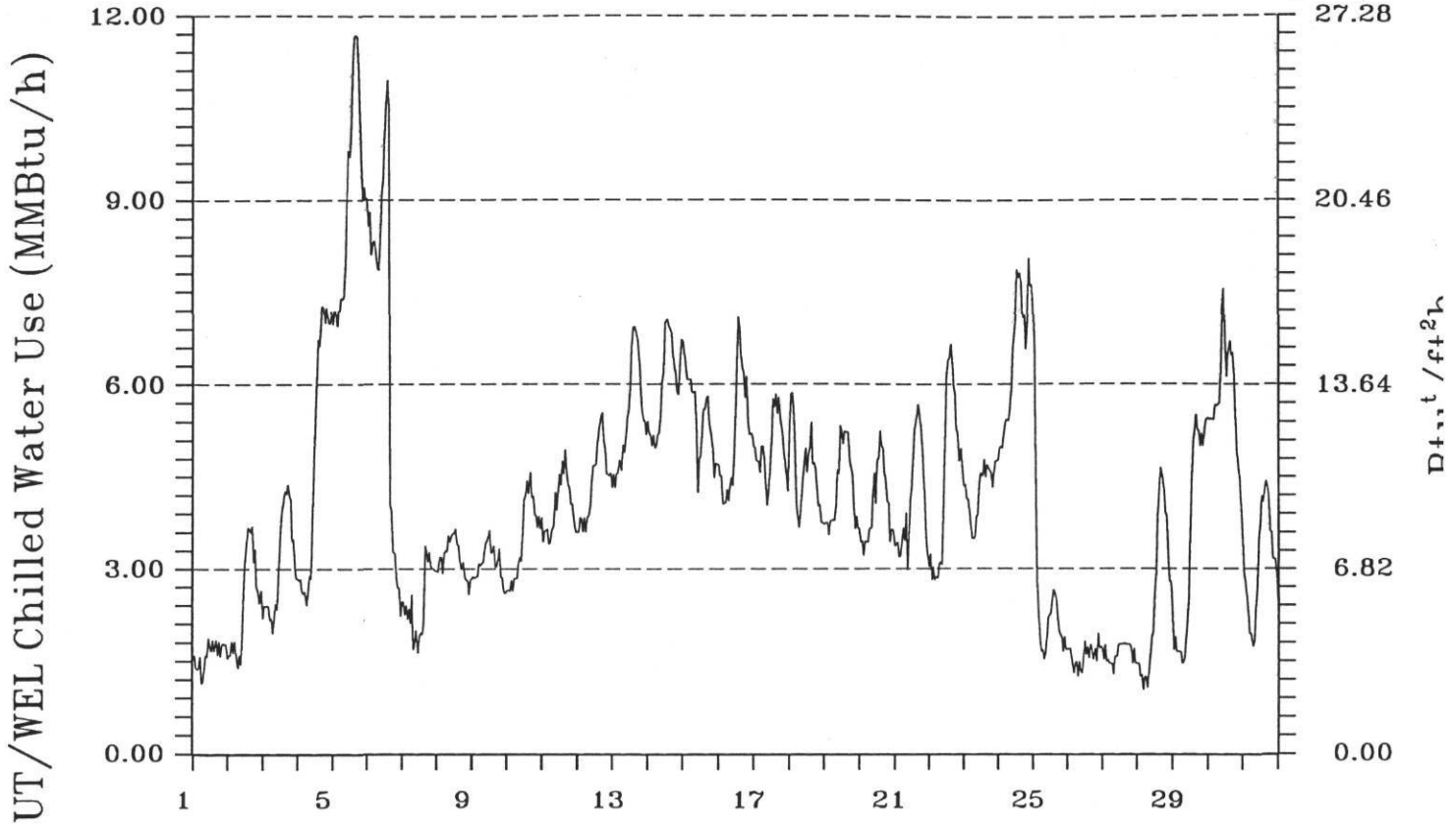


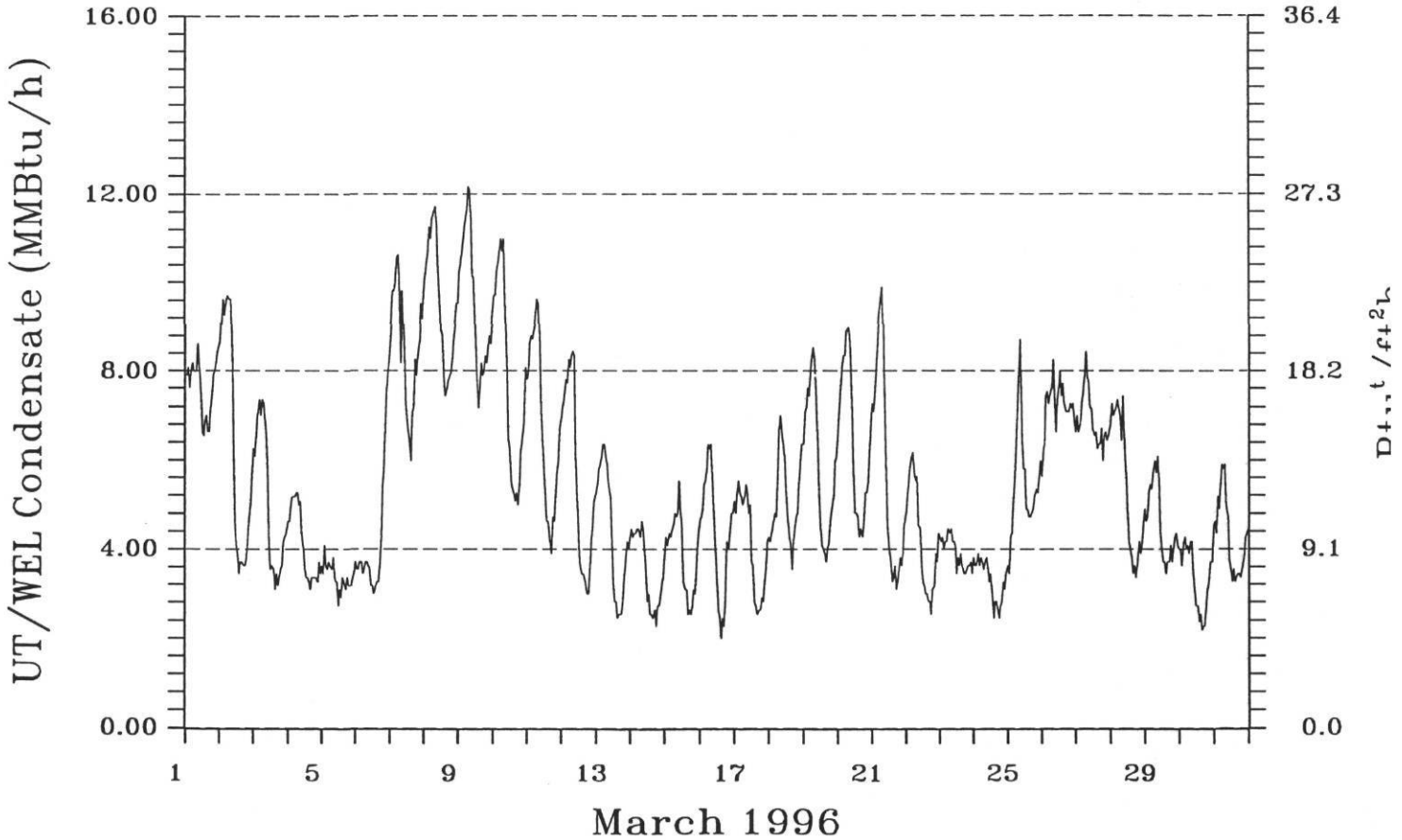
Mar 01 1995 – Mar 31 1996

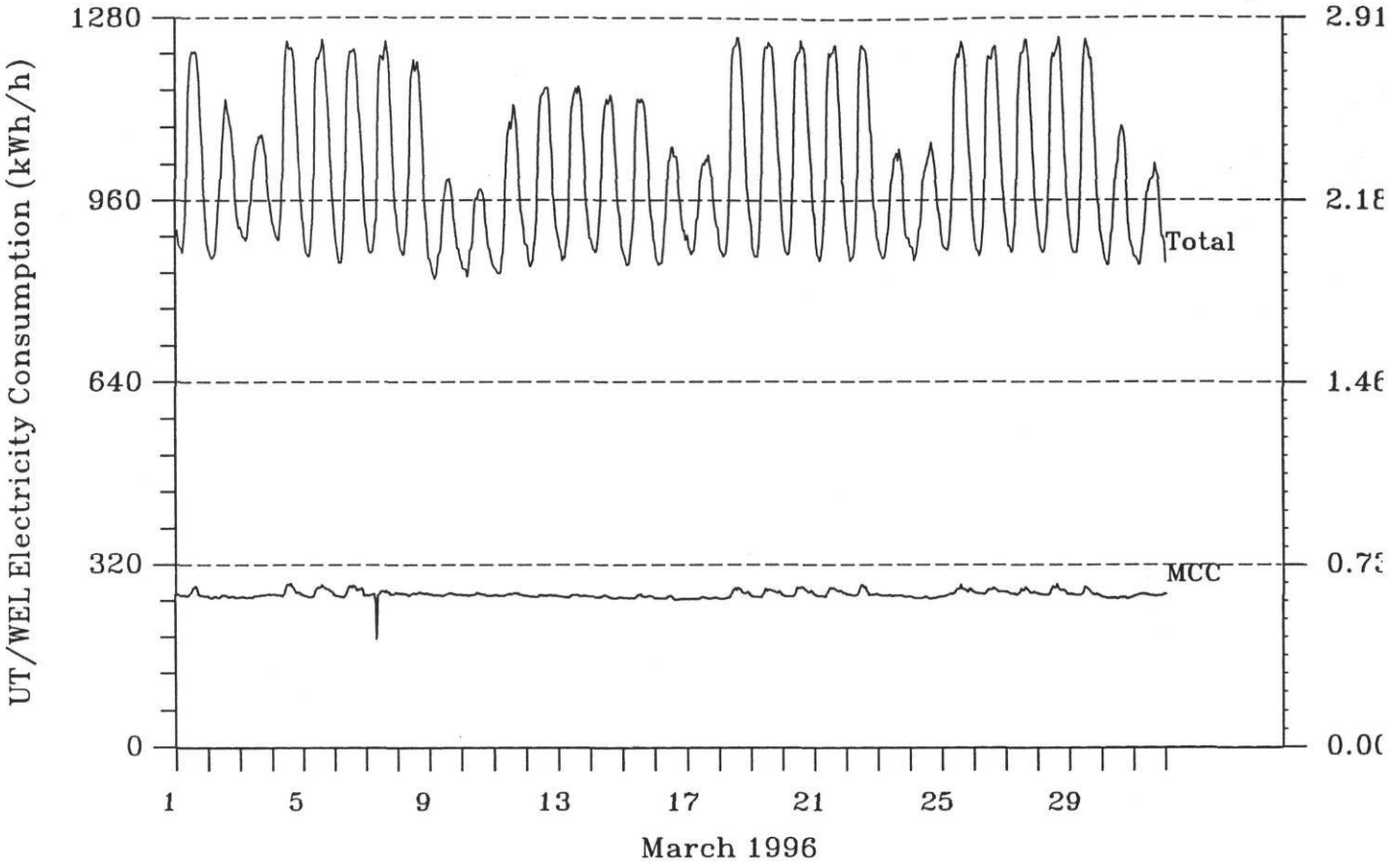


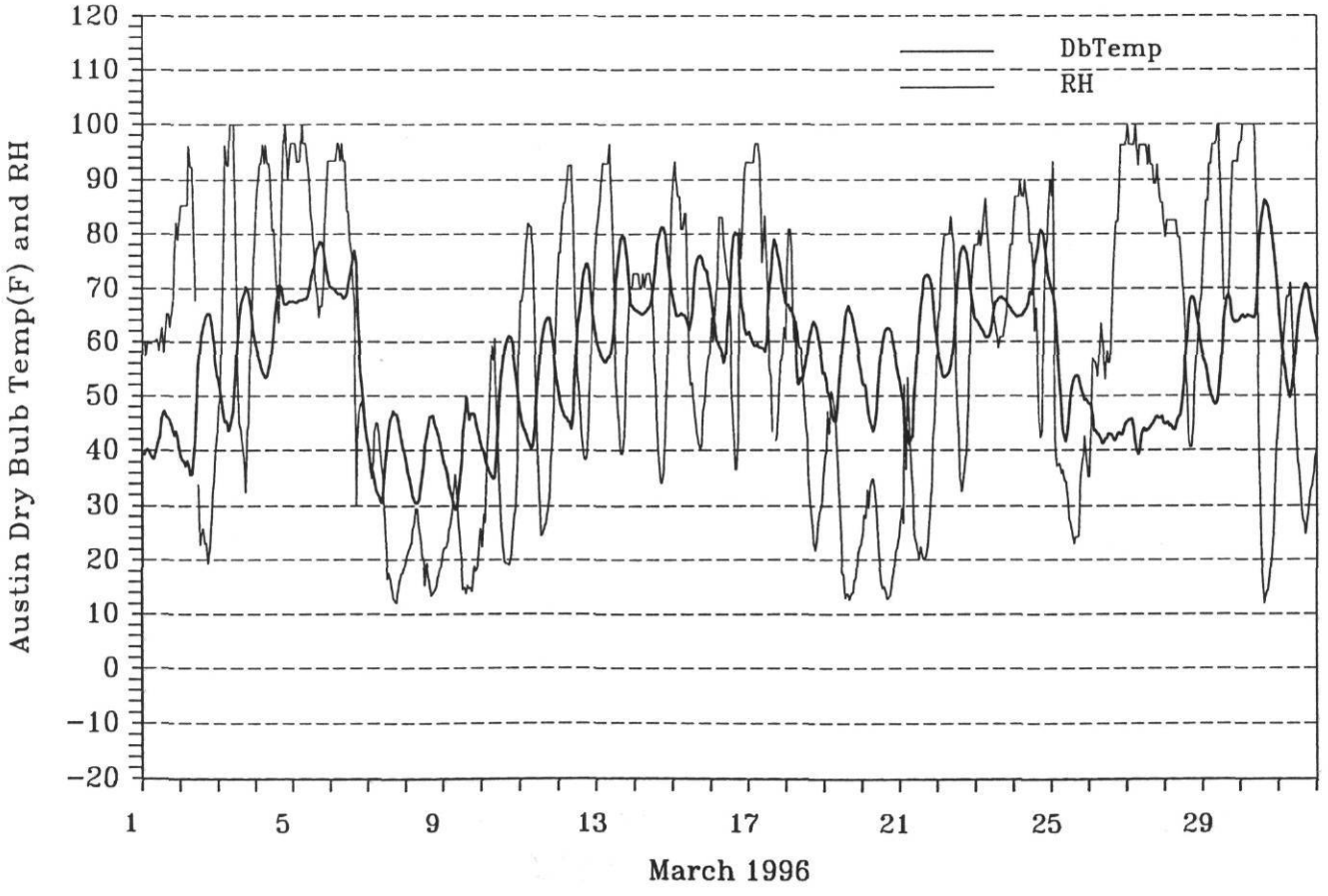
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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


UT/WEL Chilled Water Use (MMBtu/h)
12.00
9.00
6.00
3.00
0.00
27.28
20.46
13.64
6.82
0.00
1
5
9
13
17
21
25
29
March 1996

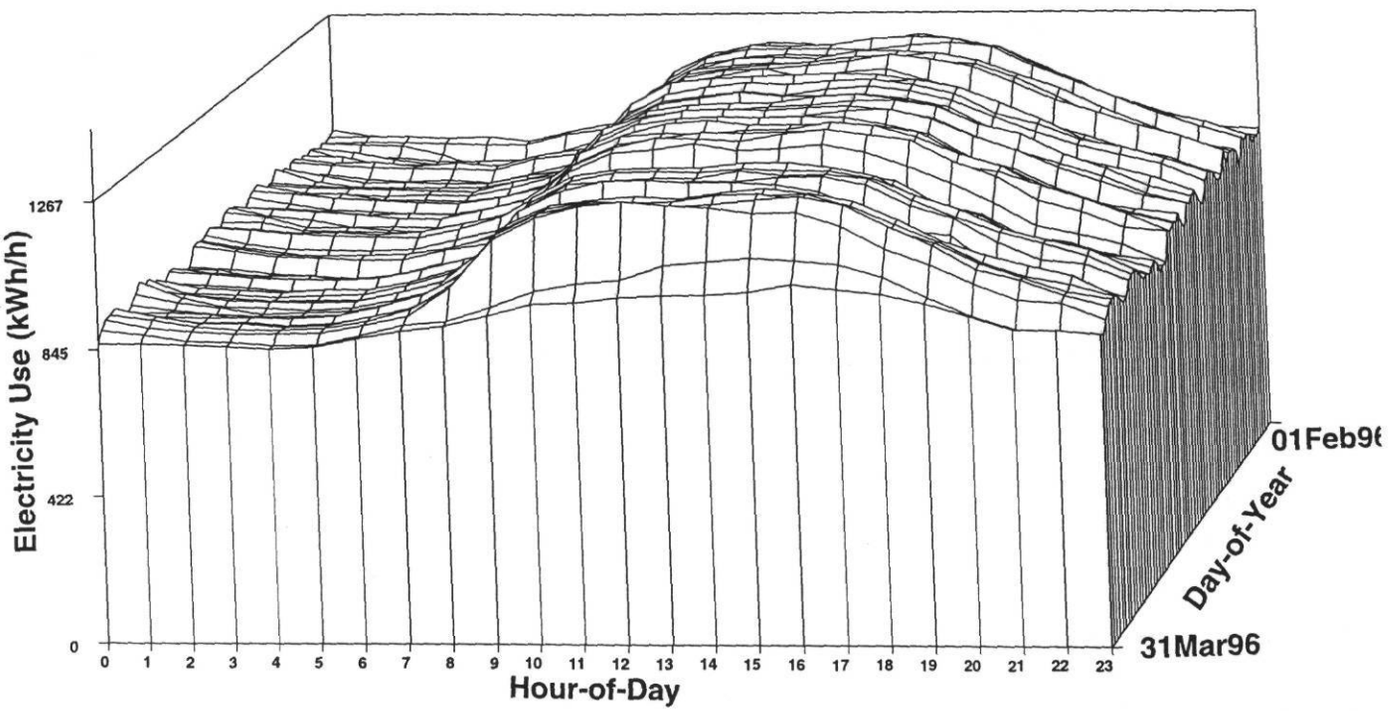

UT/WEL Condensate (MMBtu/h)
16.00
12.00
8.00
4.00
0.00
36.4
27.3
18.2
9.1
0.0
1
5
9
13
17
21
25
29
March 1996



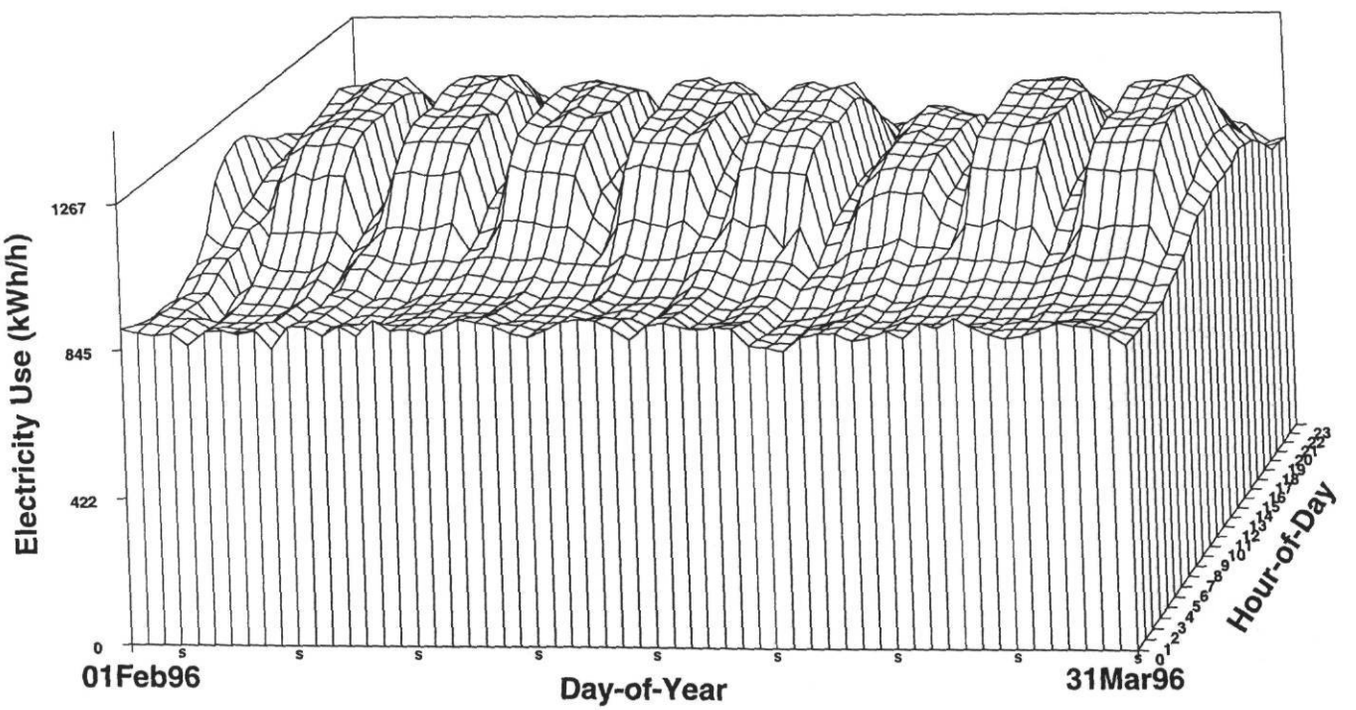


WEL0161 - Welch Hall - University of Texas - March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

Welch Building

Building Envelope:
- 439,540 sq.ft
- 6-story, erected 1974, classrooms, offices, and labs.
- walls: red face brick on block
- windows: 20% of the total wall area, single pane tinted glass
- roof: build-up roof with 4.5" insulation

Building Schedule:
- 18 hrs/day (7:30 am to 10:30 pm) all week long

Building HVAC:
- 4 constant volume dual duct AHUs (4-100hp SFs of AC1, AC2)
- 2 variable volume dual duct SFs of AC3 (2-100hp)
- 1 variable speed return air fan for AC3 (50hp, originally 30hp)
- 1 variable speed hot deck fan for AC3 (60 hp, originally 30hp return air fan for AC3)
- 3 return air fans (2-30hp, 1-60hp)
- 24 exhaust fan units (6-7.5 hp, 6-15hp, 6-0.75hp)
- 2 variable speed chilled water pump (2-75hp, 1-7.5hp)
- 1 constant speed chilled water pump (7.5hp for AC4)
- economizer cycle has been added on AC-3A and AC-3B as a part of the retrofit (not operable at this moment).

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent (34 - W), incandescent, and mercury vapor

Retrofits Implemented:
- replace incand. lights
- variable air volume (AC3 only, 30hp return air fan converted to 60hp hot deck fan. AC3 constitute of two cold deck fans (100hp each), one hot deck fan (60 hp) and one return air fan (50 hp)).
- variable speed pumping

Date of Retrofits:
- retrofit completion date: February 1992 (VAV & VSP)

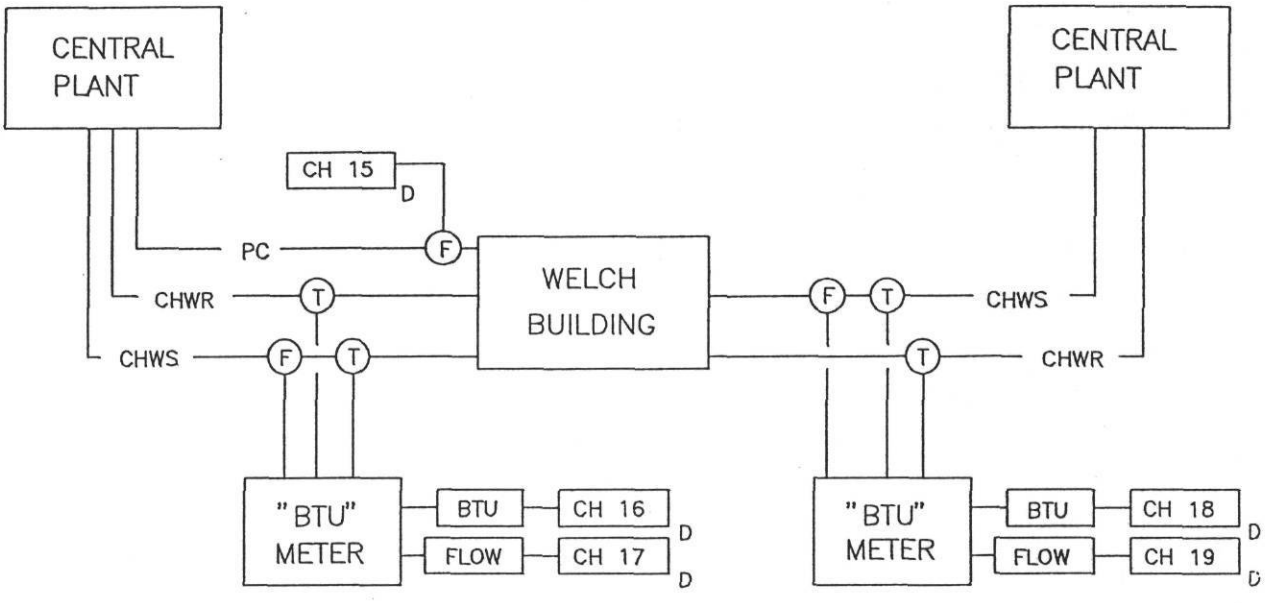
Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – WELCH

LEGEND

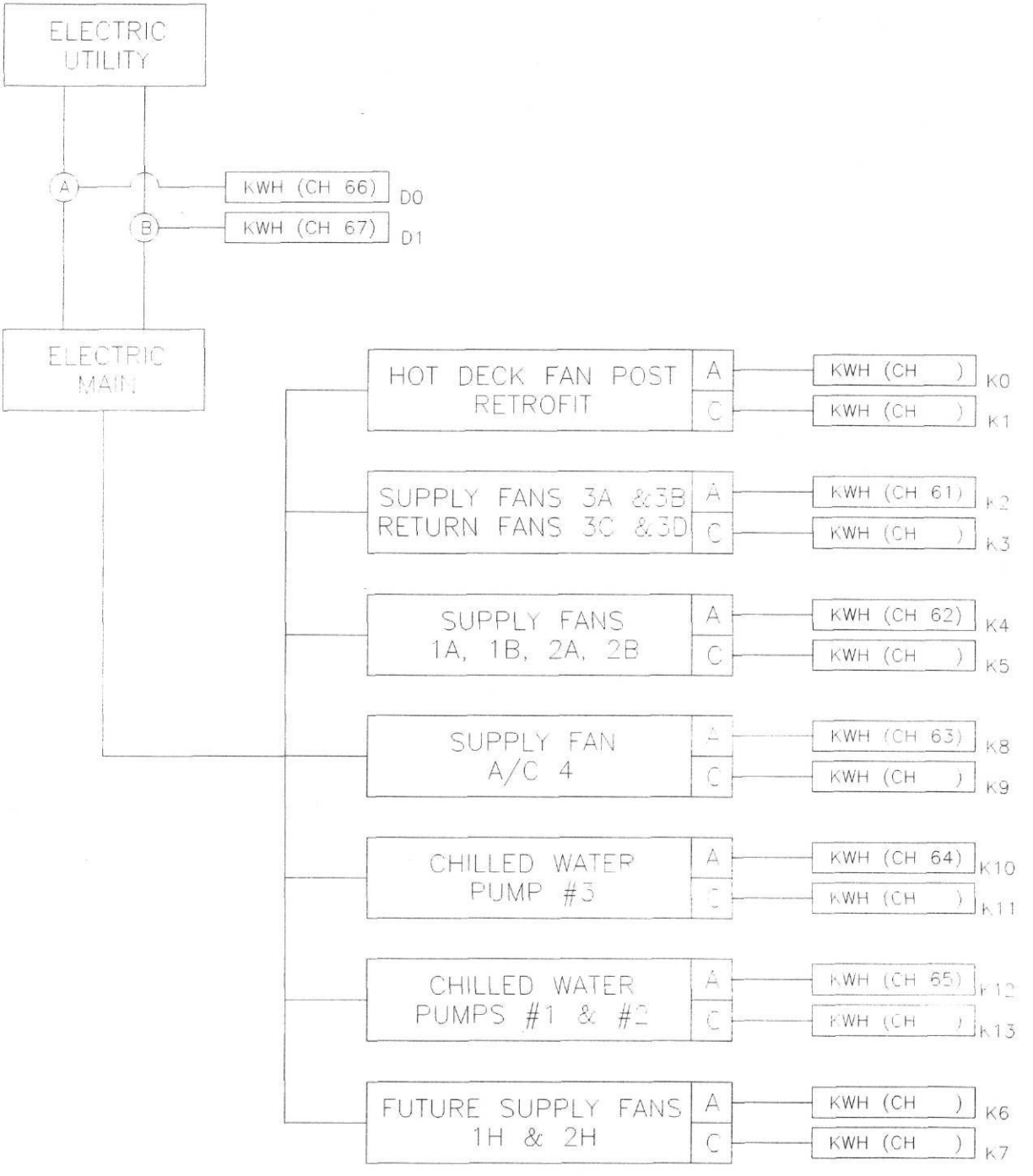
K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



ELECTRICAL MONITORING DIAGRAM
UT AUSTIN – WELCH

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



BUR0099

Burdine Hall

University of Texas
103,441 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	80351	$3656	100	$1955	323	$2398	100	$3082	628	$3894	100	$1004	$6041	$6041
Feb	72980	$3321	100	$2159	294	$2183	100	$2807	472	$2926	100	$809	$5775	$11816
Mar	75106	$3417	100	$2617	369	$2740	100	$2925	430	$2666	100	$501	$6043	$17859
Apr	70467	$3206	99	$2783	410	$3044	99	$2984	300	$1860	99	$356	$6123	$23982
May	63778	$2902	100	$2800	529	$3928	100	$3218	233	$1445	100	$198	$6216	$30198
Jun	60720	$2763	100	$2760	717	$5324	100	$4996	150	$930	100	$207	$7963	$38161
Jul	59813	$2722	100	$2904	798	$5925	100	$6672	130	$806	100	$145	$9721	$47882
Aug	61191	$2784	100	$2874	816	$6059	100	$7616	132	$818	100	$7	$10497	$58379
Sep	71168	$3238	100	$2760	667	$4952	100	$5943	134	$831	100	$253	$8956	$67335
Oct	78745	$3583	100	$2709	430	$3193	100	$4817	191	$1184	100	$821	$8347	$75682
Nov	77082	$3507	100	$2583	266	$1975	100	$3503	447	$2771	100	$1145	$7231	$82913
Dec	65674	$2988	100	$2890	274	$2034	100	$3562	536	$3323	100	$669	$7121	$90034
Total	837075	$38087		$31794	5893	$43755		$52125	3783	$23454		$6115		$90034
EUI	8.1	$\frac{kWh}{ft^2yr}$			56969	$\frac{Btu}{ft^2yr}$			36571	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

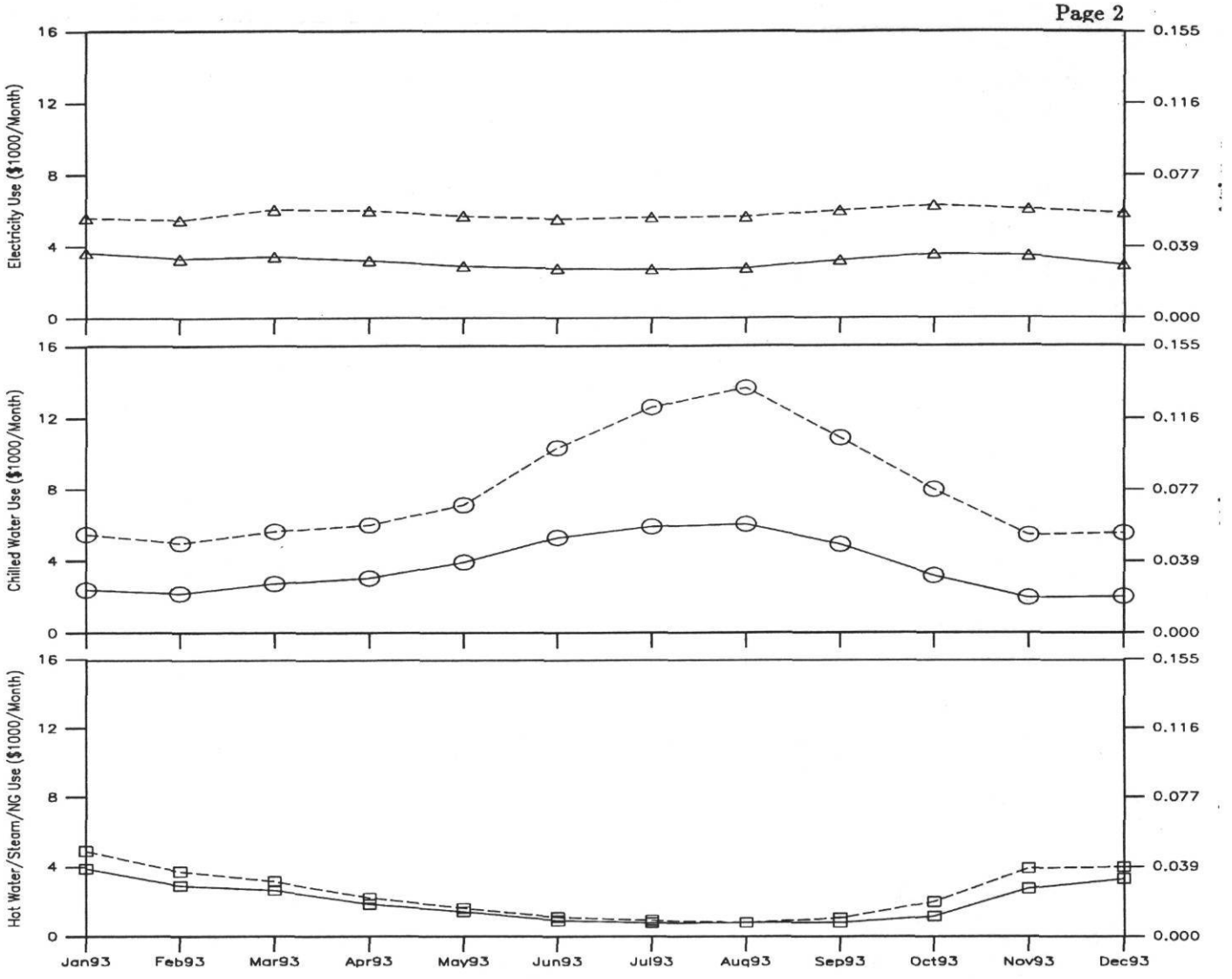
★ **The LoanSTAR monitoring began in November 1990.**

★ **The HVAC retrofit was completed in May 1991.**

★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

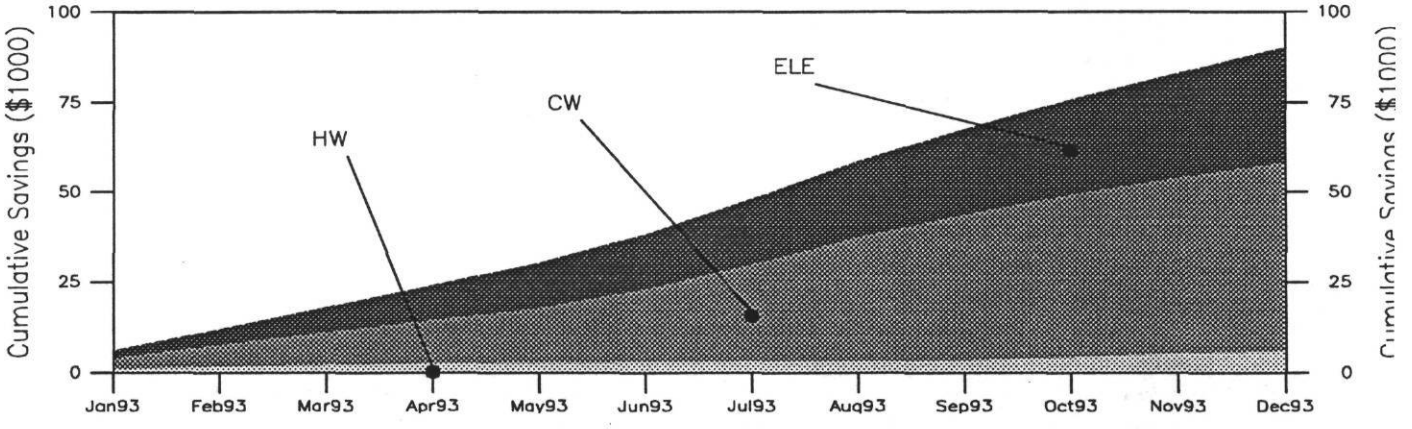
★ **The audit estimated savings for HVAC retrofits are: $45,600 (ELE), $18,900 (CW), $9,700 (Steam) and $74,200 (Total).**

★ **Increase in electricity savings ($4,000) and chilled water savings ($10,000) were noticed when compared to 1992. Conversations with UT personnel have revealed that the AHUs were put on slow roll after 3/24/93.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



UT AUSTIN

Burdine Building

Building Envelope:
- 103,441 sq.ft
- classrooms, lecture halls, offices, and auditorium
- walls: concrete with face brick
- windows: single pane
- roof: flat concrete

Building Schedule:
- 7:30 am to 9:30 pm

Building HVAC:
- 2 variable volume dual duct AHUs (1-100hp,1-75hp)
- 2 constant volume single zone AHUs (1-15hp, 1-0.5hp)
- 2 outside air fans (2-10hp)
- 1 variable volume chilled water pump (40hp)
- 1 constant volume chilled water pump (40 hp)
- 1 domestic hot water pump (0.75hp)
- 10 exhaust fans (0.5hp-1.5hp)

HVAC Schedule:
- 24 hours

Lighting:
- fluorescent and some incandescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- all the retrofits completed late May 1991.

Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

BUR0099

Burdine Hall

University of Texas
103,441 square feet

Site Contact
Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact
Aamer Athar
053D 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	71425 kWh	100	$0.04550	$3250
Peak 60 Minute Demand	165 kW	100	-	-
Chilled Water	459.3 MMBtu	100	$7.425	$3411
Condensate	619.3 MMBtu	100	$6.200	$3840

Peak 60 minute demand was recorded at 1400 Tuesday 03/05/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	55954	$2546	83571	$3802
Chilled Water (MMBtu)	299	$2220	212	$1574
Cond./H.W./N.G. (MMBtu)	7	$43	130	$806
Monthly Total		$4809		$6183
Total to Date*	(59 months)	$395243	(58 months)	$358590

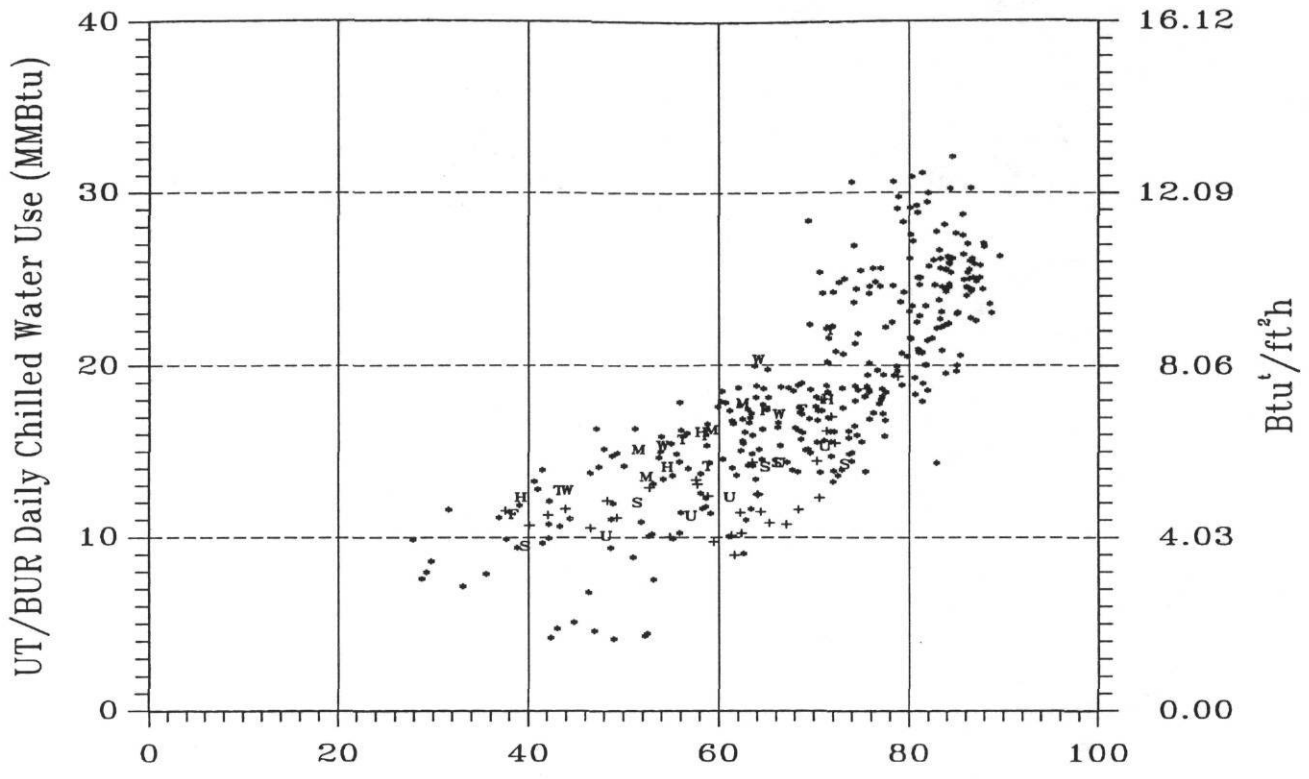
*Measured savings include construction period. Audit estimated savings do not.

Comments

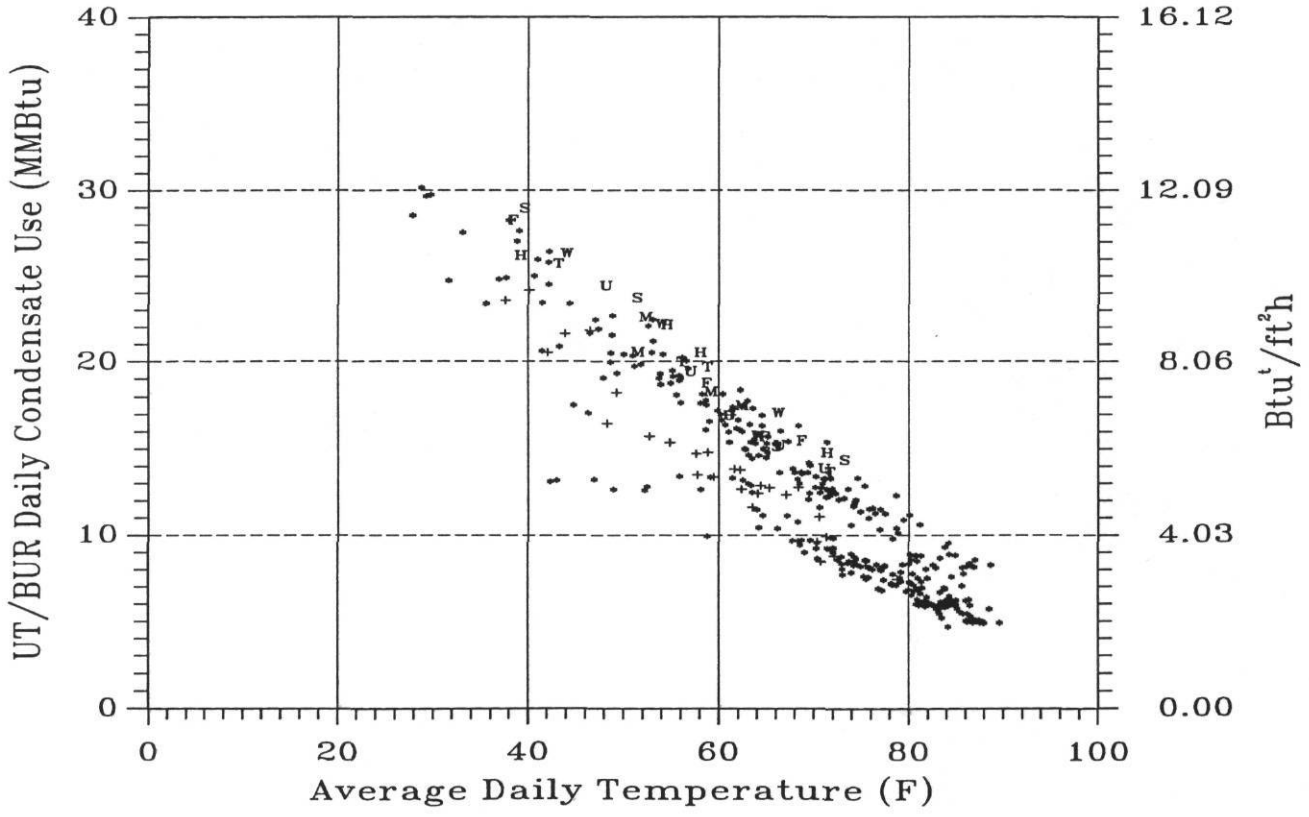
★ Electricity use, chilled water energy consumption, and steam energy consumption have increased slightly compared to March 1995.

★ Spring Break is evident as reduced electricity consumption from 3/11/96 to 3/17/96.

Mar 01 1995 – Mar 31 1996



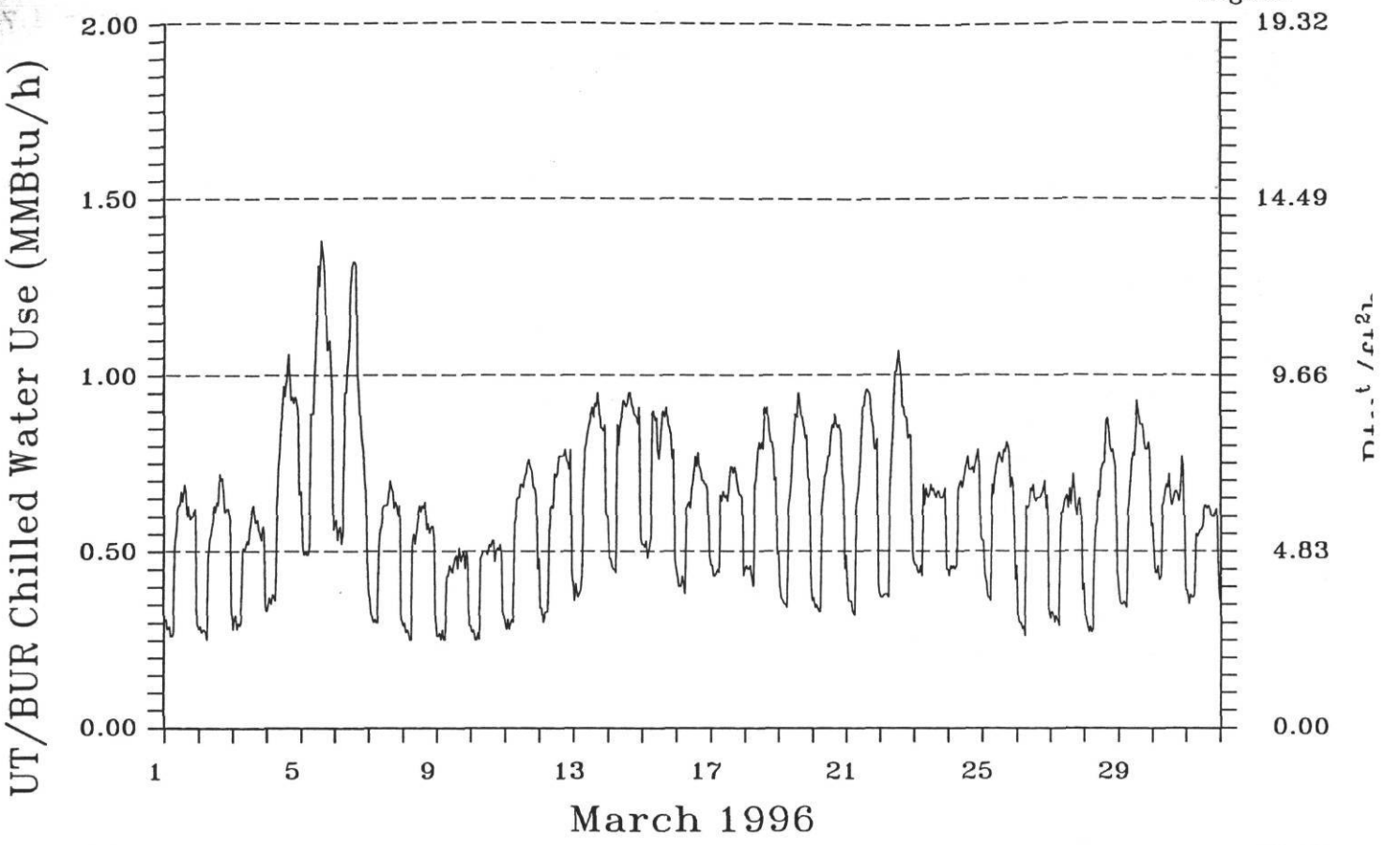
Mar 01 1995 – Mar 31 1996

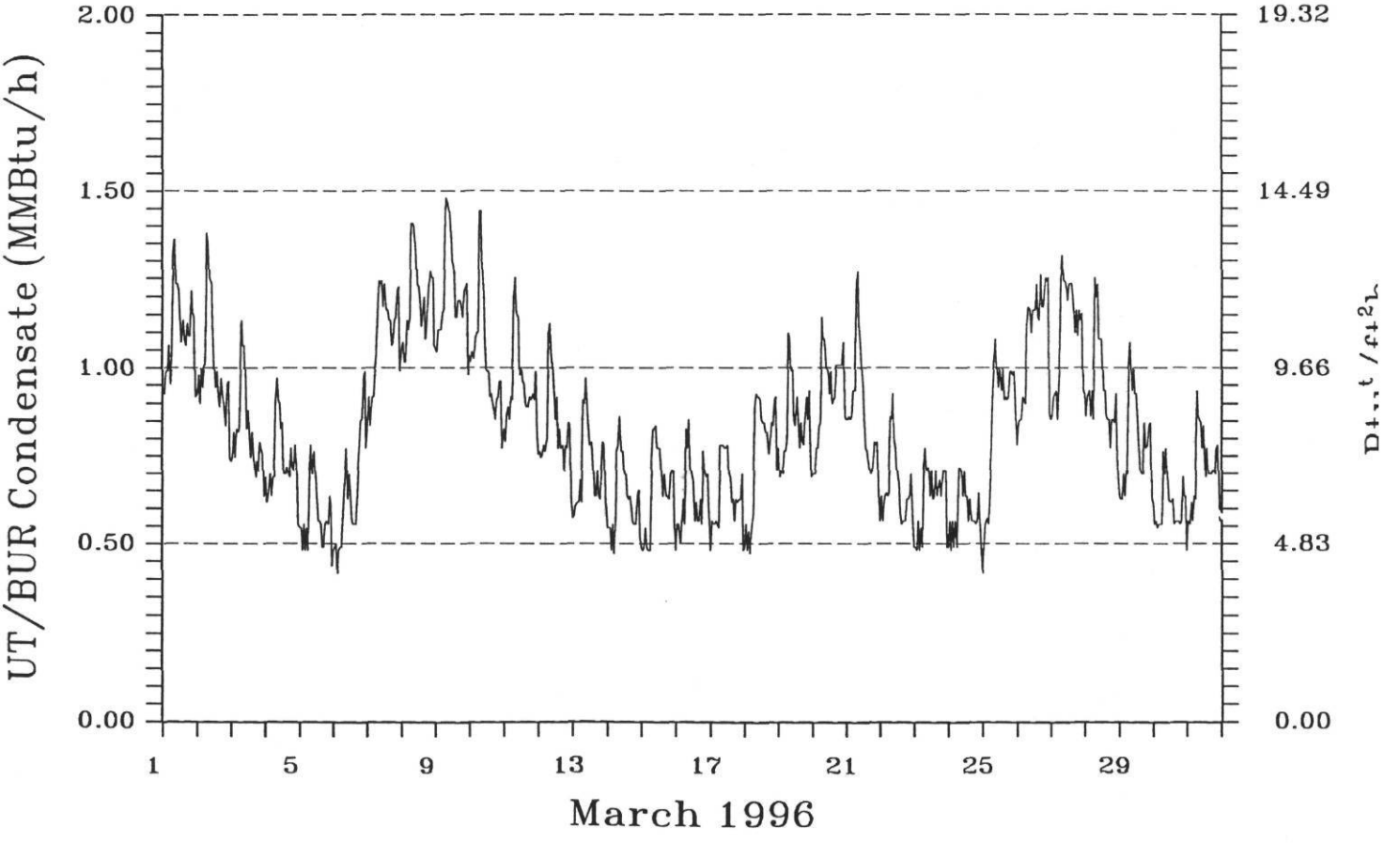


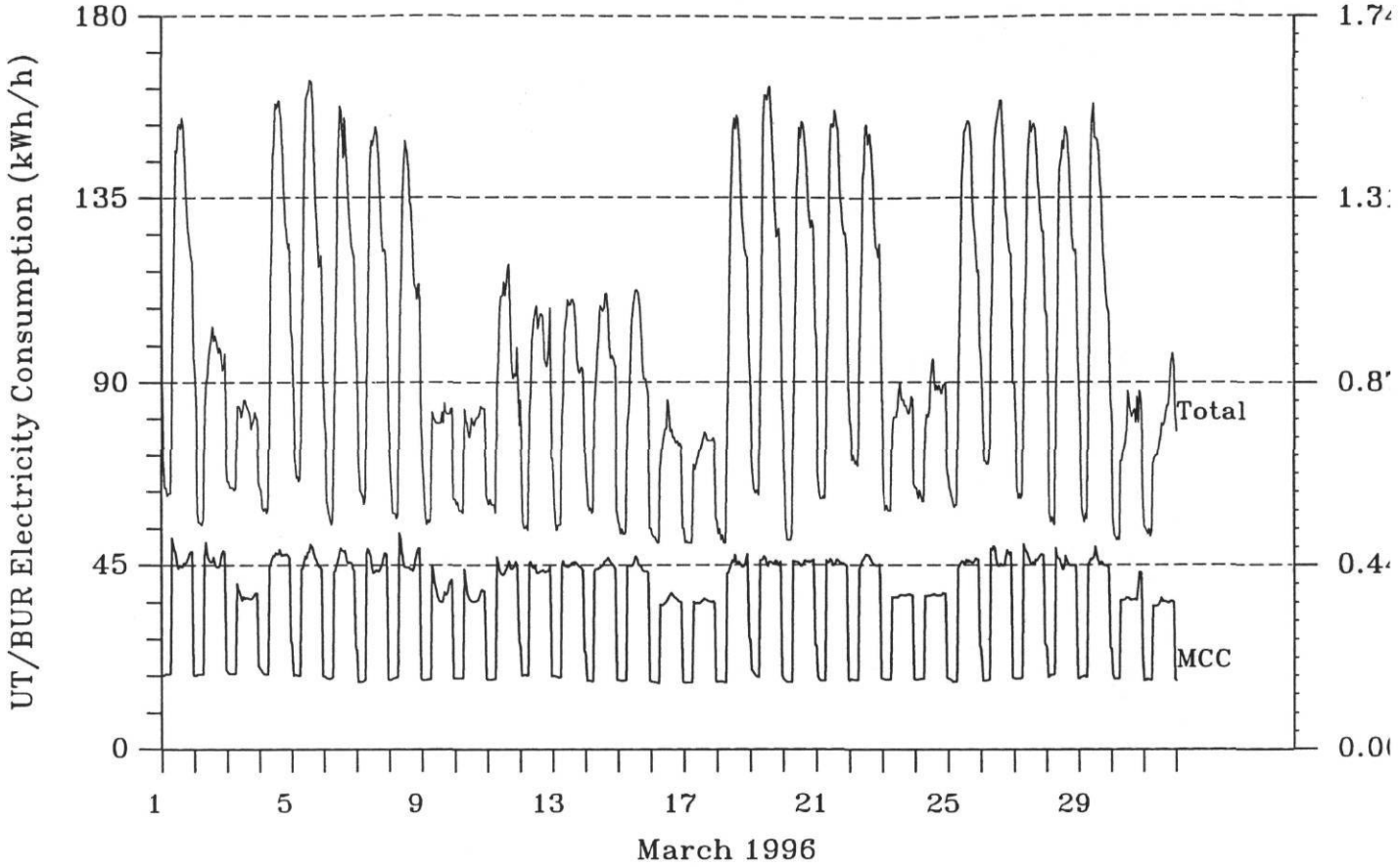
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

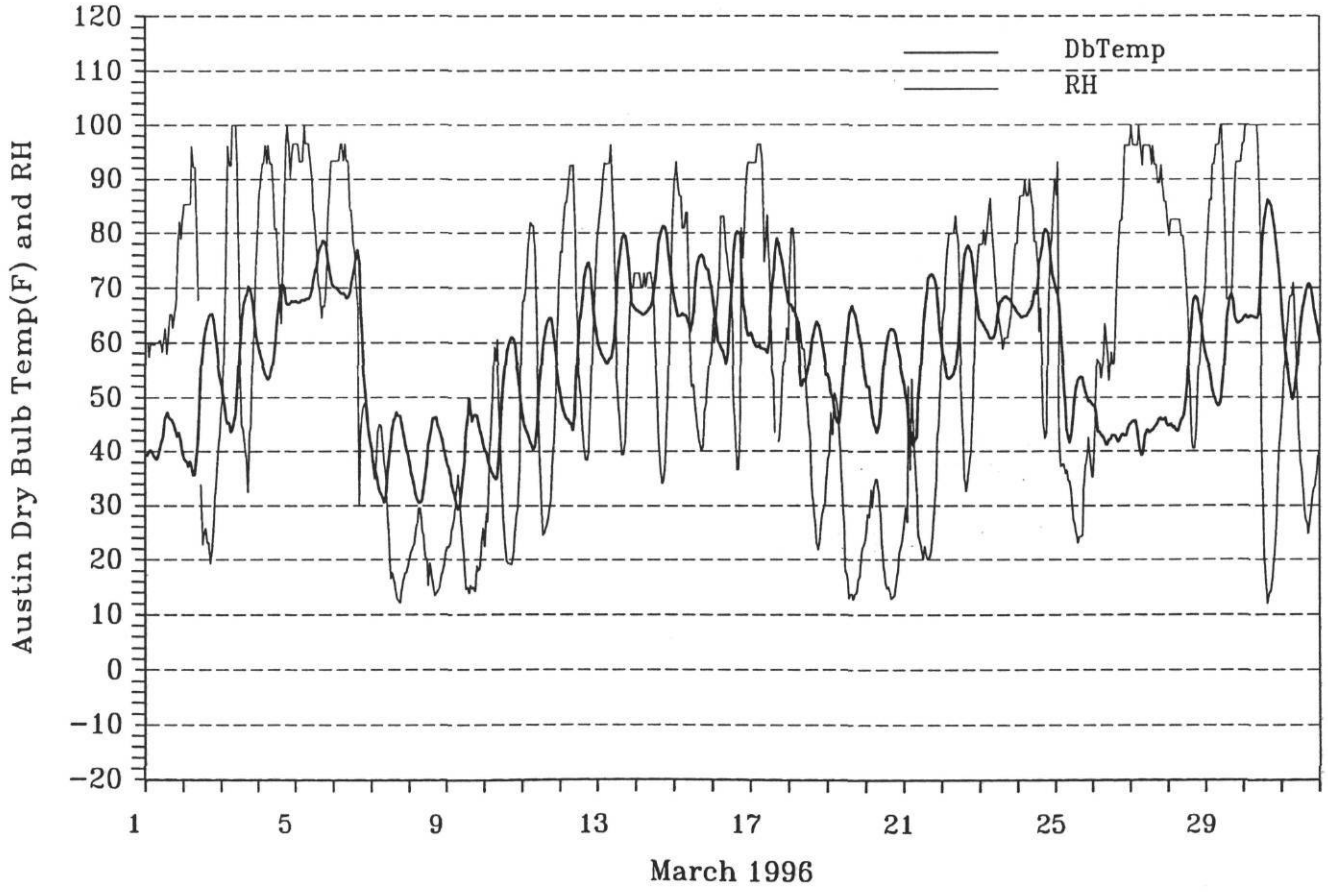
Points from this month last year are shown as +.
All other points are shown as *.

BUR0099 - Burdine Hall - University of Texas - March 1996

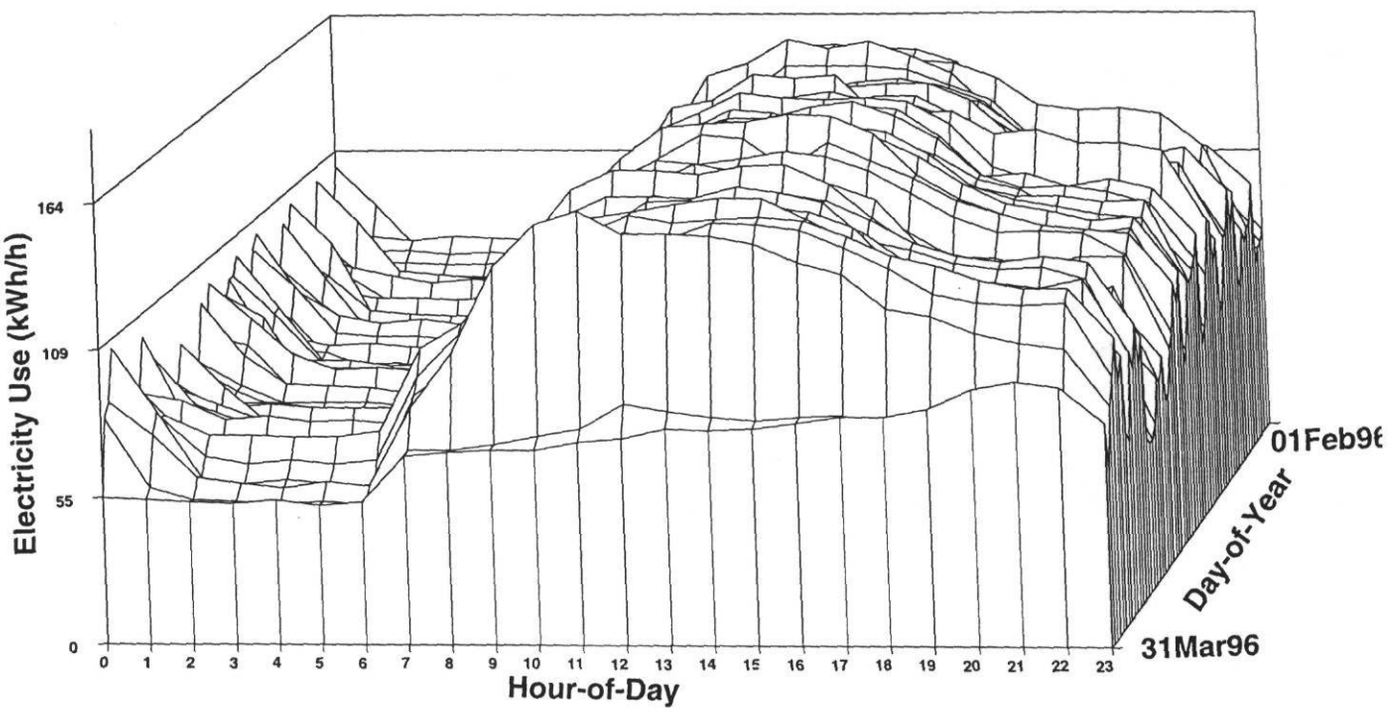

UT/BUR Chilled Water Use (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
19.32
14.49
9.66
4.83
0.00
1
5
9
13
17
21
25
29
March 1996


UT/BUR Condensate (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
19.32
14.49
9.66
4.83
0.00
1
5
9
13
17
21
25
29
March 1996

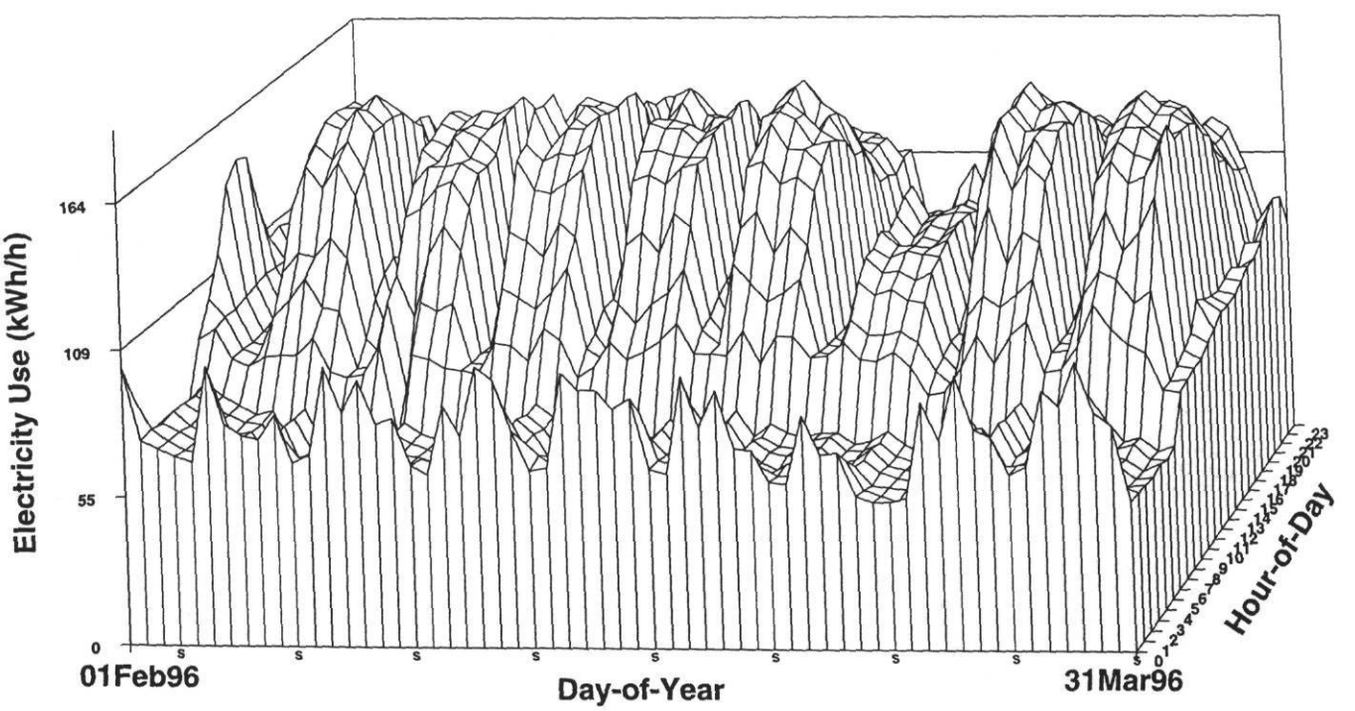

UT/BUR Electricity Consumption (kWh/h)
180
135
90
45
0
1.7
1.3
0.8
0.4
0.0
Total
MCC
1
5
9
13
17
21
25
29
March 1996


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

Whole-Building Electric



Whole-Building Electric



Sundays are marked with an "S"

UT AUSTIN

Burdine Building

Building Envelope:
- 103,441 sq.ft
- classrooms, lecture halls, offices, and auditorium
- walls: concrete with face brick
- windows: single pane
- roof: flat concrete

Building Schedule:
- 7:30 am to 9:30 pm

Building HVAC:
- 2 variable volume dual duct AHUs (1-100hp,1-75hp)
- 2 constant volume single zone AHUs (1-15hp, 1-0.5hp)
- 2 outside air fans (2-10hp)
- 1 variable volume chilled water pump (40hp)
- 1 constant volume chilled water pump (40 hp)
- 1 domestic hot water pump (0.75hp)
- 10 exhaust fans (0.5hp-1.5hp)

HVAC Schedule:
- 24 hours

Lighting:
- fluorescent and some incandescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- all the retrofits completed late May 1991.

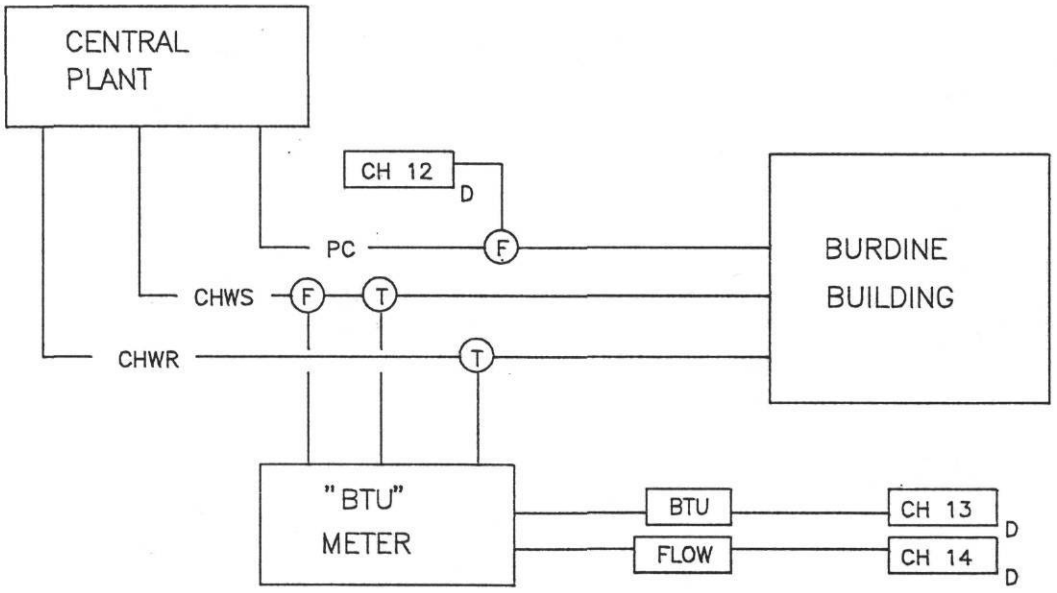
Savings Calculations:
- estimated savings are the average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – BURDINE

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

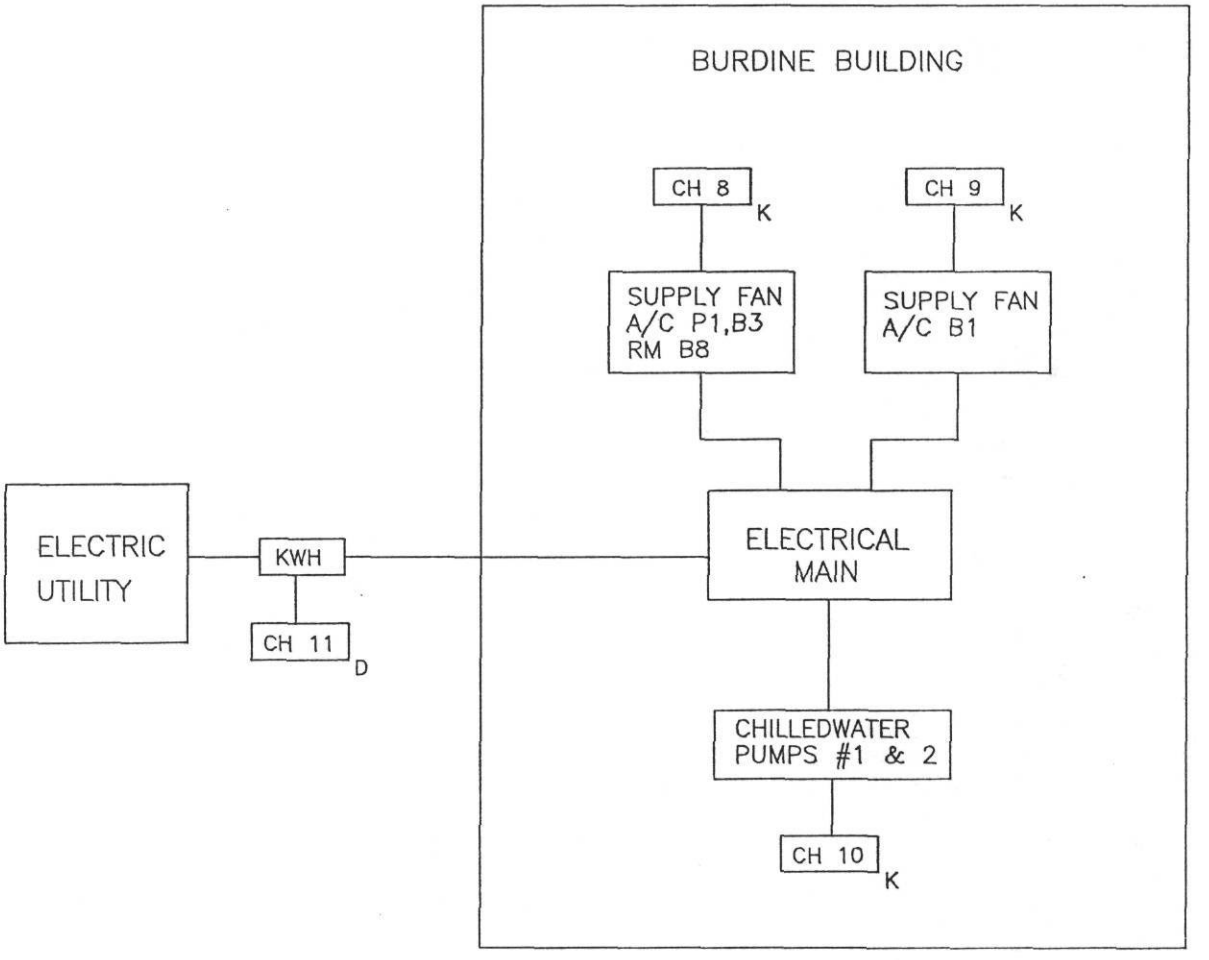


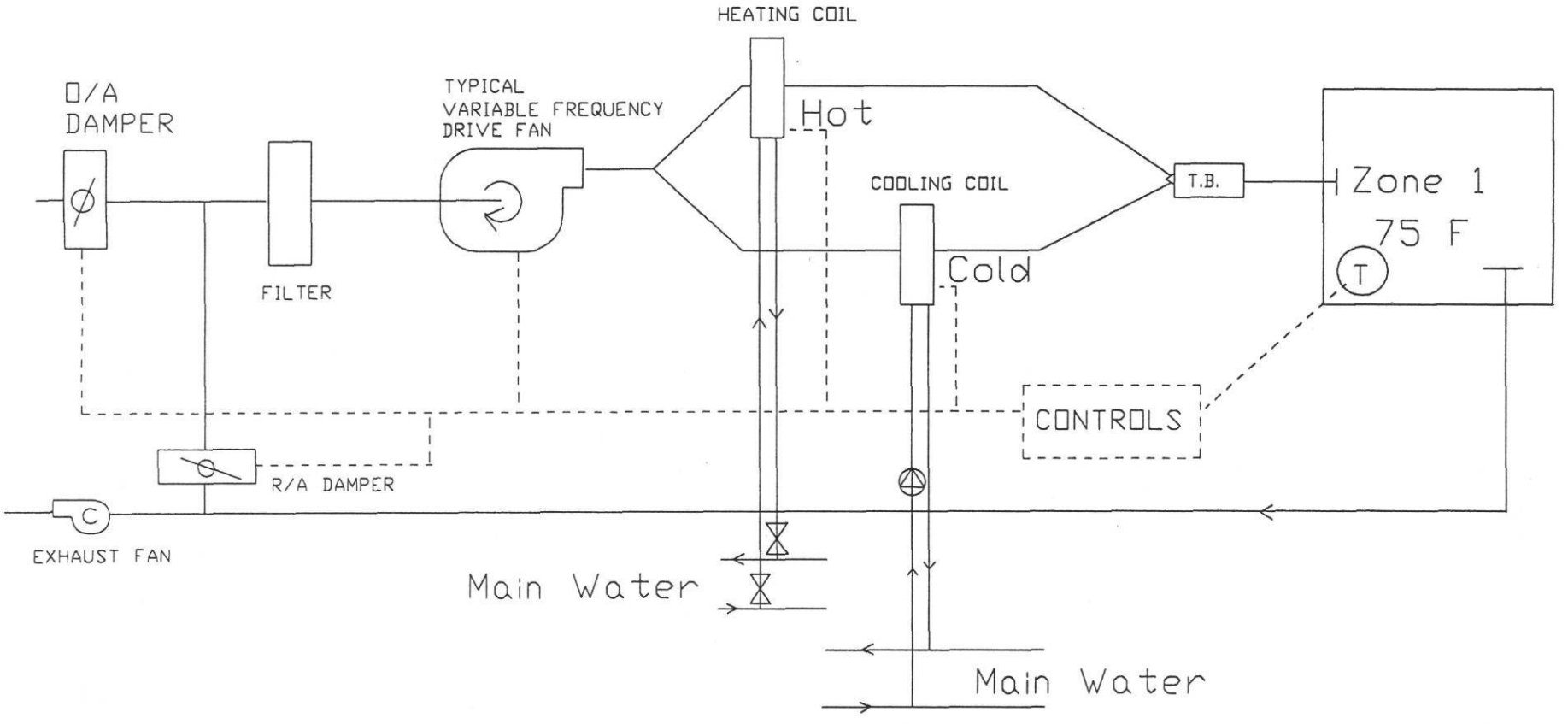
ELECTRICAL MONITORING DIAGRAM

UT AUSTIN – BURDINE

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL





*VARIABLE VOLUME CHILLED WATER PUMP WITH VARIABLE FREQUENCY DRIVE.

Variable-volume

Texas LoanSTAR Program	
Typical Zone 1	Date: May 1, 1991
BUR-107	Drawn by: Mark Rivera

NUR8008

Nursing Building

University of Texas

99,815 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

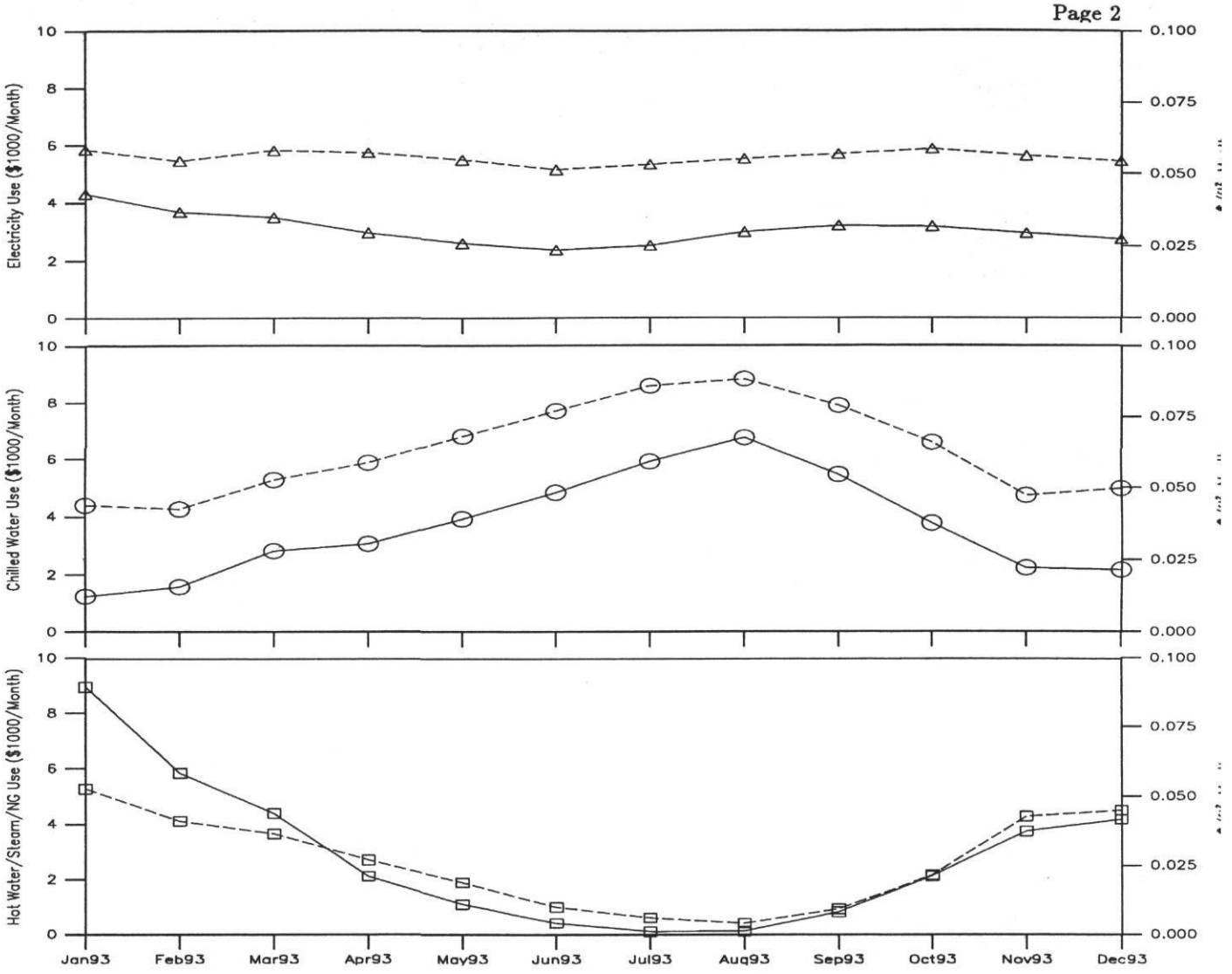
Aamer Athar
053D WERC
Texas A&M University
College Station, TX 77843-3123
(409)–845–9213

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	94739	$4311	100	$1528	168	$1247	100	$3150	1444	$8953	100	$-3677	$1001	$1001
Feb	80724	$3673	100	$1779	213	$1582	100	$2688	941	$5834	100	$-1722	$2745	$3746
Mar	76657	$3488	100	$2320	383	$2844	100	$2437	708	$4390	100	$-734	$4023	$7769
Apr	65114	$2963	99	$2759	417	$3096	99	$2785	342	$2120	99	$583	$6127	$13896
May	57205	$2603	100	$2866	531	$3943	100	$2862	177	$1097	100	$790	$6518	$20414
Jun	52057	$2369	96	$2766	652	$4841	96	$2857	68	$422	96	$575	$6198	$26612
Jul	55479	$2524	88	$2790	796	$5910	88	$2687	18	$112	88	$503	$5980	$32592
Aug	65506	$2981	100	$2530	911	$6764	100	$2085	21	$130	100	$295	$4910	$37502
Sep	70542	$3210	100	$2479	735	$5457	100	$2432	133	$825	100	$104	$5015	$42517
Oct	69924	$3182	100	$2671	508	$3772	100	$2809	343	$2127	100	$40	$5520	$48037
Nov	64700	$2944	100	$2658	299	$2220	100	$2506	604	$3745	100	$536	$5700	$53737
Dec	60137	$2736	100	$2694	290	$2153	100	$2823	673	$4173	100	$319	$5836	$59573
Total	812784	$36984		$29840	5903	$43829		$32121	5472	$33928		$-2388		$59573
EUI	8.1	$\frac{kWh}{ft^2yr}$			59139	$\frac{Btu}{ft^2yr}$			54821	$\frac{Btu}{ft^2yr}$				

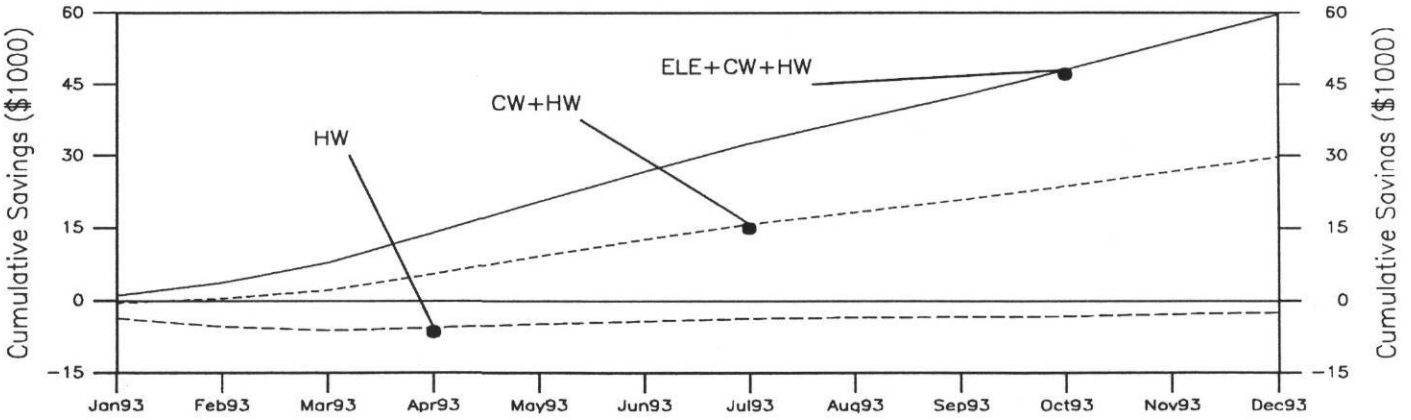
Comments

★ **The percent columns indicate the number of hours reported in that month.**
★ **The LoanSTAR monitoring began in November 1990.**
★ **The HVAC retrofit was completed in April 1991.**
★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**
★ **The audit estimated savings for HVAC retrofits are: $38,600 (ELE), $22,500 (CW), $13,200 (Steam) and $74,300 (Total).**
★ **Negative steam savings in January, February and March are due to use of the economiser cycle.**
★ **Electricity, chilled water and steam consumption for part of July were estimated using post retrofit regression models because of missing data due to hardware problems.**
★ **Increase in electricity and chilled water savings were noticed when compared to 1992. Conversations with UT personnel have revealed that AHUs where put on slow roll after 4/16/93 and that the economiser cycle was disabled in 10/93.**
★ **Savings attributable to O&M improvements include: disabling the economiser cycle $5,500 (included in the cumulative savings).**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



NUR8008

Nursing Building

University of Texas
99,815 square feet

Site Contact

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LoanSTAR Metering Contact

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053D 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	88220 kWh	100	$0.04550	$4014
Peak 60 Minute Demand	202 kW	100	-	-
Chilled Water	459.4 MMBtu	100	$7.425	$3411
Condensate	1015.6 MMBtu	100	$6.200	$6296

Peak 60 minute demand was recorded at 1100 Thursday 03/07/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	39807	$1811	70625	$3213
Chilled Water (MMBtu)	213	$1582	253	$1879
Cond./H.W./N.G. (MMBtu)	-315	$-1953	177	$1097
Monthly Total		$1440		$6189
Total to Date*	(60 months)	$255909	(59 months)	$365172

*Measured savings include construction period. Audit estimated savings do not.

Comments

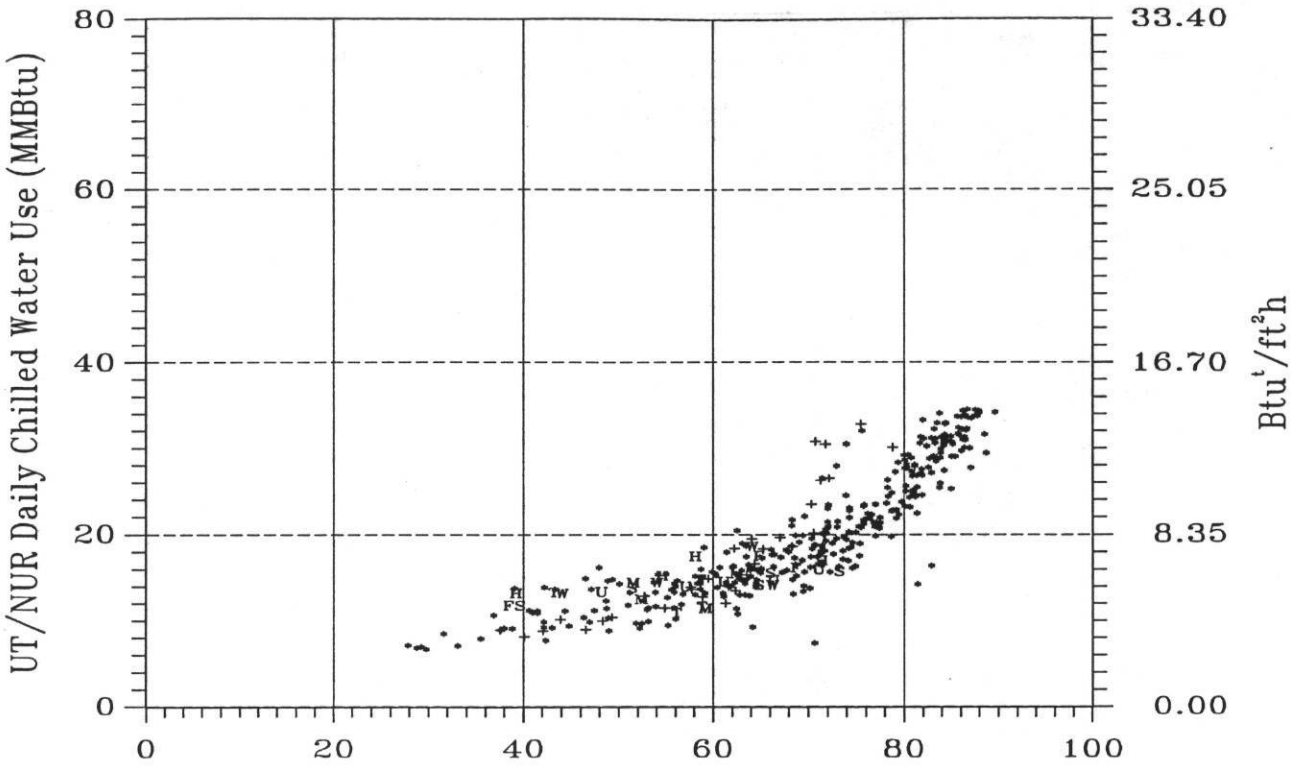
★ The slow rolling of the AHUs restarted on 2/6/96.

★ Weekend electricity use is 25 kW higher in the evenings than during the day. This pattern was not observed in 1995.

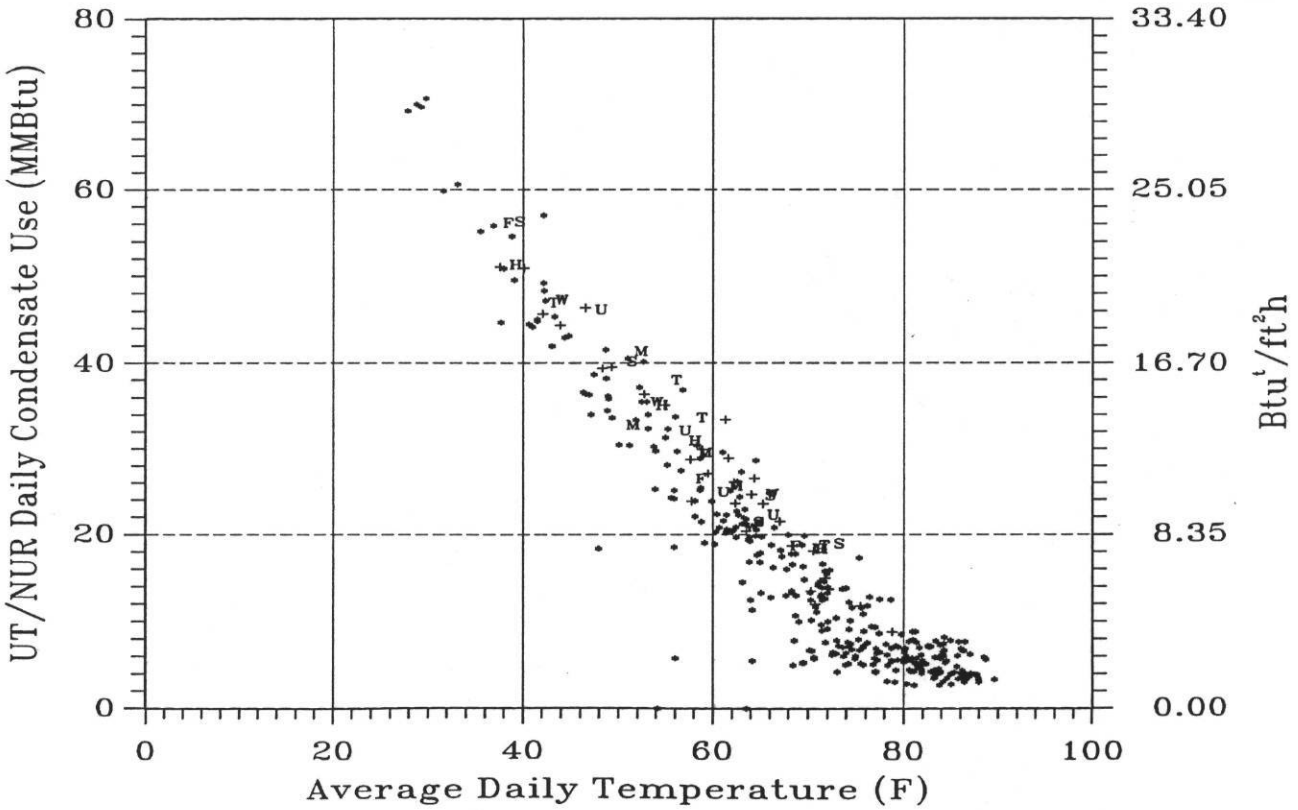
★ Chilled water energy consumption has decreased when compared to March 1995 for temperatures greater than 60°F.

★ Spring Break is evident as reduced electricity consumption from 3/11/96 to 3/17/96.

Mar 01 1995 – Mar 31 1996

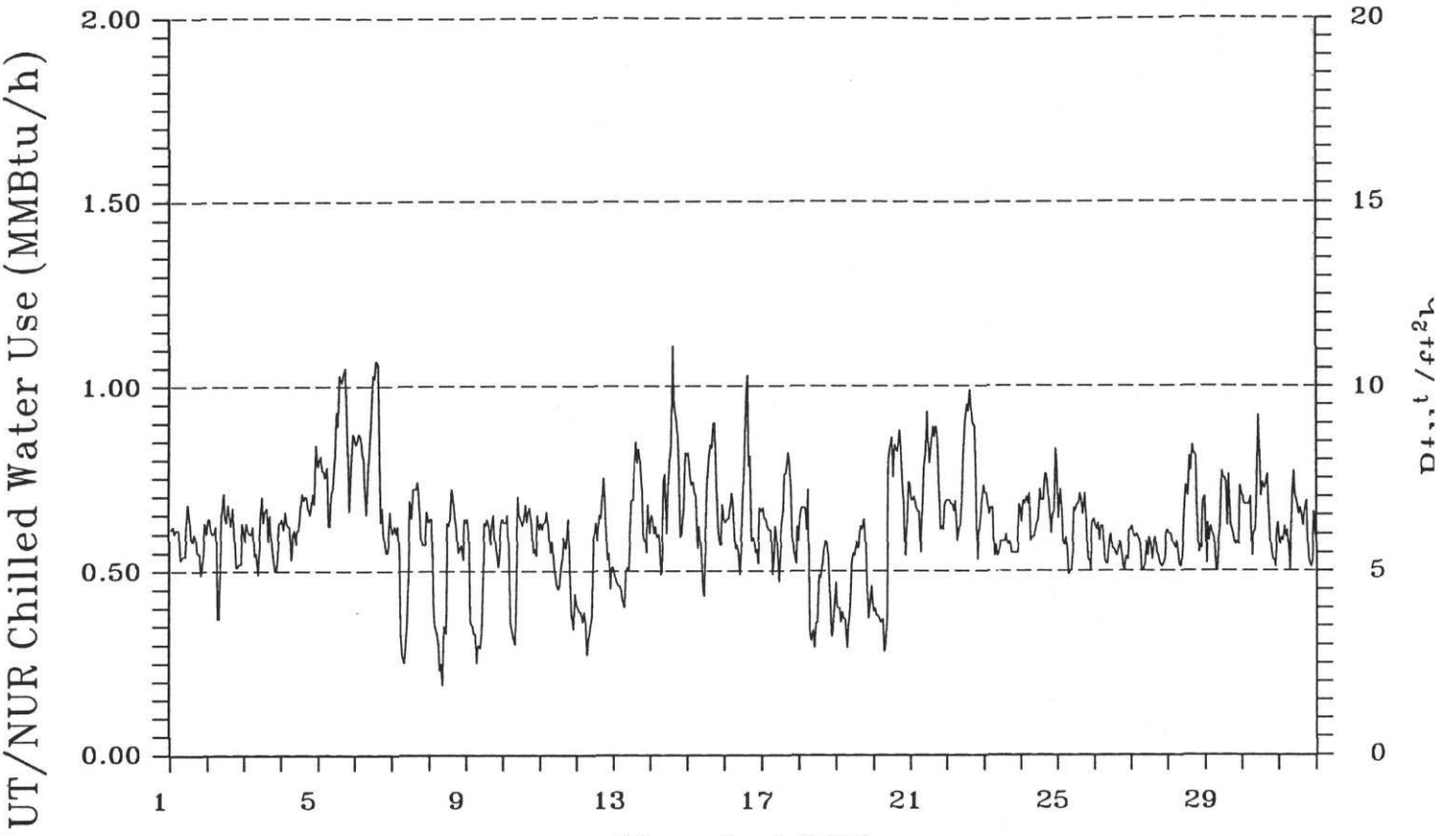


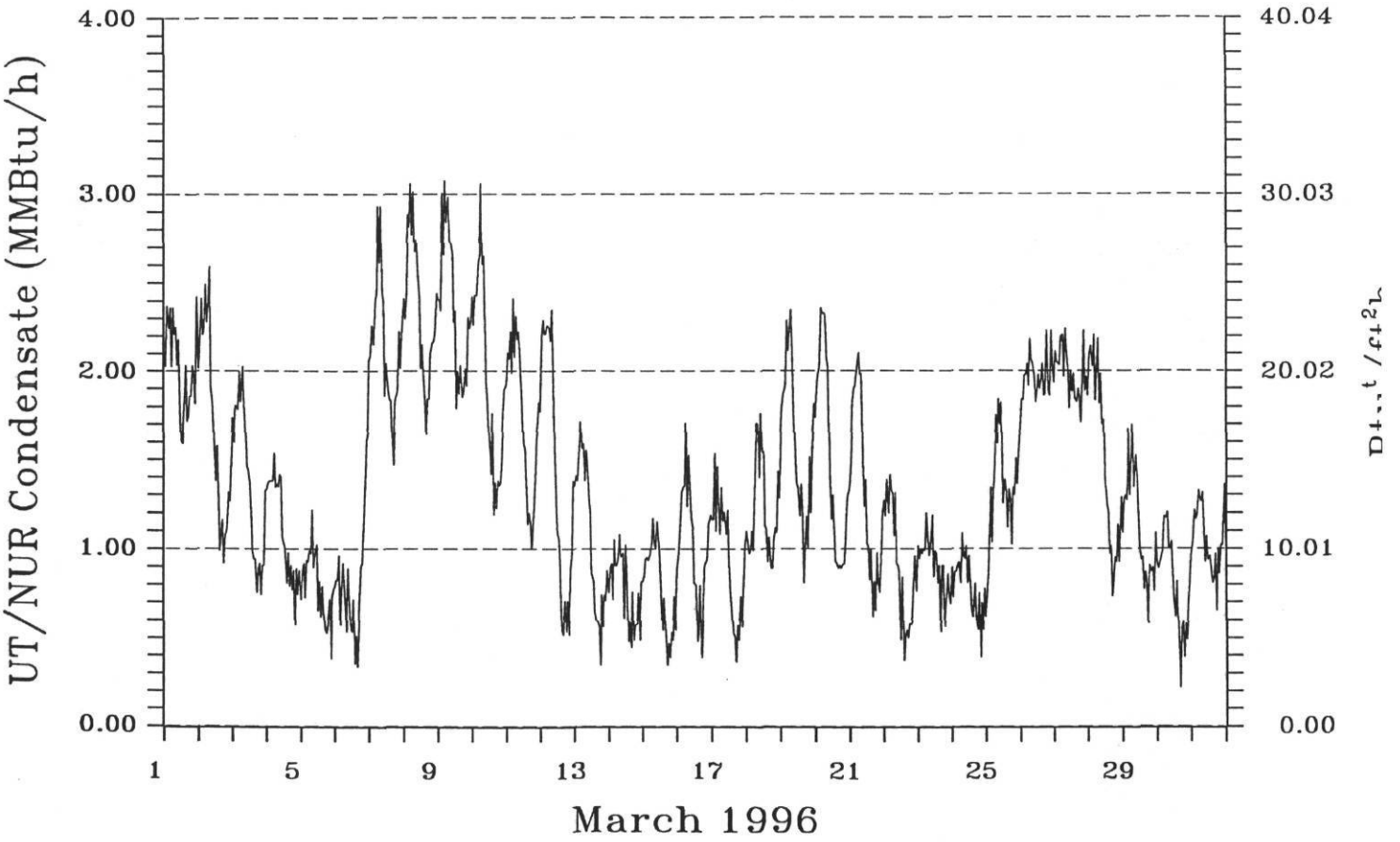
Mar 01 1995 – Mar 31 1996

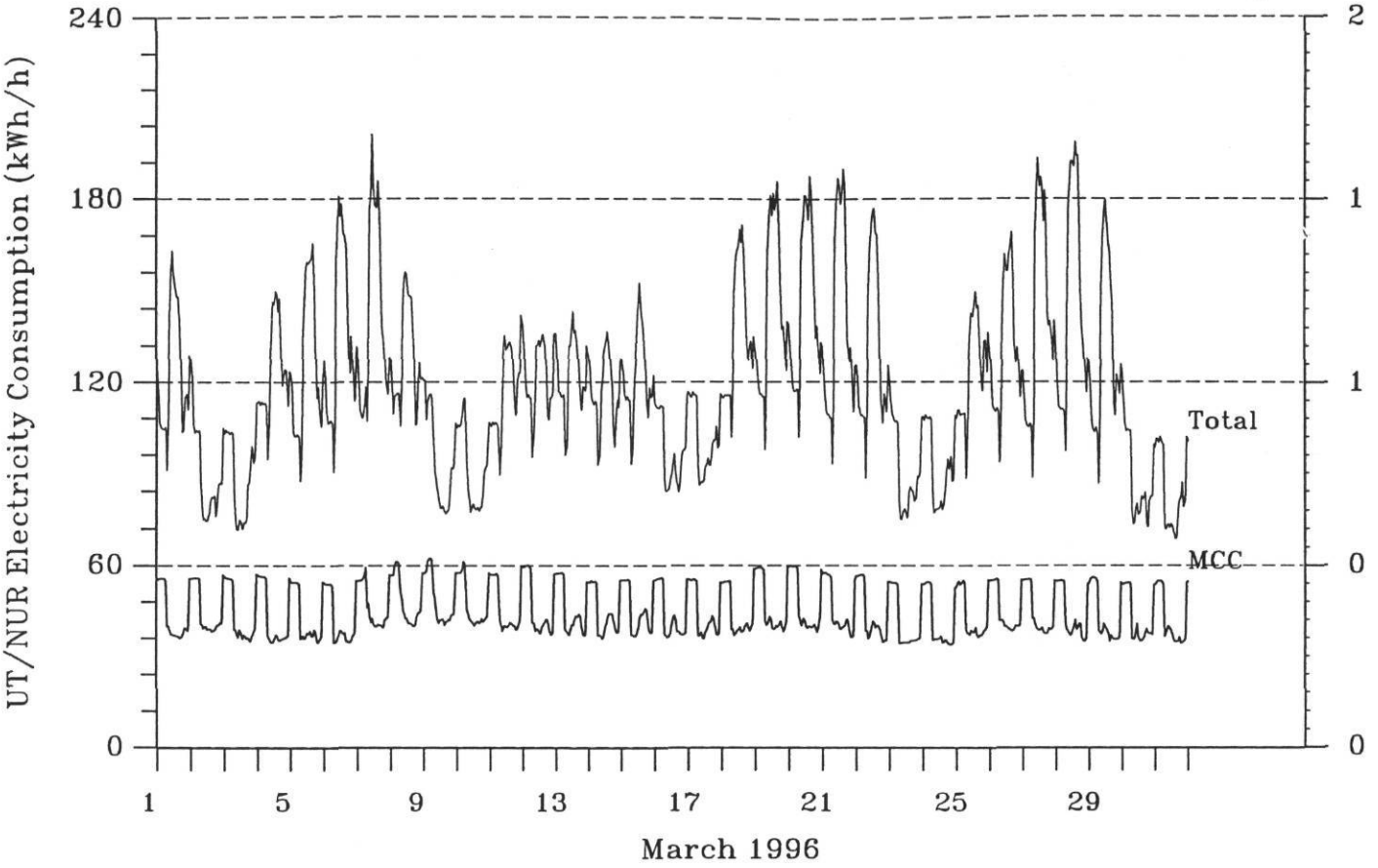


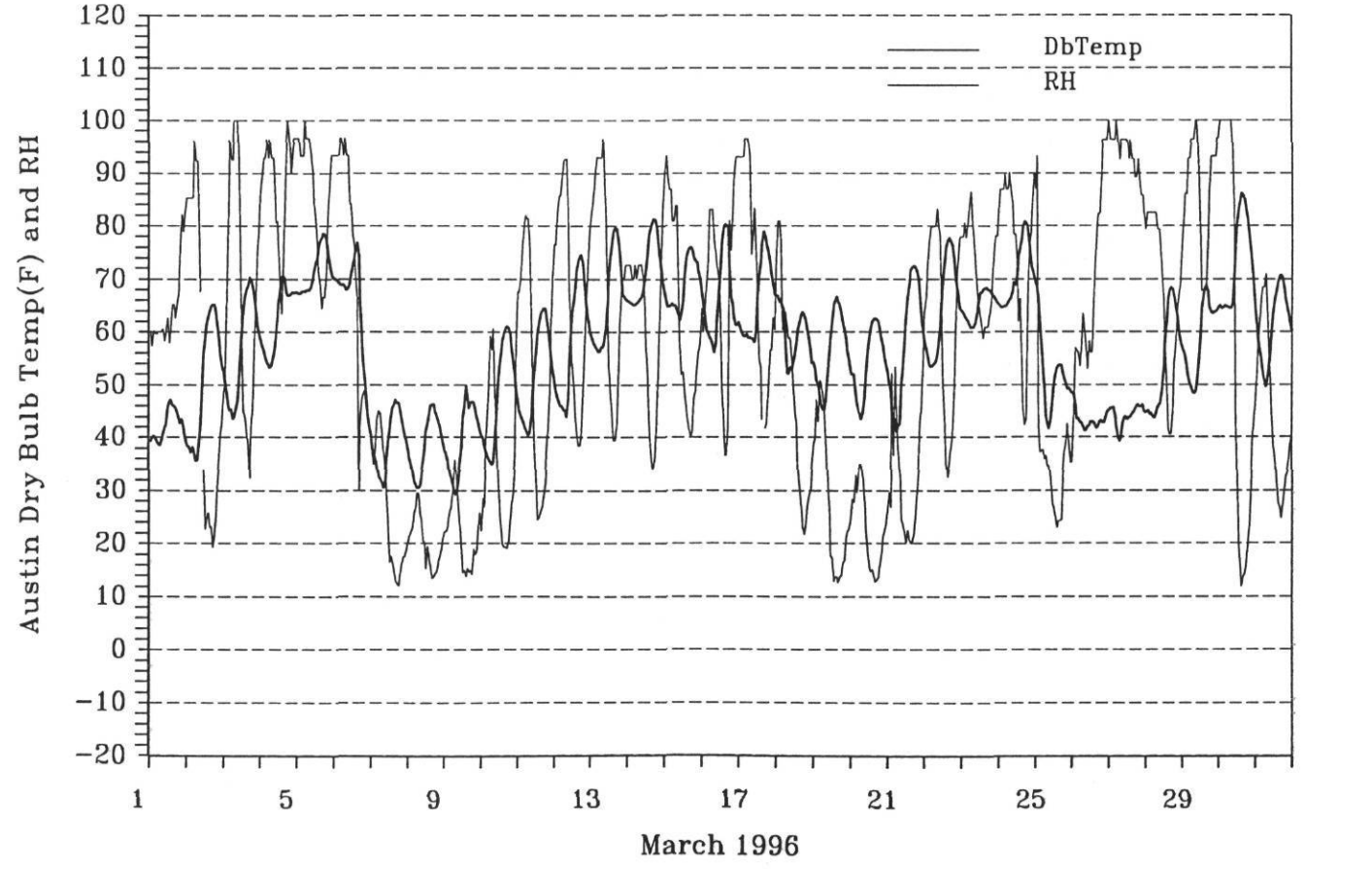
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

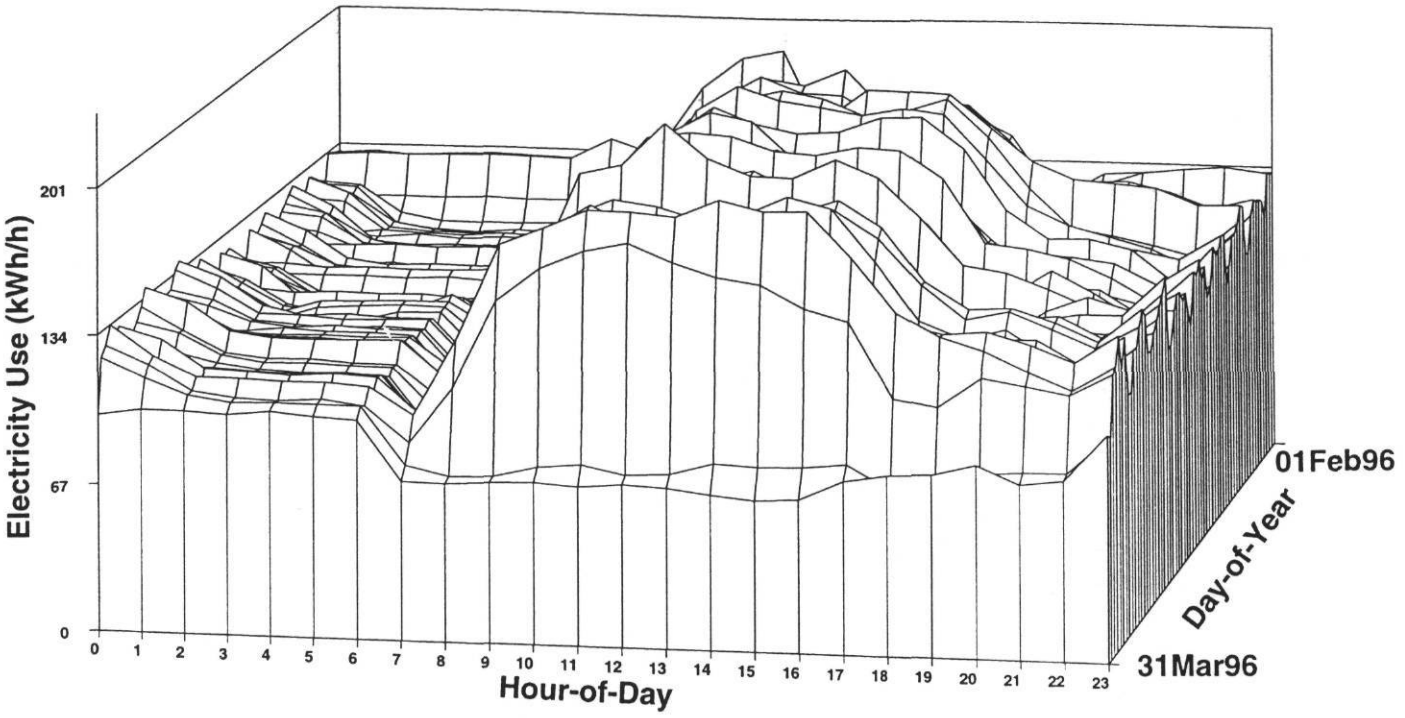

UT/NUR Chilled Water Use (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
20
15
10
5
0
1
5
9
13
17
21
25
29
March 1996


UT/NUR Condensate (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
40.04
30.03
20.02
10.01
0.00
1
5
9
13
17
21
25
29
March 1996

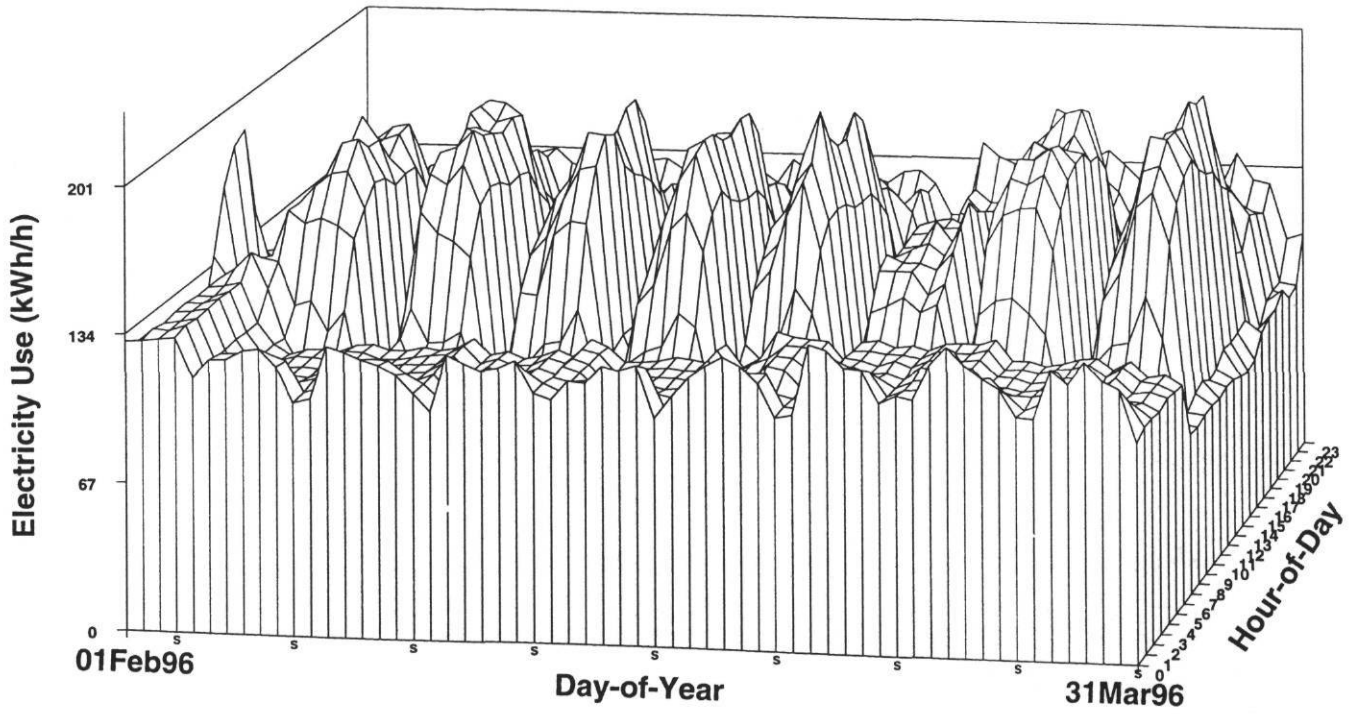

UT/NUR Electricity Consumption (kWh/h)
240
180
120
60
0
2
1
1
0
0
Total
MCC
1
5
9
13
17
21
25
29
March 1996


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

Whole-Building Electric



Whole-Building Electric



Sundays are marked with an "S"

UT AUSTIN

Nursing Building

Building Envelope:
- 94,815 sq.ft
- classrooms, lecture halls, lounges
- walls: pre-cast concrete
- windows: single pane clear
- roof: flat concrete

Building Schedule:
- 6:30 am to 9:30 pm, 7 days a week, all year long

Building HVAC:
- 2 variable volume AHUs (2-100hp)
- 8 relief air fans (8-5hp)
- 1 variable volume chilled water pump (30 hp)
- 1 domestic hot water pump (1/12hp)
- 10 exhaust fans (1/20hp - 1hp)
- economizer cycle has been added as a part of the retrofit

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent and some incandescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- Both the retrofits were completed at the end of April 1991.

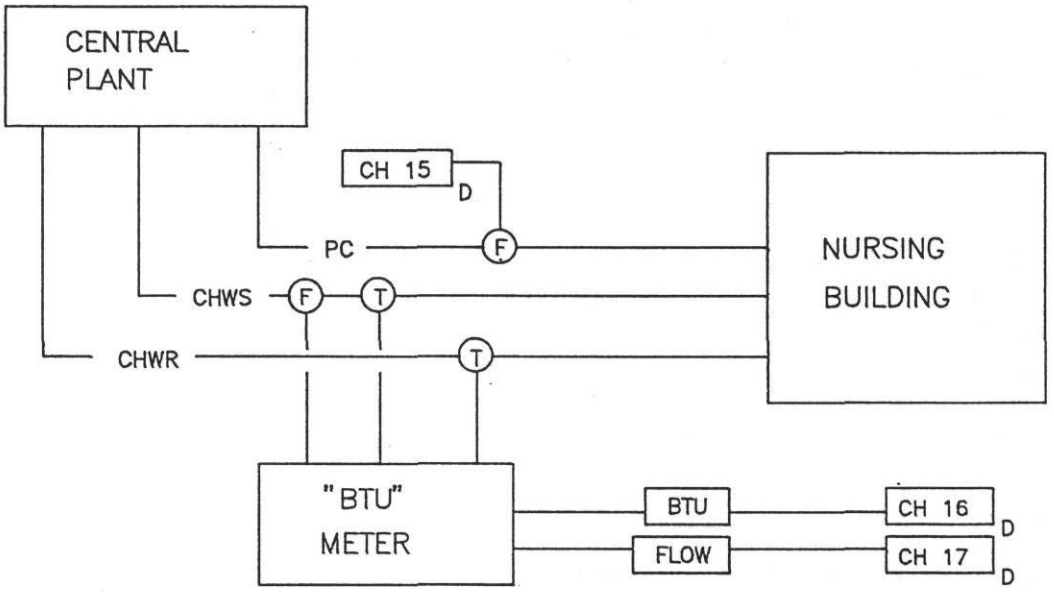
Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – NURSING

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

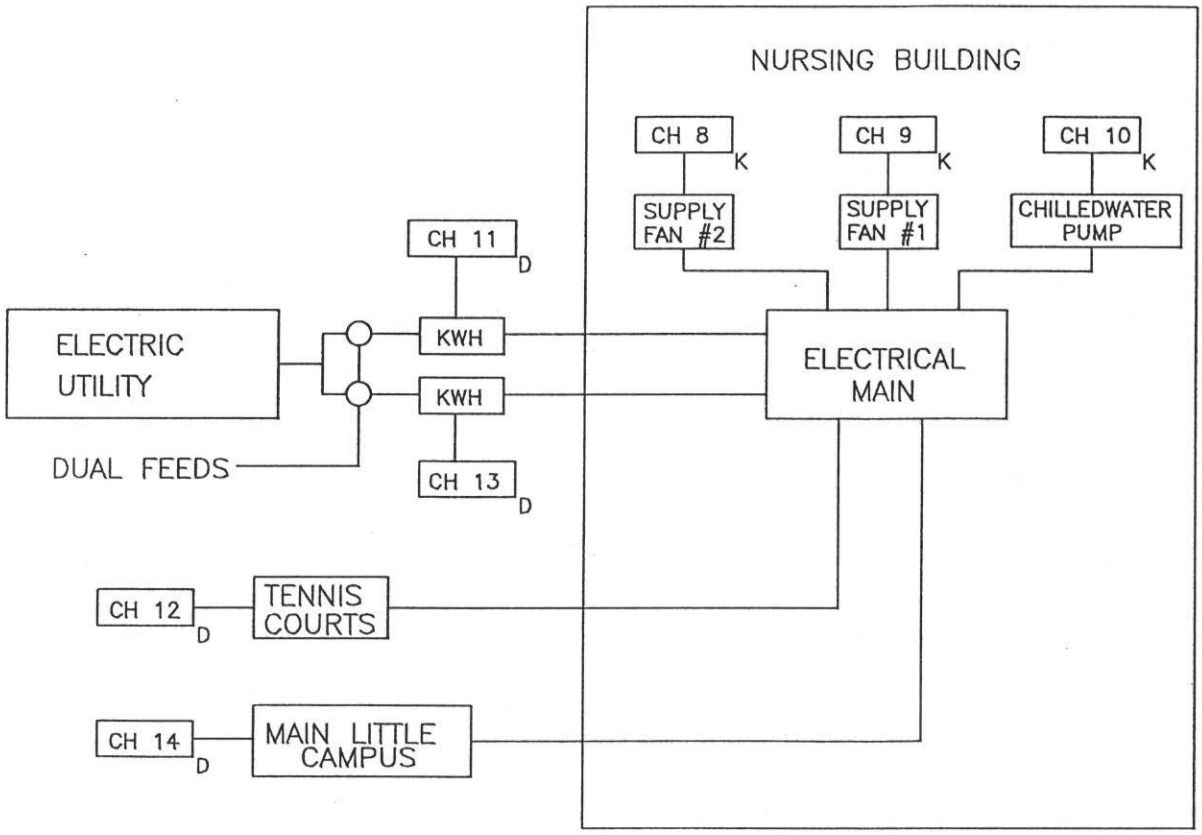


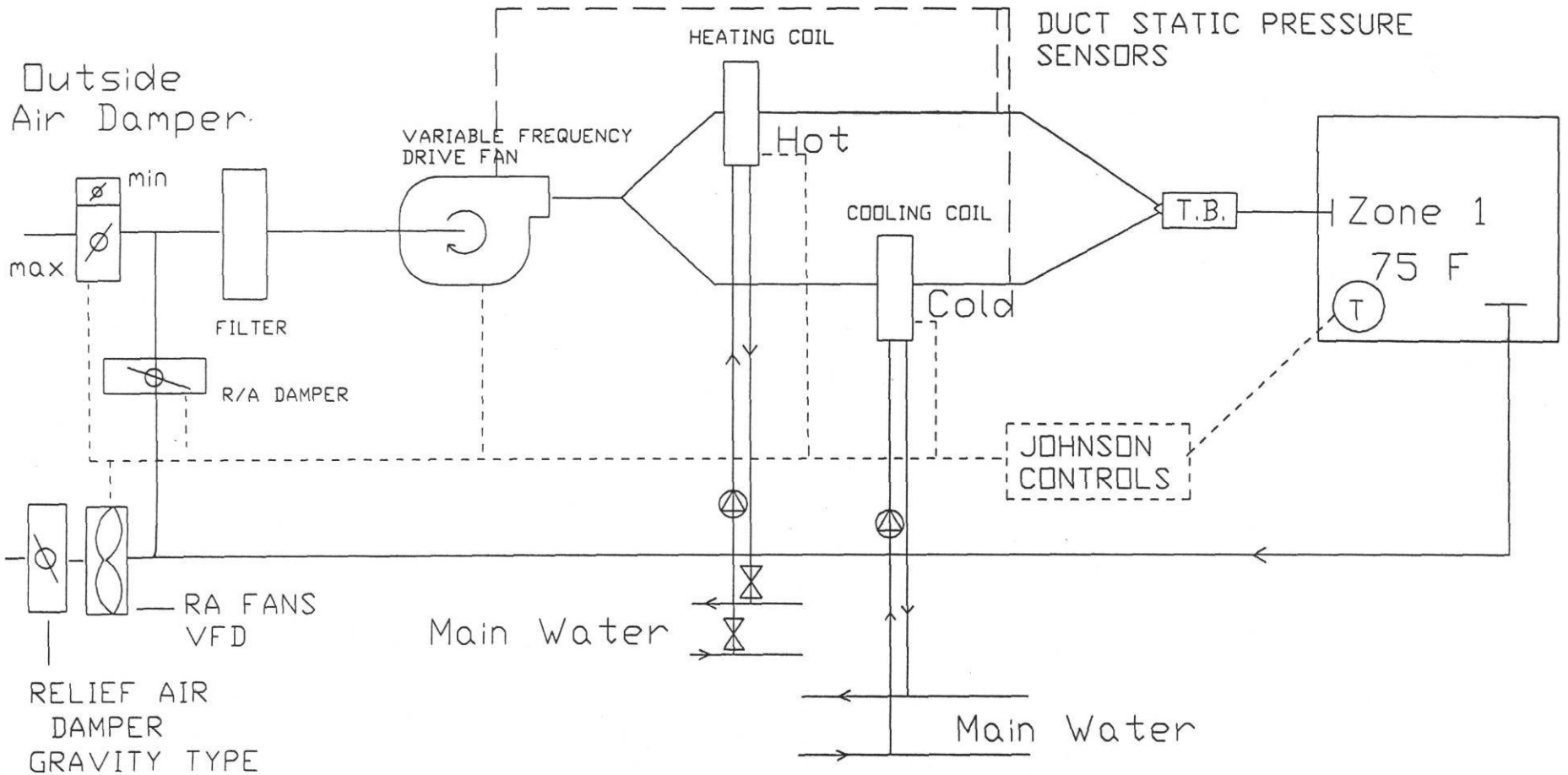
ELECTRICAL MONITORING DIAGRAM

UT AUSTIN – NURSING

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL





Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- NURSING BUILDING	
Typical Dual-Duct System	Date: May 1, 1991
NUR-108	Drawn by: Mark Rivera

GAR0249

Garrison Hall

University of Texas
54,069 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	24542	$1117	59	$1037	59	$438	59	$1478	110	$682	59	$712	$3227	$3227
Feb	23941	$1089	100	$1098	109	$809	100	$1397	139	$862	100	$722	$3217	$6444
Mar	25049	$1140	100	$1203	141	$1047	100	$1807	106	$657	100	$861	$3871	$10315
Apr	27850	$1267	99	$1043	229	$1700	100	$1459	68	$422	99	$109	$2611	$12926
May	23928	$1089	99	$1121	231	$1715	99	$1947	40	$248	99	$-210	$2858	$15784
Jun	23491	$1069	100	$1051	364	$2703	100	$1619	31	$192	100	$-137	$2533	$18317
Jul	23841	$1085	100	$1036	444	$3297	100	$1473	33	$205	100	$-148	$2361	$20678
Aug	26088	$1187	100	$1009	444	$3297	100	$1661	34	$211	100	$-154	$2516	$23194
Sep	27858	$1268	100	$1065	359	$2666	100	$1724	34	$211	100	$-158	$2631	$25825
Oct	27510	$1252	100	$1145	179	$1329	100	$2350	61	$378	100	$-188	$3307	$29132
Nov	29067	$1323	100	$1086	55	$408	100	$2051	158	$980	100	$677	$3814	$32946
Dec	24281	$1105	99	$1182	29	$215	99	$2322	496	$3075	99	$-1360	$2144	$35090
Total	307446	$13991		$13076	2643	$19624		$21288	1310	$8123		$726		$35090
EUI	5.7	$\frac{kWh}{ft^2yr}$			48881	$\frac{Btu}{ft^2yr}$			24228	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in November 1990.**

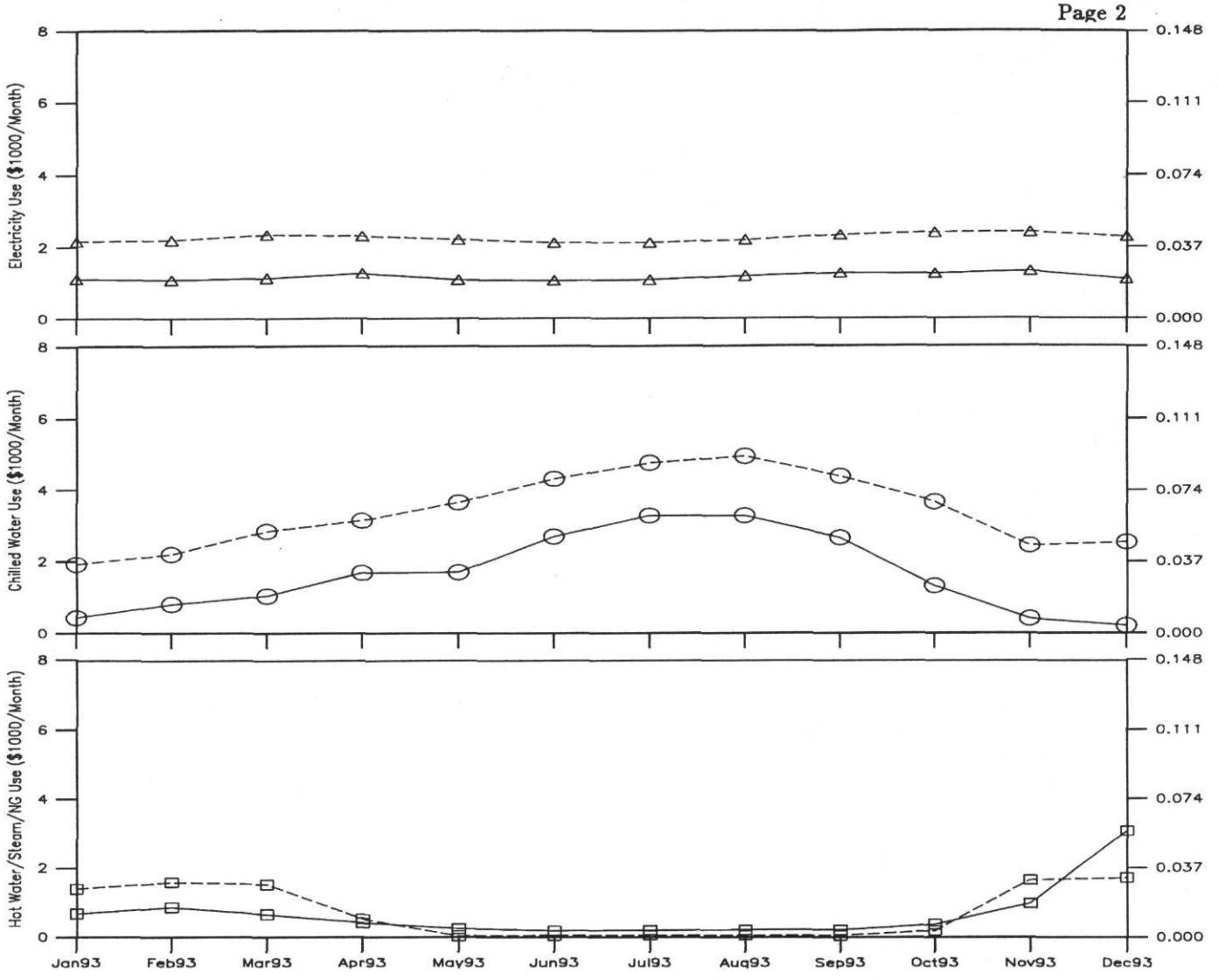
★ **The HVAC retrofit was completed in May 1991.**

★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.425/MMBtu (CW), and $6.2/MMBtu (Steam).**

★ **The audit estimated savings for HVAC retrofits are: $15,900 (ELE), $10,400 (CW), $7,800 (Steam), and $34,100 (Total).**

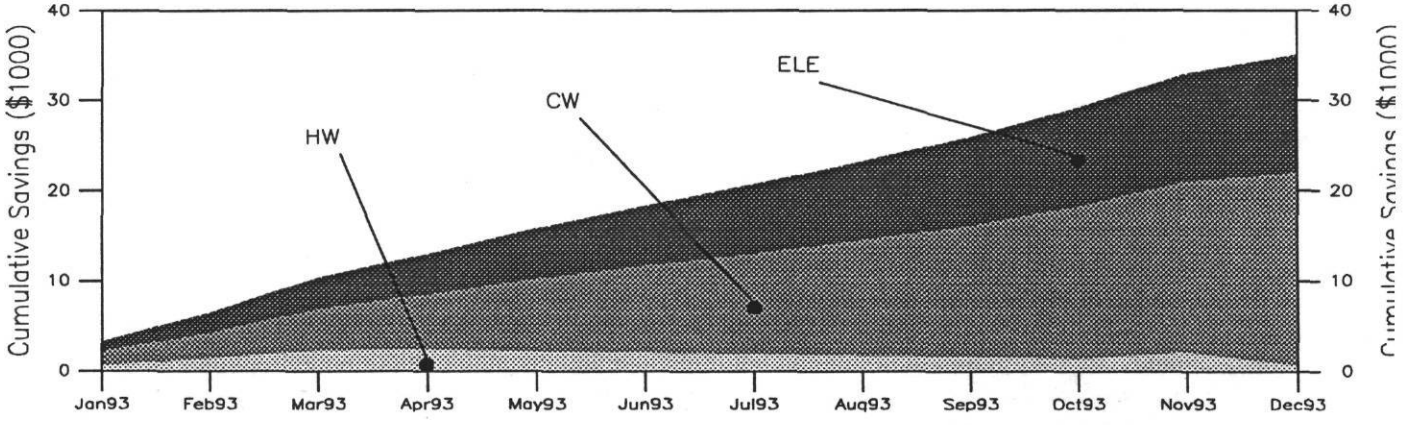
★ **Negative steam savings from May through October 1993 were due to non-closure of steam valve this year.**

★ **Negative steam savings for December 1993 were due to a change in the hot deck setting.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



UT AUSTIN

Garrison Hall

Building Envelope:
- 54,069 sq.ft
- 4 floors and a basement, erected 1926, classes, offices, and auditorium
- walls: hollow clay tile with a cut stone exterior
- windows: 19% of total wall area, single pane clear operable
- roof: pitched with clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- auditorium: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 2 variable volume dual duct AHUs (1-30 hp, 1-25 hp)
- 1 variable volume multizone AHU (5 hp)
- 1 constant volume single zone AHU (3 hp)
- 1 variable volume chilled water pump (1-15hp)
- 1 constant volume hot water pump (1-3hp)
- 7 ex. fans (6-1hp, 1-15hp)

HVAC Schedule:
- 5 am - 11pm (Mon - Sat) Air Handling units are turned off/slow rolled by Facility Control & Monitoring System (FCMS) from 11:00 pm to 5:00 am (Mon thru Sun).

Lighting:
- fluorescent, some incandescent lights

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- VAV conversion and variable speed pumping was completed at the end of May 1991.

Savings Calculations:
- estimated savings are average monthly savings from the audir report (total annual savings divided by 12).

GAR0249

Garrison Hall

University of Texas
54,069 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

Aamer Athar
053D 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	30088 kWh	100	$0.04550	$1369
Peak 60 Minute Demand	81 kW	100	-	-
Chilled Water	- MMBtu	-	-	-
Condensate	127.0 MMBtu	100	$6.200	$787

Peak 60 minute demand was recorded at 1100 Wednesday 03/27/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	24196	$1101	33251	$1513
Chilled Water (MMBtu)	339	$2517	117	$869
Cond./H.W./N.G. (MMBtu)	143	$887	105	$651
Monthly Total		$4505		$3033
Total to Date*	(63 months)	$190456	(59 months)	$178926

*Measured savings include construction period. Audit estimated savings do not.

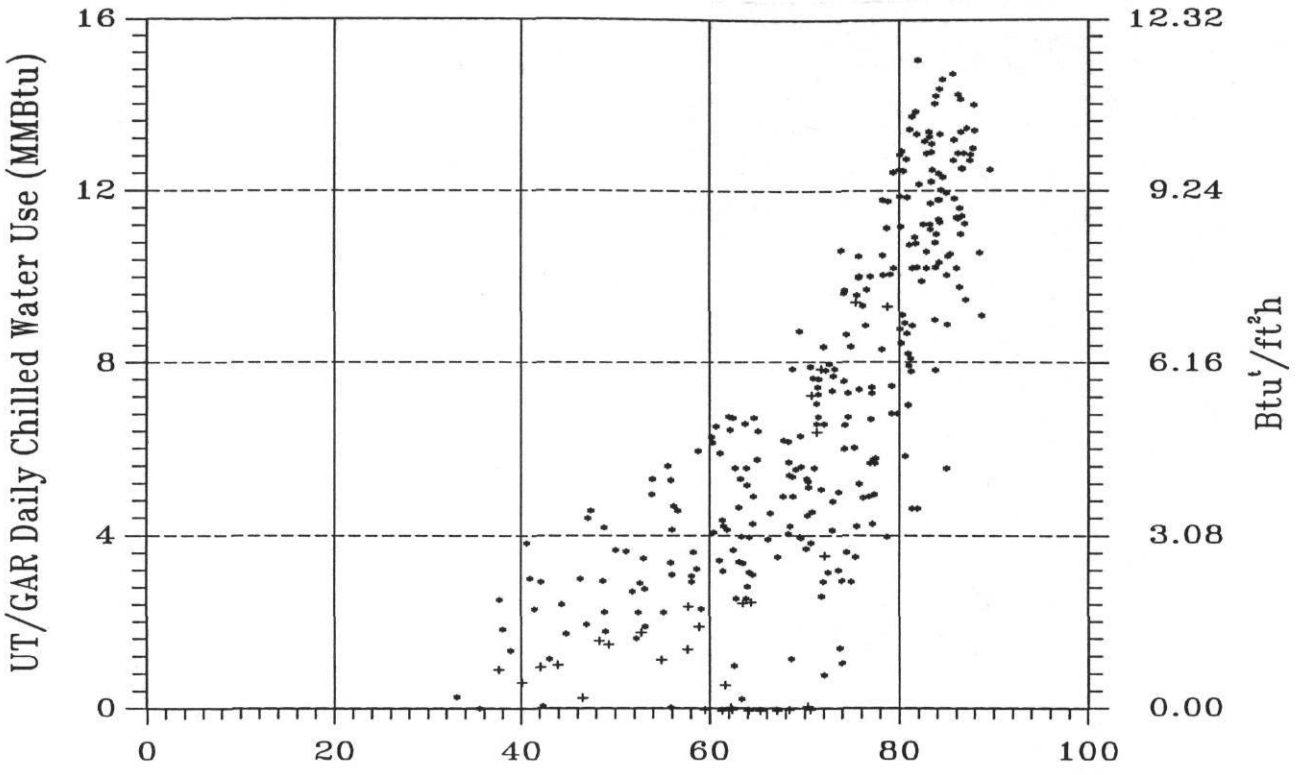
Comments

★ Electricity consumption has increased when compared to March 1995.

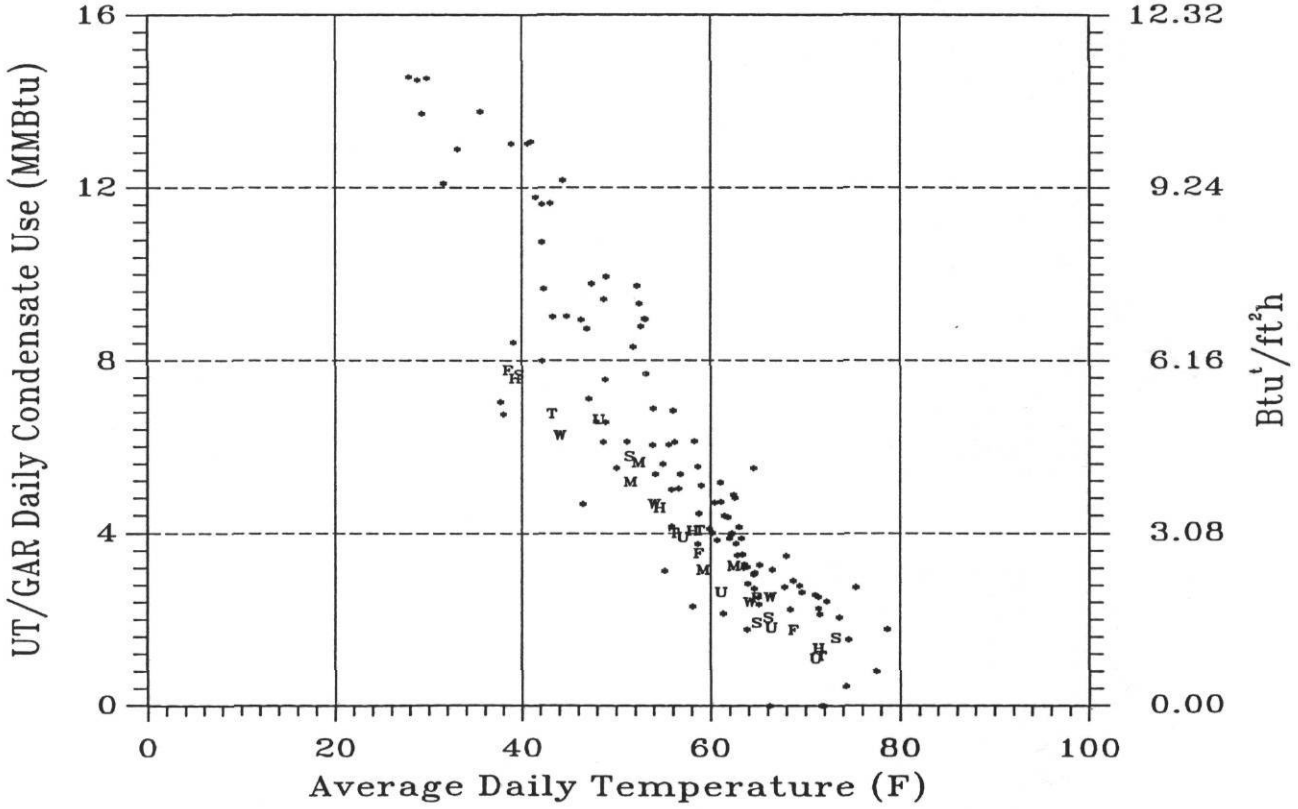
★ Chilled water energy use data are missing from 3/1/96 to 3/31/96 due to a monitoring hardware problem.

★ Chilled water savings are estimated using a post-retrofit regression model.

Mar 01 1995 – Mar 31 1996

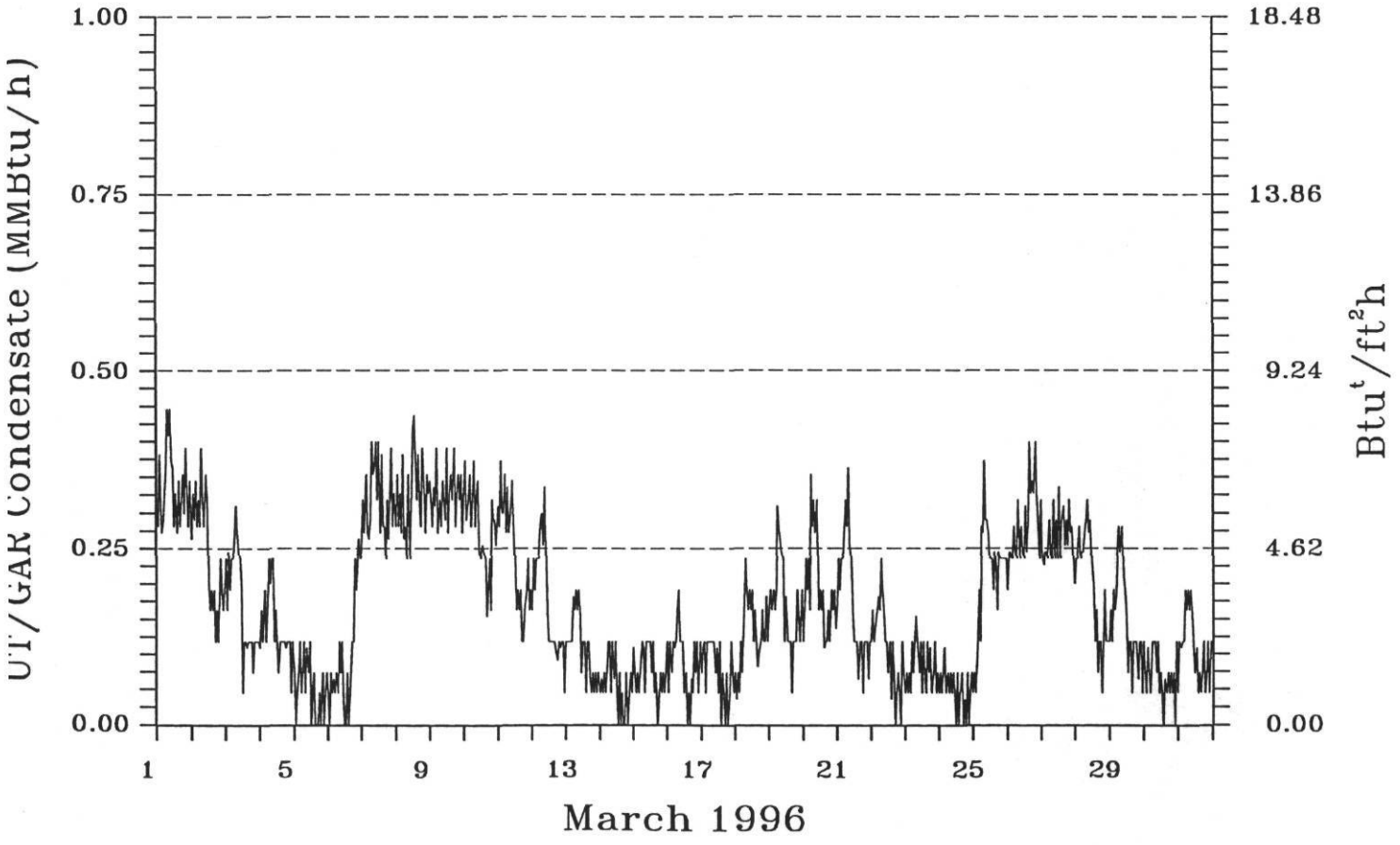


Mar 01 1995 – Mar 31 1996

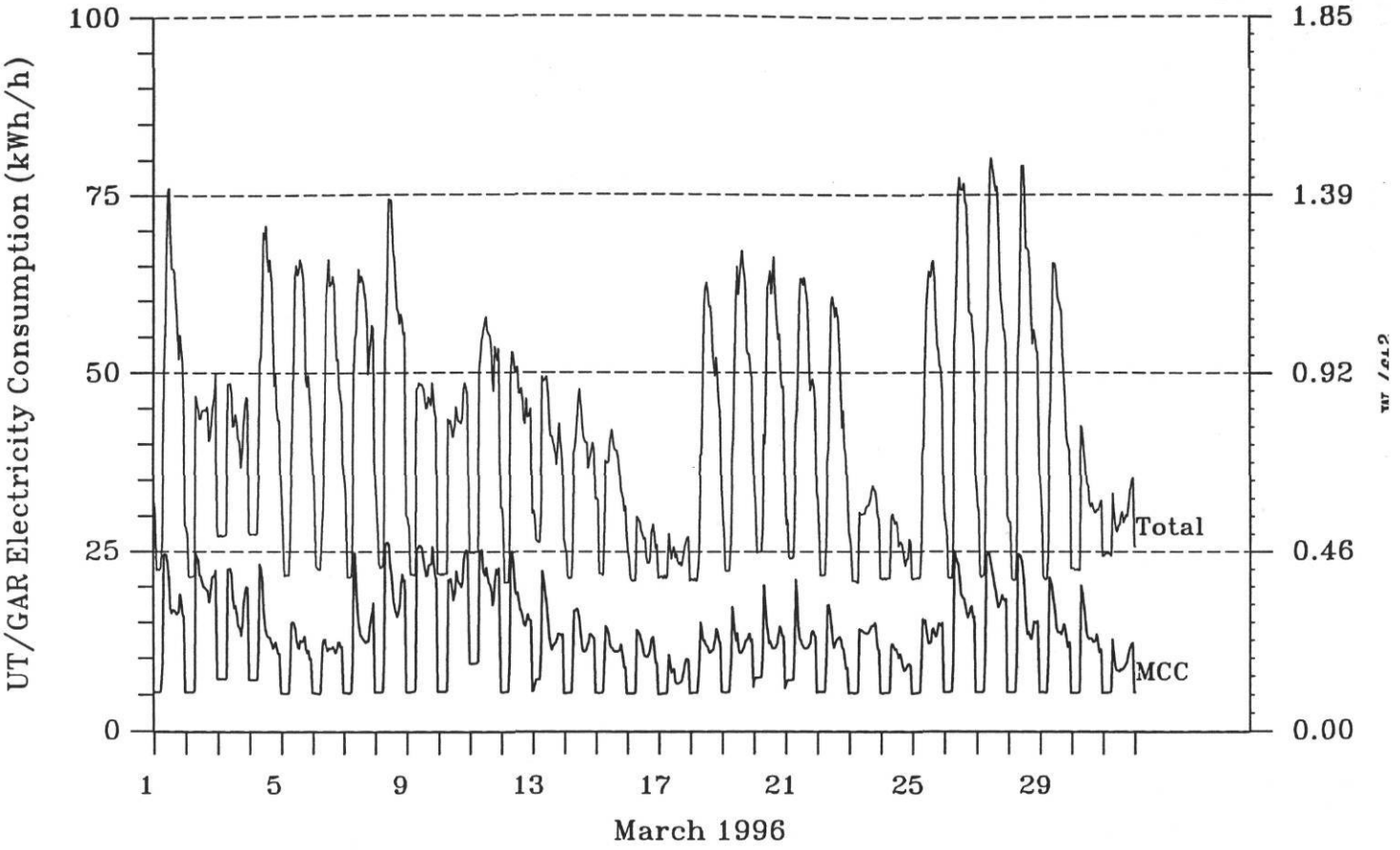


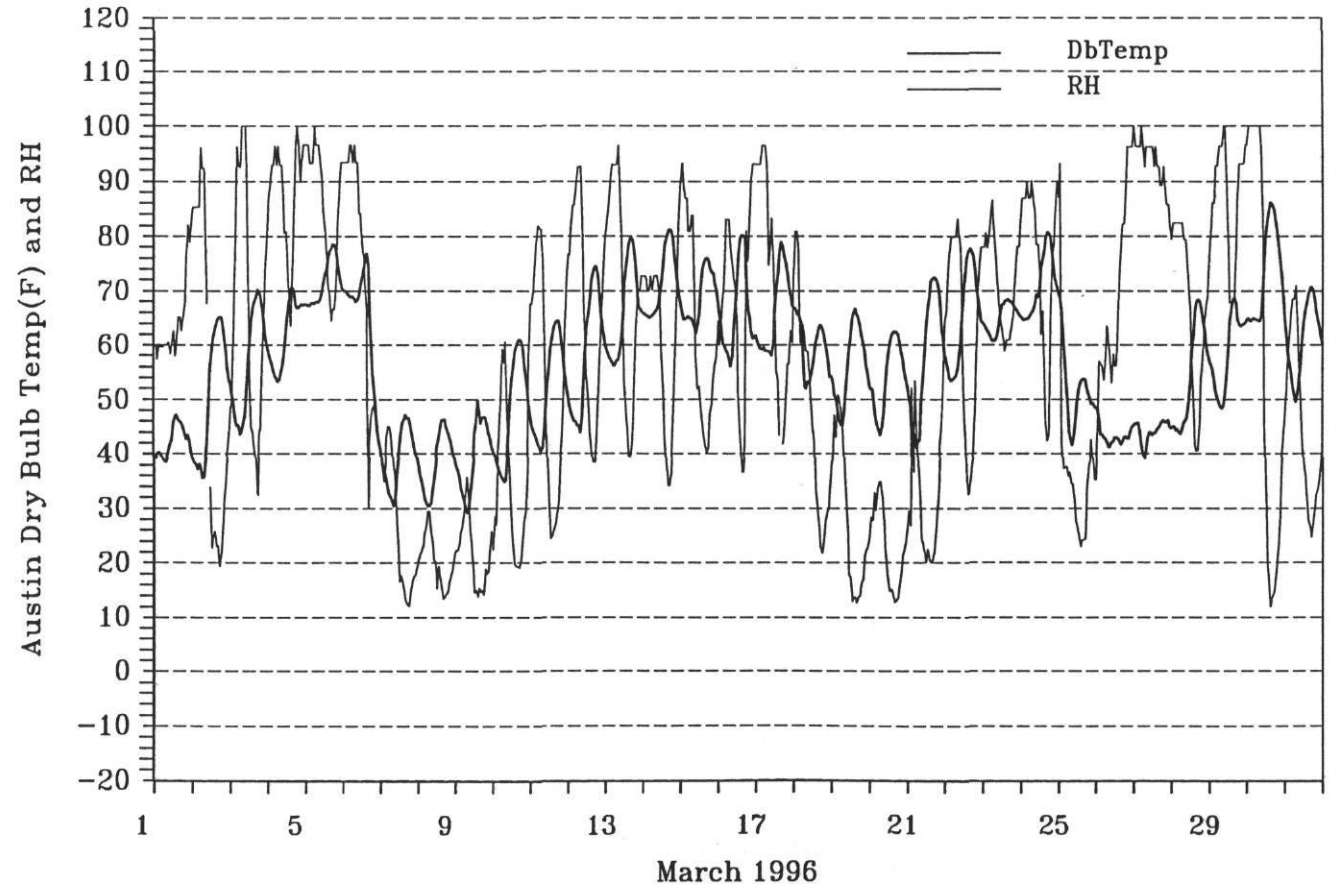
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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



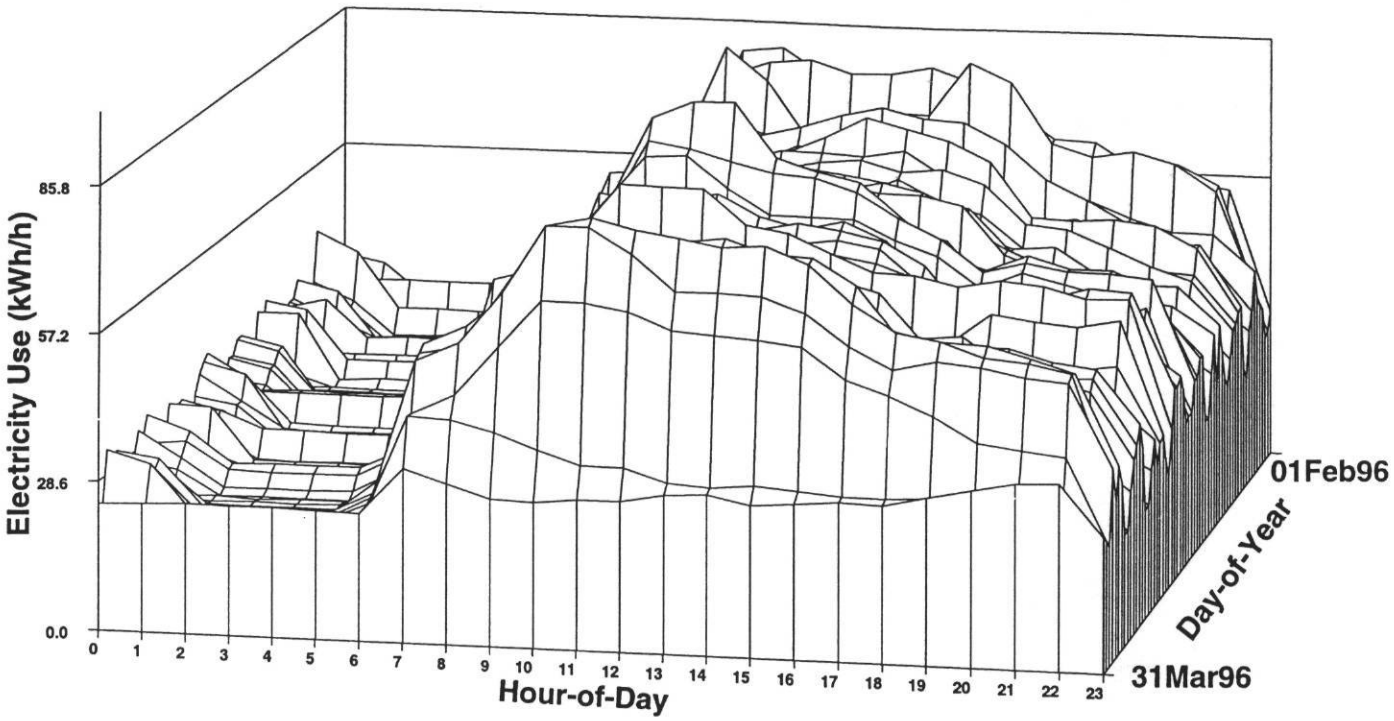
GAR0249 - Garrison Hall - University of Texas - March 1996



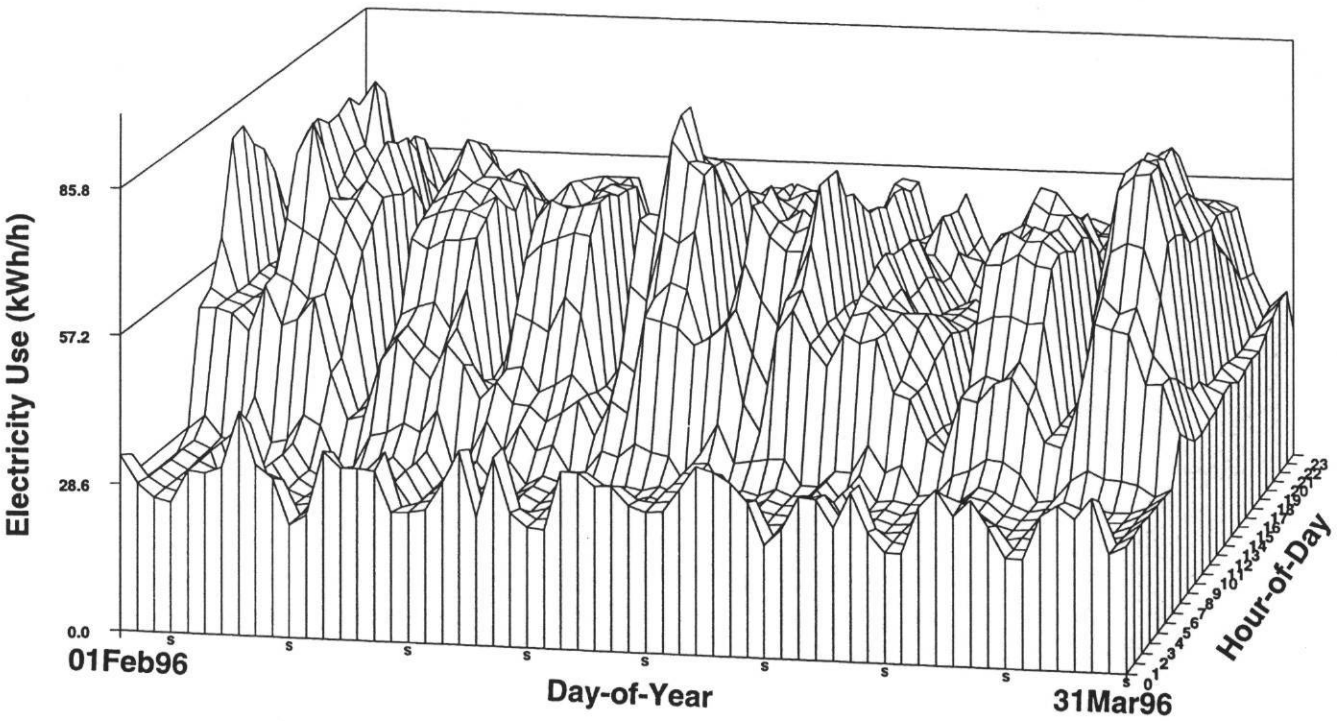


GAR0249 - Garrison Hall - University of Texas - March 1996

Whole-Building Electric



Whole-Building Electric



Sundays are marked with an "S"

UT AUSTIN

Garrison Hall

Building Envelope:
- 54,069 sq.ft
- 4 floors and a basement, erected 1926, classes, offices, and auditorium
- walls: hollow clay tile with a cut stone exterior
- windows: 19% of total wall area, single pane clear operable
- roof: pitched with clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- auditorium: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 2 variable volume dual duct AHUs (1-30 hp, 1-25 hp)
- 1 variable volume multizone AHU (5 hp)
- 1 constant volume single zone AHU (3 hp)
- 1 variable volume chilled water pump (1-15hp)
- 1 constant volume hot water pump (1-3hp)
- 7 ex. fans (6-1hp, 1-15hp)

HVAC Schedule:
- 5 am - 11pm (Mon - Sat) Air Handling units are turned off/slow rolled by Facility Control & Monitoring System (FCMS) from 11:00 pm to 5:00 am (Mon thru Sun).

Lighting:
- fluorescent, some incandescent lights

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- VAV conversion and variable speed pumping was completed at the end of May 1991.

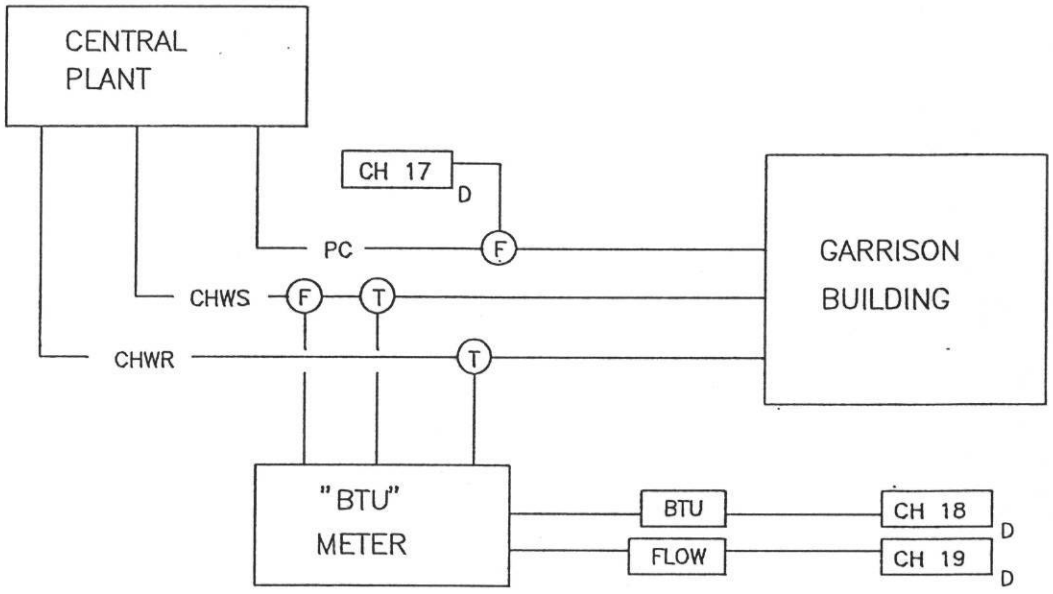
Savings Calculations:
- estimated savings are average monthly savings from the audir report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – GARRISON

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

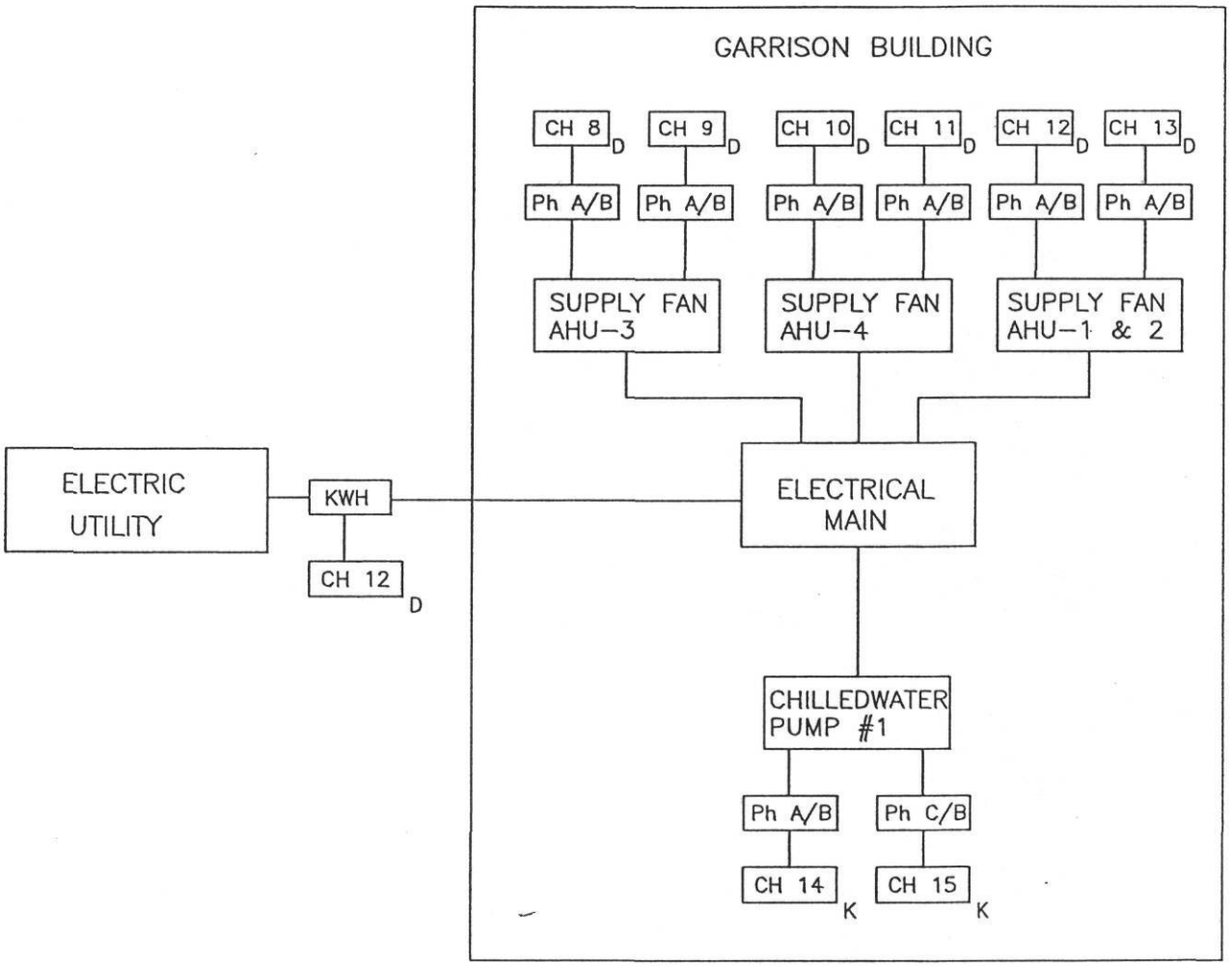


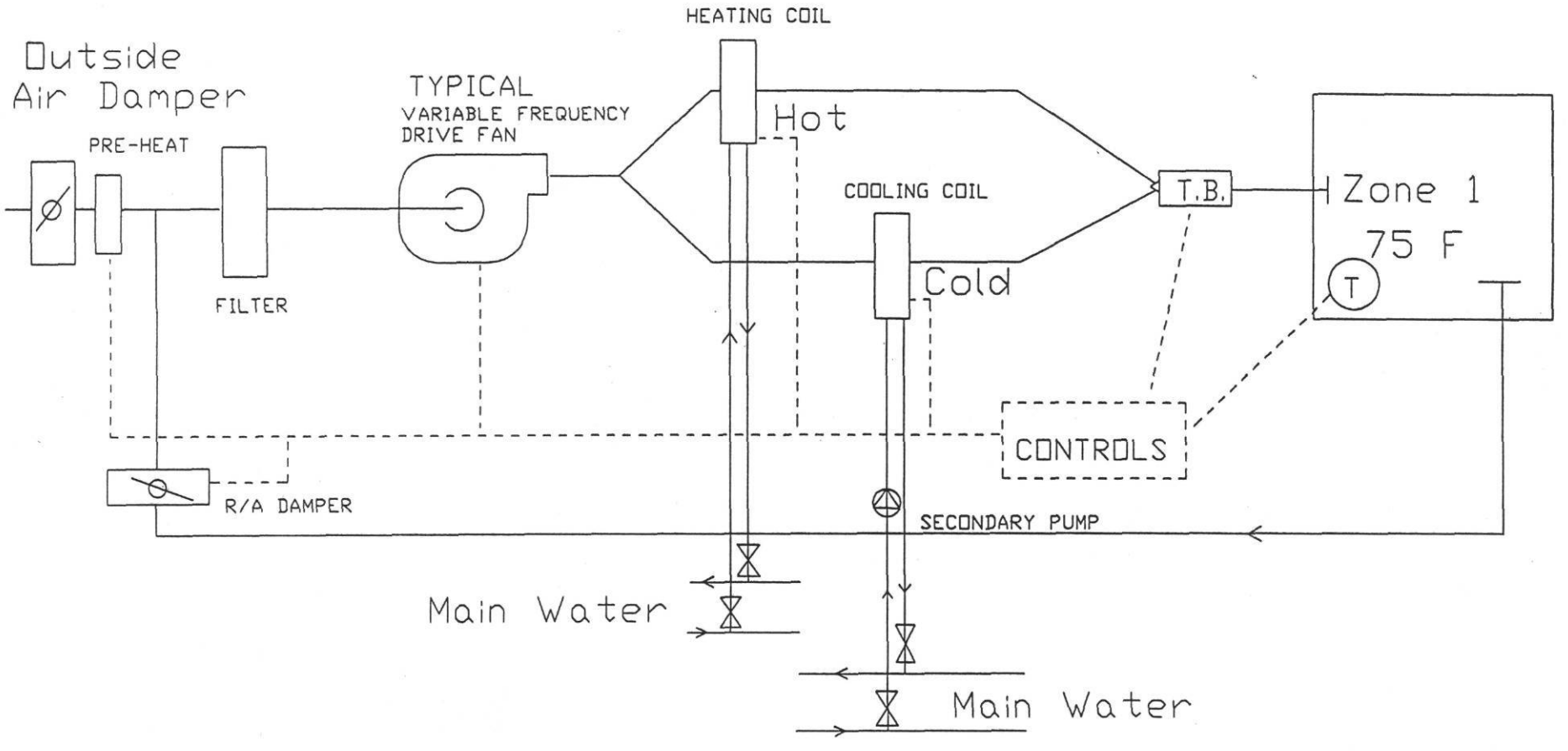
ELECTRICAL MONITORING DIAGRAM

UT AUSTIN – GARRISON

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL

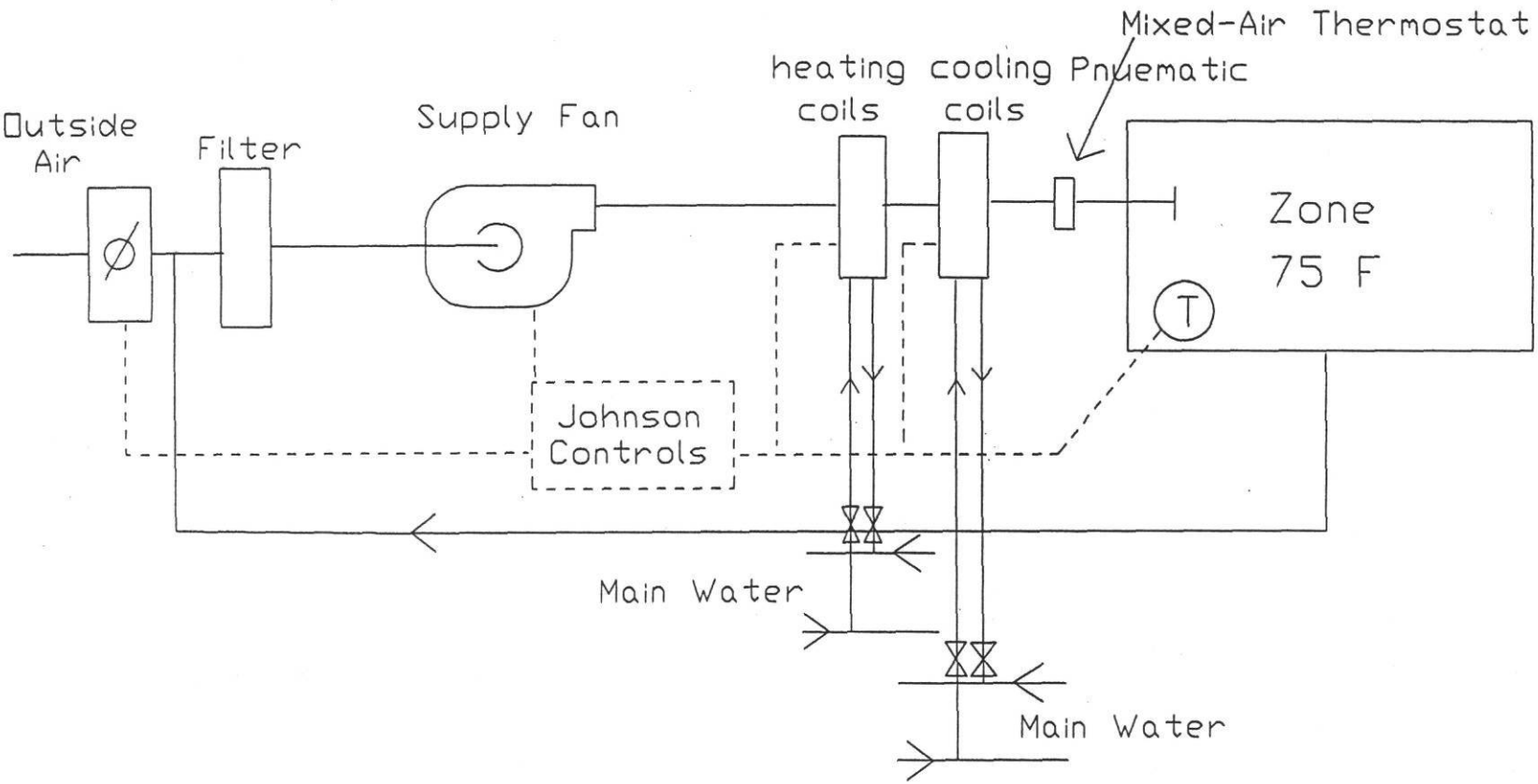




Variable-volume

* 1st & 2nd Floor 30 HP VFD fans

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- GARRISON HALL	
Typical Dual-Duct System	Date: May 1, 1991
GAR-103D	Drawn by: Mark Rivera



Constant-Volume

* Suppy Fan 3 Hp in auditorium
5 HP multizone in basement

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- GARRISON HALL	
Typical Single-Duct System	Date: May 1, 1991
GAR-103S	Drawn by: Mark Rivera

GEA0305

Gearing Hall

University of Texas
61,041 square feet

Site Contact

Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
PO Box 7580
Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact

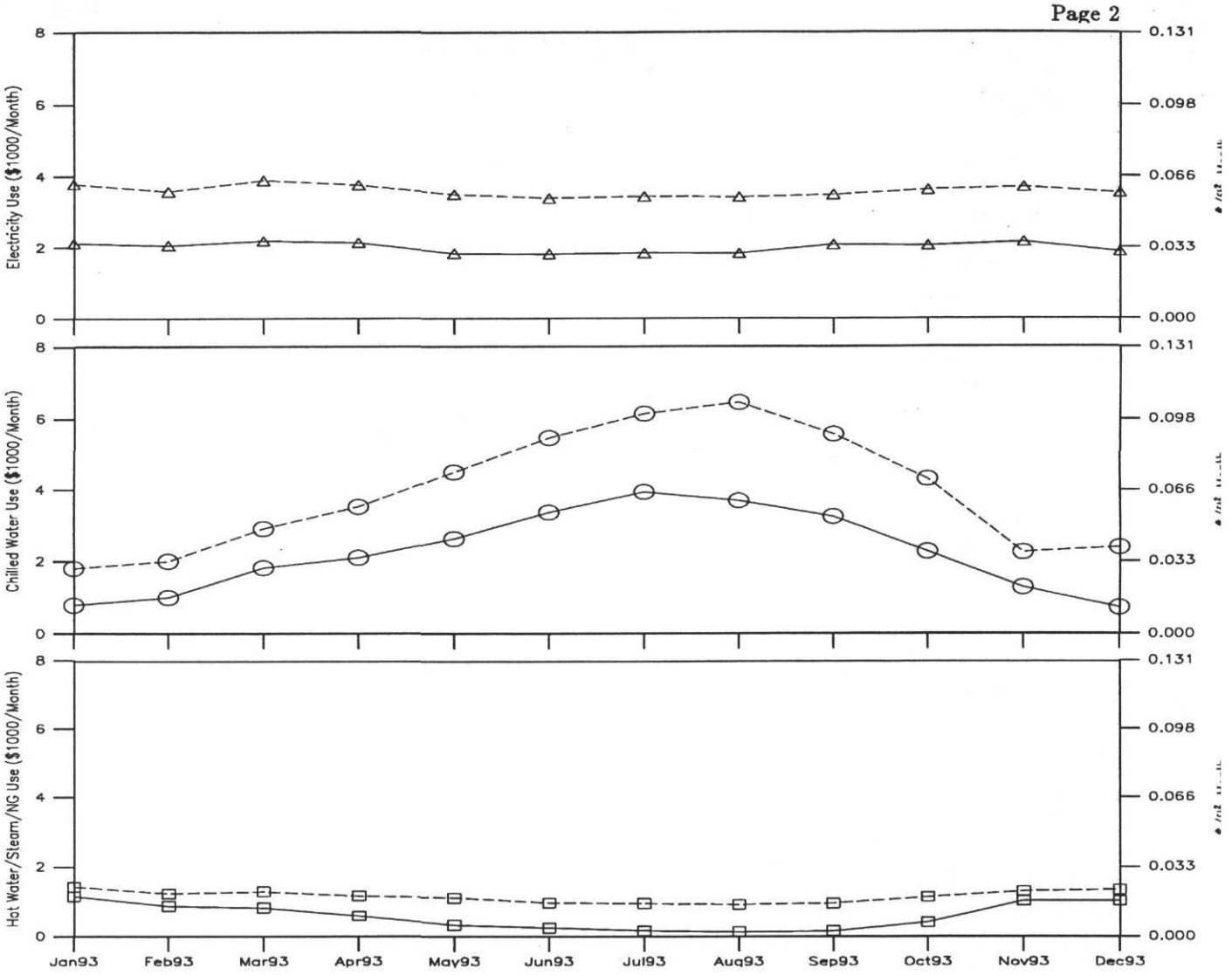
Aamer Athar
053D WERC
Texas A&M University
College Station, TX 77843-3123
(409)–845–9213

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	46566	$2119	100	$1679	105	$780	100	$1023	185	$1147	100	$275	$2977	$2977
Feb	45143	$2054	100	$1526	135	$1002	100	$996	141	$874	100	$356	$2878	$5855
Mar	47861	$2178	100	$1707	246	$1827	100	$1084	133	$825	100	$460	$3251	$9106
Apr	46810	$2130	99	$1627	284	$2109	100	$1426	95	$589	99	$576	$3629	$12735
May	39991	$1820	100	$1668	355	$2636	100	$1872	53	$329	100	$780	$4320	$17055
Jun	39781	$1810	100	$1571	455	$3378	100	$2092	40	$248	100	$720	$4383	$21438
Jul	40037	$1822	100	$1606	532	$3950	100	$2203	27	$167	100	$781	$4590	$26028
Aug	39867	$1814	100	$1596	499	$3705	100	$2757	22	$136	100	$781	$5134	$31162
Sep	45469	$2069	100	$1415	439	$3260	100	$2316	26	$161	100	$796	$4527	$35689
Oct	45038	$2049	100	$1578	307	$2279	100	$2040	66	$409	100	$725	$4343	$40032
Nov	47401	$2157	100	$1546	173	$1285	100	$973	166	$1029	100	$278	$2797	$42829
Dec	41313	$1880	100	$1661	98	$728	100	$1665	166	$1029	100	$321	$3647	$46476
Total	525277	$23902		$19180	3628	$26939		$20447	1120	$6943		$6849		$46476
EUI	8.6	$\frac{kWh}{ft^2yr}$			59435	$\frac{Btu}{ft^2yr}$			18348	$\frac{Btu}{ft^2yr}$				

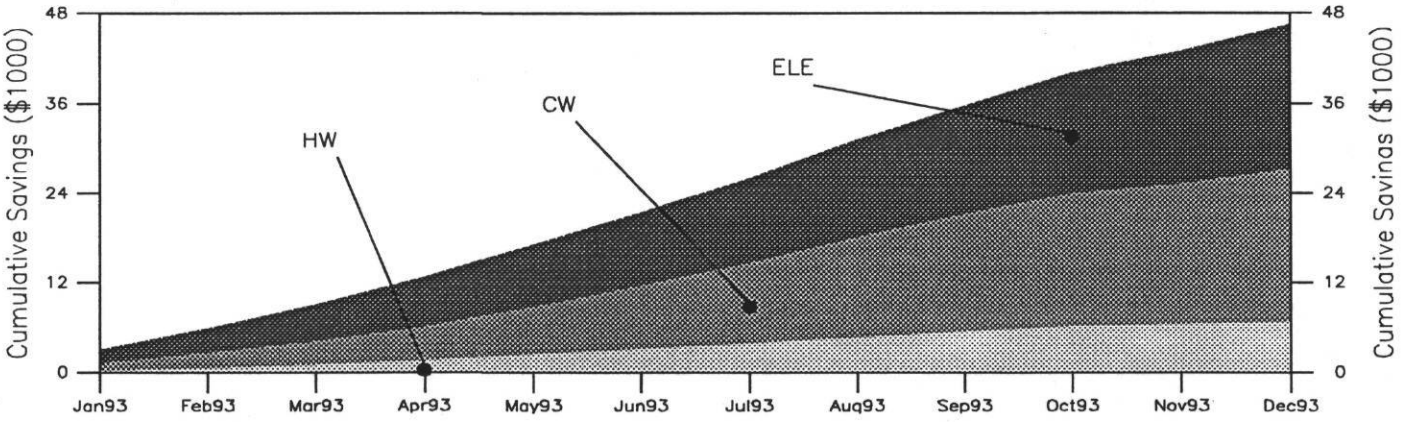
Comments

★ **The percent columns indicate the number of hours reported in that month.**
★ **The LoanSTAR monitoring began in October 1990.**
★ **The HVAC retrofit was completed in May 1991.**
★ **The unit costs used for estimating the audit and the measured savings are: $0.0455/kWh, $7.25/MMBtu (CW), and $6.2/MMBtu (Steam).**
★ **The audit estimated savings for HVAC retrofits are: $29,900 (ELE), $11,000 (CW), $5,400 (Steam) and $46,300 (Total).**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



GEA0305 - Gearing Hall - University of Texas

1993 Annual Energy Consumption Report©

UT AUSTIN

Gearing Hall

Building Envelope:
- 61,041 sq.ft
- 4-story, erected 1933, classes, offices, and lab
- walls: hollow clay tile with a cut stone exterior
- windows: 18% of total wall area, single pane clear operable
- roof: pitched and constructed of clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- labs: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 4 variable volume dual duct AHUs (2-30hp, 2-25hp)
- 2 constant volume single zone AHU (1-5hp, 1-2hp)
- 1 constant volume hot water pump (1-7.5hp)
- 1 variable volume chilled water pump (15 hp)
- 1 constant volume chilled water pump (2 hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- retrofit construction completed mid-May 1991.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

GEA0305

Gearing Hall

University of Texas
61,041 square feet

Site Contact
Mr. Jim Von Wolske
University of Texas at Austin
Utilities Department
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Austin, TX 78713
(512)–471–1010

LoanSTAR Metering Contact
Aamer Athar
053D 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	52561 kWh	100	$0.04550	$2392
Peak 60 Minute Demand	122 kW	100	-	-
Chilled Water	155.6 MMBtu	100	$7.425	$1156
Condensate	331.9 MMBtu	100	$6.200	$2058

Peak 60 minute demand was recorded at 1200 Tuesday 03/19/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	32040	$1458	54787	$2493
Chilled Water (MMBtu)	182	$1351	123	$913
Cond./H.W./N.G. (MMBtu)	-115	$-713	73	$453
Monthly Total		$2096		$3859
Total to Date*	(58 months)	$179523	(58 months)	$223804

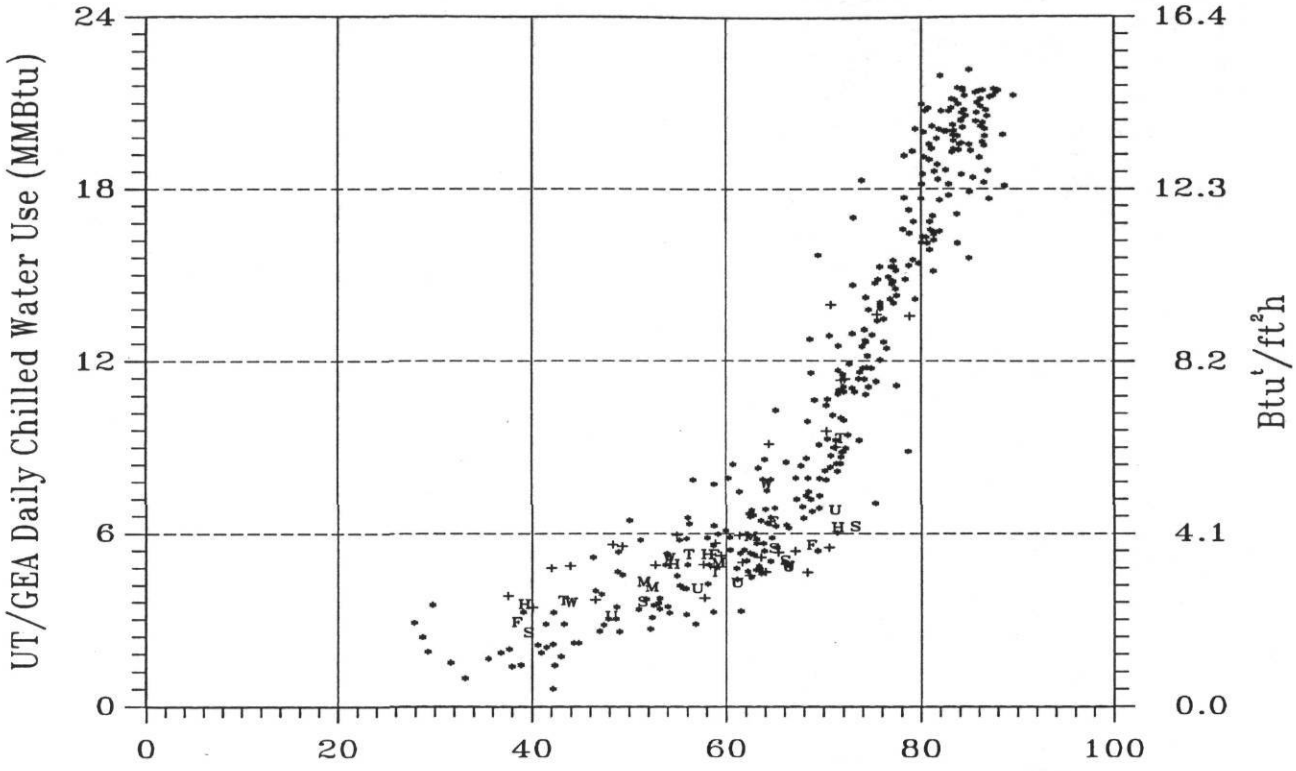
*Measured savings include construction period. Audit estimated savings do not.

Comments

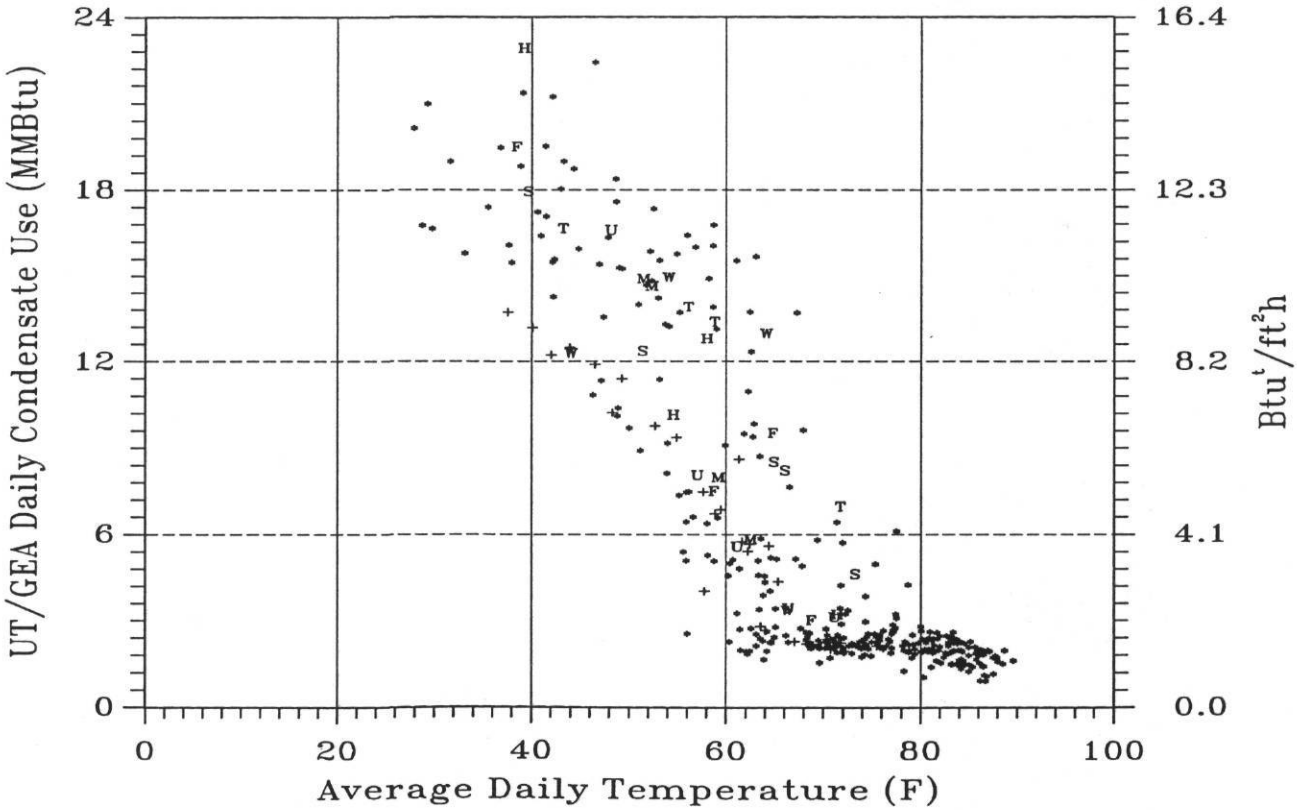
★ Steam energy consumption has increased significantly when compared to previous consumption under similar conditions.

★ Spring Break is evident as reduced electricity consumption from 3/11/96 to 3/17/96.

Mar 01 1995 – Mar 31 1996

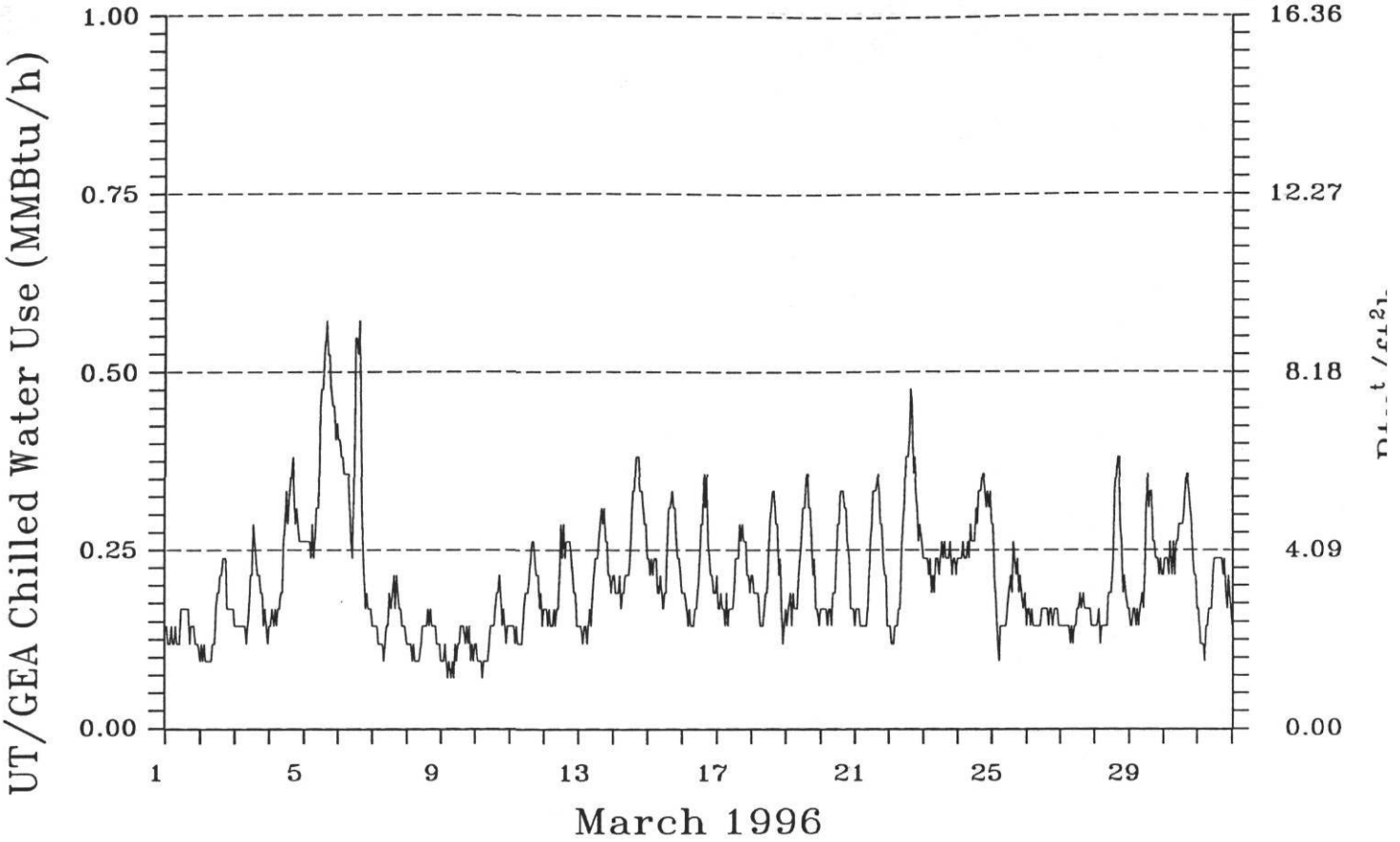


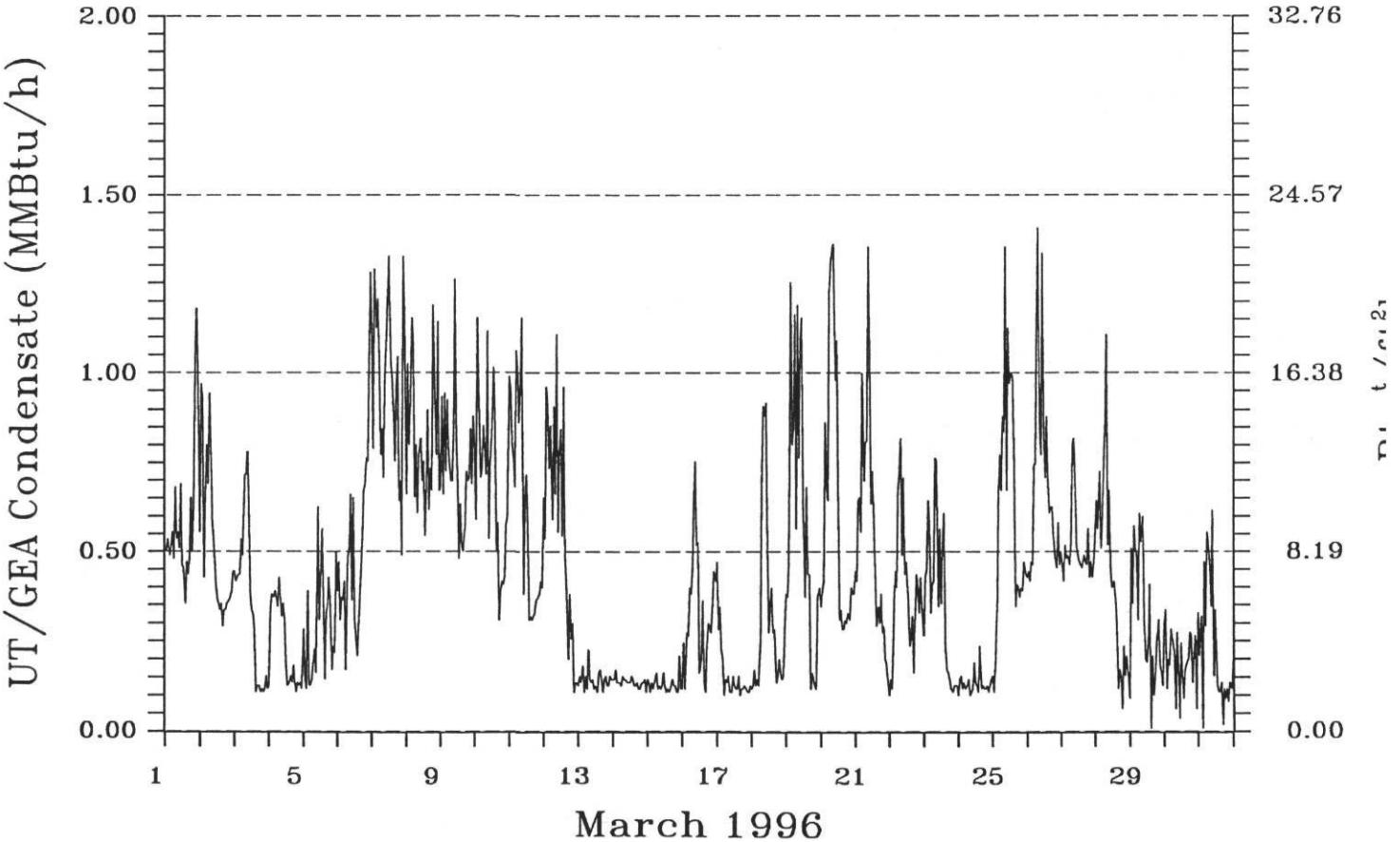
Mar 01 1995 – Mar 31 1996



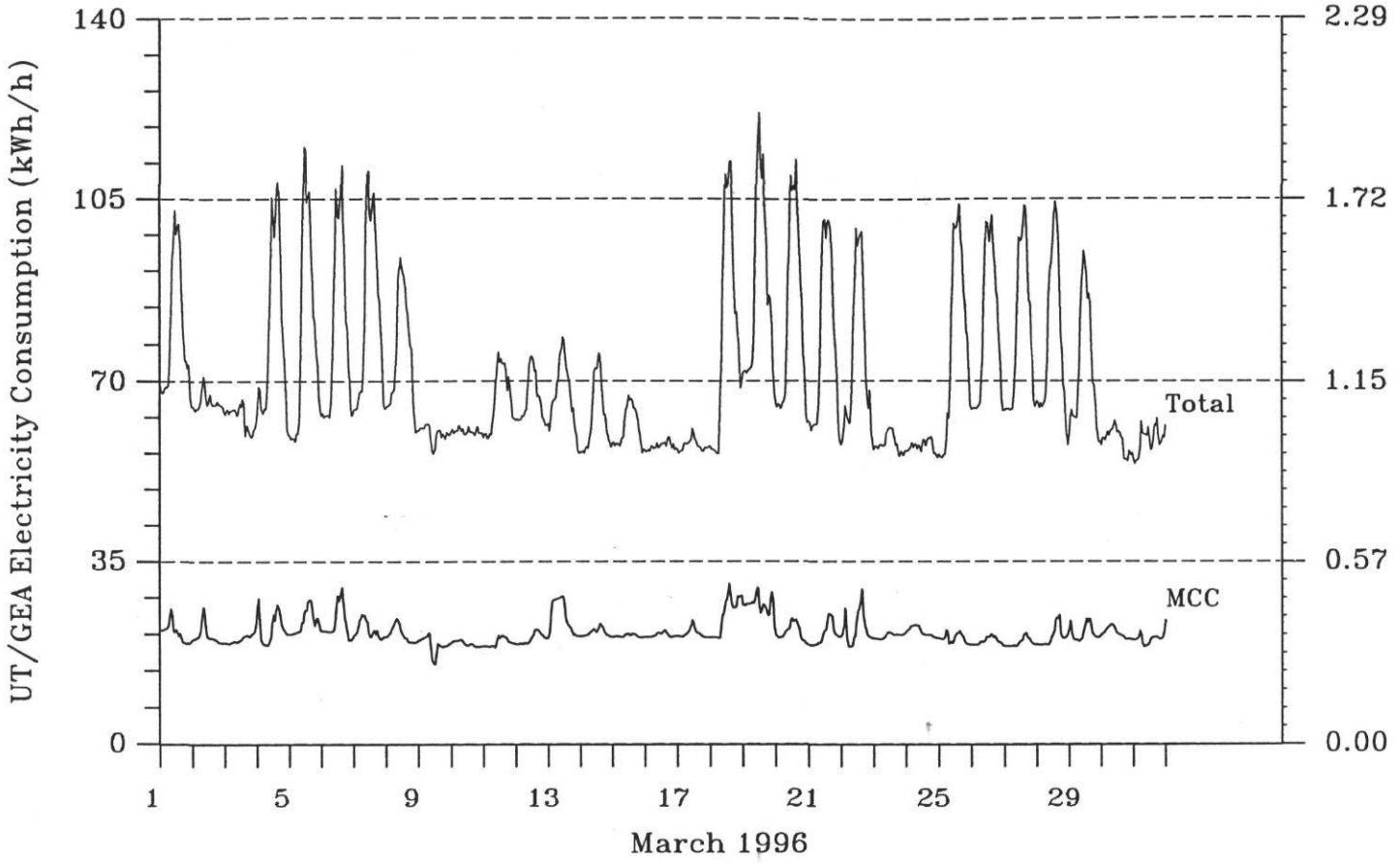
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

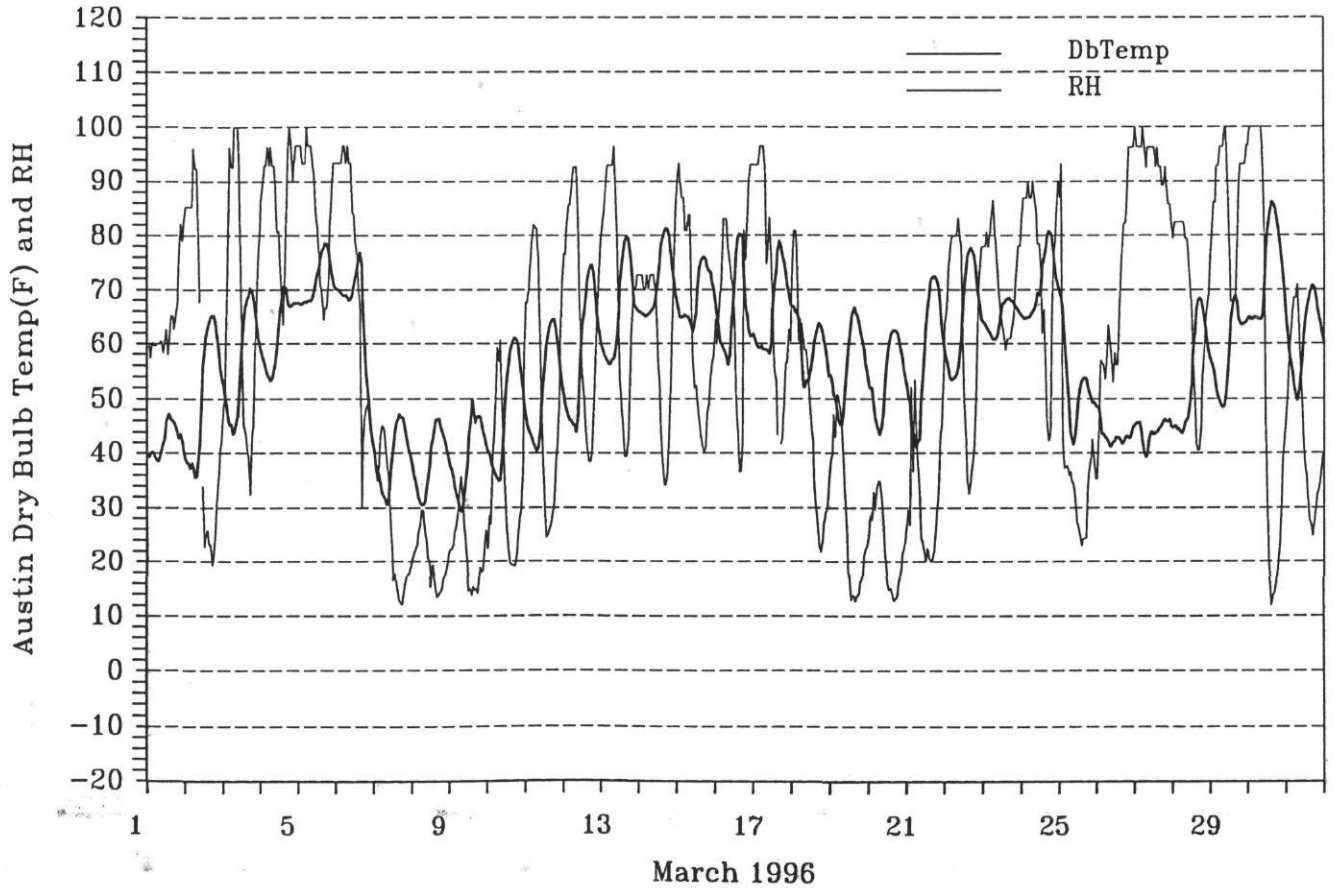
Points from this month last year are shown as +.
All other points are shown as *.





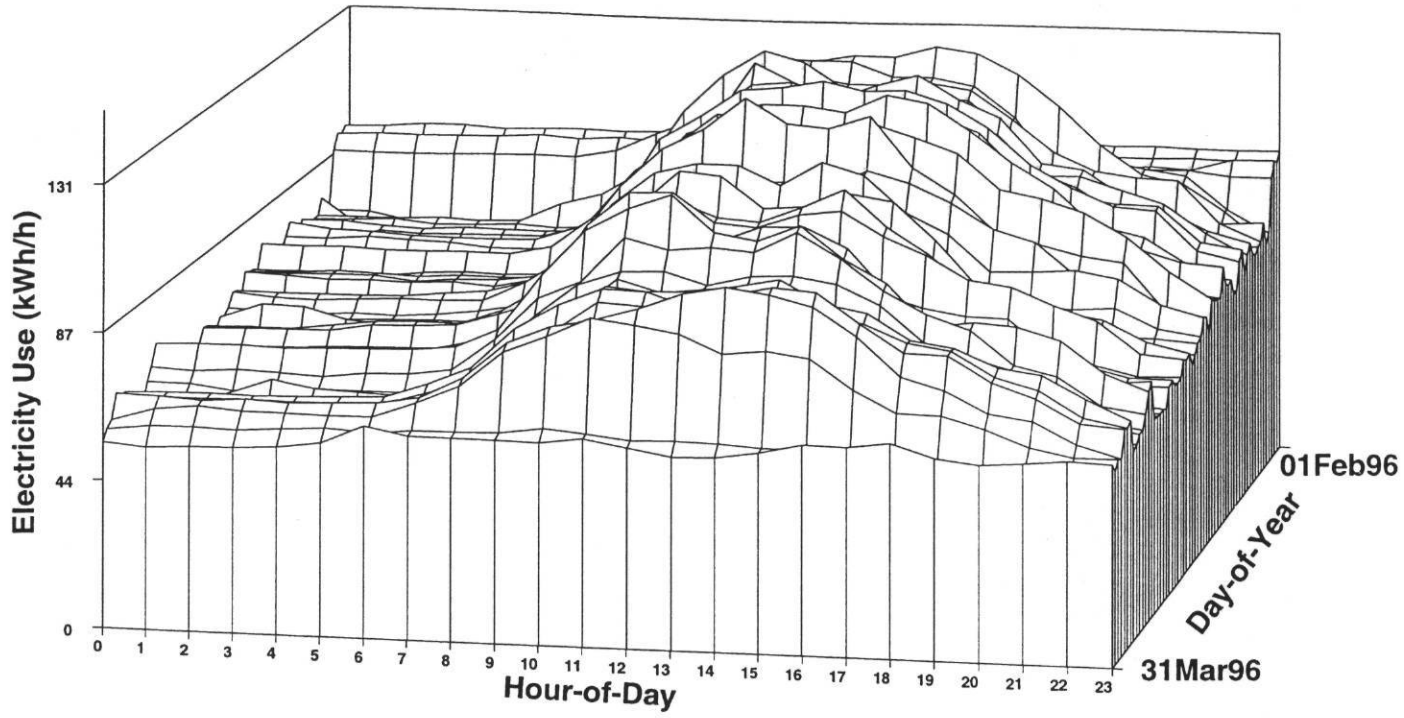
GEA0305 - Gearing Hall - University of Texas - March 1996



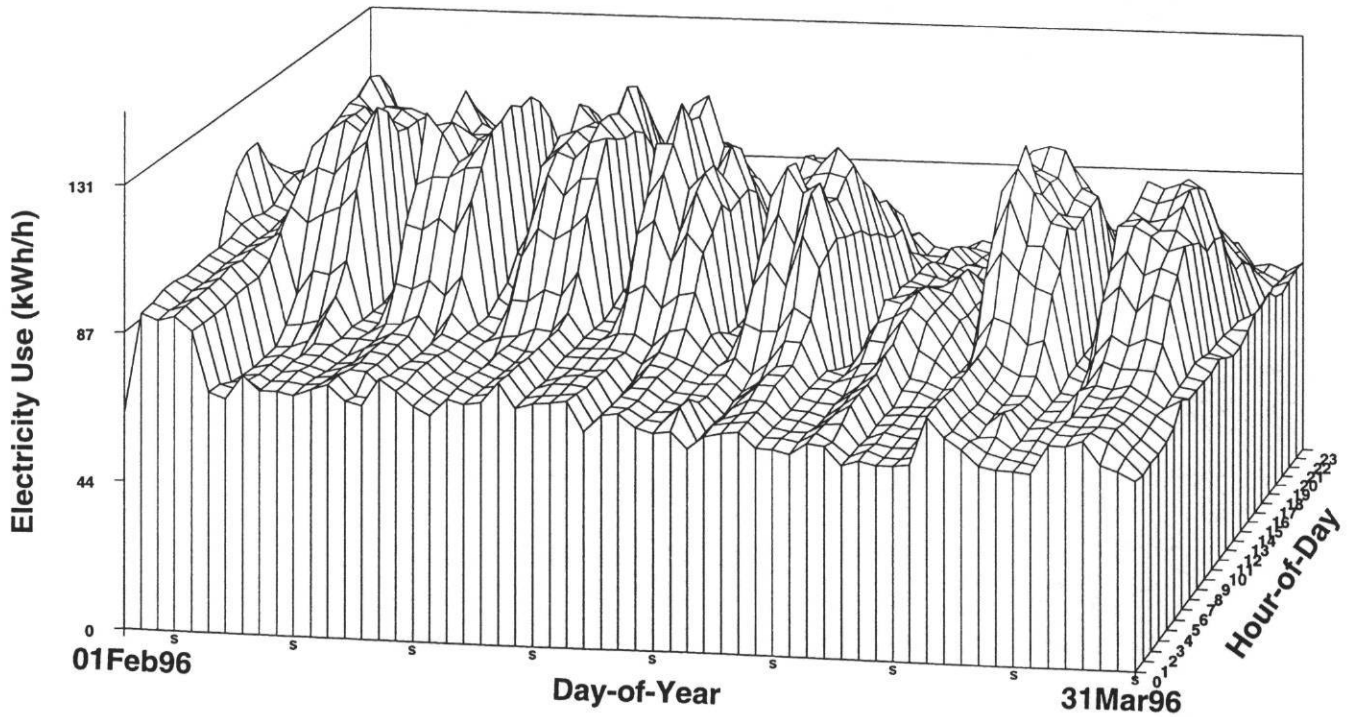


GEA0305 - Gearing Hall - University of Texas - March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

UT AUSTIN

Gearing Hall

Building Envelope:
- 61,041 sq.ft
- 4-story, erected 1933, classes, offices, and lab
- walls: hollow clay tile with a cut stone exterior
- windows: 18% of total wall area, single pane clear operable
- roof: pitched and constructed of clay tile

Building Schedule:
- classrooms: 7:30 am to 6:30 pm (M-F)
- offices: 7:30 am to 5:30 pm (M-F)
- labs: 7:30 am to 9:30 pm (M-F)

Building HVAC:
- 4 variable volume dual duct AHUs (2-30hp, 2-25hp)
- 2 constant volume single zone AHU (1-5hp, 1-2hp)
- 1 constant volume hot water pump (1-7.5hp)
- 1 variable volume chilled water pump (15 hp)
- 1 constant volume chilled water pump (2 hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- variable air volume
- variable speed pumping

Date of Retrofits:
- retrofit construction completed mid-May 1991.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

University Hall

University of Texas at Arlington
123,450 square feet

Site Contact

Mr. Donald A. Decker
Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	119377	$3499	100	$965	430	$1899	100	$1366	421	$1532	100	$-146	$2185	$2185
Feb	125305	$3673	99	$898	454	$2005	100	$1065	325	$1183	99	$-144	$1819	$4004
Mar	126051	$3695	100	$971	492	$2173	100	$1589	252	$917	100	$-127	$2433	$6437
Apr	120454	$3531	99	$944	418	$1846	100	$1623	142	$517	99	$50	$2617	$9054
May	103501	$3034	100	$1049	542	$2394	100	$1228	23	$84	100	$356	$2633	$11687
Jun	108991	$3195	100	$852	879	$3883	100	$124	1	$4	100	$414	$1390	$13077
Jul	112300	$3292	100	$692	938	$4143	100	$-58	2	$7	100	$292	$926	$14003
Aug	104703	$3069	100	$795	863	$3812	100	$256	3	$11	100	$10	$1061	$15064
Sep	122338	$3586	100	$734	589	$2602	100	$1357	3	$11	100	$121	$2212	$17276
Oct	145262	$4258	100	$400	262	$1157	100	$2499	155	$564	100	$-35	$2864	$20140
Nov	133721	$3919	99	$720	180	$795	99	$2702	456	$1660	99	$-840	$2582	$22722
Dec	107184	$3142	100	$998	184	$813	100	$2814	447	$1627	100	$-536	$3276	$25998
Total	1429187	$41893		$10018	6231	$27522		$16565	2230	$8117		$-585		$25998
EUI	11.6	$\frac{kWh}{ft^2yr}$			50473	$\frac{Btu}{ft^2yr}$			18063	$\frac{Btu}{ft^2yr}$				

Comments

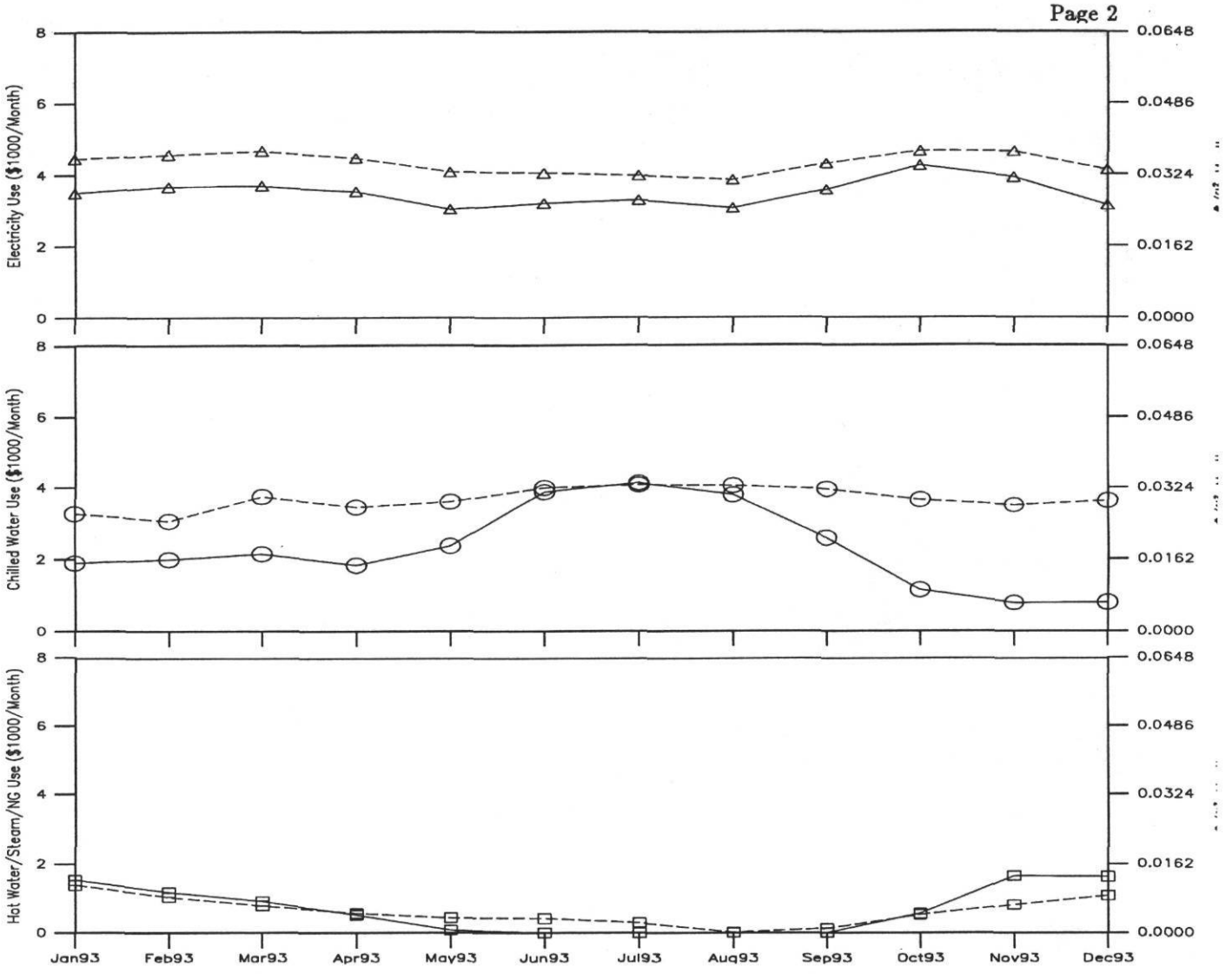
★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in January 1991.**

★ **The HVAC retrofit was completed in August 1991.**

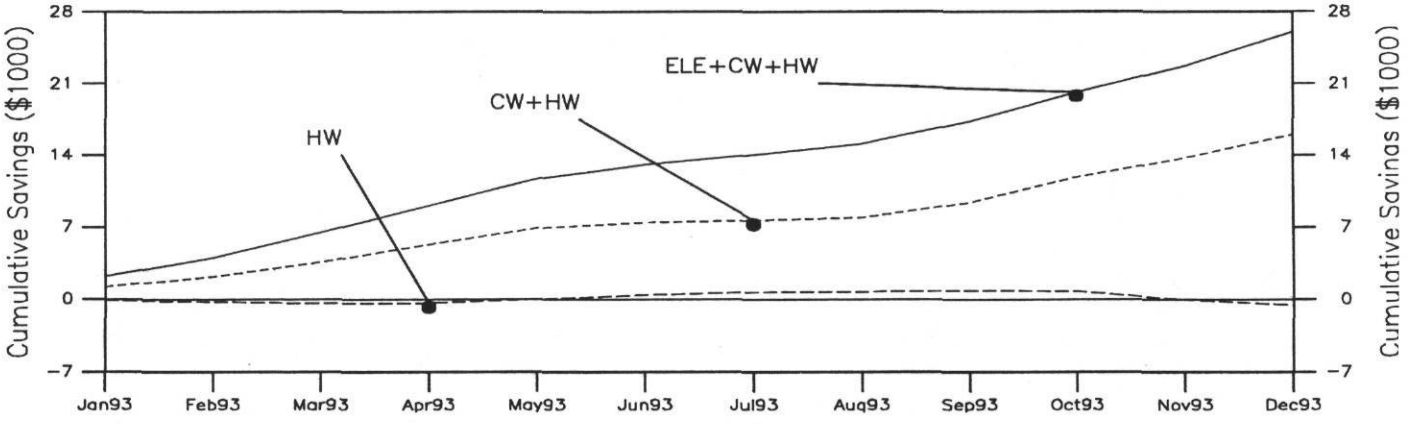
★ **The unit costs used for estimating the energy use are: $0.02931/kWh, $5.827/MMBtu (CW) and $3.44/MMBtu (Steam).**

★ **The audit estimated savings for HVAC retrofits are: $38,100 (ELE), $23,700 (CW), $6,400 (Steam) and $68,200 (Total).**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



University Hall - University of Texas at Arlington

1993 Annual Energy Consumption Report©

U.T. Arlington

University Hall Building

Building Envelope:
- 123,450 sq.ft.
- 6 floors; offices, classrooms, and lecture halls; built in 1970.
- walls: face brick
- windows: single pane, tinted, operable, 10% of total wall area
- roof: N/A

Building Schedule:
- offices: 8:00 a.m. to 6:00 p.m. (M-F), some night classes

Building HVAC:
- 2 variable volume dual duct AHUs (2-125hp)
- 2 return fans (2-15hp)
- 2 outside air units (2-5hp)
- 2 constant volume chilled water pump (2-30hp)
- 1 hot water pump (N/A)
- 7 exhaust fans (total of 3hp)
- equiped with an economizer cycle

HVAC Schedule:
- 6:00 am to 11:00 pm (Mon -Sat) & 12:00 noon to 11:00 pm (Sun)

Lighting:
- fluorescent 34W

Proposed Retrofits:
- variable speed pumping for chilled water pumps
- lighting control
- VAV conversion of AHUs

Date of Retrofits:
- VAV conversion and lighting modifications were completed in August 1991.

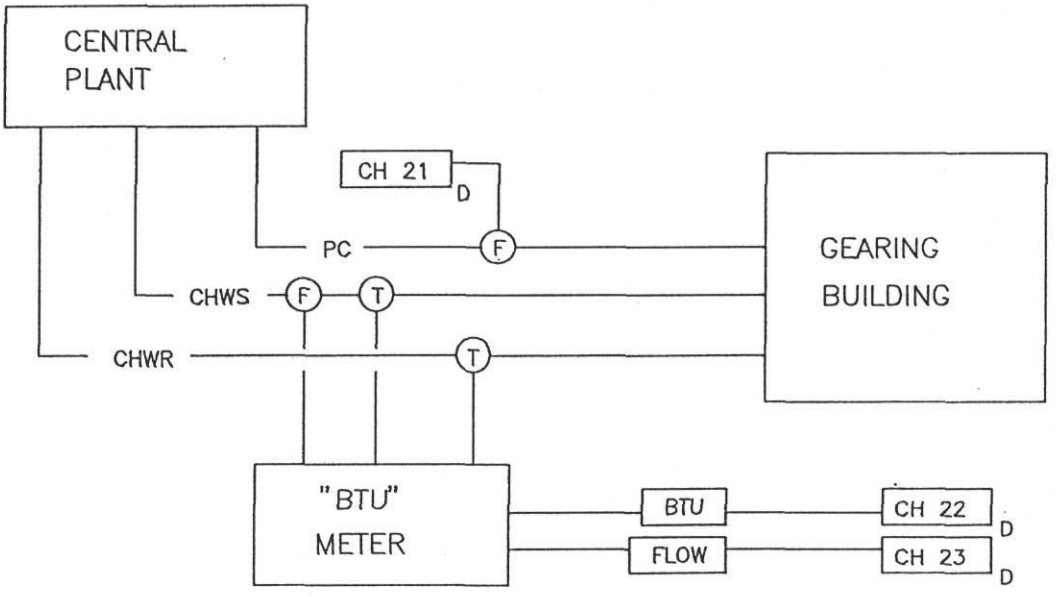
Savings Calculations:
- measured and estimated savings do not include lighting savings.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT AUSTIN – GEARING

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

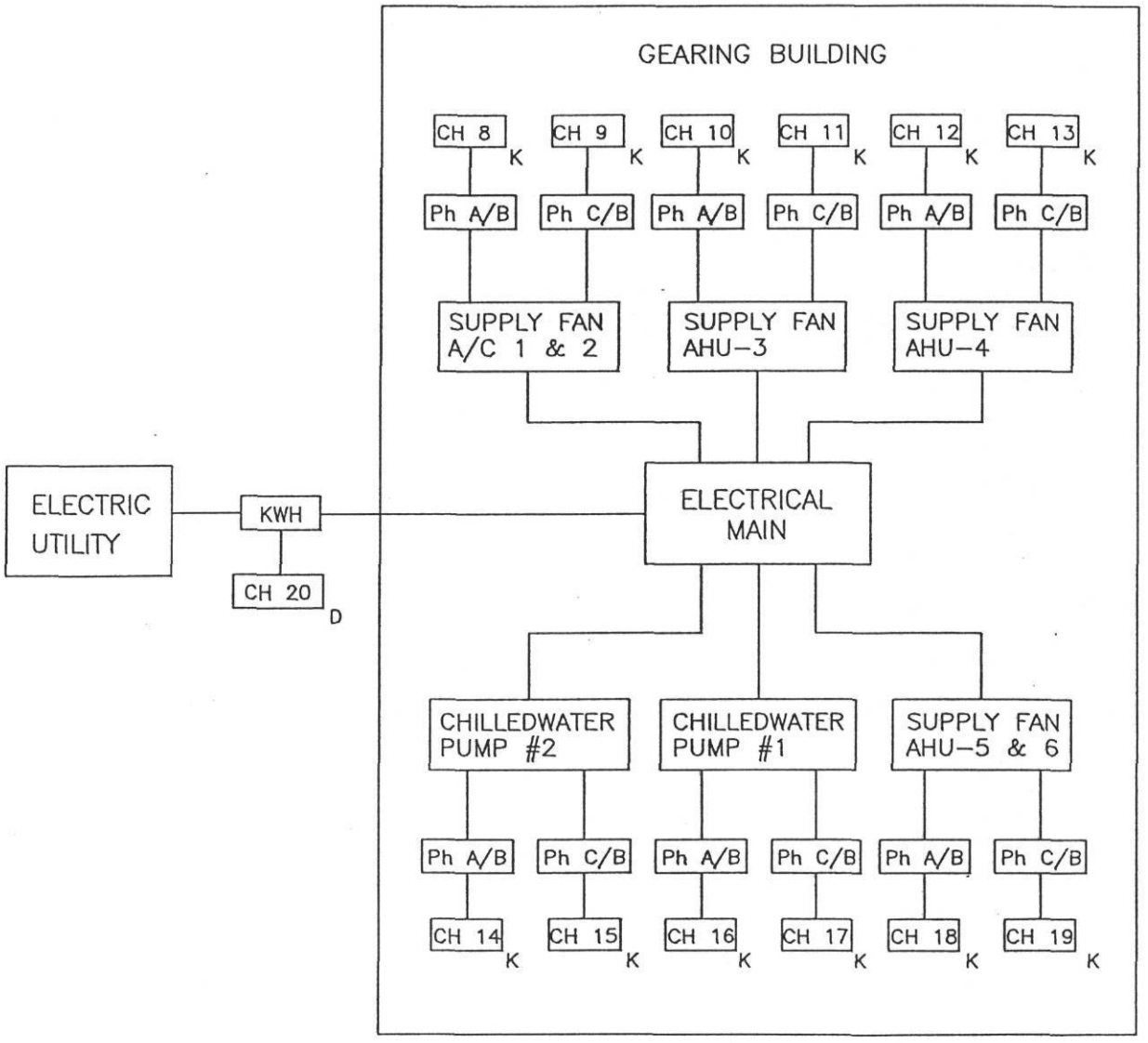


ELECTRICAL MONITORING DIAGRAM

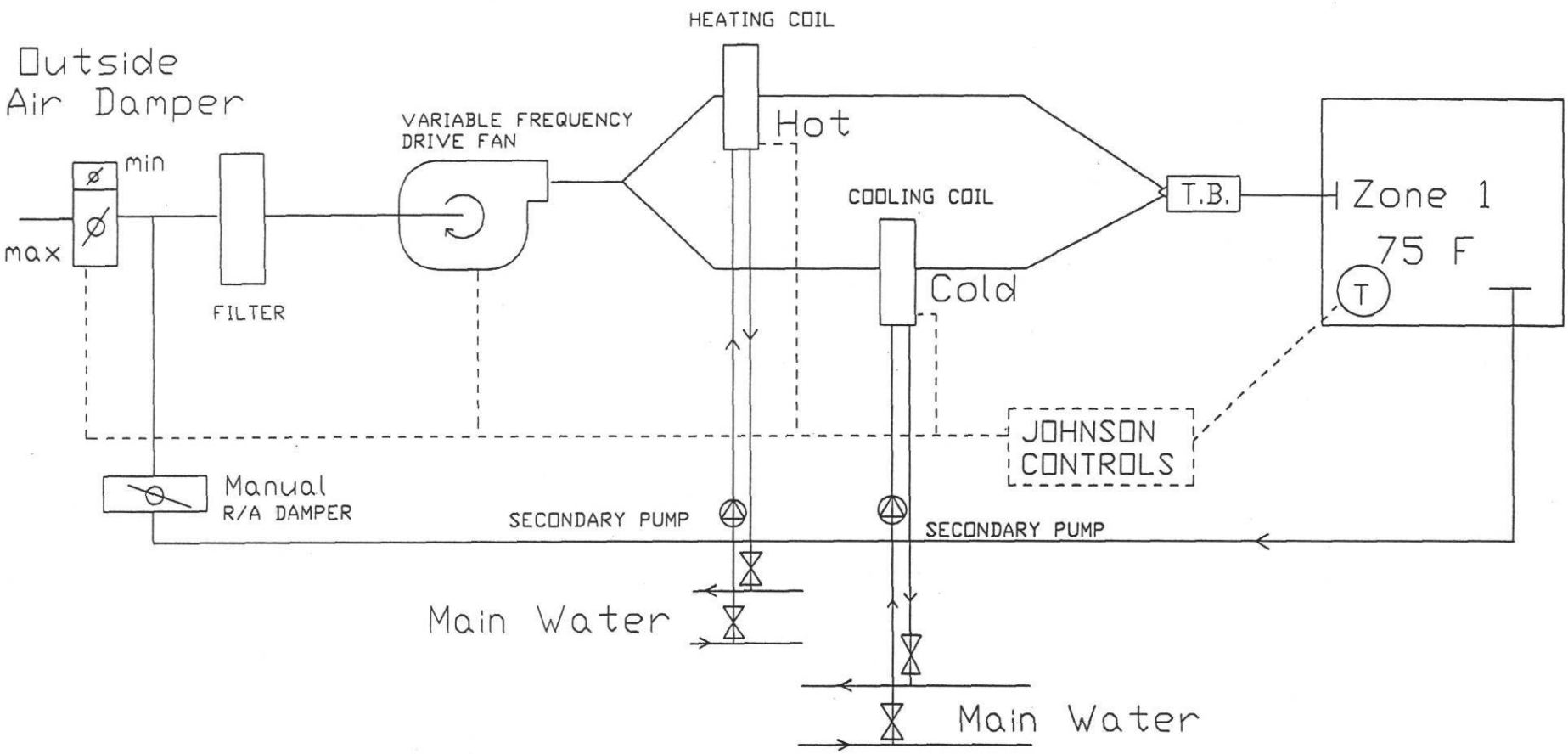
UT AUSTIN – GEARING

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



UT AUSTIN/GEARING – SITE 119



Variable-volume

* suppy Fan HP -30 HP Rm #20 x 2
  25 HP 4th Floor x 2

* Pump HP- two CW 1HP & 15 HP
  - one HW 7.5 HP

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- GEARING HALL	
Typical Dual-Duct System	Date: May 1, 1991
GEA-104	Drawn by: Mark Rivera

University Hall

University of Texas at Arlington
123,450 square feet

Site Contact

Mr. Donald A. Decker
Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

Aamer Athar
053D 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	112069 kWh	95	$0.02931	$3285
Peak 60 Minute Demand	353 kW	95	$6.81	$2397
Chilled Water	156.8 MMBtu	95	$4.417	$692
Condensate	367.2 MMBtu	95	$3.640	$1337

Peak 60 minute demand was recorded at 1400 Wednesday 03/06/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	30465	$893	108303	$3174
Chilled Water (MMBtu)	580	$2562	448	$1979
Cond./H.W./N.G. (MMBtu)	-183	$-666	147	$535
Monthly Total		$2789		$5688
Total to Date*	(56 months)	$79246	(56 months)	$318542

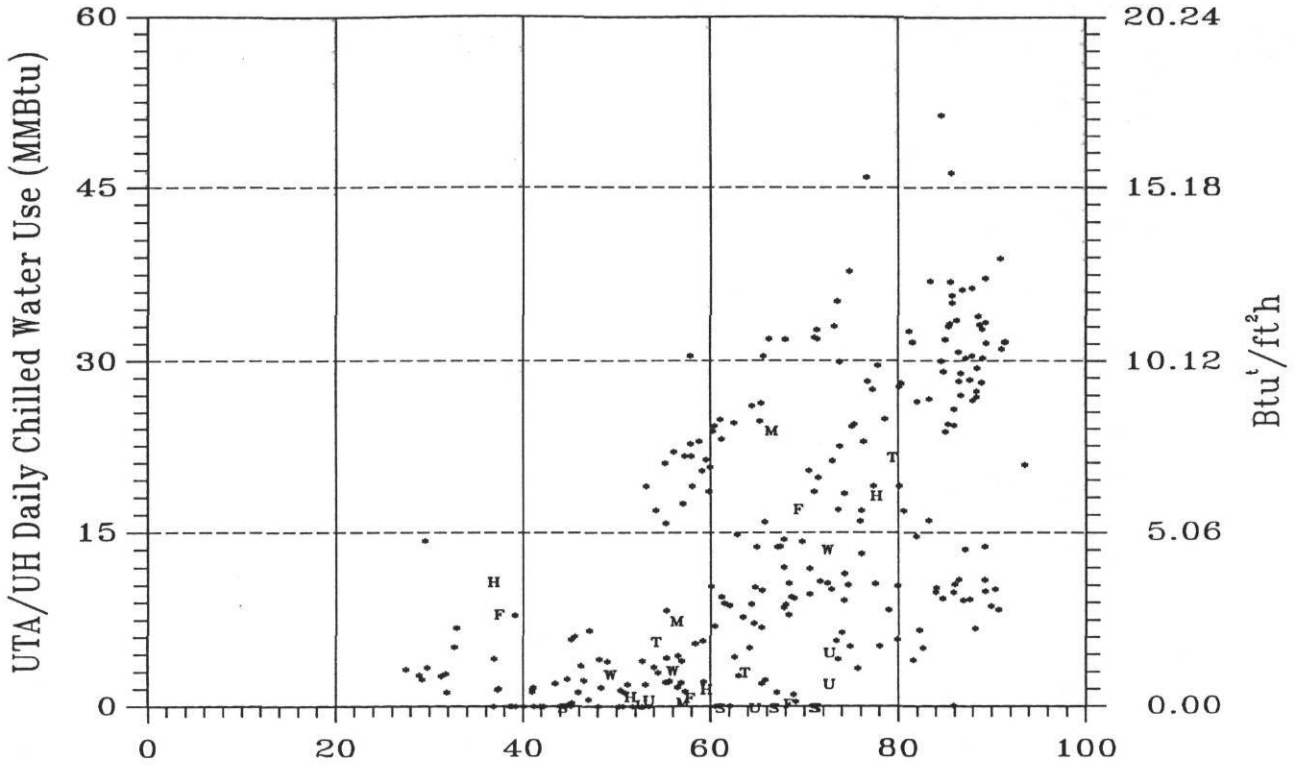
*Measured savings include construction period. Audit estimated savings do not.

Comments

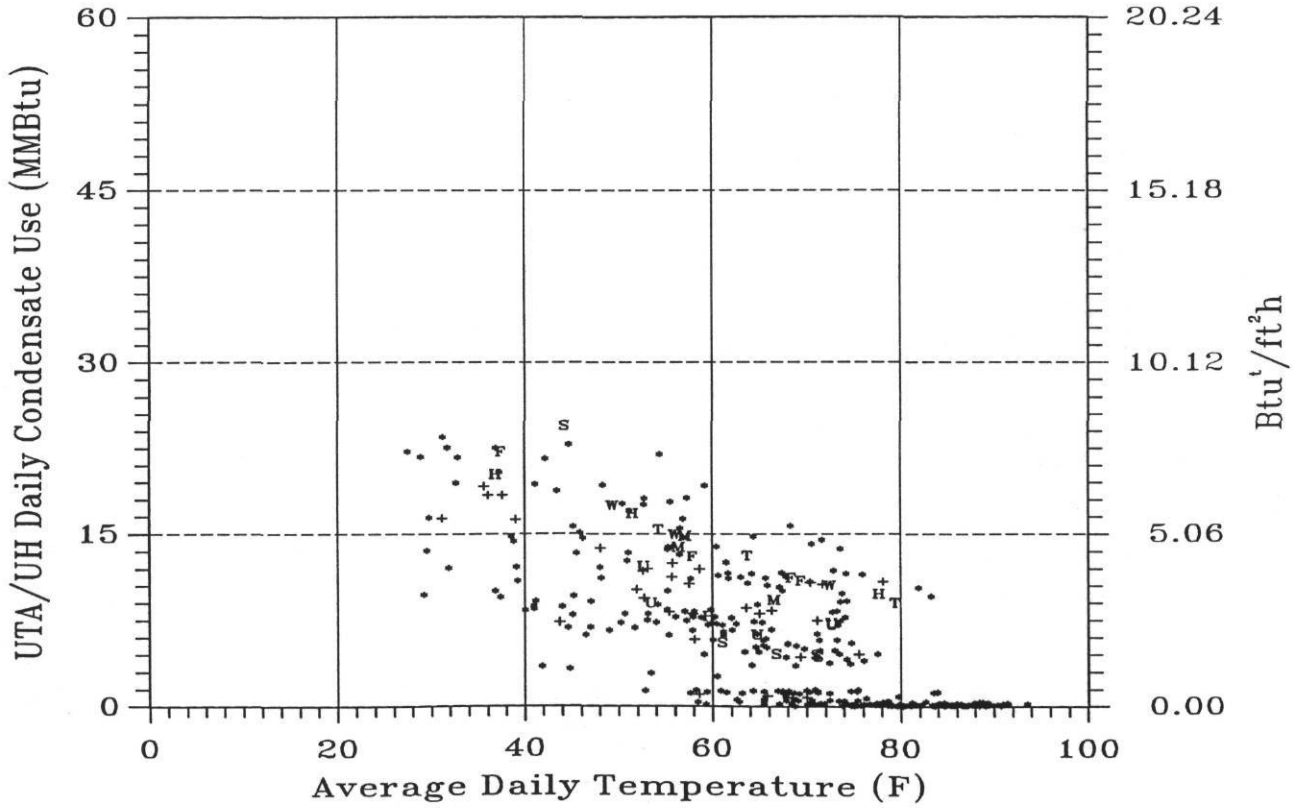
★ Electricity consumption, chilled water, condensate, and Arlington dry bulb temperature and relative humidity data are missing from 3/26/96 to 3/28/96 due to a monitoring hardware problem.

★ Spring Break is evident as reduced electricity consumption from 3/17/96 to 3/24/96.

Mar 01 1995 – Mar 31 1996

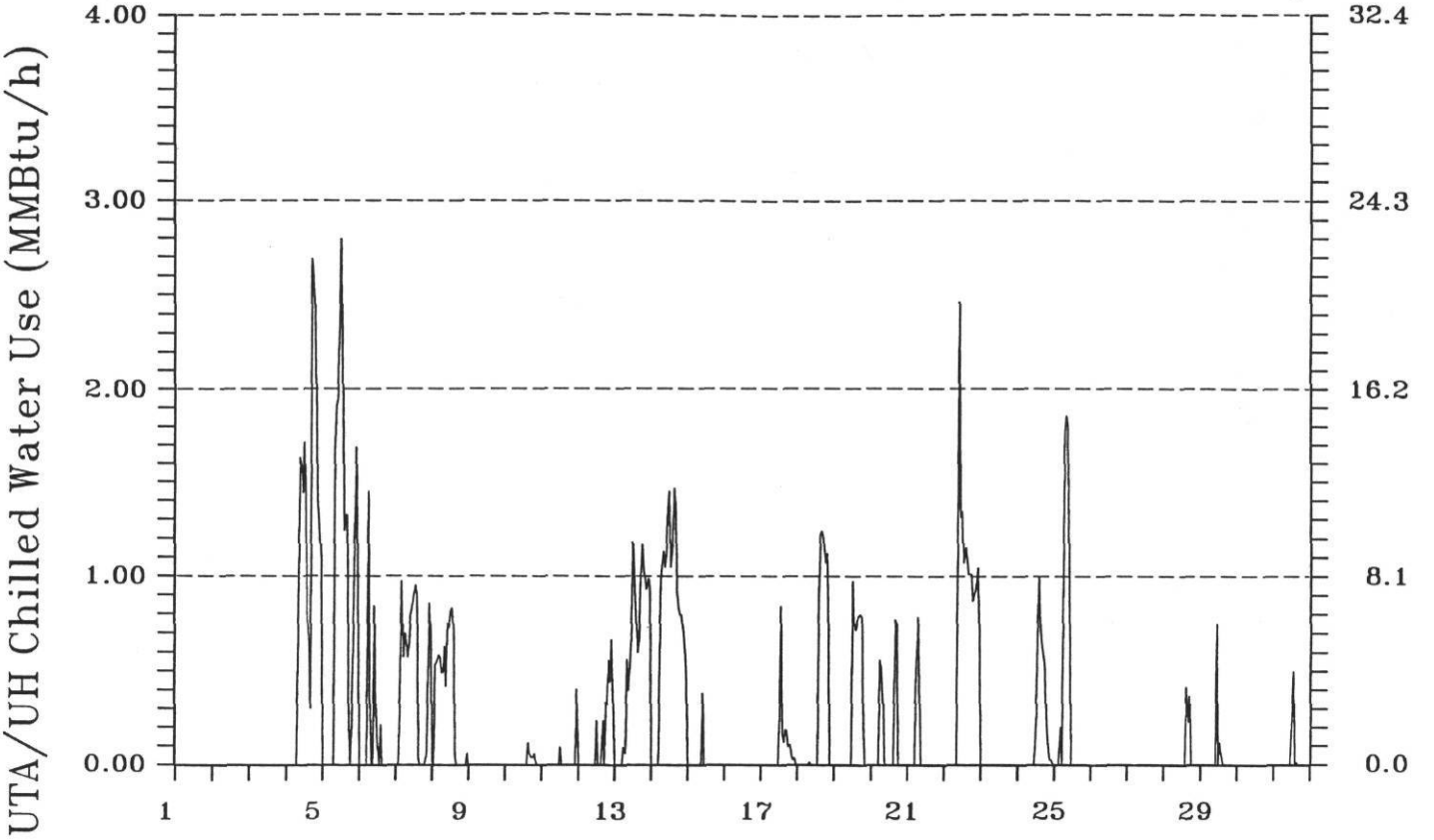


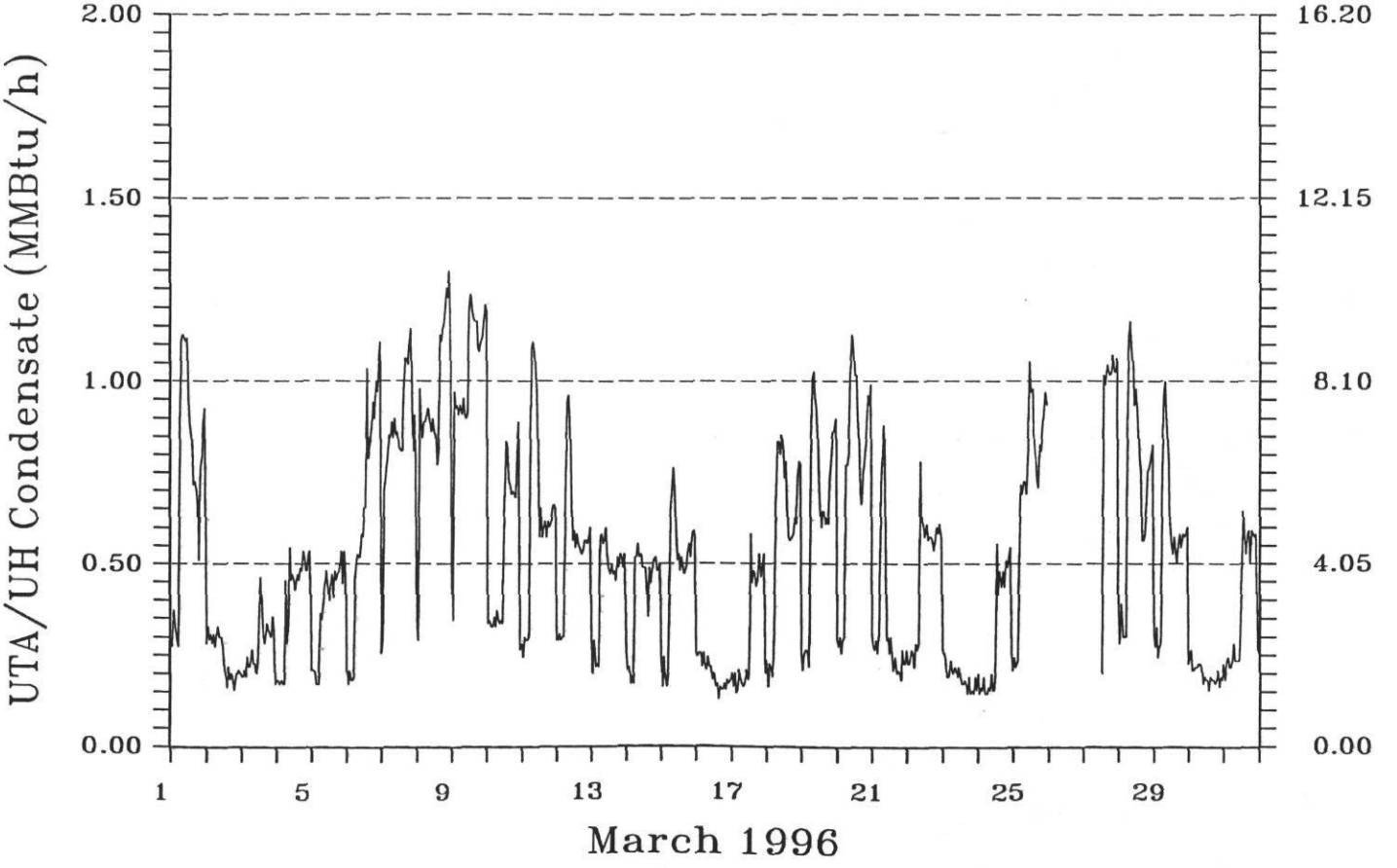
Mar 01 1995 – Mar 31 1996

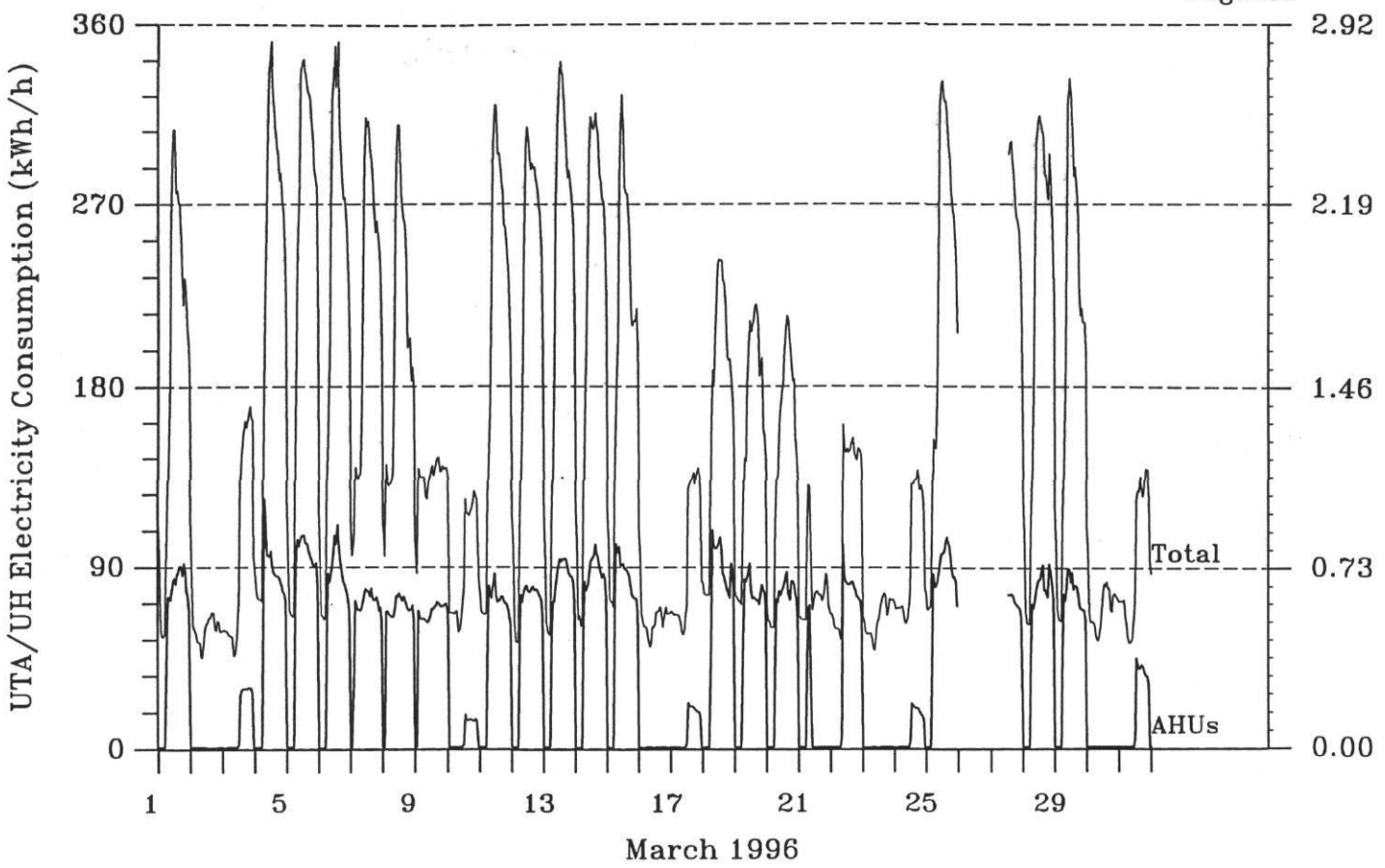


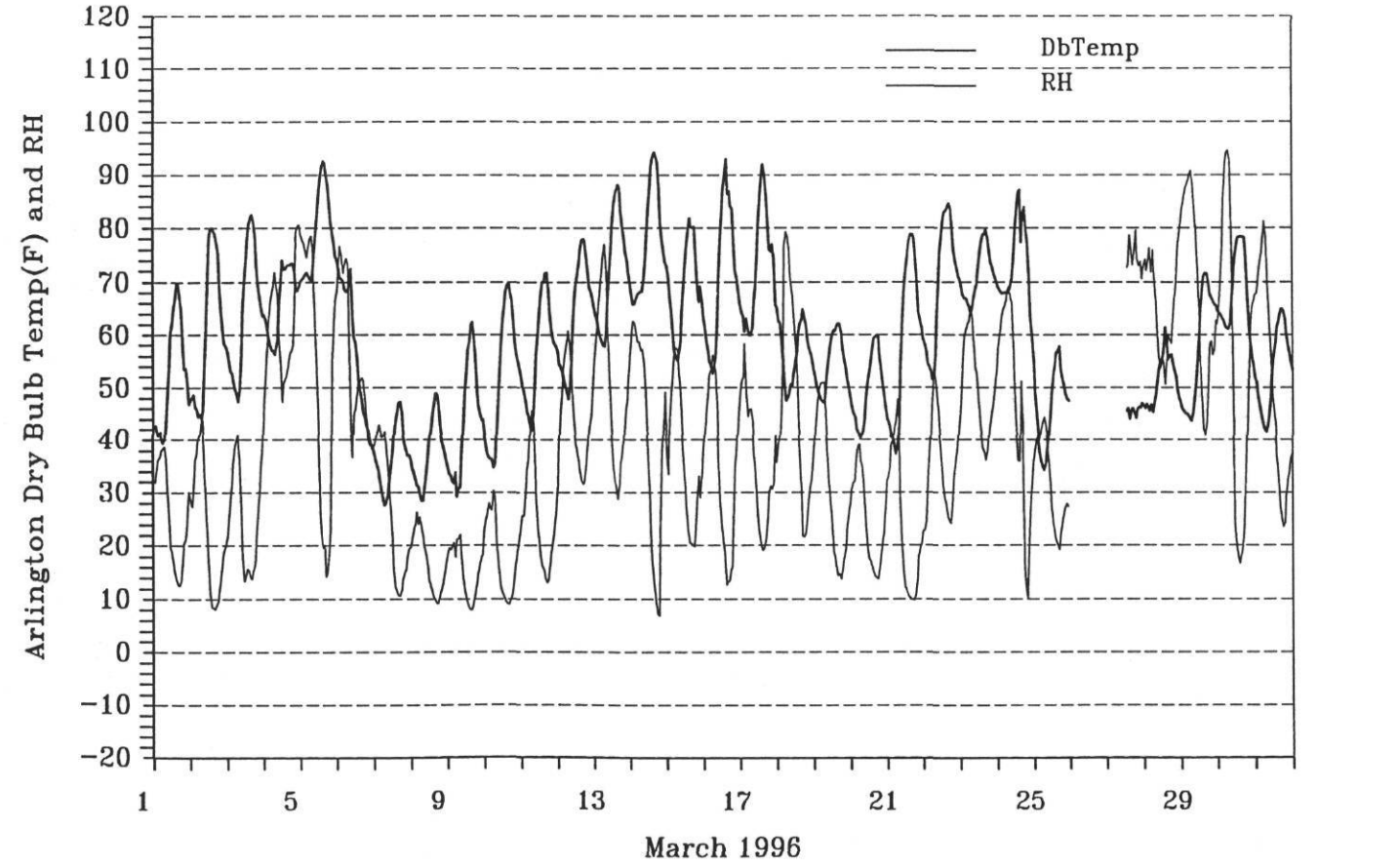
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

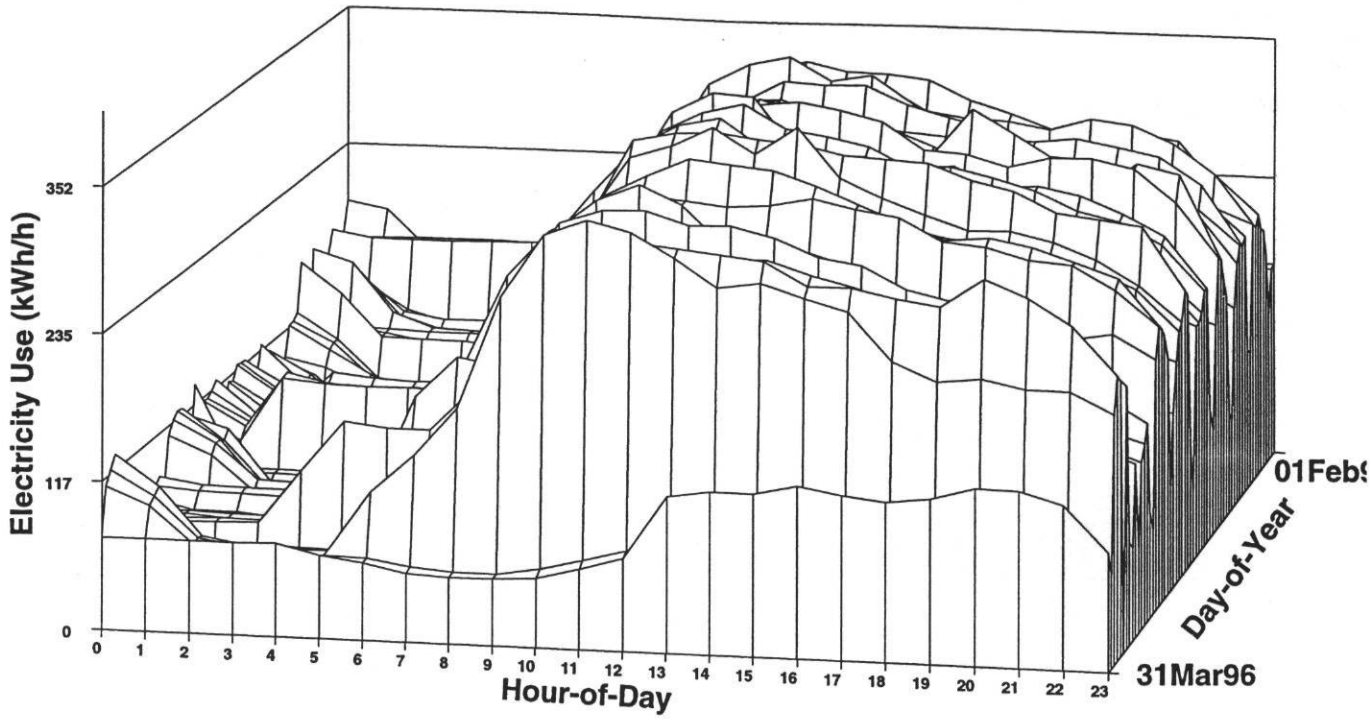

UTA/UH Chilled Water Use (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
32.4
24.3
16.2
8.1
0.0
1
5
9
13
17
21
25
29
March 1996


UTA/UH Condensate (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
16.20
12.15
8.10
4.05
0.00
1
5
9
13
17
21
25
29
March 1996

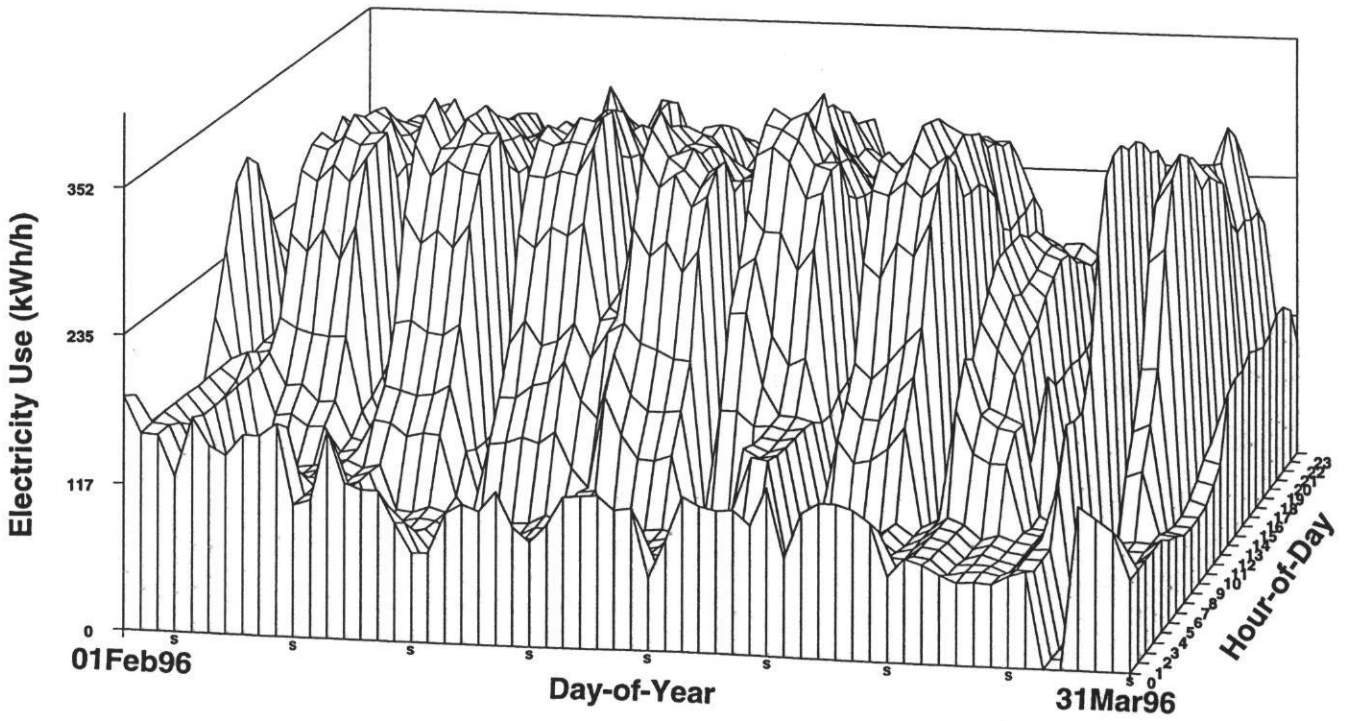

UTA/UH Electricity Consumption (kWh/h)
360
270
180
90
0
2.92
2.19
1.46
0.73
0.00
Total
AHUs
1
5
9
13
17
21
25
29
March 1996


Arlington Dry Bulb Temp(F) and RH
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
DbTemp
RH
1
5
9
13
17
21
25
29
March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

U.T. Arlington

University Hall Building

Building Envelope:
- 123,450 sq.ft.
- 6 floors; offices, classrooms, and lecture halls; built in 1970.
- walls: face brick
- windows: single pane, tinted, operable, 10% of total wall area
- roof: N/A

Building Schedule:
- offices: 8:00 a.m. to 6:00 p.m. (M-F), some night classes

Building HVAC:
- 2 variable volume dual duct AHUs (2-125hp)
- 2 return fans (2-15hp)
- 2 outside air units (2-5hp)
- 2 constant volume chilled water pump (2-30hp)
- 1 hot water pump (N/A)
- 7 exhaust fans (total of 3hp)
- equipped with an economizer cycle

HVAC Schedule:
- 6:00 am to 11:00 pm (Mon -Sat) & 12:00 noon to 11:00 pm (Sun)

Lighting:
- fluorescent 34W

Proposed Retrofits:
- variable speed pumping for chilled water pumps
- lighting control
- VAV conversion of AHUs

Date of Retrofits:
- VAV conversion and lighting modifications were completed in August 1991.

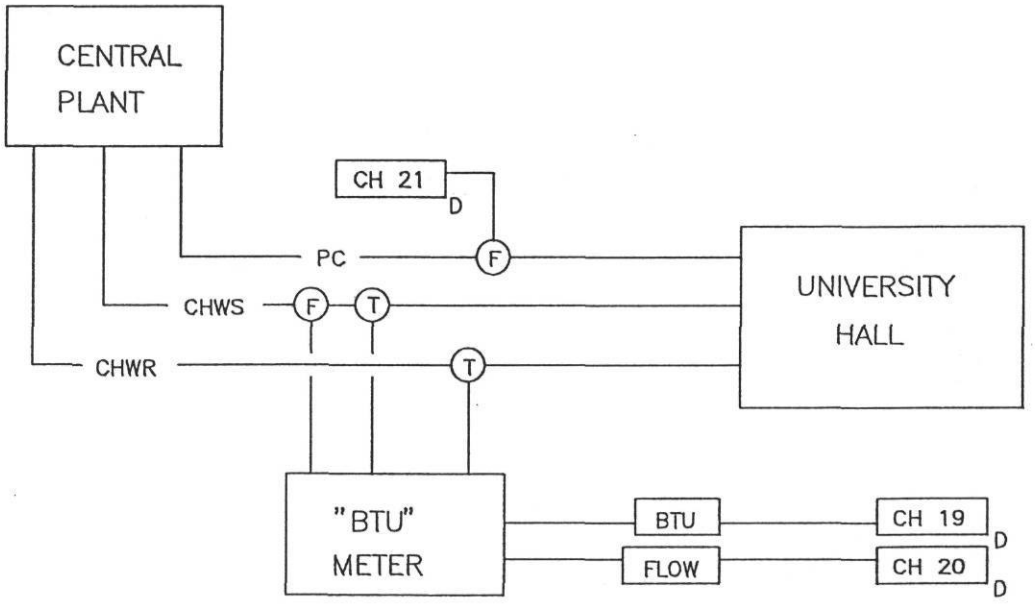
Savings Calculations:
- measured and estimated savings do not include lighting savings.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT ARLINGTON – UNIVERSITY HALL

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

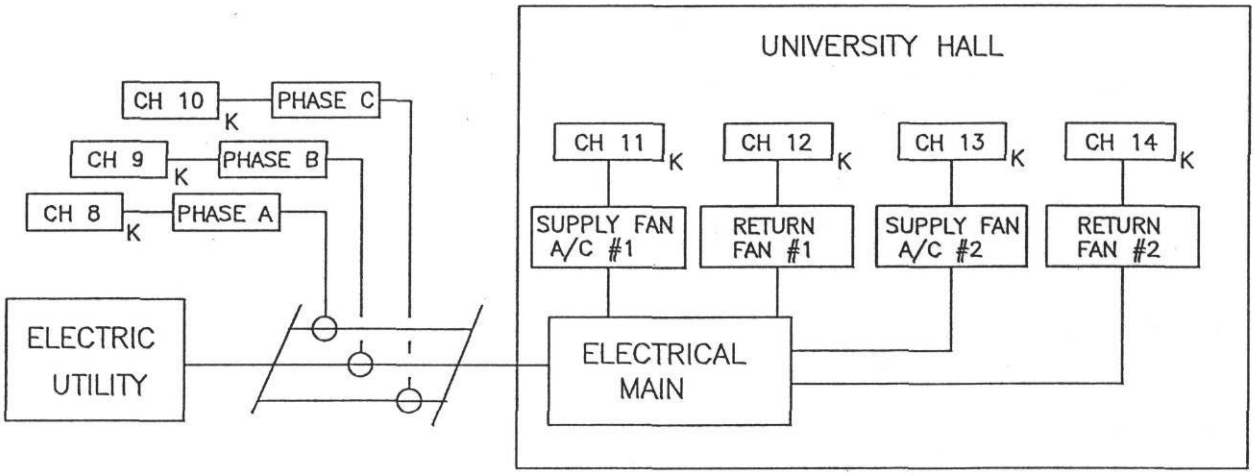


ELECTRICAL MONITORING DIAGRAM

UT ARLINGTON – UNIVERSITY HALL

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL

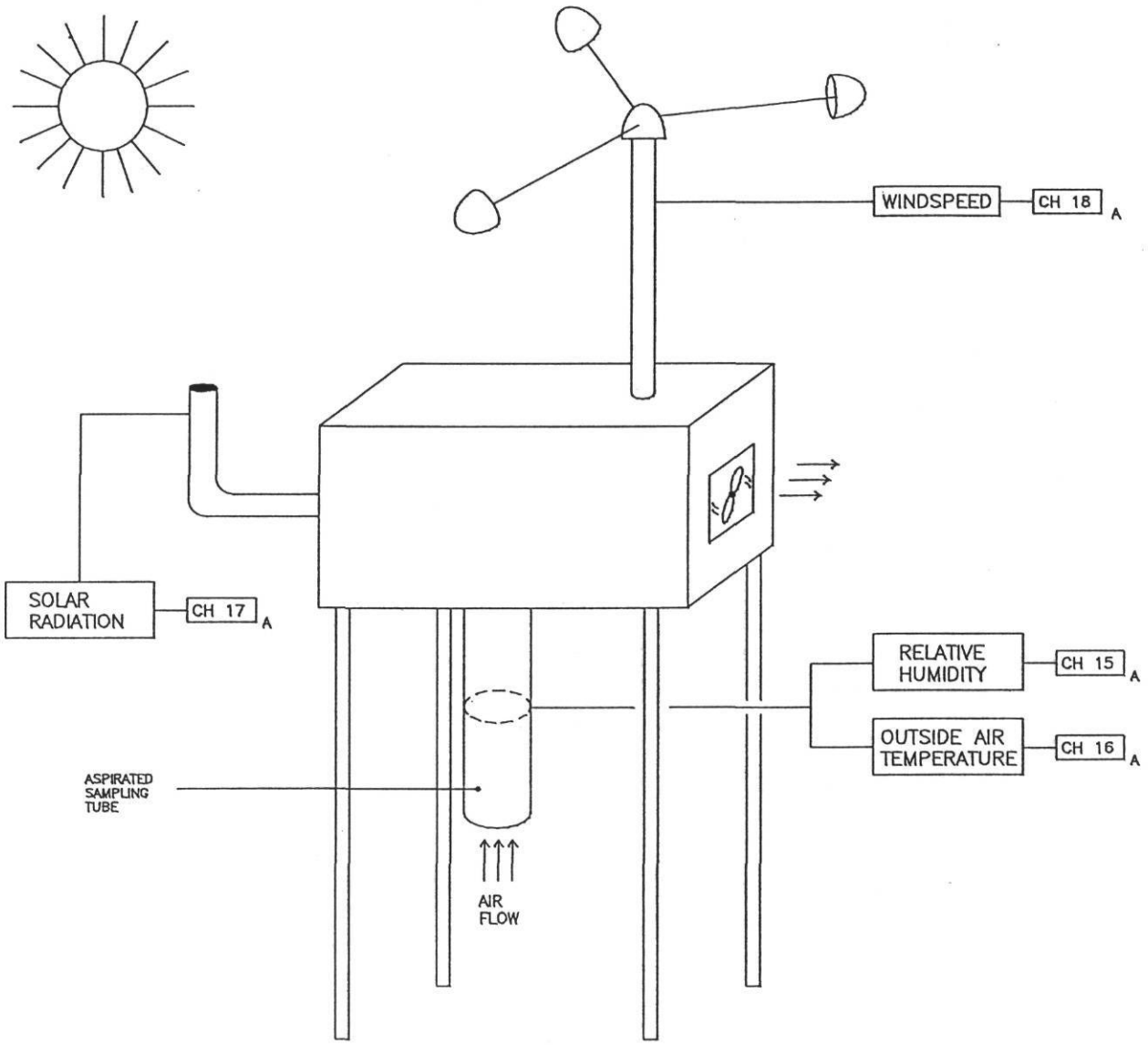


WEATHER MONITORING DIAGRAM

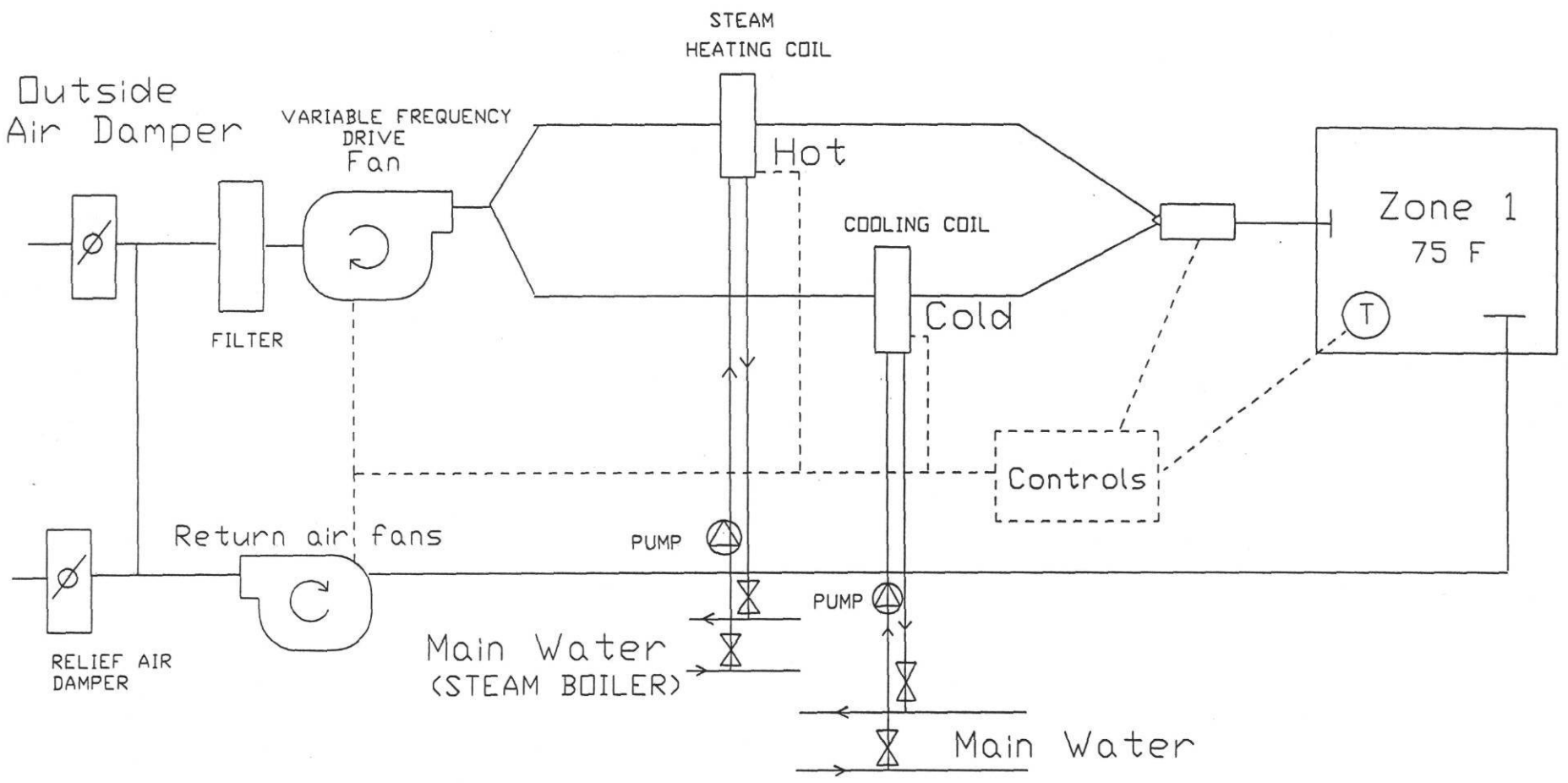
UT ARLINGTON – UNIVERSITY HALL

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



UT ARLINGTON/UNIVERSITY HALL – SITE 111



Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS ARLINGTON-UNIVERSITY HALL	
Typical Dual-Duct System	Date: May 1, 1991
UT-UH 111	Drawn by: Mark Rivera

Business Building

University of Texas at Arlington
149,900 square feet

Site Contact

Mr. Donald A. Decker
Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

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

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	172907	$5068	100	$371	658	$2906	38	$1933	1072	$3902	100	$-200	$2104	$2104
Feb	198355	$5814	99	$444	567	$2504	0	$2306	710	$2584	99	$485	$3235	$5339
Mar	202026	$5921	100	$576	830	$3666	0	$2408	679	$2472	100	$550	$3534	$8873
Apr	209946	$6154	99	$467	969	$4280	0	$2218	361	$1314	99	$1162	$3847	$12720
May	173117	$5074	100	$438	1171	$5172	13	$2316	177	$644	100	$1812	$4566	$17286
Jun	191759	$5620	100	$422	1367	$6038	100	$2335	29	$106	100	$0	$2757	$20043
Jul	206455	$6051	100	$201	1665	$7354	100	$1783	31	$113	100	$0	$1984	$22027
Aug	199622	$5851	87	$323	1460	$6449	87	$2840	32	$116	87	$0	$3163	$25190
Sep	206968	$6066	100	$334	1351	$5967	100	$2131	30	$109	100	$0	$2465	$27655
Oct	216190	$6337	100	$379	1170	$5168	100	$1670	319	$1161	100	$1410	$3459	$31114
Nov	216059	$6333	100	$486	1166	$5150	100	$291	779	$2836	100	$359	$1136	$32250
Dec	195995	$5745	100	$624	1068	$4717	100	$738	819	$2981	100	$379	$1741	$33991
Total	2389399	$70034		$5065	13442	$59371		$22969	5038	$18338		$5957		$33991
EUI	15.9	$\frac{kWh}{ft^2yr}$			89673	$\frac{Btu}{ft^2yr}$			33609	$\frac{Btu}{ft^2yr}$				

Comments

★ **The percent columns indicate the number of hours reported in that month.**

★ **The LoanSTAR monitoring began in January 1991.**

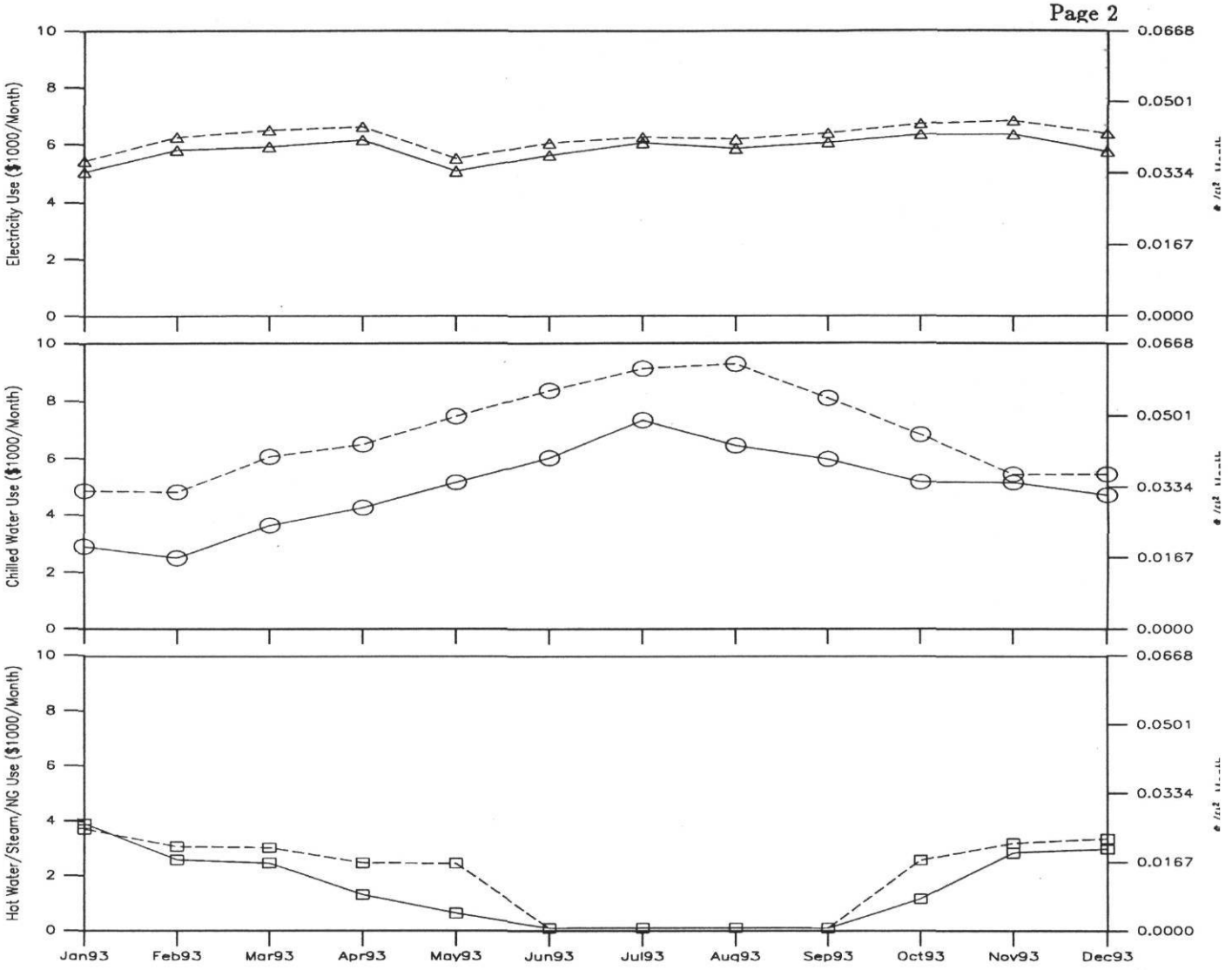
★ **The HVAC retrofit was completed in July 1991.**

★ **The unit costs used for estimating the audit and measured savings are: $0.02931/kWh, $5.827/MMBtu (CW) and $3.44/MMBtu (Steam).**

★ **The audit estimated savings for HVAC retrofits are: $31,100 (ELE), $21,600 (CW), $17,600 (Steam) and $70,300 (Total).**

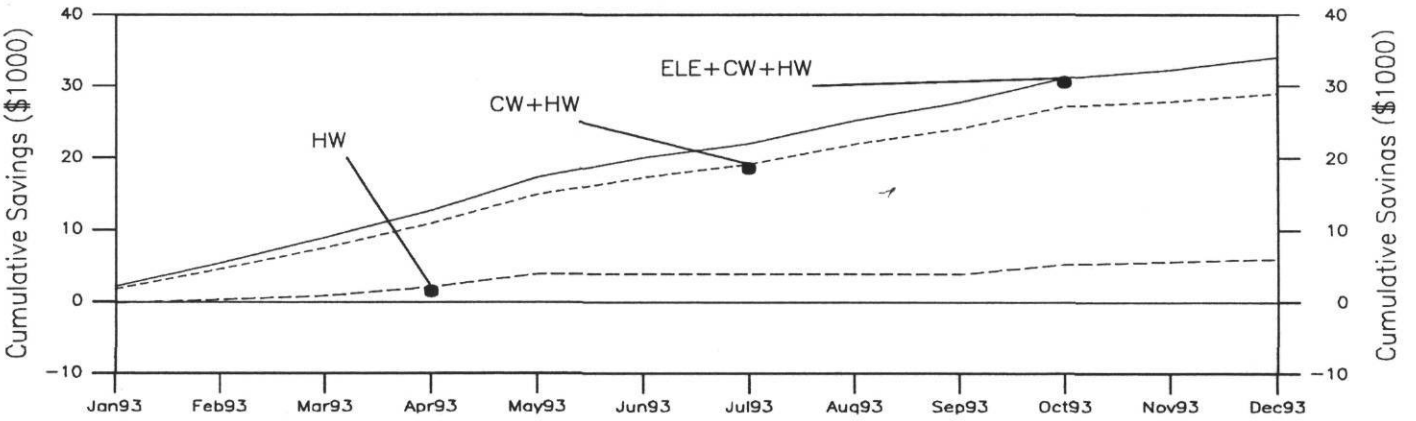
★ **Both the audit and the measured savings do not include savings from a partially completed lighting retrofit.**

★ **Chilled water consumption from January through May were estimated using a post-retrofit regression model, because of missing data due to hardware problems.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



Business Building - University of Texas at Arlington

U.T. Arlington

Business Building

Building Envelope:
- 149,900 sq.ft
- 2 sections (A&B); 3 floors in A section and 6 floors in B section.
- classrooms and lecture halls; built in 1976.
- walls: face brick
- windows: brown tinted, single pane, fixed, 4% of total wall area
- roof: N/A

Building Schedule:
- offices: 8:00 a.m. to 6:00 p.m. (M-F)

Building HVAC:
- 3 variable volume dual duct AHUs (AHU-1, 100hp, AHU-3, 50hp, AHU-2, 40hp)
- 13 exhaust fans (total of 4hp)
- 1 constant volume chilled water pump (1-30hp)
- 1 hot water pump (N/A)
- 3 return fans (RF-1, 10hp, RF-2 & RF-3, 7.5hp each)

HVAC Schedule:
- 24 hrs/day, 7 days a week (AHU-1 & RF-1)
- 6:00 am to 11:00 pm, 7 days a week (AHU-2,3 & RF-2,3)

Lighting:
- fluorescent 34W

Retrofits Implemented:
- VAV conversion for the AHUs
- lighting control

Date of Retrofits:
- VAV conversion and lighting modifications were completed in July 1991.

Savings Calculations:
- measured and estimated savings do not include lighting savings.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

Business Building

University of Texas at Arlington
149,900 square feet

Site Contact

Mr. Donald A. Decker
Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

Aamer Athar
053D 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	147239 kWh	100	$0.02931	$4316
Peak 60 Minute Demand	322 kW	100	$6.81	$2190
Chilled Water	397.8 MMBtu	100	$4.417	$1757
Condensate	649.0 MMBtu	100	$3.640	$2362

Peak 60 minute demand was recorded at 1100 Friday 03/01/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	70322	$2061	173475	$5085
Chilled Water (MMBtu)	889	$3927	407	$1798
Cond./H.W./N.G. (MMBtu)	209	$761	403	$1467
Monthly Total		$6749		$8349
Total to Date*	(57 months)	$205464	(56 months)	$370273

*Measured savings include construction period. Audit estimated savings do not.

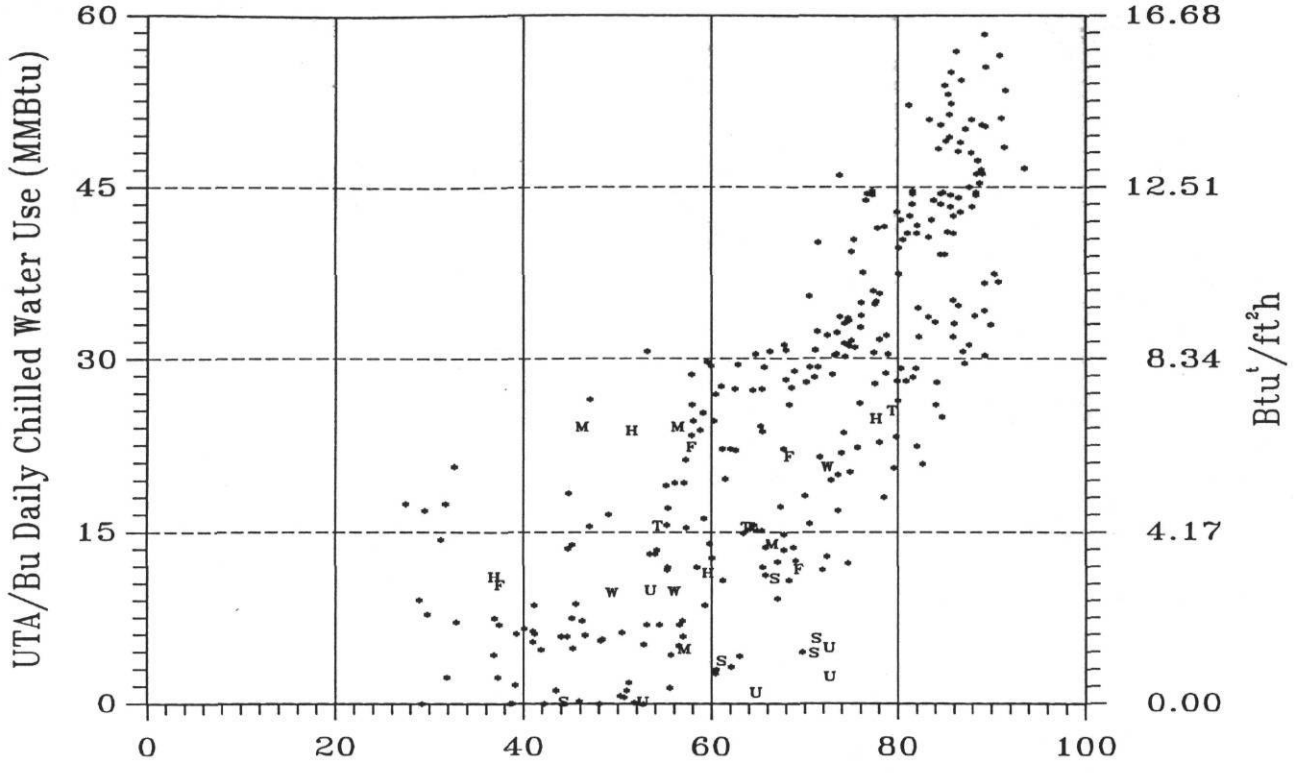
Comments

★ Steam use has increased significantly when compared to March 1995.

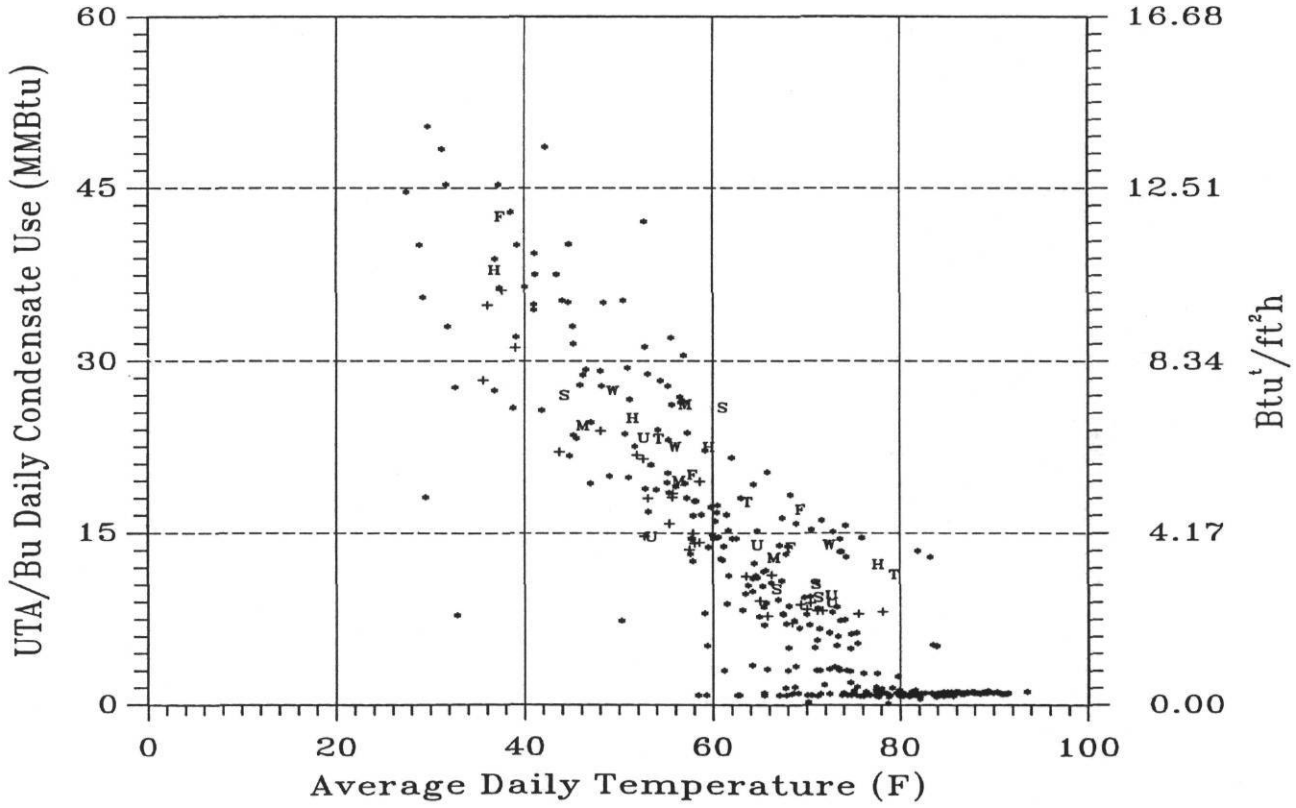
★ Spring Break is evident as reduced electricity consumption from 3/17/96 to 3/24/96.

★ Dry bulb temperature and relative humidity data are missing from 3/26/96 to 3/28/96 due to a monitoring hardware problem.

Mar 01 1995 – Mar 31 1996

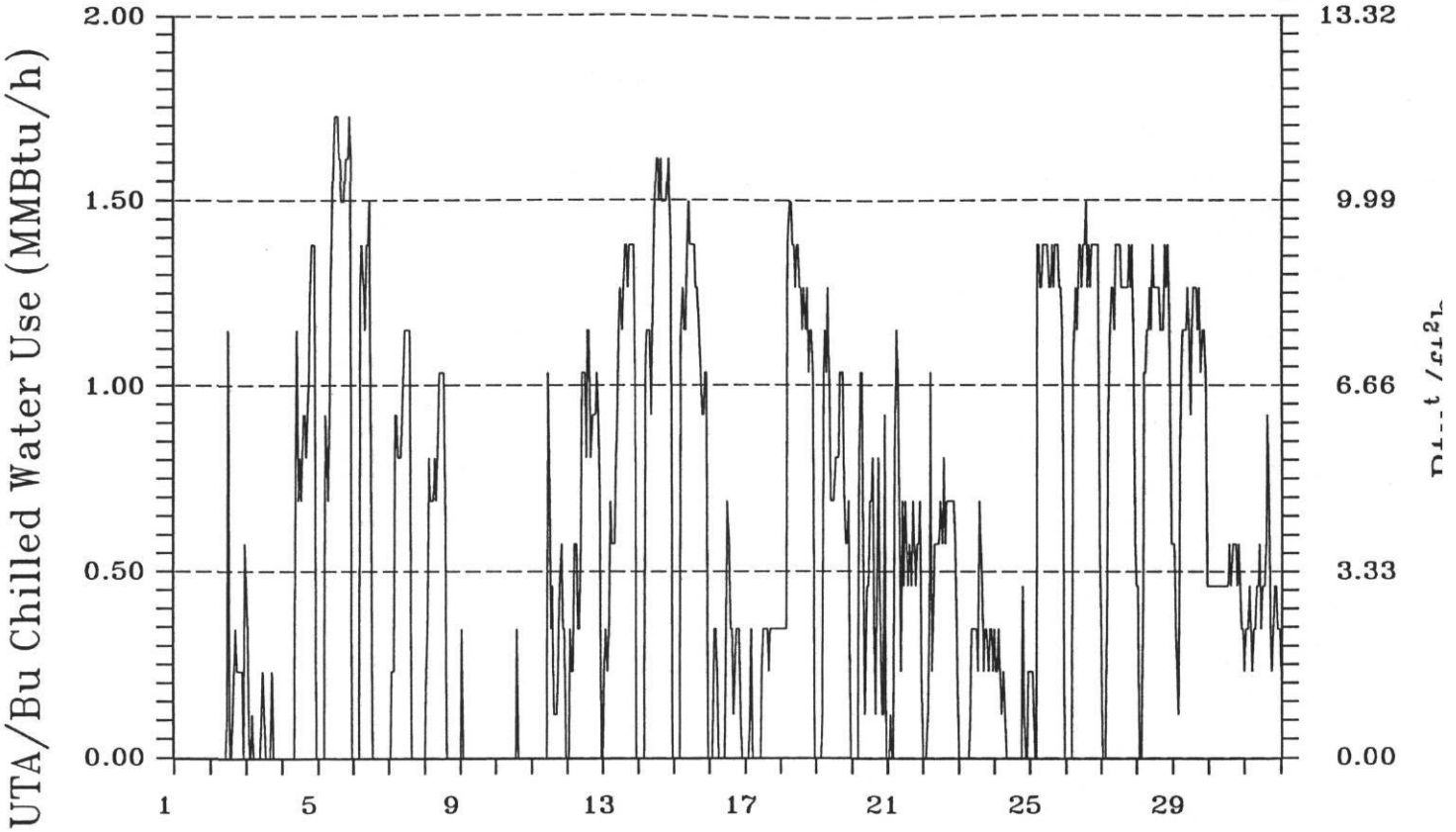


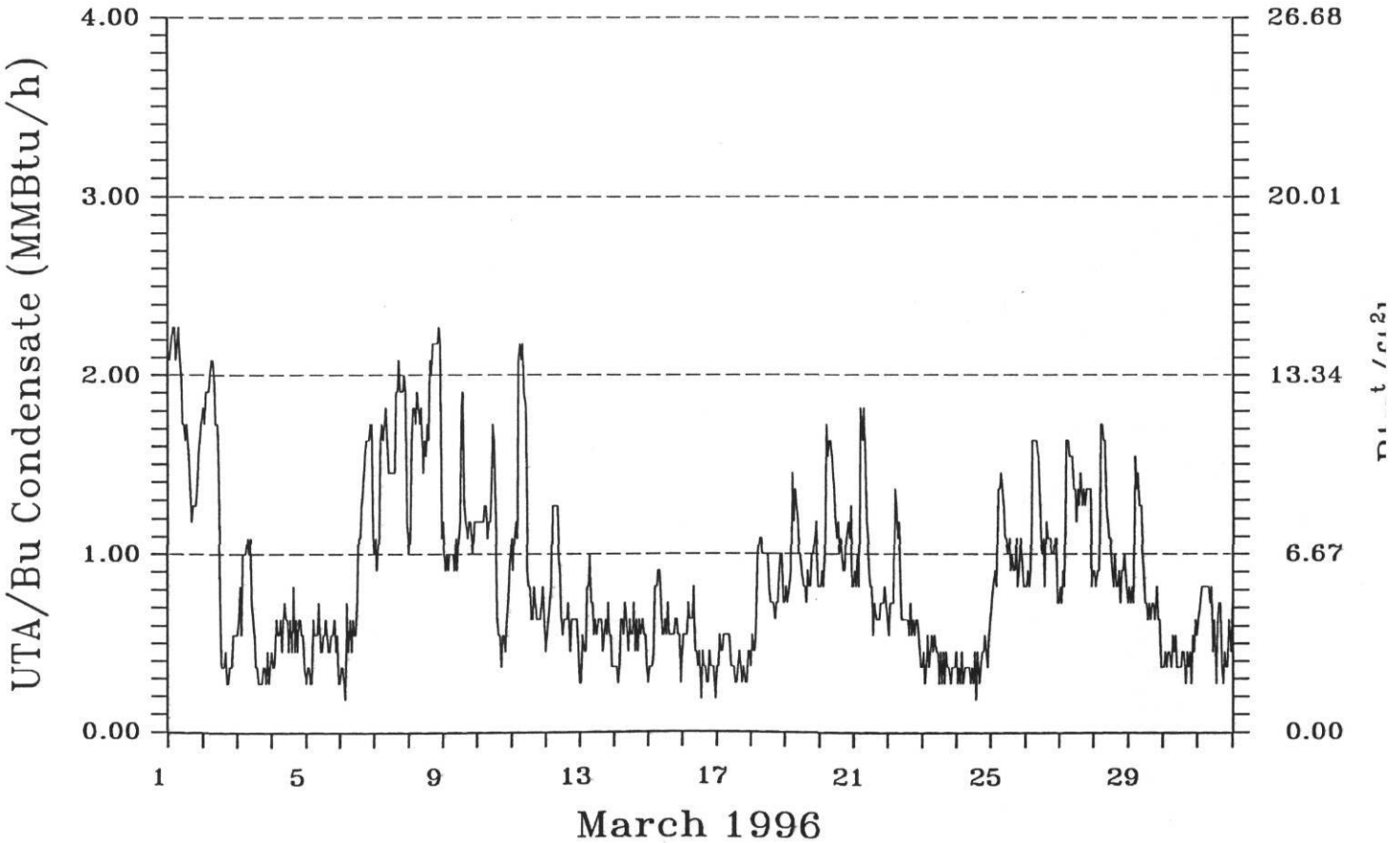
Mar 01 1995 – Mar 31 1996

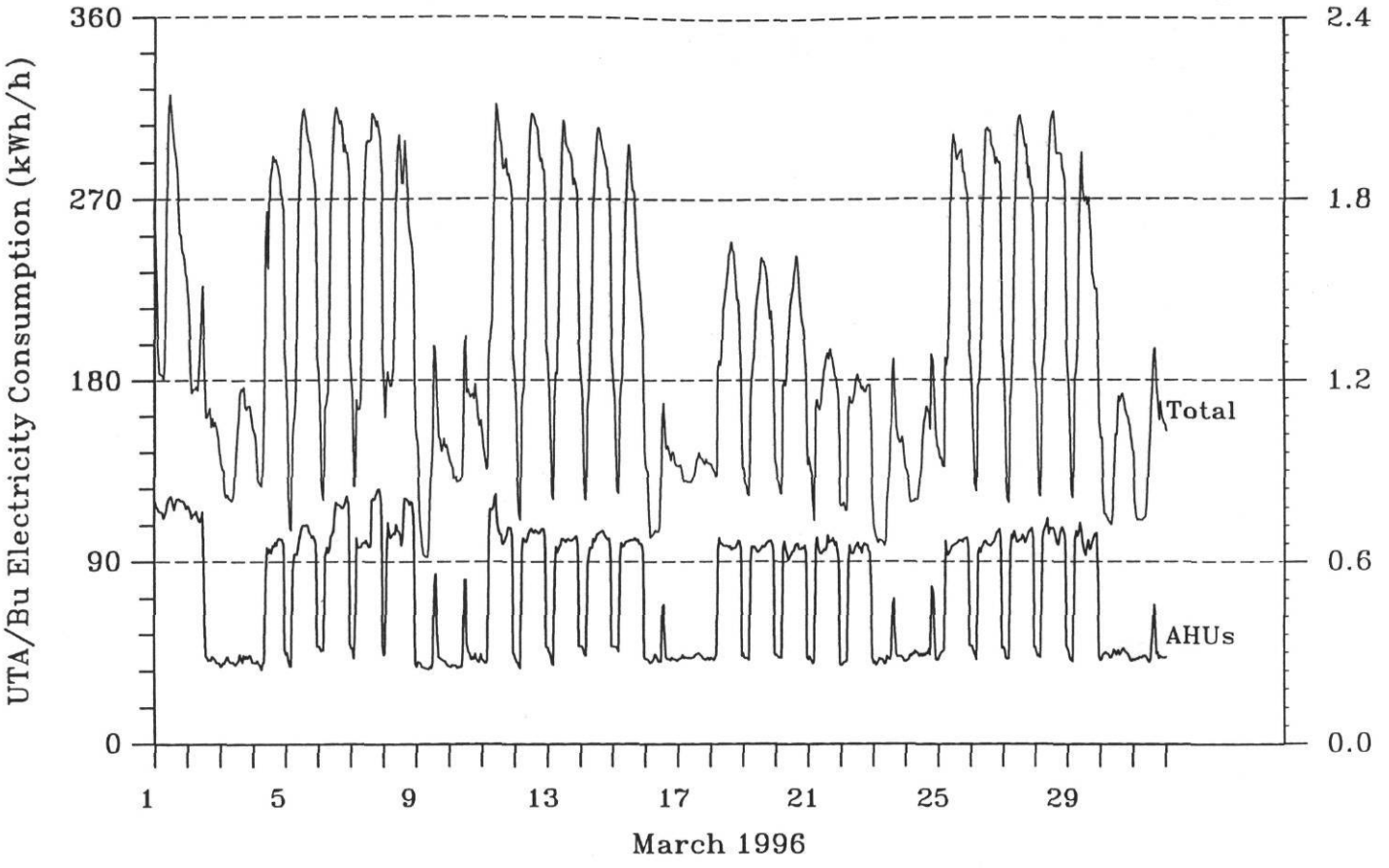


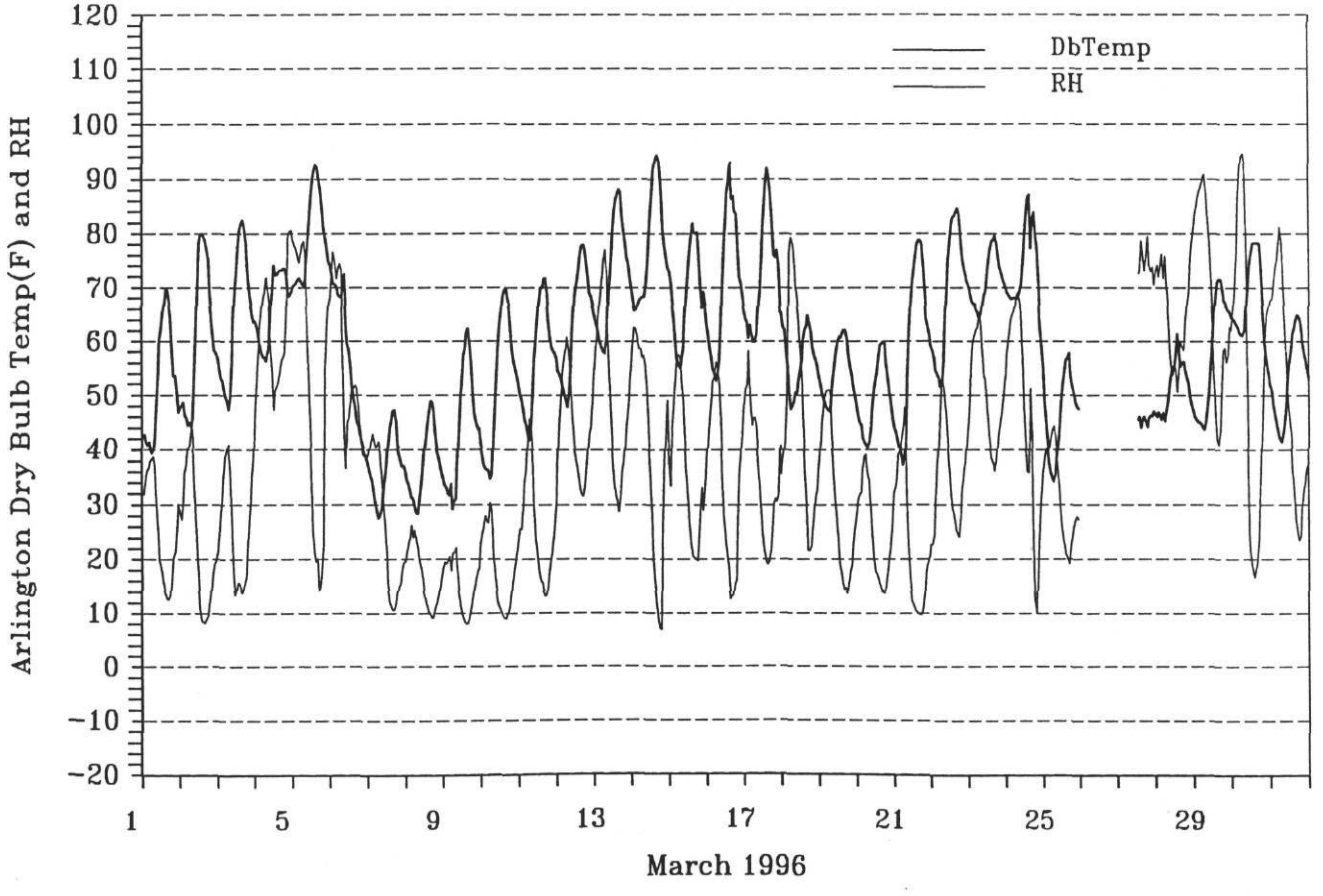
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

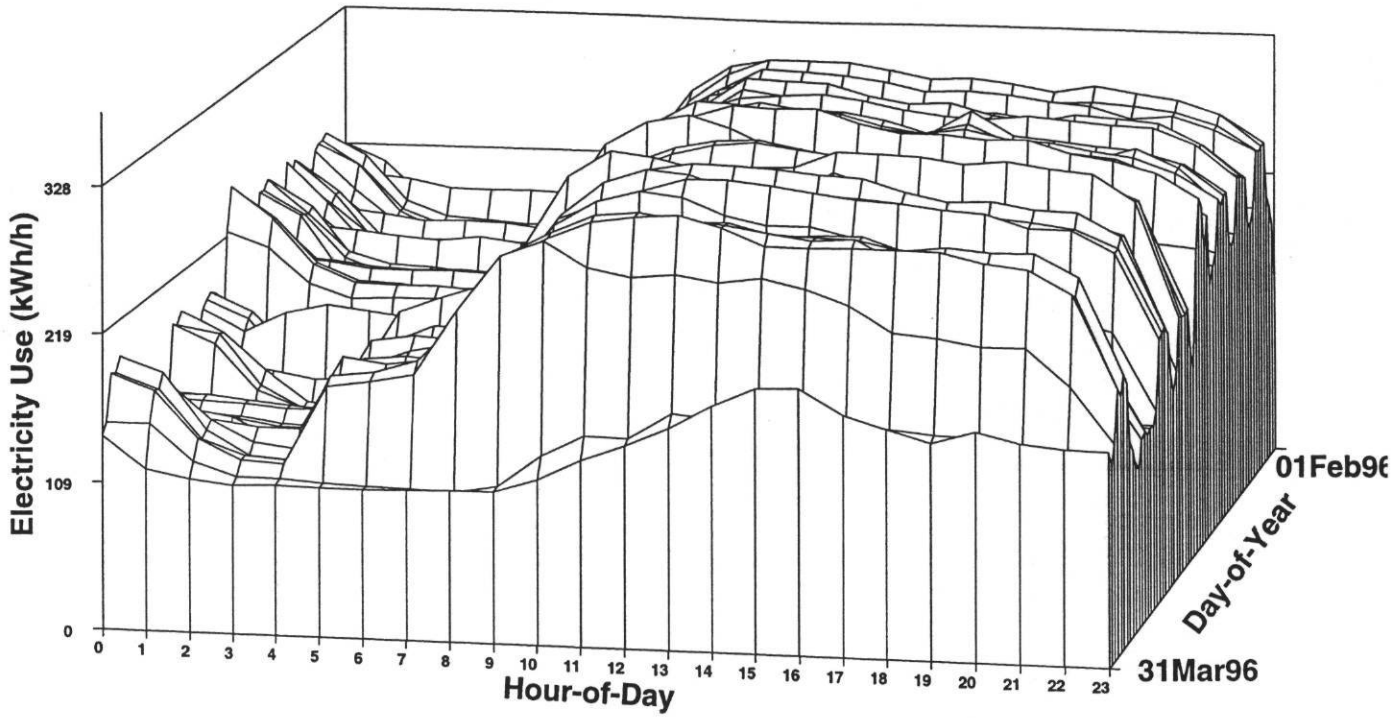

UTA/Bu Chilled Water Use (MMBtu/h)
2.00
1.50
1.00
0.50
0.00
13.32
9.99
6.66
3.33
0.00
1
5
9
13
17
21
25
29
March 1996


UTA/Bu Condensate (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
26.68
20.01
13.34
6.67
0.00
1
5
9
13
17
21
25
29
March 1996

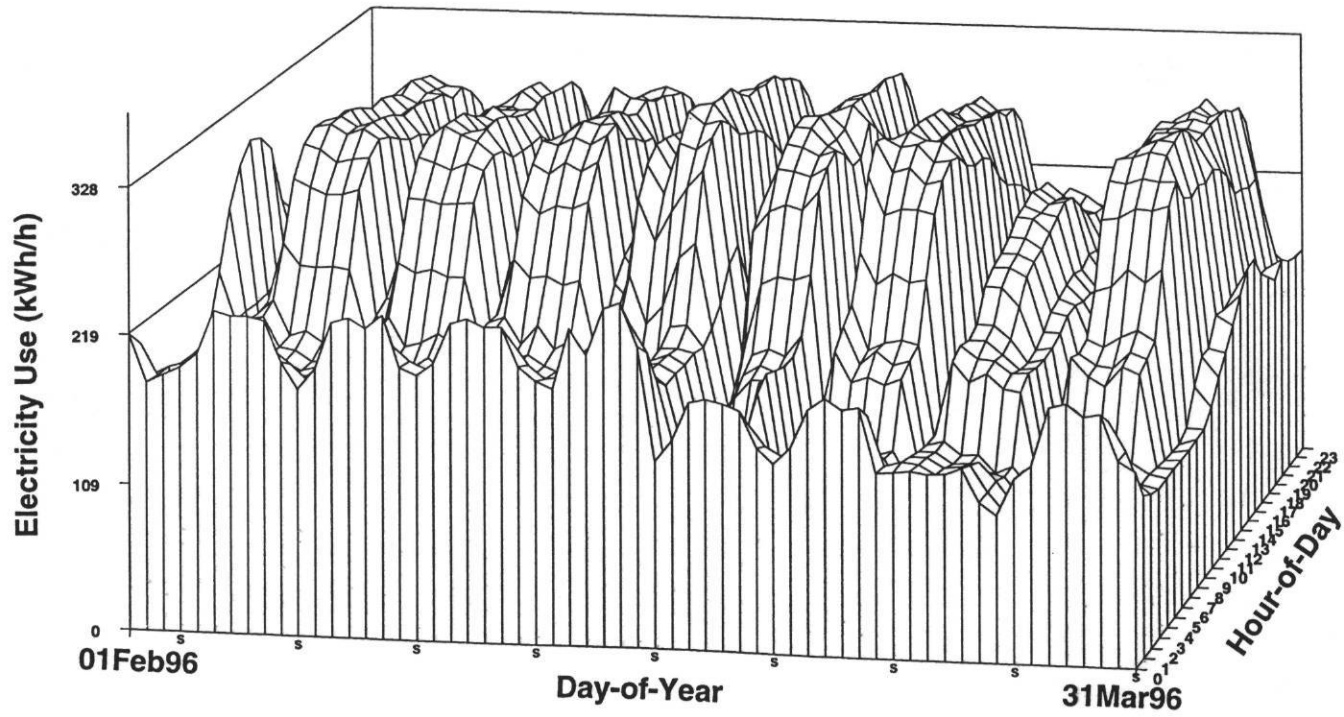

UTA/Bu Electricity Consumption (kWh/h)
360
270
180
90
0
2.4
1.8
1.2
0.6
0.0
Total
AHUs
1
5
9
13
17
21
25
29
March 1996


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

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

U.T. Arlington

Business Building

Building Envelope:
- 149,900 sq.ft
- 2 sections (A&B); 3 floors in A section and 6 floors in B section.
- classrooms and lecture halls; built in 1976.
- walls: face brick
- windows: brown tinted, single pane, fixed, 4% of total wall area
- roof: N/A

Building Schedule:
- offices: 8:00 a.m. to 6:00 p.m. (M-F)

Building HVAC:
- 3 variable volume dual duct AHUs (AHU-1, 100hp, AHU-3, 50hp, AHU-2, 40hp)
- 13 exhaust fans (total of 4hp)
- 1 constant volume chilled water pump (1-30hp)
- 1 hot water pump (N/A)
- 3 return fans (RF-1, 10hp, RF-2 & RF-3, 7.5hp each)

HVAC Schedule:
- 24 hrs/day, 7 days a week (AHU-1 & RF-1)
- 6:00 am to 11:00 pm, 7 days a week (AHU-2,3 & RF-2,3)

Lighting:
- fluorescent 34W

Retrofits Implemented:
- VAV conversion for the AHUs
- lighting control
- Fluorescent lighting upgrade and zone occupancy sensors

Date of Retrofits:
- VAV conversion and lighting modifications were completed in July 1991. Lighting projects for fluorescent upgrade and zone occupancy sensors were completed in December 1994.

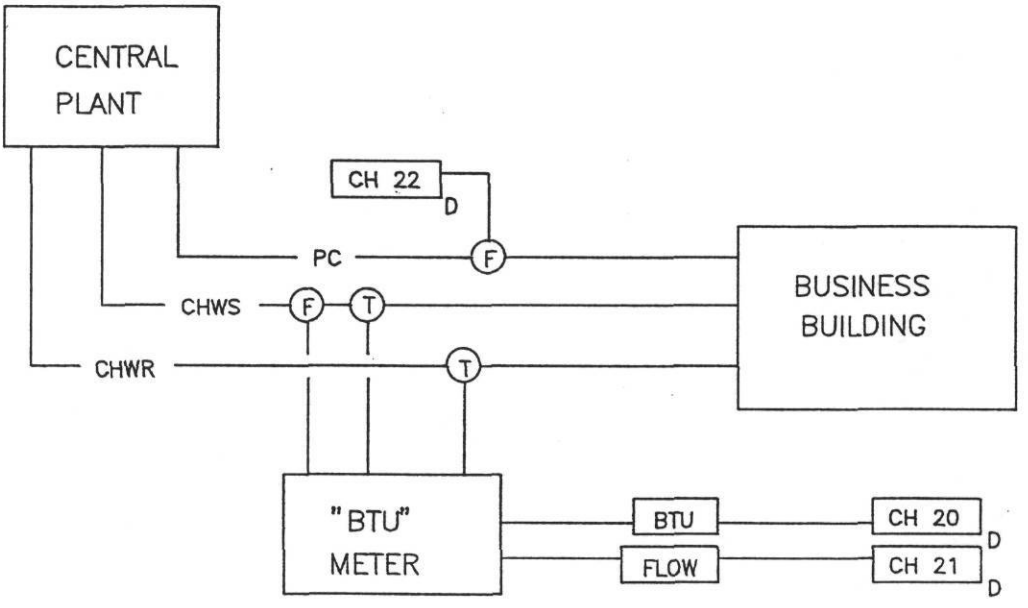
Savings Calculations:
- measured and estimated savings include lighting savings from March 1995.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT ARLINGTON – BUSINESS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

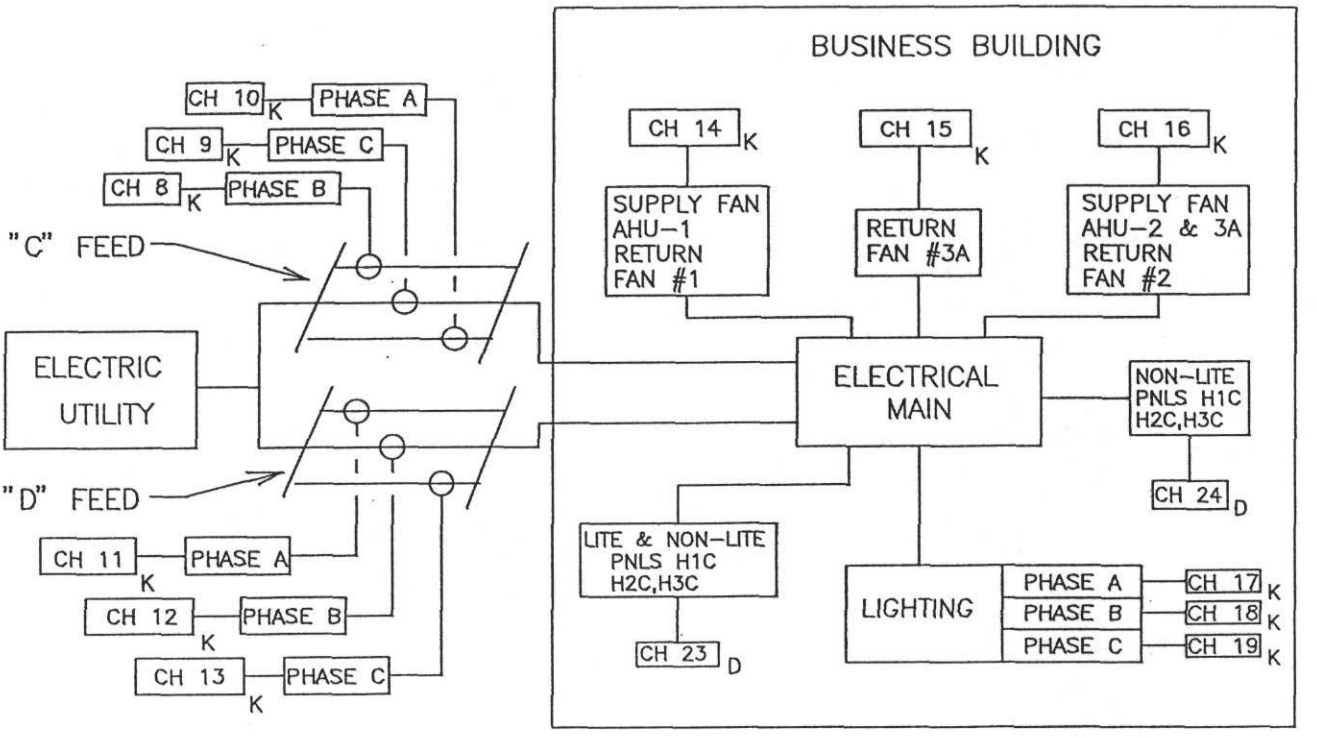


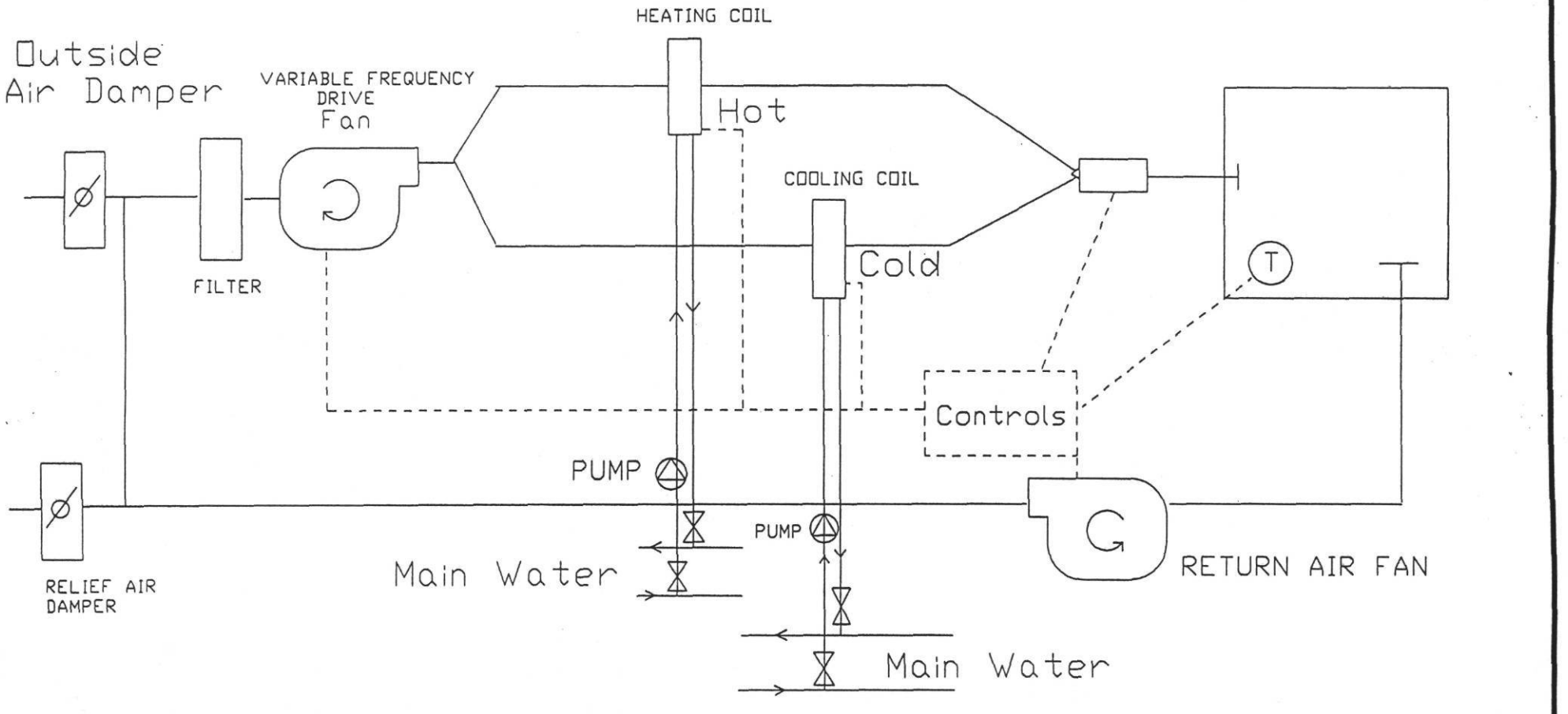
ELECTRICAL MONITORING DIAGRAM

UT ARLINGTON – BUSINESS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL





Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS ARLINGTON BUSINESS BUILDING	
Typical Dual-Duct System	Date: May 1, 1991
BUS-112	Drawn by: Mark Rivera

Fine Arts Building

University of Texas at Arlington
223,000 square feet

Site Contact

Mr. Donald A. Decker
Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

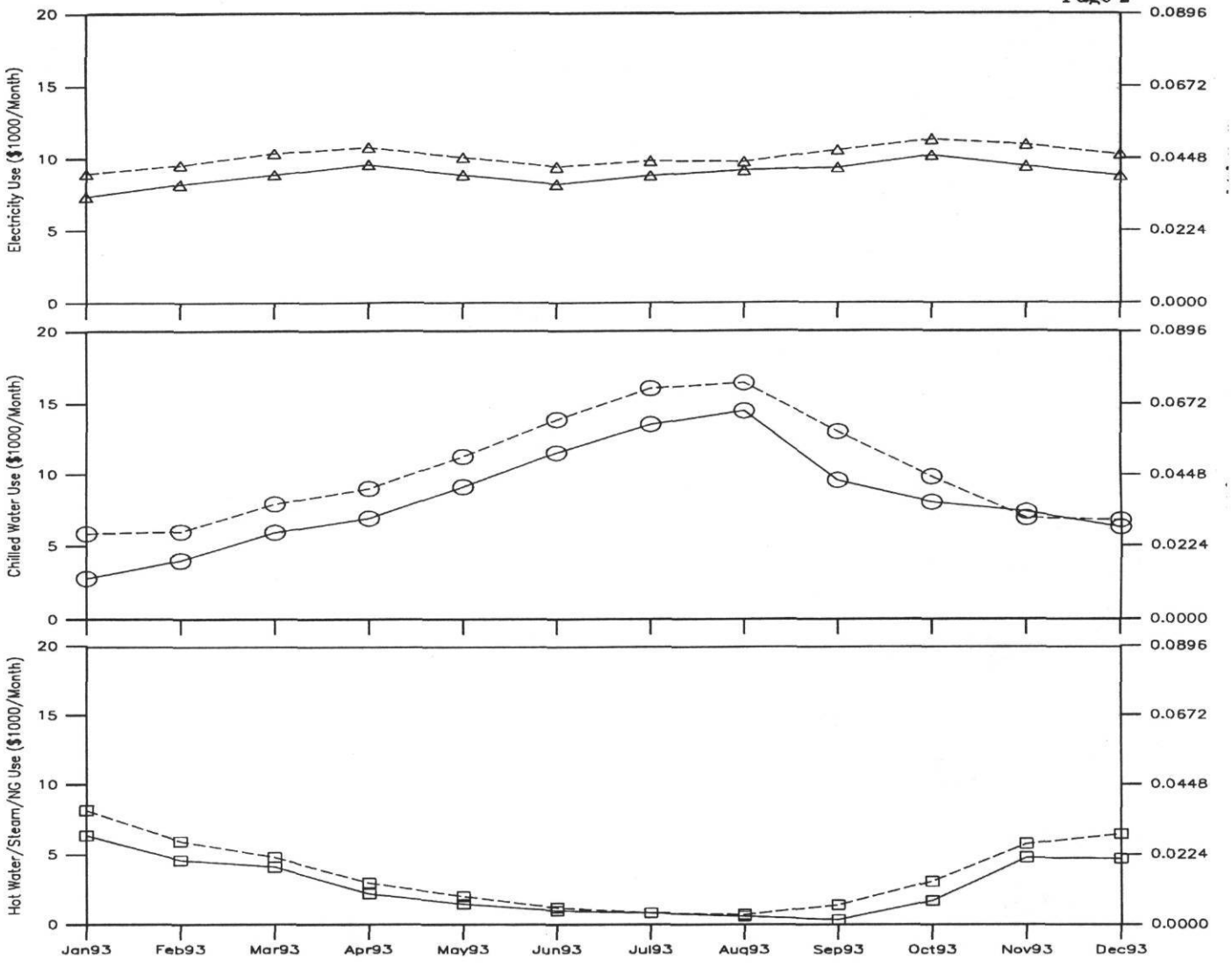
Aamer Athar
053D WERC
Texas A&M University
College Station, TX 77843-3123
(409)–845–9213

1993 Summary of Measured Energy Consumption and Savings

	Electricity				Chilled Water				Hot Water/Steam/NG				Total	
	Consumption			Savings	Consumption			Savings	Consumption			Savings	Monthly	Cumulative
Month	kWh	$	%	$	MMBtu	$	%	$	MMBtu	$	%	$	Savings	Savings
Jan	250603	$7345	100	$1616	636	$2809	100	$3041	1743	$6345	100	$1802	$6459	$6459
Feb	279418	$8190	100	$1360	907	$4006	100	$1996	1263	$4597	100	$1328	$4684	$11143
Mar	302700	$8872	100	$1490	1356	$5989	100	$1979	1135	$4131	100	$682	$4151	$15294
Apr	326873	$9581	99	$1207	1579	$6974	100	$2062	610	$2220	99	$768	$4037	$19331
May	302154	$8856	100	$1224	2078	$9179	100	$2097	406	$1478	100	$544	$3865	$23196
Jun	279468	$8191	100	$1224	2612	$11537	100	$2338	274	$997	100	$223	$3785	$26981
Jul	300851	$8818	100	$1008	3069	$13556	100	$2505	233	$848	100	$-11	$3502	$30483
Aug	313377	$9185	100	$589	3280	$14488	97	$1971	164	$597	100	$133	$2693	$33176
Sep	319647	$9369	99	$1225	2174	$9603	99	$3435	98	$357	99	$1068	$5728	$38904
Oct	348879	$10226	98	$1088	1824	$8057	99	$1796	474	$1725	99	$1376	$4260	$43164
Nov	322353	$9448	100	$1506	1672	$7385	100	$-452	1316	$4790	100	$965	$2019	$45183
Dec	300279	$8801	100	$1485	1425	$6294	100	$514	1298	$4725	100	$1721	$3720	$48903
Total	3646602	$106882		$15022	22612	$99877		$23282	9014	$32810		$10599		$48903
EUI	16.4	$\frac{kWh}{ft^2yr}$			101399	$\frac{Btu}{ft^2yr}$			40421	$\frac{Btu}{ft^2yr}$				

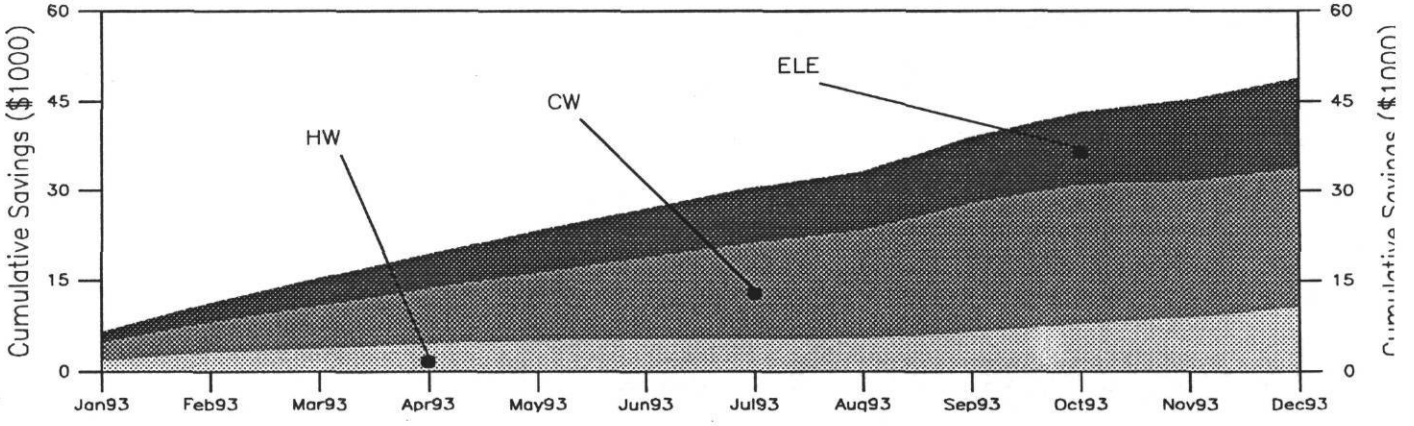
Comments

★ **The percent columns indicate the number of hours reported in that month.**
★ **The LoanSTAR monitoring began in January 1991.**
★ **The HVAC retrofit was completed in August 1991.**
★ **The unit costs used for estimating the audit and the measured savings are: $0.02931/kWh, $5.827/MMBtu (CW) and $3.44/MMBtu (Steam).**
★ **The audit estimated savings for HVAC retrofits are: $50,900 (ELE), $25,200 (CW), $22,100 (HW) and $98,200 (Total).**
★ **Both the audit and the measured savings do not include savings from a partially completed lighting retrofit.**
★ **Electricity and chilled water savings have decreased significantly when compared to 1992.**



Solid line represents measured energy use while the dashed line indicates the energy that would have been consumed had the retrofit not been installed

△ Electric ○ Cooling □ Heating



U.T. Arlington

Fine Arts Building

Building Envelope:
- 223,000 sq.ft.
- 5 section building was constructed in 1972 around an existing theatre.
- four departments: Music, Art, Communications, and Architecture
- walls: face brick
- windows: brown tinted, single pane, fixed, 6% of total wall area
- roof: N/A

Building Schedule:
- Offices: 8:00 a.m. to 6:00 p.m. (M-F); various schedules

Building HVAC:
- 4 variable volume dual duct AHUs (AHU-3, 100hp, AHU-1, 50hp, AHU-5 &7, 75hp each)
- 8 constant volume single-zone units (3-15hp, 1-10hp,1-5hp,1-3hp,1-2hp,1-1hp)
- 30 exhaust fans (total of 14hp)
- 2 constant speed chilled water pump (2-100hp)
- 2 constant speed chilled water pump (2-5hp)
- 1 hot water pump (N/A)
- 7 return fans (2-7.5hp, 2-5hp, 2-25hp,1-20hp)
- 4 variable volume duct units are equiped with an economizer cycle

HVAC Schedule:
- 24 hrs/day, 7 days a week (AHU-1, RF-1)
- 17 hrs/day (6:00 am to 11:00 pm, all other AHUs)

Lighting:
- fluorescent 34W

Retrofits Implemented:
- VAV conversion for the AHUs
- lighting control
- variable speed control for chilled water pumps

Date of Retrofits:
- VAV conversion and lighting modifications were completed by August 1991.

Savings Calculations:
- measured and estimated savings do not include lighting savings.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

Fine Arts Building

University of Texas at Arlington
223,000 square feet

Site Contact

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Director of Physical Plant
University of Texas at Arlington
Box 19228
Arlington, TX 76019-0228
(817)–273–3571

LoanSTAR Metering Contact

Aamer Athar
053D 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	254272 kWh	100	$0.02931	$7453
Peak 60 Minute Demand	527 kW	100	$6.81	$3583
Chilled Water	1165.6 MMBtu	100	$4.417	$5149
Condensate	1281.1 MMBtu	100	$3.640	$4663

Peak 60 minute demand was recorded at 1300 Wednesday 03/06/96.
There were 744 hours in this month.

Monthly Retrofit Savings

	Measured Savings		Audit Estimated Savings	
Electricity (kWh)	104999	$3078	272359	$7983
Chilled Water (MMBtu)	526	$2323	475	$2098
Cond./H.W./N.G. (MMBtu)	271	$986	505	$1838
Monthly Total		$6387		$11919
Total to Date*	(58 months)	$216350	(55 months)	$532135

*Measured savings include construction period. Audit estimated savings do not.

Comments

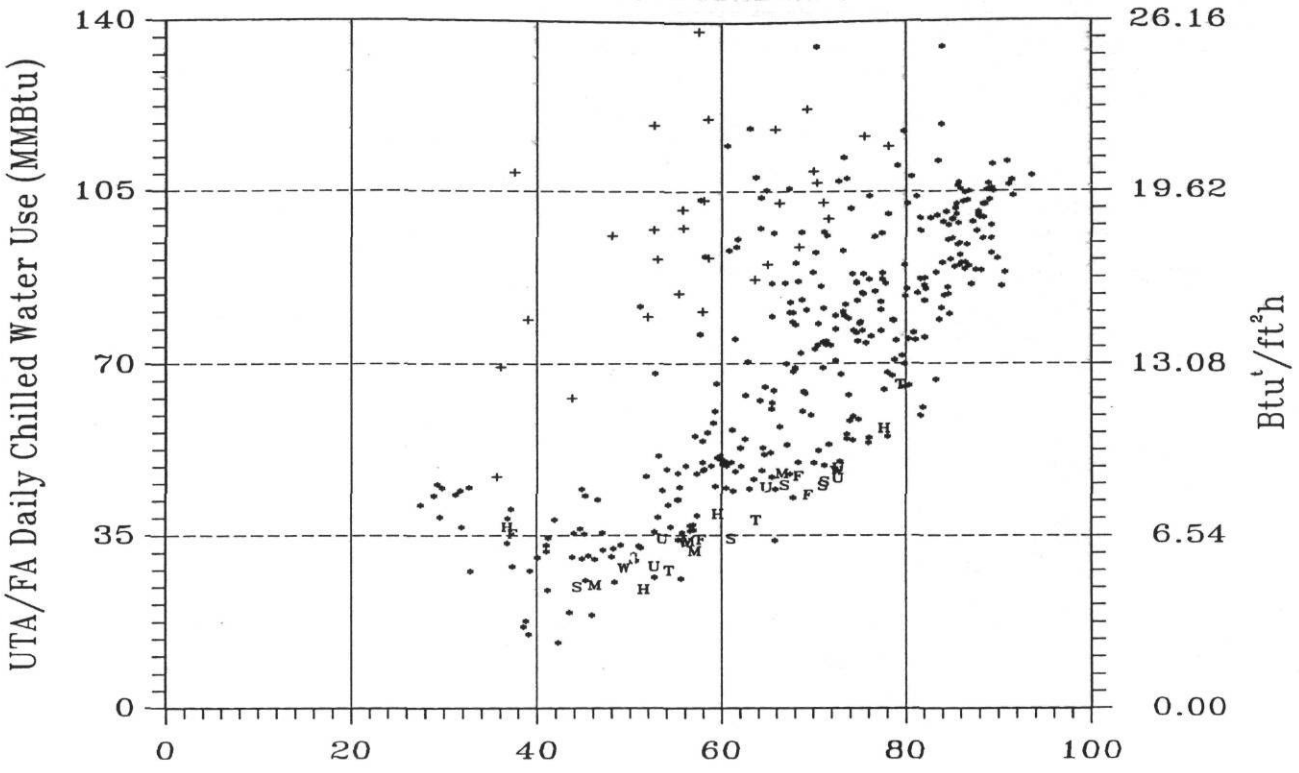
★ Chilled water energy consumption has decreased significantly when compared to March 1995.

★ Spring Break is evident as reduced electricity consumption from 3/17/96 to 3/24/96.

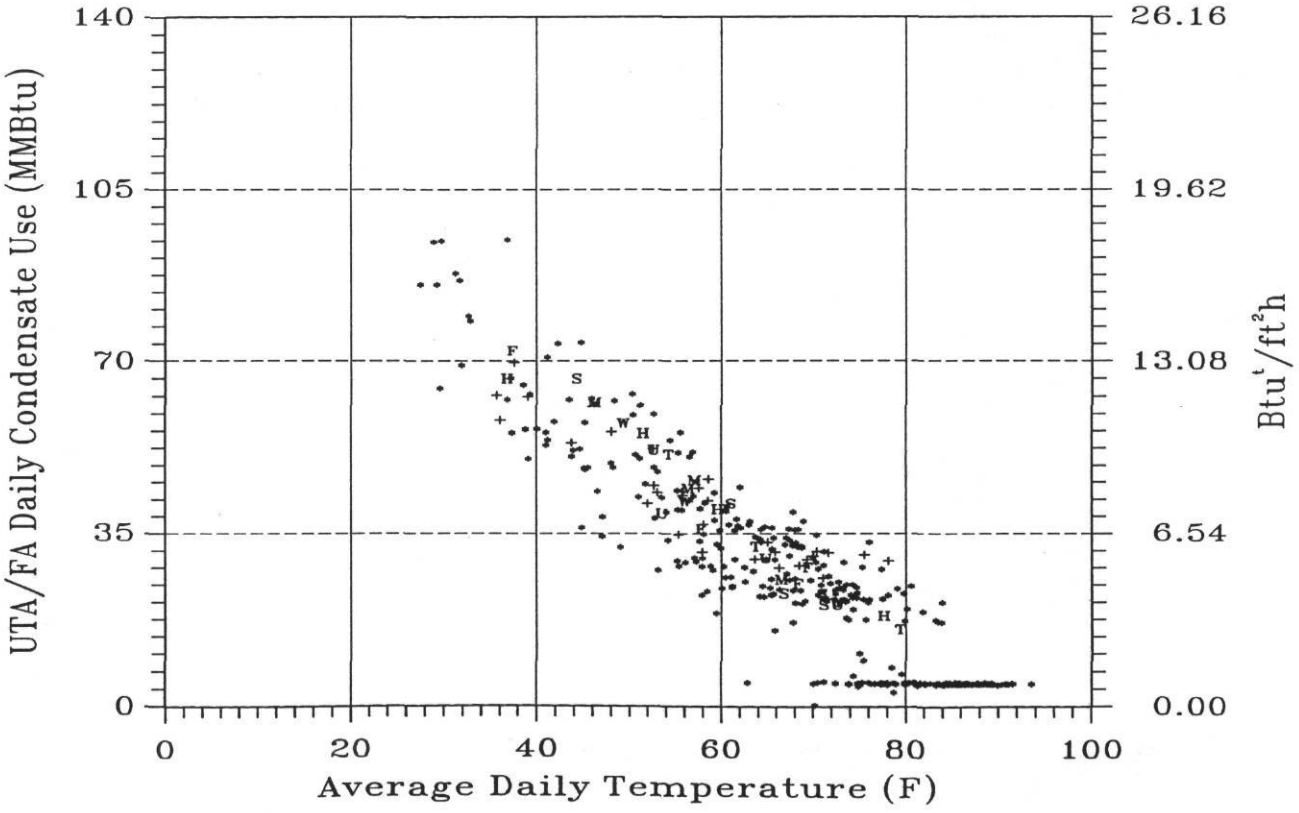
★ Daytime AHU electricity consumption has decreased slightly when compared to March 1995. Nighttime AHU use has increased slightly.

★ Dry bulb temperature and relative humidity data are missing from 3/26/96 to 3/28/96 due to a monitoring hardware problem.

Mar 01 1995 – Mar 31 1996

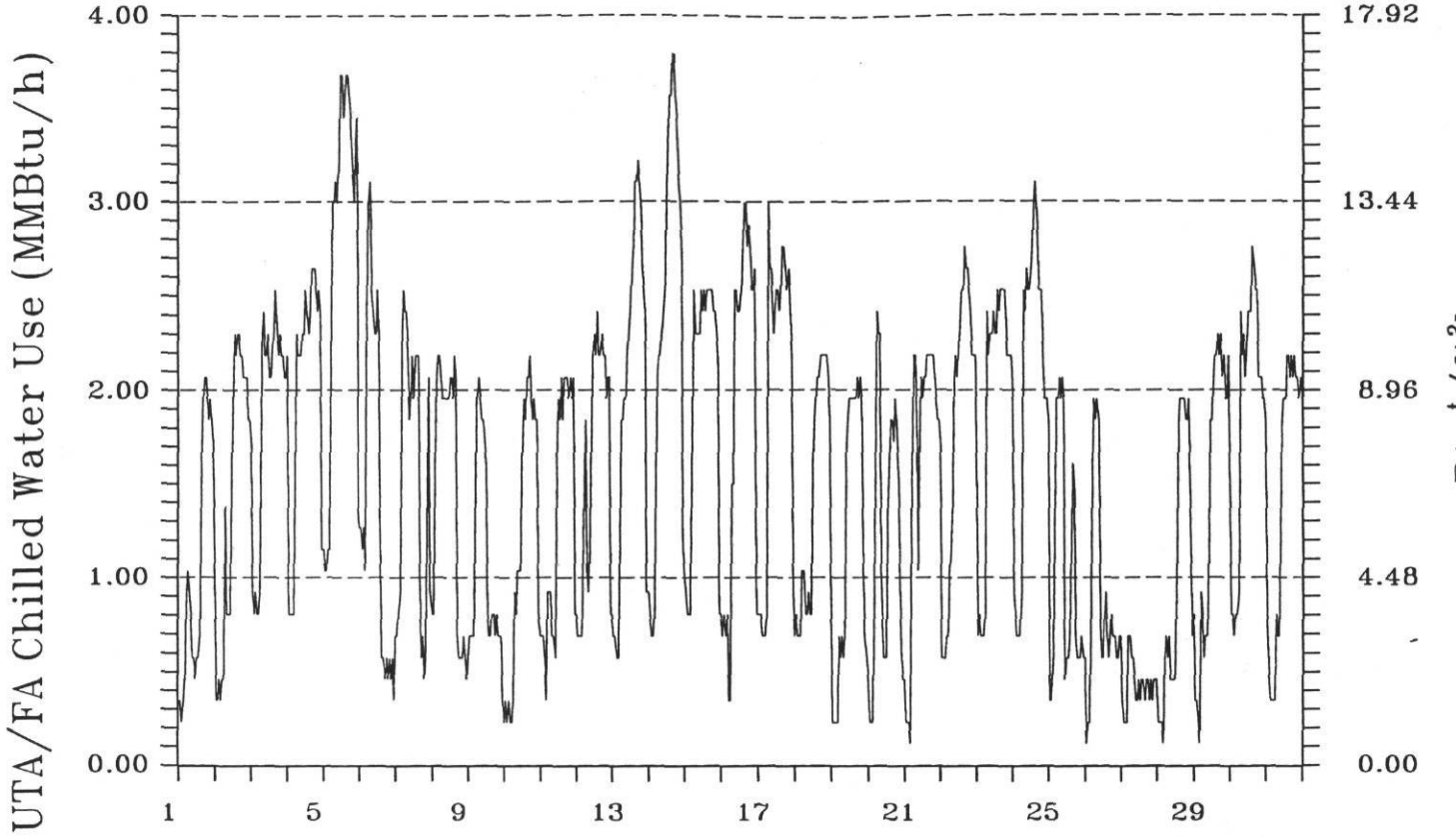


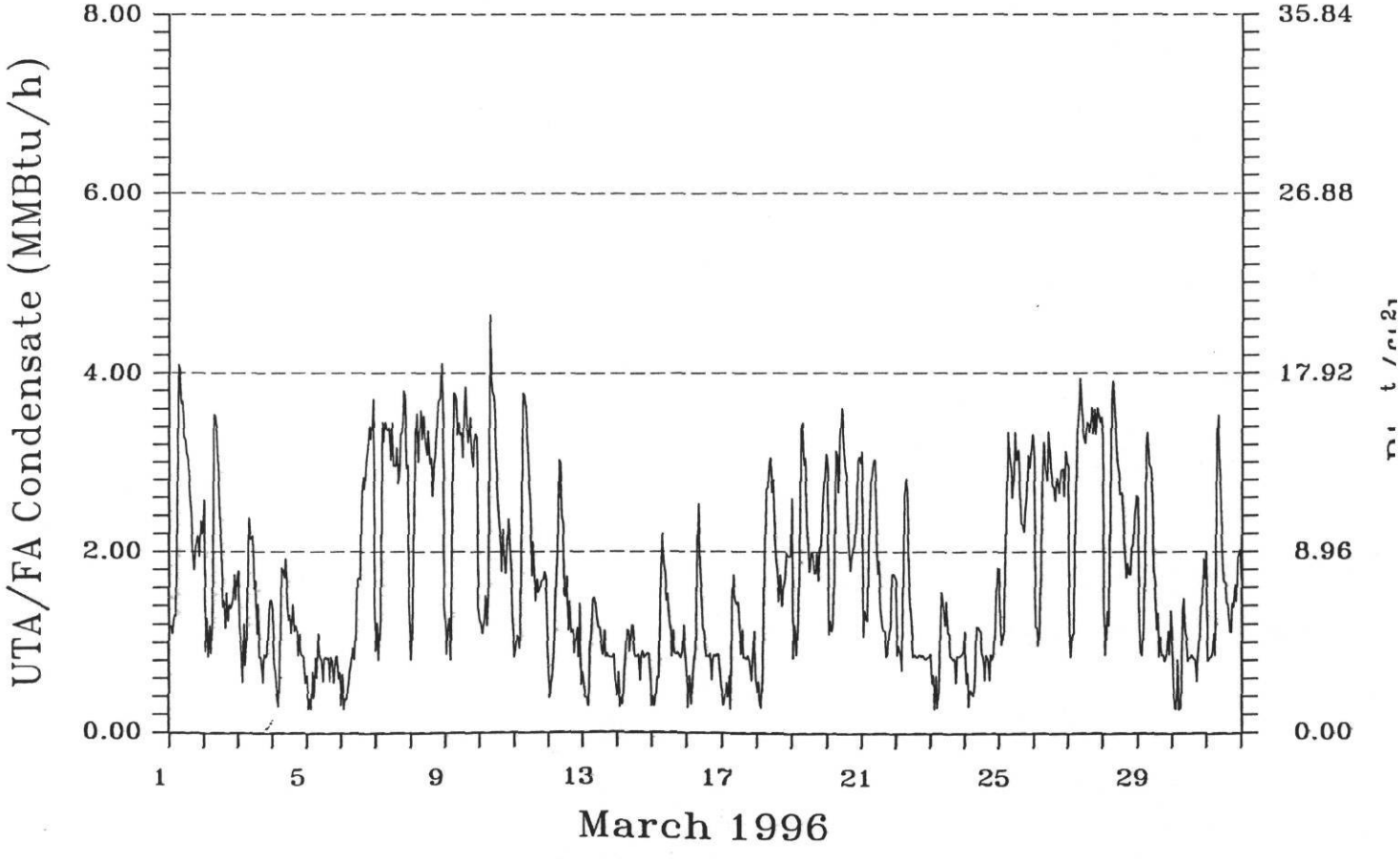
Mar 01 1995 – Mar 31 1996

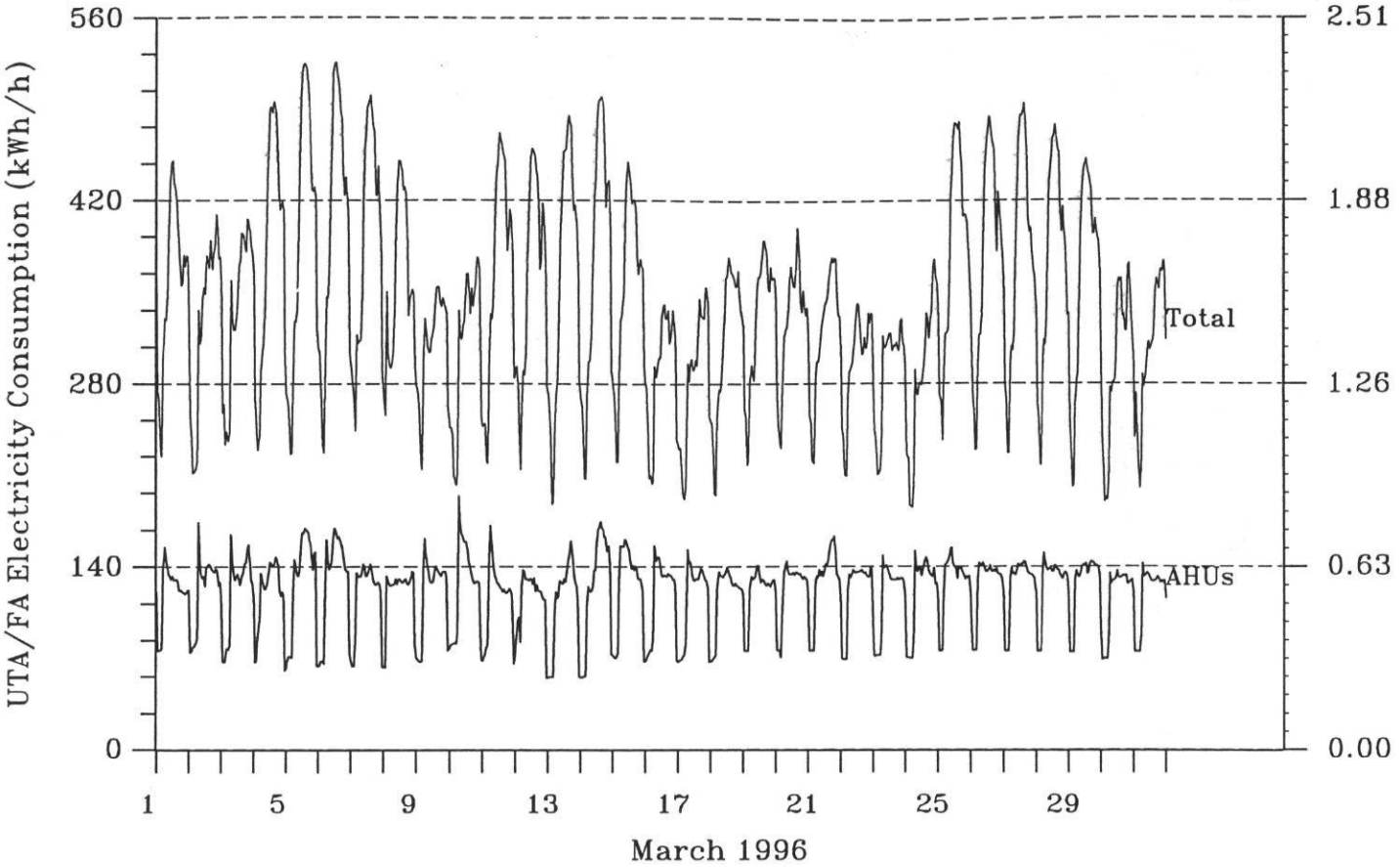


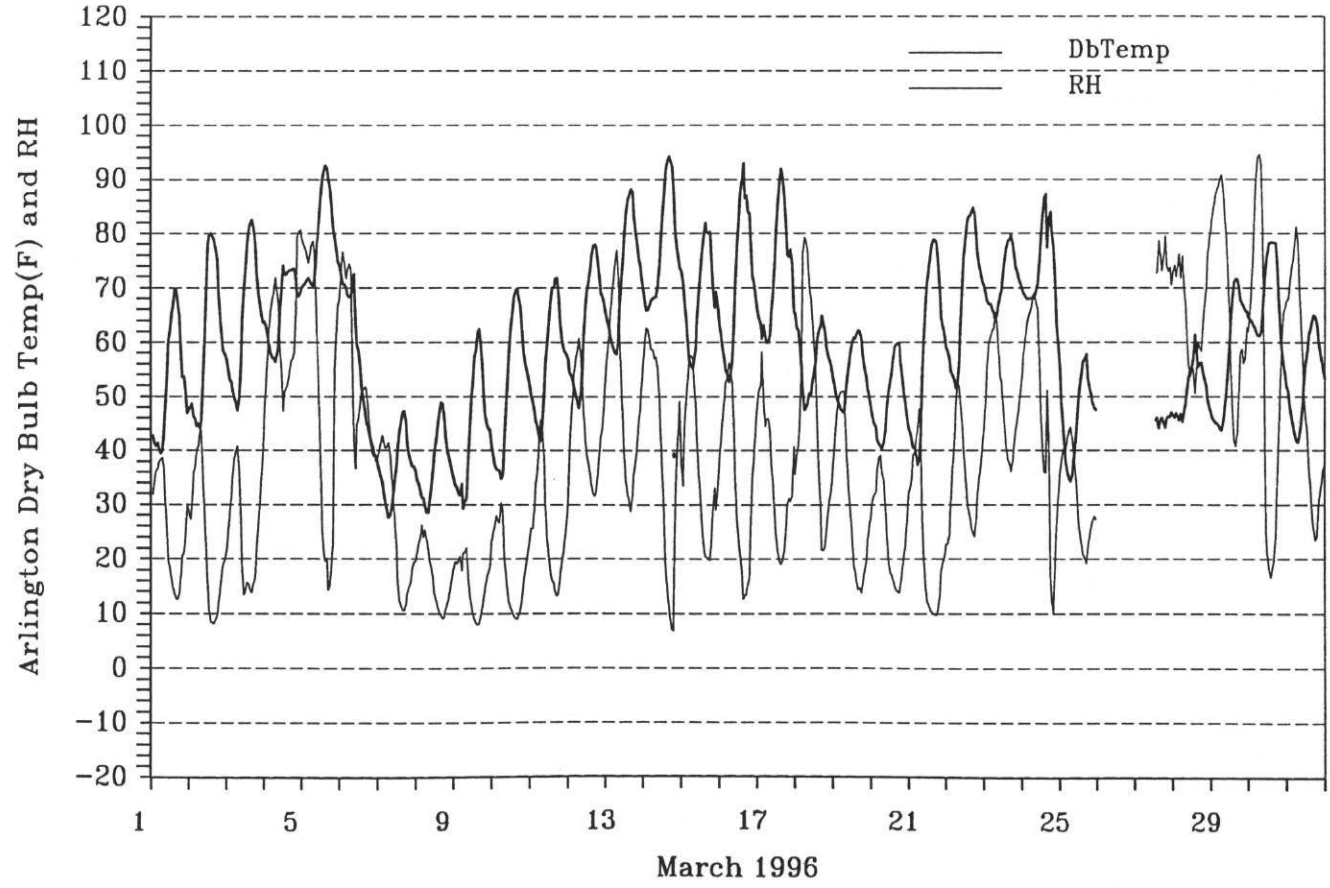
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

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

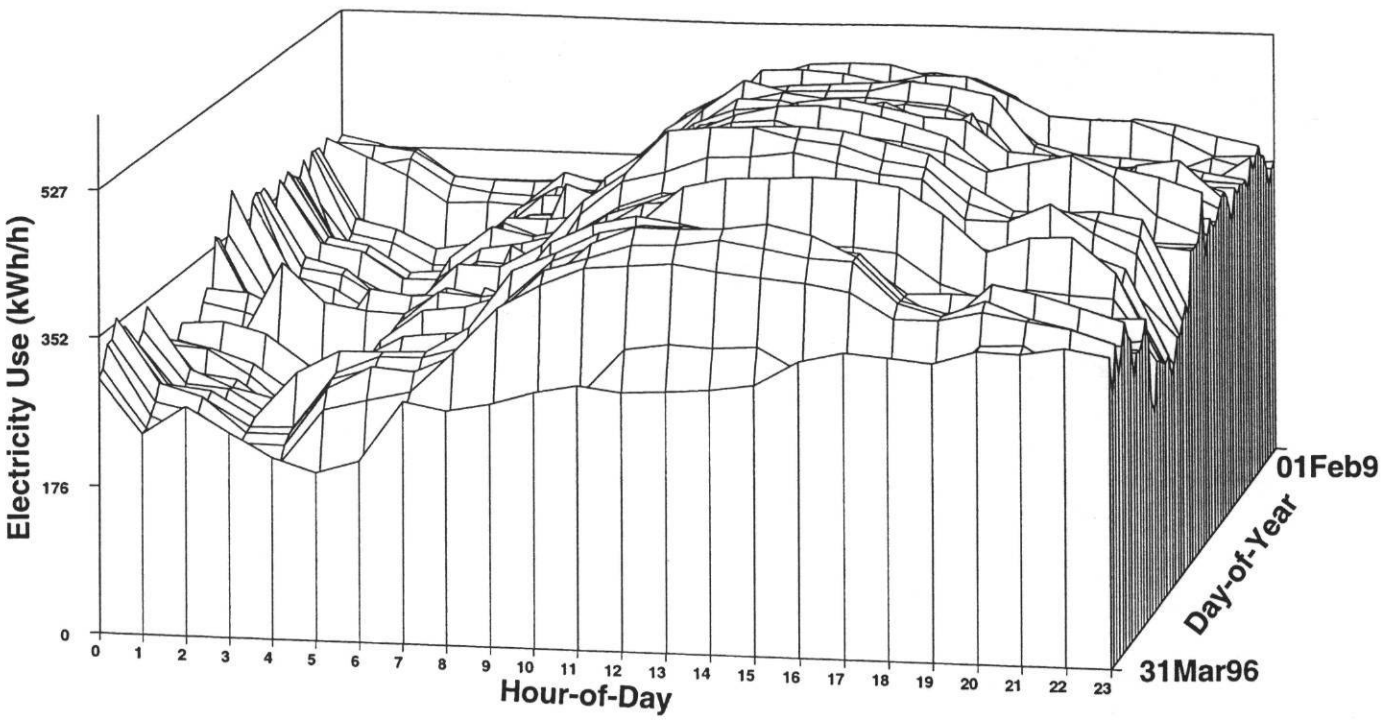

UTA/FA Chilled Water Use (MMBtu/h)
4.00
3.00
2.00
1.00
0.00
17.92
13.44
8.96
4.48
0.00
1
5
9
13
17
21
25
29
March 1996


UTA/FA Condensate (MMBtu/h)
8.00
6.00
4.00
2.00
0.00
35.84
26.88
17.92
8.96
0.00
1
5
9
13
17
21
25
29
March 1996

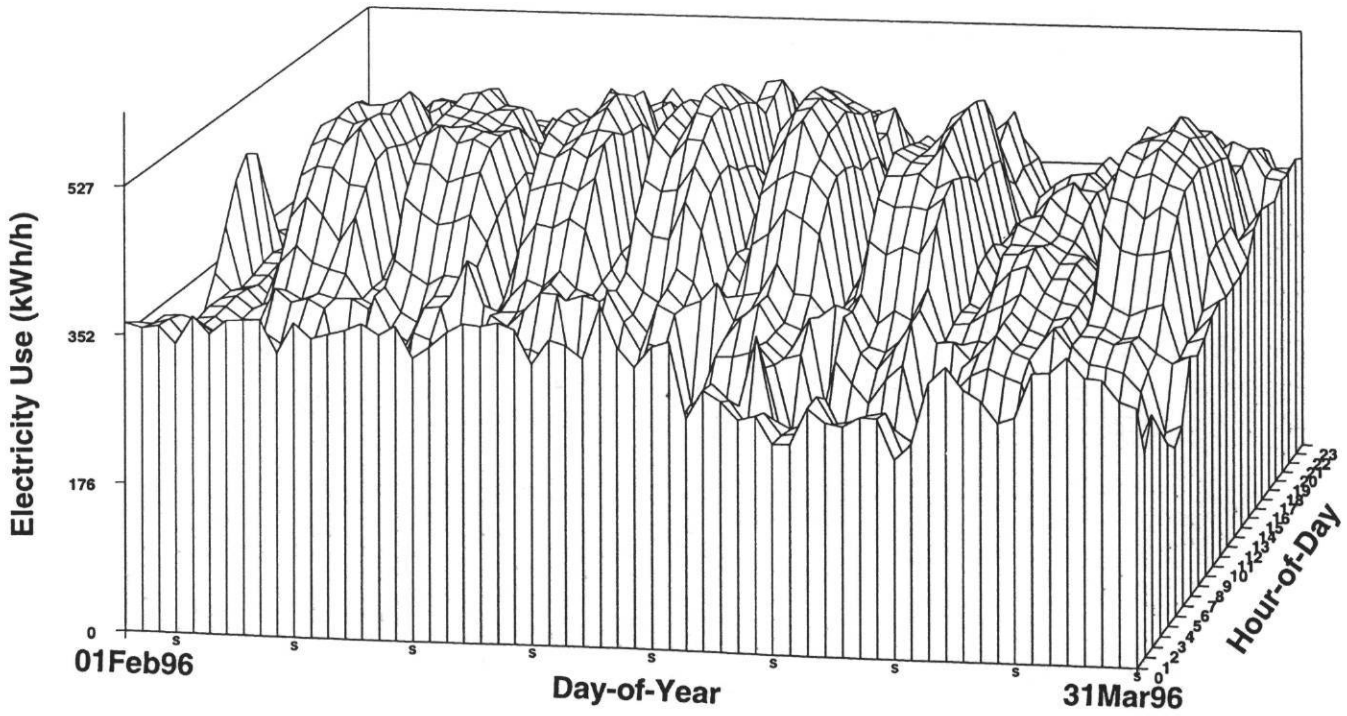

UTA/FA Electricity Consumption (kWh/h)
560
420
280
140
0
2.51
1.88
1.26
0.63
0.00
Total
AHUs
1
5
9
13
17
21
25
29
March 1996


Arlington Dry Bulb Temp(F) and RH
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
DbTemp
RH
1
5
9
13
17
21
25
29
March 1996

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

U.T. Arlington

Fine Arts Building

Building Envelope:
- 223,000 sq.ft.
- 5 section building was constructed in 1972 around an existing theater.
- four departments: Music, Art, Communications, and Architecture
- walls: face brick
- windows: brown tinted, single pane, fixed, 6% of total wall area
- roof: N/A

Building Schedule:
- Offices: 8:00 a.m. to 6:00 p.m. (M-F); various schedules

Building HVAC:
- 4 variable volume dual duct AHUs (AHU-3, 100hp, AHU-1, 50hp, AHU-5 &7, 75hp each)
- 8 constant volume single-zone units (3-15hp, 1-10hp,1-5hp,1-3hp,1-2hp,1-1hp)
- 30 exhaust fans (total of 14hp)
- 2 constant speed chilled water pump (2-100hp)
- 2 constant speed chilled water pump (2-5hp)
- 1 hot water pump (N/A)
- 7 return fans (2-7.5hp, 2-5hp, 2-25hp,1-20hp)
- 4 variable volume duct units are equipped with an economizer cycle

HVAC Schedule:
- 24 hrs/day, 7 days a week (AHU-1, RF-1)
- 17 hrs/day (6:00 am to 11:00 pm, all other AHUs)

Lighting:
- fluorescent 34W

Retrofits Implemented:
- VAV conversion for the AHUs
- lighting control
- Fluorescent lighting upgrade and zone occupancy sensors
- variable speed control for chilled water pumps

Date of Retrofits:
- VAV conversion and lighting modifications were completed by August 1991. Lighting projects for fluorescent upgrade and zone occupancy sensors were completed in May 1994.

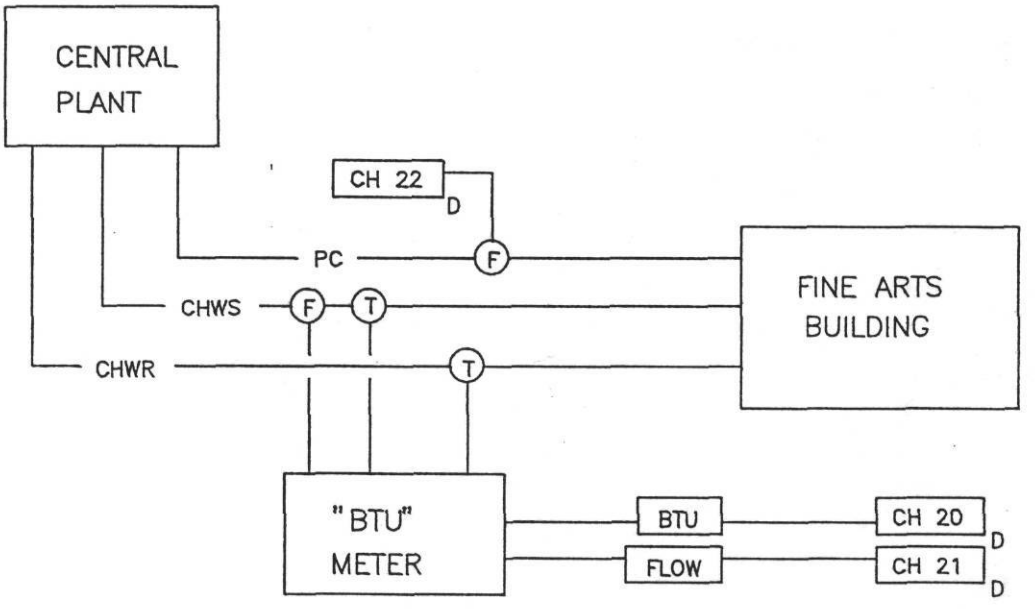
Savings Calculations:
- measured and estimated savings include lighting savings since March 1995.
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

THERMAL MONITORING DIAGRAM

UT ARLINGTON – FINE ARTS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

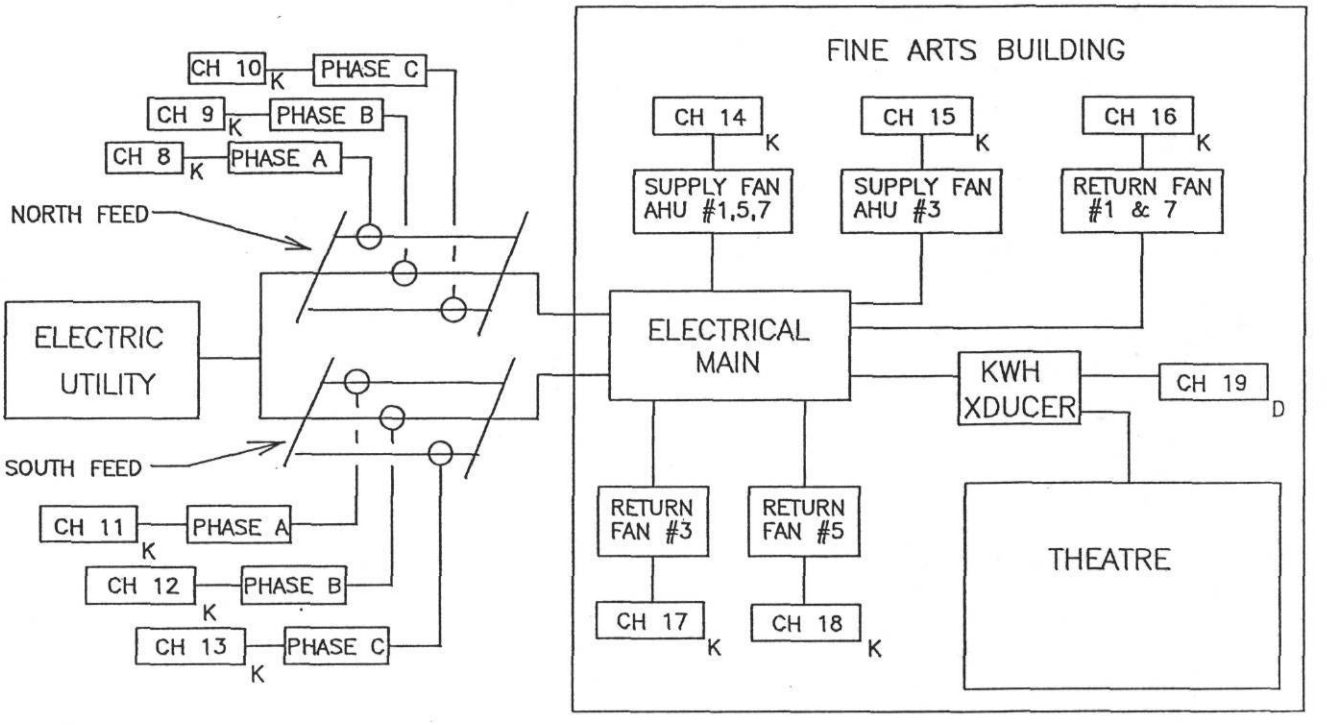


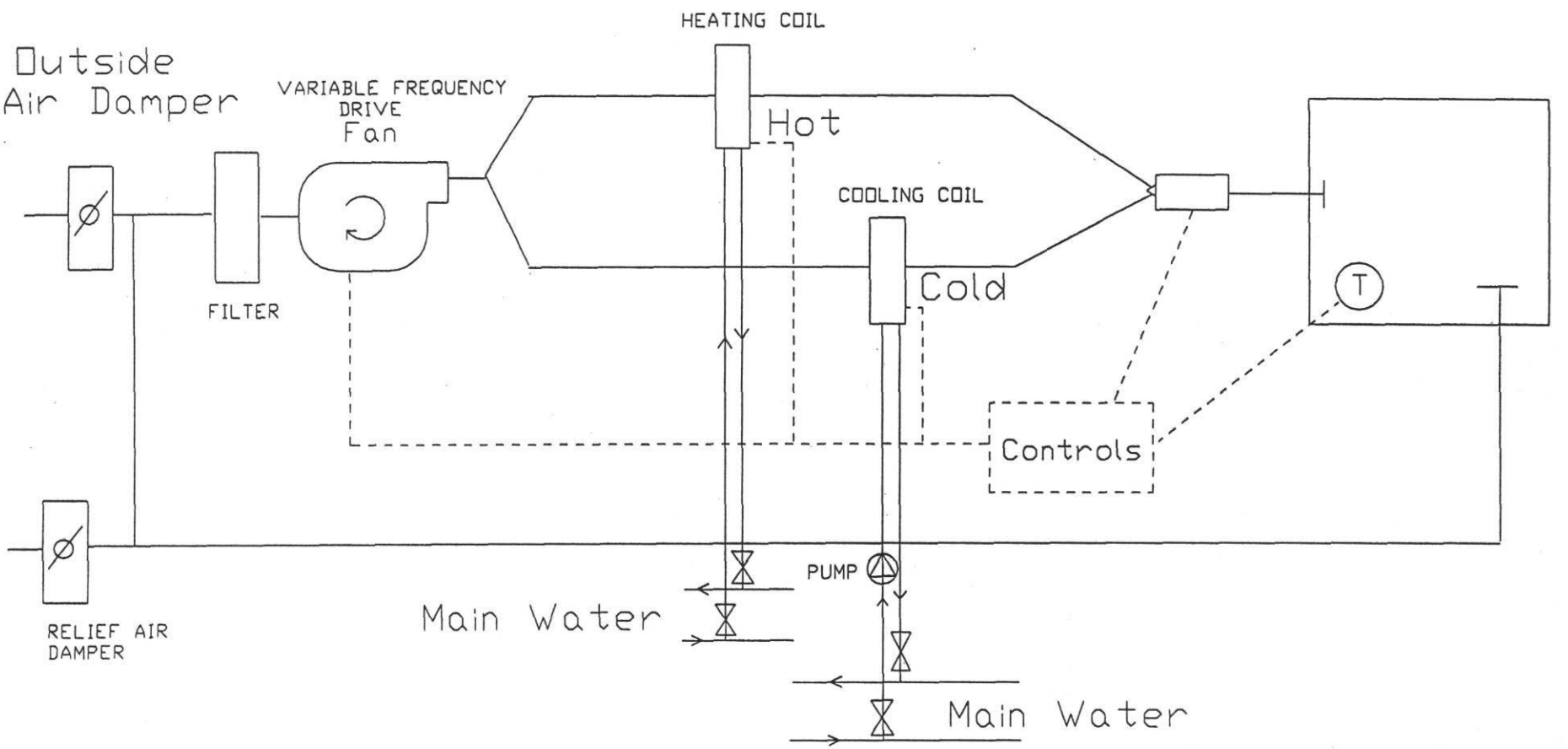
ELECTRICAL MONITORING DIAGRAM

UT ARLINGTON – FINE ARTS

LEGEND

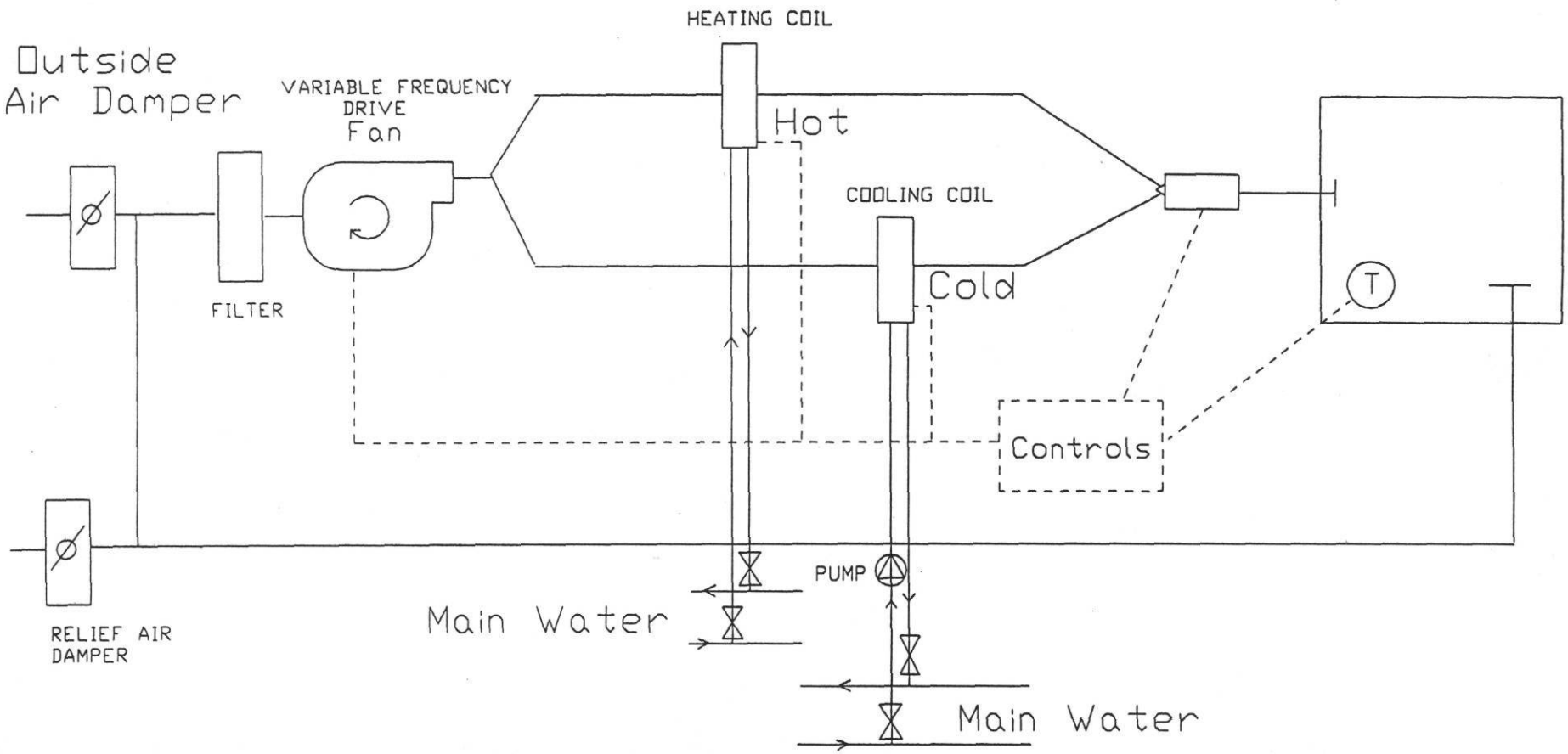
K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL





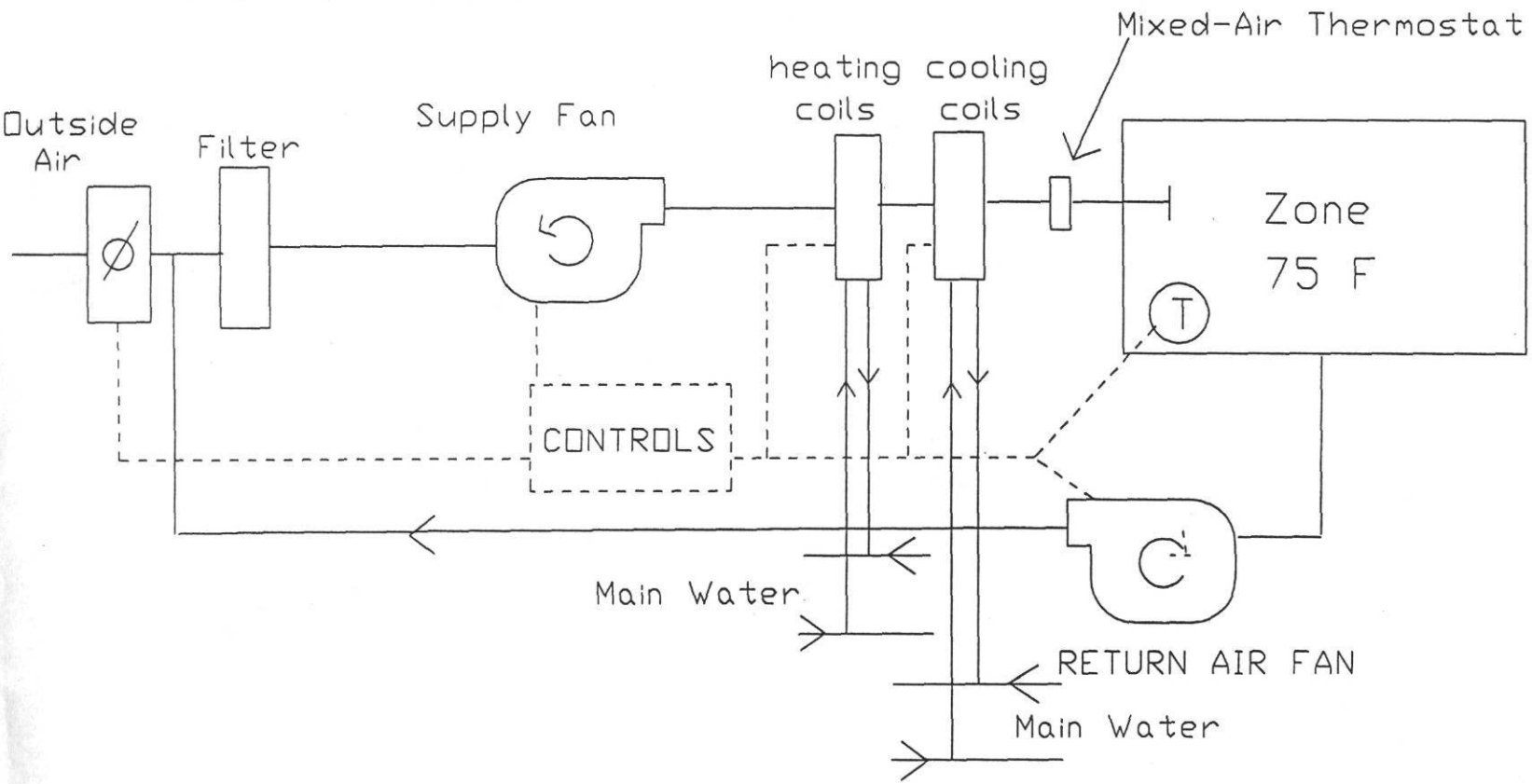
Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- FINE ARTS BUILDING	
Typical Dual-Duct System	Date: May 1, 1991
UT-FA 113	Drawn by: Mark Rivera



Variable-volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- FINE ARTS BUILDING	
Typical Dual-Duct System	Date: May 1, 1991
UT-FA 113	Drawn by: Mark Rivera



Constant-Volume

Texas LoanSTAR Program	
UNIV. OF TEXAS AUSTIN- FINE ARTS BUILDING	
Typical Single-Duct System	Date: May 1, 1991
FA-113S	Drawn by: Mark Rivera